NOTICE

All drawings located at the end of the document.

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FINAL

TECHNICAL MEMORANDUM NO. 4 TO FINAL PHASE I RFI/RI WORK PLAN HUMAN HEALTH RISK ASSESSMENT EXPOSURE SCENARIOS

ROCKY FLATS PLANT
SOLAR EVAPORATION PONDS
(OPERABLE UNIT NO. 4)

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

EG&G ROCKY FLATS, INC.
ENVIRONMENTAL RESTORATION MANAGEMENT

JUNE 1993

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EXECUTIVE SUMMARY

This Technical Memorandum No. 4 (TM4) supports the Baseline Risk Assessment (BRA) for the Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) for Operable Unit No. 4 (OU4) at the Rocky Flats Plant (RFP). OU4 is considered to be equivalent to Individual Hazardous Substance Site 101 (IHSS 101). OU4 is comprised of five ponds (207A, 207B-North, 207B-Center, 207B-South, and 207C), the Interceptor Trench System (ITS), and areas in the immediate vicinity of the ponds.

This TM4 presents the exposure scenarios for the Human Health Risk Assessment (HHRA) portion of the BRA for OU4. The HHRA will evaluate human health risks for onsite and offsite receptors under current and future land use conditions.

The RFI/RI is performed pursuant to an Interagency Agreement (IAG) among the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Health (CDH) dated January 22, 1991 (DOE, 1991a). As required by the IAG, a Phase I RFI/RI will characterize source materials and soils at OU4. For OU4, source materials are tentatively defined as sludge and sediments remaining in the Solar Ponds. completion of the Remedial Investigation for OU4 may result in a revised definition for source materials. Through subsequent discussions with CDH, it has been directed that the HHRA for the Phase I RFI/RI for OU4 include air pathway analyses. A subsequent Phase II RFI/RI will investigate the nature and extent of surface water, leachate, biota and groundwater contamination and evaluate potential contamination migration pathways.

The scope of this TM4 is limited to the identification of:

- Exposure pathways and associated intake routes and parameters for Phase I RFI/RI characterized source materials and soil within OU4; and

- Current and future human exposure scenarios for characterized source materials and soil within OU4.

Because the nature and extent of surface water, leachate, biota and groundwater contamination will not be investigated until the Phase II RFI/RI process, this TM4 addresses only direct (e.g., contact) and upward (e.g., wind suspension) exposure pathways associated with Phase I RFI/RI characterized source materials and soil. These source and soil materials will be used as input to environmental exposure models in order to assess risks to human health. Subsequent technical memoranda and human health risk analyses will be prepared as part of the Phase II RFI/RI process for OU4.

The objectives of this TM4 were to identify complete exposure: pathways by which chemicals may be transported from Phase I RFI/RI identified sources to human exposure points; associated human receptor populations that may be exposed to the identified chemicals; the route(s) of chemical intake; and intake parameters for each contaminated medium (e.g., soil). Chemical intakes have not been quantified. The magnitude of exposure is dependent on the chemical concentration at the exposure points, which will be estimated based on the analytical results of the Phase I RFI/RI and exposure assessment modeling, as appropriate. The exposure assessment focuses on media (e.g., soil) that potentially contain chemicals related to Phase I RFI/RI identified sources and associated exposure pathways, potential receptors, exposure points, and factors for potential human intake of impacted media.

A conceptual site model (CSM) of potential human exposure pathways was developed to provide a schematic representation of the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake and exposure routes, and potential human receptors. The purpose of the CSM is to provide a framework for problem definition, identify exposure pathways that may result in human health risks, indicate data gaps, and aid in identifying appropriate remediation measures. Chemical release mechanisms, environmental transport media, and potential human intake and exposure routes to the contaminated site soil were identified for each potential receptor.

Current onsite workers, current offsite residents, hypothetical future onsite workers, hypothetical future onsite ecological researchers, hypothetical future onsite construction workers, and hypothetical future onsite residents are included among the receptor scenarios to be quantitatively evaluated on the basis of their credibility and representative or bounding exposure potential. While a future hypothetical onsite resident has been shown to be improbable, this exposure scenario has been retained for quantitative evaluation so that the full range of risks can be examined by the regulatory agencies. Exposure points were selected for the current offsite resident on the basis of proximity to the plant site and the predominant wind direction. The hypothetical future onsite resident, worker, ecological researcher, and construction worker are all located within the boundaries of OU4. While the hypothetical future onsite worker is a credible exposure scenario, this receptor category is more likely to have an exposure location within the existing developed area of the plant site because of its existing infrastructure of facilities and utilities. Complete human health exposure pathways to be evaluated as part of the HHRA for OU4 are:

- Current Offsite Resident
    - Inhalation of airborne particulates;
    - Soil ingestion following airborne deposition of particulates on residential soil;
    - Dermal contact with organic compounds in soil, following airborne deposition of particulates; and
    - Ingestion of fruits and vegetables following surface deposition of particulates.

- Current Onsite Worker
    - Inhalation of airborne particulates;
    - Soil ingestion following airborne deposition of particulates on residential soil;
    - Dermal contact with organic compounds in soil, following airborne deposition of particulates; and
    - Ingestion of fruits and vegetables following surface deposition of particulates.

- Hypothetical Future Onsite Worker
    - Inhalation of airborne particulates and indoor volatile organic compounds (VOCs);
    - Incidental soil ingestion;
    - Direct dermal contact with organic compounds in soil; and
    - Groundshine (external radiation) (direct contact).

- Hypothetical Future Onsite Ecological Worker
    - Inhalation of airborne particulates;
    - Incidental soil ingestion;
    - Direct dermal contact with organic compounds in soil; and
    - Groundshine (direct contact).

- Hypothetical Future Onsite Construction Worker
    - Inhalation of airborne particulates;
    - Incidental soil ingestion;
    - Direct dermal contact with organic compounds in soil; and
    - Groundshine (direct contact).

- Hypothetical Future Onsite Resident
    - Inhalation of airborne particulates and indoor VOCs;
    - Ingestion of homegrown fruits and vegetables (surface deposition of particulates and root uptake of site-related chemicals);
    - Incidental soil ingestion;
    - Direct dermal contact with organic compounds in soil; and
    - Groundshine (direct contact).

- Hypothetical Future Offsite Resident
    - Inhalation of airborne particulates:
    - Soil ingestion following airborne deposition of particulates on residential soil;
    - Dermal contact with organic compounds in soil, following airborne deposition of particulates; and
    - Ingestion of fruits and vegetables following surface deposition of particulates.

Intakes and exposures were estimated using reasonable estimates of body weight, inhalation volume, ingestion rates, soil or food matrix effects, and frequency and duration of exposure. Intakes and exposures will be estimated for reasonable maximum exposure (RME) conditions. The RME was estimated by selecting values for exposure that can reasonably be expected to occur at the site. Overall, exposure parameter values were employed which would result in the derivation of exposure levels that err on the side of over-estimation, rather than under-estimation. The intake and exposure parameters to be used in the HHRA for each of the exposure scenarios indicated above are presented in Section 5.0 of this TM4.

1.0 INTRODUCTION

This Technical Memorandum No. 4 (TM4) supports the Baseline Risk Assessment (BRA) for the Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) for Operable Unit No. 4 (OU4) at Rocky Flats Plant (RFP). OU4 consists of the Solar Evaporation Ponds (Solar Ponds) Waste Management Unit which is equivalent to Individual Hazardous Substance Site 101 (IHSS 101). OU4 is comprised of five ponds:

- Pond 207A;
- Pond 207B-North;
- Pond 207B-Center;
- Pond 207B-South; and
- Pond 207C.

Also included within the OU4 boundary are the Original Pond, the Interceptor Trench System (ITS) and areas in the immediate vicinity of the ponds.

The BRA is comprised of a Human Health Risk Assessment (HHRA) and an environmental evaluation. This memorandum presents the exposure assessment approach for the HHRA portion of the BRA for OU4. The HHRA will evaluate human health risks for onsite and offsite receptors under current and future land use conditions.

The RFI/RI is performed pursuant to the Interagency Agreement (IAG) among the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Health (CDH) dated January 22, 1991 (DOE, 1991a). As required by the IAG, a Phase I RFI/RI will characterize source materials and soils at OU4. Pending completion of the RFI/RI, source materials are tentatively defined as sludge and sediments remaining in the bottom of the Solar Ponds. Through subsequent discussions with CDH, it has been directed that the HHRA for the Phase I RFI/RI for OU4 include air pathway analyses. A subsequent Phase II RFI/RI will investigate the nature and extent of surface water, leachate, biota and groundwater contamination and evaluate potential contamination migration pathways.

1.1 OBJECTIVES

The objectives of this TM4 are to identify: complete exposure pathways by which chemicals may be transported from Phase I RFI/RFI identified sources to human exposure points; associated human receptor populations that may be exposed to the identified chemicals; the route(s) of chemical intake; and intake parameters for each contaminated medium (e.g., soil). Chemical intakes have not been quantified. The magnitude of exposure is dependent on the chemical concentration at the exposure points, which will be estimated based on the analytical results of the Phase I RFI/RI and fate and transport modeling, as appropriate. The exposure assessment focuses on media (e.g., soil) that potentially contain chemicals related to Phase I RFI/RI identified sources and associated exposure pathways, potential receptors, exposure points, and factors for potential human intake of impacted media.

1.2 SCOPE

The scope of this TM4 is limited to the identification of:

- Exposure pathways and associated intake routes and parameters for Phase I RFI/RI characterized source materials and soil within OU4; and
- Current and future human exposure scenarios for characterized source materials and soil and residual pond sediment within OU4.

Because the nature and extent of surface water, leachate, biota and groundwater contamination will not be investigated until the Phase II RFI/RI process, this TM4 addresses only direct (e.g., contact) and upward (e.g., wind suspension) exposure pathways associated with Phase I RFI/RI characterized source materials and soil. Subsequent technical memoranda and human risk analyses will be prepared as part of the Phase II RFI/RI process for OU4.

Potential scenarios were identified according to the EPA concept of reasonable maximum exposure (RME), defined as the highest exposure reasonably expected to occur at a site (EPA, 1989b). The term "potential" is used to mean "a reasonable chance of occurrence within the context of the reasonable maximum exposure scenario" (EPA, 1990). Using this approach, potential exposures are evaluated in Section 4.0 using a conceptual site model (CSM). In the CSM, the likelihood of an exposure pathway occurring is classified as significant, insignificant, or negligible (i.e., incomplete). In this document, negligible pathways are those that are unlikely to occur, significant pathways are those that could conceivably occur, and insignificant pathways are those that could also occur but are expected to result in relatively lower levels of exposure (i.e., by one or more orders of magnitude) with respect to significant exposure pathways.

This TM4 is organized as follows:

- Section 2.0, Site Description, describes site characteristics that potentially impact human exposures;

- Section 3.0, Potentially Exposed Receptor Populations, identifies the populations that may be exposed to chemicals originating from identified site-related sources. Land uses and exposure scenarios that are most likely to occur, given the site-specific conditions, are identified for quantitative assessment in the HHRA;

- Section 4.0, Exposure Pathways, discusses the potential release and transport of chemicals from the site, and identifies exposure pathways to be evaluated in the HHRA using a conceptual site model;

- Section 5.0, Estimating Chemical Intakes, describes the methodology used to approximate the intake of chemicals in various media and identifies chemical intake factors for the calculation of chemical intake by human receptors; and

- Section 6.0 lists the references cited throughout this document.

2.0 SITE DESCRIPTION

A brief description of the OU4 history, physical setting, meteorology, geology, hydrology, and ecology is presented in this section. Such information was derived primarily from the Phase I RFI/RI Work Plan for OU4 (DOE, 1991b). It should be noted that the results implementation of the Work Plan and sampling and analysis will likely provide additional information regarding the site description. Such information will be incorporated into this section when such data become available.

2.1 LOCATION AND PLANT HISTORY

RFP is located on approximately 6,550 acres of federally owned land in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 2-1). Surrounding communities include Boulder, Broomfield, Westminster, and Arvada, which are located less than 10 miles to the northwest, north, northeast, and southeast, respectively. RFP includes an industrial complex of approximately 400 acres known as the protected area (PA), surrounded by a buffer zone of approximately 6,150 acres. A general description of RFP is presented in this section. For a more detailed description, please refer to the Phase I RFI/RI Work Plan for OU4 (DOE, 1991b).

RFP's historical mission was to produce metal components for nuclear weapons. These components were fabricated from plutonium, uranium, and nonradioactive metals and shipped elsewhere for final assembly. When a nuclear weapon is determined to be obsolete, components of these weapons fabricated at RFP are returned for special processing to recover plutonium. Other activities at RFP have included research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics. RFP is currently performing environmental restoration activities and transition planning for decontamination and decommissioning (D&D).

2.2 HISTORY OF OU4

The Solar Ponds are located in the central portion of the RFP on the northeast side of the PA. Figure 2-2 illustrates the locations of the five ponds, the Original Pond, the ITS, and adjacent areas within the OU4 boundary. The Solar Ponds were constructed primarily to store and treat low-level radioactive wastes containing high nitrates, and neutralized acidic wastes containing aluminum hydroxide. In addition, these ponds have received wastes such as sanitary sewage sludge, lithium metal, sodium nitrate, ferric chloride, lithium chloride, sulfuric acid, ammonium persulfates, hydrochloric acid, nitric acid, hexavalent chromium and cyanide solutions.

2.3 PHYSICAL SETTING

The natural environment of RFP and vicinity is influenced primarily by its proximity to the Front Range of the Southern Rocky Mountains. RFP is located less than 2 miles east of the north-south trending Front Range and approximately 16 miles east of the Continental Divide. A more detailed description of the Colorado Piedmont can be found in the Phase I RFI/RI Work Plan for OU4 (DOE, 1991b).

2.4 METEOROLOGY

The Phase I RFI/RI Work Plan for OU4 provides a detailed description of site meteorology (DOE, 1991b). The region has a highly continental, semi-arid climate. Mean annual precipitation of the RFP vicinity is approximately 15 inches. More than half of this total occurs as snowfall, which averages approximately 85 inches per year. Approximately 40 percent of the annual precipitation occurs in the spring. The relative humidity annual average is approximately 50 percent. Annual free-water evaporation is approximately 45 inches (DOE, 1992). The 1990 wind rose for RFP is shown in Figure 2-3. Mean wind speed for 1990 was 4.0 m/sec. The frequency of occurrence of atmospheric stability during 1990, in terms of Pasquill stability classes, was: 50.1 percent for neutral stability classes (Class D), 42.5 percent for stable classes (Class E and F), and 7.37 percent for unstable classes (Class A, B, and C).

2.5 GEOLOGY

The description of the geology in the vicinity of OU4 is derived from previous studies performed at the site. A more detailed description of the site geology can be found in the Phase I RFI/RI Work Plan for OU4 (DOE, 1991b). Much of the information in the Work Plan has been summarized from the Solar Evaporation Ponds Closure Plan (Rockwell International, 1988), the

1989 drilling program performed by Weston, EG&G Rocky Flats Summary of Field Investigations and EG&G Rocky Flats Draft Final Geologic Characterization Report (EG&G, 1991b).

2.5.1 Surficial Geology

Four distinct surficial deposits of quaternary age are present in the vicinity of OU4: Rocky Flats alluvium, colluvium, valley-fill alluvium, and artificial fill or disturbed ground. These surficial deposits unconformably overlie the bedrock units. Rocky Flats Alluvium caps the interfluves north and south of the unnamed tributary to North Walnut Creek. Colluvium covers the hillsides down to the drainage. Valley-fill alluvium is present along the channel of the unnamed tributary. The erosional surface on which the alluvium was deposited slopes gently eastward, truncating the Arapahoe and Laramie Formations. Most of the Solar Ponds area has been disturbed by construction of the ponds and the ITS; therefore, artificial fill or disturbed surficial materials are present near the Solar Ponds area.

2.5.2 Bedrock Geology

The Upper Cretaceous Arapahoe unconformably underlies surficial materials in the vicinity of the Solar Ponds area. The Arapahoe Formation is composed primarily of claystones and silty claystones that are very similar lithologically to those in the underlying Laramie Formation.

2.6 HYDROLOGY

2.6.1 Groundwater

According to the Phase I RFI/RI Work Plan for OU4, groundwater in the area of the Solar Ponds flows east (DOE, 1991b). Flow in the unconsolidated material follows the contact with the Arapahoe Formation claystones. Groundwater flow in the Solar Ponds area is influenced by recharge of precipitation, leakage from the Solar Ponds and drainage into the ITS. North of the Solar Ponds, the ITS drains groundwater from the alluvial materials creating an area of unsaturation.

2.7 ECOLOGY

A detailed description of the site ecology is presented in the Phase I RFI/RI Work Plan for OU4 (DOE, 1991b). The results of sampling and analysis and the ecological evaluation will be utilized to provide additional information regarding the site ecology.

2.7.1 Terrestrial Ecosystems

The terrestrial ecosystems are highly modified and in the first stages of revegetation by plants and invasion by smaller animals. Weedy vegetation has established on and around the ponds, on bare soil, in adjacent level construction fill and in cracks in liners. The fill slope to the north of the ponds has a grass/weed vegetation with small marshy areas around two seeps. Arthropods and other invertebrates were observed on plants, and birds occasionally visit the site. Small mammals such as deermice are expected. Cottontails were seen and scat from either a fox or a coyote was observed. Aquatic ecosystems are lacking on the OU4 study area which is at the head of a drainage and there are no streams or natural bodies of water. The ponds cannot be considered as aquatic ecosystems due to use and management practices and the lack of viable aquatic organisms and food webs. Algae mats grow seasonally on the ponds and were observed on Pond 207B-North during the site visit in September 1991. The areas north and east of the ponds are the drainages of Walnut Creek which include both terrestrial and aquatic ecosystems (DOE, 1993).

3.0 POTENTIALLY EXPOSED RECEPTOR POPULATIONS

The *1989 Population, Economic, and Land Use Data for Rocky Flats Plant* (DOE, 1990) was used to characterize land use and population distributions around the plant site. This study encompassed an area with a radius of 50 miles from the center of RFP and included all or part of 14 counties and 72 incorporated cities, with a 1989 combined population of 2,206,550. The study projected populations through the year 2010.

3.1 DEMOGRAPHICS

The 1989 study (DOE, 1990) was used for consistency with other risk assessments performed at Rocky Flats. Although the study was based on 1980 U.S. Census data, actual growth rates and more recent population estimates were used as the basis for projecting future growth patterns. The information in this study was not used to eliminate potential exposure scenarios. If more current data becomes available it will be incorporated into the BRA.

RFP is located on a 6,550-acre parcel of federally owned land in a rural area of Jefferson County, approximately 16 miles northwest of Denver and 10 miles south of Boulder. The plant facility is located near the center of the parcel and is surrounded by a buffer zone of approximately 6,150 acres.

Two general receptor population groups can be identified for RFP, namely, the population base located "near" RFP and the population base located "distant" from RFP (i.e., located farther than the two-mile radius around RFP). The population located near RFP inhabits land which is sparsely or not populated. Projections for population growth in these "near" and "distant" areas indicate that the growth will continue with the same general trends whereby the near population areas will remain as sparsely populated regions and the far population areas will undergo population increases.

The area west of RFP is mountainous, sparsely populated, and primarily government-owned. The area east of RFP is generally a high, semi-arid plain, densely populated, and privately owned.

Most of the population included in the DOE study is located within 30 miles of RFP, primarily in the Denver metropolitan area to the east and southeast.

Most of the development near RFP has occurred since the plant was built, with future development expected to continue (DOE, 1992). Approximately 316,000 people reside within a 10-mile radius. The most significant development 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 also contain significant developments within this 10-mile radius (DOE, 1992).

Figure 3-1 (DOE, 1990) illustrates the distribution of the residential population within a 5-mile radius of RFP in 1989. The projected residential population for the year 2010 is illustrated in Figure 3-2 (DOE, 1990). Sectors 1 and 2 represent land within RFP boundaries and therefore are relevant to onsite scenarios. Sectors 1 and 2 also provide information relevant to the near population area for RFP. The current population for Sectors 1 and 2 is zero. The total population for Sector 3 is 24. Sectors 4 and 5 provide the primary contribution to the total population figure of 8,172.

Sectors 3, 4, and 5 mostly include property outside RFP boundaries and thus are relevant to offsite scenarios, and the distant population area for RFP. Radial Segments D through I, which lie in the predominant downwind directions from OU4, represent the primary areas relevant to upward exposure pathways.

The 1989 and projected 2010 population data shown in Figures 3-1 and 3-2 are summarized in Table 3.1. The information presented in Table 3.1 indicates that zero population growth is projected in the next 18 years for the near population areas immediately adjacent to RFP boundaries (Sectors 1 through 3). The potential exists that the population may grow in sectors which border RFP. An increase in population and the number of households is predicted for the three- to six-mile radius areas around RFP boundaries (Figures 3-1 and 3-2 and Table 3.1).

The school closest to RFP is Witt Elementary School, approximately 2.7 miles east of the buffer zone (EG&G, 1991a). All other sensitive subpopulation facilities (e.g., hospitals and nursing homes) are located beyond the 5-mile radius from the center of RFP. Ninety-three schools, eight nursing homes, and four hospitals occur within a 10-mile radius of RFP, but all are outside the five-mile radius (DOE, 1992).

The nearest drinking water supply is Great Western Reservoir, located approximately 2.3 miles east of the center of RFP. The continued use of Great Western as a drinking water source is limited. The City of Broomfield has, with DOE's assistance, set into motion a plan to obtain drinking water for the municipality from other sources that are distal from RFP. The current plan is for the alternative water supply to be in place and functioning by 1997. The City of Broomfield operates a water treatment facility immediately downstream from Great Western Reservoir. This facility supplies drinking water to approximately 28,000 persons. Standley Lake Park, a recreational area and a drinking water supply for the cities of Thornton, Northglenn, Westminster, and Federal Heights, is located 3.5 miles to the southeast of RFP. After 1997, Standley Lake will be the closest water supply with respect to the location of OU4. However, Standley Lake does not drain the watershed to which OU4 supplies recharge. From Standley Lake, water is piped to each city's water treatment facility. Boating, picnicking, and limited overnight camping are permitted at Standley Lake Park.

3.2 OFFSITE LAND USE

3.2.1 Current

Current land use in the area surrounding RFP is shown in Figures 3-3 and 3-4. Table 3.2 is a summary of land use corresponding to the Jefferson County Land Use Map. In general, current land use surrounding RFP includes open space (recreational), agricultural, residential, and commercial/industrial. The Northeastern Jefferson County and RFP includes one of the most concentrated areas of industrial development in the Denver metropolitan area (Jefferson County, 1989).

Based on observation, current land use in the area relevant to the OU4 exposure scenarios (immediately southeast of RFP and OU4) includes all of the uses mentioned above. Predominant uses appear to be open space, single-family detached dwellings, and horse-boarding operations. Two small cattle herds (approximately 10 to 20 cattle in each) were observed: one to the southeast, where 96th Avenue turns into Alkire and crosses Woman Creek; and one to the east of RFP, between Alkire and Simms Streets and north of 100th Avenue. Industrial facilities within the relevant area, include the TOSCO laboratory, Great Western Inorganics Plant, and Frontier Forest Products (EG&G, 1991a). All are located to the south, along Colorado Highway 72.

3.2.2 Future

Future land use generally follows existing patterns. Jefferson County (1989) developed a baseline profile of growth and land use in the area as part of a socioeconomic study of its northeastern area (*Northeast Community Profile*). As a result of this study, Jefferson County expects that industrial land uses will continue to dominate the northeastern portion of the county. Along with the increase in industrial development, the county expects income and employment growth to increase dramatically, while household and population growth is expected to increase only moderately. In other words, with industrial growth, employment opportunities are expected to increase; yet, as the land is developed for industry, the availability of land for residential development decreases. As a result, household and population growth will be limited.

Industrial and commercial development of the area is attractive to businesses and developers because of the availability of undeveloped, lower-cost lands, and the lower taxes associated with locating in an unincorporated portion of the county.

Both the proposed construction of highway W-470 and its alignment are uncertain. Near-term (5 years) development of the highway is unlikely. Proposed alignments have included skirting either the southern and eastern or western and northern boundaries of RFP. Commercial growth, particularly light industries and office parks, would be expected to occur along the highway (Jefferson County, 1989).

Residential development is not as attractive as industrial development of the area for several reasons, including the proximity to Jefferson County Airport, and the proximity to RFP. The decreased desirability of living near a major highway or an airport, for traffic and noise reasons, is a deterrent to residential development. The proximity of RFP and the general industrial nature of the area also decreases the desirability of housing in the area.

Future land use in the area is the topic of *The North Plains Community Plan* (Jefferson County, 1990). The plan is intended to serve as a guide to the county and cities to achieve compatible land use and development decisions, regardless of the jurisdiction. It was developed cooperatively by representatives of Jefferson County and five communities (Arvada, Broomfield, Golden, Superior, and Westminster) as well as a variety of interest groups, including homeowners, businesses, builders/developers, environmentalists, and special districts. The plan identifies RFP and the Jefferson County Airport as constraints to future residential development in the area and recommends office and light industrial development. It further identifies the acquisition of lands for open-space uses as a high priority for the area and recommends that large amounts of undeveloped land be provided for this purpose (Jefferson County, 1990).

The North Plains Community Development Plan Study Area Summary Map (Figure 3-5) and the Jefferson Center Comprehensive Development Plan (Figure 3-6) show that the predominant future land uses south and southeast of RFP will consist of commercial, industrial, and office space. Directly to the east, land use is expected to remain open space and agricultural/vacant. Residential development is projected to occur farther from RFP than these other uses. This planning is consistent with the zero projected residential growth rate in the next 18 years for areas immediately adjacent to RFP (DOE, 1990). Projected industrial growth will place additional demands on finite resources such as water and land and will probably result in increasing costs for these resources. At some point in the future, these increasing costs are expected to make agricultural use of the land impracticable.

North of RFP in Boulder County, the predominant land uses include open space, parkland, and industrial development, as shown in Figure 3-4. Two areas adjacent to RFP have been annexed by the towns of Broomfield and Superior. These two communities have participated in the

Jefferson County cooperative planning process and are planning business, industrial, and mixed-land uses for the area (City of Broomfield, 1990; Jefferson County, 1990; Boulder County, 1991).

The information presented above indicates that current land use in the immediate vicinity of RFP is agricultural and low-density residential. It is likely that such land use will continue into the future. It is likely that the potential for residential development in the buffer zones around RFP will be superseded by plans to preserve open space.

3.3 ONSITE LAND USE

3.3.1 Current

OU4 is located within the buffer zone, north of the PA. Current activities within OU4 include environmental investigations, maintenance activities and routine security surveillance. Access into the OU4 area is limited to individuals with appropriate security clearance credentials. The secured area is fenced and security personnel are on duty 24 hours a day. Thus, the potential for trespassers or other non-authorized individuals to enter into the area is virtually non-existent. Each of the ponds are roped off and signs are posted to indicated that the ponds are radiologically controlled areas; that consumables are not allowed in the areas; and that a radiologic work permit, a dosimetry badge, and appropriate safety glasses are required for entry.

3.3.2 Future

Future plans for RFP activities are discussed in the Nuclear Weapons Complex Reconfiguration Study. The two preferred reconfiguration options in the study include relocation of RFP functions (DOE, 1992). Future land-use alternatives are discussed in the RFP *Final Environmental Impact Statement* (EIS) (DOE, 1980). Four alternatives are addressed in the document, including the no-action alternative. These alternatives, which may be subject to change, are summarized below (DOE, 1992):

- The no-action alternative involves completion of nuclear production upgrades, maintenance of production standby, and compliance with the IAG environmental restoration (ER) commitments;

- Alternative 1 involves nuclear production at reduced levels, compliance with IAG ER commitments, and placement of surplus facilities into safe storage. This alternative is no longer considered viable, owing to the recent decision to implement D&D at RFP;

- Alternative 2 allows nuclear production at up to 1989 levels, increased non-nuclear production, placement of surplus facilities into safe storage, and completion of ER by 2020. This alternative is no longer considered viable, for the same reason as Alternative 1; and

- Alternative 3 involves transition to no production of nuclear or non-nuclear components, completion of ER by 2020, D&D of selected facilities, and placement of other facilities into safe storage.

Use of onsite production facilities by private industry is planned for the future at RFP, according to a June 12, 1992 speech by Secretary of Energy, James Watkins. Watkins characterized RFP as an attractive site for manufacturers and other businesses (Denver Post, 1992). Private industry could relocate to existing buildings and use existing equipment at RFP, after necessary decontamination is complete (Boulder Daily Camera, 1992). One organization working to achieve this objective is the Rocky Flats Local Impacts Initiative (RFLII). This group is comprised of representatives from local businesses and government agencies and has been formed to develop a strategy to transform future changes at RFP into economic, socioeconomic, educational, land use, environmental, and infrastructural advantages. One of this group's goals is to work with the DOE and local economic development agencies to identify and attract businesses to occupy existing buildings at RFP (RFLII, 1992).

Future land use of the RFP Site will be also impacted as result of the DOE RFP Mission Transition Management Plan (DOE, 1992a). The Transition Plan indicates that the future plant site uses will change to include alternative uses. Additionally, the Transition Plan discusses economic development of the plant site. The DOE Rocky Flats Office opened an Economic Development Office in July 1992. The purpose of this Office is to identify and implement opportunities for economic development at RFP with the ultimate goal of retaining and using the unique technologies and capabilities of RFP and its skilled workforce. Commercialization of any facility at the plant will be coordinated closely with the community through the RFLII (DOE, 1992b).

Though still in its preliminary stages of development, the Transition Plan indicates that alternative uses of the plant site could emulate the industrial setting presently in place. As a result, it is very possible that population potentially exposed to materials at OU4, in a plausible future use scenario will be workers producing products that employ RFPs unique technologies and capabilities.

When the Atomic Energy Commission (AEC) acquired the undeveloped land surrounding the production area, it established plans to preserve the land as open space (AEC, 1972). It is plausible that the buffer zone and OU4 area will be preserved as open space. However, this is only one of several potential uses under consideration for the buffer zone. The buffer zone is being considered as a potential ecological preserve or National Environmental Research Park.

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

Ecological surveys of the buffer zone, performed as part of the RFI/RI process and for compliance with the Endangered Species Act, have indicated the high quality of habitats at RFP and the documented or potential presence of several species of special concern. Additional surveys are ongoing to identify and provide protection of any threatened and endangered species at the site, if necessary (EG&G, 1992b). Because the buffer zone has not been impacted by commercial development for many years, progressive re-establishment of native habitats has occurred. Thus the future use of this area as an ecological reserve is reasonable and consistent with DOE policy and plans (DOE, 1992). This type of use is also consistent with the Jefferson County Planning Department's recommendations for the provision of large amounts of undeveloped land in the area (Jefferson County, 1990). An ecological reserve is also consistent with the Jefferson County Planning Department's recommendations to preserve large amounts of undeveloped land in the area of RFP (Jefferson County, 1990). However, other uses of the buffer zone may also be considered the mission of RFP as it continues to change. Future uses of the buffer zone are uncertain at this time.

The limited availability of water is also a factor affecting development of the RFP area, as with all of the Denver metropolitan area. The Denver Water Board (DWB) controls most of the metropolitan water supply and currently provides much of the suburban area's water. DWB, however, is under no obligation to supply water to the suburbs, making the future supply questionable (Jefferson County, 1989). The amount of industrial development expected in the area surrounding RFP will also result in competition for water. In addition, existing facilities within RFP are already served by municipal water supplies from the City of Golden, increasing the likelihood that existing structures will be targeted for use by industry and business.

In summary, future land use of OU4 cannot be definitively predicted. However, considering the information presented above, future land use of OU4 will generally follow existing land-use patters and will likely involve industrial office or open-space uses.

3.4 QUALITATIVE EVALUATION OF POTENTIAL RECEPTORS

Current and future human population groups on and near the site are potential candidates for evaluation based on their likelihood of exposure to site-related chemicals of concern. EPA guidance does not require an exhaustive assessment of every potential receptor and exposure scenario (EPA, 1992a). Rather, the RME should be evaluated, along with an assessment of any associated uncertainty (EPA, 1989a).

The current pattern of land use and the likelihood of future land uses are summarized in Table 3.3. The probability of future land-use scenarios is defined in terms of increasing credibility, as follows: improbable (unlikely to occur); plausible (conceivable, though not expected); and credible (believable with reasonable grounds).

Future onsite uses for agriculture and residential communities and future offsite use as an ecological reserve are classified as improbable. Future agricultural use of OU4, as it presently exists is considered improbable because:

- Growth pressures on water and land resources from planned offsite development, as discussed in Section 3.2.2;

- Competition with more credible future onsite land uses (e.g., ecological reserve, industrial), as noted in Section 3.3.2;

- The physical structures of the asphalt ponds and the steep terrain in much of OU4 would make it difficult to cultivate or graze livestock, and

- Other future land uses (e.g., ecological reserve, industry are more likely as noted in Section 3.3.2.

Future onsite residential use of OU4, as it presently exists, is classified as improbable for multiple reasons, as summarized below:

- The physical structures of the asphalt ponds make a large portion of the level ground in OU4 unsuitable for housing construction;

- Inconsistency with planned offsite industrial and commercial development of the area;

- Unattractiveness for residential development because of proximity to current and future industrial uses, including RFP facilities and the Jefferson County Airport;

- Limited water resources for residential development;

- Inconsistency with proposed onsite uses for the buffer zone (e.g., ecological open space) and the current developed areas (e.g., industrial use); and

- Consistent with the transition and economic development plans which emphasize use of Rocky Flats unique technological facilities and skilled workforce.

Future offsite use of the immediate area surrounding RFP as an ecological reserve is designated as improbable based on:

- Projected offsite industrial and commercial development of the area; and

- Unattractiveness of the area as an ecological reserve because the native habitat has been largely disturbed by current agricultural, grazing, and development activities.

Future offsite agricultural land uses are identified as plausible (as opposed to credible) because it is believed that current agricultural areas will be phased out because of Front Range development and associated demands and increasing costs on land and water resources. Future offsite land uses for residential communities, commercial/industrial development, and recreational activities are identified in Table 3.3 as credible exposure scenarios. It is expected that the portion of the plant where buildings now exist will continue to be industrial, and the buffer zone will remain undisturbed due to the reasons outlined in Sections 3.2 and 3.3. These reasons are:

- Future offsite land use plans point toward continued agricultural, low-density residential and open space usage around the plant;
- Private industry is expected to occupy the buildings in the industrial onsite areas;
- It would be advantageous to keep the buffer zone surrounding the industrialized onsite area as an ecological preserve/open space due to its unique nature; and
- Residential development is relatively unattractive, as discussed previously.

Offsite residential, commercial/industrial, and recreational exposure scenarios are considered credible in the future because they currently exist offsite.

3.5 RECEPTORS SELECTED FOR QUALITATIVE RISK ASSESSMENT

As noted in Section 3.4, exposure scenarios that are more credible are more appropriate candidates for quantitative assessment in the HHRA. Additionally, where multiple scenarios are credible, not all need to be analyzed, because those scenarios having less potential exposure will be bounded by those having greater potential exposure. Scenarios having a greater potential exposure may be determined based on various factors, including exposure route, exposure frequency and duration, and contact rates. Exposure scenarios selected for quantitative evaluation and the basis for their selection are presented in Table 3.4. Current onsite workers, current offsite residents, hypothetical future onsite workers, and hypothetical future onsite ecological researchers, hypothetical future onsite construction workers, and future hypothetical offsite residents are included among the receptor scenarios to be quantitatively evaluated on the basis of their credibility and representative or bounding exposure potential. While a future hypothetical onsite resident has been shown to be improbable, this exposure scenario has also been retained for quantitative evaluation so that the full range of risks can be examined as required by the regulatory agencies. The future hypothetical onsite construction worker is evaluated in association with the development/maintenance activities which could be required to modify the site for commercial use, residential use, or for use as an ecological reserve. Each of these receptor scenarios is described in further detail below.

Exposure points for these receptors are shown in Figure 3-7. The current onsite worker and the hypothetical future onsite resident, worker, construction worker, and ecological researcher are all located within the boundaries of OU4. While the hypothetical future onsite worker is a credible exposure scenario, this receptor category is more likely to have an exposure location within the existing developed area of the plant site because of its existing infrastructure of facilities and utilities. The future hypothetical onsite resident and ecological worker may be more likely to have exposure locations which are relegated to areas in OU4 where such development is most feasible. Exposure sources will be characterized by aggregating data into two groups to characterize the Solar Ponds area and the hillside areas as separate exposure source areas.

3.5.1 Current Onsite Worker

The HHRA will evaluate current onsite workers who work within OU4. Such workers may include workers who are responsible for operations/maintenance of the ponds; guards and/or surveillance personnel; truck drivers and delivery personnel; and workers in the storage area for non-recyclable materials and the hazardous waste satellite collection area. Exposure data have been collected for such workers over-time. These data are presented in Appendix A. A preliminary analysis of the exposure data is also presented in Appendix A.

In addition, employees use the roadway below the ponds and hillside for recreational jogging and walking. This roadway is fenced on both sides precluding joggers or runners from entering into OU4. However, the amount of time per day that a person walking or jogging along the path by OU4 is estimated to be 5-10 minutes, at a maximum. This is considerably less potential exposure than may be experienced by individuals who spend most of their workday in the vicinity of OU4. The present Solar Ponds maintenance/operations worker was selected as the current onsite worker to be evaluated quantitatively in the HHRA. Consequently, the risks of jogging or walking near OU4 are considered to be much less than potentially experienced by the current Solar Ponds maintenance worker. The maintenance/operation worker may have the greatest potential for exposure in OU4 based upon consideration of relative exposure frequency, duration, and contact rates compared to other workers who enter into the OU4 area.

EG&G Rocky Flats Plant, Inc. (EG&G) Health and Safety (H&S) activities at RFP are directed by the Associate General Manager for Support Operations and supported by several divisions, including Radiological Operations, Occupational Safety, Health and Safety Area Engineering, Industrial Hygiene, Radiological Engineering, and Occupational Health (EG&G, 1990). For environmental restoration work at RFP, EG&G and DOE have adopted the federal Occupational Safety and Health Administration's (OSHA) standards for hazardous-waste site workers (EG&G, 1990). EG&G has superseded some of the OSHA standards with more stringent policies established by EG&G, DOE, or other governmental agencies (EG&G, 1990). At RFP, H&S programs are written for everyday activities as well as specific projects. All EG&G subcontractors must prepare their own site/project-specific H&S plans and must require and enforce standards at least as stringent as those of EG&G (EG&G, 1990).

Programs at RFP that support the H&S plans and programs include radiation protection, emergency response, occupational safety, vehicular and pedestrian safety, fire protection, and contractor safety (EG&G, 1992c). The written programs contain the requirements and procedures to be followed to ensure a work environment that is free from exposure to chemical, physical, and biological hazards (EG&G, 1992c). Workers at RFP potentially exposed to radionuclides, including those around OU4, are governed by DOE Order 5480.11, *Radiation Protection for Occupational Exposures* (DOE, 1988). Order 5480.11 prescribes practices to implement DOE's policy with respect to workers at DOE facilities. This policy establishes radiation protection standards that are consistent with approved guidance to federal agencies promulgated by the EPA and based on the recommendations by authoritative organizations including the National Council on Radiation Protection (NCRP) and the International Council on Radiation Protection (ICRP) (DOE, 1988). Additionally, responsibility for all aspects of compliance with the programs and plans is established, and an audit program is in place to evaluate whether compliance is in effect. RFP personnel are trained in personal hygiene and safety, use of protective clothing, and emergency response procedures. The H&S of current workers at RFP is thoroughly monitored, with required baseline, annual, and exit physical examinations. The exposure of these workers to chemicals of concern is controlled and limited by monitoring to acceptable levels and is ensured by reporting requirements. Industrial hygiene monitoring, monitoring during sampling activities in OU4 and external dosimetry data for workers employed in the Solar Ponds Area at RFP are presented in Appendices A, B, and C respectively. The present Solar Ponds maintenance/operations worker was selected as the current onsite worker to be evaluated on the basis of his greater potential for exposure considering exposure frequency, duration, and contact rates.

It is understood that methods and guidelines established for regulating exposures to radionuclides in occupational settings are not appropriate for use in a BRA for RCRA or CERCLA sites. However, the *Risk Assessment Guidance for Superfund* (EPA, 1989a), Chapter 10 describes a two-phase evaluation for radiation risk assessment which includes a calculation of dose equivalents and subsequent comparison to radiation protection standards and criteria. Consequently, the preceding discussion of H&S programs, including radiation protection, at RFP is considered a relevant addition to this TM4.

3.5.2 Current Offsite Resident

The HHRA will evaluate current offsite residents at existing locations, since the public is restricted from access to RFP. Present levels of security at RFP include fencing, armed security patrols, and modern electronic security and surveillance systems. Fencing is posted to warn potential intruders that they are trespassing on federal property and, if caught, will be arrested. Plant security personnel report that there have been no incidents of trespassing in the buffer zone in the past seven years. Thus, even if trespassing were to occur at RFP, it is highly unlikely that such events would occur repeatedly for the same individual.

This scenario will evaluate the reasonable maximum risk to the present residential population. Two existing residential locations are selected for evaluation as shown in Figure 3-7. These locations correspond to the most reasonable locations for maximum exposures based on their proximity to the site and the direction of prevailing winds. They are also expected to be representative of future residential exposures because future industrial/commercial land use plans for the area exclude the likelihood of any significant additional residential development.

Some insight into the exposure potential for offsite residents from OU4 can be gleaned from the radiation dose assessments presented in the RFP Site Environmental Report for 1991. In that report a conservative radiation dose assessment based on monitoring data from air, water, and soil sampling programs is presented. The conservatively estimated maximum individual dose from all pathways (for 1991) was 0.32 mrem (effective dose equivalent [EDE]) (EG&G, 1992). This dose, when contrasted with the ICRP and NCRP recommended standard of 100 mrem, demonstrates that RFP as a whole is well within compliance with consensus standards. An additional comparison with the estimated annual natural background individual radiation dose for the Denver Metropolitan Area of 350 mrem EDE indicates that the dose attributable to RFP is less than 1/1000 of an individual's background dose (EG&G, 1992a).

3.5.3 Future Onsite Worker

The HHRA will evaluate future onsite workers. Based on the future industrial development plans in the area, the worker will be assumed to be an industrial or office worker. The location of this receptor is shown in Figure 3-7. As discussed in Section 3.3.2, it is expected that desirable locations for future development of commercial facilities will be in close proximity to existing structures and utilities. Thus, the more likely location of the hypothetical future onsite worker is within the currently developed area of the plant site. However, the exposure location for this hypothetical receptor is conservatively assumed to be within the boundaries of OU4.

It is also assumed that the future onsite worker may or may not be a "radiation worker" as defined by DOE Order 5480.11 (DOE, 1988). Thus, effective dose equivalents, computed in accordance with U.S. EPA risk assessment guidance, will be compared to the 5 mrem/year radiation worker guideline and to the 100 mrem/year guideline for exposure to members of the public (EPA, 1989a-Chapter 10; NCRP, 1987). This approach is consistent with U.S. EPA guidelines for the performance of *Risk Assessments for Radionuclides* (EPA, 1992a - Chapter 10).

Based on the future industrial development plans for the area, the future onsite worker is assumed to be an industrial or office worker at an appropriate facility.

3.5.4 Future Onsite Ecological Researcher

Because the future use of onsite undeveloped areas (e.g., buffer zone) at RFP will most likely involve open space or an ecological reserve, this scenario will be evaluated for the area within OU4. The receptors in an open-space scenario would include day hikers and a research biologist/ecologist conducting area studies. Of these two potential receptors, the research biologist is likely to spend more time at the site and come in closer contact with the soils, plants, and surface water. Field work may involve kneeling or sitting on bare ground or vegetation and contacting site soils, sediments, and surface water. The day hiker would probably spend less time at the site and come in less contact with soils and surface water. Therefore, the most RME scenario in this setting is the hypothetical future ecological researcher. As with the future onsite worker, the future onsite ecological researcher may or may not be characterized as a "radiation worker" according to DOE Order 5480.11 (DOE, 1988). Effective dose equivalents will be computed for the future onsite ecological worker and compared to applicable NCRP guidelines for radiation workers and for members of the general public (EPA, 1989a; NCRP, 1987). The area applicable to this receptor is shown in Figure 3-7.

3.5.5 Future Onsite Construction Worker

A future onsite construction worker scenario will be evaluated quantitatively to represent potential exposures to workers involved in outdoor maintenance, repair, or construction activities. Potential activities for a construction worker could include trenching in site soil, installing sewer and/or other utility lines, use of machinery to bulldoze or level site soils, paving of soil surfaces, etc. It is assumed that such work would occur over a limited time period (i.e., less than seven years).

The future onsite construction worker may or may not be considered a "radiation worker" in accordance with DOE Order 5480.11 (DOE, 1988). Effective dose equivalents will be calculated for the future onsite construction worker and compared to applicable NCRP guidelines for radiation workers and for members of the general public (EPA, 1989a; NCRP, 1987).

Construction work might result in direct contact with site soil, both surface (0-3") and subsurface (>3") soils, and with vapors or dusts from site soils. It is anticipated that the exposure duration for work at OU4 would encompass periods where the worker's employment duration may be more or less frequent, as well as times when adverse weather will prohibit access to the site.

3.5.6 Hypothetical Future Onsite Resident

The HHRA will include quantification of future onsite resident exposures, though land use projections make exposures to this receptor category improbable. It is further assumed that the hypothetical future resident exposure location is within the OU4 boundaries. The future hypothetical onsite resident would be unprotected and untrained in H&S matters. Additionally, the future onsite resident is likely to spend the greatest amount of time at or near OU4 because of its proximity to the resident's home. Consequently, the future onsite resident scenario will represent the maximum frequency, duration, and level of exposure among the receptor categories evaluated and would thus be considered members of the public with respect to NCRP Report No. 91 and effective dose equivalent guidelines outline in EPA guidance for risk assessment (NCRP, 1987; EPA, 1989a).

3.5.7 Hypothetical Future Offsite Resident

The HHRA will evaluate future offsite resident exposures. The residential locations selected for existing residents (Figure 3-7) are also considered to be applicable for a future offside residential receptor. The locations correspond to the most reasonable locations for maximum exposures relative to their proximity to the site and the prevailing wind direction. The locations are also representative of future residential exposures because future industrial/commercial land use plans for the area exclude the likelihood of any significant additional residential development.

4.0 EXPOSURE PATHWAYS

This section discusses the potential release and transport of chemicals from OU4 and exposure pathways to receptor populations identified in Section 3.0.

An exposure pathway is a specific environmental route by which an individual may potentially be exposed to chemical constituents present on, or originating from, a site. An exposure pathway includes five necessary elements:

- Source of chemicals or radionuclides;
- Mechanism of chemical release;
- Environmental transport medium;
- Exposure point; and
- Human intake route.

All five elements must be present for an exposure pathway to be complete. An incomplete pathway means that no human exposure can occur. Only potentially complete and relevant pathways for the Phase I Investigation will be addressed in the HHRA for OU4. An exposure pathway is considered to be potentially complete and relevant if there are potential chemical release and transport mechanisms and receptors for that pathway.

4.1 CHEMICAL RELEASE SOURCES AND TRANSPORT MEDIA

The identified site sources at OU4 are the present Ponds and contaminated soil. The Phase I HHRA will evaluate ponds solid waste and contaminated soil at these areas as the primary sources of chemical release. A description of activities conducted at OU4 is provided in Section 2.1. Environmental media that may transport chemicals of concern from OU4 to exposure points are described below in the conceptual site model.

4.2 POTENTIALLY EXPOSED RECEPTOR POPULATIONS

Potentially exposed receptor populations selected for quantitative assessment in the baseline HHRA were characterized in Section 3.0. The following receptors were selected:

- Current onsite worker;
- Current offsite resident;

- Hypothetical future onsite worker;
- Hypothetical future onsite ecological researcher;
- Hypothetical future onsite construction worker;
- Hypothetical future onsite resident; and
- Hypothetical future offsite resident.

The current offsite resident is evaluated under current land use conditions. The future land use scenarios assume no action takes place at OU4 and estimate exposure for future receptor populations under this condition.

4.3 EXPOSURE POINTS

An exposure point is a specific location where human receptors may come in contact with site-related chemicals. Exposure points are selected so that reasonable maximum exposures will be quantitatively evaluated. Any "hot spots" that are detected at OU4 will be specifically evaluated according to existing guidance. The approach to be utilized to evaluate hot spots will be determined in the future as that methodology is currently in the developmental stages (according to OSWER Publication No. 9285.7-08, EPA, 1992d) In addition any methods to be used to address hot spots will be expected to be concurred upon and approved by the agencies. Evaluation of receptor risks at these exposure points will bound the risks for receptors at other exposure points not selected for quantitative evaluation. The following exposure points were selected based on RME of risk. The exposure point locations are shown in Figure 3-7.

4.3.1 Current Scenario

- Occupational Receptor. Present ponds worker within the boundary of OU4; and
- Residential receptor. Nearest residence to RFP (located at the southeastern corner of RFP property boundary) and nearest residence in the predominant wind direction.

4.3.1 Future Scenario

- Occupational Receptor - Hypothetical onsite worker within the boundary of OU4;
- Ecological Researcher - Hypothetical onsite ecological researcher within the boundary of OU4;

- Construction Receptor - Hypothetical onsite construction worker within the boundary of OU4;

- Residential Receptor - Hypothetical onsite resident within the boundary of OU4; and

- Residential Receptor - Hypothetical offsite resident located at nearest residence to RFP (located at the southeastern corner of RFP boundary) and at nearest residence in the predominant wind direction.

4.4 HUMAN UPTAKE MECHANISMS

A human uptake mechanism is the route by which a chemical is absorbed by the receptor. The four basic human uptake mechanisms are dermal absorption, inhalation, ingestion, and, if gamma-producing radionuclides are present, external exposures. Exposure pathways that potentially lead to these mechanisms include inhalation of volatile organic compounds (VOCs) and airborne particulates, ingestion of soil, and dermal contact with soil or surface water. These uptake mechanisms are described further in Section 5.0.

Dermal absorption of metals from contact with soil is not considered by EPA to be a significant uptake route. The *Preliminary Risk Assessment for Leadville, Colorado*, prepared by EPA Region VIII, states:

> Metals bind strongly to soil greatly reducing their bioavailability. Through complex processes, most metals form strong, stable bonds with other soil constituents that reduce the available concentration of a dissolved metal. In addition, due to polarity and solubility, metals are not absorbed well across the skin. Therefore, relative to other exposure routes, dermal absorption is expected to be inconsequential (EPA, 1989b). Additionally, according to recent EPA guidance (EPA, 1992b), dermal exposures to contaminants in soils are significant relative to oral or inhalation exposures, only when the skin surface area available for contact is significant, and only for "chemicals which have a percent absorbed exceeding about 10%." This same guidance says that the dermal absorption percentage for metal (based on cadmium) is on the order of 0.1% to 1.%, thus showing that the magnitude of exposure to metals at the site via dermal absorption will not be significant relative to other routes of exposure. Therefore, dermal exposure to metals will not be evaluated in this assessment.

For radionuclides, EPA guidance states that "dermal uptake is generally not an important route of uptake for radionuclides, which have small dermal permeability constants" (EPA, 1989b).

However, exposure to external radiation will be evaluated as a potential exposure pathway. Dermal contact with soil will be assessed quantitatively only if results of OU4 Phase I sampling programs demonstrate the presence of organic chemicals of concern in surface soils at concentrations exceeding background levels.

Although previous investigations detected VOCs in soil and sediment samples from OU4, the concentrations of the VOCs and the frequency of detection of the VOCs were minimal. In many cases, the VOC concentrations were reported as estimated values which were lower than the laboratory detection limits. In addition, potential blank contamination was also found at very low concentrations or at the laboratory detection limit (DOE, 1991b). However, if the present RFI/RI reveals the presence of VOCs in soils at OU4, this group of chemicals will be considered for inclusion as potential Chemicals of Concern (COC) quantitatively evaluated for indoor pathways and exposure scenarios for the future on-site worker and hypothetical future on-site resident.

As a preliminary screening, Preliminary Remediation Goals (PRGs) were calculated for the individual VOCs detected in previous investigations at OU4. The maximum concentrations previously detected in soils and pond sediment do not exceed the PRGs developed in Appendix C. It should be clarified that the PRG concentrations correspond to an estimated risk of 1×10^{-6} or hazard of 1.0 for each chemical, and does not consider additive risks.

The results of personal breathing zone and real time air sampling performed during water and sludge sampling and breathing zone air sampling during pondcrete puck reprocessing operations and provided in Appendices A and B. The airborne VOC exposure levels measured for the OU4 workers during this monitoring event were very low, and below applicable OSHA and ACGIH standards for the protection of workers. The greatest exposure to airborne VOCs from OU4 soils and sediments would be experienced by receptors who are in the closest proximity to the emissions source. As VOCs are dispersed into the atmosphere, the air concentrations will be diluted and the VOCs will also be subject to degradation (through photolysis and reactions with free radical species). Thus, the farther the distance between the emissions source and the receptor, the lower the potential exposure concentration for the receptor.

4.5 CONCEPTUAL SITE MODEL

Information concerning waste sources, waste constituent release and transport mechanisms, and locations of potentially exposed receptors is used in this section to develop a conceptual understanding of the site in terms of potential human exposure pathways. Figure 4-1 shows a CSM of potential human exposure pathways for OU4. As noted in Section 1.2, the nature and extent of contamination in surface water and groundwater will not be investigated until the Phase II RFI/RI. Therefore, this TM4 addresses only direct and upward exposure pathways. Potential downward pathways are shown in the CSM in order to put the current scope of analysis in context with the overall remedial action analysis.

The CSM is a schematic representation of the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors. The purpose of the CSM is to provide a framework for problem definition, identify exposure pathways that may result in human health risks, indicate data gaps, and aid in identifying appropriate remediation measures. Chemical release mechanisms, environmental transport media, and potential human intake routes to the contaminated site source materials and soil were identified for each potentially exposed receptor and are discussed below in Section 4.5.1.

As shown in the CSM, professional judgement was used to identify potentially complete and incomplete exposure pathways. All potentially complete exposure pathways, relative significance or insignificance of exposure pathways are designated on the CSM as complete exposure pathways. Quantitatively addressing potentially complete exposure pathways will provide for risk estimates that are conservative and do not underestimate actual risks.

4.5.1 Sitewide Incomplete or Negligible Exposure Pathways

As indicated on the CSM, the following OU4 exposure pathways have been determined to be incomplete or negligible for all receptors. These pathways will not be quantitatively addressed in the risk assessment.

- Inhalation of VOCs in outdoor ambient air;
- Oral intake of chemicals in vegetables and plants by site workers; and

- Direct physical contact (oral, dermal, groundshine) with *in-situ* soils at OU4 will not be evaluated for current offsite residents, since these individuals are prevented from accessing the site by existing security measures.

No other sitewide negligible or incomplete exposure pathways are believed to exist for the site. Specific exposure pathways that will be evaluated for each exposure scenario are described below by receptor.

4.5.2 Potentially Complete Exposure Pathways

4.5.2.1 Current Onsite Worker

For the purposes of this evaluation, it is assumed that the population of current onsite workers consists of those individuals involved with operations, maintenance, and surveillance of the Solar Ponds area. As indicated on the CSM, it has been determined that these current onsite workers could potentially be exposed to site-related compounds via inhalation of wind-suspended particulate matter or from the pond soil and sediment areas, as well as via direct contact with site soils. Therefore, exposures incurred via inhalation or direct contact are included in this evaluation.

Owing to the close proximity of the pond operations/maintenance workers with the Solar Pond area, it is anticipated that this population would be the most likely to incur exposure to particulate emissions from the pond soils. Because of the nature of the work on the ponds, these onsite workers would be expected to incur exposures to airborne particulates. However, the limited daily duration of exposure of workers in the pond area, the low likelihood that they will spend significant amounts of time downwind from the pond area, and the fact that current onsite workers are operating under an occupational H&S plan suggest that exposure to airborne particulates would also be relatively insignificant. To ensure that final estimates of exposure (and the associated risk) are health-conservative, potential exposure to airborne particulates will be included in the evaluation of exposures potentially incurred by the current onsite workers.

Because the current onsite workers are active in the Solar Ponds area, it is assumed that these individuals will come into direct contact with the site soils and could, therefore, incur incidental ingestion exposures as well as direct dermal contact with soils. Dermal contact would be limited to exposure to organic compounds in soil. As with inhalation exposures, the magnitude of these exposures should be mitigated since the pond workers are specifically trained and working under an occupational H&S plan. Therefore, as indicated on the CSM, these exposures are assumed to be potentially complete and are included in the assessment in order to be comprehensive and health-conservative.

External irradiation from decay of radioactive materials in contaminated surface soils (groundshine) is also a potentially complete but insignificant exposure pathway. Radioactive materials have been detected in the soil above sitewide background levels. Therefore, external radiation from groundshine will be evaluated as a potentially complete exposure pathway for the current onsite worker.

Several exposure pathways are considered to be incomplete for the current onsite worker. First, it is assumed that there will be no exposures to indoor air because there are currently no structures on the site. Exposure to VOCs in outdoor air is also considered a negligible or incomplete pathway because soil VOC levels are minimal and would be further diluted as VOCs are dispersed into the atmosphere. It is assumed that secondary exposure to soils following wind deposition of particulates will be accounted for in the assumptions used to evaluate direct exposures to site soils. Finally, all exposures incurred via ingestion of plants (particulate deposition and plant uptake) are incomplete exposure pathways because no edible crops are grown on the site for workers to ingest.

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

- Inhalation of airborne particulates;
- Incidental soil ingestion from direct contact;
- Direct dermal contact with site soils; and
- Groundshine.

4.5.2.2 Current Offsite Resident

As the CSM for the current offsite resident indicates, airborne dispersal following suspension of particulates is the primary transport mechanism from contaminated site soils to the current offsite resident. Therefore, exposures associated with exposure of the current offsite residents to site-related particulate compounds in the air or particulates deposited onto soils and vegetation are included in the evaluation.

Direct ingestion and dermal contact with site soils and onsite external irradiation from radioactive decay of radionuclides on site soils are also primary release mechanisms but are incomplete exposure pathways for offsite receptors because site access is restricted. Therefore, current offsite residents could not come into direct contact or even close proximity to contaminated soils on site. Similarly, exposure to site contaminants from consumption of vegetables that have taken up compounds directly from site soils is an incomplete pathway because offsite residents would not have access to vegetation grown onsite. Exposure to VOCs in outdoor air is not considered a complete pathway because of the very low soil VOC concentrations on-site and the fact that considerable dilution of airborne VOC levels would occur between the site and offsite resident receptor locations.

Chemicals bound to soils transported via wind as particulates represent potential inhalation, oral, and dermal exposure pathways. Current offsite residents may inhale chemicals adsorbed to airborne particulates. Homegrown garden vegetables subject to deposition of airborne particulates from the sites also represent a potentially complete ingestion pathway. Similarly, contaminated soil (from deposition of airborne particulates) provides potentially complete oral and dermal exposure pathways for this receptor. It is assumed that airborne particulates originating from OU4 soils may contain both chemical and radionuclide constituents.

Plant uptake of contaminants deposited as windblown particulates on soil may potentially occur. However, this uptake is considered to provide a potentially insignificant contribution to overall exposure for the following reasons:

- As mentioned in Section 4.4, metals and many organic compounds bind tightly to soil, thus greatly reducing their bioavailability to plants (EPA, 1991a);

- Chemical concentrations from particulates deposited on residential soil will be significantly diluted by tilling. Tilling will mix the thin layer of surface soils that are impacted by site-related contaminants in with several inches of soils that are not impacted;

- Transfer from soil to plant will again dilute any uptake into the plant; and

- Soil particles will be largely stripped of VOCs during wind transport.

For these reasons, chemical concentrations in garden vegetables that result from surface deposition of contaminated particulates are expected to be greater than those from uptake by vegetables from the soil. Therefore, current residential intake of homegrown fruits and vegetables will only be evaluated for surface deposition of particulates on plants.

In summary, potentially complete human exposure pathways for the current offsite resident include:

- Inhalation of airborne particulates;
- Soil ingestion following airborne deposition of particulates on residential soil;
- Dermal contact with soil, following airborne deposition of particulates; and
- Ingestion of fruits and vegetables following surface deposition of particulates.

4.5.2.3 Hypothetical Future Onsite Worker

In order to characterize exposures that could potentially occur should the site be developed into office buildings, this assessment includes an evaluation of a hypothetical future onsite office worker who is exposed indoors during the work day and outdoors during a lunch break.

As the CSM for the future onsite worker indicates, wind suspension and direct contact are the primary chemical release mechanisms from the site to this exposed population.

Future onsite workers may be exposed to airborne particulate matter through inhalation, settling of particles on the skin, and ingestion of a fraction of inhaled particulates. Inhalation of suspended particulates and VOCs will be examined for indoor workers at OU4 only in the event that further sampling of the soils or subsoils shows significant contamination by VOCs. Because soil VOC concentrations are very low and significant dilution occurs when VOCs are dispersed into the atmosphere, outdoor exposure to VOCs in air will not be evaluated as a complete exposure pathway. It is assumed that suspended particulate which settles on the skin is indistinguishable from the source soil and is included in the entire mass of constituents available for ingestion and dermal absorption. Dermal absorption will be evaluated only for volatile and semivolatile organic chemicals present in soils at OU4. It is assumed that workers would not consume vegetation grown onsite.

External irradiation from decay of radioactive materials in contaminated surface soils (groundshine) is also a potentially complete exposure pathway. Radioactive materials have been detected above site-wide background levels. Therefore, external radiation from direct contact with the soil will be analyzed as a potentially complete human exposure pathway for the hypothetical future onsite worker.

Exposure to radioactive materials via ingestion, oral, or dermal uptake routes, other than external irradiation, is accounted for in the other potentially complete exposure pathways described for this receptor.

In summary, potentially complete human exposure pathways for the future onsite worker are:

- Inhalation of airborne particulates;
- Incidental soil ingestion;
- Direct dermal contact with soil; and
- Groundshine.

4.5.2.4 Hypothetical Future Onsite Ecological Researcher

As the CSM indicates, it has been determined that wind suspension and direct contact are the primary release mechanisms that are part of complete exposure pathways from site soils to a future onsite ecological researcher. External radiation exposure from contaminated soils is also a potentially complete pathway.

Inhalation of indoor air is an incomplete exposure pathway for an ecological researcher because the researchers will spend their time outdoors while on site. Inhalation of VOCs in outdoor air is not considered to be a complete exposure pathway for this receptor due to the low soil VOC concentrations and subsequent dilution of VOCs dispersed into the atmosphere.

These primary release mechanisms have associated exposure routes that are potentially complete for the future ecological researcher. Chemicals bound to soils that are released via wind as particulate matter represent potential inhalation, oral, and dermal exposure pathway following deposition. Of these, exposures to airborne particulate matter via inhalation is potentially significant because the receptor is located so near the source area. As with onsite workers, it is assumed that suspended particulates which subsequently settle on the receptor's skin or are ingested, will be indistinguishable from the source soils. Consequently, this pathway will be encompassed in dermal contact with, and incidental ingestion of, soils at OU4. For direct contact with site soils, incidental ingestion is expected to be potentially significant. Relative to these ingestion exposures, dermal exposure is expected to be insignificant.

It is assumed that an ecological researcher working at RFP would not consume vegetation grown on the site. Therefore, wind deposition of particulates onto plants and subsequent uptake of these contaminants are considered to be incomplete exposure pathways for the researcher scenario.

External irradiation from decay of radioactive materials in contaminated site surface soils (groundshine) is also a potentially complete exposure pathway. Radioactive materials have been detected in the Solar Pond area soil above sitewide background levels. Therefore, external radiation from direct contact with the soil will be analyzed as a potentially complete human exposure pathway.

Exposure to radioactive chemicals via ingestion, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for this receptor.

In summary, potentially complete exposure pathways for chemicals released from contaminated site soils for the future ecological researcher are:

- Inhalation of airborne particulates;

- Incidental soil ingestion;
- Direct dermal contact with soil; and
- Groundshine.

4.5.2.5 Hypothetical Future Onsite Construction Worker

As the CSM indicates, it has been determined that wind suspension and direct contact are the primary release mechanisms that are part of complete exposure pathways from site soils to a future onsite construction worker. External radiation exposure from contaminated soils is also a potentially complete pathway.

Chemicals that volatilize from the site may be released to indoor air and outdoor air. Inhalation of indoor air is an incomplete exposure pathway for a construction worker because the workers will spend their time outdoors while on site. Inhalation of VOCs in outdoor air is not considered to be a complete exposure pathway due to the soil VOC concentrations and subsequent dilution of VOCs dispersed into the atmosphere.

These primary release mechanisms have associated exposure routes that are potentially complete for the future construction worker. Chemicals bound to soils that are released via wind as particulate matter represent potential inhalation, oral, and dermal exposure pathways following deposition. Of these, exposures to airborne particulate matter via inhalation is potentially significant because the receptor is located so near the source area. As with onsite workers, it is assumed that suspended particulates which subsequently settle on the receptor's skin or are ingested, will be indistinguishable from the source soils. Consequently, this pathway will be encompassed in dermal contact with, and incidental ingestion of, soils at OU4. For direct contact with site soils, incidental ingestion is expected to be potentially significant. Relative to these ingestion exposures, dermal exposure is expected to be insignificant. It is assumed that soils will be disturbed during construction of buildings, parking lots, or other structures. Consequently, it is likely that a construction worker in the Solar Ponds area may be exposed to constituents in surface and subsurface soils.

It is assumed that a construction worker employed at RFP would not consume vegetation grown on the site. Therefore, wind deposition of particulates onto plants and subsequent uptake of these contaminants are considered to be incomplete exposure pathways for the construction worker scenario.

External irradiation from decay of radioactive materials in contaminated site surface soils (groundshine) is also a potentially complete exposure pathway. Radioactive materials have been detected in the Solar Pond area soil above sitewide background levels. Therefore, external radiation from direct contact with the soil will be analyzed as a potentially complete but relatively insignificant human exposure pathway.

Exposure to radioactive chemicals via ingestion, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for this receptor.

In summary, potentially complete exposure pathways for chemicals released from contaminated site soils for the future construction worker are:

- Inhalation of airborne particulates;
- Incidental soil ingestion;
- Direct dermal contact with soil; and
- Groundshine.

4.5.2.6 Hypothetical Future Onsite Resident

As the CSM indicates, wind suspension, uptake of compounds into plants, and direct contact are all chemical release mechanisms that are part of complete exposure pathways from site soils to a hypothetical future onsite resident.

It is assumed that any hypothetical future residents on the site will include both adults and young children. These individuals may come into contact with chemicals and radionuclides through direct skin contact with soils (including *in-situ* soils, house dust, and suspended particulates), incidental ingestion of soils, inhalation of suspended particulates or indoor VOCs, and ingestion of homegrown fruits and vegetables. Further, inhalation of VOCs in indoor air will only be evaluated if further sampling of the soils or subsoils shows significant contamination by VOCs.

Hypothetical future onsite residents could maintain home gardens. Vegetables grown in these gardens could accumulate site-related contaminants as a result of both uptake from site soils and deposition onto exposed surfaces. Because the hypothetical future resident is assumed to live directly on the site, fruits and vegetables grown by these residents could be in direct contact with impacted soils. This maximizes the possibility that human consumption of home grown fruits and vegetables would result in potentially significant exposure to site-related chemicals. This assessment assumes that site soils are not tilled prior to planting, so no dilution of site contaminants would occur.

Deposition of particulates onto the surface of vegetables may contribute to the concentration of chemicals in a plant (Whicker, 1990). Particulate deposition and subsequent absorption or adherence to edible plant tissues in a highly complex and dynamic process. For example, deposition onto exposed portions of food crops must be balanced against removal by weathering and senescence (McKone and Daniels, 1991). A multitude of assumptions must be made to estimate atmospheric deposition of particulate bound chemicals and radionuclides and subsequent concentration in food plates. The literature (e.g., *Transuranium Elements*, EPA, 1990b) will be consulted to identify appropriate dust loading and washoff factors (i.e., water removal processes including precipitation, fog, dew, and mist) for evaluating the particulate deposition pathway. DOE will submit the proposed factors for EPA approval prior to proceeding with the development of the particulate deposition evaluation.

Although root uptake is comparatively unimportant, at least for long-lived contaminants in soils, evaluation of potential human exposure to site-related chemicals from consumption of plants will include possible root uptake to ensure that final estimates of exposure are conservative. Chemicals and radionuclides in a soil matrix may be taken up through the roots and translocated into edible portions of the plant. Uptake studies on plutonium and other transuranics have provided estimates of the relationship between plant uptake and concentration in soil. Such information can be used to estimate concentrations of radionuclides in homegrown vegetables.

Chemical-specific uptake values for non-radionuclides will be based on availability of uptake values in the literature. DOE will confer with EPA with regard to identifying appropriate uptake factors for use in evaluating the root uptake pathway.

It has been demonstrated that resuspension and deposition of particulates onto the surface of fruits and vegetables can dominate contaminant concentrations in plants (Whicker, 1990). Although root uptake is comparatively unimportant, at least for long-lived contaminants in soils, evaluation of potential human exposures to site-related chemicals from consumption of plants will include possible root uptake to ensure that final estimates of exposure are conservative.

External irradiation from decay of radioactive materials in contaminated site surface soils (groundshine) is also a potentially complete exposure pathway. Radioactive materials have been detected in the OU4 soils above sitewide background levels. Therefore, external radiation from direct contact with the soil will be analyzed as a potentially complete but relatively insignificant human exposure pathway.

Exposure to radioactive chemicals via ingestion, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for this receptor. Because soil VOCs concentrations are very low and significant dilution occurs when VOCs are dispensed into the atmosphere, outdoor exposure to VOCs in air will not be evaluated as a complete exposure pathway.

In summary, potentially complete human exposure pathways for chemicals released from contaminated site soils for the hypothetical future onsite resident are:

- Inhalation of airborne particulates and indoor VOCs;
- Ingestion of homegrown fruits and vegetables (surface deposition of particulates and root uptake of site-related chemicals);
- Incidental soil ingestion ;
- Direct dermal contact with soil; and
- Groundshine.

A summary of potentially complete exposure pathways that will be quantitatively evaluated in the baseline human health risk assessment is provided in Table 4.1.

4.5.2.7 Hypothetical Future Offsite Resident

As the CSM for the current offsite resident indicates, airborne dispersal following suspension of particulates is the primary transport mechanism from contaminated site soils to the future hypothetical offsite resident. Therefore, exposures associated with exposure of the hypothetical future offsite residents to site-related particulate compounds in the air or particulates deposited onto soils and vegetation are included in the evaluation.

The future hypothetical offsite resident will only be assumed to be exposed on the premises of their residence. Therefore, direct ingestion and dermal contact with site soils and onsite external irradiation from radioactive decay of radionuclides on site soils will be considered to be an incomplete exposure pathways for offsite receptors. Therefore, future offsite residents will not come into direct contact with, or even close proximity to, contaminated soils on site.

Similarly, exposure to site contaminants from consumption of vegetables that have taken up compounds directly from site soils in an incomplete pathway because offsite residents would not have access to vegetation grown onsite. Exposure to VOCs in outdoor air is not considered a complete pathway because of the very low soil VOC concentrations on-site and the fact that considerable dilution of airborne VOC levels would occur between the site and offsite resident receptor locations.

Chemicals bound to soils transported via wind as particulates represent potential inhalation, oral, and dermal exposure pathways. Future hypothetical offsite residents may inhale chemicals adsorbed to airborne particulates. Homegrown garden vegetables subject to deposition of airborne particulates from the sites also represent a potentially complete ingestion pathway. Similarly, contaminated soil (from deposition of airborne particulates) provides potentially complete oral and dermal exposure pathways for this receptor. It is assumed that airborne particulates originating from OU4 soils may contain both chemical and radionuclide constituents.

Plant uptake of contaminants deposited as windblown particulates on soil may potentially occur. However, this uptake is considered to provide a potentially insignificant contribution to overall exposure for the following reasons:

- As mentioned in Section 4.4, metals and many organic compounds bind tightly to soil, thus greatly reducing their bioavailability to plants (EPA, 1991a);
- Chemical concentrations from particulates deposited on residential soil will be significantly diluted by tiling. Tilling will mix the thin layer of surface souls that are impacted by site-related contaminants in with several inches of soils that are not impacted;
- Transfer from soil to plant will again dilute any uptake into the plant; and
- Soil particles will be largely stripped of VOCs during wind transport.

For these reasons, chemical concentrations in garden vegetables that result from surface deposition of contaminated particulates are expected to be greater than those from uptake by vegetables from the soil. Therefore, future residential intake of homegrown fruits and vegetables will only be evaluated for surface deposition of particulates on plants.

In summary, potentially complete human exposure pathways for the hypothetical future offsite resident include:

- Inhalation of airborne particulates;
- Soil ingestion following airborne deposition of particulates on residential soil;
- Dermal contact with soil, following airborne deposition of particulates; and
- Ingestion of fruits and vegetables following surface deposition of particulates.

5.0 ESTIMATING CHEMICAL INTAKES

This section presents reasonable maximum intake parameters for each of the receptors and exposure pathways identified in previous sections. Specific chemical intakes are not presented in this memorandum since they are dependent on pending site characterization to provide exposure point concentrations.

Using the exposure point concentrations of chemicals in soils and air, it is possible to estimate the potential human intake of those chemicals via each exposure pathway. Intakes are expressed in terms of chemical (mg)/body weight (kg)/day. Intakes are calculated following guidance in *Risk Assessment Guidance for Superfund Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors"* (EPA, 1989a) and "Calculating the Concentration Term" (EPA, 1992d), and *Exposure Factors Handbook* (EPA, 1989b), other EPA guidance documents as appropriate, and professional judgment regarding likely site-specific exposure conditions. Intakes are estimated using reasonable estimates of body weight, inhalation volume, ingestion rates, soil or food matrix effects, and frequency and duration of exposure.

Intakes are estimated for RME conditions. 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 general equation for calculating intake in terms of mg/kg/day is:

$$\text{Intake} = \frac{\text{chemical conc.} * \text{contact rate} * \text{exposure freq.} * \text{exposure duration} * \text{absorption fraction}}{\text{body weight} * \text{averaging time}}$$

$$\text{mg/kg/day} = \frac{\text{mg/vol} * \text{vol/day} * \text{day/year} * \text{year} * \%}{\text{kg} * \text{day}}$$

The variable "averaging time" is expressed in days to calculate 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 cumulative 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 of action. The approach for carcinogens is based on the current scientific opinion that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime. Therefore, for whatever exposure duration, the intake of a carcinogen is averaged over a 70-year lifetime (EPA, 1989a). Intake of noncarcinogens is averaged over the period of exposure since the average concentration of a noncarcinogen is compared with the threshold dose for an effect.

Omitting chemical concentrations from the intake equation yields an "intake factor" that is constant for each exposure pathway and receptor. The intake factor can then be multiplied by the concentration of each chemical to obtain the pathway-specific intake of that chemical. Intake factors are calculated separately for each potentially exposed receptor and exposure pathway that was identified in Section 4.5. In the case of the soil ingestion pathway, a time-weighted average intake will be developed taking into account age-specific ingestion rates and body weights for a child (0-6 years of age) and an adult (as per EPA guidance, EPA, 1991b). The assumptions used in deriving intake factors are discussed below.

5.1 INTAKE FACTOR ASSUMPTIONS

Several exposure parameters, such as exposure duration, body weight, and averaging times, have general application in all intake estimations, regardless of pathway. These general assumptions, as well as pathway-specific assumptions, are detailed in the section below. The term "occupational exposures" includes exposures to both the future onsite worker and the hypothetical future ecological researcher. In general, conservative parameter value assumptions were made in order that the resulting exposure estimates would be over-, rather than underestimated.

5.1.1 General Exposure Assumptions

- For all exposure scenarios, the RME exposure frequency has been estimated to be 5 days/week for 50 weeks/year for the current onsite worker, 7 days/week for 50 weeks/year for the current and future offsite resident (EPA, 1991b), 5 days/week for 50 weeks for the hypothetical future onsite worker (EPA, 1991b), 5 days/week for 6 weeks for a future onsite construction worker, (EPA, 1991b), and 5 days/week for 13 weeks/year for 2.5 years for the ecological researcher. Based on information from the Assistant State Climatologist for Colorado (Doesken, 1992) the 30-year average precipitation record indicates that there is at least one inch of snow cover on the ground for 60 days each year. Exposure frequencies were adjusted to account for snowfall in the area, assuming that accumulation will prevent exposure via the appropriate pathways (e.g., inhalation of particulates, dermal contact with soils).

- Residential RME exposure duration is assumed to be 30 years; for the soil ingestion pathway for existing and future resident receptors, 6 years are assumed to be spent as a child, age 0-6 years; and the remaining 24 years as an older child through adulthood. The time periods will be added for a total of 30 years residential exposure (EPA, 1991b);

- The RME exposure duration for the current ponds worker is assumed to be 5 years, based on the assumption that the solar ponds will be closed within this period. Unless better information becomes available, it is assumed that the ponds will be closed in five years and that no additional monitoring will be required for OU4.;

- The RME exposure duration for the future ecological worker is assumed to be 2.5 years, and 30 days for the future construction worker.

- Occupational RME exposure durations for hypothetical future onsite workers are assumed to be 25 years. This reasonable maximum duration is the 95th percentile duration of work at the same location (EPA, 1991b);

- Averaging time for exposure to non-carcinogenic compounds is the product of the exposure duration and the number of days in a year (365);

- Averaging time for carcinogenic effects is 70 years (25,550 days) in the reasonable maximum case; and

- The average adult body weight is assumed to be 70 kg and the average body weight of a child age 0-6 years is assumed to be 15 kg (EPA, 1989b).

5.1.2 Inhalation Assumptions

Uptake of chemicals through inhalation is a function of the volume of air inhaled per day, the exposure frequency and duration, and pulmonary deposition (for particulate inhalation). Intake factors for exposure via particulate or VOC inhalation were estimated for appropriate receptors. The following assumptions will be used to estimate exposure to COCs through this route:

- The RME respiratory volume of air for all residential receptors is assumed to be 0.83 m^3/hr (20 m^3/day). This is a suggested average value for continuous (i.e., 24-hour) exposures. Separate inhalation rates for indoor and outdoor workers of 0.63 and 1.4

m^3/hr, respectively, were incorporated for the appropriate occupational receptors (EPA, 1989b);

- Current and future onsite workers and future construction workers are assumed to be exposed to contaminants associated with OU4 for four hours of an eight hour work day;

- Future ecological workers are assumed to breathe airborne contaminant levels associated with OU4 for two hours out of an eight hour day in the field;

- Current and future residential receptors are assumed to be exposed for 24 hours/day in the RME case. This exposure frequency incorporates the health-conservative assumption that residential receptors are at home all day;

- Seventy-five percent of inhaled particles are deposited in the lung; it is assumed that all chemicals in that fraction are absorbed; and

- It is assumed that inhaled VOCs are retained in the lung and absorbed on a chemical-specific basis. Unless the toxicity factors used are based on inhalation exposure studies (e.g., RFC available) values on lung retention available from the literature will be used to determine the chemical-specific absorption value.

5.1.3 Soil Ingestion Assumptions

Uptake of chemicals via incidental ingestion of soil and dust is a function of the ingestion rate, the fraction of ingested soil or dust that is contaminated, the frequency and duration of exposure, and the bioavailability of the chemical adhered to the particulates ingested.

The calculation of an RME 30-year residential exposure to soil will be divided into two parts. First, a six-year exposure duration is evaluated for young children, thus accounting for the period of highest soil ingestion and lowest bodyweight. Second, a 24-year exposure duration is assessed for older children and adults using a lower soil ingestion rate. By time-averaging the child residential soil ingestion exposures with the exposures calculated for the adult, a child residential exposure from soil ingestion is taken into account.

Intake factors for exposure via soil ingestion were calculated for current pond workers, an adult resident, a child resident, a future hypothetical onsite ecological researcher, a hypothetical future onsite worker, a hypothetical future onsite construction worker and a hypothetical future onsite resident. The following assumptions will be used in estimating intake through this route.

- Occupational receptors are assumed to ingest 50 mg/day of soil in the RME case (EPA, 1991b);

- The calculation of a 30-year residential exposure to soil is time-averaged by assessing a six-year childhood exposure duration followed by a 24-year adult exposure duration. The six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg) (EPA, 1991b). The 24-year exposure duration is assessed for older children and adults and accounts for the period of lower soil ingestion (100 mg/day) and an adult body weight (70 kg) (EPA, 1991b);

- The fraction ingested (FI) from the contaminated source is assumed to be 0.5 for all onsite exposure scenarios. The FI of 0.5 for current onsite workers assumes that 4 hours of each day are spent in the Solar Ponds area. The FI for the future onsite worker is based on 4 hours of exposure to contaminated soil per 8-hour workday. This assumes that the onsite worker spends half his/her time at work outside. The future onsite ecological researcher and construction worker is assumed to spend 50 percent of their time in time in the area of OU4 during a career of research/construction work at RFP. Residential receptors are assumed to be exposed to contaminated soils for 50 percent of the time that they are present at their homes; and

- The matrix effect of soil on bioavailability of ingested contaminants can be significant and will be evaluated for all soil ingestion exposures on a chemical-specific basis. The matrix effect describes the reduced availability of site-related chemicals due to adsorption of chemicals to soil compared to the same chemical dose administered in solution. Chemical-specific matrix effects will be assessed once the chemicals of concern have been identified for OU4. Backup documentation and rationale for chemical specific matrix effect factors will be presented in the Toxicity Factors Technical Memorandum.

5.1.4 Homegrown Produce Ingestion Assumptions

It is assumed that contamination of homegrown produce may occur by surface deposition of particulates or by root uptake of chemicals into the plant. Human exposure to chemicals via ingestion of homegrown produce is a function of the ingestion rate, the fraction of contaminated homegrown fruits or vegetables ingested, the frequency and duration of exposure, and the amount and bioavailability of the chemical adhered to, or taken up into, and the produce ingested. An intake factor for exposure via fruits and vegetable ingestion was calculated for current and hypothetical future residential receptors. Current or future onsite workers, construction workers and ecological researchers are not expected to ingest produce from the site. The following assumptions will be used in estimating intake through this route:

- Current and hypothetical future residential receptors are assumed to ingest an average of 80,000 mg of homegrown vegetables per day and 42,000 mg of homegrown fruits per day. These ingestion rates are based on a "typical" daily ingestion of 200,000 mg of vegetables, of which 40% may be homegrown. Of the 140,000 mg of fruits "typically" consumed per day, 30% is assumed to be homegrown (EPA, 1991b). It is further assumed that these patterns of produce ingestion are constant throughout 350 days of the year.

- Homegrown fruits and vegetables are assumed to be potentially contaminated by surface deposition of airborne particulates from OU4 soils at both offsite and onsite locations. Modeled soil loading rates and washoff factors will be applied to reasonable maximum estimates of vegetable surface areas, weights, and human consumption rates to estimate chemical intake from this potential exposure pathway. For hypothetical future onsite residential exposure, it is also assumed that plants may contain site-related chemicals following root uptake. Anticipated chemical concentrations in plants will be calculated using values available in the literature; and

- The matrix effect of produce on bioavailability of ingested contaminants will be evaluated on a chemical-specific basis, and is assumed to be the same as the values used for soil ingestion where contaminants are present as a result of surface deposition.

Reductions in chemical concentrations due to washing prior to consumption, cooking, or peeling of produce are not accounted for although they may have a significant effect on concentrations. Thus, these calculations yield a health-conservative estimate of exposure.

5.1.5 Dermal Contact with Soil

Uptake of COCs through dermal contact with soil is a function of body surface area, absorbed fraction, an adherence factor that describes how much soil adheres to skin, the fraction of soil contacted that is from a contaminated source, and exposure frequency and duration. As described in the above discussion of Uptake Mechanisms (Section 4.4), dermal uptake of metals is expected to be negligible and is not addressed in this assessment. Dermal contact with soil will only be evaluated if sampling demonstrates the presence of organic compounds. The following assumptions will be used to estimate exposure to COCs through dermal contact with soil for all receptors.

- The RME exposed body surface area for all adult receptors is assumed to be 5,000 cm^2. The reasonable maximum surface area is assumed to be equivalent to face, forearms, and hands (or 25 percent of total body surface area) (EPA, 1992b);

- The absorbed fraction is the estimated fraction of organic compounds (if available) adhered to soil particles that partitions to and is absorbed through skin. This fraction is chemical-specific. Percent absorbed depends upon soil loading, organic carbon content of soil, contaminant concentration, duration of exposure, animal species used in the experiment, and whether the experiment is conducted in vitro or in vivo. The absorbed fraction will be determined on a chemical-specific basis using data available in the scientific literature;

- The soil adherence factor used is 1.0 mg/cm^2 in the RME case. This is the default value of currently recommended values for soil adherence (EPA, 1992b); and

- The matrix effect of soil on bioavailability of chemicals in soil relative to dermal exposure will be evaluated on a chemical-specific basis. Chemical-specific matrix effects will be assessed once the chemicals of concern have been identified for OU4. Backup documentation and rationale for chemical specific matrix effect factors will be presented in the Toxicity Factors Technical Memorandum.

- The fraction contacted (FC) from the contaminated medium is assumed to be 0.5, for all onsite receptors.

5.1.6 Internal Exposure to Radionuclides

Intake of radionuclides by ingestion, inhalation, or absorption (which leads to incorporating the radionuclides into the tissues and organs of the body) will result in a radiation dose to those organs as well as to surrounding tissues. This intake is a function of the radionuclide concentration and the frequency and duration of exposure to the radioactive material. Calculation of intake rates for radionuclides from the environment into the body can be made in the same manner as other nonradioactive chemicals except neither averaging time nor body weight are used as parameters. The resulting calculation is an estimate of the radionuclide intake, expressed in units of radioactivity (e.g., Bq or Ci) (EPA, 1989a).

The radiation dose from the intake of radioactive material is a function of the type of radiation emitted by the radionuclide. The dose equivalent was developed to normalize the unequal biological effects from the different types of radiation. Because radiation doses from systemically incorporated radionuclides may continue long after the intake of the nuclide has ceased, doses committed to specific organs or tissues for several decades following an intake are normally considered. These Committed Dose Equivalents (CDEs) to each organ or tissue by each systemically incorporated radionuclide are determined using Dose Conversion Factor (DCFs). DCFs correlate internal radionuclide intake with anticipated dose for many years into the future by careful consideration of biological uptake, distribution and removal along with physical properties for each nuclide. DCFs also consider radionuclide progeny when appropriate thereby providing a comprehensive correlation between total radionuclide intake and the expected dose to specific organs or tissues over time. CDEs may be summed for each radionuclide and each organ or tissue (with appropriate tissue weighing) to determine the Committed Effective Dose Equivalent (CEDE) which is readily considered in conjunction with external radiation exposure for comparison to applicable standards and regulations and consideration of health risk.

Additionally, CDE methodology has been utilized by the EPA in determination of slope factors for radionuclide carcinogenicity following internal intake. We will follow the dose calculation criteria as outlined in *Risk Assessment Guidance for Superfund* (RAGS) (EPA, 1989a) which includes both CEDE determination and slope factor calculations.

5.1.7 External Irradiation

Carcinogenic risks from exposure to external irradiation from radionuclide contaminated pond materials are determined using external source slope factors found in HEAST (EPA, 1992c). Slope factor for each radionuclide of concern correlate best estimate risks of radiation induced carcinomas with the activity concentration and time of exposure having units of risk/year per Bq or pCi/gm soil (source material). Average radionuclide activity concentrations (Bq/gm or pCi/gm) will be determined by direct measurement or model estimation as appropriate. Carcinogenic risk from external irradiation may then be estimated by multiplying appropriate slope factors for each radionuclide of concern by radionuclide activity concentrations and the correct cumulative time of exposure. One method of determining the correct cumulative time of exposure is to employ an exposure factor which adjusts a 24 hour/day 365 day/year potential exposure to more reasonable exposure times on a case by case basis. The exposure factor is analogous to an intake factor and is calculated by:

$$\text{Exposure factor} = \frac{\text{Exposure time x exposure frequency x exposure duration}}{\text{Baseline exposure time x baseline exposure frequency}}$$

Dividing of RME exposure times and exposure frequencies by the baseline values of 24 hours per day and 365 days per year accommodates exposure scenarios that are not continuous.

The total dose of radiation experienced by a receptor on OU4 is comprised of both an external (groundshine) and internal (ingestion, inhalation, dermal absorption) dose component. According to the *Risk Assessment Guidance for Superfund* (EPA, 1989a), the dose equivalent for external and internal exposures are considered to be additive. Consequently, radionuclide dose equivalents will be summed for all pathways of exposure for each receptor evaluated in the BRA.

5.2 INTAKE FACTOR CALCULATIONS

The assumptions and values described above will be used to calculate intake or exposure factors for each exposure pathway and receptor. Parameters to be used for calculations of intake and exposure factors are shown in Tables 5.1 through 5.25. Exposure point concentrations will be used with these parameters to obtain pathway-specific intakes or exposures.

Effective dose equivalents will also be calculated for potential onsite OU4 workers. The estimates of dose equivalent will be used to estimate risk.

5.2.1 Exposure Point Concentrations

The sampling results for the OU4 soils will be divided into two exposure source areas, namely: the Solar Ponds area, comprised of the surface impoundments and adjacent areas; and the Hillside area, comprised of the area below the Solar Ponds area. The rationale for categorizing the source areas is based on the differences between the two source areas with respect to the soils composition and historical areal use. The Solar Ponds area has been used for pond operation and maintenance, storage, etc, and represents an industrial area. The Hillside area has not been an active area of operations and is characterized by a steep vegetated slope. The Solar Ponds area is frequented by current site workers on a daily basis. However, current site workers do not perform daily operations or maintenance work in the Hillside area with any regular frequency.

Exposure point concentrations will be determined for the two source areas according to the EPA "Supplemental Guidance to RAGS: Calculating the Concentration Term" (EPA, 1992d; OSWER Publication No. 9285.7-081) and the Human Health Evaluation Manual Requirements (EPA, 1989a). The exposure concentration for the RME evaluation will consist of the 95 percent upper confidence level or maximum concentration detected (whichever is lower in magnitude) in the Solar Ponds area and Hillside area.

6.0 REFERENCES

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Table 3.1 Current and Projected Population in the OU4 Exposure Assessment Area

	Year 1989/2010					
Sector	D	E	F	G	H	I
1	0/0	0/0	0/0	0/0	0/0	0/0
2	0/0	0/0	0/0	0/0	0/0	0/0
3	0/0	0/0	0/0	17/17	0/0	7/7
4	0/14	283/644	46/142	50/50	215/1007	3/3
5	25/25	3671/5009	477/601	578/1879	2355/10186	469/2124

Source: DOE, 1990. *1989 Populaton, Economic, and Land Use Data for Rocky Flats Plant.*

Table 3.2 Rocky Flats Plant OU4 Current Surrounding Land Use In Jefferson County

Parcel #	Current Use/Project Name	Zoning[1]	Land Use Type
22009			
44001	Vacant	A-2	Vacant
44002			
44003	Vacant	I-1	Industrial
44004	Vacant	A-2	Vacant
44005			
44006	Vacant	I-3	Industrial
44007	Vacant	A-2	Vacant
45001			
45002	Walnut Creek Unit 1	P-D	Single Family - Detached
45002	Walnut Creek Unit 1	P-D	Retail
45003	Vacant	A-2	Vacant
45004	Single Family - Detached	A-2	Single Family - Detached
45005	Single Family - Detached	A-2	Vacant
45006	Water	A-2	Water
45007	Single Family - Detached	A-2	Single Family - Detached
45007	Single Family-Detached	A-2	Farm/Ranching
46005	Vacant	A-2	Single Family - Detached
46006	Triple C Quarter Horses	A-2	Retail
46007	Horse Barn-Boarding & Breeding	A-2	Retail
46008	Single Family - Detached	A-1	Single Family - Detached
46009	Single Family - Detached	SR-2	Single Family - Detached
46011	Mountain View Tech Center	P-D	Industrial
46012	Jefcope	P-D	Industrial
46017	Water	A-2	Water
46019	Single Family - Detached	A-2	Single Family - Detached
47036	Vacant	SR-2	Single Family - Detached
47040			
71001	Rocky Flats	A-2	Industrial
72001	Vacant	I-2	Industrial
72002	Vacant	A-2	Vacant
72003	Single Family - Detached	A-2	Single Family - Detached

Table 3.2 Rocky Flats Plant OU4 Current Surrounding Land Use In Jefferson County (cont.)

Parcel #	Current Use/Project Name	Zoning[1]	Land Use Type
22009			
72004	Vacant	I-2	Vacant
72004	Vacant	I-2	Industrial
72005	Tosco Flg 1	I-2	Industrial
72006	Rocky Flats Ind Park Flg 2	I-2	Industrial
72007	Rocky Flats Ind District Flg 1	I-2	Industrial
72008	Water Tank Ralston Val Stn 2	I-2	Utilities
72009	Vacant - Rocky Flats	A-2	Industrial
72010	Vacant	I-2	Industrial
72011	Northwest Industrial	I-2	Industrial
72012	Vacant	A-2	Vacant
72013			
73001	Vacant	A-2	Vacant
73005	Wheat Ridge Gardens	A-2	Vacant
73019	Vacant	A-1	Vacant
73020	Single Family - Detached	SR-2	Single Family - Detached
73021	Vacant	RC	Office/Retail
73022	Westminster Gardens	A-2	Single Family - Detached
99001	Great Western Aggregate Quarry	I-1	Industrial
99005	Sawmill Operation	I-2	Industrial
99006	Great Western Aggregates	I-2	Industrial
99007	Vacant	I-2	Industrial
99008	Colorado Brick Comp Clay Mine	M-C	Mining
99009	Vacant	I-2	Industrial
100001	Rock Creek Ind Park Vacant	P-D	Industrial
100002	Vacant	I-1	Industrial
100003	Rocky Flats - Vacant	I-1	Industrial
100004	Rocky Flats - Clay Extraction	M-C	Industrial
100005	Rocky Flats - Vacant	I-2	Industrial
100006	Electric Substation	M-C	Utilities
100006	Gravel Mine	M-C	Industrial
101001	Vacant	A-2	Vacant

Table 3.2 Rocky Flats Plant OU4 Current Surrounding Land Use In Jefferson County (cont.)

Parcel #	Current Use/Project Name	Zoning[1]	Land Use Type
22009			
101002	Vacant	M-C	Industrial
101003	Vacant	I-2	Industrial
101004	Mine and Water	I-2	Industrial
101005	Northwest Industrial	I-2	Industrial
101006	Vacant	M-C	Industrial
101007	Sanitary Ponds and Gravel	P-DA	Industrial
101008	Rocky Flats Lake	M-C	Water

[1] Zoning Abbreviations are as follows:

A-1	Agricultural 1
A-2	Agricultural 2
I-1	Industrial 1
I-2	Industrial 2
I-3	Industrial 3
M-C	Mineral Conservation
P-D	Planned Development
SR-2	Suburban Residential 2
RC	Restricted Commercial
P-DA	Planned Development Amended
Source:	Jefferson County

Table 3.3 Summary of Current and Future Land Uses[a,b,c]

Land Use Category	Current		Future	
	Offsite	Onsite	Offsite	Onsite
Residential	Yes	No	Credible	Improbable
Commercial/Industrial	Yes	Yes	Credible	Credible[d]
Recreational	Yes	No	Credible	Plausible[e]
Ecological Reserve	No	No	Improbable	Credible[e]
Agricultural	Yes	No	Plausible	Improbable

[a] Credible is used to indicate scenarios that may reasonably occur.
[b] Plausible is used to indicate scenarios that are conceivable, though not expected.
[c] Improbable is used to indicate scenarios that are unlikely to occur.
[d] Expected in the currently developed area of the plant site.
[e] Expected in the buffer zone.

Table 3.4 Current and Future Land Use Scenarios Retained for Quantitative Evaluation

Land Use Category	Current		Future	
	Offsite	Onsite	Offsite	Onsite
Residential	Quantitative[a]	None[d]	None[f]	Quantitative[i]
Commercial/Industrial	None[b]	Quantitative[e]	None[g]	Quantitative[jk]
Recreational	None[b]	None[d]	None[g]	None[g]
Ecological Reserve	None[b]	None[d]	None[d]	Quantitative[j]
Agricultural	None[c]	None[d]	None[h]	None[d]

[a] This current exposure scenario exists and is retained for quantitative evaluation.

[b] This current exposure scenario is judged to be bounded by the exposure of an offsite resident on the basis of exposure frequency and duration and contact rates.

[c] Current offsite agricultural land use down wind of OU4 primarily consists of horse boarding operations and intermittent cattle grazing.

[d] This land use category does not currently apply or is improbable in the future and thus is not quantitatively evaluated.

[e] This current scenario has low exposure potential, considering the comprehensive health and safety program at RFP, but is included for the sake of completeness.

[f] The current offsite residential exposure scenario is representative of the future offsite residential exposure potential.

[g] This future land use category is judged to be bounded by the exposure potential for other future onsite categories quantitatively evaluated on the basis of exposure frequency and duration and contact rates.

[h] Growth pressures of Front Range development on land and water resources and associated increasing costs indicate that future agricultural land use around RFP will diminish from current uses and thus need not be evaluated.

[i] This future land use scenario is improbable; however, it is retained for evaluation to ensure that the most conservative scenario is included in the evaluation.

[j] This future land use scenario is credible and is anticipated to have a high exposure potential based on exposrue frequency and duration and contact rates.

[k] This scenario will include both a hypothetical long-term worker as well as a hypothetical short-term construction worker.

Table 4.1 Rocky Flats Plant OU4
Potentially Complete Exposure Pathways to be Quantitatively Evaluated

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite worker	Current	Inhalation of airborne particulates Incidental soil ingestion Direct dermal contact with organic compounds in surface soil Groundshine (direct contact)
Offsite resident	Current	Inhalation of airborne particulates Soil ingestion (following deposition of particulates) Dermal contact with surface soil (following deposition of particulates) Ingestion of vegetables and fruits (following deposition of particulates)
Hypothetical onsite worker	Future	Inhalation of indoor volatile organic compounds Incidental soil ingestion Dermal contact with organic compounds in soil Groundshine (direct contact)
Hypothetical onsite ecological researcher	Future	Inhalation of airborne particulates Incidental soil ingestion Direct dermal contact with surface soil Groundshine (direct contact)
Hypothetical onsite resident	Future	Inhalation of airborne particulates and indoor volatile organic compounds Ingestion of vegetables and fruits (surface deposition of particulates and root uptake) Incidental soil ingestion Direct dermal contact with organic compounds in surface soil Groundshine (direct contact)
Hypothetical onsite construction worker	Future	Inhalation of airborne particulates Incidental soil ingestion Dermal contact with organic compounds in soil Groundshine (direct contact)
Hypothetical future offsite resident	Future	Inhalation of airborne particulates Soil ingestion (following deposition of particulates) Dermal contact with surface soil (following deposition of particulates) Ingestion of fruit and vegetables (following deposition of particulates)

Table 5.1 Soil Ingestion,
Current Onsite Worker

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
IR	=	Ingestion rate (mg/day)[a]	50
FI	=	Fraction ingested from contaminated source[b]	0.5
ME	=	Matrix effect[c]	chemical-specific
EF	=	Exposure frequency (days/year)[d, f]	205
ED	=	Exposure duration (years)[e]	5
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	1,825
		Carcinogenic	25,550

a EPA, 1991b

b Based on 4-hours of exposure to site soils per 8-hour work day.

c The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the dose of a compound (Poiger and Schlatter, 1980). These values are chemical-specific.

d EPA, 1991b. Assumes exposure at the Solar Ponds Area 5 days per week, 50 weeks per year.

e Assumes ponds to be closed within 5 years.

f The exposure frequency assumes 60 days of continuous snow cover during which there is no completed pathway of exposure to soils.

Table 5.2 Inhalation of Particulates, Current Onsite Worker

$$\text{Intake Factor} = \frac{IR \times ET \times FC \times EF \times ED \times DF}{BW \times AT}$$

		Parameter	RME
IR	=	Inhalation rate (m^3/hr)[a]	0.83
ET	=	Exposure time (hours/day)[b]	8
FI	=	Fraction inhaled from contaminated source[c]	0.5
EF	=	Exposure frequency (days/year)[d, g]	205
ED	=	Exposure duration (years)[e]	5
DF	=	Deposition factor[f]	0.75
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	1,825
		Carcinogenic	25,550

[a] This is equivalent to 20 m^3/day EPA, 1991b.

[b] The ET is based on 4 hours of exposure at the site per day.

[c] Based on 4-hours of exposure to site soils per 8-hour work day.

[d] Assumes exposure at the Solar Ponds Area 5 days per week, 50 weeks per year (EPA, 1991b).

[e] Assumes pond closure within 5 years.

[f] Seventy-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all of the chemicals in that fraction are absorbed (Hawley, 1985; EPA, 1986; ICRP, 1980).

[g] The exposure frequency assumes 60 days of continuous snow cover per year during which there is no completed pathway of exposure to soils.

Table 5.3 Dermal Contact with Organic Compounds in Surface Soil, Current Onsite Worker

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
SA	=	Surface area (cm²)[a]	5,000
AB	=	Absorption factor[b]	chemical-specific
AF	=	Adherence factor (mg/cm²)[c]	1.0
FC	=	Fraction contacted from contaminated source[d]	0.5
EF	=	Exposure frequency (days/year)[f, g]	205
ED	=	Exposure duration (years)[e]	5
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	1,825
		Carcinogenic	25,550

[a] The RME surface area is equivalent to face, forearms, and hands, or 25 percent of total body surface (EPA, 1992b). The 5,000 cm^2 represents the midpoint of the range of body surface areas for adult men and women.

[b] Absorption of metals from a soil matrix is negligible (EPA, 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be lower than 100% and will be determined on a chemical-specific basis.

[c] This is a value from the range (average to upper estimate) for soil adherence values recommended by EPA (EPA, 1992b).

[d] Based on 4 hours of exposure to soil per 8-hour workday.

[e] Assumes pond closure within 5 years.

[f] EPA, 1991b. Assumes exposure at the Solar Ponds Area 5 days per week, 50 weeks per year.

[g] The exposure frequency assumes 60 days of continuous snowcover during which there is no contact with soil.

Table 5.4 External Irradiation (Groundshine), Current Onsite Worker

$$\text{Exposure Factor} = \frac{ET \times EF \times ED \times FE}{ET_B \times EF_B}$$

		Parameter	RME
ET	=	Exposure time (hours/day)	8
FE	=	Fraction of Exposure from contaminated surface[a]	0.5
ET_B	=	Baseline exposure time (hours/day)[b]	24
ED	=	Exposure duration (years)[c]	5
EF	=	Exposure frequency (days/year)[d]	250
EF_B	=	Baseline exposure frequency (days/year)[e]	365

[a] The FE is based on 4 hours of exposure to site soils per 8-hour work day.
[b] Baseline exposure time from HEAST (EPA, 1992c).
[c] Based on continued use of the present ponds for a maximum of 5 years.
[d] EPA, 1991b. Based on the current ponds worker schedule of 5 days/week, 50 weeks per year.
[e] Baseline exposure frequency from HEAST (EPA, 1992c).

Table 5.5 Soil Ingestion, Hypothetical Future Onsite Worker

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
IR	=	Ingestion rate (mg/day)[a]	50
FI	=	Fraction ingested from contaminated source[b]	0.5
ME	=	Matrix effect[c]	chemical-specific
EF	=	Exposure frequency (days/year)[d, e]	205
ED	=	Exposure duration (years)[a]	25
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	9,125
		Carcinogenic	25,550

[a] EPA, 1991b.

[b] Based on 4-hours of exposure to site soil per 8-hour workday.

[c] The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the dose of a compound (Poiger and Schlatter, 1980). These values are chemical-specific.

[d] EPA, 1991b. Assumes the standard 250 days/year occupational exposure frequency.

[e] The exposure frequency assumes 60 days of continuous snowcover per year during which there is no completed pathway of exposure to soils.

Table 5.6 Inhalation of Particulates and Indoor Volatile Organic Compounds, Hypothetical Future Onsite Worker

$$\text{Intake Factor} = \frac{IR \times FI \times ET \times EF \times ED \times DF}{BW \times AT}$$

		Parameter	RME
IR	=	Inhalation rate (m^3/hr)[a]	0.83
ET	=	Exposure time (hours/day)[b]	8
FI	=	Fraction inhaled from contaminated source[c]	0.5
EF	=	Exposure frequency (days/year)[d, e, f]	205
EF	=	Exposure frequency (days/year)[d, g]	250
ED	=	Exposure duration (years)[a]	25
DF	=	Deposition factor[e]	0.75
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	9,125
		Carcinogenic	25,550

[a] This is equivalent to 20m^3/day (EPA, 1991b).
[b] The ET is based on an 8-hour workday.
[c] Based on 4-hours of exposure to site soils per 8-hour work day.
[d] EPA, 1991b. Assumes the standard 250 days/year occupational exposure frequency.
[e] Seventy-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all of the chemicals in that fraction are absorbed (Hawley, 1985; EPA, 1986; ICRP, 1980).
[f] The exposure frequency assumes 60 days of continuous snowcover per year during which there is no completed pathway of exposure to soils.
[g] The exposure frequency is for indoor VOCs.

**Table 5.7 Dermal Contact with Organic Compounds in Surface Soil
Hypothetical Future Onsite Worker**

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
SA	=	Surface area (cm^2)[a]	5,000
AB	=	Absorption factor[b]	chemical-specific
AF	=	Adherence factor (mg/cm^2)[c]	1.0
FC	=	Fraction contacted from contaminated source[d]	0.5
EF	=	Exposure frequency (days/year)[e, f]	205
ED	=	Exposure duration (years)[e]	25
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	9,125
		Carcinogenic	25,550

a The RME surface area is equivalent to face, forearms, and hands, or 25 percent of total body surface (EPA, 1992b). The 5,000 cm^2 represents the midpoint of the range of body surface areas for adult men and women.

b Absorption of metals from a soil matrix is negligible (EPA, 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be lower than 100% and will be determined on a chemical-specific basis.

c This is a value from the range (average to upper estimate) for soil adherence values recommended by EPA (EPA, 1992b).

d Based on 4-hours of exposure to soil per 8-hour workday.

e EPA, 1991b. Assumes the standard 250 days/year occupational exposure frequency.

f The exposure frequency assumes 60 days of continuous snowcover during which there is no contact with soils.

Table 5.8 External Irradiation (Groundshine), Hypothetical Future Onsite Worker

$$\text{Exposure Factor} = \frac{ET \times EF \times ED \times FE}{ET_B \times EF_B}$$

		Parameter	RME
ET	=	Exposure time (hours/day)	8
FE	=	Fraction of exposure from contaminated surface[a]	0.5
ET_B	=	Baseline exposure time (hours/day)[b]	24
ED	=	Exposure duration (year)[c]	25
EF	=	Exposure frequency (days/year)[d]	250
EF_B	=	Baseline exposure frequency (day/year)[e]	365

[a] The FE is based on 4 hours of exposure to site soils per 8-hour work day.
[b] Baseline exposure time from HEAST (EPA, 1992c).
[c] Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors" (EPA, 1991b).
[d] Assumes the standard 250 days/year occupational exposure frequency.
[e] Baseline exposure frequency from HEAST (EPA, 1992c).

Table 5.9 Soil Ingestion, Hypothetical Future Onsite Ecological Researcher

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
IR	=	Ingestion rate (mg/day)[a]	50
FI	=	Fraction ingested from contaminated source[b]	0.5
ME	=	Matrix effect[c]	chemical-specific
EF	=	Exposure frequency (days/year)[d]	65
ED	=	Exposure duration (years)[e]	2.5
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	912.5
		Carcinogenic	25,550

[a] EPA, 1991b.

[b] The FI assumes that, while at RFP, the ecological researchers spend time at OU4 for 4-hours during an 8-hour work day.

[c] The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of a compound (Poiger and Schlatter, 1980). These values are chemical-specific.

[d] Equivalent to 5 days/week for 13 weeks each year (field season).

[e] Based on guidance provided by IAG members.

Table 5.10 Inhalation of Particulates, Hypothetical Future Onsite Ecological Researcher

$$\text{Intake Factor} = \frac{IR \times ET \times FC \times EF \times ED \times DF}{BW \times AT}$$

		Parameter	RME
IR	=	Inhalation rate (m^3/hr)[a]	0.83
ET	=	Exposure time (hours/day)[b]	4
FC	=	Fraction from Contaminated Source[c]	0.5
EF	=	Exposure frequency (days/year)[d]	65
ED	=	Exposure duration (years)[e]	2.5
DF	=	Deposition factor [f]	0.75
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	912.5
		Carcinogenic	25,550

[a] This is equivalent to $20m^3/day$ (EPA, 1991b).
[b] The ET assumes 4 hours spent in the field during a work day.
[c] The FC assumes that, while at RFP, the ecological researchers spend time at OU4 for 4-hours during an 8-hour work day.
[d] Equivalent to 5 days/week for 13 weeks (field season).
[e] Based on guidance provided by IAG members.
[f] Seventy-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed (Hawley, 1985; EPA, 1986; ICRP, 1980).

Table 5.11 Dermal Contact with Organic Compounds in Surface Soil, Hypothetical Future Onsite Ecological Researcher

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
SA	=	Surface area (cm^2)[a]	5,000
AB	=	Absorption factor[b]	chemical-specific
AF	=	Adherence factor (mg/cm^2)[c]	1.0
FC	=	Fraction contacted from contaminated source[d]	0.5
EF	=	Exposure frequency (days/year)[e]	65
ED	=	Exposure duration (years)[f]	2.5
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	912.5
		Carcinogenic	25,550

[a] The RME surface area is equivalent to face, forearms, and hands, or 25 percent of total body surface (EPA, 1992b). The 5,000 cm^2 represents the midpoint of the range of body surface areas for adult men and women.

[b] Absorption of metals from a soil matrix is negligible (EPA, 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be lower than 100% and will be determined on a chemical-specific basis.

[c] This is a value from the range (average to upper estimate) for soil adherence values recommended by EPA (EPA, 1992b).

[d] The FC assumes that while at RFP, the ecological researchers spend time at OU4 for 4-hours during an 8-hour work day in the field.

[e] Equivalent to 5 days/week for 13 weeks (field season).

[f] Based on guidance provided by IAG members.

Table 5.12 External Irradiation (Groundshine), Hypothetical Future Onsite Ecological Researcher

$$\text{Exposure Factor} = \frac{ET \times EF \times ED \times FE}{ET_B \times EF_B}$$

		Parameter	RME
ET	=	Exposure time (hours/day)[a]	4
ET_B	=	Baseline exposure time (hours/day)[b]	24
ED	=	Exposure duration (yr)[c]	2.5
EF	=	Exposure frequency (days/yr)[d]	65
EF_B	=	Baseline exposure frequency (day/yr)[e]	365
FE	=	Fraction exposed from contaminated surface[f]	0.5

[a] Based on a 4-hour work day in the field.
[b] Baseline exposure time from HEAST (EPA, 1992c).
[c] Based on guidance provided by IAG members.
[d] Equivalent to 5 days/week for 13 weeks (field season).
[e] Baseline exposure frequency from HEAST (EPA, 1992c).
[f] The FE assumes that while at RFP, the ecological researcher spends half of his/her time at OU4.

Table 5.13 Soil Ingestion, Hypothetical Future Construction Worker

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
IR	=	Ingestion rate (mg/day)[a]	50
FI	=	Fraction ingested from contaminated source[b]	0.5
ME	=	Matrix effect[c]	chemical-specific
EF	=	Exposure frequency (days/year)[d]	30
ED	=	Exposure duration (years)[e]	1.0
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	365
		Carcinogenic	25,550

a EPA, 1991b.

b Based on 4 hours of exposure to site soils per 8 hour work day.

c The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of a compound (Poiger and Schlatter, 1980). These values are chemical-specific.

d Estimated time required to excavate the foundation for a building.

e Based on guidance provided by IAG members.

Table 5.14 Inhalation of Particulates, Hypothetical Future Onsite Construction Worker

$$\text{Intake Factor} = \frac{IR \times ET \times FC \times EF \times ED \times DF}{BW \times AT}$$

		Parameter	RME
IR	=	Inhalation rate (m^3/hr)[a]	0.83
ET	=	Exposure time (hours/day)[b]	8
FC	=	Fraction from contaminated Source[c]	0.5
EF	=	Exposure frequency (days/year)[d]	30
ED	=	Exposure duration (years)[d]	1
DF	=	Deposition factor [e]	0.75
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	365
		Carcinogenic	25,550

[a] This is equivalent to 20m^3/day (EPA 1991b).

[b] The ET assumes an 8-hour workday.

[c] Based on 4-hours of exposure in an 8-hour work day.

[d] Estimated time required to excavate the foundation for a building.

[e] Based on assumption that the worker will only be on-site for a maximum duration of seven years to represent potential subchronic exposure to the future site worker. Seventy-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed (Hawley, 1985; EPA, 1986; ICRP, 1980).

Table 5.15 Dermal Contact With Organic Compounds in Surface Soil, Hypothetical Future Onsite Construction Worker

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
SA	=	Surface area (cm^2)[a]	5,000
AB	=	Absorption factor[b]	chemical-specific
AF	=	Adherence factor (mg/cm^2)[c]	1.0
FC	=	Fraction contacted from contaminated source[d]	0.5
EF	=	Exposure frequency (days/year)[e]	30
ED	=	Exposure duration (years)	1
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	365
		Carcinogenic	25,550

[a] The RME surface area is equivalent to face, forearms, and hands, or 25 percent of total body surface (EPA, 1992b). The 5,000 cm^2 represents the midpoint of the range of body surface areas for adult men and women.

[b] Absorption of metals from a soil matrix is negligible (EPA, 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be lower than 100% and will be determined on a chemical-specific basis.

[c] This is a value from the range (average to upper estimate) for soil adherence values recommended by EPA (EPA, 1992b).

[d] Based on 4-hours exposure to site soils per 8-hour work day.

[e] Estimated time required to excavate the foundation for a building.

Table 5.16 External Irradiation (Groundshine), Hypothetical Future Onsite Construction Worker

$$\text{Exposure Factor} = \frac{ET \times EF \times ED \times FE}{ET_B \times EF_B}$$

		Parameter	RME
ET	=	Exposure time (hours/day)[a]	8
ET_B	=	Baseline exposure time (hours/day)[b]	24
ED	=	Exposure duration (yr)[c]	1
EF	=	Exposure frequency (days/yr)[c]	30
EF_B	=	Baseline exposure frequency (day/yr)[d]	365
FE	=	Fraction exposed from contaminated surface[e]	0.5

[a] The ET assumes an 8-hour work day.
[b] Baseline exposure time from HEAST.
[c] Estimated time required to excavate the foundation for a building.
[d] Baseline exposure frequency from HEAST.
[e] Based on 4-hours exposure to site soils per 8-hour work day.

Table 5.17 Soil Ingestion, Hypothetical Future Onsite Resident (Adult and Child)[a]

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

Parameter			RME Adult	RME Child
IR	=	Ingestion rate (mg/day)[b]	100	200
FI	=	Fraction ingested from contaminated source[c]	0.5	0.5
ME	=	Matrix effect[d]	chemical-specific	chemical-specific
EF	=	Exposure frequency (days/year)[b, e]	290	290
ED	=	Exposure duration (years)[b]	24	6
CF	=	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW	=	Body weight (kg)	70	15
AT	=	Averaging time (days)		
		Noncarcinogenic	8,760	2,190
		Carcinogenic	25,550	25,550

[a] The calculation of a 30-year residential exposure to soil is divided into two parts. First, a six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second, a 24-year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg). These two periods are then time-averaged (EPA, 1991b).

[b] EPA-recommended value (1991b).

[c] The RME (FI) assumes that residents are in contact with contaminated soils 50 percent of their time at home.

[d] The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. These values are chemical-specific.

[e] The exposure frequency assumes 60 days of continuous snow cover during which there is no completed pathway of exposure to soils.

Table 5.18 Ingestion of Homegrown Vegetables and Fruits, Hypothetical Future Onsite Resident

$$\text{Intake Factor} = \frac{[(IRV \times FIV) + (IRF \times FIF)] \times ME \times EF \times ED \times CF}{BW \times AT}$$

Parameter	RME
IRV: Ingestion rate, vegetables (mg/day)[a]	200,000
IRF: Ingestion rate of fruit (mg/day)[a]	140,000
FIV: Fraction of vegetables ingested from contaminated source[b]	0.4
FIF: Fraction of fruit ingested from contaminated source[c]	0.3
ME: Matrix effect	chemical-specific
EF: Exposure frequency (days/year)	350
ED: Exposure duration (years)	30
CF: Conversion factor (kg/mg)	10^{-6}
BW: Body weight (kg)	70
AT: Averaging time (days)	
Noncarcinogenic	10,950
Carcinogenic	25,550

[a] This ingestion rate is based on the typical consumption value of fruits and vegetables (EPA, 1991b).

[b] "Reasonable worst case" proportion of homegrown vegetables is 40% (EPA, 1991b).

[c] "Reasonable worst case" proportion of homegrown fruit is 30% (EPA, 1991b).

Table 5.19 Inhalation of Particulates and Indoor Volatile Organic Compounds, Hypothetical Future Onsite Resident

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF \times FC}{BW \times AT}$$

		Parameter	RME
IR	=	Inhalation rate (m^3/hr)[a]	0.83
ET	=	Exposure time (hours/day)[b]	24
EF	=	Exposure frequency (days/year)[c]	290
EF	=	Exposure frequency (days/year)[d]	230
ED	=	Exposure duration (years)[e]	30
FI	=	Fraction inhaled from contaminated source	0.5
DF	=	Deposition factor[d]	0.75
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	10,950
		Carcinogenic	25,550

[a] This is equivalent to 20 m^3/day (EPA, 1991b).

[b] This RME exposure time assumes that 24 hours per day is spent at home.

[c] The exposure frequency assumes 60 days of continuous snow cover per year during which there is no completed pathway of exposure to soils.

[d] Seventy-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all of the chemicals in that fraction are absorbed (Hawley, 1985; EPA, 1986; ICRP, 1980).

Table 5.20 Dermal Contact with Organic Compounds in Surface Soil, Hypothetical Future Onsite Resident

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
SA	=	Surface area (cm^2)[a]	5,000
AB	=	Absorption factor[b]	chemical-specific
AF	=	Adherence factor (mg/cm^2)[c]	1.0
FC	=	Fraction contacted from contaminated source[d]	0.5
EF	=	Exposure frequency (days/year)[e]	290
ED	=	Exposure duration (years)[e]	30
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	10,950
		Carcinogenic	25,550

[a] The RME surface area is equivalent to face, forearms, and hands, or 25 percent of total body surface (EPA, 1992b). The 5,000 cm^2 for adults represents the midpoint of the range of body surface areas for adult men and women. All values were taken from the Dermal Exposure Assessment: Principles and Applications.

[b] Absorption of metals from a soil matrix is negligible (EPA, 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be lower and will be determined on a chemical-specific basis.

[c] EPA, 1992b.

[d] The FC assumes that residents are in contact with chemical-containing media 50 percent of their time at home.

[e] The exposure frequency assumes 60 continuous days of snow cover per year during which there is no contact with soils.

Table 5.21 External Irradiation (Groundshine), Hypothetical Future Onsite Resident

$$\text{Exposure Factor} = \frac{ET \times EF \times ED \times FE}{ET_B \times EF_B}$$

		Parameter	RME
ET	=	Exposure time (hours/day)[a]	24
ET_B	=	Baseline exposure time (hours/day)[b]	24
ED	=	Exposure duration (yr)[c]	30
FE	=	Fraction of exposure to contaminated soils[e]	0.5
EF	=	Exposure frequency (days/yr)[c]	350
EF_B	=	Baseline exposure frequency (day/yr)[d]	365

[a] The RME exposure time assumes 24 hours per day are spent at home.
[b] Baseline exposure time from HEAST (EPA, 1992c).
[c] Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors" (EPA 1991b).
[d] Baseline exposure frequency from HEAST (EPA, 1992c).
[e] Assumes that a resident will be in contact with contaminated soils 50% of the time.

Table 5.22 Soil Ingestion, Current Offsite Resident

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME	
			Adult	Child
IR	=	Ingestion rate (mg/day)[b]	100	200
FI	=	Fraction ingested from contaminated source[c]	0.5	0.5
ME	=	Matrix effect[d]	chemical-specific	
EF	=	Exposure frequency (days/year)[b]	290	290
ED	=	Exposure duration (years)[b]	24	6
CF	=	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW	=	Body weight (kg)	70	15
AT	=	Averaging time (days)		
		Noncarcinogenic	8,760	2,190
		Carcinogenic	23,360	2,190

[a] The calculation of a 30-year residential exposure to soil is divided into two parts. First, a six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second, a 24-year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg). These two periods are then time-averaged (EPA, 1991b).

[b] The exposure frequency assumes 60 days of continuous snow cover per year during which there is no contact with soils.

[c] The RME (FI) assumes that residents are in contact with contaminated soils 50 percent of their time at home.

[d] The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. These values are chemical-specific.

Table 5.23 Ingestion of Homegrown Vegetables and Fruits, Current Offsite Resident

$$\text{Intake Factor} = \frac{[(IRV \times FIV) + (IRF \times FIF)] \times ME \times EF \times ED \times CF}{BW \times AT}$$

Parameter	RME
IRV: Ingestion rate, vegetables (mg/day)[a]	200,000
IRF: ingestion rate of fruit (mg/day)[a]	140,000
FI: Fraction ingested from contaminated source[b]	0.4
FIF: Fraction of fruit ingested from contaminated source[c]	0.3
ME: Matrix effect	chemical-specific
EF: Exposure frequency (days/year)	350
ED: Exposure duration (years)	30
CF: Conversion factor (kg/mg)	10^{-6}
BW: Body weight (kg)	70
AT: Averaging time (days)	
Noncarcinogenic	10,950
Carcinogenic	25,550

a This ingestion rate is based on the typical consumption value of fruits and vegetables (EPA, 1991b).

b "Reasonable worst case" proportion that of homegrown is 40% (EPA, 1991b).

c "Reasonable worst case" proportion that of homegrown is 30% (EPA, 1991b).

Table 5.24 Inhalation of Particulates and Volatile Organic Compounds, Current Offsite Resident

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$$

		Parameter	RME
IR	=	Inhalation rate (m^3/hr)[a]	0.83
ET	=	Exposure time (hours/day)[b]	24
EF	=	Exposure frequency (days/year)[e, f]	290
ED	=	Exposure duration (years)[c]	30
FC	=	Fraction inhaled from contaminated source[d]	0.5
DF	=	Deposition factor	0.75
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	10,950
		Carcinogenic	25,550

[a] This is equivalent to 20 m^3/day (EPA, 1991b).
[b] This RME exposure time assumes that 24 hours per day is spent at home.
[c] EPA, 1991b.
[d] Assumes that 50 percent of the air breathed by residents contains particulates or volatile organic compounds originating from soils at OU4.
[e] Seventy-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed (Hawley, 1985; EPA, 1986; ICRP, 1980).
[f] The exposure frequency assumes 60 days of continuous snow cover per year during which there is no completed pathway of exposure to soils.

Table 5.25 Dermal Contact with Organic Compounds in Surface Soil, Current Offsite Resident

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

Parameter			RME
			Adult
SA	=	Surface area (cm^2)[a]	5,000
AB	=	Absorption factor[b]	chemical-specific
AF	=	Adherence factor (mg/cm^2)[c]	1.0
FC	=	Fraction contacted from contaminated source[d]	0.5
EF	=	Exposure frequency (days/year)[e]	290
ED	=	Exposure duration (years)	30
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	10,950
		Carcinogenic	25,550

a The RME surface area is equivalent to face, forearms, and hands, or 25 percent of total body surface (EPA, 1992b). The 5,000 cm^2 for adults represents the midpoint of the range of body surface areas for adult men and women. All values were taken from the Dermal Exposure Assessment: Principles and Applications.

b Absorption of metals from a soil matrix is negligible (EPA, 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be lower than 100% and will be determined on a chemical-specific basis.

c EPA, 1992b.

d The FC assumes that residents are in contact with chemical-containing media 50 percent of their time at home.

e The exposure frequency assumes 60 days of continuous snow cover per year during which there is no contact with soils.

Table 5.26 Soil Ingestion, Hypothetical Future Offsite Resident

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME	
			Adult	Child
IR	=	Ingestion rate (mg/day)[a]	100	200
FI	=	Fraction ingested from contaminated source[b]	0.5	0.5
ME	=	Matrix effect[c]	chemical-specific	
EF	=	Exposure frequency (days/year)[d]	290	290
ED	=	Exposure duration (years)	24	6
CF	=	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW	=	Body weight (kg)	70	15
AT	=	Averaging time (days)		
		Noncarcinogenic	8,760	2,190
		Carcinogenic	23,360	2,190

[a] The calculation of a 30-year residential exposure to soil is divided into two parts. First, a six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second, a 24-year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg). These two periods are then time-averaged (EPA,1991b).

[b] The RME FI assumes that residents are in contact with contaminated soils 50 percent of their time at home.

[c] The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. These values are chemical-specific.

[d] The exposure frequency assumes 60 days of continuous snow cover per year during which there is no contact with soils.

Table 5.27 Ingestion of Homegrown Vegetables and Fruits, Hypothetical Future Offsite Resident

$$\text{Intake Factor} = \frac{[(IRV \times FIV) + (IRF \times FIF)] \times ME \times EF \times ED \times CF}{BW \times AT}$$

Parameter	RME
IRV: Ingestion rate, vegetables (mg/day)[a]	200,000
IRF: Ingestion rate of fruit (mg/day)[a]	140,000
FIV: Fraction of vegetables ingested from contaminated source[b]	0.4
FIF: Fraction of fruit ingested from contaminated source[c]	0.3
ME: Matrix effect	chemical-specific
EF: Exposure frequency (days/year)	350
ED: Exposure duration (years)	30
CF: Conversion factor (kg/mg)	10^{-6}
BW: Body weight (kg)	70
AT: Averaging time (days)	
Noncarcinogenic	10,950
Carcinogenic	25,550

a This ingestion rate is based on the typical consumption value of fruits and vegetables (EPA, 1991b).

b "Reasonable worst case" proportion of homegrown vegetables is 40% (EPA, 1991b).

c "Reasonable worst case" proportion of homegrown fruit is 30% (EPA, 1991b).

Table 5.28 Inhalation of Particulates, Hypothetical Future Offsite Resident

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$$

		Parameter	RME
IR	=	Inhalation rate (m^3/hr)[a]	0.83
ET	=	Exposure time (hours/day)[b]	24
EF	=	Exposure frequency (days/year)[c]	290
ED	=	Exposure duration (years)[d]	30
FC	=	Fraction inhaled from contaminated source[e]	0.5
DF	=	Deposition factor[f]	0.75
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	10,950
		Carcinogenic	25,550

[a] This is equivalent to 20 m^3/day (EPA, 1991b).
[b] This RME exposure time assumes that 24 hours per day is spent at home.
[c] The exposure frequency assumes 60 days of continuous snow cover per year during which there is no commpleted pathway of exposure to soils.
[d] EPA, 1991b.
[e] Assumes that 50 percent of the air breathed by residents contains particulates or volatile organic compounds originating from soils at OU4.
[f] Seventy-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed (Hawley, 1985; EPA, 1986; ICRP, 1980).

Table 5.29 Dermal Contact with Organic Compounds in Surface Soil, Hypothetical Future Offsite Resident

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

		Parameter	RME
			Adult
SA	=	Surface area (cm^2)[a]	5,000
AB	=	Absorption factor[b]	chemical-specific
AF	=	Adherence factor (mg/cm^2)[c]	1.0
FC	=	Fraction contacted from contaminated source[d]	0.5
EF	=	Exposure frequency (days/year)[e]	290
ED	=	Exposure duration (years)[c]	30
CF	=	Conversion factor (kg/mg)	10^{-6}
BW	=	Body weight (kg)	70
AT	=	Averaging time (days)	
		Noncarcinogenic	10,950
		Carcinogenic	25,550

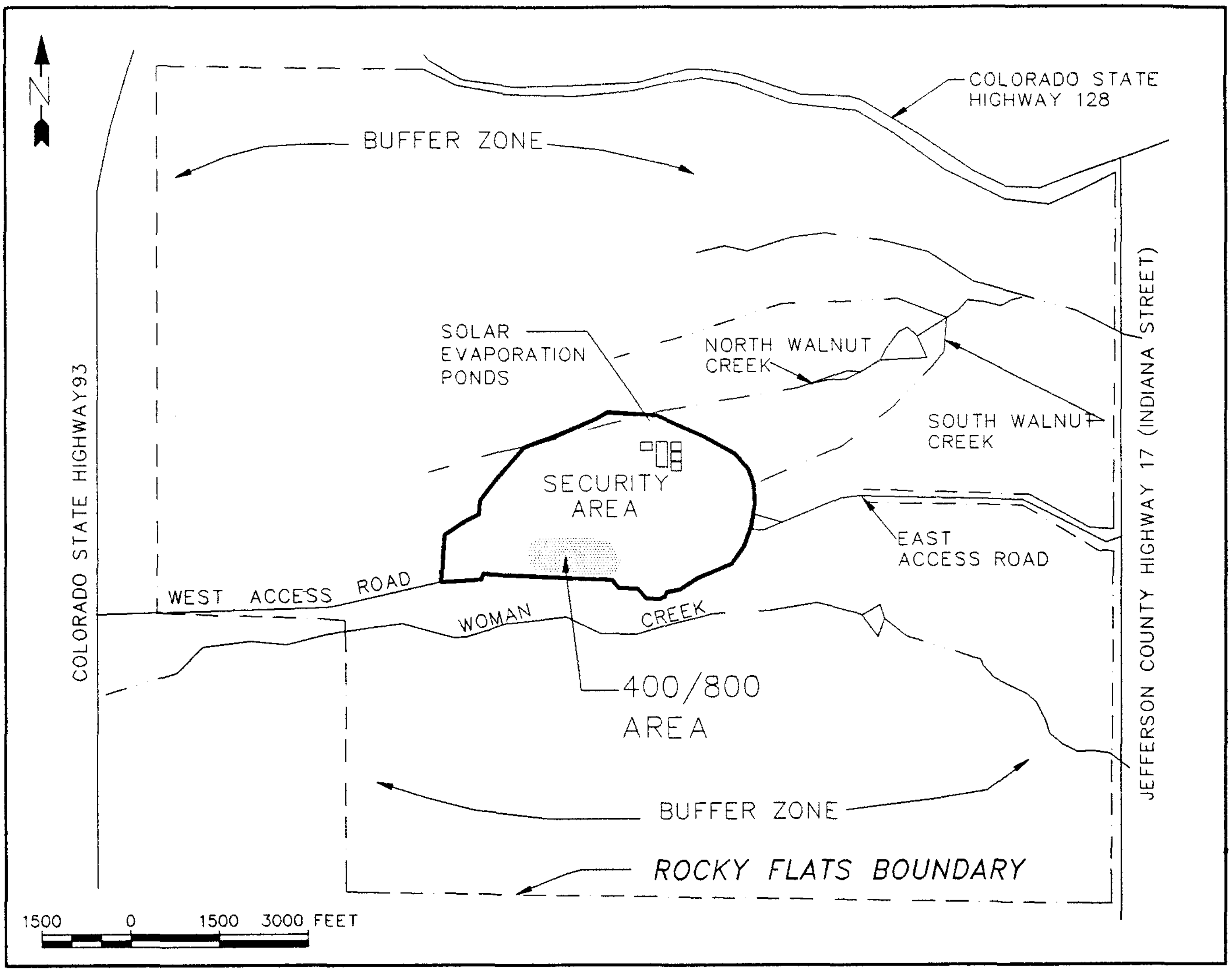
[a] The RME surface area is equivalent to face, forearms, and hands, or 25 percent of total body surface (EPA, 1992b). The 5,000 cm^2 for adults represents the midpoint of the range of body surface areas for adult men and women. All values were taken from the Dermal Exposure Assessment: Principles and Applications.

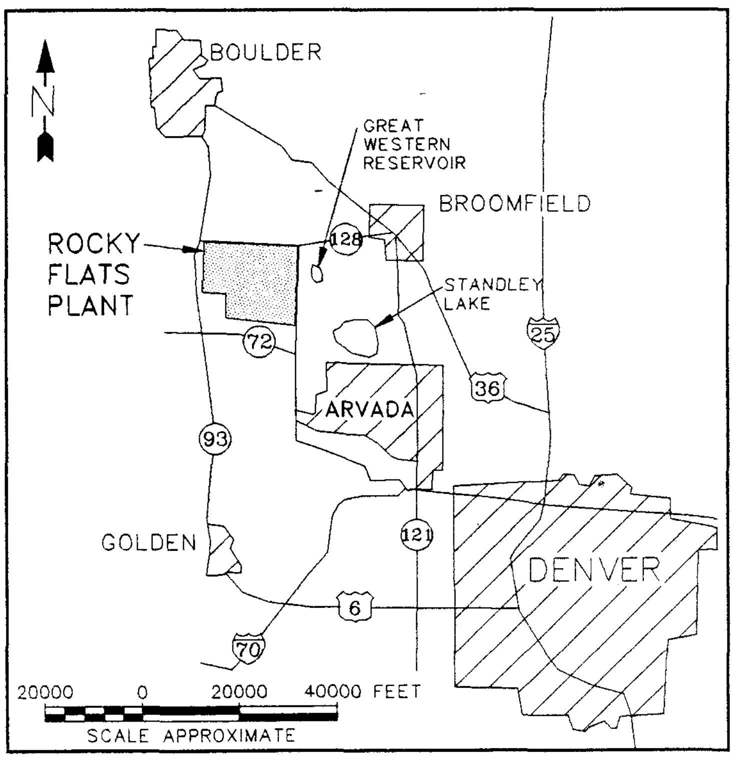
[b] Absorption of metals from a soil matrix is negligible (EPA, 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be lower than 100% and will be determined on a chemical-specific basis.

[c] EPA, 1992b.

[d] The FC assumes that residents are in contact with chemical-containing media 50 percent of their time at home.

[e] The exposure frequency assumes 60 days of continuous snow cover per year during which there is no contact with soils.





MODIFIED FROM: PHASE ONE RFI/RI WORK PLAN, OU9, EG&G 1992a

PREPARED FOR

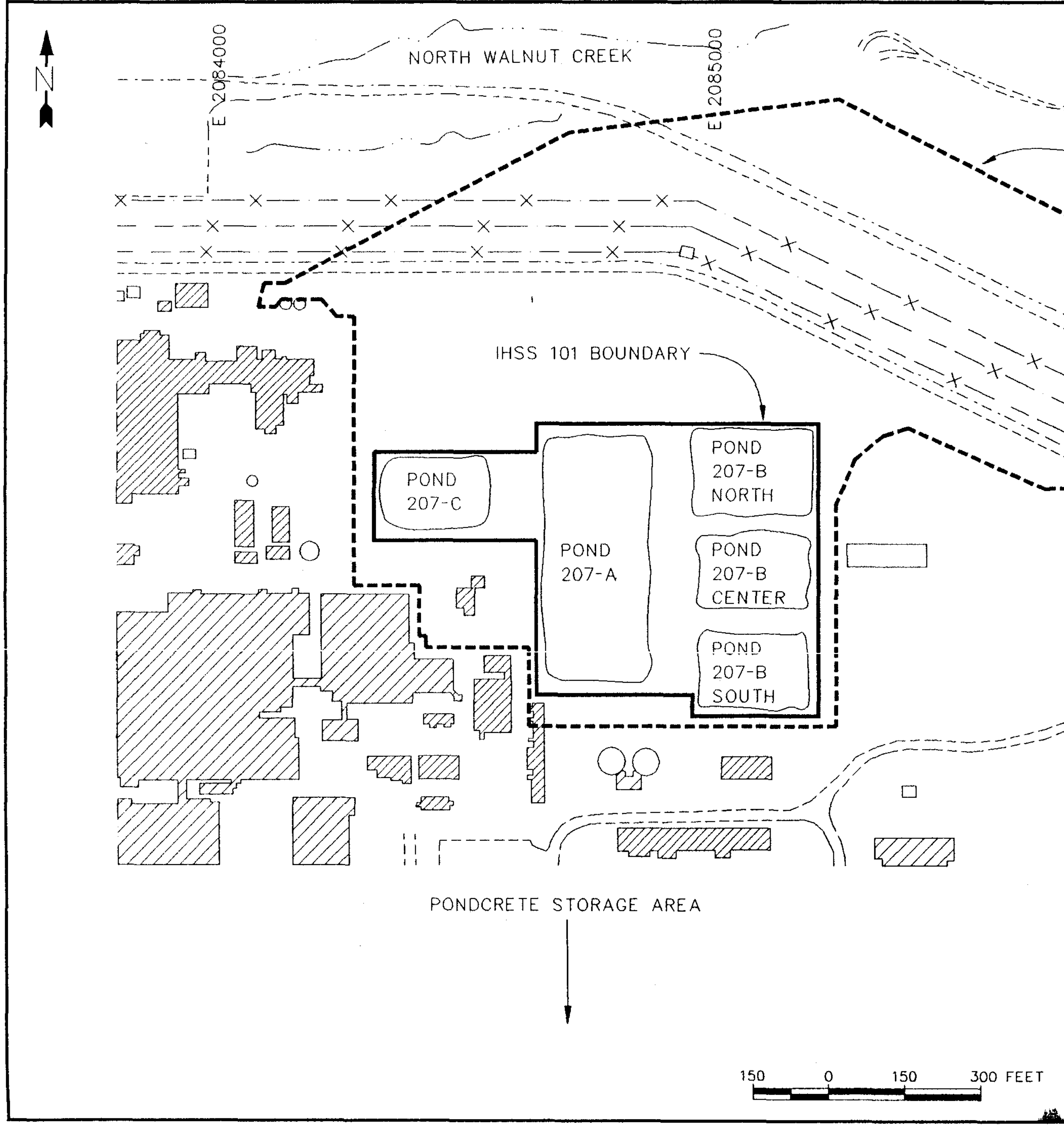
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2-1

ROCKY FLATS LOCATION MAP

REVISION NO. 0 | FILE NAME 40103\F01-101.DWG | DATE 2/10/93 | DRAWN BY EMH | APPROVED BY | CHECKED BY

CHECKED BY	APPROVED BY	DRAWN BY EMH	DATE 2/11/93	FILE NAME 40104\F03-102.DWG	REVISION NO. 0



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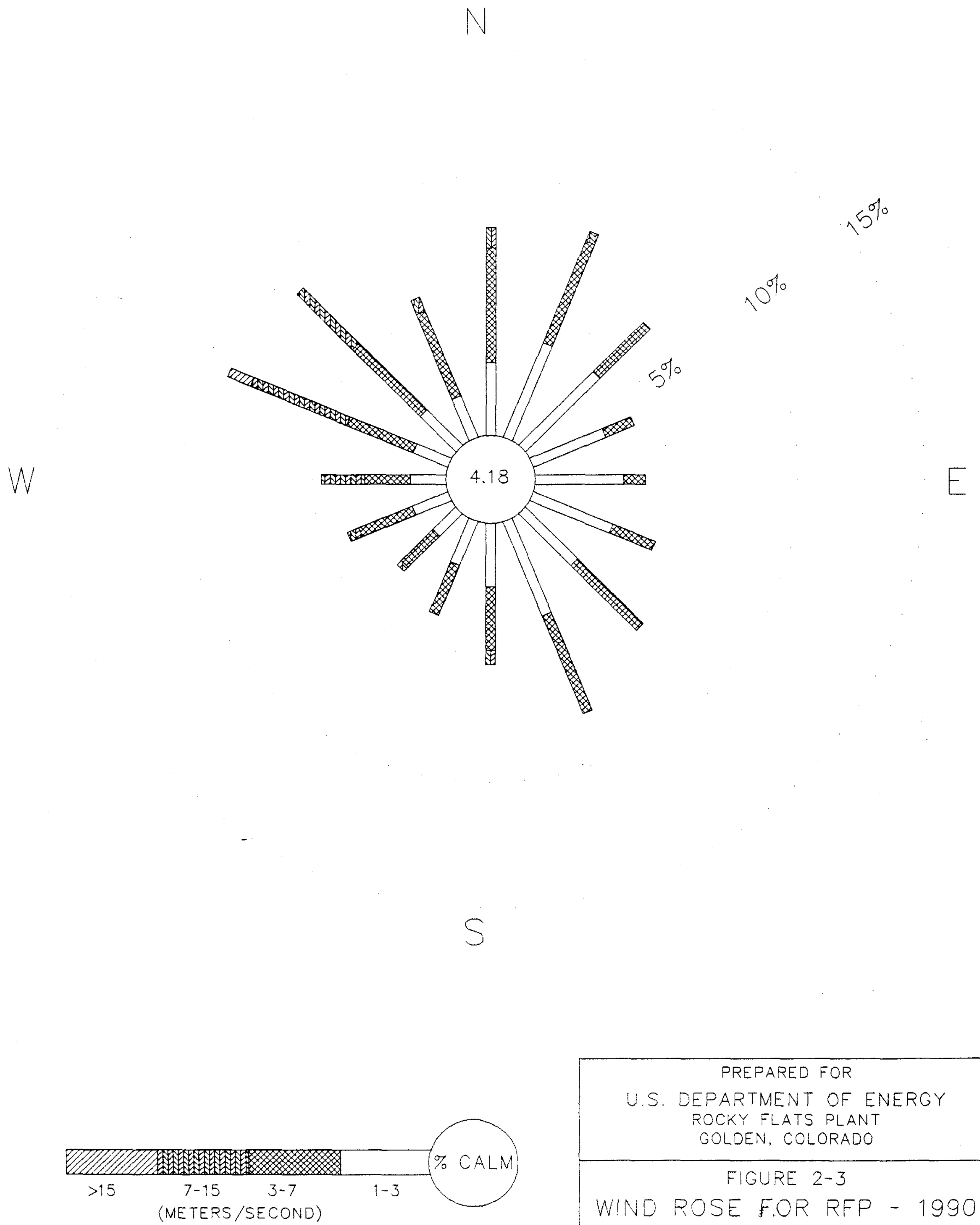
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2-2
SITE PLAN
SOLAR PONDS - OU4



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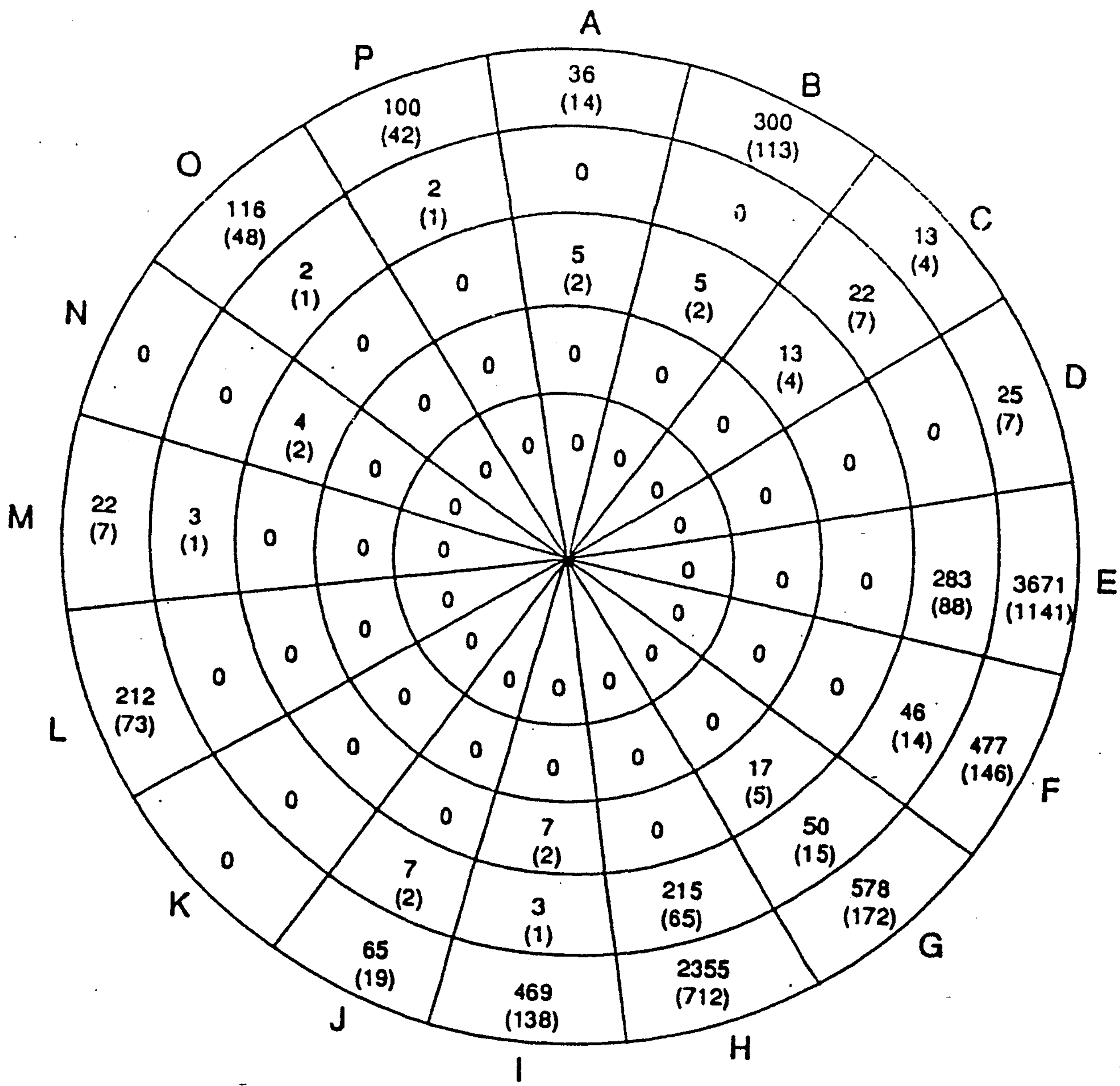
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2-3

WIND ROSE FOR RFP - 1990
0600-1900 MOUNTAIN
STANDARD TIME

REVISION NO. 0
FILE NAME 40103\F01-102.DWG
DATE 2/10/93
DRAWN BY EMH
APPROVED BY
CHECKED BY



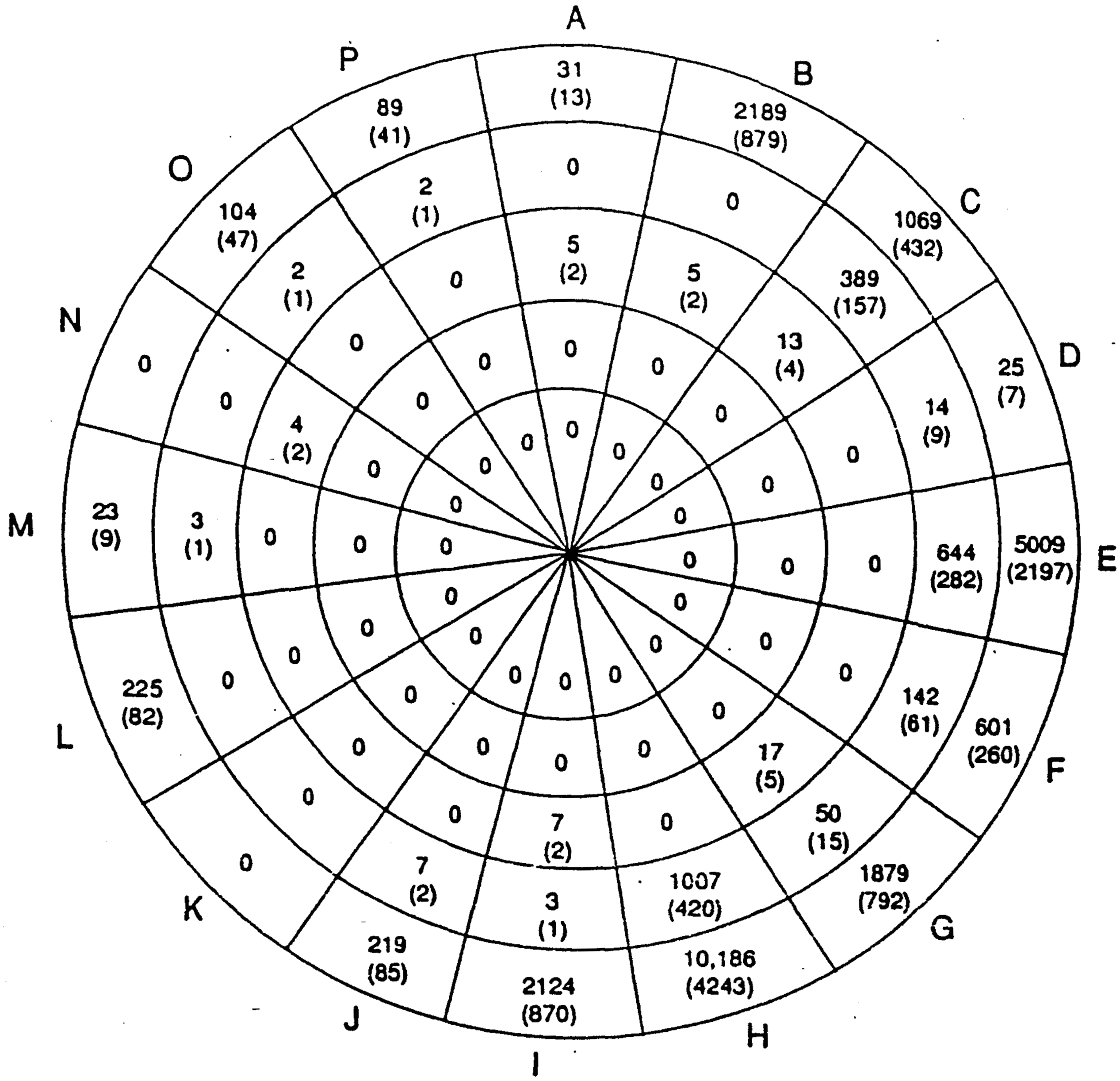
Miles	Sector Name
0-1	Sector 1
1-2	Sector 2
2-3	Sector 3
3-4	Sector 4
4-5	Sector 5

REFERENCE: DOE, 1989 POPULATION ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT (1991b)

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 3-1
1989 POPULATIONS AND (HOUSEHOLDS) SECTORS 1-5

REVISION NO. 0
FILE NAME 40103\F01-105.DWG
DATE 2/11/93
DRAWN BY EMH
APPROVED BY
CHECKED BY



Miles	Sector Name
0-1	Sector 1
1-2	Sector 2
2-3	Sector 3
3-4	Sector 4
4-5	Sector 5

REFERENCE: DOE, 1989 POPULATION ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT (1991b)

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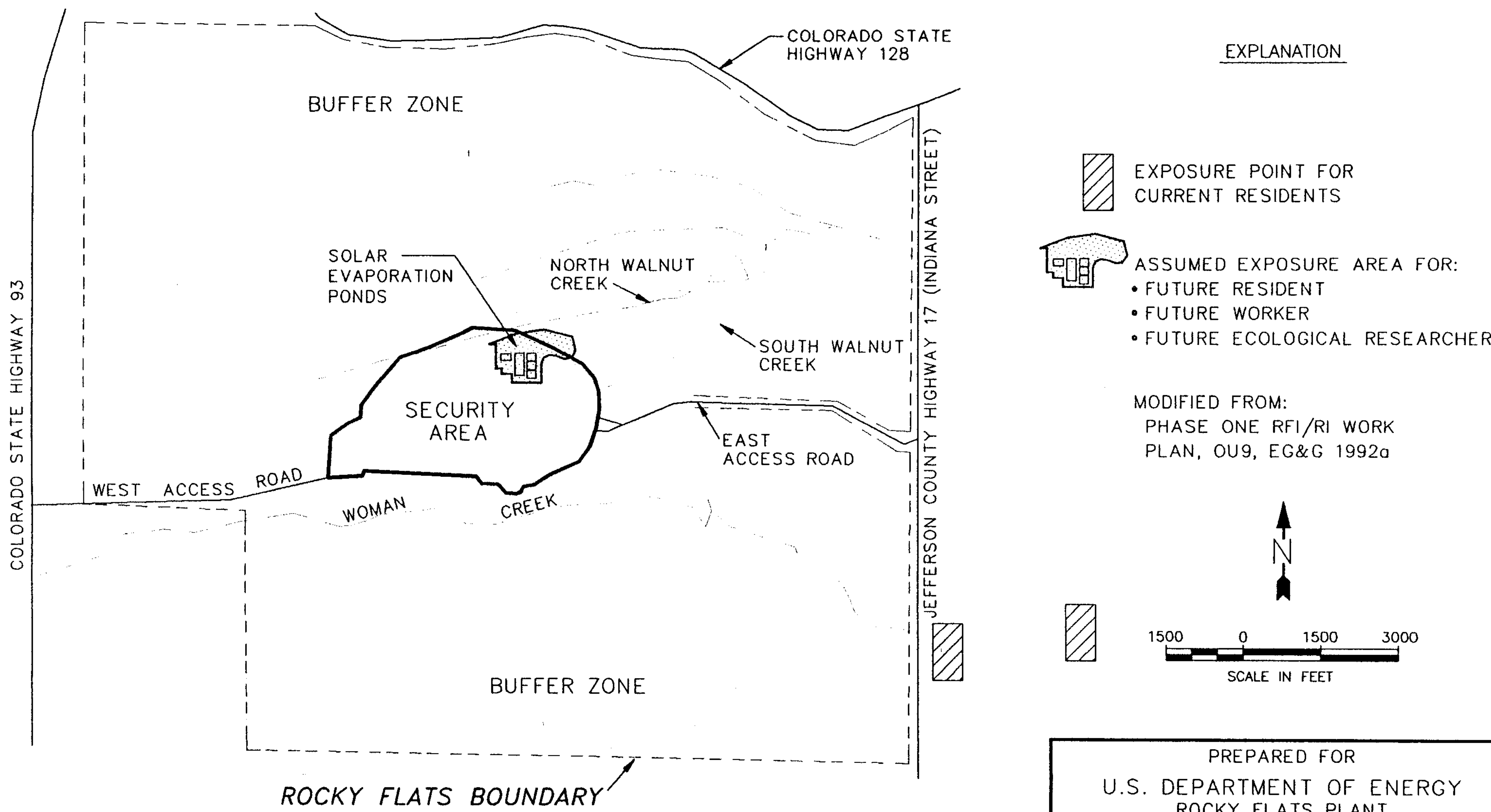
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 3-2
2010 ESTIMATED POPULATIONS AND (HOUSEHOLDS) SECTORS 1-5

REVISION NO. 0
FILE NAME 40103\F01-107.DWG
DATE 2/11/93
DRAWN BY EMH
APPROVED BY
CHECKED BY

CHECKED BY	APPROVED BY	DRAWN BY BC, MSE	DATE 05-21-93	FILE NAME RECEPTOR.DWG	REVISION NO. 1



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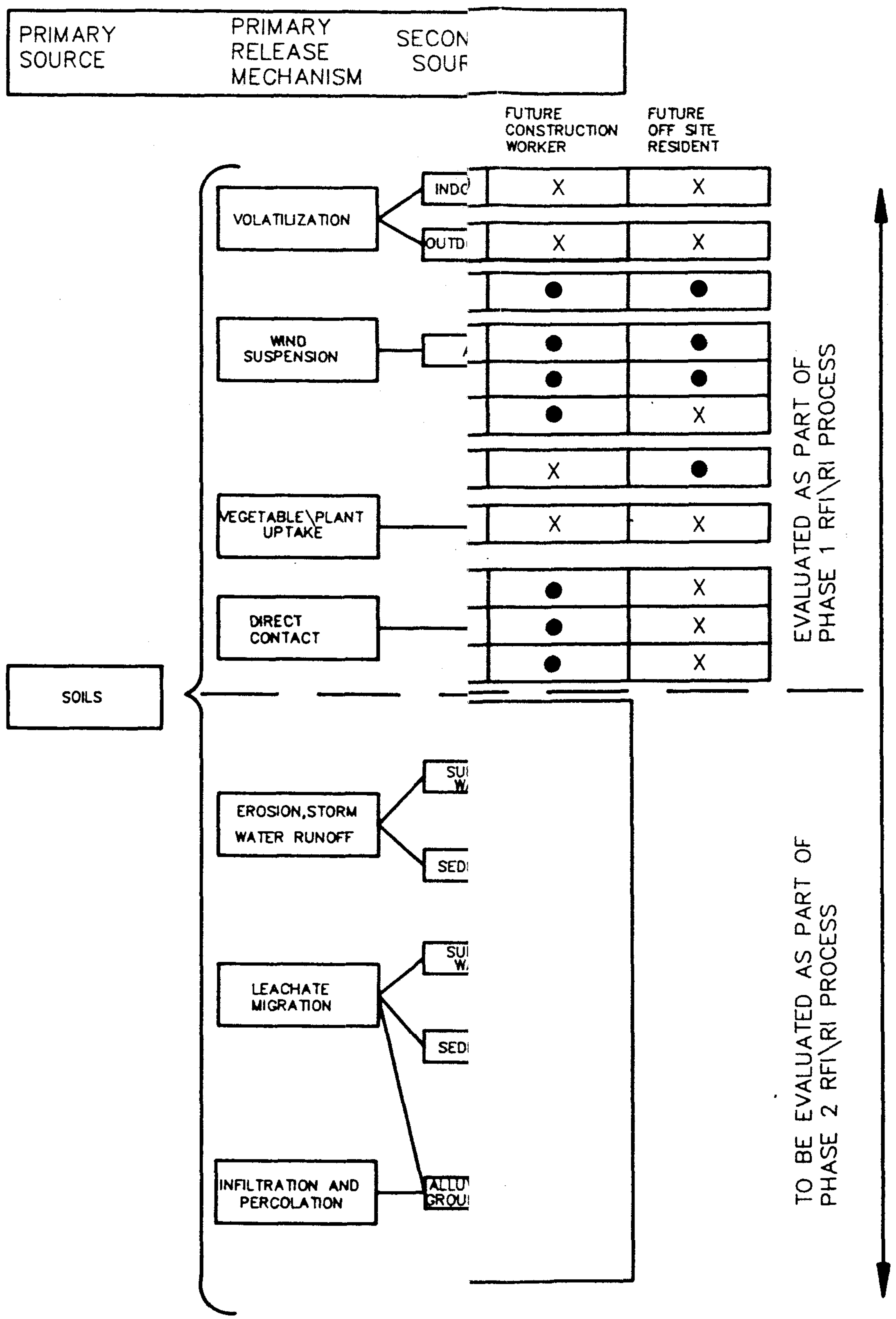
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 3-7

RECEPTOR LOCATIONS



LEGEND

● POTENTIALLY COMPLETE PATHWAY

X NEGLIGIBLE AND\OR INCOMPLETE EXPOSURE PATHWAY (U

(I) COMPLETE ONLY IF SOIL (SURFACE/SUBSURFACE) SAMPLI
VOC CONTAMINATION

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT,GOLDEN,COLORADO
OPERABLE UNIT 4
PHASE 1 RFI/RI EXPOSURE
ASSESSMENT
FIGURE 4–1 CONCEPTUAL SITE MODEL

APPENDIX A

APPENDIX A
TABLE I
PERSONAL BREATHING ZONE AIR SAMPLING SUMMARY
WATER AND SLUDGE SAMPLING AT 207 A-C SOLAR PONDS
May 13-23, 1991 and July 15-18, 1991

Agent	STD Ratio[1]	8-Hour TWA Standard[2] (mg/m³)	Range of Values			Total Personal Samples	Days Sampled Pond 207		
			207A	207B	207C		A	B	C
Acetone	<0.00006	1780	<0.10	0.0008-<0.1	<0.10-<0.11	19	1	5	3
Ammonia	<0.008	17	<0.12	<0.01-<0.12	<0.10-<0.13	22	1	6	3
Carbon Tetrachloride	<0.0016	12.6	<0.10	<0.20-<0.2	<0.10-<0.11	19	1	5	3
Ethyl Benzene	<0.0003	434	<0.10	<0.01-<0.1	<0.10-0.11	19	1	5	3
Methylene Chloride	<0.0006	174	<0.10	0.0004-<0.1	<0.10-<0.11	20	1	5	3
Methyl Ethyl Ketone	<0.0002	590	---	<0.01	<0.10	13	0	4	2
Methyl Isobutyl Ketone	<0.0005	205	<0.10	<0.01-<0.1	<0.10-<0.11	19	1	5	3
Non Polar Organics Scan	N/A	N/A	---	<0.05<0.32	---	13	0	6	0
Polar Organics Scan	N/A	N/A	<0.06	0.0004-<0.68	<0.05	24	1	7	3
1, 1, 2, 2-Tetrachloroethane	<0.016	6.9	<0.10	<0.01	<0.10-<0.11	17	1	4	3
Tetrachloroethene	<0.0006	170	<0.10	<0.01-<0.1	<0.10-<0.11	19	1	5	3
Toluene	<0.0003	375	<0.10	<0.01-<0.1	<0.10-<0.11	19	1	5	3
Trichloroethylene	<0.0004	269	---	<0.01	<0.10	13	0	4	2
TOTAL	N/A	N/A	0.0004-<0.68			236	1	7	3

NOTES:

[1] = Standard ratio refers to the ratio of 8-hour time-weighted average to the permissible exposure level. Standard ratios greater than 1.0 would indicate an exposure above the established standard. Standard ratios less than 0.5 indicate exposures less than 1/2 the established standard.

[2] = Standard refers to the most stringent published by the Occupational Safety and Health Administration (OSHA) or the American Conference of Governmental Industrial Hygienists (ACGIH).

APPENDIX A
TABLE II
REPRESENTATIVE BREATHING ZONE AIR SAMPLING SUMMARY
PONDCRETE OPERATIONS
FEBRUARY, 1990

Material Sampled	8-Hour TWA Standard/ Guideline (mg/m^3)	STEL/Ceiling (mg/m^3)	Range of Values (mg/m^3)	Building	People Samples	Days Sampled	Total Samples
Toluene	375 (1)	---	LT 2 - 6	788 750	4 6	2 3	6 6
Toluene	---	560(1)(S)	LT 4	788 750	7 6	4 3	22 22
Carbon tetrachloride	12.6(1)	NA	LT 3 - LT 9	788 750	4 6	2 3	6 6
Ethyl benzene	434 (2)	---	LT 2 - LT 5	788 750	4 6	2 3	6 6
Acetone	1780 (2)	---	LT 7 - LT 30	788 750	4 6	2 3	6 6
Acetone	---	2380 (2)(S)	LT 20	788 750	7 6	4 3	22 22
Methylene chloride	174 (2)	NA	LT 2 - LT5	788 750	4 6	2 3	6 6
1,1,2,2-tetrachloro-ethane	6.9 (2)	NA	LT 1 - LT 2	788 750	4 5	2 2	7 6
Ammonia (area only)	17 (2)	---	LT 0.6 - 8	788 750	4 3	2 2	6 6
Respirable dust	5 (1)	NA	LT 0.3 - LT 2	788 750	4 4	2 2	6 4
Unknown polar org. (areas and personals	NA	NA	ND	788 750	4 6	2 3	6 8
Hydrogen cyanide (area only)	NA	11 (1)(C)	LT 0.5 - LT 0.7	788 750	6 4	5 2	12 9
Aluminum	10 (2)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6

APPENDIX A
TABLE II
REPRESENTATIVE BREATHING ZONE AIR SAMPLING SUMMARY
PONDCRETE OPERATIONS
FEBRUARY, 1990

Material Sampled	8-Hour TWA Standard/ Guideline (mg/m^3)	STEL/Ceiling (mg/m^3)	Range of Values (mg/m^3)	Building	People Samples	Days Sampled	Total Samples
Antimony	0.5 (1)(2)	NA	LT 0.03 - LT 0.01	788 750	4 6	2 2	6 6
Arsenic	0.01 (1)	NA	LT 0.003 - LT 0.007	788 750	4 6	2 2	6 6
Barium	0.5 (1)(2)	NA	LT 0.003 - LT 0.007	788 750	4 6	2 2	6 6
Beryllium	0.002 (1)	NA	LT 0.002 - LT 0.004	788 750	4 6	2 2	6 6
Cadmium	0.05 (2)	0.05 (2)(C)	LT 0.003 - LT 0.02	788 750	7 6	4 3	26 24
Chromium	0.5 (1)(2)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6
Cobalt	0.05 (1)(2)	NA	LT 0.006 - LT 0.02	788 750	4 4	2 2	6 6
Copper	1 (1)(2)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6
Iron	5 (2)	NA	0.008 - 0.03	788 750	4 6	2 2	6 6
Lead	0.05 (2)	NA	LT 0.003 - LT 0.007	788 750	4 6	2 2	6 6
Magnesium	10 (1)(2)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6
Manganese	5 (2)	NA	LT 0.003 - LT 0.007	788 750	4 6	2 2	6 6
Molybdenum	10 (1)	NA	LT 0.003 - LT 0.007	788 750	4 6	2 2	6 6

APPENDIX A
TABLE II
REPRESENTATIVE BREATHING ZONE AIR SAMPLING SUMMARY
PONDCRETE OPERATIONS
FEBRUARY, 1990

Material Sampled	8-Hour TWA Standard/ Guideline (mg/m^3)	STEL/Ceiling (mg/m^3)	Range of Values (mg/m^3)	Building	People Samples	Days Sampled	Total Samples
Nickel	1 (1)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6
Selenium	0.2 (1)(2)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6
Silver	0.01 (1)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6
Thallium	0.1 (1)(2)	NA	LT 0.005 - LT 0.03	788 750	4 6	2 2	6 6
Tin	2 (1)(2)	NA	LT 0.003 - LT 0.007	788 750	4 6	2 2	6 6
Titanium (as titanium dioxide)	10 (1)(2)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6
Vanadium	0.05 (1)(2)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6
Zinc	10 (1)(2)	NA	LT 0.006 - LT 0.02	788 750	4 6	2 2	6 6

(1) = Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit
(2) = American Conference of Governmental and Industrial Hygienists (ACGIH) Threshold
(C) = Ceiling
(S) = Short Term Exposure Limit (STEL)
mg/m^3 = milligrams per cubic meter
NA = Not Applicable (no OSHA PEL or ACGIH TLV)

APPENDIX A
TABLE III
PERSONAL BREATHING ZONE AIR SAMPLING SUMMARY
PONDCRETE PUCK REPROCESSING OPERATIONS[1]
904 PAD, TENT 10 PERMACON
April 19, 1990 through December 11, 1990

Materials Sampled	8-Hour TWA Standard[2] (mg/m^3)	STEL/Ceiling	Range of Values (mg/m^3)	People Sampled	Days Sampled	Total Samples
Acetone	1780.0	---	<0.54 - <7.0	12	6	13
Acetone	---	2380.0	<4.0	4	2	12
Aluminum	10.0	---	<0.002 - 0.02	8	4	8
Ammonia	17.0	---	<0.01 - <4.0	6	4	6
Ammonia	---	24.0	<0.02 - <4.0	6	2	12
Antimony	0.5	---	<0.009 - <0.02	4	2	4
Arsenic	0.01	---	<0.0003 - <0.002	7	4	7
Barium	0.5	---	<0.0009 - <0.0002	4	2	4
Beryllium	0.002	---	<0.00004 - 0.0003	9	4	9
Beryllium	---	0.005	<0.0009 - 0.001	5	2	10
Cadmium	0.05	---	<0.0006 - 0.002	8	3	8
Cadmium	---	0.6	<0.005 - 0.01	5	2	10
Calcium (as calcium silicate)	10.0	---	0.020 - 0.36	7	3	7
Carbon tetrachloride	12.6	---	<0.12 - <9.0	10	5	11
Chromium	0.05	---	<0.002 - 0.008	9	4	9
Cobalt	0.05	---	<0.002 - <0.003	9	4	9
Copper	1.0	---	<0.002 - <0.003	7	4	7
Cristobalite	0.05	---	<0.03 - <0.08	5	3	5
O-Dichlorobenzene	---	300.0	<4.0 - <20.0	6	2	12
Dioctyl phlalate	N/A	N/A	<0.06 - <0.07	2	1	2
Dust, respirable	5.0	---	<0.1 - 0.76	6	4	6

APPENDIX A
TABLE III
PERSONAL BREATHING ZONE AIR SAMPLING SUMMARY
PONDCRETE PUCK REPROCESSING OPERATIONS[1]
904 PAD, TENT 10 PERMACON
April 19, 1990 through December 11, 1990

Materials Sampled	8-Hour TWA Standard[2] (mg/m^3)	STEL/Ceiling	Range of Values (mg/m^3)	People Sampled	Days Sampled	Total Samples
Dust, total	15.0	---	<0.4 - 0.63	2	1	2
Ethyl benzene	434.0	---	<0.15 - .05	9	4	10
Ethyl benzene	---	543.0	<4.0	6	2	12
Iron	1.0	---	<0.0005 - 0.054	10	5	10
Lead	0.05	---	<0.0009 - <0.006	8	3	8
Lithium (as lithium hydride)	0.025	---	<0.0009 - <0.002	4	2	4
Magnesium	10.0	---	0.0002 - 0.028	10	5	10
Manganese	5.0	---	<0.0009 - <0.002	7	4	7
Manganese	---	5.0	<0.007 - <0.007	5	2	10
Methylene chloride	174.0	---	<0.12 - 0.8	8	4	8
Methylene chloride	---	2000.0	<4.0 - <20.0	6	2	12
Methyl isobutyl ketone	205.0	---	<0.12 - <2.0	8	4	8
Molybdenum	5.0	---	<0.0009 - <0.002	4	2	4
Nickel	1.0	---	<0.002 - <0.003	9	4	9
Nitrogen dioxide	5.6	---	<0.07 - 0.14	5	2	5
Nitrogen dioxide	---	1.8	<0.001 - 0.3	6	2	12
Nitromethane	50.0	---	<2.0 - <5.43	3	2	3
Phosphorus	0.1	---	<0.003 - 0.01	4	2	4
Polar organics scan	N/A	N/A	<0.001 - 0.73	5	3	5
Quartz	0.1	---	<0.03 - <0.08	6	4	6
Selenium	0.39	---	<0.002 - <0.003	4	2	4

APPENDIX A
TABLE III
PERSONAL BREATHING ZONE AIR SAMPLING SUMMARY
PONDCRETE PUCK REPROCESSING OPERATIONS[1]
904 PAD, TENT 10 PERMACON
April 19, 1990 through December 11, 1990

Materials Sampled	8-Hour TWA Standard[2] (mg/m^3)	STEL/Ceiling	Range of Values (mg/m^3)	People Sampled	Days Sampled	Total Samples
Silver	0.01	---	<0.002 - <0.003	6	3	6
Sodium (as sodium bisulfite)	5.0	---	<0.09 - 0.2	4	2	4
1,1,2,2 - Tetrachloroethane	6.9	---	<0.12 - <0.5	7	4	7
Tetrachloroethylene (perchloroethylene)	170.0	---	<0.12 - <2.0	8	4	9
Thallium	0.1	---	<0.005 - 0.008	4	2	4
Tin	2.0	---	<0.009 - <0.002	4	2	4
Titanium	10.0	---	<0.002 - <0.003	4	2	4
1,1,1 Trichloroethane	1900.0	---	<0.4	1	1	1
Toluene	375.0	---	0.007 - <4.0	12	6	13
Toluene	---	560.0	<4.0	6	2	12
Vanadium	0.05	---	<0.002 - <0.02	9	4	9
Xylene	434.0	---	0.037 - 0.167	2	1	2
Zinc	5.0	---	0.002 - 0.033	6	3	6
Zinc	---	2.0	0.002 - 0.033	5	2	10

NOTES:

[1] = Pondcrete puck reprocessing included: reprocessing of failed pucks, test reprocessing runs with portland cement and soil, cleaning of reprocessing equipment, core sampling pucks, and mixing samples under Tent #10 laboratory hood.

[2] = Standard refers to the most stringent standard published by the Occupational Safety and Health Administration (SHA) or the American Conference of Governmental Industrial Hygienist (ACGIH).

mg/m^3 = milligrams per cubic meter

APPENDIX A
TABLE IV
AREA AIR SAMPLING SUMMARY
PONDCRETE PUCK REPROCESSING OPERATIONS[1]
904 PAD, TENT 10 PERMACON
April 19, 1990 through December 11, 1990

Material Sampled	8-Hour TWA Standard[2] (mg/m^3)	STEL/Ceiling (mg/m^3)	Range of Values (mg/m^3)	Date	Total Samples
Ammonia	---	24.0	1.4 - 3.5	09/17/90	3
Ammonia	---	24.0	1.4 - 7.6	09/24/90	4
Ammonia	---	24.0	3.5 - 10.4	10/01/90	4
Hydrogen cyanide	---	5.0	<1.0	08/27/90	2
Hydrogen cyanide	---	5.0	<2.2	09/17/90	3
Hydrogen cyanide	---	5.0	<2.2	09/24/90	1
Hydrogen cyanide	---	5.0	<2.2	10/01/90	3
Nitric acid	---	10.0	<2.6	09/24/90	1
Nitrogen dioxide	---	1.8	<0.9	09/24/90	1

NOTES

[1] = Pondcrete puck reprocessing included: reprocessing of failed pucks, test reprocessing runs with portland cement and soil, cleaning of reprocessing equipment, core sampling pucks, and mixing samples under Tent #10 laboratory hood.

[2] = Standard refers to the most stringent standard published by the Occupational Safety and Health Administration (OSHA) or the American Conference of Governmental Industrial Hygienists (ACGIH).

mg/m^3 = milligrams per cubic meter

APPENDIX B

APPENDIX B
TABLE I
REAL TIME MONITORING DATA
WATER AND SLUDGE SAMPLING AT 207A-C SOLAR PONDS
May 13-23, 1991[1]

Date	Activity	Agent	Level (in ppm)	Standard[2] (in ppm)
05/13/91	207B Water sample preparation	Volatile Organic Compounds Carbon Tetrachloride Ammonia	<background[3] <1.0 <2.0	N/A 2.0 25.0
05/17/91	207A Water sample preparation	Volatile Organic Compounds	<background	N/A
05/19/91	207B Water sample preparation	Volatile Organic Compounds	< background	N/A
05/22/91	207C Water sample preparation	Volatile Organic Compounds Carbon Tetrachloride Ammonia	< background < 1.0 < 2.0	N/A 2.0 25.0
05/22/91	207C Water and sludge collection on boat	Volatile Organic Compounds	< background	N/A

[1] = Real-time monitoring was not performed July 15-18, 1991, since sample preparation was performed on the boat

[2] = Standard refers to the most stringent standard published by Occupational Safety and Health Administration (OSHA) or American Conference of Governmental Industrial Hygienists (ACGIH)

[3] = Background levels before activities began ranged from 0.0 - 4.0 ppm

N/A = Not applicable. No standard exists for general volatile organic compounds. A stop work level of 1.0 ppm above background levels in the breathing zone was established

ppm = Parts per million

APPENDIX C

APPENDIX C
TABLE I
EXTERNAL DOSIMETRY
SUMMATION REPORTS

Individual Dose of Solar Pond Workers in Millrem: January through December 1992			
HS ID	DEEP	SKIN	HAND
443165	21	58	58
445084	32	32	32
448028	16	17	17
448032	10	35	35
448049	8	28	28
448279	11	18	18
448370	33	36	36
448371	17	17	17
448425	38	38	38
448467	0	7	7
448513	48	51	51
448514	7	7	7
448519	7	33	33
448524	20	31	31
448544	4	7	7
448545	13	13	13
448569	4	17	17
448570	19	20	20
448571	19	20	20
448572	17	25	25
448590	1	3	3
448592	21	33	33
448593	10	30	30
448594	30	16	16
448595	13	13	13
448596	3	16	16
448598	12	28	28
448599	10	12	12
448602	5	1	1
448624	8	8	8
448626	6	6	6

Individual Dose of Solar Pond Workers in Millrem: January through December 1992			
HS ID	DEEP	SKIN	HAND
448641	0	0	0
448643	0	0	0
448659	3	0	0
448660	3	0	0
448661	6	0	0
448662	0	12	12
448707	1	0	0
448708	5	9	9
448742	2	3	3
448743	2	3	3
448753	5	5	5
448767	7	10	10
511829	16	19	19
512669	9	28	28
513390	10	10	10
513618	15	22	199
513699	41	140	140
514247	16	53	53
515871	3	3	3
515885	15	29	29
515995	50	49	49
516057	41	50	50
516112	0	5	5
516115	52	61	61
516185	33	41	41
516187	38	46	46
516190	9	12	12
516309	18	22	22
516334	18	32	32
516354	16	25	25
516372	7	10	10

APPENDIX C
TABLE I
EXTERNAL DOSIMETRY
SUMMATION REPORTS

Individual Dose of Solar Pond Workers in Millrem: January through December 1992			
HS ID	DEEP	SKIN	HAND
516741	127	127	127
516571	12	12	12
516759	63	74	74
516777	50	52	52
516783	41	46	46
516788	6	10	10
516921	26	31	31
516923	20	28	28
516924	13	17	17
516925	3	10	10
516926	49	67	67
516928	9	16	16
517357	0	17	17
517391	20	86	86
518225	4	8	8
SUM	1,347	1,976	1,153

APPENDIX C
TABLE I
EXTERNAL DOSIMETRY
SUMMATION REPORTS

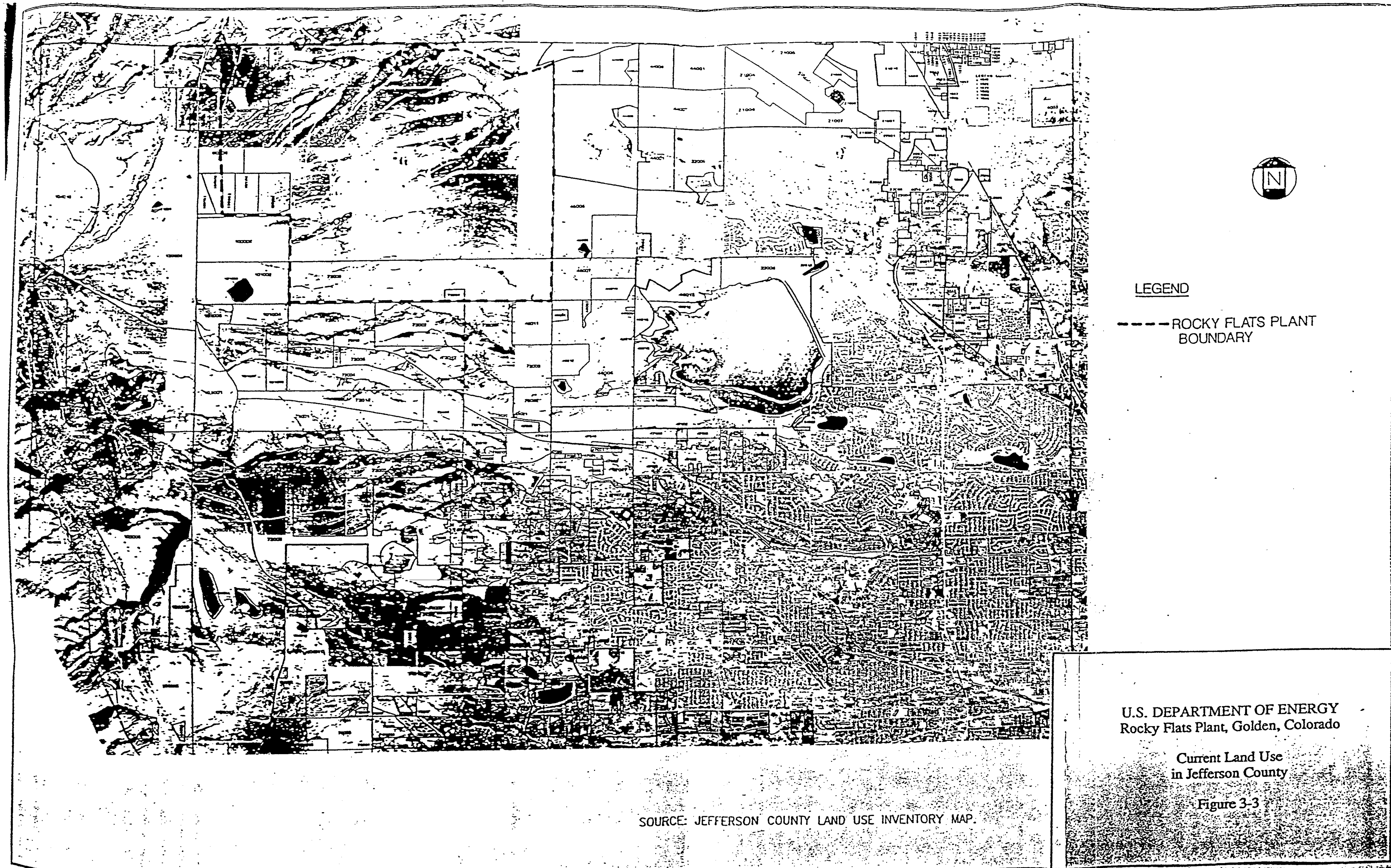
Individual Dose of Solar Pond Workers in Millrem: January through December 1992			
HS ID	DEEP	SKIN	HAND
516741	127	127	127
516571	12	12	12
516759	63	74	74
516777	50	52	52
516783	41	46	46
516788	6	10	10
516921	26	31	31
516923	20	28	28
516924	13	17	17
516925	3	10	10
516926	49	67	67
516928	9	16	16
517357	0	17	17
517391	20	86	86
518225	4	8	8

SUM	1,347	1,976	1,153

APPENDIX C
TABLE I
EXTERNAL DOSIMETRY
SUMMATION REPORTS

Individual Dose of Solar Pond Workers in Millrem: January through December 1992			
HS ID	DEEP	SKIN	HAND
516741	127	127	127
516571	12	12	12
516759	63	74	74
516777	50	52	52
516783	41	46	46
516788	6	10	10
516921	26	31	31
516923	20	28	28
516924	13	17	17
516925	3	10	10
516926	49	67	67
516928	9	16	16
517357	0	17	17
517391	20	86	86
518225	4	8	8

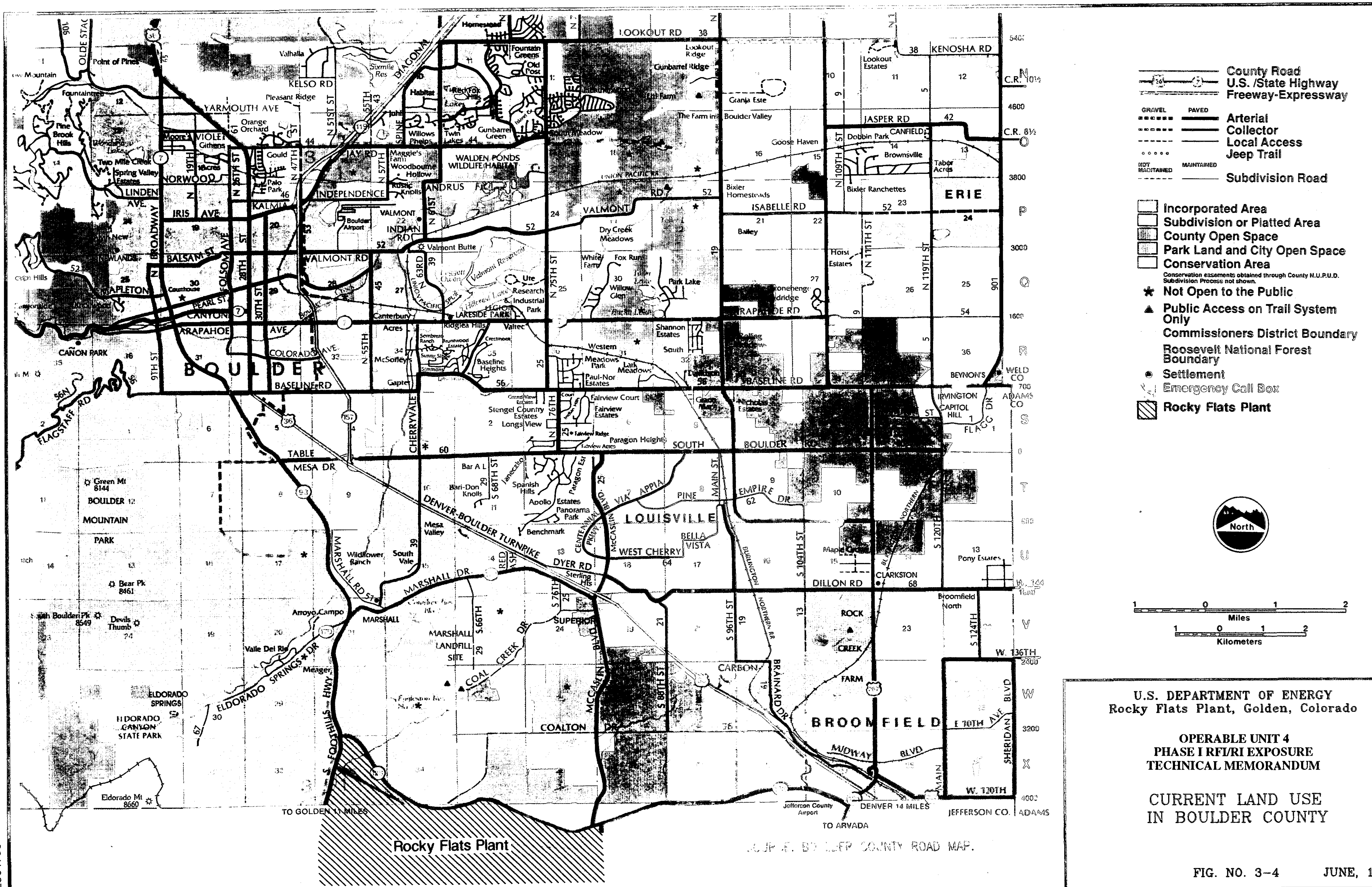
SUM	1,347	1,976	1,153



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

Current Land Use
in Jefferson County

Figure 3-3



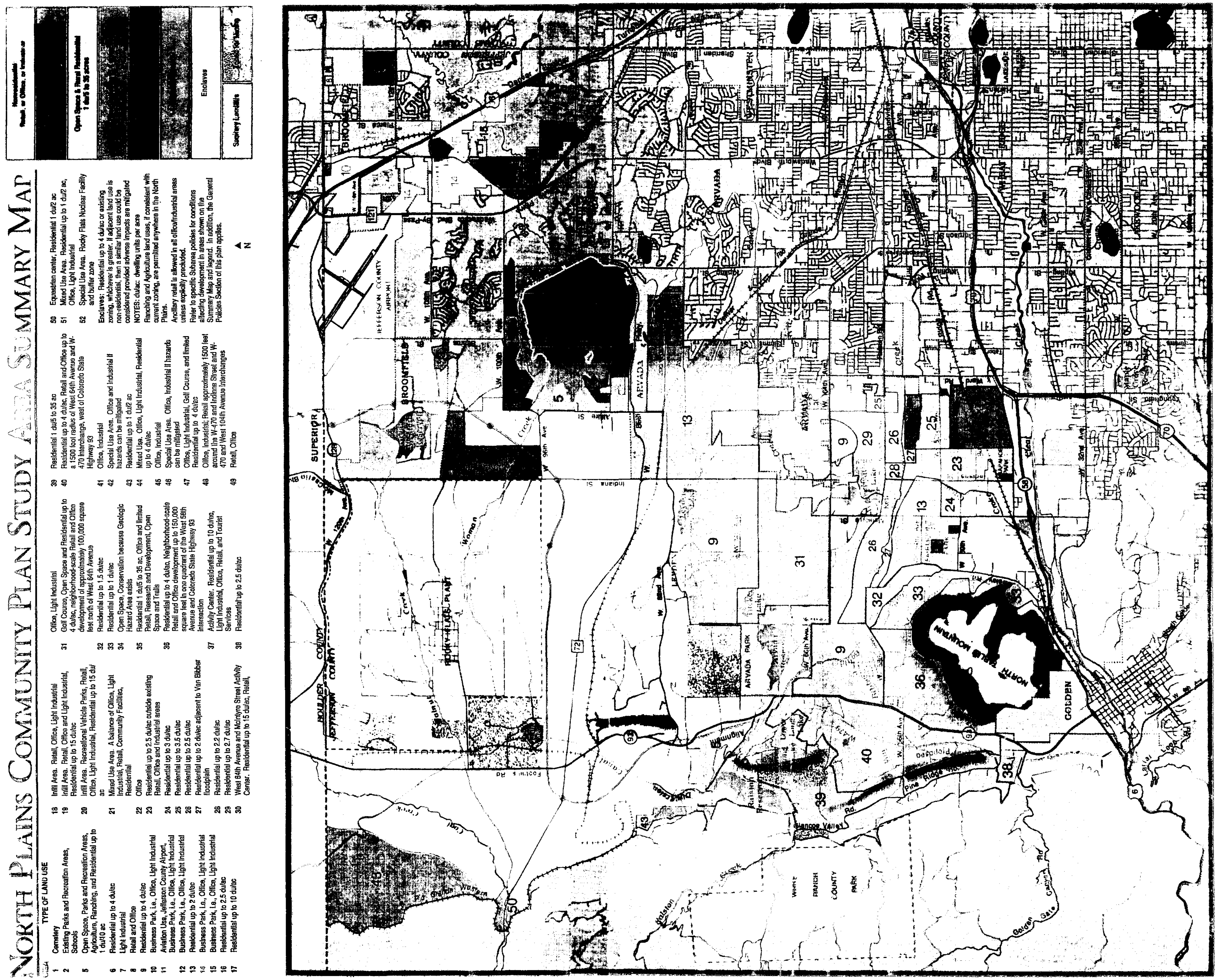
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 4
PHASE I RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

CURRENT LAND USE
IN BOULDER COUNTY

FIG. NO. 3-4 JUNE, 1992

23047034

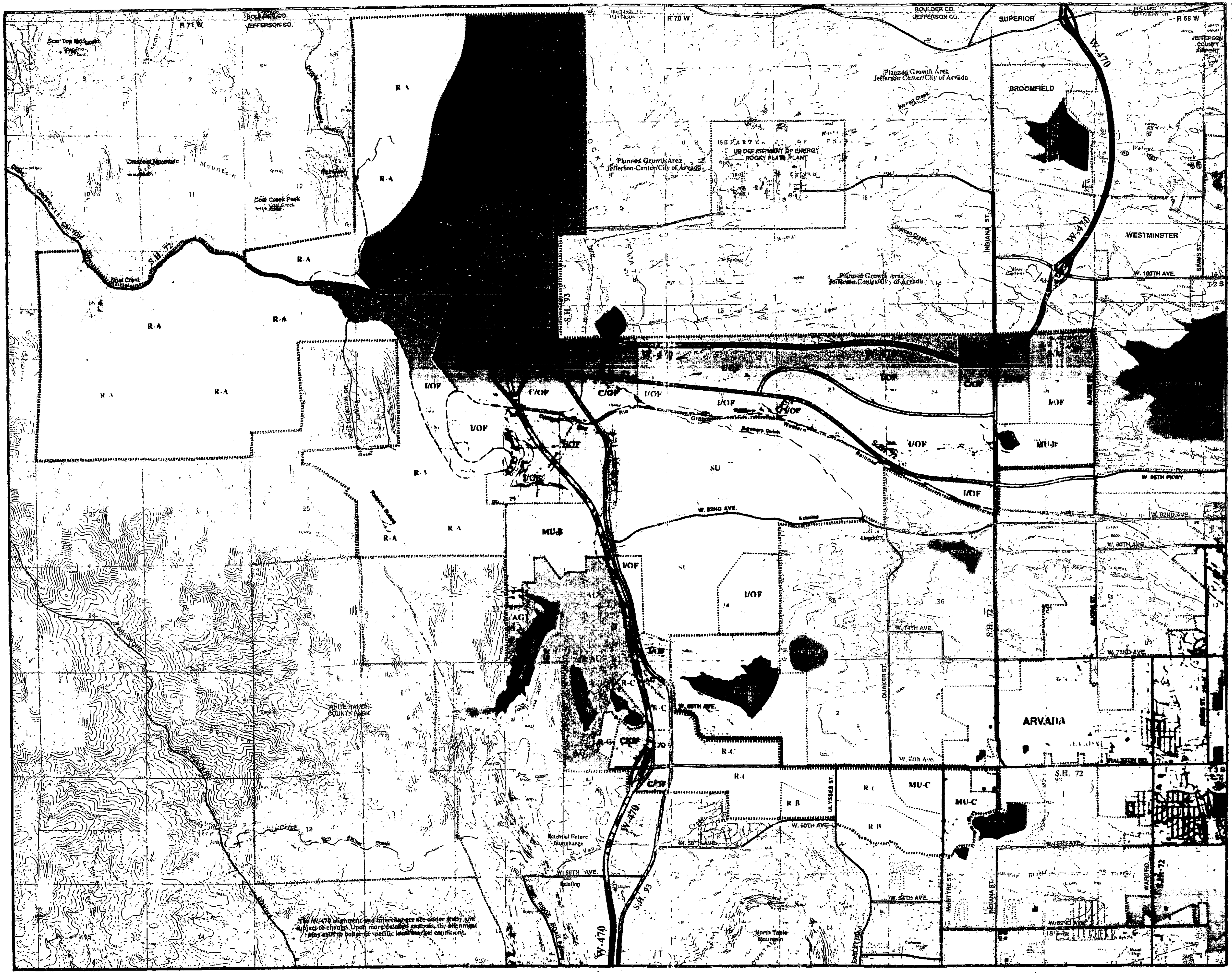


U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 4
PHASE I RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

FUTURE LAND USE
IN JEFFERSON COUNTY

FIG. NO. 3-5 JUNE, 1992



JEFFERSON COUNTY

City of Arvada

JCMD NO. 1

Jefferson Center Metropolitan District No. 1

Jefferson CENTER Associates

Jefferson Center Comprehensive Development Plan

FIGURE 3-6

Legend

- Commercial and Office
- Industrial and Office
- MU — Mixed-Use: A B or C
- R — Residential (A, B or C)
- Agricultural
- Open Space
- SU — Special Use
- W-470
- Arterial Roadways
- Collector Roadways
- Existing Roadways
- Jefferson Center Development Area

SOURCE: DOE 1992.

Approval

Jefferson County

By: Date: 9/15/89

Title: Chairman of the Board of the County Commissioners

ATTEST:

By: Date: 8-15-89

Title: County Clerk and Recorder

City of Arvada

By: Date: 8-14-89

Title: Mayor

ATTEST:

By: Date: 8-14-89

Title: City Clerk

Jefferson Center Metropolitan District No. 1

By: Date: 11/7/89

Title: President

ATTEST:

By: Date: 11-9-89

Title:

Jefferson Center Associates

By: Date: 8/1/89

Title: President

ATTEST:

By: Date: 8/1/89

Title: Vice President

NORTH

Scale: 1" = 3000'-0"

August 1,