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RCRA Facility Investigation – Remedial Investigation/ Corrective Measures Study – Feasibility Study Report for the Rocky Flats Environmental Technology Site Appendix A – Comprehensive Risk Assessment

Volume 1 of 15
Executive Summary

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ACRONYMS AND ABBREVIATIONS

AEU	Aquatic Exposure Unit
AT	alternative toxicity
BAF	bioaccumulation factor
bgs	below ground surface
BW	body weight
BZ	Buffer Zone
CDPHE	Colorado Department of Public Health and Environment
CMS	Corrective Measures Study
COC	contaminant of concern
CRA	Comprehensive Risk Assessment
CSF	cancer slope factor
DHHS	Department of Health and Human Services
DOE	Department of Energy
DQA	Data Quality Assessment
DQO	data quality objective
ECOI	ecological contaminant of interest
ECOPC	ecological contaminant of potential concern
EcoSSL	ecological soil screening level
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	Ecological Risk Assessment
ESL	ecological screening level

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EU	Exposure Unit
FS	Feasibility Study
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
IAG	Interagency Agreement
ICA	Institutional Control Area
IHSS	Individual Hazardous Substance Site
LOAEL	lowest observed adverse effect level
MDC	maximum detected concentration
mg	milligrams
mg/kg	milligrams per kilogram
mg/kg/BW/day	milligrams per kilograms of body weight per day
mrem	millirems
NCP	National Oil and Hazardous Substances Pollution Contingency Plan (National Contingency Plan)
NOAEL	no observed adverse effect level
NOEC	no observed effect concentration
PAC	Potential Area of Concern
PAH	polycyclic aromatic hydrocarbons
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCOC	potential contaminants of concern
PMJM	Preble's meadow jumping mouse
PRG	preliminary remediation goal
QA/QC	Quality Assurance/Quality Control

QC	quality control
RCRA	Resource Conservation and Recovery Act
RESRAD	RESidual RADioactivity (software program)
RFCA	Rocky Flats Cleanup Agreement
RfD	reference dose
RFETS	Rocky Flats Environmental Technology Site
RI	Remedial Investigation
ROC	receptor of concern
SAP	Sampling and Analysis Plan
SCM	Site Conceptual Model
SCMTM	Site Conceptual Model Technical Memorandum
tESL	threshold ESL
TRV	toxicity reference value
UBC	Under Building Contamination
UCL	upper confidence limit
USFWS	U.S. Fish and Wildlife Service
UTL	upper tolerance limit
VOC	volatile organic compound
WHO	World Health Organization
WRS	Wilcoxson Rank Sum
WRV	wildlife refuge visitor
WRW	wildlife refuge worker

1.0 INTRODUCTION

This volume presents a summary of the Draft Comprehensive Risk Assessment (CRA) for the Rocky Flats Environmental Technology Site (RFETS). The CRA comprises Appendix A of the Resource Conservation and Recovery Act (RCRA) Facility Investigation-Remedial Investigation (RI)/Corrective Measures Study (CMS)-Feasibility Study (FS) Report (hereafter referred to as the RI/FS Report), and was conducted in accordance with the regulatory-approved Final CRA Work Plan and Methodology (CRA Methodology) (DOE 2005). The CRA consists of two parts: a Human Health Risk Assessment (HHRA) and an Ecological Risk Assessment (ERA).

A risk assessment is an evaluation of potential adverse impacts to human health and the environment that may exist from contaminated environmental media associated with site-related activities. Risk assessments are designed to provide information to decision makers to help determine the final remedy that is adequately protective of human health and the environment.

The U.S. Environmental Protection Agency (EPA) considers environmental concentrations corresponding to a 1×10^{-6} to 1×10^{-4} cancer risk range and a total noncancer hazard index (HI) of 1 to be adequately protective of human health (National Oil and Hazardous Substances Pollution Contingency Plan ([NCP]) 1990 and EPA 1989, respectively). The Colorado Department of Public Health and Environment (CDPHE) defines acceptable human health risk as a lifetime excess cancer risk of 1×10^{-6} from exposure to carcinogens and no adverse effect from exposure to systemic toxicants (CDPHE 1994). The purpose of the HHRA is to identify whether site concentrations meet EPA and CDPHE goals for the protection of human health.

The overall risk management goal identified for use in this ERA, as stated in the CRA Methodology, is the following:

> *"Site conditions due to residual contamination should not represent significant risk of adverse ecological effects to receptors from exposure to Site-related residual contamination."*

The ERA was designed and implemented to determine whether site conditions meet the defined goal.

1.1 Purpose of the Executive Summary

Both the HHRA and the ERA consist of the following four basic steps and are intended to answer the corresponding questions:

1. Hazard Identification – What contaminants exist at the site and which of these contaminants are present at concentrations that may impact humans or ecological receptors?

2. Exposure Assessment – How could humans or ecological receptors be exposed to these contaminants?

3. Toxicity Assessment –What are the potential effects of the contaminants to human health or ecological receptors?

4. Risk characterization – What are potential risks to human and ecological receptors based on potential exposures at the site and the toxicity of the contaminants that are present?

The Executive Summary presents an overview of the results of these characterization steps for RFETS. Further detail regarding data and methods used in this risk assessment is presented in Appendix A, Volume 2 of the RI/FS Report, and a more detailed description of the results is contained in the individual risk assessments for each Exposure Unit (EU) and Aquatic Exposure Unit (AEU) (see Section 1.2).

1.2 Contents of the CRA

This Executive Summary comprises Volume 1 of the CRA, which in all, consists of an additional 14 volumes, as follows:

- Comprehensive Risk Assessment Methodology and Data Description (Volume 2)
- Risk Assessment for the West Area Exposure Unit (Volume 3)
- Risk Assessment for Rock Creek Drainage Exposure Unit (Volume 4)
- Risk Assessment for Inter-Drainage Exposure Unit (Volume 5)
- Risk Assessment for No Name Gulch Drainage Exposure Unit (Volume 6)
- Risk Assessment for Upper Walnut Drainage Exposure Unit (Volume 7)
- Risk Assessment for Lower Walnut Drainage Exposure Unit (Volume 8)
- Risk Assessment for Wind Blown Area Exposure Unit (Volume 9)
- Risk Assessment for Upper Woman Drainage Exposure Unit (Volume 10)
- Risk Assessment for Lower Woman Drainage Exposure Unit (Volume 11)
- Risk Assessment for Southwest Buffer Zone Area Exposure Unit (Volume 12)
- Risk Assessment for Southeast Buffer Zone Area Exposure Unit (Volume 13)
- Risk Assessment for Industrial Area Exposure Unit (Volume 14)
- Risk Assessment for Wide-Ranging Ecological Receptors and Aquatic Species (Volumes 15A and 15B)

2.0 SITE DESCRIPTION

RFETS is divided into 12 EUs and seven AEUs, as shown in Figures ES.1 and ES.2, respectively.

The EUs were designated based on known sources and potential contaminant release patterns to collectively assess areas with similar types of potential contamination. Other criteria that were used in distinguishing the EUs included separate watersheds, similar topography and vegetation, and expected land use. The units were also divided into "functional areas," meaning that they all fall within a size range in which future on-site workers would likely spend their time.

A brief description of the historical sources and release patterns for each EU is provided below. These and other EU characteristics are summarized in Table ES.1.

- The Industrial Area EU, which includes the approximately 300-acre former industrialized portion of RFETS, has the most historical Individual Hazardous Substances Sites (IHSSs), Potential Areas of Concern (PACs), and Under Building Contamination (UBC) sites, and was the area with the most potential contaminant sources due to industrial activities at RFETS. However, it is also the EU where the majority of the accelerated actions at RFETS have taken place.

- The Wind Blown Area EU includes surface soil that was affected by the 903 Pad release prior to the accelerated actions and which was characterized by elevated plutonium activities.

- The Upper Walnut Drainage EU includes the A- and B-series ponds.

- The No Name Gulch Drainage EU encompasses the Present Landfill and downgradient areas.

- The Lower Walnut Drainage EU stream sediments were affected by surface water flows from the A-series and B-series ponds as well as erosion from the Wind Blown Area EU.

- The Upper Woman Drainage EU includes the Original Landfill as well as other IHSSs and PACs.

- The Lower Woman Drainage EU was affected by the 903 Pad and contains several historical IHSSs and PACs.

- The Inter-Drainage EU contains two historical IHSSs and PACs, including the West Spray Field, but has not been significantly affected by site activities.

The remaining four EUs at RFETS, the West Area, Rock Creek Drainage, Southwest Buffer Zone (BZ), and the Southeast BZ, were not significantly affected by releases from the site. There were no significant RFETS-related activities in these EUs.

The AEUs represent a framework for evaluating population risks to aquatic receptors from exposure to surface water and sediment within aquatic systems at RFETS. The AEUs established for RFETS include the North Walnut Creek AEU, South Walnut Creek AEU, Woman Creek AEU, No Name Gulch AEU, Rock Creek AEU, McKay Ditch AEU, and the Southeast AEU. These AEUs represent separate drainages or the upper and lower portions of a large single drainage, and were designated on this basis.

3.0 DATA EVALUATION

After the environmental data for a site have been collected, a data evaluation is performed to ensure the data are adequate for HHRAs and ERAs. The following questions are addressed during the data assessment:

- Are the data sufficient?
- Are the data of adequate quality?
- Were the sampling locations appropriate and were all potentially impacted media sampled?
- Did the analyses include all analytes that can reasonably be assumed to be present?
- Were the detection limits appropriate?

The results of the data evaluation for RFETS are presented below.

3.1 Results of the Data Quality and Adequacy Evaluations

The data used in the CRA are the result of implementation of regulatory agency-approved Sampling and Analysis Plans (SAPs) that were prepared to characterize background and site conditions for soil, sediment, groundwater, and surface water. Data quality was assessed using a standard precision, accuracy, representativeness, completeness, and comparability (PARCC) parameter analysis (EPA 2000). Field and laboratory quality control (QC) sample data were reviewed and it was determined that the CRA data meet the data quality objectives for the CRA.

Sufficient samples must also be collected in each medium to adequately estimate the long-term average exposure of receptors to contaminants in an EU. Through the consultative process, the Rocky Flats Cleanup Agreement (RFCA) parties identified specific data adequacy guidelines in order to evaluate the adequacy of the data. The guidelines pertain to: 1) the number of samples; 2) spatial representativeness; and 3) temporal representativeness. The evaluation of data adequacy was performed for each EU and AEU with respect to these guidelines, and it was concluded that the data are adequate for the purposes of the CRA. More information is provided in Appendix A, Volume 2, Section 2.0 of the RI/FS.

3.2 Overview of Site Data

There are approximately 2 million data records for use in the CRA. Environmental data at RFETS were collected for surface soil, subsurface soil, sediment, groundwater, and surface water, and comprise a considerable data set. The CRA data set contains data for all the media that were sampled in numerous locations at RFETS. The sampling locations are shown in Figures ES.3 through ES.5.

In accordance with the CRA Methodology, only data collected on or after June 28, 1991, were used in the CRA. Only data from June 1991 to September 1, 2005, are used in the CRA because these data meet the approved analytical Quality Assurance/Quality Control (QA/QC) programs established by the Interagency Agreement (IAG) and RFCA. For the CRA, analytical data for samples collected over this time frame constitute a reasonably representative data set for use in calculating concentration estimates for the CRA. For subsurface soil and subsurface sediment, only samples from a depth of up to 8 feet below ground surface (bgs) were used in the CRA.[1] This was done because it is not anticipated that workers or burrowing animals will dig to depths deeper than 8 feet bgs.

The sampling data used for the HHRA and ERA for each EU are as follows:

- Combined surface soil/surface sediment data (HHRA);
- Combined subsurface soil/subsurface sediment data (HHRA);
- Surface soil data (ERA); and
- Subsurface soil data (ERA).

For the HHRA, the surface soil and surface sediment data were combined into one medium because both are surficial media and exposure patterns are assumed to be similar. For the same reason, the subsurface soil and subsurface sediment data were also combined for the HHRA.

Sitewide evaluations in the HHRA are performed using the following data:

- Groundwater data;
- Subsurface soil/subsurface sediment data (indoor air pathway); and
- Surface water data.

For the AEUs (ERA), the following data are used:

- Sediment data; and

[1] Subsurface soil samples are often samples collected over a large depth interval. All samples with a starting depth less than or equal to 8 feet bgs and an ending depth less than 0.5 feet bgs were included, even if the ending depth was deeper than 8 feet.

- Surface water data.

4.0 HUMAN HEALTH RISK ASSESSMENT

4.1 Selection of Contaminants of Concern (COCs)

In the first step of the HHRA, contaminants of concern (COCs) were identified. This is the hazard assessment portion of the HHRA, in which chemical concentrations in each EU are evaluated to assess whether a quantitative assessment of risks needs to be conducted.

The human health COC selection process is illustrated in Figure ES.6 and the human health COCs selected for each EU are listed in Table ES.2. In Figure ES.6, chemicals entering the COC selection process, which include all chemicals that were detected at the site, are called potential contaminants of concern (PCOCs). Only those chemicals that are retained for the risk assessment are called COCs.

The four principal steps of the HHRA COC selection process are as follows:

Step 1. The maximum detected concentrations (MDCs) and upper confidence limits on the mean concentration (UCL) for each EU were compared to "acceptable" concentrations. The acceptable concentrations, which are called preliminary remediation goals (PRGs) in the CRA Methodology, were developed using conservative exposure assumptions for a future on-site worker and are based on a cancer risk of 1E-06 and a hazard quotient (HQ) of 1. The PRGs have been agreed to by the RFCA parties. Chemicals that have both an MDC and UCL above the PRG were retained for further evaluation. All other analytes were not further evaluated.

Step 2. Chemicals retained after Step 1 were not evaluated further if they had a detection frequency of less than 5 percent for a medium within an EU. Before excluding a chemical, a "hotspot" analysis was performed to evaluate whether an infrequently detected chemical is present at high concentrations (i.e., greater than 30 times the PRG). Chemicals present at such high concentrations were retained, regardless of detection frequency.

Step 3. Inorganic chemicals and radionuclide concentrations were compared to background concentrations using statistical testing methods, and were not evaluated further if the site concentrations were not statistically greater than those in background. Background analyses were not performed for organic chemicals because these chemicals are not naturally occurring. Therefore, they were automatically carried forward into the next evaluation step.

Step 4. A professional judgment analysis was performed to evaluate historic, spatial, geochemical, and other evidence to assess whether the chemicals are site-related. For chemicals retained after this step, a quantitative characterization of risks was performed.

Based on this process, COCs at the site were identified for surface soil/surface sediment, but not for subsurface soil/subsurface sediment. COCs were identified for five of the 12 EUs at RFETS, including the Industrial Area EU, Upper Woman Drainage EU, No Name Gulch Drainage EU, Wind Blown Area EU, and Upper Walnut Drainage EU. The COCs for RFETS include arsenic, vanadium, benzo(a)pyrene, dioxin, and plutonium 239/240, as shown in Table ES.2.

4.2 Exposure Assessment

An exposure assessment is conducted to evaluate the ways by which people might be exposed to the COCs at a site (i.e., the exposure pathway) and to estimate the amount and duration of the exposure. People may be exposed to chemicals by breathing, touching, or consuming (in some cases incidentally) contaminated air, soil, water, or food. The quantity of chemicals that people take in is affected by the land use of the site and the associated activities. Therefore, land use and expected activities are important considerations in risk assessments. Anticipated site uses and exposures are described below.

4.2.1 Overview of Potential Exposures

The site conceptual model (SCM) provides an overview of potential human exposures at RFETS. It describes what kind of human populations may be present, through which environmental media humans may be exposed, and through which pathways exposure may occur. The SCM is illustrated in Figures ES.7 and ES.8 and is described in the following sections.

The land use for RFETS is a wildlife refuge and, therefore, human populations who may be present in a wildlife refuge include wildlife refuge workers (WRWs) and wildlife refuge visitors (WRVs). Workers may staff a visitor center, monitor and maintain the trail system, and track the on-site wildlife populations. Visitors may hike, bike, and bird watch at RFETS. WRWs are assumed to be adults, while WRVs will likely include both adults and children.

Workers and visitors could theoretically contact contaminants in surface soil, subsurface soil, sediment, surface water, and groundwater. All exposure pathways included in the SCM are identified as complete (meaning that exposure through the pathway is at least theoretically possible). In addition, the pathways are identified as either significant or insignificant. Insignificant pathways are those that are associated with such low exposure that there will be negligible risk, even if exposure occurs. Risk calculations are only performed for significant pathways. However, pathways considered to be insignificant are evaluated to ensure that the pathways are appropriately identified as such.

The following exposure pathways are identified as potentially complete and significant in the SCM:

- Incidental ingestion of surface soil/surface sediment;
- Inhalation of dust released from surface soil/surface sediment;

- Dermal exposure to surface soil/surface sediment;
- External irradiation exposure from surface soil/surface sediment;
- Incidental ingestion of subsurface soil/subsurface sediment;
- Inhalation of particulates released from subsurface soil/subsurface sediment;
- Dermal exposure to subsurface soil/subsurface sediment; and
- External irradiation exposure from subsurface soil/subsurface sediment.

These pathways are quantitatively characterized for an EU if COCs are identified. However, COCs were not identified for subsurface soil/subsurface sediment in any EU. Therefore, quantitative risk characterization for subsurface soil/subsurface sediment was not performed.

The following exposure pathways are identified as insignificant in the SCM:

- Incidental ingestion of and dermal contact with surface water;
- Incidental ingestion of and dermal contact with groundwater that surfaces at springs and seeps;
- Inhalation of volatiles released from subsurface soil/subsurface sediment or groundwater to indoor air; and
- Ingestion of deer and/or grazing animals.

4.2.2 Evaluation of Insignificant Exposure Pathways

Exposure pathways that were identified as insignificant in the CRA Methodology were evaluated on a sitewide basis below. Analyses were conducted to confirm that these pathways were correctly identified as insignificant. Additional detail for these analyses is presented in Appendix A, Volume 2 of the RI/FS Report.

Surface Water Ingestion Pathway

The WRW and WRV may contact surface water while working or recreating on the site. In areas where chemicals have been detected in surface water, people who contact surface water may be exposed to these chemicals. However, because the chemical concentrations in surface water are generally low and any contact with surface water is expected to be infrequent and of short duration, the surface water exposure pathway is not considered significant. This assumption is further evaluated below.

The surface water exposure pathway was evaluated by comparing the MDCs of analytes in surface water to "acceptable concentrations" for surface water that were developed for the CRA Methodology. The acceptable concentrations are referred to as PRGs.

Surface water sampling locations that exceeded PRGs were then presented on a map of the site. Exceedances of surface water PRGs occurred within three EUs: the Industrial Area EU, Upper Walnut Drainage EU, and Upper Woman Drainage EU. Several organics, inorganics, and radionuclides in surface water exceeded their PRGs. Further analyses for each analyte indicated that 1) the exceedances were generally slight and infrequent, and 2) the exceedances were in data from 1998 or older, whereas no exceedances occurred in the newer data. The newer data are more representative of current conditions at the site than the older data. For these reasons, significant exposure from the surface water pathway is not expected.

Groundwater-to-Surface Water Migration Pathway

In some areas of the site, groundwater surfaces in seeps. Contact with groundwater in these seeps is theoretically possible for the WRW and WRV. However, because the chemical concentrations in the seeps are low and any contact with water in the seeps is expected to be infrequent and of short duration, the groundwater-to-surface water migration pathway is not considered significant. This assumption is further evaluated below.

The groundwater-to-surface water pathway was evaluated using data from groundwater wells located within 100 feet from a seep. The evaluation was performed by comparing the MDCs of analytes in groundwater wells to surface water PRGs, as in the previous analysis. MDCs in groundwater exceeded surface water PRGs in three EUs: the Industrial Area EU, Upper Woman Drainage EU, and Wind Blown EU. Several inorganics and organics had exceedances. Most of these analytes were never detected above the PRG in surface water, indicating that the quantities being discharged from groundwater into surface water are not likely to pose a threat to human health. For the few analytes that were detected above the PRG in surface water, the exceedances in both groundwater and surface water are in data from 1995 or older. There are no exceedances for these analytes in the later data. Exceedances are also not expected in the future, because three passive groundwater collection and treatment systems were installed to protect surface water in the areas where the PRGs were previously exceeded.

For the reasons presented above, the groundwater-to-surface water pathway is not considered significant.

Indoor Air Inhalation Pathway

Volatile chemicals have been detected in the subsurface in some areas of the site. If a building is erected in these areas in the future, the volatile chemicals may migrate through the building foundation indoors and be inhaled by people. However, the indoor air inhalation pathway is not considered significant for most areas of the site. This assumption is further evaluated below.

The evaluation for the indoor air inhalation pathway was performed by comparing the MDCs of volatile organic compounds (VOCs) in subsurface soil/subsurface sediment and groundwater to "acceptable concentrations" for indoor air. The acceptable concentrations or PRGs were developed in the CRA Methodology using the Johnson and Ettinger Indoor Air Model that has been endorsed by the EPA (EPA 2000). This model estimates migration of

volatile compounds in the subsurface into air inside a building. Assuming that these compounds are then inhaled by people, the model develops acceptable concentrations for chemicals in the subsurface. Site-specific exposure assumptions for WRWs at RFETS were used in the model.

The MDCs of volatile compounds in subsurface soil/subsurface sediment and groundwater were compared to the PRGs, and maps were created showing all locations where maximum concentrations exceeded the PRGs. Most of the locations with volatilization PRG exceedances are in the Industrial Area EU, western portion of the Wind Blown Area EU, and western portion of the Upper Walnut Drainage EU. In these areas, the indoor air inhalation pathway is potentially significant if buildings are constructed within these EUs. In areas where there are no exceedances of the volatilization PRGs the indoor air inhalation pathway is assumed to be insignificant. The results of this evaluation are used in the CMS-FS to determine boundaries of an Institutional Control Area (ICA) for the site.[2]

Ingestion of Deer and Grazing Animals

Two of the alternatives outlined in the Rocky Flats National Wildlife Refuge Final Comprehensive Conservation Plan and Environmental Impact Statement (EIS) include a limited public hunting program at the site. The program currently is described as a controlled youth and/or disabled person's deer and/or elk hunting program occurring several weekends a year. However, the program may be extended to include a wider human population in the future. Livestock grazing on the site is also a possible future consideration. For these reasons, ingestion of meat from animals on the site is a possibility, and the significance of this exposure pathway is further evaluated.

The evaluation was conducted by comparing the potential risks from the meat ingestion pathway to the total potential risk for Rocky Flats visitors. If risks from this ingestion pathway are less than 10 percent of the total risk, they are considered insignificant. Because any contaminants in deer and livestock would be associated with surface soil (through incidental ingestion of soil during feeding and ingestion of contaminated plants), the risk from the meat ingestion pathway is compared to that for other surface soil exposure pathways.

The meat ingestion pathway was evaluated for radionuclides. Risks were calculated using the RESRAD computer model with sitewide radionuclide concentrations. Because this analysis was conducted before completion of the accelerated actions, some of the data did not reflect conditions that would exist after the cleanup (i.e., lower contaminant concentrations). The existing data set, therefore, was modified by reducing all reported radionuclide concentrations above the action levels for soil to the action levels. The UCL concentrations were then calculated using the modified data set. Risks were estimated assuming that a single individual consumes venison taken from Rocky Flats every year for 30 years. Based on the limited hunting proposed at Rocky Flats in the future, this is likely an overestimation. In

[2] The U.S. Department of Energy (DOE) is expected to retain administrative jurisdiction over portions of the wildlife refuge, referred to as the ICA.

addition, the evaluation of venison consumption is a conservative estimate of consumption of meat from other livestock.

The results from RESRAD indicate that the relative contribution of venison consumption to the total risk from soil exposure is low (less than 10 percent in all cases) and, consequently, the meat consumption pathway may be considered insignificant relative to the other soil exposure pathways. This conclusion was supported by the results of another risk assessment for the deer ingestion pathway that was conducted by the U.S. Fish and Wildlife Service (USFWS).

4.2.3 Exposure Point Concentrations (EPCs)

Exposure point concentrations (EPCs) are calculated for the COCs identified in surface soil/surface sediment. EPCs are an estimate of COC concentrations to which people may be exposed. Two types of concentration estimates are used to evaluate exposure at RFETS: Tier 1 and Tier 2.

It is usually assumed that the best estimate for the EPC is the average concentration for an area. Because there is some uncertainty in having measured the average concentration accurately, a value higher than the calculated average is used in risk assessments. This value is the UCL on the average or mean concentration within an area (i.e., the 95 percent UCL is defined as the value that equals or exceeds the true mean 95 percent of the time). This is the Tier 1 concentration.

If most of the data for an EU have been collected in areas associated with historic releases, and few data points are available for the non-impacted areas, the average concentration will overestimate the concentration for the EU as a whole. Therefore, a second approach is used that equally weighs the data for different subareas of an EU. In this approach, averages are first calculated for 30-acre subareas of an EU and these averages are then combined to calculate an EU-wide average. Due to the uncertainty in having accurately characterized the average, a UCL is again calculated. These are the Tier 2 concentration estimates. Risks for COCs in surface soil/surface sediment are calculated using both Tier 1 and Tier 2 EPCs.

4.2.4 Exposure Assumptions

Exposure assumptions are factors that describe how exposure is assumed to occur. Exposure assumptions describe, for example, how long exposure will occur (exposure duration), how often (exposure frequency), and how much air will be inhaled for every hour spent on the site (inhalation rate). Risk assessments typically use values that are intended to be protective of humans (i.e., to overestimate rather than underestimate potential exposures). Most assumptions used to evaluate WRW and WRV receptors follow EPA guidelines. In addition, several site-specific assumptions were developed based on the input from the RFCA parties and other interested parties. All exposure assumptions are documented in the regulatory agency-approved CRA Methodology.

For RFETS, it is assumed that a future WRW will ingest 100 milligrams (mg) of surface soil/surface sediment every day, 230 days per year, for 18.7 years. Because this exposure is

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assumed for every EU, and RFETS is comprised of a total of 12 EUs, it is, therefore, assumed there will be one WRW in each EU. This is a conservative assumption because it is unlikely that many workers will be present at the site fulltime. In addition, a WRW is assumed to be dermally exposed to and inhale soil and sediment particles in the air with the same frequency and for the same duration. Several of the key exposure assumptions for WRW and WRV, including the site-specific parameters, are summarized in Table ES.3. These and other exposure assumptions were combined with the EPCs to calculate estimates of exposure.

4.3 Toxicity Assessment

A toxicity assessment is an estimate of how much of a chemical it would take to cause adverse human health effects. Chemicals may cause cancer and a variety of noncancer effects such as skin rashes, damage to organs, asthma and other respiratory disorders, and nervous system problems. Different chemicals have different potencies, and these are reflected in the toxicity criteria that are used in HHRAs.

Toxicity criteria for the COCs are shown in Table ES.4. These criteria have been developed by the EPA and other regulatory agencies following a review of all available data for each chemical. Two types of toxicity criteria are used: cancer slope factors (identified as CSFs in Table ES.4) and reference doses (RfDs). The former are used to estimate cancer risks, while the latter are used to estimate noncancer health effects. Because one of the COCs for the site is a radionuclide, a radionuclide dose is also estimated.

4.4 Risk Characterization

In the risk characterization, the estimated exposures are combined with the toxicity criteria to calculate risks. For example, cancer risks are calculated by multiplying the exposure estimate for a COC by the CSF, as illustrated by the following equation:

Cancer Risk (Unitless) = Dose Estimate (milligrams per kilogram (mg/kg) - day) x CSF (mg/kg - day) - 1

The estimated cancer risk represents the probability of a person developing cancer. The EPA considers risks from 1 in 1,000,000 to 1 in 10,000 the acceptable risk range, where the acceptable risk for each site is determined based on site-specific conditions. In the CRA volumes and the results presented in Table ES.5, a 1-in-1,000,000 risk is written as 1E-06 or 1×10^{-6}.

Noncancer health effects are calculated by dividing the exposure estimate by the noncancer toxicity criterion (RfD). The ratio between the two values is called an HQ, and an HQ less than or equal to 1 indicates that people are unlikely to have adverse health effects. The summation of the HQ values is termed an HI.

Dose estimates are developed using the RESRAD computer model, which can be programmed to evaluate all applicable exposure pathways at a site. The acceptable total radionuclide dose for exposure from the site is 25 millirems (mrem) (CDPHE 2005).

For RFETS, risks are estimated for exposure to surface soil/surface sediment by workers and visitors in five EUs: the Industrial Area EU, Upper Woman Drainage EU, No Name Gulch Drainage EU, Wind Blown Area EU, and Upper Walnut Drainage EU. No COCs were identified for subsurface soil/ subsurface sediment and, therefore, a quantitative risk characterization for this medium is not necessary. Cancer risks, noncancer risks, and radionuclide doses are estimated.

A summary of cancer and noncancer risks and dose estimates for future WRWs and WRVs at RFETS is presented in Table ES.5. Risks were calculated for five EUs for which COCs had been identified. The cancer risk estimates for all EUs were at the low end of EPA's 1E-06-to-1E-04 risk range. The noncancer health effects estimates (HI) were all below 1, indicating that noncancer health effects are unlikely. Dose estimates were calculated for plutonium in the Wind Blown Area EU. The estimated doses are less than 1 mrem, well below the radiation dose limit of 25 mrem.

Background cancer risks and noncancer health effects from naturally occurring metals at RFETs were calculated on a sitewide basis. All detected metals for which toxicity criteria are available were included in this evaluation. Background cancer risk for WRW and WRV is approximately 2E-06 and HIs are 0.3 for WRW and 0.1 for WRV.

4.5 Uncertainty Discussion

Risk assessments are designed to be protective of human health and employ conservative EPC estimates, exposure assumptions, and toxicity criteria. Using the UCL rather than the average concentration, even when the site has been well characterized, helps to ensure that the EPC is protective of human health. The exposure assumptions are expected to overestimate typical exposures at a site. For example, it is highly unlikely that an individual would ingest 100 mg of soil every day when working or recreating at the site, or that soil would come in contact with a significant percentage of a human receptor's body. In addition, there are safety factors built into the toxicity criteria. Depending on the amount of uncertainty in the data, scientists may apply uncertainty factors of 100 to 10,000 to the toxicity criteria. Because so many conservative assumptions are combined, it is expected that the calculated risk for RFETS is protective of any potential future exposures for WRW and WRV receptors.

5.0 ECOLOGICAL RISK ASSESSMENT

Two types of ecological receptors were evaluated as part of the ecological risk assessment (ERA): terrestrial and aquatic. The terrestrial ecological analysis was conducted for the same EUs as defined for the HHRA (Figure ES.1). A sitewide analysis was also conducted for wide-ranging receptors. The aquatic ecological analysis was conducted on a watershed-specific basis using the AEUs shown on Figure ES.2.

5.1 Site Conceptual Model

The ecological SCM for RFETS reflects the most appropriate ecological receptors for the site as a wildlife refuge (Figure ES.9) and identifies the potential pathways by which ecological

receptors may be exposed to ecological contaminants of potential concern (ECOPCs). These identified pathways become the focus of the ERA. The SCM is also used to identify measurement endpoints, which are the analysis tools used to evaluate potential risks to ecological receptors.

Figures ES.9 and ES.10 depict the ecological SCM. The figures identify pathways that are potentially complete as well as potentially significant pathways for exposure of the ecological receptor groups (Table ES.6). Some of the pathways (inhalation and dermal contact with surface water for terrestrial fauna) were designated in the CRA Methodology as potentially complete but insignificant and, therefore, are not quantitatively evaluated.

5.2 Ecological Risk Management Goals and Endpoints

Development of overall site management goals, and assessment and measurement endpoints is an important part of ecological risk assessments. Site management goals define the assessment endpoints or ecological values that are to be protected at a site. Assessment endpoints describe the ecological values to be protected as a result of management actions at a site, while measurement endpoints are the data and analysis tools that are used to evaluate the assessment endpoints.

The overall risk management goal identified for use in this ERA, as stated in the CRA Methodology, is:

> *"Site conditions due to residual contamination should not represent significant risk of adverse ecological effects to receptors from exposure to Site-related residual contamination."*

Significant risk of adverse ecological effects implies toxicity that threatens populations or communities of wildlife or aquatic organisms at RFETS. For species that have additional regulatory protection due to their rare or threatened status, such as the Preble's meadow jumping mouse (PMJM), significant adverse effects can occur even if individuals are affected. Therefore, the assessment for PMJM addresses the potential for individual mice to be adversely affected by contact with ECOPCs. For other species with stable or healthy populations, the assessment focused on population-level effects, where some individuals may suffer adverse effects but the effects are not ecologically meaningful because the overall site population is not significantly affected.

5.3 Data Quality Objective (DQO) Approach To Ecological Risk Assessment

The approach to the ERA was designed around the use of data quality objectives (DQOs) as defined in the CRA Methodology. The DQO process is a seven-step procedure designed to focus the assessment and identify the problem to be addressed as well as the decisions that are necessary following completion of the CRA. The CRA Methodology defined the inputs to the decisions and the boundaries of the study to be performed, and established the rules by which the decisions are to be made. Once the decisions are set along with the methods used to reach them, tolerable error limits and rules for optimization of the ERA design were provided. This approach, which was designed and agreed upon by the EPA, CDPHE,

USFWS, and DOE, and documented in the CRA Methodology, provides a scientifically sound approach to making risk-based decisions at RFETS.

5.4 Identification of ECOPCs

Identification of ECOPCs to be evaluated in detail in the risk characterization portion of the CRA was based on a comparison of site media concentrations (surface soil, subsurface soil, sediment, and surface water) to ecological screening levels (ESLs) for each ecological receptor. ESLs for wildlife were developed based primarily on potential ingestion of ecological contaminants of interest (ECOIs) in abiotic media, forage, and prey, and the transfer of ECOIs among these media. ESLs for aquatic receptors were based upon concentrations protective of the aquatic community as a whole based on the total exposure from either sediment or surface water. Figure ES.11 depicts the process used to identify ECOPCs for the ERA.

The ECOPC selection process consists of several steps designed to focus the ERA on those chemicals that may have the potential to cause risk to ecological receptors at the site. Because of the presence of the special-status PMJM receptor that requires a different level of protection than the other receptors, the ECOPC identification process consists of two parallel evaluations, one for PMJM and one for other ecological receptors. Two different data sets were used in these evaluations, one including all data for an EU or an AEU and the other including only sampling locations within PMJM habitat.

The five principal steps of the ECOPC selection process are as follows:

Step 1. The MDCs of chemicals were compared to no observed-adverse effects level (NOAEL)-based ESLs. MDCs above the NOAEL-based ESLs were retained for further analysis. Those ECOIs with MDCs less than all NOAEL ESLs were considered to be of *de minimus* risk and not quantitatively evaluated further.

Step 2. ECOIs remaining after Step 1 were further evaluated based on their frequency of detection. If an ECOI was detected in less than 5 percent of the samples, it was evaluated using best professional judgment as to its potential to cause risk to wildlife receptors at the site. The determination considered process knowledge and spatial and temporal factors as well as the physical and chemical properties of the ECOI as they pertain to the potential for risk to the wildlife receptors at the site. Chemicals not likely to be associated with risks were dropped from further quantitative analysis. Analytes with detection frequencies greater than 5 percent were retained. Step 2 was not performed for PMJM because frequency of detection was not one of the ECOPC selection tools to be used for this sensitive receptor.

Step 3. Separate background comparisons were conducted for PMJM and other ecological receptors. For the PMJM receptors, the data set from the PMJM habitat areas within an EU were statistically compared to the background surface soil data. For the other ecological receptors, the data set for the entire EU (surface soil) or AEU (sediment or surface water) was statistically compared

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to the background surface soil, sediment, or surface water data set. ECOIs with concentrations not exceeding those in background were not further evaluated quantitatively.

Step 4. The upper-bound concentration of each ECOI retained up to this point was compared to threshold ESLs for terrestrial receptors. For receptors with large home ranges, the upper-boundexposure concentration was represented by the UCL on the mean. For receptors with small home ranges, the upper-bound exposure concentration was represented by the 95th UCL of the 90th percentile (denoted as the upper tolerance limit (UTL)). Chemicals with UCL or UTL concentrations less than the threshold ESLs were not retained. This step was not conducted for PMJM receptors.

For aquatic receptors, upper-bound exposure concentrations were compared to the NOAEL ESLs for sediment and surface water.

Step 5. Each ECOI remaining at this point of the ECOPC evaluation process was evaluated using professional judgment. The purpose of the professional judgment evaluation was to determine if the chemical was related to possible use or historical releases at the site. If sufficient evidence suggested that the chemical is not related to historical RFETS operations, it was not further evaluated.

All chemicals remaining after Step 5 are considered ECOPCs and are further evaluated in the risk characterization. A summary of the ECOPCs identified for each EU is presented in Tables ES.7, ES.8, and ES.9.

5.5 Exposure Assessment

Exposure results from contact between a receptor and ECOPCs in an environmental medium. For exposure to occur, a release must have occurred and a receptor must have a point of potential contact with that medium. The potential for receptor contact and identification of exposure routes are shown on the SCM (Figure ES.9).

The exposure assessment describes the relationships and equations used to estimate how much of a given chemical in a given medium is taken up by the receptor via a given exposure route. Two basic exposure models are used in the CRA: the concentration-based model (used for aquatic receptors, terrestrial plants, and invertebrates) and a dosage-based model (used for wildlife receptors). The concentration-based exposure model is a simple method where the EPC is representative of the total exposure to that receptor. The exposure-based model used for birds and mammals is based on estimated exposure to contaminants through multiple pathways including the ingestion of soils, food items (plant, invertebrate, and bird/mammal tissue), and surface water.

5.5.1 Receptor-Specific Exposure Assessment

Exposures to terrestrial ecological receptors were calculated on an EU-by-EU basis. Wide-ranging species that generally utilize areas larger than an individual EU (that is, coyote and mule deer) were also addressed separately using sitewide data (Appendix A, Volume 15A of the RI/FS Report). The EUs are reasonable aggregations of common source areas, hydrological systems, and habitat for assessing ecological risk. Only the PMJM receptor was evaluated on a sub-EU basis due to its status as a protected species and the individual level of protection afforded to it under the assessment endpoints. PMJM receptors were evaluated using functional habitat patches (Figure ES.12). The habitat patches were designed to represent realistic home ranges for individual PMJM or sub-populations of PMJM.

Exposure to aquatic receptors was calculated on a watershed-specific basis (Volumes 15B1 and 15B2), but also considered smaller, but highly important, habitat areas such as ponds within each AEU.

5.5.2 Exposure Point Concentrations (EPCs)

Tier 1 and Tier 2 EPCs were calculated for the ERA as described in Section 4.2.3. For small home-range receptors, the UTL concentrations were used as the EPCs. For large home-range receptors, the UCLs were used as the EPCs. For the PMJM, the UCLs (Tier 1 only) are calculated for habitat patch areas and those UCLs were used as the EPCs.

5.6 Ecological Toxicity Assessment

Exposure to ecological receptors was estimated for representative species of functional groups based on taxonomy, habitat, and feeding behavior. For wildlife receptors, exposure was calculated in the form of a daily rate of intake for each ECOPC/receptor pair. For aquatic receptors, terrestrial plants, and invertebrates, exposure was estimated using media concentrations.

Calculated intakes (birds and mammals) or exposure concentrations were then compared to the toxicological properties of each ECOPC. For wildlife receptors, laboratory-based toxicity benchmarks are termed toxicity reference values (TRVs) and consist of several basic types. The NOAEL TRVs are intake rates or soil concentrations below which no ecologically significant effects are expected. NOAEL TRVs were used to calculate the NOAEL ESLs employed in screening steps of the ECOPC identification process to eliminate chemicals that have no potential to cause risk to the representative receptors. The lowest observed adverse effects level (LOAEL) TRV is a concentration above which the potential for some ecologically significant adverse effect could be present. Threshold TRVs represent the hypothetical dose at which the response in a group of exposed organisms may first begin to be significantly greater than in unexposed receptors and are calculated as the geometric mean of the NOAEL and LOAEL. Threshold TRVs were calculated based on specific data quality rules for use in the ECOPC identification process for a small subset of ECOIs in the CRA Methodology. TRVs for ECOPCs in each EU were obtained from the CRA Methodology.

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For concentration-based exposure models, the no observed effect concentration (NOEC) is analogous to the NOAEL TRV, but represents a media concentration below which no effects are expected. In the aquatic risk assessment, alternative toxicity (AT) values were presented that represent analogues to the LOAEL TRVs used in the wildlife risk assessments. The ATs were not presented in the CRA Methodology, but care was taken to identify ATs that represented the same requirements for LOAEL TRVs as outlined in the CRA Methodology.

5.7 Risk Characterization

The risk characterization process defines a range of potential risks to receptors from the ECOPCs. Characterization of risk focuses on the overall results for each assessment endpoint. The overall risk is then summarized for each receptor group and level of biological organization (that is, individual or population level of protection), as appropriate for the assessment endpoints. When interpreting the results of the risk characterization to all receptors (except the PMJM), it is important to consider that the assessment endpoint is based on the sustainability of exposed populations, and risks to some individuals in a population may be acceptable if the population is expected to remain healthy and stable. For the PMJM, the interpretation of results is based on potential risks to individuals rather than populations.

The risk characterization provided for each EU and AEU has two main components: the risk estimation and the risk description. The risk estimation summarizes results of the analysis, identifying the receptors and ECOPCs, and a range of potential risks and the locations/EUs/AEUs where risk may be present. The risk description then provides context for the analysis, including uncertainties related to each ECOPC and an interpretation of overall results.

5.7.1 Risk Estimation

The risk estimation summarizes results of the analysis, identifying the receptors and ECOPCs, and a range of potential risks and the EUs/AEUs where risk may be present. HQs are the major tool used in the risk estimations for each EU and AEU. The HQ is a ratio of the estimated exposure concentration to the TRV where:

$$HQ = Intake/TRV$$

Or

$$HQ = Exposure/TRV$$

In general, if the NOAEL-based HQ is less than or equal to 1, then no adverse effects are predicted. If the LOAEL-based HQ is less than 1 but the NOAEL-based HQ is above 1, then some adverse effects are possible, but it is expected that the magnitude and frequency of the effects will usually be low. If the LOAEL-based HQ is greater than or equal to 1, the risk of an adverse effect is potentially significant, with the probability and/or severity of effect tending to increase as the value of the HQ increases.

HQs were first calculated using the default exposure assumptions and toxicity values from the CRA Methodology. Where no LOAEL HQs exceeded 1 using the default values, no further HQs were calculated. Because the default HQs are generally the most conservative risk estimations, if low risk is estimated using these values, then further reductions of conservatism would only serve to reduce risk estimates further. When HQs greater than 1 were calculated using default assumptions, and the uncertainty analysis indicated that alternative bioaccumulation factors (BAFs) and/or toxicity values would be beneficial to reduce uncertainty, alternative HQs were calculated.

HQs were calculated using Tier 1 EPCs for aquatic receptors and habitat patch-specific EPCs for PMJM receptors. HQs were calculated using both the Tier 1 and Tier 2 EPCs for other wildlife receptors.

5.7.2 ECOPC-Specific Uncertainty Discussion

Uncertainty in the risk estimation is a major consideration when describing risks. The risk characterization process uses environmental data to estimate intake and toxicity through the use of models and professional judgment. While steps are taken to minimize this uncertainty, no ERA is without considerable levels of uncertainty.

For each ECOPC discussed in the risk estimation, a discussion of the uncertainties related to the toxicological properties of the TRVs selected is presented. Additionally, because very little food tissue data were available for use, the uncertainties related to the estimation of ECOPC concentrations in prey tissues were also provided for each ECOPC. If high levels of uncertainty were found for a specific ECOPC in terms of the toxicity value or BAFs, alternative toxicity values and BAFs were provided along with the rationale for their selection. If risks were not determined to be low when using the most conservative default assumptions as provided in the CRA Methodology, alternative HQs were calculated to help characterize risk. These evaluations were intended to provide risk managers with a summary of the chemical-specific uncertainties and provide a range of risk estimates to consider when making risk management decisions.

5.7.3 Risk Description

The risk description provides context for the analysis, including uncertainties related to each ECOPC and an interpretation of overall results. The risk description incorporates results of the risk estimates along with the uncertainties associated with the risk estimations, alternative HQ calculations, and other lines of evidence to evaluate potential chemical effects on ecological receptors at RFETS following accelerated actions. Information considered in the risk description includes receptor groups potentially affected, type of TRV exceeded (e.g., NOAEL versus LOAEL), relation of EU or AEU concentrations to other criteria such as EPA ecological soil screening levels (EcoSSLs), ATs, and risk above background conditions. In addition, other site-specific and regional factors are considered such as the use of a given ECOPC within the EU or AEU related to historical RFETS activities, comparison of ECOPC concentrations within each EU or AEU to the rest of RFETS as it relates to background, and/or comparison to regional background concentrations.

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The conclusions reached in the risk description for each EU and AEU are presented in Table ES.10. In making the final risk estimation, the conclusions for the ERA considered results from the default HQ calculations, chemical-specific uncertainty evaluations, HQs calculated using alternative toxicity values and BAFs (if appropriate), background media concentrations, and ecosystem health data.

5.8 General Uncertainty Analysis

Quantitative evaluation of ecological risks is limited by uncertainties regarding the assumptions used to predict risk and the data available for quantifying risk. These limitations are usually addressed by making estimates based on the data available or by making assumptions based on professional judgment when data are limited. Because of these assumptions and estimates, the results of the risk calculations themselves are uncertain, and it is important for risk managers and the public to view the results of the risk assessment with this in mind. The general uncertainties related to the ERAs are provided in Appendix A, Volume 2 of the RI/FS Report. Those specific to each ERA are summarized in the EU-specific or AEU-specific volume of the RI/FS Report.

5.9 Background Risk Analysis

As part of the uncertainty analysis, risks to the receptors evaluated in the ERA were also evaluated based on concentrations to which they could be exposed in background areas. Background risks were assessed for surface soils only. No background risks were calculated for subsurface soils, surface water, or sediment.

The exposure assumptions and toxicity values used for the background risks are the default scenario presented in the CRA Methodology. NOAEL HQs for background are greater than 1 for at least one receptor for cadmium, chromium, lead, nickel, vanadium, and zinc. LOAEL HQs for background are greater than 1 for three receptors for chromium and nickel. Risks calculated for these receptor/ECOPC pairs in each EU risk assessment are presented in the context of these background risk results.

6.0 CONCLUSIONS

This volume has presented an overview of the methods and approaches used in the CRA as well as the CRA results for RFETS. The overall results and conclusions of the CRA are summarized below.

6.1 Human Health Risk Assessment

An HHRA was conducted separately for each of the 12 EUs identified for RFETS. The HHRA consisted of a data evaluation, COC selection step, exposure assessment, toxicity assessment, and risk characterization. Exposure and toxicity assessments and a risk characterization were only performed if COCs were identified for at least one medium in an EU.

COCs were identified for surface soil/surface sediment, but not for subsurface soil/subsurface sediment. Five of the 12 EUs have COCs in surface soil/surface sediment, as listed below:

- Industrial Area EU (arsenic, benzo(a)pyrene),
- Upper Woman Drainage EU (benzo(a)pyrene, dioxins),
- No Name Gulch Drainage EU (vanadium),
- Wind Blown Area EU (arsenic and plutonium 239/240); and
- Upper Walnut Drainage EU (benzo(a)pyrene).

The COCs were quantitatively evaluated for the WRW and WRV receptors, which are consistent with the anticipated land use of RFETS as a wildlife refuge. Cancer risks, noncancer health effects, and radiation doses were estimated.

The cancer risk estimates for all EUs are at the low end of EPA's 1E-06-to-1E-04 risk range. The highest Tier 1 cumulative cancer risk for the WRW (8E-06) was estimated for exposure to benzo(a)pyrene and dioxins in the Upper Woman Drainage EU. It is important to note that the benzo(a)pyrene samples that were used in the risk estimate for the Upper Woman Drainage Area EU are located in an area that is now several feet beneath a landfill cover. As part of the uncertainty analysis for the HHRA, the EPC for benzo(a)pyrene was recalculated using only samples from the Upper Woman Drainage EU that are located outside the landfill cover. This EPC is less than the PRG and, therefore, benzo(a)pyrene would not be identified as a COC for the portion of the Upper Woman Drainage EU that is outside the landfill cover. Accordingly, risks associated with exposure to benzo(a)pyrene in the areas of the EU outside the landfill cover are less than 1E-06.

In addition, the soil containing the dioxin in the Upper Woman Drainage EU is located approximately 20 feet below the ground surface where exposure is not anticipated. Because the dioxin samples in this EU were confirmation samples collected after an accelerated action, the samples were classified as surface soil and included in the risk assessment. However, the locations are actually approximately 20 feet bgs and, therefore, not accessible to the WRW or WRV.

The Tier 1 cancer risk estimates for the Industrial Area EU (3E-06) and the Upper Walnut Drainage EU (1E-06) are all from exposure to arsenic and/or benzo(a)pyrene. Arsenic concentrations in these EUs are similar to background concentrations. Although identified as a COC in the Industrial Area EU and the Upper Walnut Drainage EU, benzo(a)pyrene has not been directly associated with any historical source areas at the site, but could be associated with traffic, pavement degradation, or pavement operations.

The Tier 1 cancer risk estimates for the Wind Blown Area EU (4E-06) are estimated for exposure to plutonium (2E-06) and arsenic (2E-06). Arsenic concentrations in this EU are also similar to background concentrations. The Tier 1 dose estimate for plutonium is 0.3 mrem for the WRW and 0.2 mrem for the WRV child. These dose estimates are well below the acceptable radiation dose of 25 mrem.

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Noncancer health effects were estimated for arsenic in the Industrial Area and Wind Blown Area EUs and vanadium in the No Name Gulch Drainage EU. The noncancer health effects estimates (HIs) were all below 1, indicating that noncancer health effects are unlikely for WRW and WRV receptors at RFETS.

For EUs that did not have COCs, risks are expected to be similar to risks associated with background conditions. Background cancer risks from naturally occurring metals at RFETS are approximately 2E-06 for the WRW and WRV, and HIs are 0.3 for the WRW and 0.1 for the WRV.

6.2 Ecological Risk Assessment

An ERA for terrestrial receptors was conducted separately for each of the 12 EUs identified for RFETS. In addition, an ERA for aquatic receptors was conducted for each of the seven AEUs. The ERA consisted of a data evaluation, ECOPC identification step, exposure assessment, toxicity assessment, and risk characterization. Exposure and toxicity assessments and a risk characterization were only performed if ECOPCs were identified for at least one medium in an EU or AEU.

Of the 12 EUs that were evaluated for potential risk to terrestrial ecological receptors, eight EUs had ECOPCs identified for surface soil for risk characterization for non-PMJM receptors. PMJM receptors were evaluated for eight EUs, and of these, four had surface soil ECOPCs for the PMJM receptor. The four EUs that did not have any ECOPCs identified for either non-PMJM or PMJM receptors (West Area EU, Rock Creek Drainage EU, Southeast Buffer Zone EU, and Southwest Buffer Zone EU) are part of the BZ area of RFETS. No ECOPCs were identified for subsurface soil for any of the EUs.

The ECOPC/receptor pairs were evaluated in the risk characterization using a range of EPCs, exposure scenarios, and toxicity values to give a range of risk estimates. No significant risks were identified for any receptor in any EU based on the chemical data. In addition, the high species diversity and continued use of the site by numerous vertebrate species verify that habitat quality for these species remains acceptable and the ecosystem functions are being maintained. As discussed for each EU or AEU in the ERA, data collected on wildlife abundance and diversity indicate that wildlife populations are stable and species richness remains high at RFETS. This supports the chemical risk conclusions that no significant risks are predicted for receptor populations at RFETS.

Of the seven AEUs that were evaluated for potential risk to aquatic ecological receptors, five AEUs had ECOPCs identified for surface water and sediment. The two AEUs that did not have ECOPCs identified are Rock Creek AEU and Southeast AEU, both located in the BZ area of RFETS. The ECOPCs were evaluated in the risk characterization using multiple lines of evidence including an HQ assessment using chemical data and review of drainage-specific conclusions from previous studies. As discussed for each AEU, the previous studies included tissue analyses, aquatic population studies, toxicity bioassays, waterfowl and wading bird exposure studies, and contaminant loading analyses.

The AEU assessments indicate that there are no continuing, significant risks to aquatic life from residual ECOPCs due to RFETS-related operations. Overall, the aquatic communities in the AEUs are limited by natural environmental conditions (i.e., low flows and poor habitat) characteristic of this area along the Colorado Front Range. No additional risks above what would be expected to be encountered in the natural environment in the vicinity of the AEUs are predicted for the aquatic life receptors evaluated in the ERA.

The overall conclusions from the ERA indicate that site conditions due to residual contamination do not represent significant risk of adverse ecological effects to receptors from exposure to site-related residual contamination.

7.0 REFERENCES

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TABLES

Table ES.1

Summary of Exposure Unit Characteristics

Exposure Unit	Number of Acres	Topography	Predominant Vegetation Type	Number of PMJM Habitat Patches[a]	Number of Historical IHSS/PACs and UBCs[a]	Topographic and Hydrologic Location Relative to the Industrial Area
West Area	468	Upland	Xeric tallgrass prairie	3	1	Upgradient
Rock Creek Drainage	735	Drainage	Mesic mixed grassland and xeric tallgrass prairie	10	0	Upgradient
Inter-Drainage	596	Upland	Xeric tallgrass prairie	3	7	Upgradient
No Name Gulch Drainage	425	Drainage	Mesic mixed grassland, xeric tallgrass prairie, and disturbed reclaimed areas	2	21	Upgradient
Upper Walnut Drainage	403	Drainage	Mesic mixed and reclaimed grassland	5	25	Downgradient
Lower Walnut Drainage	390	Drainage	Mesic mixed grassland	3	1	Downgradient
Wind Blown Area	715	Upland	Mesic mixed grassland and xeric tallgrass prairie	1	46	Downgradient
Upper Woman Drainage	524	Drainage	Mesic mixed grassland and xeric tallgrass prairie	3	23	Cross-gradient
Lower Woman Drainage	448	Drainage	Reclaimed and mesic mixed grasslands	7	6	Downgradient
Southwest Buffer Zone Area	476	Upland	Xeric tallgrass prairie and mesic mixed grasslands	3	1	Upgradient
Southeast Buffer Zone Area	579	Upland	Reclaimed and mesic mixed grasslands	3	1	Upgradient
Industrial Area	428	Upland	Disturbed	0	285	N/A

[a] Some IHSS and PACs extend into more than one EU. In this event, they are counted in each of the EUs in which they occur.
IHHS = Individual Hazardous Substance Site.
PAC = Potential Area of Concern.
PMJM = Preble's meadow jumping mouse.
UBC = Under Building Contamination.

Table ES.2
Summary of Human Health Contaminants of Concern (COCs)

Medium	Contaminant of Concern	Exposure Unit[a]				
		Industrial Area (Volume 14)	Upper Woman Drainage (Volume 10)	No Name Gulch Drainage (Volume 6)	Wind Blown Area (Volume 9)	Upper Walnut Drainage (Volume 7)
Surface Soil/Surface Sediment[b]	**Inorganics**					
	Arsenic	X			X	
	Vanadium			X		
	Organics					
	Benzo(a)pyrene	X	X			X
	2,3,7,8-TCDD TEQ		X			
	Radionuclides					
	Plutonium-239/240				X	

[a] No COCs were selected for any of the other exposure units that are not listed here.
[b] No COCs were selected for any other media.

Table ES.3
Site-Specific and Key Exposure Assumptions for RFETS

Exposure Assumption	Wildlife Refuge Worker	Wildlife Refuge Visitor
Exposure frequency (days/year)	230	100
Exposure duration (years)	18.7	30 (6 [Child], 24 [Adult])
Exposure time (hours/day)	8	2.5
Soil ingestion rate (milligrams [mg]/day)	100	50 (Adult), 100 (Child)
Exposed skin-surface area (square centimeters [cm^2])	3,300[a]	5,700 (Adult), 2,800 (Child)[b]
Outdoor inhalation rate (cubic meters [m^3]/hour)	1.3[c]	2.4 (Adult), 1.6 (Child)[d]

[a] Assumes worker is wearing short-sleeved shirt and long pants.
[b] Assumes visitor is wearing short-sleeved shirt, shorts, and shoes, and would contact soil with all body parts not covered by clothing.
[c] This value is an average that incorporates light, moderate, and heavy activity levels.
[d] These values represent breathing during heavy activity.

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Table ES.4
Toxicity Criteria

Contaminant of Concern	Cancer Slope Factor for Non-Radionuclide Chemicals[a]		Cancer Slope Factor for Radionuclides[a]			Reference Doses for Noncarcinogens[b]	
	Oral/Ingestion Slope Factor (mg/kg-day)$^{-1}$	Inhalation Slope Factor (mg/kg-day)$^{-1}$	Soil Ingestion Oral Slope Factor (Risk/pCi)	Inhalation Slope Factor (Risk/pCi)	External Slope Factor (Risk/yr/pCi/g)	Oral RfD (mg/kg-day)	Inhalation RfD (mg/kg-day)
Inorganics							
Arsenic	1.50E+00	1.51E+01	N/A	N/A	N/A	3.00E-04	n/a
Vanadium	N/A	N/A	N/A	N/A	N/A	1.00E-03	n/a
Organics							
Benzo(a)pyrene	7.30E+00	3.10E-01	N/A	N/A	N/A	n/a	n/a
2,3,7,8-TCDD	1.50E+05	1.50E+05	N/A	N/A	N/A	n/a	n/a
Radionuclides							
Plutonium-239	N/A	N/A	2.76E-10	3.33E-08	2.00E-10	n/a	n/a
Plutonium-240	N/A	N/A	2.77E-10	3.33E-08	6.98E-11	n/a	n/a

N/A = Not applicable; the chemical does not fall within this group.
n/a = Toxicity for evaluating noncancer health effects of this chemical are not available.
mg/kg = Milligrams per kilogram.
pCi = Picocuries.
pCi/g = Picocuries per gram.
RfD = Reference dose.
[a] Because the exposure estimate is multiplied by the slope factor to arrive at a risk, a larger slope factor indicates a greater carcinogenic potency.
[b] The exposure estimate is divided by the reference dose; therefore, the smaller the reference dose, the greater the toxicity.

Table ES.5
Summary of Human Health Risk Estimates[a]

Exposure Unit	Surface Soil/Surface Sediment COC	Wildlife Refuge Worker						Wildlife Refuge Visitor					
		Excess Lifetime Cancer Risk		Noncancer Hazard Quotient		Annual Dose Rate[b]		Excess Lifetime Cancer Risk		Noncancer Hazard Quotient		Annual Dose Rate[b]	
		Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Industrial Area (Volume 14)	Arsenic	2E-06	2.E-06	0.01	0.01	N/A	N/A	2E-06	2E-06	0.01	0.01	N/A	N/A
	Benzo(a)pyrene	1E-06	1.E-06	NC	NC	N/A	N/A	1E-06	1E-06	NC	NC	N/A	N/A
Upper Woman Drainage (Volume 10)	2,3,7,8-TCDD TEQ	2E-06	2.E-06	NC	NC	N/A	N/A	2E-06	2E-06	NC	NC	N/A	N/A
	Benzo(a)pyrene	6E-06	9E-07	NC	NC	N/A	N/A	7E-06	1E-06	NC	NC	N/A	N/A
No Name Gulch Drainage (Volume 6)	Vanadium	NC	NC	0.1	0.04	N/A	N/A	NC	NC	0.01	0.02	N/A	N/A
Wind Blown Area (Volume 9)	Arsenic	2E-06	2E-06	0.02	0.01	N/A	N/A	2E-06	1E-06	0.01	0.01	N/A	N/A
	Plutonium-239/240	2E-06	8E-07	NC	NC	3E-01	2E-01	1E-06	5E-07	NC	NC	2E-01[c]	1E-01[c]
Upper Walnut Drainage (Volume 7)	Benzo(a)pyrene	1E-06	9E-07	NC	NC	N/A	N/A	2E-06	1E-06	NC	NC	N/A	N/A

TEQ = Toxicity equivalence.
TCDD = Tetrachlorodibenzo-p-dioxin.
NC = Not calculated. Appropriate toxicity criteria are not available.
N/A = This health effect is not applicable for the chemical.
COC = Contaminant of concern.
[a] Includes only EUs and media for which COCs have been selected.
[b] Annual dose rate is in millirems (mrem) per year.
[c] Child annual dose rate. Adult annual dose rate: Tier 1 = 7E-02; Tier 2 = 4E-02.

Table ES.6
Representative Species for the ERA

Functional Group	Representative Species
Burrowing Small Mammal	Black-Tailed Prairie Dog
Herbivorous Small Mammal	Deer Mouse
Insectivorous Small Mammal	Deer Mouse PMJM
Herbivorous Bird	Mourning Dove
Insectivorous Bird	Mourning Dove
Ruminant Wildlife	Mule Deer
Mammalian Predator	Coyote
Avian Predator	American Kestrel
Plant	General
Terrestrial Invertebrate	General
Aquatic Life	General Aquatic Life (including amphibians and benthic macroinvertebrates ([sediment exposure])

Table ES.7
Summary of Terrestrial ECOPCs

Exposure Unit	Non-PMJM Surface Soil ECOPCs	PMJM Surface Soil ECOPCs	Burrowing Receptor Subsurface Soil ECOPCs
West Area EU (Volume 3)	None	Not Evaluated	None
Rock Creek Drainage EU (Volume 4)	None	None	None
Inter-Drainage EU (Volume 5)	Antimony	None	None
	Lead		
No Name Gulch EU (Volume 6)	Antimony	Nickel	None
	Barium	Vanadium	
	Copper	Zinc	
	Mercury		
	Molybdenum		
	Nickel		
	Tin		
	Bis(2-ethylhexyl)phthalate		
	Di-n-butylphthalate		
	Total PCBs		
Upper Walnut Drainage EU (Volume 7)	Antimony	Antimony	None
	Copper	Nickel	
	Molybdenum	Tin	
	Nickel	Vanadium	
	Silver	Zinc	
	Tin		
	Vanadium		
	Zinc		
	Bis(2-ethylhexyl)phthalate		
	Di-n-butylphthalate		
	Total PCBs		
Lower Walnut Drainage (Volume 8)	4,4'-DDT	None	None
Wind Blown Area EU (Volume 9)	Chromium	Not Evaluated	None
	Manganese		
	Nickel		
	Silver		
	Thallium		
	Tin		

Table ES.7
Summary of Terrestrial ECOPCs

Exposure Unit	Non-PMJM Surface Soil ECOPCs	PMJM Surface Soil ECOPCs	Burrowing Receptor Subsurface Soil ECOPCs
	Bis(2-ethylhexyl)phthalate		
	Endrin		
	Total PCBs		
Upper Woman Drainage EU (Volume 10)	Antimony	Antimony	None
	Copper		
		Chromium	
	Nickel	Copper	
	Silver	Manganese	
	Tin	Molybdenum	
	Uranium	Nickel	
	Vanadium		
	Bis(2-ethylhexyl)phthalate	Tin	
	Di-n-butylphthalate	Vanadium	
	Dioxin (2,3,7,8-TCDD TEQ)	Zinc	
	Total PCBs	Total PCBs	
Lower Woman Crainage EU (Volume 11)	Chromium	Chromium	None
	Copper	Manganese	
	Manganese	Nickel	
	Nickel	Selenium	
	Thallium	Tin	
	Tin	Vanadium	
	Vanadium	Zinc	
Southwest Buffer Zone Area EU (Volume 12)	None	None	None
Southeast Buffer Zone Area EU (Volume 13)	None	Not Evaluated	None
Industrial Area Exposure Unit (Volume 14)	Antimony	Not Evaluated	None
	Chromium		
	Copper		
	Molybdenum		
	Tin		
	Bis(2-ethylhexyl)phthalate		
	Di-n-butylphthalate		
	Dioxin (2,3,78-TCDD TEQ)		
	Total PCBs		
Sitewide EU (Volume 15A)	Nickel	Not Evaluated	Not Evaluated

Table ES.7
Summary of Terrestrial ECOPCs

Exposure Unit	Non-PMJM Surface Soil ECOPCs	PMJM Surface Soil ECOPCs	Burrowing Receptor Subsurface Soil ECOPCs
	Dioxin (2,3,78-TCDD TEQ)		

ECOPC = Ecological contaminant of potential concern.
PMJM = Preble's meadow jumping mouse.

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Table ES.8
Surface Water ECOPCs in the AEUs

ECOPC	No Name	Rock Creek	McKay Ditch	Southeast	North Walnut	South Walnut	Woman Creek
Inorganics							
Aluminum (T)			x		x		
Ammonia (T)					x	x	x
Antimony (T)							
Barium (T)	x						
Beryllium (T)							
Cadmium (D)			x		x	x	x
Chromium (D)							
Cobalt (D)							
Copper (D)							
Cyanide (T)					x	x	
Fluoride (T)							
Iron (D)							
Lead (D)	x						
Lithium (T)					x		
Manganese (D)							
Mercury (D)							
Nickel (D)							
Nitrite							
Selenium (T)			x				
Silver (D)	x				x	x	x
Strontium (T)							
Tin (T)							
Vanadium (T)					x		
Zinc (D)	x		x				
Organics							
44-DDT						x	
Aroclor-1254					x		

Table ES.8
Surface Water ECOPCs in the AEUs

ECOPC	No Name	Rock Creek	McKay Ditch	Southeast	North Walnut	South Walnut	Woman Creek
Pentachlorophenol	x						
Phenanthrene	x						
Radium-228					x		
Total ECOPCs	**6**	**0**	**4**	**0**	**9**	**5**	**3**

T = Total metal.
D = Dissolved metal.
ECOPC = Ecological contaminant of potential concern.
AEU = Aquatic Exposure Unit.
The ECOPC selection was conducted on the MDC, either dissolved or total.
x = ECOPC

Table ES.9
Sediment ECOPCs in the AEUs

ECOPC	No Name	Rock Creek	McKay Ditch	Southeast	North Walnut	South Walnut	Woman Creek
Inorganics							
Aluminum	x		x		x	x	x
Antimony					x	x	x
Arsenic							
Barium	x				x	x	x
Cadmium					x	x	x
Chromium			x				
Copper					x	x	x
Fluoride			x		x	x	x
Iron	x				x		x
Lead	x				x	x	x
Manganese					x		
Mercury					x		x
Nickel			x		x		x
Selenium			x		x		x
Silver					x	x	x
Zinc					x	x	x
Organics							
2-Methylnaphthalene					x		
4-Methylphenol							x
4,4-DDT					x		
Acenaphthene					x	x	x
Anthracene					x	x	x
Aroclor-1254					x	x	x
Aroclor-1260						x	
Atrazine					x		
Benzo(a)anthracene	x				x	x	x
Benzo(a)pyrene	x				x	x	x

Table ES.9
Sediment ECOPCs in the AEUs

ECOPC	No Name	Rock Creek	McKay Ditch	Southeast	North Walnut	South Walnut	Woman Creek
Benzo(g,h,i)perylene	x				x	x	x
Benzo(k)fluoranthene					x	x	x
Bromomethane						x	
Carbazole					x	x	
Chrysene	x				x	x	x
Dibenz(a,h)anthracene							
Fluoranthene							x
Fluorene							
Heptachlor							x
Indeno(1,2,3-cd)pyrene	x						x
Naphthalene							
Pentachlorophenol							
Phenanthrene	x						x
Pyrene	x						x
2,3,7,8-TCDD TEQ					x		x
Total PCBs					x	x	x
Total ECOPCs	**11**	**0**	**5**	**0**	**28**	**21**	**29**

x = ECOPC
ECOPC = Ecological contaminant of potential concern.
AEU = Aquatic Exposure Unit.

Table ES.10
Summary of Ecological Risk Conclusions

EUs	Non-PMJM Receptor	PMJM Receptor	Burrowing Receptor
West Area EU (Volume 3)	No ECOPCs. No risk is predicted.	Not Evaluated.	No ECOPCs. No risk is predicted.
Rock Creek Drainage EU (Volume 4)	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
Inter-Drainage EU (Volume 5)	No significant risk is predicted.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
No Name Gulch Drainage EU (Volume 6)	No significant risk is predicted.	No significant risk is predicted.	No ECOPCs. No risk is predicted.
Upper Walnut Drainage EU (Volume 7)	No significant risk is predicted.	No significant risk is predicted.	No ECOPCs. No risk is predicted.
Lower Walnut Drainage (Volume 8)	No significant risk is predicted.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
Wind Blown Area EU (Volume 9)	No significant risk is predicted.	Not Evaluated	No ECOPCs. No risk is predicted.
Upper Woman Drainage EU (Volume 10)	No significant risk is predicted.	No significant risk is predicted.	No ECOPCs. No risk is predicted.
Lower Woman Drainage EU (Volume 11)	No significant risk is predicted.	No significant risk is predicted.	No ECOPCs. No risk is predicted.
Southwest Buffer Zone EU (Volume 12)	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.
Southeast Buffer Zone EU (Volume 13)	No ECOPCs. No risk is predicted.	Not Evaluated.	No ECOPCs. No risk is predicted.
Industrial Area Exposure Unit (Volume 14)	No significant risk is predicted.	Not Evaluated.	No ECOPCs. No risk is predicted.
Sitewide EU (Volume 15A)	No significant risk is predicted.	Not Evaluated.	Not Evaluated.
AEUs	**Surface Water**	**Sediment**	
Sitewide Aquatic ERA (Volume 15B)			
No Name Gulch AEU	No significant risk is predicted.	No significant risk is predicted.	
McKay Ditch AEU	No significant risk is predicted.	No significant risk is predicted.	
Rock Creek AEU	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	
Southeast AEU	No ECOPCs. No risk is predicted.	No ECOPCs. No risk is predicted.	
North Walnut Creek AEU	No significant risk is predicted.	No significant risk is predicted.	
South Walnut Creek AEU	No significant risk is predicted.	No significant risk is predicted.	
Woman Creek AEU	No significant risk is predicted.	No significant risk is predicted.	

FIGURES

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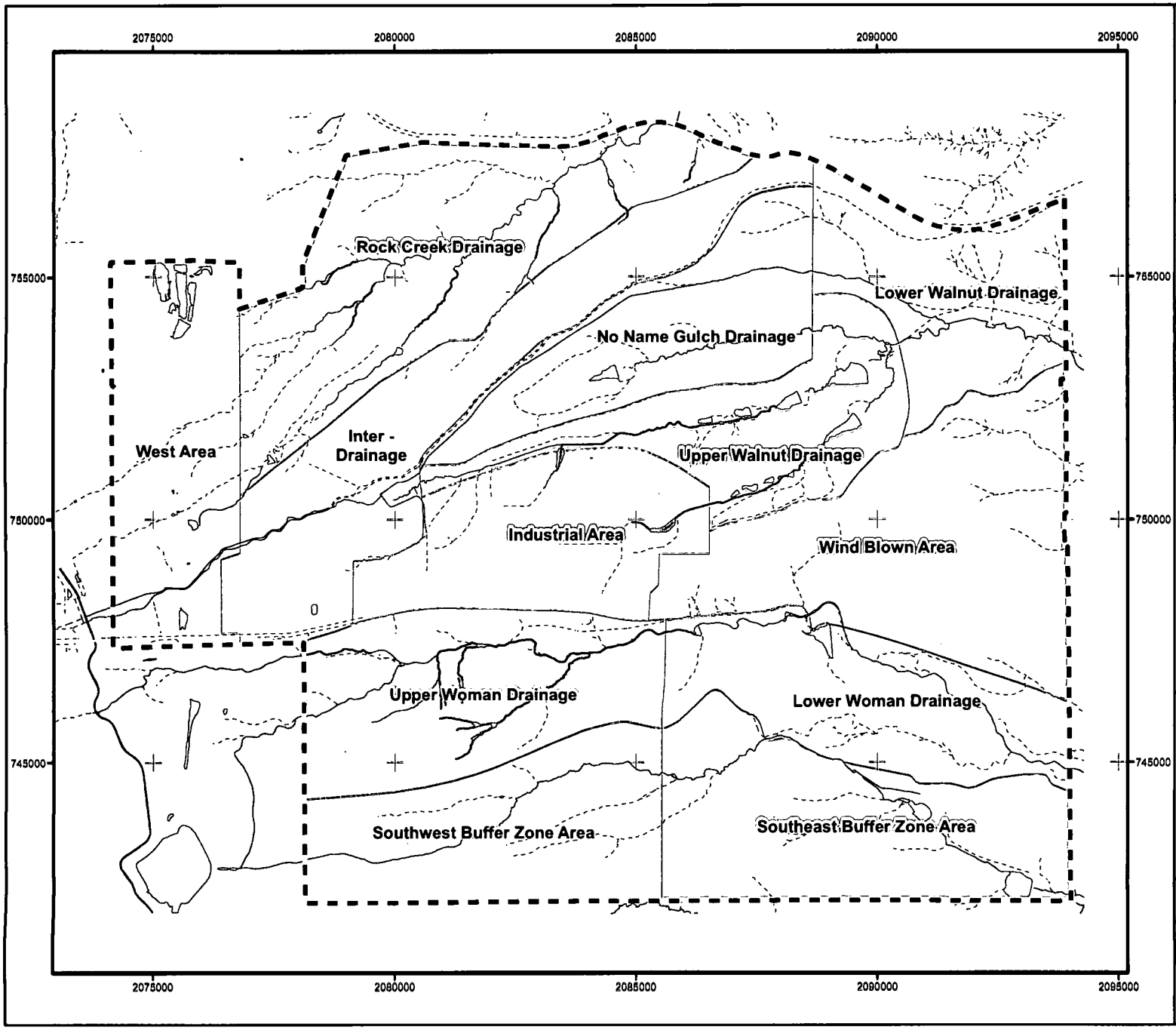

Figure ES.1
Rocky Flats Environmental Technology Site
Exposure Units

KEY

- Exposure unit boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

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0 1,500 3,000
Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

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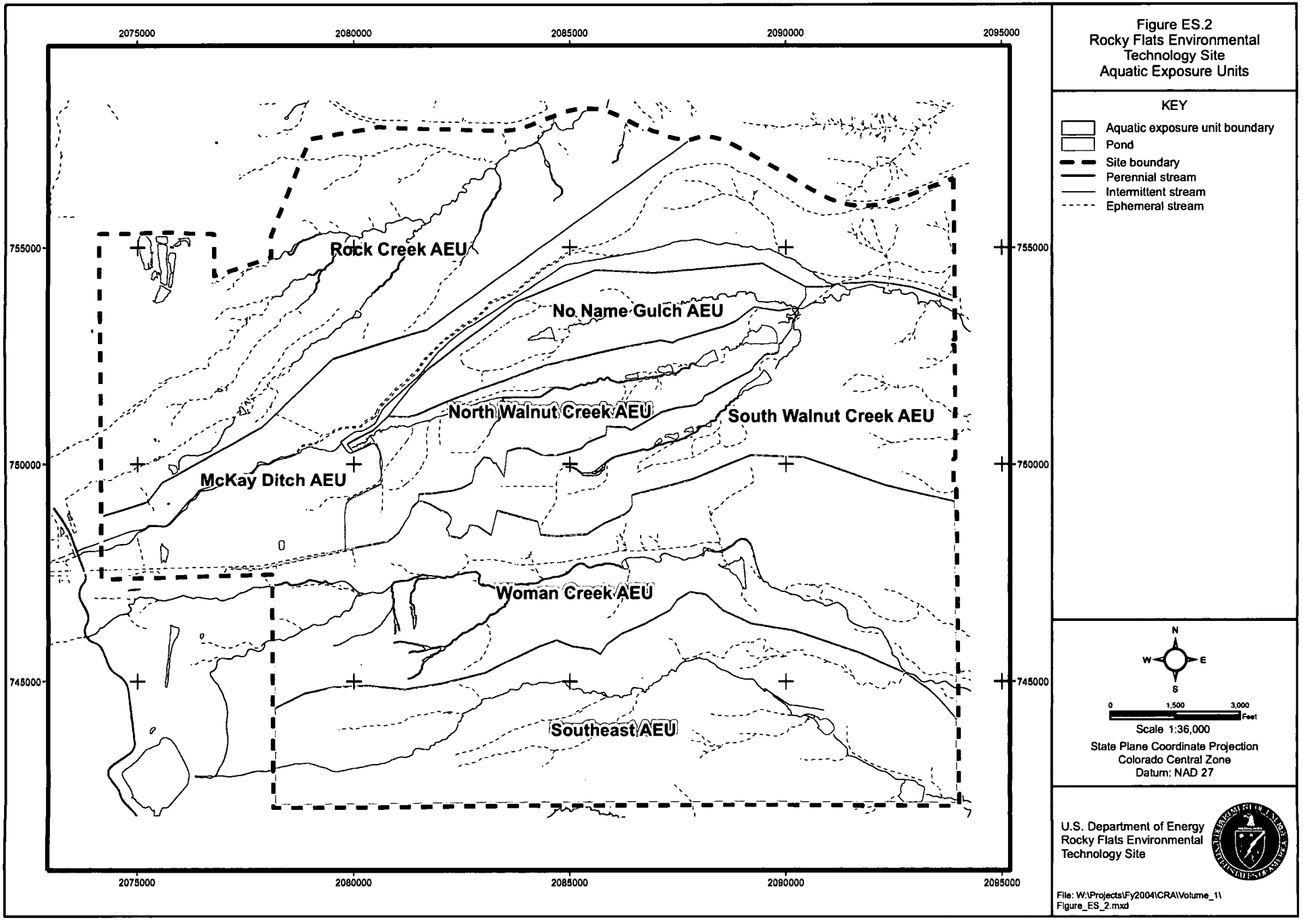
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745000
Rock Creek AEU
No Name Gulch AEU
North Walnut Creek AEU
South Walnut Creek AEU
McKay Ditch AEU
Woman Creek AEU
Southeast AEU
Figure ES.2
Rocky Flats Environmental
Technology Site
Aquatic Exposure Units
KEY
Aquatic exposure unit boundary
Pond
Site boundary
Perennial stream
Intermittent stream
Ephemeral stream
N
W
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Feet
Scale 1:36,000
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27
U.S. Department of Energy
Rocky Flats Environmental
Technology Site
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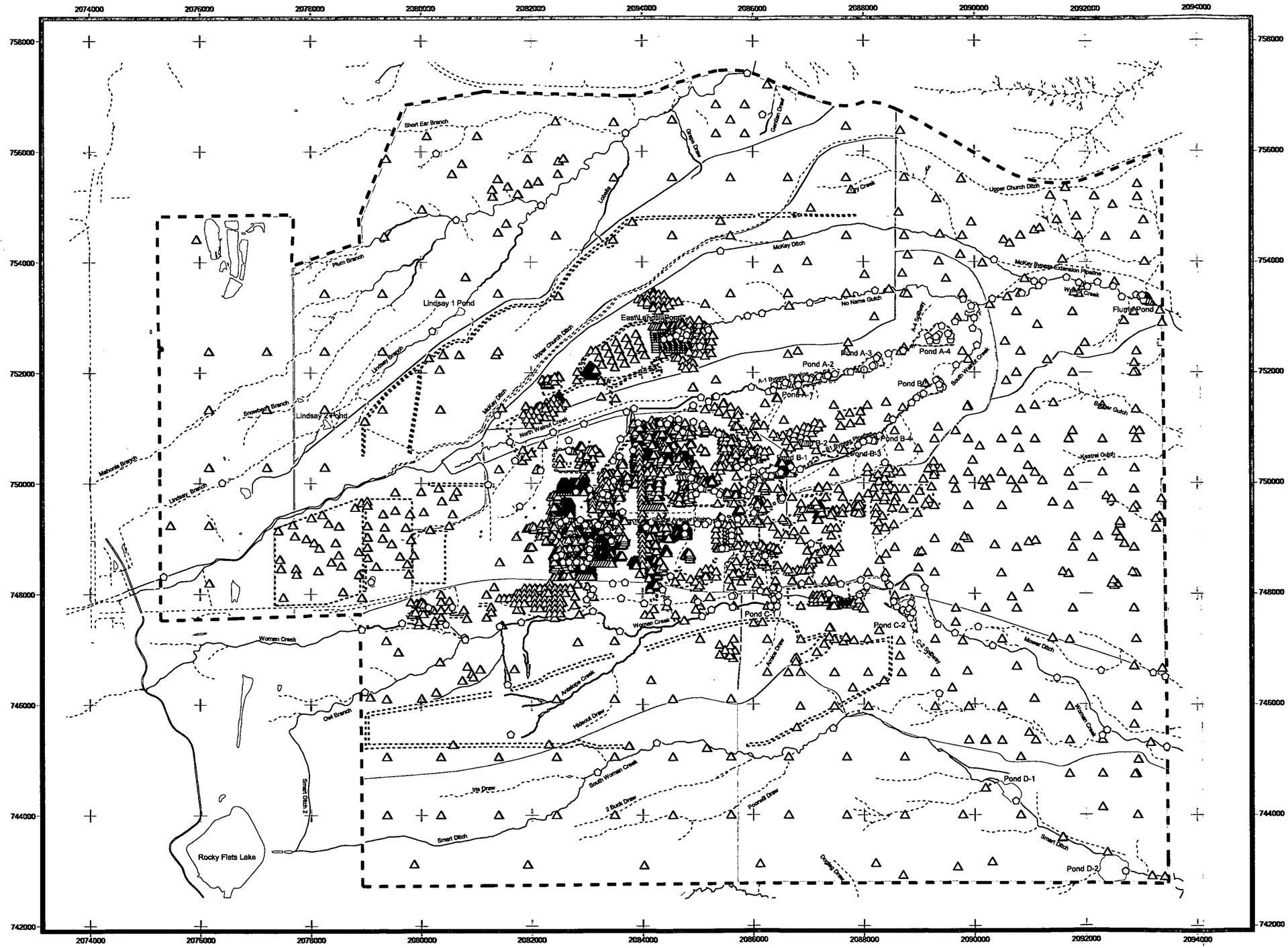
Figure ES.3

Surface Soil and Surface Sediment Sample Locations



KEY

- △ Surface soil sample location
- ⬠ Surface sediment sample location

Standard Map Features

- Historical IHSS/PAC
- Pond
- Perennial stream
- Intermittent stream
- Ephemeral stream
- Site boundary

Exposure Units

- Industrial Area
- Inter-Drainage
- Lower Walnut Drainage
- Lower Woman Drainage
- No Name Gulch Drainage
- Rock Creek Drainage
- Southeast Buffer Zone Area
- Southwest Buffer Zone Area
- Upper Walnut Drainage
- Upper Woman Drainage
- West Area
- Wind Blown Area

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Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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Technology Site

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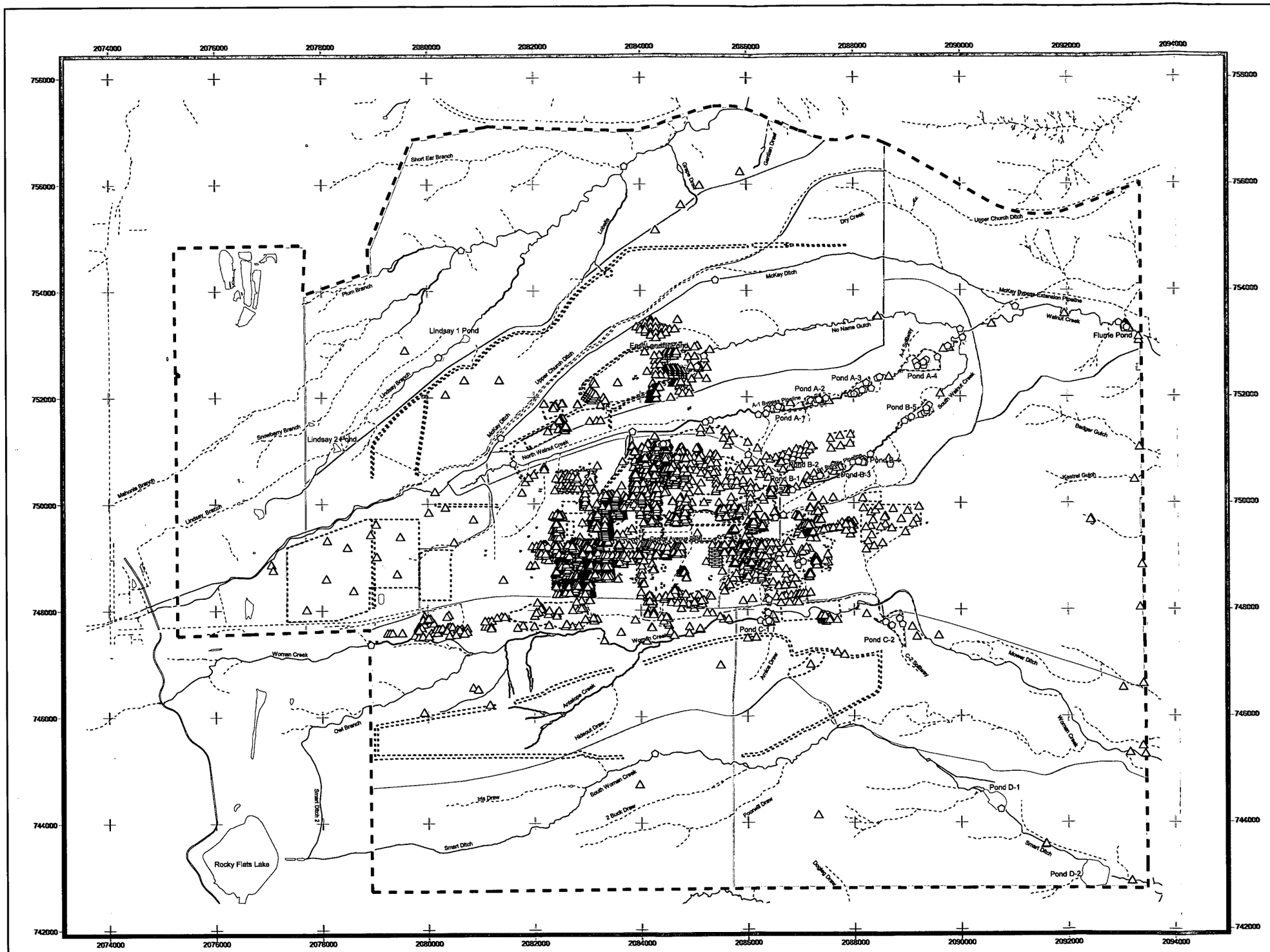

Figure ES.4

Subsurface Soil and Subsurface Sediment Sample Locations

KEY

- △ Subsurface soil sample location
- ⬠ Subsurface sediment sample location

Standard Map Features

- Historical IHSS/PAC
- Pond
- Perennial stream
- Intermittent stream
- Ephemeral stream
- Site boundary

Exposure Units

- Industrial Area
- Inter-Drainage
- Lower Walnut Drainage
- Lower Woman Drainage
- No Name Gulch Drainage
- Rock Creek Drainage
- Southeast Buffer Zone Area
- Southwest Buffer Zone Area
- Upper Walnut Drainage
- Upper Woman Drainage
- West Area
- Wind Blown Area

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State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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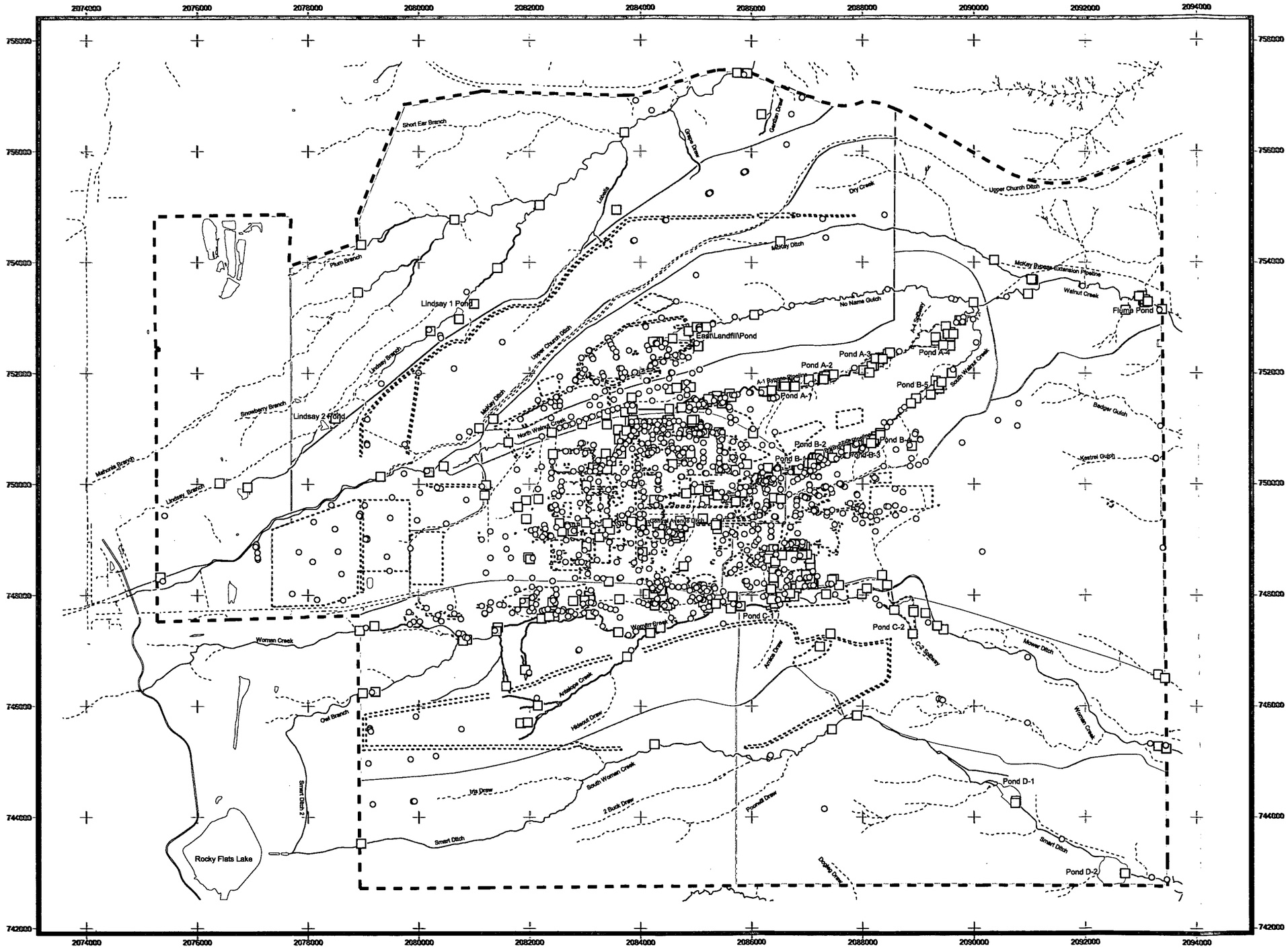
Figure ES.5

Ground Water and Surface Water Sample Locations



KEY

- ○ Groundwater Sample Location
- □ Surface Water Sample Location

Standard Map Features

- Historical IHSS/PAC
- Pond
- Perennial stream
- Intermittent stream
- Ephemeral stream
- Site boundary

Exposure Units

- Industrial Area
- Inter-Drainage
- Lower Walnut Drainage
- Lower Woman Drainage
- No Name Gulch Drainage
- Rock Creek Drainage
- Southeast Buffer Zone Area
- Southwest Buffer Zone Area
- Upper Walnut Drainage
- Upper Woman Drainage
- West Area
- Wind Blown Area

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0 1000 2000 Feet

Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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Technology Site

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Figure ES.6 Human Health CRA COC Selection Process

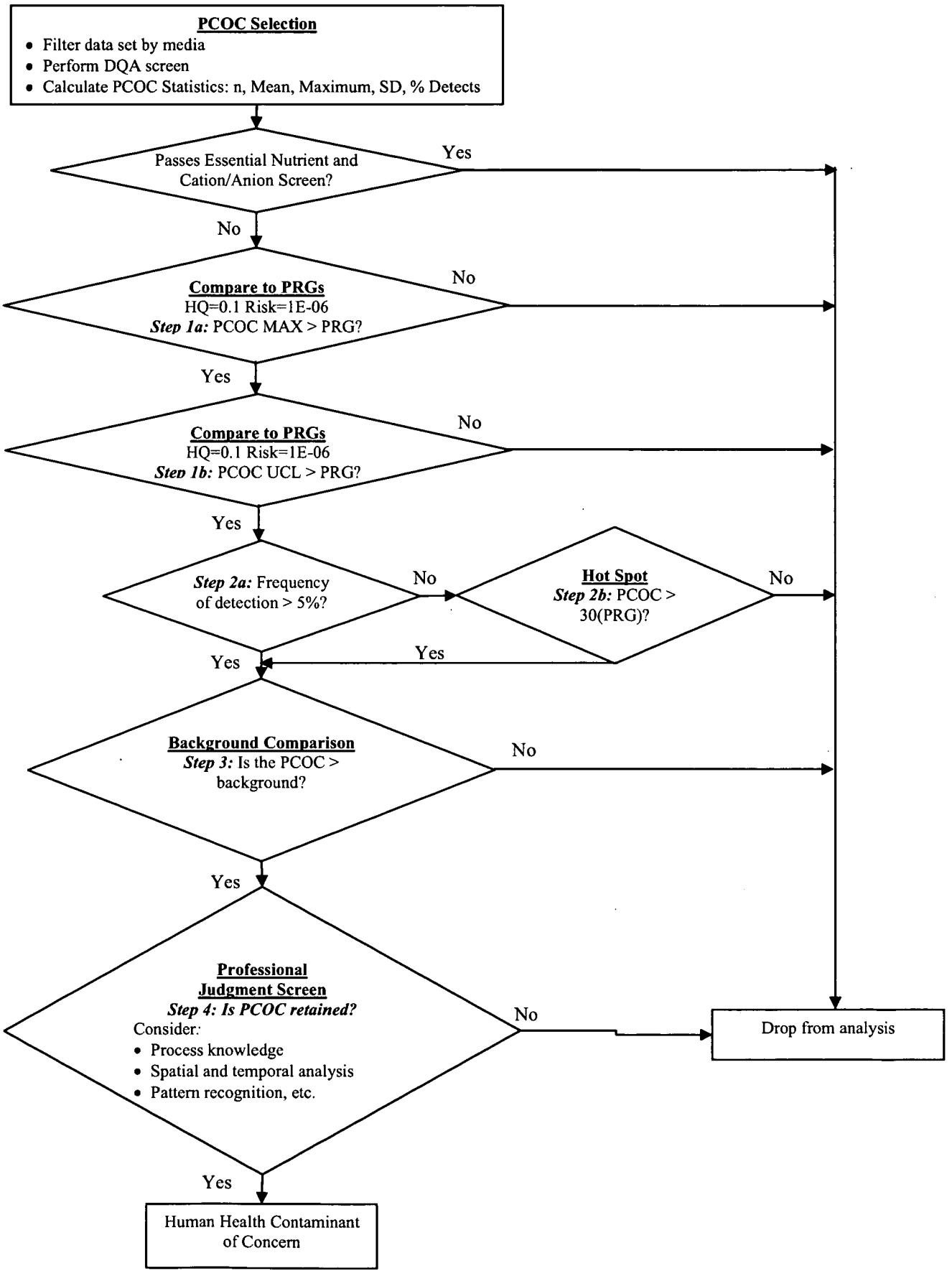


Figure ES.7
Human Health Site Conceptual Model

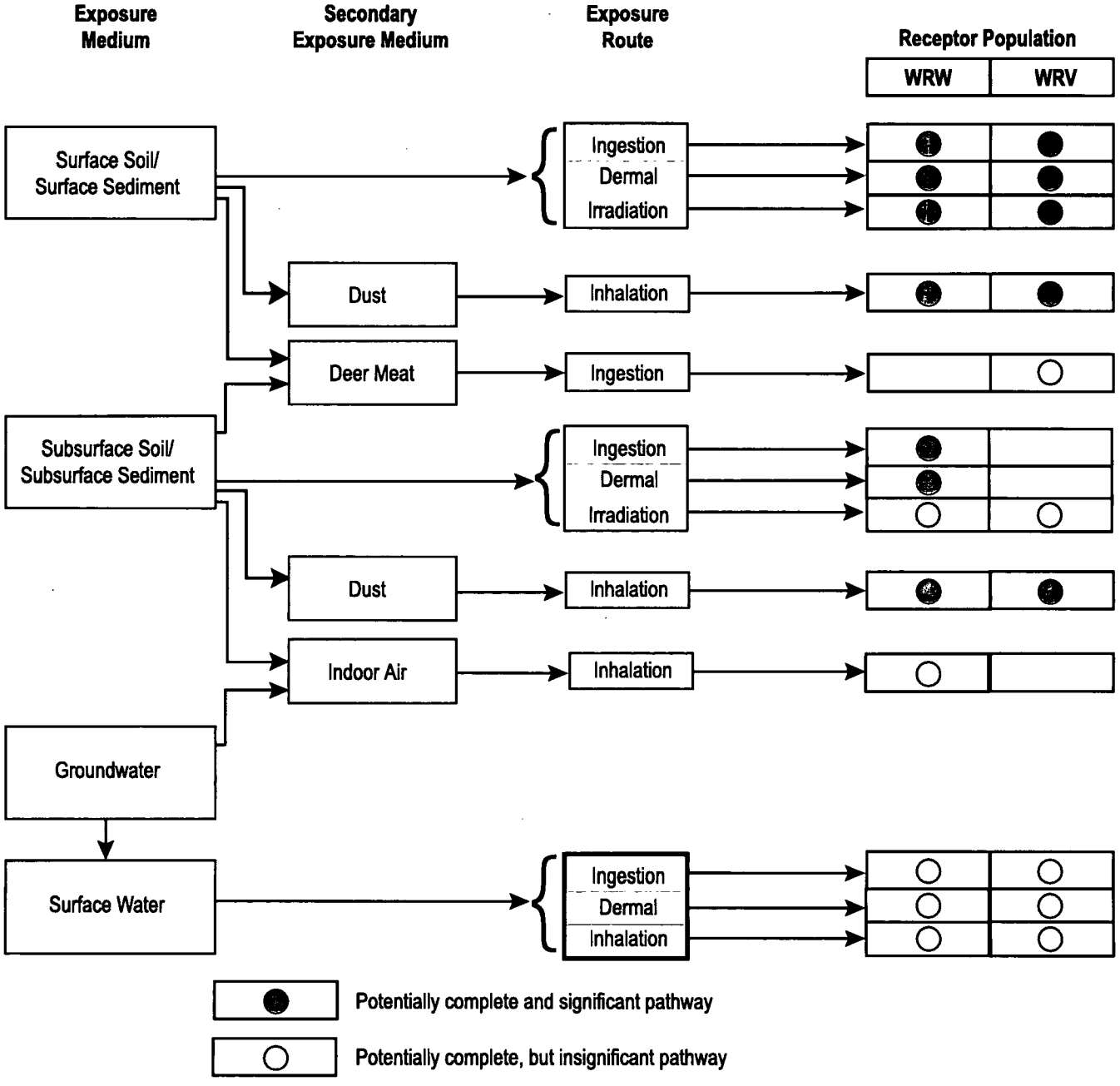


Figure ES.8
Illustrated Human Health Site Conceptual Model

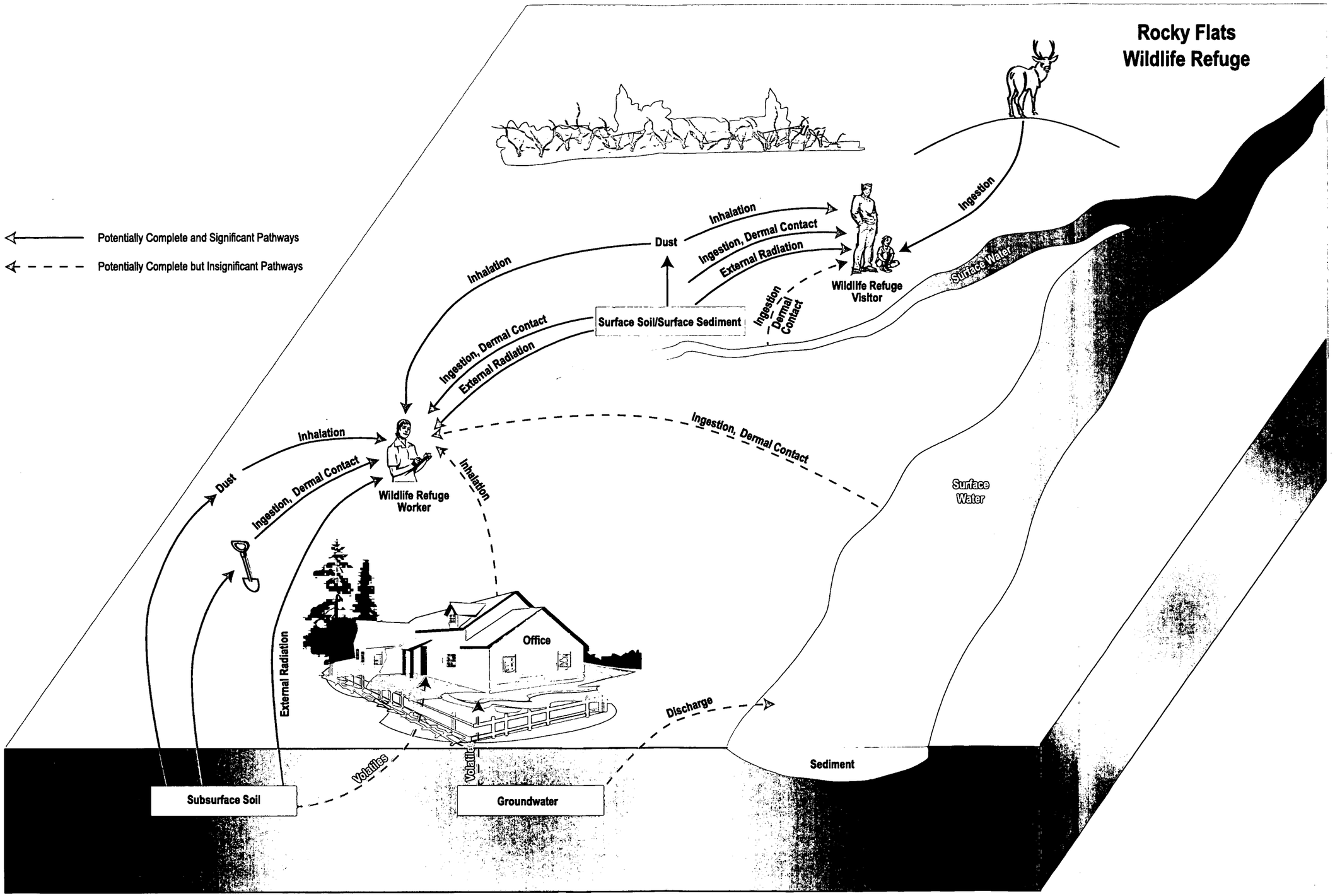


Figure ES.9 Ecological Site Conceptual Model

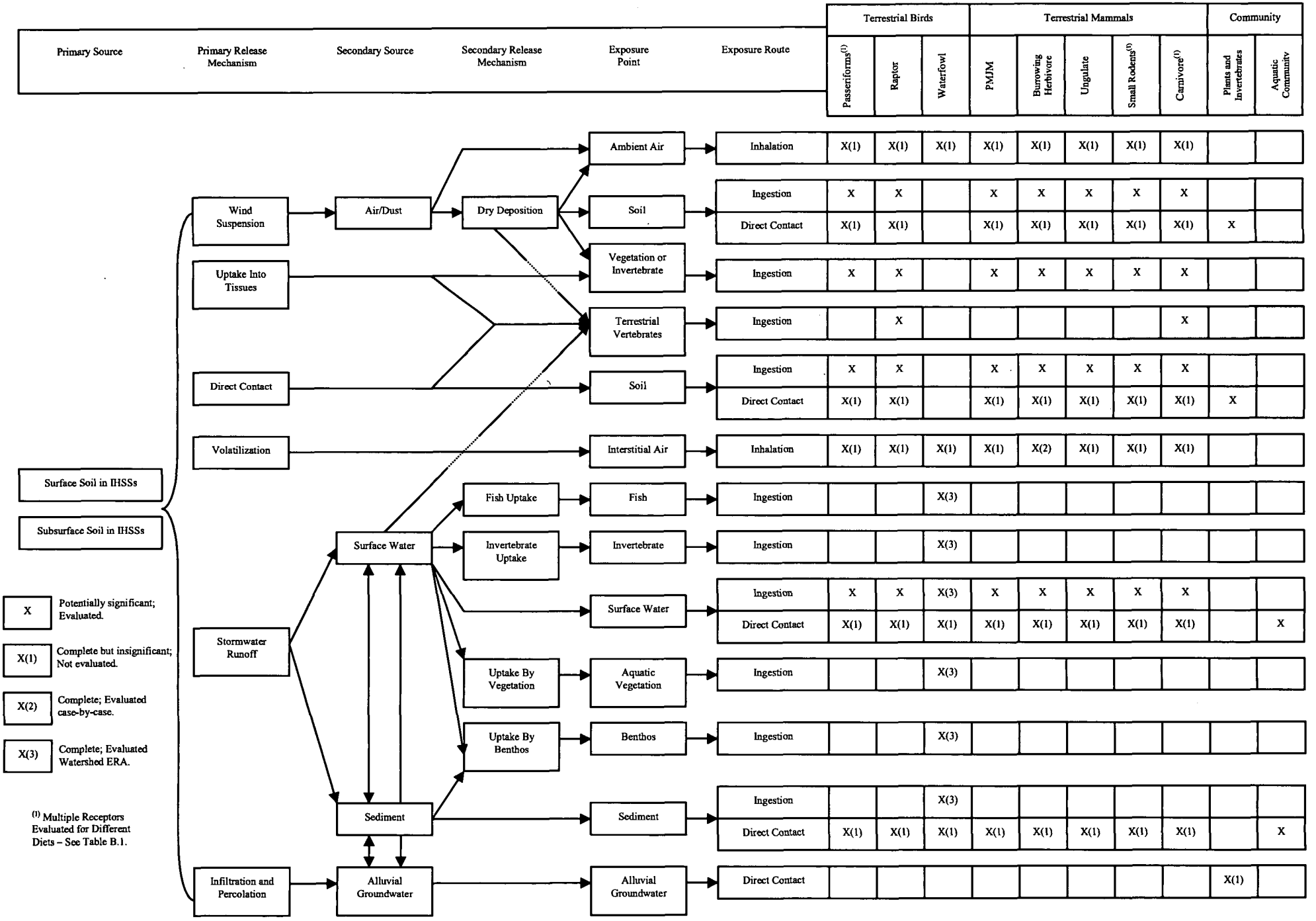


Figure ES.10
Illustrated Ecological Site Conceptual Model

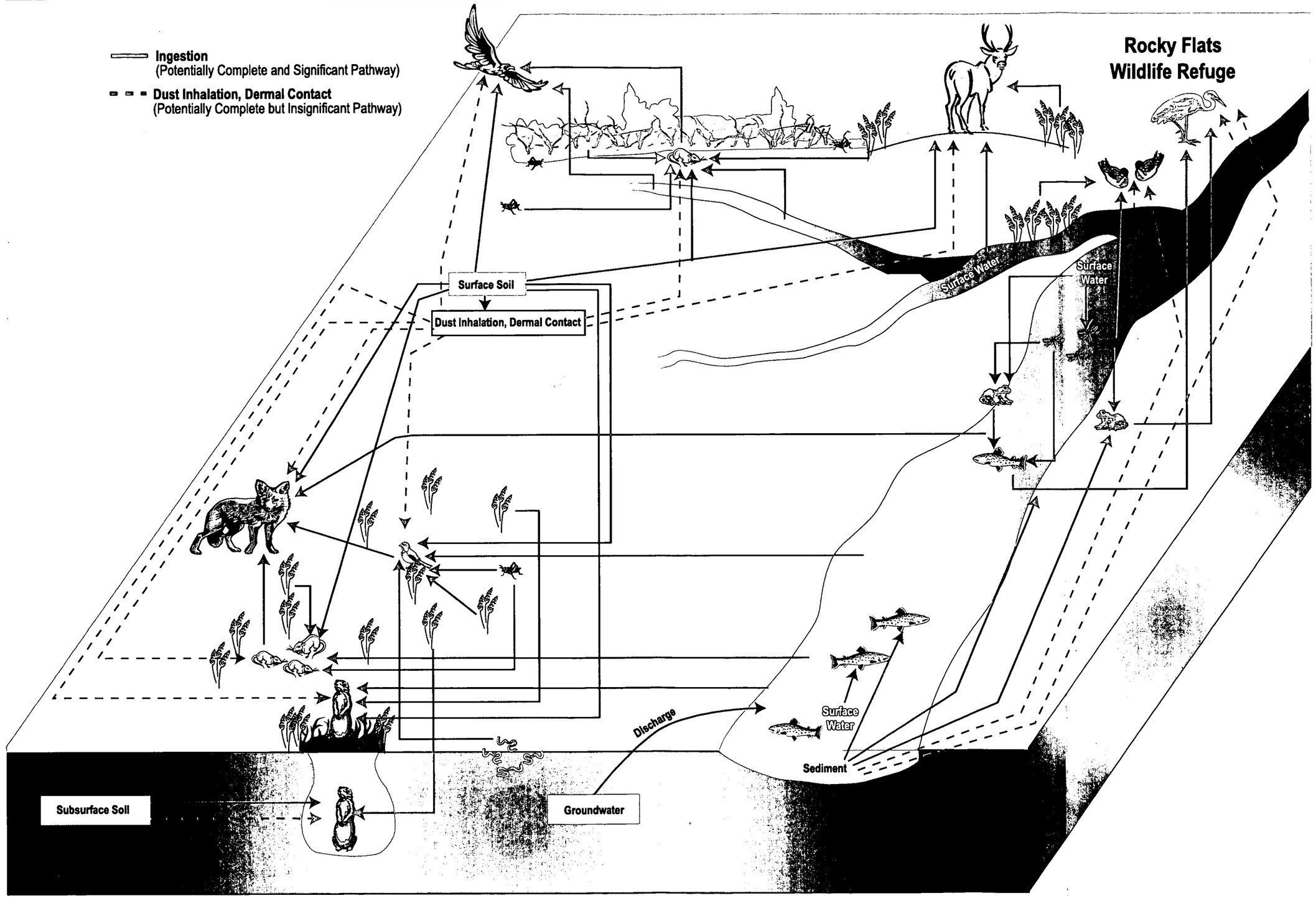
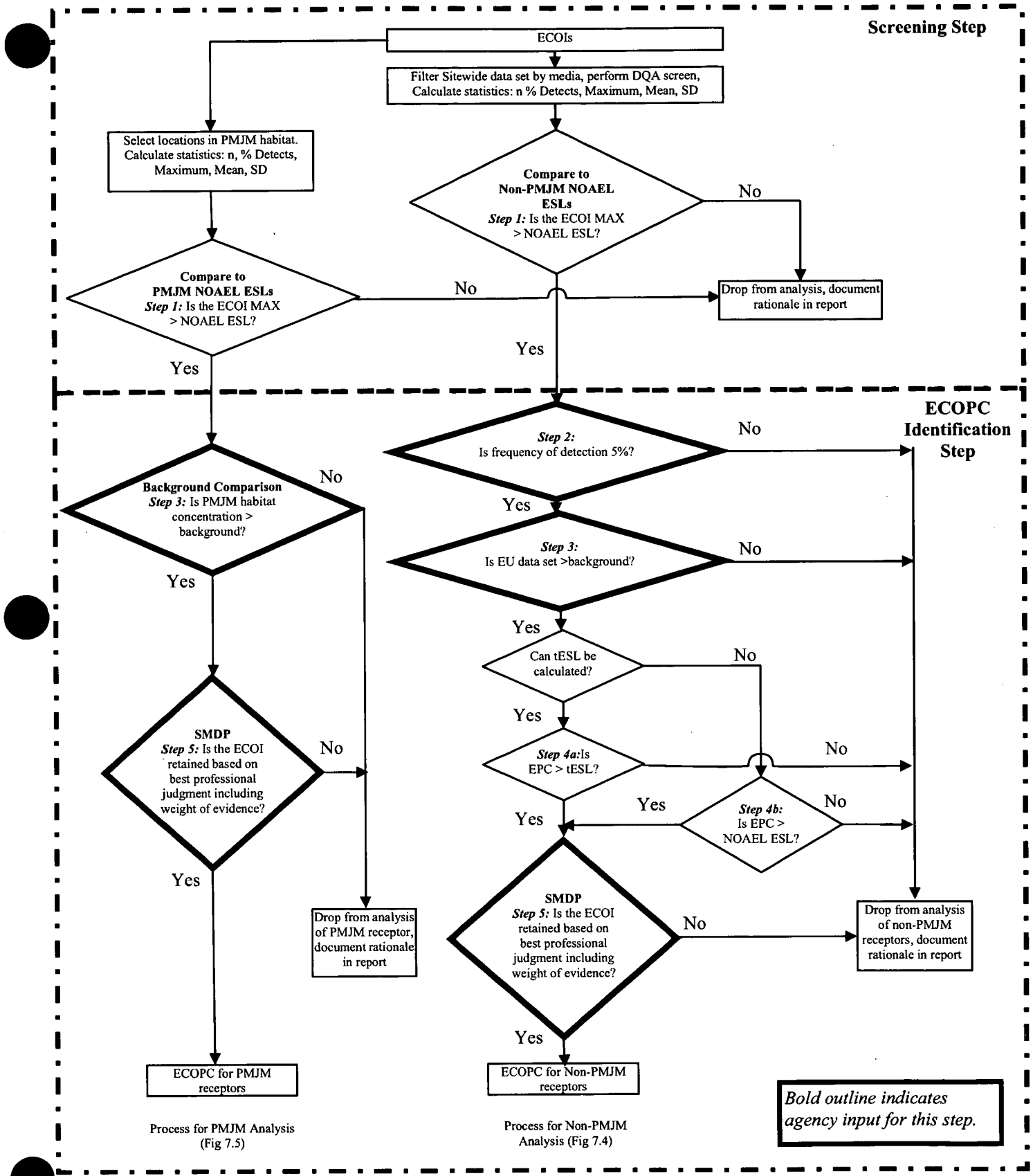


Figure ES.11 ECOPC Identification Process



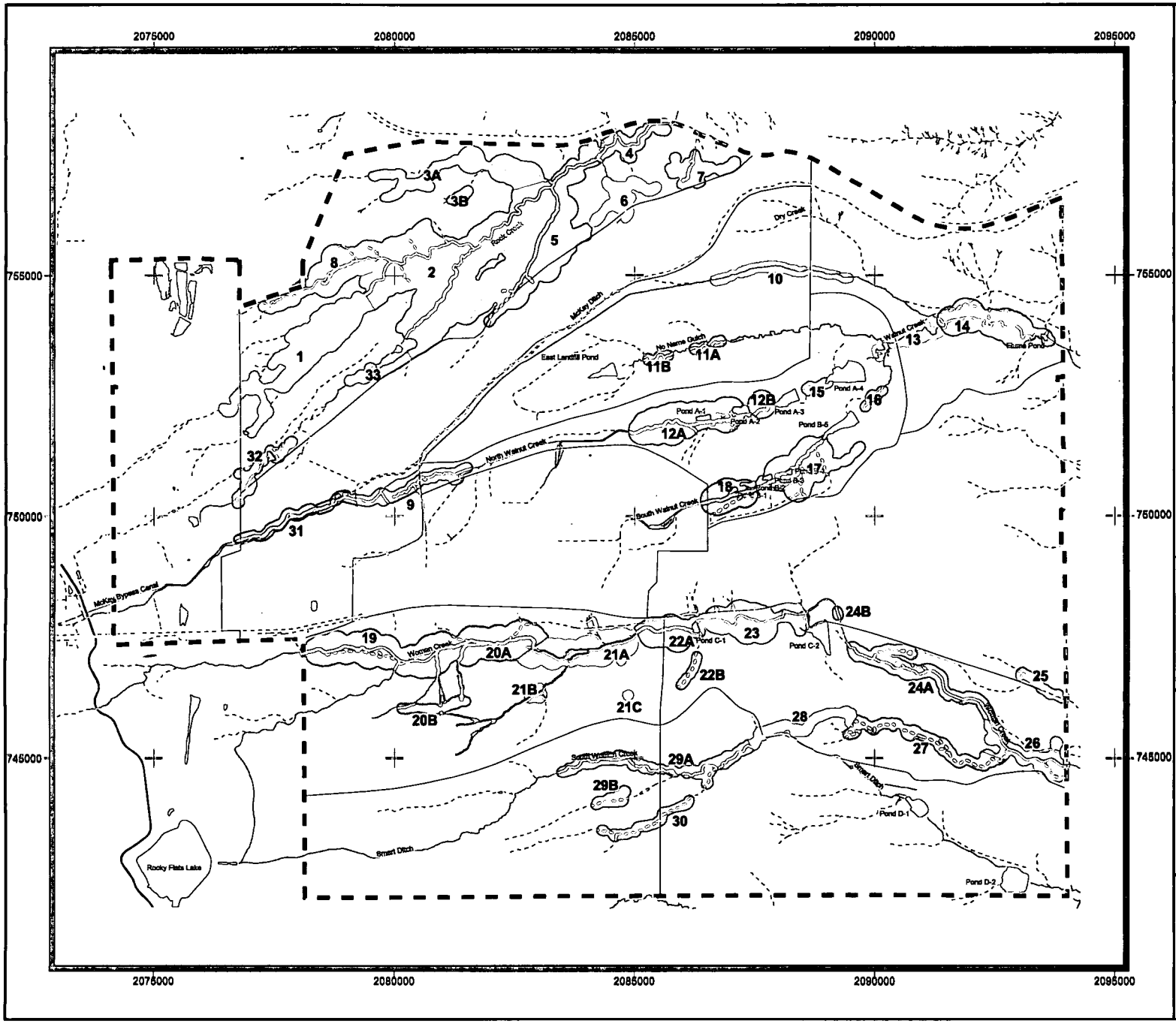


Figure ES.12

Preble's Meadow Jumping Mouse Functional Habitat Patches

KEY

PMJM habitat patch

1 PMJM habitat patch ID

Standard Map Features

- Exposure unit boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N W E S

0 1000 2000 Feet

Scale 1:36000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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Files: W:\Projects\Fy2004\CRA\Volume_1\executive_summary_figs.apr