Rocky Mountain Arsenal
Offpost Operable Unit
Final Record of Decision
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared for

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THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATIVE RECORD FOR THIS CERCLA OPERABLE UNIT.

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CONTENTS

TABLES

FIGURES

APPENDIXES

DECLARATION STATEMENT

Rocky Mountain Arsenal
Offpost Operable Unit
Commerce City, Colorado

DECLARATION FOR THE RECORD OF DECISION

SITE NAME AND LOCATION

Rocky Mountain Arsenal
Offpost Operable Unit
Commerce City, Adams County, Colorado

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedial action for the Rocky Mountain Arsenal (RMA) Offpost Operable Unit (OU) in southern Adams County, east of Commerce City, Colorado, chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and the National Environmental Policy Act (NEPA), and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This decision is based on the administrative record file for the Offpost OU, and this document explains the basis and purpose of the selected remedy for the Offpost OU.

ASSESSMENT OF THE SITE

The Offpost Study Area risk assessment showed that even without remedial action, the baseline cumulative cancer risks from contamination in surface water, soil, sediment, air, and groundwater are within the acceptable cancer risk range established by the U.S. Environmental Protection Agency (EPA). However, several site-specific factors suggest that remedial alternatives for groundwater should be developed. These site-specific factors are: (1) groundwater contributes a maximum of 2×10^{-4}, or approximately 75 percent of the total carcinogenic risk, (2) maximum contaminant levels (MCLs), maximum contaminant level goals (MCLGs), and Colorado Basic Standards for Groundwater (CBSGs) are exceeded for some groundwater contaminants, and (3) hazard indices (HIs) for children exceed 1.0 in Zones 2, 3, and 4. Although the hazard indices exceed 1.0 in Zones 2, 3, and 4, the bulk of the HI value is contributed through an assumed domestic use of alluvial groundwater, which is not presently occurring and under this remedy is not intended to occur in the future. The elevated

HIs occur only when considering the contribution of groundwater. Therefore, groundwater contamination is the focus of this decision document.

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present a potential threat to public health, welfare, or the environment.

DESCRIPTION OF THE REMEDY

The Offpost OU is one of two OUs at RMA. The Onpost OU addresses the contamination within the 27 square miles of RMA. The Offpost OU addresses groundwater contamination north of RMA that migrated (1) before the RMA boundary groundwater extraction and treatment systems were installed, and (2) around the boundary systems prior to recent improvements. The selected remedy described in this Record of Decision (ROD) will permanently address contaminants at the site through treatment to reduce the toxicity, mobility, or volume of contaminants. Groundwater containment system remediation goals are based on the risk assessment and on federal Safe Drinking Water Act MCLs, proposed MCLs, nonzero MCLGs, and CBSGs. Action levels also meet those state drinking water standards found to be applicable or relevant and appropriate requirements (ARARs).

The major components of the selected remedy are as follows:

- Operation of the Offpost Groundwater Intercept and Treatment System
  - Removal of contaminated groundwater from the alluvial and the weathered upper portion of the Denver Formation (hereafter called the unconfined flow system [UFS]) north of the RMA boundary in the First Creek and northern paleochannels using groundwater extraction wells
  - Treatment of the organic chemicals of concern (COCs) present in the groundwater using carbon adsorption
  - Recharge of treated groundwater to the UFS using wells and trenches
- Natural attenuation of inorganic chloride and sulfate concentrations to meet applicable standards for groundwater in a manner consistent with the Onpost remedial action

- Continued operation of the North Boundary Containment System (NBCS) and the Northwest Boundary Containment System (NWBCS) - In addition, the Irondale Contaminant System (ICS) will continue to operate, as required, for onpost contaminants consistent with the Irondale Interim Response Action (IRA). These containment systems will be operated to the requirements of Section 2.7 of the FFA, the Agreement for a Conceptual Remedy for the Cleanup of the Rocky Mountain Arsenal (Conceptual Remedy Agreement), and the onpost ROD, when it is signed. Cessation may occur as provided in Sections 35.3 and 35.4 of the FFA and paragraph 20 of the Conceptual Remedy Agreement.

- Improvements to the NBCS, NWBCS, ICS, and the Offpost Groundwater Intercept and Treatment System as necessary

- Long-term groundwater monitoring (including monitoring after groundwater treatment has ceased to assure continued compliance with the groundwater containment system remediation goals)

- Five-year site reviews

- Exposure control/provision of alternate water supply as follows:

  - As of the date of the Onpost ROD, and based on a .392 parts per billion (ppb) detection limit, the U.S. Army will use the last available quarterly monitoring results to determine the DIMP plume footprint.

  - As part of the Onpost ROD, the U.S. Army and Shell Oil company will pay for the extension of, and hook-up to, the current distribution system for all existing well owners within the DIMP plume footprint referenced above.

  - Existing domestic well owners outside of the DIMP plume footprint as of the date of the Onpost ROD where it is later determined that levels of DIMP are eight ppb or greater (or other relevant CBSG at the time) will be hooked up at the U.S. Army and Shell Oil Company's expense to the SACWSD distribution system or provided a deep well or other permanent solution.

  - For new domestic wells with DIMP levels of eight ppb or greater (or other relevant CBSG at the time), the Offpost ROD institutional controls will provide that the U.S. Army and Shell Oil Company will pay for hook-up to the distribution system or provided a deep well or other permanent solution.

  - Any user of a domestic well within the Offpost Operable Unit that contains groundwater contaminants derived from RMA at concentrations that exceed the greater of the remediation goals in Tables 7.1 through 7.3 or the ARARs in Table 10.1 will be provided an alternative water supply. Bottled water will be provided for cooking and drinking until a permanent alternative water supply is provided. Permanent alternative water supplies could include installation of a deep uncontaminated well or connection to a municipal potable water-supply system. This commitment applies to both users of existing domestic wells and users of wells that are lawfully drilled in the future.

- Institutional controls to prevent the use of groundwater exceeding remediation goals.

- Closure of poorly constructed wells within the Offpost Study Area that could be acting as migration pathways for contaminants found in the Arapahoe Aquifer.

- The U.S. Army and Shell Oil Company agree to continue monitoring and to complete an assessment of the NDMA plume by June 13, 1996, using a 20 ppt method detection limit.

- The U.S. Army and Shell Oil Company agree to prepare a feasibility study of potential actions, both onpost and at the boundary, or adjacent to the boundary in order to achieve NDMA remediation goals at the RMA boundary and to use 7.0 ppt PRG or a certified analytical detection level readily available at a certified commercial laboratory (currently 33 ppt).

- The U.S. Army and Shell Oil Company agree to revegetate approximately 160 acres located in the southeast portion of Section 14 and the southwest portion of Section 13 as depicted in Figure 9.1. Revegetation will involve tilling and seeding. No sampling will be conducted before or after revegetation. Existing soil risks in the are to be revegetated fall within EPA;s establish acceptable risk range and revegetation is not necessary. However, the U.S. Army and Shell Oil Company agree to the revegetation program as part of the offpost settlement.

- The Army will treat any contaminated extracted groundwater prior to discharge or reinjection so that it meets the current water quality standards established in the Colorado Basic Standards for Groundwater and the Colorado Basic Standards and Methodologies for Surface Water.

- As part of the Onpost remedy, the U.S. Army and Shell Oil Company will pay for and provide, or arrange for the provision, of 4000 acre-feet of water to SACWSD.

STATUTORY DETERMINATIONS

The selected remedy is protective of human health and the environment, complies with federal and state requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost-effective. The remedy uses permanent solutions and alternative treatment technologies to the maximum extent practicable. The remedy satisfies the statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element.

Because this remedy may result in hazardous substances remaining in the groundwater of the Offpost OU for more than five years, a review will be conducted within five years after commencement of remedial action to ensure that the remedy continues to adequately protect human health and the environment.

SIGNATURE PAGE

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DECISION SUMMARY FOR THE RECORD OF DECISION

1.0 SITE NAME, LOCATION, AND DESCRIPTION

The Rocky Mountain Arsenal (RMA) National Priorities List (NPL) site is comprised of two Operable Units (OUs): Onpost and Offpost. As shown in Figure 1.1, the Offpost Study Area occupies approximately 27 square miles in southern Adams County, Colorado, and lies north of the Denver metropolitan area and east of Commerce City, Colorado. The Offpost Study Area is defined as the area southeast of the South Platte River, north of 80th Avenue, southwest of Second Creek, and north of the north and northwest boundaries of RMA. Additionally, the Offpost Study Area includes the surface waters of O'Brian Canal and Burlington Ditch as they extend northeast from Second Creek to Barr Lake and the surface waters of First Creek and Barr Lake. The Offpost OU (also shown in Figure 1.1) is defined by the RMA Federal Facility Agreement (FFA) as that portion of the Offpost Study Area where hazardous substances, pollutants, or contaminants from RMA are found and are subject to remediation. The Offpost OU encompasses rural residential, agricultural, and commercial and industrial areas located north and northwest of RMA.

Areas within the Offpost OU are used for rangeland, dryland farming, and irrigated farming with some rural residential areas and scattered areas of intensive agricultural use. Parts of the Offpost OU are currently zoned and developed for commercial/industrial activities. Commerce City, located west of RMA, is the only urban area in the immediate vicinity of the Offpost OU and has recently annexed lands within the Offpost OU.

On the basis of an evaluation of planning information provided by the Adams County Planning Commission, it is projected that areas of commercial, industrial, and urban residential land use will increase in the Offpost OU (Adams County Planning Commission, 1987). Rural residential (including agricultural) land use is expected to decrease in the Offpost OU because anticipated increases in property values are expected to preclude increased traditional crop and livestock production land use, including hobby farming as discussed in the Airport Environs Plan (Adams County, City of Aurora, City of Brighton, City of Commerce City, 1990).

1.1 Environmental Setting

The topography of the Offpost Study Area consists of stream-valley lowlands separated by gently rolling uplands. The maximum local topographic relief in the Offpost Study Area is approximately 100 feet. The elevation above mean sea level ranges from approximately 5140 feet at the northern and northwestern boundary of RMA to approximately 5030 feet at the South Platte River.

Cropland and rangeland provide habitat for numerous animal species. Lake and wetland areas at Barr Lake provide feeding, breeding, and roosting areas for waterfowl and endangered species, including the bald eagle. The climate of the Offpost Study Area is characterized by sunny, semiarid conditions.

The regional surface drainage is to the northwest toward the South Platte River. Surface water originating south of RMA, on RMA, or in the Offpost Study Area flows toward the South Platte River. Two major canals, O'Brian Canal and Burlington Ditch, and several smaller ditches flow from southwest to northeast between RMA and the South Platte River. O'Brian Canal receives some drainage from the Offpost Study Area and RMA where the canal intercepts First Creek. Burlington Ditch may receive surface water infrequently from First Creek.

1.2 Geology

Sediment at the land surface in the Offpost Study Area consists of unconsolidated alluvial and eolian deposits. The composition of the unconsolidated sediment varies from clays to coarse gravels, and the thickness varies from less than 10 feet to approximately 100 feet. The thickest deposits of unconsolidated sediment occur in paleochannels eroded into the underlying Denver Formation.

The Denver Formation consists of 250 to 300 feet of interbedded shale, claystone, siltstone, and sandstone, with a regional dip of 1/2 to 1 degree to the southeast. The presence of paleochannels in the Denver Formation surface impacts groundwater flow in the unconsolidated sediment and the upper weathered portion of the Denver Formation. Three such paleochannels, the First Creek,

northern, and northwestern paleochannels, are present in the Offpost Study Area. Coarse, unconsolidated materials commonly found within these paleochannels provide preferential pathways for groundwater movement. Groundwater contaminant plumes that have historically migrated across the RMA boundaries to the Offpost OU contain the highest concentrations of contaminants in and near these paleochannels. The Arapahoe Formation lies beneath the Denver Formation at depths of 230 to 300 feet at the RMA north boundary and has a regional dip of 1/2 to 1 degree to the southeast. The formation consists of 400 to 700 feet of interbedded conglomerate, sandstone, siltstone, and shale. The upper portion of the Arapahoe Formation consists predominantly of 200 to 300 feet of blue to gray shale with some conglomerate and sandstone beds. The lower portion consists largely of sandstone and conglomerate with less prevalent beds of shale. The lower portion is a source zone for many water-supply wells in the area. A thick, impermeable claystone unit is variously assigned to the lower Denver formation and the upper Arapahoe Formation. The claystone unit is called the "Buffer Zone" and is approximately 50-ft. thick. This unit further isolates the underlying Arapahoe aquifer from any localized contamination in the Denver confined flow system. The Arapahoe Formation is the oldest geologic unit present beneath the Offpost Study Area that was investigated during the Offpost Remedial Investigation program.

Alluvial and eolian deposits form the ground surface in the Offpost Study Area. The Denver Formation and Arapahoe Formation are not present at the ground surface anywhere in the Offpost Study Area.

1.3 Hydrogeology

The two principal water-bearing units in the Offpost Study Area that have been impacted by contaminants originating from RMA are the unconsolidated alluvial deposits and the underlying Denver Formation. The hydraulic properties of these two units, including hydraulic conductivity, porosity, and associated groundwater flow velocities, are distinctly different. The low permeability of the Denver Formation and upper Arapahoe Formation limit contaminant transport into the lower

Arapahoe Formation. Hydraulically, the two units generally behave as two distinct hydrostratigraphic units: the unconfined flow system (UFS) and the confined flow system (CFS).

The UFS includes groundwater present in the unconsolidated materials overlying the Denver Formation, the weathered upper portion of the Denver Formation, and, where the Denver Formation is missing near the South Platte River, the weathered upper portion of the Arapahoe Formation. The CFS includes the deeper portions of the Denver Formation and the underlying Arapahoe Formation. On the basis of an evaluation of the distribution of contaminant plumes in the Offpost Study Area, the UFS is considered the principal migration route for groundwater contaminants from RMA to the Offpost Study Area, although some contaminants are present in the CFS. Although low-level contamination may be present in isolated portions of the Denver Formation CFS, this formation has low productivity as a groundwater resource.

2.0 SITE HISTORY AND ENFORCEMENT ACTIVITIES

2.1 Operational History

Congress established RMA in 1942. The United States acquired land included within the boundaries of the Arsenal for chemical weapons manufacturing, constructed a base, and commenced Army weapons production and ancillary activities in 1943. From 1945 to 1950, RMA distilled available stocks of mustard, demilitarized several million rounds of mustard-filled shells and incendiary munitions, and test-fired mortar rounds filled with smoke and high explosives. Also, many different types of obsolete World War II ordnance were destroyed by detonation or burning.

After the conclusion of World War II, selected surplus facilities were leased to nongovernment entities as warehouses and for the manufacture of agricultural chemicals. Colorado Fuel and Iron (CF&I) leased facilities at RMA in 1946. Julius Hyman & Company (Hyman) first leased facilities in 1947 and succeeded to the CF&I leasehold interest, with some modifications and additions in 1949. Shell Oil Company (Shell) acquired a majority interest in Hyman in 1952 and operated the plant as the Julius Hyman Company until 1954, when the operation became the Shell Chemical Company - Denver Plant.

RMA was selected as the site for construction of a facility to produce Sarin, a nerve agent. The facility was completed in 1953, with the manufacturing operation continuing until 1957 and the munitions-filling operations continuing until late 1969. From 1970 until 1984, the primary operation at RMA was the disposal of chemical warfare material. Disposal practices included incinerating TX anticrop agent and mustard agent explosive components and destroying Sarin and related munitions casings by caustic neutralization.

Chemicals were introduced to the RMA environment primarily by the burial or surface disposal of solid wastes, discharge of wastewater to basins, and leakage of wastewater and industrial fluid from chemical and sanitary sewer systems. Munitions were destroyed and disposed in trenches.

Wastewater generated by the U.S. Department of the Army (Army) and private industry in the South Plants and North Plants areas was discharged to a series of unlined evaporation and holding basins (Basins A, B, C, D, and E) and to asphalt-lined Basin F at various times throughout the history of RMA operations. The locations of these source areas are shown in Figure 2.1.

The primary areas that have contributed to groundwater contamination at RMA include (1) former manufacturing facilities, (2) former waste storage basins, (3) solid waste disposal areas, (4) the chemical sewer system, (5) locations within the rail classification yard, and (6) the motor pool area.

2.2 Previous Investigations

From 1975 to the present, numerous groundwater monitoring programs have been conducted at RMA, both onpost and offpost, by the Army. The U.S. Environmental Protection Agency (EPA) has also conducted several offpost investigations. The Army designed and implemented monitoring programs to monitor regional groundwater and surface-water quality. The Army also designed and implemented the boundary system monitoring program to support the operation of the boundary groundwater containment systems.

2.2.1 U.S. Environmental Protection Agency Study Area

Several organic chemicals were detected in South Adams County Water and Sanitation District (SACWSD) wells in 1981, as part of a random national survey of drinking water systems conducted by EPA. Additional sampling in 1982 and 1985 confirmed these initial findings. As a result, EPA began a remedial investigation/feasibility study (RI/FS) of an area west of RMA and south of the Offpost Study Area (Figure 1.1).

RMA was suspected as one of the possible sources of contaminants in the EPA study area because of RMA's historical waste disposal practices. To mitigate the groundwater contamination problem, the Army and EPA built a water-supply system for SACWSD. Further investigation by EPA's Field Investigation Team indicated that source areas in addition to RMA contributed to groundwater

contamination detected within the EPA study area. Groundwater monitoring wells installed on the Chemical Sales Company (CSC) property have since identified CSC as a significant source of groundwater contamination in the EPA study area. Recent investigations by EPA and the Army have detected the presence of a trichloroethene plume entering RMA at Section 9, Township 3S, Range 67W along the southern boundary of RMA, as described in the Western Tier Report, the Stapleton Airport Environmental Assessment (Camp Dresser & McKee, Inc., 1993), and the CSC ROD (EPA, 1991a, 1991b, 1992). (Ebasco Services, Inc., 1988),

2.2.2 U.S. Department of the Army Investigation

Because chemicals were detected in the Offpost Study Area, the Army initiated a regional hydrogeologic surveillance program requiring the quarterly collection and analysis of samples from more than 100 onpost and offpost wells and surface-water stations. The program was carried out under the direction of the RMA Contamination Control Program, established in 1974 to ensure compliance with federal and state environmental laws. The objectives of the program were to (1) evaluate the nature and extent of contamination and (2) develop response actions to control contaminant migration. Potential and actual contaminant sources were assessed, and contaminant migration pathways were evaluated.

From 1975 to the present, numerous groundwater monitoring programs have been conducted at RMA. The Army designed and implemented the 360 Degree Monitoring Program to monitor regional groundwater and surface water. The Army designed and implemented a boundary system monitoring program to support the operation of the boundary groundwater containment systems. Studies conducted at RMA to assess groundwater and surface-water conditions are discussed below.

The RMA Offpost Contamination Assessment Report (CAR) (Environmental Science and Engineering, Inc. [ESE], 1987a) incorporated data from several studies to define the concentrations and distribution of offpost contamination north and northwest of RMA. The scope of the CAR investigation

was intended to address critical data gaps required to evaluate a comprehensive set of multimedia exposure pathways.

The potential for contamination of private wells was investigated in the mid-1980s during the Consumptive Use (CU) Studies, Phases I, II, and III. The CU Phases I and II studies addressed the Offpost Study Area. In the CU Phase III study, the Army conducted an inventory of privately-owned drinking water wells in an area bound by East 80th Avenue on the south, East 96th Avenue on the north, the South Platte River on the west, and RMA on the east. The objectives of the CU Phase III study were as follows:

- Locate all shallow domestic wells (less than 100 feet) in the Offpost Study Area.
- Sample a representative number of the located wells.
- Assess the groundwater quality of the shallow alluvial aquifer.

The Army developed the Comprehensive Monitoring Program (CMP), a long-term multimedia monitoring program designed to provide data to facilitate evaluation of response actions, in the mid-1980s. Sample collection under the CMP commenced in 1987 and is continuing as the Groundwater Monitoring Program (GMP).

An RI was initiated in 1985 by the Army in the Offpost Study Area. The primary objectives of the Offpost RI were as follows:

- Collect additional data to refine the current understanding of groundwater flow and surface-water patterns and the nature and extent of contaminants offpost of RMA.
- Evaluate the potential for chemical migration to the Offpost Study Area in various environmental media, such as groundwater, surface water, sediment, air, and biota.

Following completion of the RI, it was apparent that additional data were needed before evaluation and selection of a remedial alternative could occur. Therefore, a second RI was initiated in 1988 to collect additional data for groundwater, surface water, soil, sediment, and biota (plants and animals). The results of the second RI are reported in the Offpost Operable Unit Remedial Investigation, Final Addendum (HLA, 1992b).

2.3 Boundary Containment Systems

Concurrent with and as a result of the EPA and Army investigations, the Army constructed three boundary containment systems (the North Boundary Containment System [NBCS], the Northwest Boundary Containment System [NWBCS], and the Irondale Containment System [ICS] at the north, northwestern, and western boundaries of RMA, respectively) to minimize offpost discharge of RMA chemicals via groundwater. The locations of these containment systems are shown in Figure 1.1. All three systems currently intercept and treat contaminated groundwater and recharge treated water to the UFS.

2.3.1 North Boundary Containment System

The NBCS is just south of the RMA north boundary in Sections 23 and 24. The NBCS consists of (1) a system of extraction wells that remove contaminated groundwater from the UFS, (2) a soil-bentonite barrier that impedes migration of contaminated groundwater to the Offpost Study Area, (3) a carbon-adsorption treatment system that removes organic contaminants from extracted groundwater, and (4) a system of recharge wells and trenches that return treated groundwater to the UFS.

The NBCS pilot system became operational in 1978. The pilot system was expanded approximately 1400 feet to the west and 3840 feet to the east in 1981 during the second phase of construction. Several improvements have been made to the NBCS since 1981: ten recharge trenches were added to the west end of the system and became operational in December 1988, and five additional recharge trenches were added to the east end of the system in 1990. Currently, the soil-bentonite barrier is 6740 feet long, approximately 3 feet wide, and varies in depth from 20 feet at the western end to more than 40 feet along the eastern extension. The barrier is anchored in the Denver Formation.

Review of groundwater contaminant distribution patterns indicates that the NBCS is having a significant effect on the distribution of organic compounds in the Offpost Study Area. Monitoring program data indicate that contaminant concentrations downgradient of the NBCS are decreasing.

Activated carbon is being used to effectively remove the organic contaminants from the extracted groundwater to meet containment system remediation goals. Organic contaminant concentrations are generally below certified reporting limits (CRLs) in system effluent.

2.3.2 Northwest Boundary Containment System

The NWBCS is along the northwest boundary of RMA in the southeast quarter of Section 22. Constructon of the NWBCS began in 1983, and the system became operational in 1984. The NWBCS originally consisted of (1) 15 extraction wells, (2) a soil-bentonite-barrier approximately 1600 feet in length, (3) a carbon adsorption treatment system, and (4) a system of 21 downgradient recharge wells. The carbon adsorption system was designed to intercept and remove dibromochloropropane and other organic compounds from a plume of contaminated groundwater originating onpost.

Contaminant bypass was observed at the southwest and northeast ends of the NWBCS in 1988. An interim resonse action (IRA) to improve the NWBCS was initiated in 1989. In April 1990, the NWBCS Improvements IRA was divided into two phases: NWBCS Short-term Improvements IRA and NWBCS Long-term Improvements IRA. Under the NWBCS Short-term Improvements IRA, which was completed in 1991, the existing slurry wall was extended 665 feet to the northeast to prevent contaminant bypass, and two additional extraction wells were added at the northeast end of the extraction well alignment. Three additional extraction wells and four additional recharge wells were installed in Section 27, southwest of the NWBCS in August 1991. The NWBCS Long-term Improvements IRA is being used to assess the NWBCS and its short-term improvements by reviewing groundwater monitoring data.

2.3.3 Irondale Containment System

The ICS, which became operational in 1981, is at the southern end of the RMA northwest boundary within Section 33 and consists of (1) a hydraulic control system of extraction and recharge wells, and (2) a carbon adsorption treatment system. The ICS was originally developed to intercept the migration of dibromochloropropane (DBCP) at the RMA boundary. There have been no downgradient

detections of DBCP after the first two years of operation. The majority of the area downgradient of the ICS is contained within the EPA study area, although portions of the downgradient area are within the confines of the Offpost Study Area. Therefore, the design and operation of the ICS was not included in the evaluation of alternatives; however, the continued operation of the ICS, as required, for onpost contaminants consistent with the Irondale IRA remains an integral part of the Army's offpost contaminant reduction program to meet onpost cleanup goals defined in the Irondale IRA. Cessation of operation of the ICS will be in accordance with paragraphs 35.2 and 35.4 of the FFA and paragraph 20 of the Conceptual Remedy Agreement.

2.4 Interim Response Actions

As part of the Army's compliance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and as described in the FFA, the Army has instituted several IRAs that have been performed concurrently with the ongoing onpost and offpost RI programs. IRAs, which are designed to be compatible with the final remedy, are actions taken before the signing of the Record of Decision (ROD) and are expedited remedial measures to contain, remove, or treat wastes before the final remedy is selected. Numerous IRAs have been implemented to mitigate contamination both onpost and offpost. As indicated in the previous sections, some portions of the boundary containment systems have been constructed as IRAs. The Offpost IRA is discussed in the following section.

2.4.1 Offpost Interim Response Action

The Offpost IRA addresses groundwater contaminant migration north of RMA and downgradient of the NBCS along two primary contaminant pathways, defined by the First Creek and northern paleochannels.

Evaluation and selection of the collection and treatment system components that comprise IRA A, referred to as the Offpost Groundwater Intercept and Treatment System, began in 1988. The Offpost Groundwater Intercept and Treatment System Decision Document (HLA, 1989) presents the basis for

system placement to address remediation of contamination in alluvial groundwater in the First Creek and northern paleochannels. The system was designed to intercept and extract contaminated groundwater from the UFS, treat the groundwater for organics, and recharge treated water to the UFS. Construction of the Offpost Groundwater Intercept and Treatment System began in November 1991 and was completed in June 1993. Groundwater extraction is accomplished through a network of extraction wells. The organic contaminants in extracted groundwater are treated using activated carbon adsorption, and the treated water is then recharged to the UFS using a combination of recharge wells and trenches.

The Offpost Groundwater Intercept and Treatment System was designed to be flexible and to be compatible with the final remedy, consistent with EPA guidance and the FFA.

2.5 History of CERCLA Enforcement Activities

Most of RMA was added to the National Priorities List (NPL) in 1987; Basin F was added in 1989. As such, RMA is subject to compliance with CERCLA (also known as Superfund). A facility is subject to compliance with CERCLA when a release or a threat of a release of hazardous substances from the facility has occurred and when response costs have been incurred. In some cases, the potentially responsible parties (PRPs) either cannot respond or cannot be found, so funding for the response comes from the government fund called Superfund. At RMA, the Army and Shell were identified as PRPs and are funding the cleanup.

On February 1, 1988, a proposed Consent Decree was filed in the case of *U.S. v. Shell Oil Company* with the U.S. District Court in Denver, Colorado. A modified version of the Consent Decree was filed on June 7, 1988. The Consent Decree was entered by the U.S. District Court on February 12, 1993. On February 17, 1989, an FFA was executed by the Army, Shell, EPA, the U.S. Department of the Interior (DOI), the U.S. Department of Justice (DOJ), and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR). The FFA sets forth the procedures to be followed by the Organizations (i.e., signatories to the FFA) to cooperate in the assessment, selection, and implementation of

response actions resulting from the release or threat of release of contaminants from RMA. The FFA designates the Army as the lead agency.

3.0 HIGHLIGHTS OF COMMUNITY PARTICIPATION

Community participation opportunities were provided during the remedy selection process to fulfill the requirements of CERCLA Sections 113(k)(2)(B)(i-v) and 117.

The RI, RI Addendum, Endangerment Assessment/Feasibility Study (EA/FS), and Proposed Plan for the Offpost OU were released to the public on March 21, 1993. The documents were made available to the public in the Administrative Record (located at the Joint Administrative Record Document Facility at the west entrance to RMA at 72nd Avenue and Quebec Street), in an information repository maintained at the EPA Docket Room in Region VIII, and at the Adams County, Aurora, Commerce City, Denver, Lakewood, Montbello, and Thornton Public Libraries. The notice of availability for these four documents was published in the Denver Post and Rocky Mountain News newspapers.

An expanded Community Relations outreach was implemented to ensure community members had the opportunity to comment on the Proposed Plan for the Offpost OU. Community outreach started in January 1993 with the announcement that all documents supporting an impending Proposed Plan were available for review in local libraries. A direct mailing to more than 1200 local citizens was made.

In March 1993, a press release was made and a legal notice was published announcing that a public meeting was scheduled for April 28, 1993, at Dupont Elementary School, Commerce City, Colorado, to address the Proposed Plan. A separate letter was sent to citizens informing them of the documents availability in the libraries. The letter also included a brief fact sheet summarizing the Proposed Plan. Originally, the public meeting was scheduled for April 21, 1993, at RMA. The Army received requests to hold the meeting on a different day and offpost. Because of these factors and Earth Day events in Denver for April 21, the meeting was moved to April 28, 1993.

A Media Day was held the day of the public meeting to provide local media information on the Army's proposal. Both print and video media representatives attended.

Knowing the importance of the public meeting, the announcement was expanded to include display advertising in 12 local and weekly newspapers in the Denver metropolitan area. This was in addition to the normal press release and Media Day event.

As a result of comments received at the public meeting concerning the official comment period, the Army published a legal notice and sent letters to citizens announcing that the comment period was extended to June 21, 1993.

At the April 28, 1993, public meeting, representatives from the Army, EPA, and the State of Colorado answered questions regarding issues at the site and the remedial alternatives under consideration. Responses to comments received during the public comment period are included in the Responsiveness Summary, which is part of this ROD (Appendix A). This decision document presents the selected remedial action for the RMA Offpost OU in Adams County, Colorado, chosen in accordance with CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA), and with the NEPA, and, to the extent practicable, with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The decision for this site is based on the Administrative Record for the Offpost OU.

Additionally, settlement discussions involving municipalities, local health departments, special districts, and citizen groups were held from late 1994 until April 1, 1995, to discuss the final remedies for both Onpost and Offpost OUs. The Draft Final ROD (December 7, 1993) was revised taking into account comments presented by the public, local communities, and the Parties.

4.0 SCOPE AND ROLE OF THE OFFPOST OPERABLE UNIT

Three RMA boundary containment systems currently intercept, treat, and recharge groundwater at the RMA north, northwest, and west boundaries. These boundary systems, along with the physical boundaries of RMA, provide a logical delineation between OUs. Therefore, the FFA divided the work into the following two OUs:

- Onpost OU: Media requiring remediation within the Onpost Study Area (within RMA boundaries)
- Offpost OU: Media requiring remediation within the Offpost Study Area (outside RMA boundaries)

The Offpost OU addresses contamination in the groundwater north and northwest of RMA. As discussed in Section 6.0 of this ROD, groundwater contamination in the UFS poses the principal potential threat to human health because of the risks from possible exposure to groundwater. Although health risks are possible, the estimated risk levels are within the acceptable risk range established by EPA. The purpose of the remedy is to (1) reduce groundwater contaminant concentrations, (2) reduce risk to human health and the environment, and (3) reduce the potential human exposure to contaminated UFS groundwater.

The potential risks to ecological receptors were also evaluated. Wildlife are not exposed to contaminated groundwater; therefore, there are no risks to wildlife from the groundwater exposure. Wildlife exposures to soil and surface water and potential livestock exposure to contaminated groundwater were evaluated. However, the potential risks associated with these exposures were shown to be negligible. Therefore, the selected remedy for the Offpost OU addresses the reduction of potential human exposure to contaminated UFS groundwater.

5.0 SUMMARY OF SITE CHARACTERISTICS

Six media were evaluated in the RI for the Offpost Study Area: groundwater, soil, surface water, sediment, air, and biota. Each medium was evaluated in the Offpost EA with respect to (1) the nature and extent of contamination and (2) potential exposure pathways and associated risk to humans and the environment. A map delineating the boundaries of the Offpost Study Area is included as Figure 1.1. The site characteristics are more fully described in the Offpost Operable Unit Remedial Investigation Report (ESE, 1988a) and the Offpost Operable Unit Remedial Investigation, Final Addendum (HLA, 1992b).

5.1 Sources of Contamination

As described in Section 2.1, chemicals were introduced to the RMA environment primarily by the burial or surface disposal of solid wastes, discharge of wastewater to basins, and leakage of waste-water and industrial fluid from chemical and sanitary sewer systems. Chemicals migrated to the Offpost Study Area primarily by shallow (i.e., shallow or unconfined) groundwater and airborne pathways. Contaminant transport in the shallow or unconfined groundwater has been controlled by construction of the boundary containment systems and improvements to these systems (completed as IRAs). Offpost Study Area surface water was contaminated primarily by the natural interaction with offpost groundwater. Offpost Study Area surface soil was contaminated by the deposition of airborne contaminants, non-RMA-related agricultural application of pesticides, and irrigation practices. Agricultural sources of pesticides are discussed in the Final Offpost RI Addendum (HLA, 1992b). Air monitoring data indicate that the air pathway does not contribute to human exposure.

5.2 Nature of Contamination

Several chemicals of concern (COCs) are present in offpost groundwater, surface water, sediment, and soil (see Tables 6.1 through 6.4). COCs include organochlorine pesticides (OCPs), halogenated aliphatics, aromatic hydrocarbons, diisopropylmethyl phosphonate (DIMP), sulfur-containing organic chemicals, arsenic, and dissolved salts.

The COCs exhibit great variability in their mobility and persistence in environmental media. OCPs are less mobile than the other COCs and more persistent, tending to associate with soil and sediment and to biomagnify in the food chain. Most of the remaining COCs are mobile in groundwater, and the aromatics and aliphatics are volatile in surface water. The fate properties of the COCs tend to determine their distribution in the Offpost Study Area. All COCs were detected in groundwater, but the more mobile chemicals are more widely distributed. The OCPs are virtually the only COCs detected at concentrations above background levels in soil and sediment. The volatile compounds were not significantly elevated above background levels in surface water and, in fact, were rarely detected.

5.3 Contamination Migration Pathways

The RI programs have shown that there are three groundwater migration pathways in the Offpost Study Area. These migration pathways (shown in Figure 5.1) are referred to as the northern paleochannel, due north of the RMA north boundary; the First Creek paleochannel, paralleling First Creek to the northwest from the RMA north boundary; and the northwest paleochannel, northwest of the RMA northwest boundary. The northern and First Creek paleochannels compose the North Plume Group, and the northwest paleochannel composes the Northwest Plume Group. These two plume groups encompass an area of approximately 590 acres in the Offpost Study Area. The alluvial flow system transports most of the contamination in paleochannels characterized by coarser sediment. Some of the groundwater traveling through the First Creek paleochannel discharges to First Creek, probably seasonally, resulting in transfer of contaminants to First Creek.

Figure 5.1 also presents the offpost surface-water features. The primary surface-water pathway is First Creek, which flows northwest from the northern RMA boundary. First Creek empties into O'Brian Canal, which flows northeast and empties into Barr Lake. Burlington Ditch, which parallels O'Brian Canal, also flows into Barr Lake. The majority of the surface-water contamination is located in First Creek, with some contamination in O'Brian Canal downstream of the confluence with First

Creek and Burlington Ditch. Barr Lake has not been shown to be contaminated with RMA-related chemicals greater than naturally occurring background levels.

In addition to the contaminant migration pathways of groundwater and surface water, prevailing winds transport onpost surface soil to offpost locations, and sediment provides a potential contaminant source for aquatic species.

5.4 Extent of Contamination

Varying levels of contamination exist in the following five media in the Offpost OU: groundwater, surface water, stream-bottom sediment, surface and subsurface soil, and biota. More detailed discussions of the offpost contaminant concentrations, along with figures showing concentration distributions are found in Sections 3.0, 4.0, 5.0, and 6.0 of the Final Offpost RI Addendum (HLA, 1992b).

5.4.1 Groundwater

Table 6.1 presents the groundwater COCs and the exposure point concentrations used in the Endangerment Assessment. The most widespread RMA-related groundwater COC in the Offpost Study Area is DIMP, which is present in the UFS at varying concentrations in a band from the west end of the NWBCS to the east end of the NBCS, and from the RMA north and northwest boundaries to the South Platte River. The other primary contaminants present in the offpost UFS are chloroform, chlorobenzene, trichloroethene, tetrachloroethene, dibromochloropropane (DBCP), dieldrin, endrin, dicyclopentadiene (DCPD), arsenic, chloride, fluoride and sulfate.

The highest concentrations of DIMP observed in the past three years are in the First Creek paleochannel. Concentrations of DIMP are lower in the northern paleochannel and lower still in the northwestern paleochannel. The maximum concentrations of DIMP in the Offpost Study Area have decreased by approximately 50 percent over the past 10 years. The NBCS is currently operating and has been operated in the past to remove multiple contaminants. DIMP concentrations are being

reduced to less than 8 ppb. Cut-off of groundwater contaminants at the NBCS and recharge of the treated groundwater has resulted in the observed decrease in DIMP concentrations specifically, as well as the other contaminants found offpost.

The highest contaminant levels downgradient from the NBCS occur upgradient of the O'Brian Canal. Certain volatile compounds such as chlorobenzene, chloroform, trichloroethene, and DBCP have been detected at low concentrations downgradient from the canals, but well-defined plumes do not exist in this area and these detections may be anomalous. Semivolatile organic compounds such as dieldrin and other OCPs are present almost exclusively upgradient of the canals. Maximum concentrations of the OCPs (i.e., aldrin, isodrin, chlordane, 2,2-bis[p-chlorophenyl]-1,1-dichloroethene[DDE], and 2,2-bis[p-chlorophenyl]-1,1,1-trichloroethane[DDT]) generally occur in the First Creek paleochannel within 500 to 1000 feet of the NBCS. Only sporadic and isolated occurrences of OCPs are observed northwest of the RMA northwestern boundary.

Contaminants found downgradient from the NWBCS are primarily chlorobenzene, chloroform, DIMP, and dieldrin. The highest concentrations of chloroform occur downgradient of the RMA boundary. Detections of chlorobenzene near the NWBCS may be anomalous. In 1989, semivolatile compounds such as dieldrin and possibly DIMP appeared to have bypassed the NWBCS at the northeast and southwest ends. Subsequently, the NWBCS IRA was initiated that included improvements and operational changes to correct the bypass. Recent modifications to the NBCS and NWBCS, in addition to the remedial action selected in this ROD, are expected to further reduce contaminant levels downgradient of the RMA boundaries.

5.4.2 Surface Water

Table 6.2 presents the surface water COCs and the exposure point concentrations used in the Endangerment Assessment. The principal organic compounds identified in Offpost Study Area surface-water samples are DIMP and dieldrin. In general, the highest concentrations of the organic and inorganic analytes were detected in First Creek. DIMP concentrations in First Creek were highest

in the area 100 to 200 feet upstream of O'Brian Canal where groundwater discharges to First Creek. DIMP was not detected in Burlington Ditch or O'Brian Canal upstream of the confluence with First Creek. DIMP was detected in Barr Lake in only one of 20 samples collected from 1985 to 1990 and was not detected in the duplicate sample collected at the same time. This one detection is anomalous and not considered representative of conditions at Barr Lake.

The highest concentrations of arsenic were detected in First Creek near the northern RMA boundary. These detections are likely associated with discharge from the onpost sewage treatment plant. Mercury and arsenic were detected in surface water in O'Brian Canal upstream of the confluence with First Creek, suggesting that sources of these contaminants other than RMA probably exist. Some contaminants identified in O'Brian Canal and Burlington Ditch may originate from the diversion of treated sewage effluent from Denver.

5.4.3 Stream-bottom Sediments

Table 6.3 presents the sediment COCs and the exposure point concentrations used in the Endangerment Assessment. The most commonly detected contaminants in stream-bottom sediment in the Offpost Study Area were dieldrin, arsenic, and mercury. The highest concentration of dieldrin was found in First Creek immediately north of the northern RMA boundary. Additional contaminants were detected in O'Brian Canal and Burlington Ditch upstream of the confluence with First Creek, suggesting that sources of these contaminants other than RMA probably exist such as diversion of treated sewage effluent from Denver.

5.4.4 Surface and Subsurface Soil

Table 6.4 presents the soil COCs and the exposure point concentrations used in the Endangerment Assessment. Approximately 100 soil samples were collected as part of the RI Addendum investigation and were analyzed for OCPs, arsenic, and mercury. Dieldrin was the most frequently detected OCP (in approximately 90 percent of the samples) with a maximum concentration located approxi-

mately 100 to 200 feet north of the northern RMA boundary. DDT, DDE, aldrin, endrin, and chlordane were detected less frequently.

The distribution of OCPs in Offpost Study Area soil appears to correlate with the dominant wind patterns at RMA. The greatest number and highest contaminant concentrations are observed in samples collected immediately north of the northern RMA boundary, consistent with the prevalent wind direction of south to north. Isolated elevated concentrations of OCPs observed between the northern RMA boundary and O'Brian Canal may be the result of local residential and/or commercial use of pesticides and not related to migration from RMA. Anomalously high concentrations of dieldrin, DDE, and DDT were also detected approximately 1.5 miles northwest of RMA. These detections are considered to be agricultural-related and not RMA-related because the area is currently and has historically been a farming community.

The uneven distribution of arsenic and mercury in Offpost Study Area surface soil suggests that the occurrence of these inorganic contaminants is not related to RMA activities.

5.4.5 Biota

The RI Addendum biota monitoring program provided additional data to assess the potential impacts on plants and animals in the Offpost Study Area. During the RI Addendum study, biota samples were analyzed for aldrin, dieldrin, endrin, DDE, DDT, DBCP, arsenic, and mercury. Dieldrin, the contaminant most often found in Offpost Study Area biota (36 percent of samples), was detected in cattle, chicken, fish, earthworm, deer mouse, prairie dog, and pheasant samples. Arsenic and mercury were detected less frequently (19 and 14 percent, respectively). DDE was detected only once, and aldrin, endrin, DDT, and DBCP were not detected in any biota samples from the Offpost Study Area. Contaminants identified in the Offpost Study Area biota survey are similar to those found onpost, although the concentrations detected in the Offpost Study Area biota are considerably lower than concentrations detected in the onpost biota.

The Offpost Study Area is known to contain suitable habitat for endangered species such as the bald eagle. A nesting pair of eagles was identified during offpost assessment activities. Contaminants (mercury, dieldrin, and DDE) were detected in a bald eagle egg collected in 1988 from a nest at Barr Lake. According to the U.S. Fish and Wildlife Service, the concentrations of these contaminants were typical of bald eagle egg contamination throughout the United States.

5.5 Potential Routes of Human and Environmental Exposure

Based on the current land uses in the Offpost Study Area, a review of local city and county planning and zoning ordinances, and consultation with local planning authorities, three primary land uses were considered in estimating the risks to human health. These land uses are urban residential, rural residential, and commercial and industrial. The exposure routes and pathways considered for the Offpost Study Area include the following:

- Ingestion of groundwater
- Ingestion of soil
- Ingestion of sediment
- Ingestion of vegetables
- Ingestion of dairy products
- Ingestion of eggs
- Ingestion of meat
- Ingestion of surface water
- Inhalation of volatile chemicals in groundwater
- Inhalation of dust
- Dermal contact with soil
- Dermal contact with sediment
- Dermal contact with surface water
- Dermal contact with groundwater

6.0 SUMMARY OF SITE RISKS

The risks estimated in the EA and summarized in this section are baseline risks corresponding to current conditions and are, therefore, pre-remediation risk estimates. Implementation of the selected remedy presented (Section 9.0) will lower the potential risks. The estimated maximum cumulative potential cancer risk to humans in the Offpost Study Area is 3×10^{-4} (or 3 in 10,000 people) on the basis of the reasonable maximum exposure (RME) risks presented in the Final EA (Volume III, Section 4.0, and Volume IV, Appendix G). This estimated potential risk level is within the acceptable risk range established by EPA (1×10^{-6} to 5×10^{-4}; letter from EPA to Army dated February 21, 1992). A cancer risk estimate of 3 in 10,000 indicates an upperbound estimate of risk. Actual cancer risks are likely to be below this level and may be as low as zero. These carcinogenic risks are usually termed "excess lifetime cancer risks," which means there is an increased chance of an individual developing cancer over 70 years of exposure to the carcinogenic chemicals in excess of the normal cancer rate. The background cancer rate determined by the American Cancer Society is about 1 in 3.

Because the Offpost Study Area cumulative risk is less than the upper risk level established by EPA, remedial action in the Offpost Study Area is not required. The Army, nevertheless, recognizes that several site-specific factors suggest that remediation of the groundwater is preferable to no action in the Offpost OU. These site-specific factors are: (1) groundwater contributes a maximum risk of 2×10^{-4}, or approximately 75 percent of the total carcinogenic risk, (2) maximum contaminant levels (MCLs), maximum contaminant level goals (MCLGs), and Colorado Basic Standards for Groundwater (CBSGs) are exceeded for some groundwater contaminants, and (3) hazard indices (HIs) for children exceed 1.0 in Zones 2, 3, and 4. Although the estimated child hazard indices exceed 1.0 in Zones 2, 3, and 4, the bulk of the HI value is contributed through an assumed domestic use of alluvial groundwater, which is not presently occurring in the Offpost OU. Treatment of groundwater to the containment system remediation goals will reduce (1) the total estimate risk to less than 1×10^{-4} and

toward 1 x 10^{-6} and (2) the HIs to less than 1.0 in Zones 2, 3, and 4. Soil, surface water, and sediment do not require remediation because of the low risk attributable to these media. Air was not identified as a medium of concern on the basis of air monitoring data and initial risk screening.

Protection of biota was evaluated through development of ecological exposure criteria for the protection of species potentially at risk. The ecological assessment indicated that the potential for adverse ecological effects is minimal.

6.1 Human Health Risks

Human health risks in the Offpost Study Area were calculated in four steps: identification of COCs, exposure assessment, toxicity assessment, and risk characterization. It should be noted that many of the exposures evaluated do not currently exist and therefore do not represent existing exposures.

6.1.1 Identification of Chemicals of Concern

A data set consisting of groundwater, surface water, sediment, soil, air, and biota data collected between 1985 and 1991 was used to evaluate which chemicals were of concern to human health and the environment. A trend of declining contaminant concentrations in groundwater since 1985 was noted in portions of the Offpost Study Area, particularly near the north boundary of RMA and downgradient of the NBCS. This trend is due to the operation and improvement of the boundary systems and natural attenuation processes. Considering this trend, only the most recent groundwater data (i.e., from 1989 through 1991) were used to estimate groundwater exposure point concentrations.

Data for the other media were also considered, and only the data resulting from analytical methods sensitive enough to detect low concentrations were used. Data were also compared statistically with background concentrations consistent with EPA guidance presented in Risk Assessment Guidance for Superfund (EPA, 1989a). Statistical procedures included the Wilcoxon rank sum test and the Method of Proportions. These procedures are discussed in Section 1.2 of the Final Offpost EA/FS (HLA, 1992a).

The primary criterion for identifying COCs was that the chemical concentrations at locations of expected maximum concentration (i.e., near the RMA borders) must be significantly greater than concentrations found at background locations (i.e., no RMA-related contamination present). By applying statistical methods, Offpost Study Area contaminant concentrations were compared to background concentrations at reference locations. If statistical analysis indicated that Offpost Study Area concentrations were significantly higher than the background concentrations, the presence of the chemical in the Offpost Study Area was considered to be RMA-related and the chemical was designated as a COC. This procedure was followed for each environmental medium. Tables 6.1 through 6.4 list the COCs for groundwater, surface water, sediment, and soil, respectively. The exposure point concentration associated with each COC is also shown in the tables.

To select COCs for biota (plants and animals), analytical data obtained from the onpost biota RI were compared to background chemical concentrations available in the scientific literature. This procedure was less precise but nonetheless indicated that two chemicals (dieldrin and arsenic) may be elevated, although in low concentrations, in the tissues of animals located in the Offpost OU.

6.1.2 Exposure Assessment

6.1.2.1 Offpost Study Area Exposure Assessment Zones

The Offpost Study Area is a large, heterogeneous area with a variety of characteristics that can affect exposure levels. Specifically, distinct zones of the Offpost Study Area exhibit different exposure concentrations of COCs in groundwater, surface water, and surface soil, including hot spots where contaminant levels are higher than the average for the entire Offpost Study Area. In addition, population density, land use, and water use varies throughout the Offpost Study Area. Therefore, to avoid diluting or averaging contaminant concentrations over the entire Offpost Study Area, the Offpost Study Area was subdivided into six zones (Figure 6.1) with different exposure conditions. The primary factor used to define the exposure zones was the pattern of COC concentrations in

groundwater. The six zones, and the land use and populations evaluated within each zone, are described below.

Zone 1 is an area with relatively low levels of COCs in groundwater and surface soil. Rural residential land use, which includes consumption of homegrown vegetables, milk, meat, and eggs, is the current and potential future population characteristic.

Zone 2 is an area of relatively high levels of COCs in groundwater, low levels of COCs in surface soil, and no permanent surface-water features. A rural residential land-use scenario, identical to Zone 1, was evaluated.

Zones 3 and 4 are similar. Zone 3 is an area of relatively high levels of pesticide COCs in groundwater, surface water, and surface soil. Zone 4 is an area of relatively high levels of COCs in groundwater and surface water, but relatively low levels of COCs in surface soil. Both Zones 3 and 4 have recently been purchased by Shell Oil Company and are expected to be unoccupied at least until completion of offpost remediation. Plans for improvement of 96th Avenue as an access road for the new Denver International Airport may result in predominantly commercial and industrial land use in these zones. An urban residential land use for Zones 3 and 4 is considered possible and was selected for evaluation because this land use would result in higher exposures than the current land use. Urban land use assumes that exposure to meat, dairy, and eggs would not occur, but that local planting and consumption of vegetables are possible.

Zone 5 is an area with moderate levels of COCs in groundwater and relatively low levels of COCs in surface soil. A commercial and industrial land use for Zone 5 was evaluated. Zone 5 is zoned for industrial use over the majority of its area, is currently developed for industrial use, and is projected as industrial land use for the future.

Zone 6 is an area with moderate levels of COCs in groundwater and relatively low levels of COCs in surface soil. Because farm residences currently exist in Zone 6, a rural residential land use was evaluated that is identical to the land use (rural residential) in Zones 1 and 2.

6.1.2.2 Offpost Study Area Potential Exposure Points

There are several potential exposure points in the Offpost Study Area. The most significant routes of exposure have already been mitigated by exposure controls in areas with the highest groundwater COC concentrations (e.g., the UFS is no longer used in Zones 3 and 4). Exposure to COCs in surface soil has also been mitigated by relocating residents from the area near the intersection of 96th Avenue and Peoria Street where soil contaminant concentrations are highest. Additionally, the Army and Shell Oil Company have agreed to till and revegetate approximately 160 acres located in the southeast portion of Section 14 and the southwest portion of Section 13 in accordance with Paragraph 22 of the Conceptual Remedy Agreement (see Figure 9.1). Shell Oil Company and the U.S. Army believe that existing soil risk in the revegetated area falls within EPA's established acceptable risk range and that remediation is not necessary. However, Shell Oil company and the U.S. Army agree to the revegetation program as part of the remedy.

Concentrations of surface-water contaminants were higher in First Creek than other surface-water bodies during 1986 through 1990, creating a potential exposure point for nonhuman receptors and a direct-contact human pathway associated with wading. First Creek does not support a recreational fishery; Barr Lake is the most likely point of human exposure to bioaccumulated residues in fish tissue. Because COCs are not elevated in Barr Lake, with the exception of a single DIMP detection that was not verified in duplicate or later sampling events, consumption of contaminated fish was not evaluated.

6.1.2.3 Potential Exposure Pathways and Routes

An exposure pathway consists of four elements: (1) a source and mechanism of release, (2) a transport medium, (3) a point of potential contact with the contaminated medium, and (4) an exposure route, such as ingestion, at the contact point.

The Site Conceptual Model (Figure 6.2) presents the potential exposure pathways identified in the Offpost Study Area. The Site Conceptual Model also indicates which exposure routes were quantitatively evaluated for risk. Because of the variations in land use and the presence or absence of surface water in the six zones, not all exposure routes are applicable to all zones. Table 6.5 summarizes the exposure zones by land-use category and identifies the exposure routes quantified in each zone.

Inhalation Route

On the basis of risk screening evaluations conducted according to EPA guidance, the release of volatile chemicals from groundwater used in the home for all purposes (e.g., showering, dishwashing, laundry, toilets) was determined to result in potentially significant exposures by the inhalation route. Therefore, inhalation of volatile chemicals resulting from domestic use was quantified. Other potential sources of exposure, such as the inhalation of contaminated dust particles, and inhalation of vapors resulting from volatilization from underlying groundwater, were found to be very minor contributors to the overall exposure potential.

Dermal Route

Dermal contact with surface soil is likely and was quantified for all potential land uses. Dermal contact with sediment in First Creek was quantified. Dermal contact with sediment of Barr Lake is not feasible, considering the depth of the water and the prohibition of swimming.

Dermal contact with surface water in First Creek was quantified. However, dermal contact with canal water is expected to be unlikely and, in the worst case, infrequent; therefore, dermal contact

was not quantified for the canals. Direct contact recreation is prohibited in Barr Lake; therefore, the dermal contact pathway was not quantified for Barr Lake.

Dermal contact with groundwater used domestically is likely. However, dermal intake during showering is approximately 0.15 percent of the intake resulting from ingestion of groundwater. Potential exposures from direct ingestion and inhalation will be much higher than from dermal contact. Therefore, the dermal intake resulting from domestic use was not quantified. EPA guidance (EPA, 1989a) allows for certain pathways to be eliminated from evaluation if other pathways have much higher exposure.

Ingestion Route

Incidental ingestion of surface soil is likely under all potential land uses; therefore, this pathway was quantified. Incidental ingestion of First Creek sediment is possible in association with wading or recreational activities; therefore, this pathway was also quantified.

Cattle and other livestock raised for human consumption may bioaccumulate COCs from (1) surface water or groundwater used for watering livestock, (2) forage grown in contaminated surface soil or irrigated by contaminated surface water or groundwater, and (3) direct ingestion of soil while grazing. This pathway was quantified, using cattle as the representative species for development of a bioaccumulation model. Additionally, bioaccumulation resulting in dieldrin contamination of chicken eggs was quantified in the EA.

Vegetable crops grown for human consumption may contain COCs because of uptake of COCs from contaminated surface soil and surface water or groundwater for irrigation. Ingestion of vegetable crops was quantified.

Although ingestion of the shallow groundwater is unlikely, this exposure pathway was quantified. It has been conservatively assumed that ingestion of untreated alluvial groundwater might occur even

though there is insufficient water in portions of the UFS contaminated above groundwater containment system remediation goals to supply a municipal water system.

6.1.2.4 Estimation of Chemical Intake

Analytical data from each media within each of the six exposure assessment zones (Section 6.1.2.1) was identified. Exposure point concentrations were selected such that they represent an RME concentration. The RME exposure point concentrations were calculated as the upper 95 percent confidence limit on the arithmetic mean of the data. The RME values for the COCs in each media are presented in Tables 6.1 through 6.4. Exposure point concentrations were combined with standard EPA intake assumptions and variables to estimate the intake of each COC by each exposure route.

To estimate the exposure point concentration for food products (e.g., meat, eggs, vegetables), several models were used to estimate the plant and animal uptake of a chemical from soil or water and the resultant concentration in the edible portion of the plant or animal. All of the uptake and partitioning coefficients were selected so that the resultant COC concentration in the food would also represent an RME value. A complete discussion of the plant and animal chemical uptake models is provided in the Offpost EA/FS.

6.1.3 Toxicity Assessment

The toxicity of chemicals is evaluated in terms of carcinogenic and noncarcinogenic effects. Cancer slope factors and reference doses are used to evaluate potential risks posed by the exposure to carcinogenic and noncarcinogenic chemicals, respectively.

EPA-established slope factors for inhalation and ingestion exposures to COCs are presented in Table 6.6. The slope factor for a given compound is multiplied by the estimated intake to obtain the carcinogenic risk estimate. The individual risks from each compound in a particular exposure

pathway are then summed to obtain an estimate of the overall carcinogenic risk for each pathway and for all pathways combined.

The reference doses (RfDs) used in the EA for inhalation and ingestion exposures are presented in Table 6.6. The estimated intake is divided by the RfD for a given compound to obtain its hazard quotient (HQ). For each exposure pathway, chemicals were segregated by their target organ. For each target organ group, the HQs for each chemical were then summed to obtain a hazard index (HI) for each pathway and for all pathways combined. When the HQ and/or the HI exceed 1.0, there may be concern for potential noncarcinogenic health effects.

6.1.4 Risk Characterization

Following the estimation of exposure point concentrations and chemical intakes, the slope factors and RfDs are used to estimate carcinogenic risks and the potential for noncarcinogenic effects. The following sections discuss the results of this procedure.

6.1.4.1 Carcinogenic Risks

Table 6.7 summarizes the estimated current carcinogenic risks corresponding to existing exposures by exposure assessment zone and exposure route. The total carcinogenic risks range from 1×10^{-4} to 3×10^{-4} (1 to 3 in 10,000) in Zones 1 through 4, 3×10^{-5} (3 in 100,000) in Zone 5, and 7×10^{-5} (7 in 100,000) in Zone 6. The total carcinogenic risks for each of the six exposure assessment zones are within the acceptable risk range established by EPA. The hypothetical risks in Zones 3 and 4 are highly conservative in that they are based on an urban residential land-use scenario and there are no humans currently living in Zones 3 and 4. Additionally, the risks estimated for a portion of Zone 1 and Zone 2 are not current risks, because residents in these areas do not use UFS groundwater for domestic use. Because there are no current residents in Zones 3 and 4, and the current residents in Zone 5 have water supplies other than shallow wells, the estimated risks from residential use in these zones are conservative because they do not represent existing exposures.

Groundwater usage (either domestic and/or agricultural) is the primary contributor to carcinogenic risk, accounting for 45 to 99 percent of the total risk estimated for each zone. This indicates the major role of the groundwater-related exposure pathways. Risks related to chemicals in soil are less than 1 in 10,000 (1×10^{-4}), and the risks resulting from the surface-water and sediment exposure pathways are less than 1 in 100,000 (1×10^{-5}). Because of the importance of the groundwater pathway, the remediation of groundwater will have the greatest effect in reducing potential offpost risks.

Dieldrin contributes the most to the total carcinogenic risk, followed by arsenic, chloroform, and atrazine. All of the estimated risks from dieldrin are conservative in that the dieldrin concentrations were considered to be constant throughout the exposure period (30 years). The natural reduction in dieldrin concentrations over time was not considered. Additionally, not all of the total carcinogenic risks for each zone are attributable to RMA activities. Background concentrations of dieldrin in soil attributable to agricultural practices may contribute up to 50 percent of the total carcinogenic risk in some zones based on a background concentration for dieldrin of approximately 8 mg/kg. Naturally occurring arsenic in groundwater may be responsible for a risk of approximately 4 in 100,000 (4×10^{-5}), based on a background concentration of arsenic in groundwater of approximately 3 μg/l.

6.1.4.2 Noncarcinogenic Effects

As presented in Section 6.1.3, HIs are derived by comparing the estimated daily chemical intake to the estimated acceptable intake. Acute, or short-term, effects were evaluated for children because children would have the highest chemical intake per body weight and would be expected to be the most sensitive to the chemical. The EA concluded that there is a low potential for adverse health effects in children from hypothetical short-term exposures to dieldrin in groundwater in Zones 2, 3, and 4. The HI exceeds 1 in Zones 2, 3, and 4, with a maximum HI of 4 in Zone 3. Dieldrin is the primary contributor to the HI.

HIs were also estimated for long-term exposures for both children and adults. The risk characterization presented in the EA found that, with the exception of ingestion of DIMP in groundwater in Zone 4, no single chemical or exposure pathway resulted in an HI greater than 1. HIs were also calculated on the basis of target organ effects and the mechanism of toxic action. For children, both liver and central nervous system (CNS) toxicants were found to exceed an HI of 1. For liver toxicants, the HI exceeds 1 in Zones 2, 3, and 4, with a maximum HI of 2 in Zone 2, predominately attributable to inhalation and ingestion of chloroform. The HI for CNS effects exceeds 1 in Zones 2 and 4, with a maximum HI of 3.7 in Zone 4. The primary contributors to the estimation of CNS effects are DIMP and manganese. Direct ingestion of groundwater and ingestion of vegetable crops irrigated with groundwater are the two primary exposure pathways for DIMP and manganese.

Adult future HIs are all less than the child HIs. Table 6.8 summarizes the adult HIs segregated by target organ. When segregated for liver toxicants, the highest HI is 1.3 in Zone 3. The HI for CNS effects also exceeds 1.0, where DIMP is the major contributor to an HI of 2.4 in Zone 4.

6.2 Estimation of Potential Ecological Effects

6.2.1 Method

An Offpost Study Area ecological risk assessment was performed to evaluate potential adverse effects to the environment and nonhuman receptors as a result of potential exposure to chemicals migrating from onpost sources. The two natural ecosystems occurring in the Offpost OU are terrestrial and aquatic. Figure 6.3 presents the ecological site conceptual model and presents the potential exposure pathways quantified. The chemicals selected for evaluation of potential effects on the terrestrial and aquatic receptors were limited to RMA-related chemicals found in surface water, surface soil, and sediment. Chemicals identified in groundwater were used to evaluate agricultural receptors (e.g., crops, livestock) because of the potential for exposure through irrigation and livestock watering. The chemicals evaluated for potential ecological effects were aldrin, arsenic, dieldrin, endrin, DDE, DDT, and mercury.

Two methods of exposure were evaluated: direct exposure and biomagnification. Direct exposure is a result of contact with the original source of the chemical (e.g., ingestion of surface water or soil, ingestion of groundwater, or fish swimming in contaminated surface water). Biomagnification occurs when the tissue concentrations of a chemical increase with progression up the food chain. Over time, the concentrations of chemicals in tissues may reach a level detrimental to the organism's health.

The evaluation of ecological effects via direct exposure is analogous to the evaluation of human effects. Direct toxicity was evaluated by comparing the estimated daily intake of a receptor to the estimated toxicity reference value for a receptor. The toxicity reference values are similar to human RfDs in their derivation and use. These toxicity reference values were animal- and chemical-specific values, or, in the case of aquatic life, federal Ambient Water Quality Criteria values established to protect aquatic life.

To evaluate the potential effects of biomagnification, the estimated tissue concentrations resulting from biomagnification were compared to residue concentrations known to be without deleterious effects. Only the top indicator species were selected to evaluate the effects of biomagnification. These species were the bald eagle, great blue heron, and mallard duck.

In coordination with the U.S. Fish and Wildlife Service, it was agreed that screening levels, developed to ensure compliance with enforceable remediation levels, would meet the requirements of the federal Endangered Species Act, the Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act. These screening levels were not exceeded in the Offpost OU. These levels are presented in the Final Offpost Operable Unit Endangerment Assessment/Feasibility Study in Table 3.3.3-1 (Toxicity Reference Values for Avian and Terrestrial Vertebrate Species of Concern Identified at Rocky Mountain Arsenal) of Volume II and Table H5-1 (Maximum Allowable Tissue Concentration [MATC] Values for the Offpost EA Ecological Assessment) of Appendix H in

Volume IV. If the screening levels are exceeded or effects are observed in the future, enforceable remediation levels will be developed consistent with CERCLA, the Endangered Species Act, the Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act.

Potential effects on wetlands and critical habitats were also evaluated. This assessment is presented in Appendix B of the Final Offpost EA/FS (HLA, 1992a). The U.S. Fish and Wildlife Service (USFWS) National Wetlands Office identified approximately 300 acres of wetlands along First Creek from the north boundary of RMA to O'Brian Canal. Potential effects of construction of the Offpost Groundwater Intercept and Treatment System included temporary dewatering during excavation of recharge trenches and pipelines near First Creek.

6.2.2 Results

Underwater aquatic life was evaluated on the basis of direct toxicity by comparing water concentrations to aquatic reference concentrations. Chlordane, dieldrin, fluoride, and DDT appeared to present a potential for an adverse effect to aquatic life in First Creek. However, because First Creek is dry much of the year and does not support a stable and ongoing fish population, adverse effects to aquatic life are expected to be minimal. Because of interaction between groundwater and First Creek, remedial actions taken to reduce the concentration of COCs north of the NBCS will also reduce concentrations of COCs in First Creek.

Agricultural life was evaluated in Zones 1, 2, and 6 (rural residential). The results of the direct toxicity evaluation indicated no potential adverse impacts to poultry from soil contaminants or to cattle from ingestion of contaminated soil and groundwater.

The ecological risk assessment concluded that for animals in the terrestrial and aquatic food webs, there is minimal potential for adverse effects. However, the Army and Shell Oil Company have agreed to till and revegetate approximately 160 acres located in the southeast portion of Section 14 and the southwest portion of Section 13 (see Figure 9.1). Shell Oil Company and the U.S. Army

believe that existing soil risk in the revegetated area falls within EPA's established acceptable risk range and that remediation is not necessary. However, Shell Oil Company and the U.S. Army agree to the revegetation program as part of the remedy.

Construction of the Offpost Groundwater Intercept and Treatment System was coordinated with USFWS to minimize the potential impacts on wetlands and habitat. Although the wetlands area has been slightly altered because of construction of roads in the area, the wetlands still exist, dewatering is no longer occurring, and the amount of recharged groundwater is equal to the amount of extracted groundwater, thereby maintaining the stability of the wetlands area.

6.3 Conclusion

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present a potential threat to public health, welfare, or the environment.

7.0 DESCRIPTION OF GROUNDWATER REMEDIATION ALTERNATIVES

An FS was conducted to develop and evaluate remedial alternatives for the Offpost OU. The first task performed during the FS was to identify media that require remedial action and correspondingly require development and evaluation of remedial alternatives. Risks calculated in the EA were compared to acceptable risk levels established by EPA in the NCP and other guidance. The Army has closely followed EPA guidance and the National Contingency Plan (NCP) regarding the use of the 10^{-4} risk threshold to assess whether remediation is necessary. Guidance states that if the cumulative cancer risk to an individual is less than 10^{-4}, remedial action may not be warranted unless certain site-specific conditions exist. If remedial action is warranted, then the 10^{-4} to 10^{-6} risk range must be achieved, with an initial preference for the 10^{-6} end. EPA guidance further states that the upper boundary of the risk range is not an absolute at 1×10^{-4}, but rather, the acceptable risk range can extend to 5×10^{-4}. The cumulative offpost cancer risk is a maximum of 3×10^{-4}, which is within the acceptable risk range.

In explaining the use of the point of departure, the EPA, in the preamble to the NCP, states

- The use of 10^{-6} expresses EPA's preference for remedial actions that result in risks at the more protective end of the risk range, but does not reflect a presumption that the final remedial action should attain such a risk level (55 FR 8718).

The operation of the Offpost Groundwater Intercept and Treatment System reflects the Army's goal of further reducing the potential risks toward the 10^{-6} level. Using conservative assumptions, including several exposure pathways that do not currently exist, the maximum cumulative cancer risk in the Offpost OU was estimated to be 3 in 10,000, which is within the acceptable risk range established by EPA.

Although the maximum offpost cumulative carcinogenic risk is below the acceptable risk level, remediation of groundwater is preferable to no action for the following reasons:

- Groundwater concentrations exceed National Primary Drinking Water Standards maximum contaminant levels (MCLs) and CBSGs in some areas of the Offpost OU.
- Groundwater is the greatest contributor to cancer risk and contributes a maximum risk of 2 in 10,000 (or approximately 75 percent) to the cumulative risk in zones 2, 3, and 4.
- Evaluation of potential noncarcinogenic health effects indicate that HIs calculated for groundwater contaminant concentrations in zones 2, 3, and 4 are slightly greater than 1.0.

Soil, surface water, sediment, and air contribute maximum cancer risks less than 1 in 10,000 in zones 1 through 6. Soil, surface water, sediment, and air do not require remediation because of the low risks contributed by these media to the total risk. Remedial alternatives were developed and evaluated to address contaminated groundwater in the Offpost OU North and Northwest Plume Groups. Additionally, as part of the Conceptual Remedy Agreement, the Army and Shell Oil Company have agreed to till and revegetate approximately 160 acres located in the southeast portion of Section 14 and southwest portion of Section 13.

Remedial alternatives for groundwater were developed by (1) establishing groundwater containment system remediation goals , (2) identifying the areas of groundwater exceedances of containment system remediation goals , and (3) assembling combinations of remedial process options into remedial alternatives.

Containment system remediation goals (Table 7.1., 7.2, and 7.3 were established on the basis of chemical-specific applicable or relevant and appropriate requirements (ARARs), health-based criteria (HBC), exposure factors, and the statutory requirements stated in Section 121 of CERCLA. ARARs were used as groundwater containment system remediation goals for contaminants with promulgated standards, and HBC based on a risk of 1×10^{-6} calculated using RME assumptions were used for carcinogens without ARARs. A risk level of 1×10^{-6} was selected to correspond to the point of departure as defined in the NCP. The promulgated standards adopted as containment system remediation goals for Offpost OU groundwater include MCLs and CBSGs. In addition, containment system remediation goals for several contaminants with promulgated standards were adjusted

downward to reduce risk corresponding to the containment system remediation goals. For some analytes, the certified reporting limit (CRL) or the practical quantitation limit (PQL) are higher than the containment system remediation goal. The CRL and PQL represent the lower practical limit for quantitation.

Attainment of the groundwater containment system remediation goals developed for the site will reduce the estimated total hypothetical cancer risks to less than 1×10^{-4} toward the 1×10^{-6} level. Because the total cancer risk assumes that all chemicals are present in groundwater at all locations, and since groundwater contamination is variable throughout the OU, the estimated risk reduction may be greater. Attainment of the groundwater containment system remediation goals developed for the site will also reduce HIs discussed in Section 6.1.4.2 to below 1.0 for all target organ groups and receptors. Again, variability in contaminants present in groundwater may increase the estimated risk reduction from that estimated by extrapolating directly from the risk assessment.

Groundwater requiring remediation in the Offpost Study Area was identified by comparing groundwater containment system remediation goals to the areal extent of groundwater contamination. Groundwater containment system remediation goals are exceeded for the carcinogens arsenic, chloroform, DBCP, tetrachloroethylene, trichloroethylene, and dieldrin. Groundwater containment system remediation goals are also exceeded for the noncarcinogens chlorobenzene, dicyclopentadiene, and DIMP. The area of groundwater exceeding containment system remediation goals (and thus the Offpost OU) encompasses approximately 590 acres of the Offpost Study Area.

Groundwater alternatives were developed and evaluated using two groundwater models. The models simulated groundwater flow and contaminant transport for the North and Northwest Plume Groups. Groundwater modeling was used for the following purposes: developing conceptual designs for sizing and locating groundwater extraction, recharge, and treatment systems; estimating future contaminant transport; evaluating the relative merits of remediation alternatives; and estimating the

time required to clean up the contaminated groundwater. Because of the approximate nature and inherent uncertainties of the models, none of the model results should be interpreted as an accurate prediction of future conditions. The predicted remediation time frames are estimates. Accordingly, estimated remediation time frames were only used to assess the relative effectiveness of the groundwater alternatives.

Remedial alternatives were initially screened on the basis of effectiveness, implementability, cost, and attainment of ARARs. The alternatives passing the initial screening were then evaluated on the basis of nine criteria required by the NCP. In addition to remedial alternatives, the NCP requires that a No Action alternative be considered at every site. The No Action alternative serves primarily as a point of comparison for other alternatives.

A total of six alternatives for the North Plume Group and four remedial alternatives for the Northwest Plume Group were developed for analysis. Following the initial screening analysis in the FS, four remedial alternatives for the North Plume Group (N-1, N-2, N-4, and N-5) and two remedial alternatives for the Northwest Plume Group (NW-1 and NW-2) remained for evaluation during the detailed analysis of alternatives. These alternatives are described below with the original alternative numbering sequence from the FS report.

7.1 Common Elements of Alternatives

All of the alternatives developed included the following elements:

- Groundwater and surface-water monitoring: Samples will be collected periodically from groundwater monitoring wells and surface-water locations throughout the Offpost Study Area and analyzed to assess changes in groundwater and surface-water quality during and after remediation.
- Site review: In accordance with CERCLA, a site review will be conducted at least every five years until groundwater containment system remediation goals are achieved to assure that human health and the environment are protected during and after remediation. The site review will use monitoring program data to assess whether additional remedial action would be warranted.

Except for the No Action alternative, each alternative also includes the following activities:

- Exposure control/provision of alternate water supply as described below:
  - As of the date of the Onpost ROD, and based on a .392 parts per billion (ppb) detection limit, the U.S. Army will use the last available quarterly monitoring results to determine the DIMP plume footprint.
  - As part of the Onpost ROD, the U.S. Army and Shell Oil Company will pay for the extension of, and hook-up to, the current distribution system for all existing well owners within the DIMP plume footprint referenced above.
  - Existing domestic well owners outside of the DIMP plume footprint as of the date of the On-post ROD where it is later determined that levels of DIMP are eight ppb or greater (or other relevant CBSG at the time) will be hooked up at the U.S. Army and Shell Oil Company's expense to the SACWSD distribution system or provided a deep well or other permanent solution.
  - For new domestic wells with levels of eight ppb or greater (or other relevant CBSG at the time), the Offpost ROD institutional controls will provide that the U.S. Army and Shell Oil Company will pay for hook-up to the distribution system or provided a deep well or other permanent solution.
  - Any user of a domestic well within the Offpost Operable Unit that contains groundwater contaminants derived from RMA at concentrations that exceed the greater of the remediation goals in Tables 7.1 through 7.3 or the ARARs in Table 10.1 will be provided an alternative water supply. Bottled water will be provided for cooking and drinking until a permanent alternative water supply is provided. Permanent alternative water supplies could include installation of a deep uncontaminated well or connection to a municipal potable water-supply system. This commitment applies to both users of existing domestic wells and users of wells that are lawfully drilled in the future.
  - As part of the Onpost ROD, the U.S. Army and Shell Oil Company agree to pay for, and provide or arrange for the provision of 4,000 acre feet of water, the details of which will be worked out between the U.S. Army, Shell Oil Company, and SACWSD. If such water is not available, the U.S. Army and Shell Oil Company will provide payment of an agreed upon amount of money in lieu of water.
- Use of institutional controls to prevent the future use of groundwater exceeding remediation goals. Institutional controls are reflected in Appendix B.
- Continued operation of the existing boundary containment systems - The NBCS and NWBCS will continue to operate and improvements will be made, as necessary, to assure that offpost groundwater containment system remediation goals are not exceeded. In addition, the ICS will continue to operate, as required, for onpost contaminants consistent with the Irondale IRA. These containment systems will be operated to the requirements of Section 2.7 of the FFA, the Conceptual Remedy Agreement, and the Onpost ROD, when it is signed. Cessation may occur as provided in Sections 35.3 and 35.4 of the FFA and paragraph 20 of the Conceptual Remedy Agreement. Currently, approximately 125 million gallons per year are treated at the NBCS, 450 million gallons per year are treated at the NWBCS, and 45 million gallons per year are treated at the ICS.

- Closure of poorly constructed wells within the Offpost Study Area - Wells that could be acting as migration pathways for contaminants in the Arapahoe Aquifer will be closed using approved methods. The pertinent criteria are presented in Appendix C - Well Closure Criteria.

7.2 Identification of Groundwater Alternatives: North Plume Group

Alternatives developed for remediation of groundwater in the North Plume Group are described below. Table 7.4 presents the alternatives corresponding to the North Plume Group and identifies process options, numbers of wells and trenches, flow rates, estimated remediation time frames, treatment facility location, and process residuals generated.

7.2.1 Alternative N-1: No Action

Under Alternative N-1, the operation of the NBCS would be discontinued. Alternative N-1 would therefore not provide for active remediation of affected groundwater within the North Plume Group. Ceasing operation of the NBCS would likely cause an increase in contaminant concentrations within the North Plume Group. Natural fate processes, including degradation and attenuation, would be the only mechanisms that would reduce contaminant concentrations in groundwater within the North Plume Group. The major components of Alternative N-1 include the following:

- Long-term groundwater and surface-water monitoring
- Site reviews

A long-term groundwater and surface-water monitoring program would be implemented. The purpose of the monitoring program is to assess changing UFS and CFS aquifer and surface-water conditions during and after remedial action. As part of Alternative N-1, a site review would be conducted at least every five years until containment system remediation goals are achieved.

The total present worth cost estimate for Alternative N-1 ranges from $4,061,000 to $6,102,000. This includes long-term operation and maintenance costs for performing site reviews, groundwater and surface-water monitoring, and regulatory oversite activities.

7.2.2 Alternative N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

Alternative N-2 would provide for active remediation of affected groundwater approaching the north boundary of RMA through continued remediation of groundwater at the NBCS. The major components of Alternative N-2 are as follows:

- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater and surface-water monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1 and C-2
- Institutional controls as described in Appendix B

Under Alternative N-2, the NBCS would continue to contain, extract, treat, and recharge approximately 125 million gallons of groundwater per year. Improvements would be made to the NBCS if it was determined that the system was allowing groundwater containing COCs at concentrations exceeding offpost groundwater containment system remediation goals to migrate from RMA to the North Plume Group.

As part of Alternative N-2, an alternative water supply would be provided to any user of a domestic well in accordance with the provisions described in Section 7.1. The long-term groundwater and surface-water monitoring and site review remedial components under Alternative N-2 would be identical to those proposed under Alternative N-1.

The total present worth cost estimate for Alternative N-2 ranges from $30,600,000 to $32,500,000. This incudes long-term operation and maintenance costs for the NBCS and the cost of long-term groundwater monitoring and site review components included under Alternative N-1.

7.2.3 Alternative N-4: Offpost Groundwater Intercept and Treatment System

Under Alternative N-4, the NBCS would continue to operate, and the Offpost Groundwater Intercept and Treatment System would be constructed and operated to contain, remove, treat, and recharge groundwater exceeding containment system remediation goals in the First Creek and northern paleochannels downgradient of the NBCS. Detailed information concerning the Offpost Groundwater Intercept and Treatment System is presented in the Final Implementation Document for the Groundwater Intercept and Treatment System North of Rocky Mountain Arsenal (HLA, 1991). The Offpost Groundwater Intercept and Treatment System has been in operation since early 1993. The major components of Alternative N-4 are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels using Offpost Groundwater Intercept and Treatment System groundwater extraction wells
- Treatment of organic contaminants in extracted groundwater using carbon adsorption
- Recharge of treated groundwater to the UFS using Offpost Groundwater Intercept and Treatment System recharge wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS and Offpost Groundwater Intercept and Treatment System as necessary
- Long-term groundwater and surface-water monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1 and C-2
- Institutional controls as described in Appendix B

Alternative N-4 would remediate UFS groundwater in the First Creek and northern paleochannels that is contaminated with organic COCs at concentrations exceeding groundwater containment system remediation goals.

Extraction wells would be used in the Offpost Groundwater Intercept and Treatment System to remove contaminated groundwater. Extracted groundwater would be conveyed to the treatment facility via double-contained polyvinyl chloride (PVC) pipelines.

Based on the results of the groundwater modeling, the configuration of five extraction wells and six recharge trenches shown in Figure 7.1 would capture and remove contaminants axially in the First Creek paleochannel. The recharge trenches would be placed both downgradient of the extraction wells and along the outer boundaries of the First Creek paleochannel. In this manner, the recharge trenches would provide both lateral hydraulic containment of the First Creek paleochannel and water flushing for enhancing the removal of contaminants. Capture would be attained using a transverse system of 12 extraction and 24 recharge wells directly downgradient of the extraction wells in the northern paleochannel system. The Offpost Groundwater Intercept and Treatment System would contain, extract, treat, and recharge approximately 480 gallons per minute (gpm). Construction of this system began in November 1991 and was completed in June 1993.

Extracted groundwater from both the First Creek and northern paleochannels would be conveyed by pipeline to a central carbon adsorption treatment facility on land in the Offpost Study Area that was previously purchased by Shell. Activated carbon adsorption is a well-developed technology that is widely used in removing organic contaminants from liquid hazardous waste streams and offgas airstreams. The waste stream comes in contact with granular activated carbon (GAC) by flowing through one or more packed-bed reactors. Organic chemicals and, to some degree, inorganic chemicals, are adsorbed onto the internal pores of the carbon granules by surface-attractive phenomena. Activated carbon removes many nondegradable organic compounds and is most effective for nonpolar, slightly soluble compounds.

Carbon adsorption is readily implementable. Carbon adsorption is a demonstrated, proven technology documented to be effective at the NWBCS, NBCS, and ICS. Activated carbon treatment would

achieve groundwater containment system remediation goals for organic contaminants before discharge via the recharge systems.

An intensive short-term monitoring component would be included in Alternative N-4 as part of the long-term monitoring program. The intensive short-term program would consist of monitoring approximately 60 wells in a network that would be finalized through implementation of the alternative. Two years of data would be collected during the period commencing with Offpost Groundwater Intercept and Treatment System operations start-up. Such a program is necessary to evaluate the performance of the NBCS and the Offpost Groundwater Intercept and Treatment System and would provide an increased understanding of contaminant transport, an estimated time to achieve groundwater containment system remediation goals, and to determine whether improvements to the Offpost Groundwater Intercept and Treatment System are warranted.

The total present worth cost estimate for Alternative N-4 ranges from $56,500,000 to $63,100,000. This includes the capital and long-term operation and maintenance cost for construction, operation, and performance monitoring of the Offpost Groundwater Intercept and Treatment System. This cost estimate also includes the continued operation of the NBCS, long-term groundwater monitoring, site review, and exposure control components of Alternative N-2.

7.2.4 Alternative N-5: Expansion of the Offpost Groundwater Intercept and Treatment System

Similar to Alternative N-4, this alternative would remediate the First Creek paleochannel and northern paleochannel groundwater downgradient of the NBCS. Based on the results of the groundwater modeling, the configuration of extraction wells and recharge systems proposed under Alternative N-5 would place additional extraction wells in locations where the limiting hydrogeologic and contaminant characteristics are controlling remediation time frames. Two additional extraction wells and four recharge trenches would be installed in the area of relatively slower groundwater velocity and high dieldrin concentrations in the First Creek paleochannel. One additional extraction

well and two recharge trenches would be installed in an area of low hydraulic conductivity in the northern paleochannel. The major components of Alternative N-5 are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using Offpost Groundwater Intercept and Treatment System groundwater extraction wells
- Expansion of the Offpost Groundwater Intercept and Treatment System extraction and recharge systems
- Treatment of extracted groundwater using carbon adsorption
- Recharge of treated groundwater to the UFS, using recharge wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater and surface-water monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1 and C-2
- Institutional controls as described in Appendix B

The expansion of the Offpost Groundwater Intercept and Treatment System is shown in Figure 7.2. The three additional extraction wells would each pump 30 gpm (90 gpm additional), and the additional trenches would recharge the same volume. Thus, Alternative N-5 would extract and treat a total of 570 gpm compared to 480 gpm for Alternative N-4. Other remedial components under Alternative N-5 would be identical to those proposed under Alternative N-4.

The total present worth cost estimate for Alternative N-5 ranges from $56,200,000 to $63,000,000. This includes the capital and operation and maintenance costs of the expansion systems to the Offpost Groundwater Intercept and Treatment System and the cost components of Alternative N-4.

7.3 Identification of Groundwater Alternatives: Northwest Plume Group

The following subsections identify the alternatives developed for the Northwest Plume Group. Table 7.4 presents the alternatives corresponding to the Northwest Plume Group and identifies process options, numbers of wells and trenches, flow rate, estimated remediation time frames, treatment facility location, and process residuals generated.

7.3.1 Alternative N-1: No Action

Under Alternative NW-1, the operation of the NWBCS would be discontinued. Alternative NW-1 would not provide for active remediation of affected groundwater within the Northwest Plume Group. Ceasing operation of the NWBCS would likely cause an increase in contaminant concentrations within the Northwest Plume Group. Natural fate processes, including degradation and attenuation, would be the only mechanisms that would reduce contaminant concentrations in groundwater within the Northwest Plume Group. The major components of Alternative NW-1 are as follows:

- Long-term groundwater monitoring
- Site reviews

A long-term groundwater monitoring program would be implemented. The purpose of the monitoring program would be to assess changing UFS and CFS aquifer conditions during and after remedial action. As part of Alternative NW-1, a site review would be conducted at least every five years until containment system remediation goals are achieved.

The total present worth cost estimate for Alternative NW-1 ranges from $608,000 to $1,260,000. This includes long-term operation and maintenance costs for performing site reviews, groundwater monitoring, and regulatory oversite activities.

7.3.2 Alternative NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

Alternative NW-2 would provide for active remediation of affected groundwater approaching the northwest boundary of RMA through continued remediation of groundwater at the NWBCS. The major components of Alternative NW-2 are as follows:

- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1 and C-2
- Institutional controls as described in Appendix B

Under Alternative NW-2, the NWBCS would continue to contain, extract, treat, and recharge approximately 450 million gallons of groundwater per year. Improvements would be made to the NWBCS if it was determined that the system was allowing groundwater containing COCs at concentrations exceeding offpost groundwater containment system remediation goals to migrate from RMA to the Northwest Plume Group.

As part of Alternative NW-2, an alternative water supply would be provided to any user of a domestic well that contains groundwater contaminants at concentrations exceeding containment system remediation goals . Other remedial components under Alternative NW-2 would be identical to those proposed under Alternative NW-1.

The total present worth cost estimate for Alternative NW-2 ranges from $12,400,000 to $13,100,000. This includes long-term operation and maintenance costs for the NWBCS and the long-term groundwater monitoring, site reviews, and exposure control components of Alternative NW-1.

8.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The remedial alternatives were evaluated with respect to nine threshold, primary balancing, and modifying criteria as required by the NCP. The criteria are as follows:

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with ARARs

Primary Balancing Criteria

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria

- State acceptance
- Community acceptance

Threshold criteria must be satisfied by the selected alterative. Primary balancing criteria are used to weigh trade-offs among alternatives. Modifying criteria may be used to alter a proposed remedial alternative. Brief descriptions of the evaluation criteria and the items considered when assessing alternatives with respect to each criterion are presented in the summary of the comparative analysis of alternatives.

The models simulating UFS groundwater flow and dissolved chemical transport were prepared for the analysis of alternatives and are approximate in nature. Because detailed models were not needed to compare the benefits of each remedial alternative, attempts were made to produce models that incorporate general features of groundwater flow and associated transport phenomena in the Offpost

Study Area. Nonetheless, the resulting models predicted flow and chemical transport phenomena that agree with historical and current hydrogeologic data and observed contaminant distributions. Because of the approximate nature of the models and the considerable uncertainty in the conceptual model and hydrogeologic parameters, none of the modeling results should be construed as accurate predictions of future contaminant distribution. Rather, the models and modeling results should be viewed as tools for assessing the relative merits of remedial alternatives. Although there are inherent uncertainties in the groundwater model, it is the tool being used to evaluate the alternatives, and predicted differences in remediation time frames are considered with respect to evaluating alternative effectiveness.

For the North Model, the following remedial action scenarios were simulated: (1) continued operation of the NBCS with improvements as necessary (Alternative N-2), (2) Offpost Groundwater Intercept and Treatment System (Alternative N-4), and (3) expansion of the Offpost Groundwater Intercept and Treatment System (Alternative N-5). The results of these simulations were evaluated on the basis of estimated remediation times measured on maximum concentrations versus time graphs. The range of estimated remediation times was based on attainment of the groundwater cleanup standards for DIMP, chloroform, and dieldrin, using a range of retardation factors. Although some remediation goals have changed since modelling was performed, these changes do not affect the assessment of the relative merits of the remedial alternatives.

For the Northwest Model, the remedial action scenario for continued operation of the NWBCS with improvements as necessary (Alternative NW-2) was simulated.

8.1 Comparative Analysis of Remedial Alternatives

The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to the others. Critical tradeoffs were identified and used to assist in selection of the preferred remedy. Summaries of the detailed analysis of the North Plume Group and Northwest Plume Group alternatives are presented in Tables 8.1 and 8.2, respectively. A brief description of the

evaluation criteria and a comparison of each alternative with respect to the evaluation criteria is presented below. Components common to all of the alternatives were not evaluated in the comparative analysis.

8.1.1 Overall Protection of Human Health and the Environment

The criterion of overall protection of human health and the environment serves as a final check in assessing whether each alternative provides adequate protection of human health and the environment. This criterion was also used to evaluate how risks would be eliminated, reduced, or controlled through treatment, engineering, institutional controls, or other remedial activities.

North Plume Group Alternatives

Overall protection of human health and the environment would be provided by all alternatives with the exception of Alternative N-1. Alternatives N-4 and N-5 would provide greater protection than Alternative N-2 because extraction, treatment, and recharge systems within the North Plume Group would decrease organic contaminant concentrations and reduce potential risks within a shorter time period. Although groundwater modeling estimates that Alternative N-5 would achieve containment system remediation goals in a shorter time period than Alternative N-4 (10-20 years for Alternatives N-5 versus 15-30 years for Alternative N-4), the two alternatives are essentially equivalent with respect to providing protection of human health and the environment for the following reasons:

- Alternatives N-4 and N-5 both provide for active remediation of the First Creek and Northern paleochannel groundwater in approximately the same time period through removal of contaminated UFS groundwater, treatment of the organics in the contaminated groundwater using carbon absorption, and recharge of the treated groundwater using recharge wells and trenches.
- Both alternatives also provide a significant reduction in potential risk in approximately the same time period through organic contaminant removal and treatment by the Offpost Groundwater Intercept and Treatment System.

Northwest Plume Group Alternatives

Alternative NW-1 would not be protective of human health and the environment because the NWBCS would cease operation. Overall protection of human health and the environment would be provided

by Alternative NW-2. Alternative NW-2 would decrease contaminant concentrations and reduce potential risks associated with groundwater entering the Offpost Study Area north of the NWBCS. Recharge of groundwater treated at the NWBCS would reduce contaminant concentrations in the Northwest Plume Group through flushing with treated groundwater. Groundwater modeling estimates that Alternative NW-2 would achieve groundwater containment system remediation goals in approximately three to eight years. Alternative NW-1 would not likely achieve groundwater containment system remediation goals because operation of the NWBCS would cease.

8.1.2 Compliance With Applicable or Relevant and Appropriate Requirements

The criterion of compliance with ARARs is used to assess whether each alternative will attain ARARs. The comparative analysis describes how each alternative exceeds, attains, or does not attain these requirements. Other information such as advisories, criteria, or guidance documents have been considered where appropriate during the ARARs analysis (see Section 10.0).

North Plume Group Alternatives

Compliance with chemical-specific ARARs would be achieved by all alternatives with the exception of Alternative N-1. Cleanup standards for Offpost OU groundwater include Safe Drinking Water Act MCLs and CBSGs. Groundwater modeling estimates that chemical-specific ARARs would be achieved in the shortest time by Alternative N-5, followed by Alternative N-4, followed by Alternative N-2.

Compliance with location-specific and action-specific ARARs will be achieved by all treatment alternatives. Because no remediation would take place under Alternative N-1, there would be no federal and state location- or action-specific ARARs. Inorganic standards for chloride and sulfate will be met by natural attenuation consistent with the onpost remedial action.

Northwest Plume Group Alternatives

Compliance with chemical-specific ARARs would be achieved only by Alternative NW-2. Groundwater modeling indicates that Alternative NW-2 would achieve chemical-specific ARARs in approxi-

mately three to eight years. Alternative NW-2 would comply with location- and action-specific ARARs.

8.1.3 Long-term Effectiveness and Permanence

The long-term effectiveness and permanence criterion addresses the risk remaining at the site after response objectives have been met. Components of the criterion that were addressed for each alternative are as follows:

- Magnitude of residual risk at the end of remedial activities
- Adequacy and reliability of controls that are used to manage either treatment residuals or untreated materials that remain at the site

North Plume Group Alternatives

Comparison of North Plume Group alternatives with respect to long-term effectiveness and permanence indicates that each alternative, except Alternative N-1, provides a high degree of effectiveness and permanence. However, Alternative N-4 is superior to Alternative N-5 because using full-scale operating data as the basis for identifying the need for placing additional wells and trenches and identifying the optimum locations will enhance long-term system performance. All of the alternatives with the exception of the No Action alternative would reduce potential risk and address exposure pathways by reducing COC concentrations in the North Plume Group. Under the No Action alternative, potential risks would likely increase after ceasing operation of the NBCS.

Northwest Plume Group Alternatives

Comparison of the Northwest Plume Group alternatives with respect to long-term effectiveness and permanence indicates that Alternative NW-2 reduces potential risk and addresses exposure pathways by reducing COC concentrations in the Northwest Plume Group. Under the No Action alternative, potential risks would likely increase after ceasing operation of the NWBCS.

8.1.4 Reduction in Toxicity, Mobility, or Volume

The reduction of toxicity, mobility, or volume criterion addresses the statutory preference for selecting remedial actions that permanently and significantly reduce toxicity, mobility, or volume of hazardous materials at the site. This preference is satisfied when treatment is used to reduce principal risks through destruction or irreversible reductions of toxicity, mobility, and/or volume.

North Plume Group Alternatives

All North Plume Group alternatives with the exception of the No Action alternative would reduce the toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU north of the NBCS. Groundwater contaminant concentrations under the No Action alternative would likely increase. Alternatives N-4 and N-5 would provide the greatest reduction in toxicity, mobility, and volume of contaminated groundwater, through extraction, treatment, and recharge within the North Plume Group. As stated previously, the uncertainty associated with the remediation time frames estimated by the groundwater modeling suggests that, in practical terms, the estimated time frames for both Alternatives N-4 and N-5 are essentially equivalent. Further, the intensive short-term groundwater monitoring component of Alternative N-4 would allow for full-scale performance data regarding the reduction of contaminant concentrations. Such data would be necessary to assess the need for and optimum location of any modifications to Alternative N-4.

Northwest Plume Group Alternatives

Alternative NW-2 would reduce the toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU northwest of the NWBCS through extraction, treatment, and recharge. Groundwater contaminant concentrations under the No Action alternative would likely increase; thus toxicity, mobility, or volume would not be reduced.

8.1.5 Short-term Effectiveness

The short-term effectiveness criterion addresses the protection of human health and the environment during the construction and implementation phase. The following factors were addressed during the evaluation process:

- Protection of the community during remedial actions - This factor addresses any risk that results from implementation of the proposed remedial alternative, such as dust from excavation or transportation of hazardous material.
- Protection of the workers during remedial actions - This factor assesses threats that may be posed to workers and the effectiveness and reliability of measures to be taken.
- Environmental impacts of the remedial action - This factor addresses the potential adverse environmental impacts that may result from construction and implementation of a remedial alternative and evaluates the reliability of mitigation measures, if necessary, to prevent or reduce potential impacts.
- Time lapse before achievement of response objectives - This factor includes an estimate of the time required to achieve protection for the site.

North Plume Group Alternatives

Assessment of the North Plume Group alternatives with respect to protection of the community and workers, short-term adverse environmental impacts, and implementation period indicates that the No Action alternative and Alternative N-2 are slightly better than the alternatives with active remediation components. However, during the implementation period, Alternatives N-4 and N-5 would be able to minimize adverse short-term impacts through standard engineering controls and adherence to standard health and safety practices.

Northwest Plume Group Alternatives

The assessment of the two Northwest Plume Group alternatives with respect to protection of the community and workers, short-term adverse environmental impacts, and implementation period shows that the No Action alternative and Alternative NW-2 are essentially equivalent except that the discontinued operation of the NWBCS, as part of the No Action alternative, has an adverse environmental impact. Neither alternative, with the exception noted above, has significant short-term effectiveness issues.

8.1.6 Implementability

The implementability criterion evaluates the technical and administrative feasibility of implementing each alternative, and it addresses the availability of required services and materials during

implementation of the alternative. The following factors were addressed during the evaluation process:

- Construction and operation - This factor considers the technical difficulties and the unknowns associated with the technology.
- Reliability of the technology - This factor considers the likelihood that problems associated with implementation may result in schedule delays.
- Implementing additional remedial action - This factor is not applicable to the alternatives developed because the alternatives considered are not interim measures.
- Monitoring the effectiveness of the remedy - This factor addresses the ability to evaluate the effectiveness of the remedy and includes an evaluation of the risks of exposure should monitoring be insufficient to detect a system failure.
- Coordination with other offices and agencies needed to implement remedial alternatives (e.g., obtaining necessary permits for offsite activities)
- Availability of necessary equipment, specialists, services and materials, and adequate offsite treatment, storage, and disposal services

North Plume Group Alternatives

All North Plume Group alternatives evaluated would be technically feasible to implement. The No Action alternative and Alternative N-2 would be the easiest to implement with respect to technical feasibility because the monitoring wells have already been installed and the NBCS system is currently operational. Alternative N-4 is constructed and is fully operational. However, Alternative N-5 would require additional design and construction. All treatment alternatives would use carbon adsorption treatment, which has been demonstrated at the boundary containment systems to be a reliable groundwater treatment process option. Groundwater monitoring is a component of all four alternatives and would provide information regarding the effectiveness of each alternative.

All alternatives with the exception of the No Action alternative would be administratively feasible. It is unlikely that the regulatory agencies or the public would accept shutdown of the NBCS as proposed under the No Action alternative. Additionally, the Army will not cease operating the NBCS until cleanup certification. Each of the three treatment alternatives would meet federal and state substantive requirements for recharging the treated groundwater to the UFS.

The No Action alternative and Alternative N-2 would not require additional equipment and services. The implementation of Alternative N-5 would not be limited with respect to availability of services and materials. Contractors with the equipment and knowledge to construct and implement this alternative are readily available. The remedial systems of Alternative N-4 were completed in June 1993.

Northwest Plume Group Alternatives

Both Northwest Plume Group alternatives evaluated would be technically feasible to implement. The No Action alternative and Alternative NW-2 would be implementable with respect to technical feasibility because the monitoring wells have already been installed and the NWBCS is currently operational. Alternative NW-2 would use carbon adsorption treatment, which has been demonstrated at the boundary containment systems to be a reliable groundwater treatment process option. Groundwater monitoring is a component of both alternatives and would provide information regarding the effectiveness of each alternative.

The No Action alternative would not be administratively feasible. It is unlikely that the regulatory agencies or the public would accept shutdown of the NWBCS as proposed under the No Action alternative. Additionally, the Army does not intend to cease operating the NWBCS. Alternative NW-2 would meet federal and state substantive requirements for recharging the treated groundwater to the UFS. Neither alternative would require additional equipment and services.

8.1.7 Cost

The cost criterion evaluates both capital costs and any long-term costs required to operate and maintain an alternative. Cost estimates for each alternative were based on vendor information, cost estimating guides, review of published cost data at previous sites, and operation and maintenance costs at the boundary containment systems.

North Plume Group Alternatives

The total present worth costs range from $4.1 to $6.0 million for Alternative N-1 to $56.5 to $63.1 million for Alternative N-4. The present worth costs are nearly identical for Alternatives N-4 and N-5 because the additional capital expenditures required for Alternative N-5 are balanced by the additional operation and maintenance (O&M) costs incurred through the estimated 10-year differences in remediation timeframe for Alternative N-4.

The additional capital expenditure of approximately $2.7 million for Alternative N-5 as compared to Alternative N-4 points out the importance of collecting additional full-scale operating data to aid in decision-making regarding any necessary expansion of the Offpost Groundwater Intercept and Treatment System. Collection of full-scale data on contaminant transport and actual plume remediation time frames through the intensive short-term monitoring program is currently being conducted. This monitoring program will provide data for use in any system expansion decision-making regarding the potential need for and placement of improvements to Alternative N-4 to reduce the remediation timeframe and/or efficiency.

Northwest Plume Group Alternatives

The total present worth costs range from $0.6 to $1.3 million for Alternative NW-1 to $12.4 to $13.1 million for Alternative NW-2.

8.1.8 State Acceptance

State acceptance evaluates technical and administrative concerns the State may communicate in its comments concerning each alternative. The State has been actively involved throughout the RI/FS and remedy selection process for the Offpost OU. The State was provided the opportunity to comment on the RI/FS document and proposed plan, and took part in the public meeting held to inform the public on the proposed plan. Written comments from the state received during the public comment period indicate that the State prefers Alternative N-5 or a slightly modified version of Alternative N-5 over Alternative N-4 because of the addition of several wells and trenches for

enhanced contaminant removal. Responses to the State's concerns on this and other issues are provided in Appendix A - Responsiveness Summary.

Additional discussions were held between the U.S. Army, Shell Oil Company, the State of Colorado, the U.S. EPA, and the U.S. Fish and Wildlife Service following the issuance of the Offpost proposed plan regarding the remedy for both the Offpost and Onpost OUs. As a result of these discussions, the State of Colorado and the other parties have agreed to the remedy as described in *Agreement for a Conceptual Remedy for the Cleanup of the Rocky Mountain Arsenal (Conceptual Remedy Agreement)*. Each party has agreed to support the conceptual remedy as the preferred remedial alternative and to support the proposed plan based on the elements of the conceptual remedy.

8.1.9 Community Acceptance

The preferred alternative for the Offpost OU was presented to the public in a Proposed Plan, which provides a brief summary of all of the alternatives evaluated during the detailed analysis of alternatives in the FS. In accordance with the NCP, the public had an opportunity to review and comment on the selected remedial alternatives presented in the Proposed Plan. The concerns expressed included (1) soil remediation issues, (2) DIMP groundwater cleanup standard, (3) why expansion of the Offpost Groundwater Intercept and Treatment System was not selected, (4) the presence of DIMP immediately downgradient of the Offpost Groundwater Intercept and Treatment System in the First Creek area, and (5) the classification of potential future land use. The public's comments are addressed in the attached responsiveness summary (Appendix A). Community participation was also included during the Conceptual Remedy Agreement negotiations.

8.2 Conclusions of the Comparative Analysis of Alternatives

The conclusions of the comparative analysis of groundwater alternatives for the North and Northwest Plume Groups are summarized below.

In terms of overall protection of human health and the environment, compliance with ARARs, effectiveness, and reduction of toxicity, mobility, or volume, Alternatives N-4 and N-5 are superior to Alternatives N-1 and N-2. Alternative N-4 is equal to Alternative N-2 in implementability. Alternative N-4 is more readily implementable than Alternatives N-1 and N-5 because Alternative N-1 would not be administratively feasible, and Alterative N-5 would require a second design and construction phase. Alternatives N-4 and N-5 are approximately equal in cost when compared to each other and higher in cost when compared to Alternatives N-1 and N-2. Therefore, Alternatives N-4 and N-5 were identified as being superior to Alternatives N-1 and N-2. Alternatives N-4 and N-5 are essentially equivalent with respect to evaluation of compliance with ARARs, short-term effectiveness, and reduction in toxicity, mobility, or volume.

Alternative N-4 was demonstrated to be superior to Alternative N-5 with respect to the detailed analysis criteria for the following reasons:

- The remedial system in Alternative N-4 is designed to effectively address groundwater contamination within the North Plume Group on the basis of all available data. The Offpost Groundwater Intercept and Treatment System is designed similar to the existing boundary containment systems in that monitoring data is being evaluated to assess whether any improvements are necessary. The intensive short-term groundwater monitoring program included under Alternative N-4 adds flexibility through providing information that will be used to identify any necessary or beneficial improvements to the Offpost Groundwater Intercept and Treatment System and provides information about the optimal location of additional wells or trenches. Because the estimates of remediation time frames developed for the groundwater alternatives are uncertain, additional capital expenditures are not justified until actual full-scale data is available.

- Alternative N-4 is superior to Alternative N-5 with respect to long-term effectiveness and permanence. The combination of full-scale operational data from the Offpost Groundwater Intercept and Treatment System and future possible system modifications will result in an optimized treatment system. Immediate placement of additional wells and trenches in Alternative N-5, based on groundwater modeling results, would not be based on the more accurate empirical data.

- Alternative N-4 is more readily implementable than Alternative N-5 because implementation of Alternative N-5 would require additional remedial design and construction. Operation of Alternative N-4 would start immediately.

Alternative NW-2 ranks above Alternative NW-1 in all criteria except cost; however, the additional costs are not prohibitive in light of the reduction in time for remediation.

9.0 IDENTIFICATION OF THE SELECTED REMEDY

The selected remedy for the Offpost OU consists of implementing Alternative N-4 for remediation of groundwater in the North Plume Group, Alternative NW-2 for remediation of groundwater in the Northwest Plume Group, and continued operation of the Irondale Containment System consistent with the Irondale IRA. The selected alternatives are described in detail in Section 7 and the Declaration to the ROD.

9.1 Alternative N-4: Offpost Groundwater Intercept and Treatment System

Construction of the Offpost Groundwater Intercept and Treatment System began in November 1991 and full-scale system operation began in June 1993. Additional detail concerning design specifics is contained in the Final Implementation Document for the Groundwater Intercept and Treatment System North of RMA (HLA, 1991). The major components of this alternative are as follows:

- Operation of the Offpost Groundwater Intercept and Treatment System
  - Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using Offpost Groundwater Intercept and Treatment System groundwater extraction wells
  - Treatment of the extracted groundwater, using carbon adsorption
  - Recharge of treated groundwater to the UFS, using Offpost Groundwater Intercept and Treatment System recharge wells and trenches
  - Natural attenuation of inorganic chloride and sulfate concentrations to meet applicable standards for groundwater in a manner consistent with the on-Post remedial action
- Continued operation of the NBCS
- Improvements to Offpost Groundwater Intercept and Treatment System and the NBCS, as necessary
- Long-term groundwater and surface-water monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1 and C-2

- Institutional controls for the selected remedy are reflected in Appendix B. These institutional controls are intended to prevent the future use of groundwater exceeding remediation goals.

The Offpost Groundwater Intercept and Treatment System is an array of extraction wells and recharge trenches in the northern and First Creek paleochannels. The system is configured to extract and treat UFS groundwater that exceeds containment system remediation goals and to recharge the treated groundwater. Figure 7.1 presents the placement of extraction wells and recharge wells in the northern paleochannel and the placement of extraction wells and recharge trenches in the First Creek paleochannel. The location of the treatment facility is also shown in Figure 7.1. The northern paleochannel collection system consists of 12 extraction wells spaced approximately 200 feet apart across the paleochannel, perpendicular to the direction of groundwater flow. The recharge system in the northern paleochannel consists of 24 recharge wells spaced 100 feet apart and placed parallel to and approximately 300 feet downgradient of the collection system. The First Creek paleochannel collection system consists of 5 extraction wells spaced 200 to 500 feet apart along the axis of the paleochannel. Recharge trenches are placed such that four of the six trenches are parallel to the flow axis and located on the margins of the paleochannel, with the remaining two trenches located downgradient of the extraction well system and oriented perpendicular to the flow axis.

The system is designed to extract and treat an average flow of 300 gpm from the northern paleochannel, an average flow of 180 gpm from the First Creek paleochannel, and a peak flow of 1.5 times the average flow. The treatment facility basic process flow includes influent storage, pumping, bag filtration for particulate removal, carbon adsorption, multimedia filtration, treated water storage, treated water pumping, and final bag filtration.

A total of approximately 250 million gallons per year would be treated by the Offpost Groundwater Intercept and Treatment System at the average flows. In addition, operation of the NBCS component of this alternative will treat approximately 125 million gallons per year. Thus, a total of approxi-

mately 375 million gallons of UFS groundwater will be treated annually to attain Offpost OU containment system remediation goals (Tables 7.1, 7.2, and 7.3) under this alternative.

An intensive short-term monitoring component will be included in Alternative N-4 as part of the long-term monitoring program. For costing purposes, it is assumed that this program will consist of a network of approximately 60 wells to be sampled semiannually for two to three years, beginning with the Offpost Groundwater Intercept and Treatment System start-up. The intensive monitoring program will allow the collection and subsequent interpretation of performance data for the full-scale operation of both the Offpost Groundwater Intercept and Treatment System and the NBCS. The data will also be used to assess the need for any improvements to the systems. The acquisition of such data will allow for increased accuracy in assessing the response of the UFS groundwater to the NBCS and Offpost Groundwater Intercept and Treatment System remediation systems.

In addition, the preferred alternative includes long-term monitoring of offpost groundwater and surface water to assess contaminant concentration reduction and remedy performance. Groundwater monitoring will continue utilizing both monitoring wells and private drinking water wells. Selected surface-water monitoring locations will be included to evaluate the effect of groundwater treatment on surface water quality. Monitoring will continue after system shut-off to assure continued compliance with containment system remediation goals. The Army will present the scope of these ongoing monitoring programs in an Implementation Plan to be submitted within 90 days following issuance of the ROD. A schedule for compliance with the containment system remediation goals will be included in the Implementation Plan.

9.2 Alternative NW-2: Continued Operation of the Northwest Boundary Containment System with Improvements as Necessary

This section summarizes Alternative NW-2, the continued operation of the NWBCS with improvements as necessary. For additional details of the extraction/recharge systems, the recent upgrades to the system, and the treatment facility at the NWBCS, the reader is referred to the following reports:

Final Implementation Document for NWBCS Short-term Improvements IRA (Morrison-Knudsen Environmental Services [MKES], 1990a); NWBCS Long-term Improvements IRA B(ii) Final Assessment Document (Woodward-Clyde [WWC], 1991a); Proposed Decision Document NWBCS RMA Long-term Improvements IRA (WWC, 1991b); Report of Field Investigations, Assessment, and Final Decision Document for the NWBCS Short-term Improvements IRA (MKES, 1990b); Implementation Document for the Northwest Boundary System long-term Improvements IRA Final Report (MKES, 1992); and Northwest Boundary Containment System Long-term Improvements IRA One-year Evaluation Report (MKES, 1993). The major components of this alternative are as follows:

- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Site reviews
- Exposure control/provision of alternate water supply as described in Section 7.1
- Well closure in conformance with criteria listed in Appendix C, pages C-1, and C-2
- Institutional controls as described in Appendix B

In addition, the preferred alternative includes long-term monitoring to assess contaminant concentration reduction and remedy performance. After attainment of groundwater containment system remediation goals and system shut-off, groundwater monitoring will continue to assure continued compliance with containment system remediation goals. The Army will present the scope of these monitoring programs in implementation plans to be submitted following issuance of the ROD.

The NWBCS began operation in 1984. The NWBCS collection system consists of 20 extraction wells and a soil bentonite barrier approximately 2300 feet in length. The recharge system consists of 25 downgradient recharge wells.

9.3 Additional Components of the Selected Remedy

In accordance with the NCP, the public had an opportunity to review and comment on the selected remedial alternatives presented in the Proposed Plan. In response, the Parties held additional discussions to determine how best to address these comments. These discussions resulted in clarifications and minor technical changes that do not significantly alter the overall scope, performance, or cost of the Offpost preferred alternative.

Because the main focus of the Offpost preferred alternative is unchanged, and the additional actions only clarify and enhance the preferred alternative, the changes were not considered to be significant.

The discussions also involved broader issues which were resolved in a document entitled "Agreement for a Conceptual Remedy for the Cleanup of the Rocky Mountain Arsenal," dated June 13, 1995. With regard to the Offpost area, the Parties agreed to several additional components which are an integral part of the overall remedy but are proposed for inclusion in the Onpost ROD. Many of these components are in the Onpost Proposed Plan, which is available for public comment from October 16, 1995, through January 19, 1995.

The additional components added in response to public comment and as part of the Conceptual Remedy Agreement discussions include:

- The U.S. Army and Shell Oil Company agree to continue monitoring and to complete an assessment of the NDMA plume by June 13, 1996, using a 20 ppt method detection limit.
- The U.S. Army and Shell Oil Company agree to prepare a feasibility study of potential actions, both onpost and at the boundary, or adjacent to the boundary in order to achieve NDMA remediation goals at the RMA boundary and to use 7.0 ppt PRG or a certified analytical detection level readily available at a certified commercial laboratory (currently 33 ppt).
- The U.S. Army and Shell Oil Company agree to revegetate approximately 160 acres located in the southeast portion of Section 14 and the southwest portion of Section 13 as depicted in Figure 9.1. Revegetation will involve tilling and seeding. No sampling will be conducted before or after revegetation. Existing soil risks in the area to be revegetated fall within EPA's established acceptable risk range and revegetation is not necessary. However, the U.S. Army and Shell Oil Company agree to the revegetation program as part of the Offpost settlement.

- The Army will treat any contaminated extracted groundwater prior to discharge or reinjection so that it meets the current water quality standards established in the Colorado Basic Standards for Groundwater and the Colorado Basic Standards and Methodologies for Surface Water.

- As of the date of the Onpost ROD, and based on a 0.392 parts per billion (ppb) detection limit, the U.S. Army will use the last available quarterly monitoring results to determine the DIMP plume footprint.

- The Army and Shell Oil Company will pay for the extension of, and hook-up to, the current water distribution system for all existing well owners within the DIMP plume footprint referenced above.

- Existing domestic well owners outside of the DIMP plume footprint as of the date of the Onpost ROD where it is later determined that levels of DIMP are eight ppb or greater (or other relevant CBSG at the time) will be hooked up at the U.S. Army and Shell Oil Company's expense to the SACWSD distribution system or provided a deep well or other permanent solution.

- For new domestic wells with levels of eight ppb or greater (or other relevant CBSG at the time), the Offpost ROD institutional controls will provide that the U.S. Army and Shell Oil Company will pay for hook-up to the distribution system or provided a deep well or other permanent solution.

- The parties to the Conceptual Remedy Agreement commit to good faith best efforts to establish a trust fund for the operations and maintenance of the remedy, including habitat and surficial soil. The parties recognize, however, that establishment of such a trust fund requires special legislation and there are restrictions on the actions federal agencies can take with respect to proposing legislation and supporting proposed legislation.

- As part of the Onpost remedy, the U.S. Army and Shell Oil Company will pay for and provide, or arrange for the provision, of 4000 acre-feet of water to SACWSD.

9.4 Cost of Selected Remedy

A detailed cost summary for the selected remedy is presented in Table 9.1. The total estimated cost ranges from approximately $69 to $76 million. This cost does not include implementation of the additional components discussed in Section 9.3. However, these additional components would be included in all the alternatives evaluated (except the No Action alternative); therefore, the relative relationship of the cost of the various alternatives will not change.

9.5 Limitations

It should be recognized that U.S. Environmental Protection Agency (EPA) studies (EPA, 1988b) have indicated that it may not always be possible to reach MCLs or proposed MCLs through currently available technology. If it becomes apparent during implementation or operation of the selected

remedy that contaminant levels are remaining constant for a significant amount of time at levels higher than the groundwater containment system remediation goals delineated in the ROD, the containment system remediation goals and the remedy will be reevaluated. Further, the NCP requires a formal review of the effectiveness of the selected remedy at least every five years. As needed, the operational design of the selected remedy will be reviewed to achieve the groundwater containment system remediation goals .

9.6 Criteria for Shutting Down Boundary and Offpost Containment Groundwater Systems

Existing wells within the boundary and offpost containment systems can be removed from production when concentrations of constituents detected in the well are less than applicable or relevant and appropriate requirements (ARARs) established in the ROD and/or it can be demonstrated that discontinuing operation of a well will not jeopardize the containment objective of the systems. Wells removed from production, and monitoring wells upgradient and downgradient of the boundary and offpost containment systems, will be monitored quarterly for a period of five years to determine if contaminants reappear. Wells turned off for hydraulic purposes will not be subject to the quarterly monitoring requirements. Boundary and offpost containment system extraction wells removed from production for water quality reasons will be placed back into production if contaminant concentrations exceed the ARARs established in the ROD. Wells with concentrations less than ARARs established in the ROD can remain in production if additional hydraulic control is required.

10.0 STATUTORY DETERMINATIONS

A description of how the selected remedy meets statutory requirements, compliance with the requirements of CERCLA, and consistency with the NCP is presented in this section.

10.1 Consistency with the Statutory Requirements of CERCLA in Section 121

The statutory requirements of CERCLA Section 121, as described below, and the statutory preference for treatment are met through implementation of the selected remedy.

10.1.1 Protection of Human Health and the Environment

The selected remedy will result in the remediation of the Offpost OU groundwater consistent with remedial action objectives and containment system remediation goals established for the site. Contaminated groundwater in the North and Northwest Plume Groups will be addressed by implementing the selected remedy through groundwater extraction, treatment, and recharge.

The groundwater remedial actions proposed under Alternatives N-4 and NW-2 will permanently address the primary threat to human health and the environment for the Offpost Study Area through carbon adsorption treatment to reduce the toxicity, mobility, and volume of contaminated groundwater. Contaminant levels in Offpost Study Area groundwater will be reduced to or below groundwater containment system remediation goals following treatment. Reduction of groundwater contaminant concentrations to these goals will further reduce the groundwater cumulative excess cancer risk toward 10^{-6}. Following groundwater remedial action, the HI for noncarcinogens will be less than 1.

It should be recognized, however, that studies conducted at other sites (by EPA and others) have indicated that it may not always be possible to reach groundwater containment system remediation goals because of the limitations of the technology used to assess groundwater hydrogeological properties, the technology used to estimate aquifer remediation time frames, and the technology used to extract and recharge groundwater. If it becomes apparent during operation of the groundwater

treatment systems that groundwater contaminant levels are remaining constant at levels higher than the Offpost OU groundwater containment system remediation goals , the selected remedy provides for improvements to the proposed remedial systems as necessary. An alternative water supply will be provided to any user of a domestic well in accordance with the provisions in Section 7.1. Institutional controls that are part of this remedy are intended to prevent the future domestic use of groundwater exceeding the containment system remediation goals.

Of the alternatives evaluated for cleaning up the groundwater, the selected remedy provides the highest degree of protection of human health without adverse impact to the environment. No unacceptable short-term risks will be caused by implementing this remedy.

Potential ecological impacts during remediation will be continually evaluated. Maintenance of existing habitats and ecosystems are important. Although the Federal Endangered Species Act, the Migratory Bird Treaty Act, and the Bald Eagle Protection Act were not considered as ARARs, the FFA requires their application. Remediation goals consistent with the substantive requirements of these Acts are being met and will be assured through close interaction with the U.S. Fish and Wildlife Service. In coordination with the U.S. Fish and Wildlife Service, it was agreed that screening levels, developed to ensure compliance with enforceable remediation levels, meet the requirements of the federal Endangered Species Act, the Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act. These screening levels were not exceeded in the Offpost OU. These levels are presented in the Final Offpost Operable Unit Endangerment Assessment/Feasibility Study in Table 3.3.3-1 (Toxicity Reference Values for Avian and Terrestrial Vertebrate Species of Concern Identified at Rocky Mountain Arsenal) of Volume II and Table H5-1 (Maximum Allowable Tissue Concentration [MATC] Values for the Offpost EA Ecological Assessment) of Appendix H in Volume IV. If the screening levels are exceeded or effects are observed in the future, enforceable remediation levels will be developed consistent with CERCLA, the Endangered Species Act, the Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act.

10.1.2 Compliance With Applicable or Relevant and Appropriate Requirements

Under Section 121(d)(l) of CERCLA, remedial actions must attain standards, requirements, limitations, or criteria that are applicable or relevant and appropriate under the circumstances of the release at a site. ARARs would be met or exceeded upon completion of the selected remedy at the Offpost OU.

Chemical-specific ARARs

Groundwater containment system remediation goals are based on chemical-specific ARARs for those chemicals having promulgated standards and on HBC for those chemicals without ARARs (Tables 7.1, 7.2, and 7.3). The preferred sitewide alternative is expected to attain or exceed chemical-specific ARARs. A summary of the chemical-specific and other ARARs that have been assessed to be applicable or relevant and appropriate is presented in Table 10.1.

Action-specific ARARs

The selected remedy will comply with action-specific ARARs. A summary of the action-specific ARARs that have been assessed to be applicable or relevant and appropriate is presented in Table 10.2.

Location-specific ARARS

The selected remedy will comply with location-specific ARARs. A summary of the location-specific ARARs that have been assessed to be applicable or relevant and appropriate is presented in Table 10.3.

10.1.3 Cost Effectiveness

The selected remedy is cost-effective in mitigating the risks posed at the site by contaminated groundwater. Cost-effectiveness is determined by evaluating three of the five balancing criteria to determine overall effectiveness: long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; and short-term effectiveness. Overall effectiveness is then compared to cost to ensure that the remedy is cost-effective.

The selected remedy for groundwater provides the best overall effectiveness of all alternatives considered proportional to its cost. The selected remedy will greatly reduce the toxicity, mobility, and volume of groundwater exceeding containment system remediation goals. Also the implementation of this remedy will result in long-term effectiveness by reducing residual carcinogenic risks through permanent treatment.

Through the groundwater monitoring program, the Army can more accurately assess the contaminant removal rates as a function of time, using the full-scale data available during operation of the Offpost Groundwater Intercept and Treatment System, the NBCS, and the NWBCS. The analysis of this data will allow for cost-effective decisions regarding any future improvements that may be required for the remedial systems.

10.1.4 Utilization of Permanent Solutions to the Maximum Extent Practicable

The selected remedy for the Offpost OU represents the maximum extent to which permanent solutions and treatment technologies can be used in a cost-effective manner to remediate groundwater at the site. Of those alternatives that are protective of human health and the environment and comply with ARARs, the selected remedy (Alternatives N-4 and NW-2) will provide the best balance of trade-offs in terms of long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; cost; the statutory preference for treatment as a principal element; and state and community acceptance.

10.2 Consistency with the National Contingency Plan

The NCP requires that the following two features be present in the remedy selection process:

- The nine criteria used to evaluate alternatives in the detailed analysis are used to select a remedy.
- Selected Superfund remedies must employ the nine criteria to make the following four determinations:
  - Each remedial action selected shall be protective of human health and the environment.

- Onsite remedial actions selected in a ROD must attain ARARs or provide grounds for invoking a waiver.
- Each remedial action selected shall be cost effective, provided that it first satisfies the threshold criteria (defined in Section 8.0).
- Each remedial action shall use permanent solutions to the maximum extent practicable.

The preferred sitewide alternative is fully consistent with the NCP, as is the selection process used to arrive at the preferred alternative. Alternatives were developed and screened, and the detailed analysis of alternatives was performed in a manner consistent with the NCP.

10.3 Summary

The preferred sitewide alternative for remediation of the Offpost OU is the combination of Alternatives N-4 and NW-2. The preferred alternative was selected in accordance with the requirements of CERCLA and the NCP. The remedial actions that compose the sitewide preferred alternative will permanently address the principal threats through groundwater extraction and treatment to reduce the toxicity, mobility, or volume of contaminants for protection of human health and the environment.

Although the requirements for provision of an alternate water supply and hookup to the SACWSD are part of the Onpost remedy, these actions will also significantly reduce the potential for exposure to offpost groundwater.

11.0 DOCUMENTATION OF SIGNIFICANT CHANGES

The Proposed Plan for the Rocky Mountain Arsenal Offpost Operable Unit was released for public comment in March 1993. The Proposed Plan identified Alternative N-4 (Offpost Groundwater Intercept and Treatment System) as the preferred alternative for groundwater in the North Plume Group and Alternative NW-2 (Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary) as the preferred alternative for groundwater in the Northwest Plume Group. The Army received written comments from the U.S. Environmental Protection Agency, the State of Colorado, the Tri-County Health Department, city and county governments, environmental action groups, and citizens. After review of these comments, it was determined that no significant changes to the preferred alternative, as it was originally identified in the Proposed Plan, were necessary.

As indicated earlier in Section 8.1.8, following the issuance of the Offpost Proposed Plan, additional discussions were held between the Parties regarding the implementation of the preferred alternative for the Offpost OU and the remedies for the Onpost OU. The main components of the preferred alternative for the Offpost OU remain intact. These components are:

- Operation (and improvement, if necessary) of the Offpost Groundwater Intercept and Treatment System
- Continued operation (and improvement, if necessary) of the NBCS and NWBCS
- Long-term groundwater and surface-water monitoring
- Five-year site review
- Well closure
- Provision of alternate water supplies and implementation of institutional controls intended to prevent future use of contaminated groundwater.

The Conceptual Remedy Agreement provides more specific criteria for the provision of alternate water supplies to current and future well owners, specific criteria for continued operation of and requirements for shutdown of the groundwater treatment systems, and additional requirements for

the Army and Shell Oil Company such as tilling and revegetation of surface soil and additional study requirements. Because the main focus of the preferred alternative is unchanged by the Conceptual Remedy Agreement, and the additional actions specified in the Conceptual Remedy Agreement only clarify and enhance the preferred alternative, the Conceptual Remedy Agreement was not considered to be a significant change. Therefore, the preferred alternative as presented in the Proposed Plan, and additional actions to enhance the preferred alternative as outlined in the Conceptual Remedy Agreement, is the selected remedy.

12.0 GLOSSARY

ARAR	Applicable or relevant and appropriate requirement
Army	U.S. Department of the Army
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
CAR	Contamination Assessment Report
CBSG	Colorado Basic Standards for Groundwater
CBSM	Colorado Basic Standards and Methodologies for Surface Water
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF&I	Colorado Fuel and Iron
CFS	Confined flow system
CMP	Comprehensive Monitoring Program
CNS	Central nervous system
COC	Chemicals of concern
CRL	Certified reporting limit
CSC	Chemical Sales Company
CU	Consumptive use
DBCP	Dibromochloropropane
DCPD	Dicyclopentadiene
DDE	2,2-bis(p-Chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis(p-Chlorophenyl)-1,1,1-trichloroethane
DIMP	Diisopropylmethyl phosphonate
DOI	U.S. Department of Interior
DOJ	U.S. Department of Justice
EA/FS	Endangerment assessment/feasibility study
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
FFA	Federal Facility Agreement

GMP	Groundwater Monitoring Program
gpm	Gallons per minute
HBC	Health-based criteria
HI	Hazard index
HQ	Hazard quotient
Hyman	Julius Hyman & Company
ICS	Irondale Containment System
IRA	Interim response action
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MKES	Morrison-Knudsen Environmental Services
NBCS	North Boundary Containment System
NDMA	N-nitrosodimethylamine
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NPL	National Priorities List
NWBCS	Northwest Boundary Containment System
O&M	Operation and maintenance
OCP	Organochlorine pesticide
OU	Operable unit
PRP	Potentially responsible party
PVC	Polyvinyl chloride
RfD	Reference dose
RI/FS	Remedial investigation/feasibility study
RMA	Rocky Mountain Arsenal
RME	Reasonable maximum exposure
ROD	Record of Decision

SACWSD	South Adams County Water and Sanitation District
SARA	Superfund Amendments and Reauthorization Act
Shell	Shell Oil Company
UFS	Unconfined flow system
WWC	Woodward-Clyde
µg/l	Micrograms per liter
µg/kg	Micrograms per kilogram

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Table 6.1: Offpost Operable Unit Groundwater Chemicals of Concern

Chemicals of Concern	Exposure Point Concentration (µg/l)#					
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Aldrin	0.029*	0.045*	0.050*	0.12*	0.039*	0.030*
Arsenic	2.15	1.63	-	2.78*	2.68*	---
Atrazine	2.87	5.31*	12.9*	7.36*	---	4.48*
Benzene	0.61	0.64	0.75	0.93	---	---
Carbon tetrachloride	---	0.76*	---	---	---	---
Chlordane	---	0.18*	0.19*	0.54*	---	---
Chloride	120,000	205,000	487,000*	660,000*	262,000*	191,000
Chlorobenzene	1.02	1.78	1.77	4.51	1.09	1.27
Chloroform	0.68	67.5*	5.01	1.51	12.0*	3.33
CPMSO	---	14.5	10.4	7.68	---	---
$CPMSO_2$	---	4.35	6.63	5.09	---	---
Dibromochloropropane	---	0.44*	0.14	0.15	0.10	---
1,2-Dichloroethane	---	0.77*	0.92*	7.32*	---	---
Dicyclopentadiene	---	3.64	163*	66.6*	---	---
DDE	0.029	0.029	0.22*	0.085	---	---
DDT	0.037	0.033	0.11*	0.10	---	---
Dichlorobenzene	---	5.1	---	2.9	---	---
DIMP	63.3*	713*	590*	4950*	7.68	4.67
Dieldrin	0.034*	0.035*	0.21*	0.055*	0.071*	0.039*
Dithiane	---	---	1.97	4.22	---	---
Endrin	0.033	0.037	0.73*	0.058	---	---
Ethylbenzene	---	---	---	0.57	---	---
Fluoride	1830	2210*	3510*	3290*	1810	2230*
Hexachlorocyclopentadiene	0.029	0.033	0.044	0.043	0.035	---
Isodrin	0.028	0.035	0.047	0.057	---	0.040
Malathion	---	0.26	0.38	0.32	---	---
Manganese	---	1580	---	1250	670	---
Oxathiane	---	---	1.32	2.21	---	---
Sulfate	340,000*	636,000*	909,000*	1,118,000*	148,000	213,000
Tetrachloroethene	0.70	10.1*	20.7*	6.09*	0.75	1.67
Toluene	---	---	1.28	1.18	---	---
Trichloroethene	---	0.64	0.51	2.70	---	4.04*
Xylene	0.75	---	---	1.11	---	---

---	Not a chemical of concern in this zone
CPMSO	4-chlorophenylmethyl sulfoxide
$CPMSO_2$	4-chlorophenylmethyl sulfone
DDE	2,2-bis(p-chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP	Diisopropylmethyl phosphonate
µg/1	Micrograms per liter

* Exceeds groundwater containment system remediation goal listed in Tables 7.1, 7.2, and 7.3.

\# All exposure point concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in monitoring and private wells.

Table 6.2: Offpost Operable Unit Surface-Water Chemicals of Concern

Chemicals of Concern	Exposure Point Concentration (μg/l)[a]	
	First Creek	Irrigation Canals
Arsenic	18	NE
Chlordane	0.18	NE
Chloride	206,000	NE
Dicyclopentadiene	10	NE
DDE	0.089	NE
DDT	0.046	NE
Dieldrin	2.6	NE
DIMP	230	20
Fluoride	2550	970
Sulfate	438,000	NE

DDE 2,2-bis(p-chlorophenyl)-1,1-dichloroethene
DDT 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP Diisopropylmethyl phosphonate
NE Chemical not significantly elevated above background levels in the irrigation canals
μg/1 Micrograms per liter

* All exposure point concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in unfiltered surface-water samples.

Table 6.3: Offpost Operable Unit Sediment Chemicals of Concern in First Creek

Chemicals of Concern	Exposure Point Concentration (mg/kg)*
Aldrin	0.011
Dibromochloropropane	0.099
Dieldrin	0.134
Endrin	0.0038
DDE	0.0005
DDT	0.0084

DDE 2,2-bis(p-chlorophenyl)-1,1-dichloroethene
DDT 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
mg/kg Milligrams per kilogram

* All exposure point concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in sediment.

Table 6.4: Offpost Operable Unit Soil Chemicals of Concern

Chemicals of Concern	Exposure Point Concentration (mg/kg)*	
	Zone 3	Outside Zone 3
Aldrin	0.014	0.0021
Chlordane	0.049	ND
Dieldrin	0.112	0.018
Endrin	0.032	0.0042
DDE	0.024	0.015
DDT	0.063	0.030

DDE 2,2-bis(p-chlorophenyl)-1,1-dichloroethene
DDT 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
mg/kg Milligrams per kilogram
ND Chlordane not detected in soil outside zone 3

* All exposure point concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in soil.

Table 6.5: Summary of Land-Use Scenarios and Exposure Routes by Zone

Scenario	Zone	Exposure Routes Quantified
Rural residential	1,2,6	Dermal, soil Inhalation, groundwater Oral, dairy Oral, eggs Oral, groundwater Oral, meat Oral, soil Oral, vegetables
Urban residential	3,4	Dermal, soil Dermal, sediment Dermal, surface water Inhalation, groundwater Oral, groundwater Oral, sediment Oral, soil Oral, vegetables
Commercial and industrial	5	Dermal, soil Inhalation, groundwater Oral, groundwater Oral, soil

Table 6.6: Reference Doses and Slope Factors for Chemicals of Concern

Chemicals of Concern	Noncarcinogenic Chronic RfD (mg/kg/day)		Carcinogenic Slope Factor $(mg/kg/day)^{-1}$		Carcinogenic Weight-of-Evidence
	Oral	Inhalation	Oral	Inhalation	
Aldrin	3E-5	NE	1.7E+1	1.7E+1	B2
Arsenic	3E-4	NE	1.75	5.0E+1	A
Atrazine	5E-3	NE	2.2E-1	NE	C
Benzene	2E-2	NE	2.9E-2	2.9E-2	A
Carbon tetrachloride	7E-4	NE	1.3E-1	5.3E-2	B2
Chlordane	6E-5	NE	1.3	1.3	B2
Chloride	7.1	NE	NA	NA	NA
Chlorobenzene	2E-2	5E-3	NA	NA	NA
Chloroform	1E-2	NE	6.1E-3	8.1E-2	B2
CPMSO	2E-2[a,b]	NE	NA	NA	NA
$CPMSO_2$	2E-2[a,b]	NE	NA	NA	NA
Dibromochloropropane	5E-3	5.7E-5	1.4	2.4E-3	B2
Dichlorobenzenes (as 1,2-)	9E-2	4E-2	2.4E-2	NE	C
DDE	5E-4	NE	3.4E-1	3.4E-1	B2
DDT	5E-4	NE	3.4E-1	3.4E-1	B2
1,2-Dichloroethane	7E-2	NE	9.1E-2	9.1E-2	B2
Dicyclopentadiene	3E-2	6E-5	NA	NA	NA
Dieldrin	5E-5	NE	1.6E+1	1.6E+1	B2
DIMP	8E-2[c]	NE	NA	NA	NA
1,4-Dithiane	3E-1[a]	NE	NA	NA	NA
Endrin	3E-4	NE	NA	NA	NA
Ethylbenzene	1E-1	3E-1	NA	NA	NA
Fluoride	6E-2	NE	NA	NA	NA
Hexachlorocyclopentadiene	7E-3	NE	NA	NA	NA
Isodrin	7E-5[a]	NE	NA	NA	NA
Malathion	2E-2	NE	NA	NA	NA
Manganese	1E-1	1.1E-4	NA	NA	NA
1,4-Oxathiane	3E-1[a]	NE	NA	NA	NA
Sulfate	1.1E+1	NE	NA	NA	NA
Tetrachloroethene	1E-2	1E-2	5.1E-2	1.8E-3	B2
Toluene	2E-1	1.1E-1	NA	NA	NA
Trichloroethene	4E-1[a]	4E-1	1.1E-2	1.7E-2	B2
Xylene	2	8.6E-2	NA	NA	NA

Weight of Evidence Classification

A = Human carcinogen

B1 or B2 = Probable human carcinogen. B1 indicates that limited human data are available. B2 indicates sufficient evidence in animals and inadequate or no evidence in humans.

C = Possible human carcinogen

Table 6.6 (continued)

CPMSO	4-chlorophenylmethyl sulfoxide
$CPMSO_2$	4-chlorophenylmethyl sulfone
DDE	2,2-bis(p-chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP	Diisopropylmethyl phosphonate
mg/kg/day	Milligrams per kilogram per day
NA	Not applicable
NE	Not established
RfD	Reference dose

a. Derived from scientific literature or obtained from agencies other than EPA.

b. Subsequent to this assessment, a Region VIII Health Advisory was issued (see letter dated January 27, 1994). This Health Advisory has not been reviewed by the other parties. The other parties may provide comments to this Health Advisory in the future. Reference to these values from EPA Region VIII's Health Advisory in this document does not constitute agreement by other parties. The Region VIII Health Advisory values are as follows:

	10-Day	Longer-term
Child	0.2 mg/l	0.02 mg/l
Adult	0.6 mg/l	0.06 mg/l

c. This RFD is taken from the 1989 EPA Health Advisory for DIMP.

Table 6.7: Summary of Reasonable Maximum Exposure Carcinogenic Risks by Zone and Exposure Route

Exposure Assessment Zone	Exposure Route			
	Ingestion	Inhalation	Dermal	Total
1A*	1.1E-4	8.7E-7	1.0E-7	1.1E-4
1B*	1.3E-4	8.7E-7	1.0E-7	1.3E-4
1C*	1.1E-4	8.7E-7	1.0E-7	1.1E-4
2	1.6E-4	6.6E-5	1.0E-7	2.3E-4
3	2.5E-4	6.5E-6	1.3E-6	2.6E-4
4	2.1E-4	1.0E-5	7.3E-7	2.2E-4
5	2.4E-5	3.4E-6	6.7E-8	2.7E-5
6	6.9E-5	4.0E-6	1.0E-7	7.3E-5

* Zone 1 is subdivided on the basis of the presence of surface water and whether the ditch water used for irrigation is collected upstream or downstream of the mouth of First Creek.

Table 6.8: Summary of Adult Reasonable Maximum Exposure Noncarcinogenic Hazard Indices by Target Organ and Exposure Assessment Zone

Target Organ	Exposure Assessment Zone							
	1A	1B	1C	2	3	4	5	6
Blood	1.7E-3	1.8E-3	1.7E-3	1.9E-3	2.4E-3	2.9E-3	---	---
Cardiovascular	1.6E-2	2.0E-2	1.6E-2	3.8E-2	9.0E-2	5.4E-2	---	2.5E-2
CNS	2.4E-2	2.6E-2	2.3E-2	8.4E-1	2.4E-1	2.4E+0	6.6E-2	1.6E-3
Gastrointestinal	1.5E-4	3.1E-4	1.5E-4	3.5E-4	4.3E-4	4.2E-4	4.9E-5	---
Hepatic	1.8E-1	2.1E-1	1.8E-1	1.1E+0	1.3E+0	9.0E-1	7.2E-2	2.0E-1
Ocular	---	---	---	---	3.1E-4	2.8E-4	---	---
Renal	7.0E-3	7.4E-3	7.0E-3	2.3E-1	8.1E-2	1.1E-1	2.0E-2	8.8E-1
Respiratory	2.4E-4	2.4E-4	2.4E-4	2.3E-4	5.8E-4	2.8E-3	---	---
Skin	2.0E-1	2.3E-1	2.0E-1	1.7E-1	2.3E-2	3.1E-1	8.7E-2	---

--- Chemicals for this target organ not detected in this zone
CNS Central nervous system

Table 7.1: Containment System Remediation Goals for the Offpost Groundwater Intercept and Treatment System

Analyte	CSRG (μg/l)	Source	PQL[a]	Rural Residential Hypothetical Cancer Risk[b]
1,2-Dichloroethane	0.4	CBSG	1.0[c]	9.1×10^{-7}
1,3-Dichlorobenzene	6.5	HBC		NA
1,4-Oxathiane	160	HBC		NA
Aldrin	0.002	CBSG	0.05[d]	4.0×10^{-7}
Atrazine	3	MCL, CBSG		NA
Benzene	3	HBC		2.0×10^{-6}
Carbon tetrachloride	0.3	CBSG	0.99[d]	7.9×10^{-7}
Chlordane	0.03	CBSG	0.095[d]	5.7×10^{-7}
Chlorobenzene	25	HBC		NA
Chloroform	6	CBSG		6.4×10^{-6}
CPMS	30	HBC		NA
CPMSO	36	HBC		NA
CPMSO2	36	HBC		NA
DBCP	0.2	MCL, CBSG		3.8×10^{-6}
DCPD	46	HBC		NA
DDE	0.1	CBSG		8.5×10^{-7}
DDT	0.1	CBSG		4.1×10^{-7}
Dieldrin	0.002	CBSG	0.05[d]	1.2×10^{-6}
DIMP	8	CBSG		NA
Dithiane	18	HBC		NA
Endrin	0.2	CBSG		NA
Ethylbenzene	200	HBC		NA
Hexachlorocyclopentadiene	0.23	HBC		NA
Isodrin	0.06	HBC		NA
Malathion	100	HBC		NA
NDMA	0.007	(e)	0.033	1.0×10^{-5}
Tetrachloroethylene	5	MCL, CBSG		4.0×10^{-6}
Toluene	1,000	MCL, CBSG		NA
Trichloroethylene	3	HBC		9.9×10^{-7}
Xylenes	1,000	HBC		NA
Arsenic	2.35	HBC		5.6×10^{-5}
Chloride	250,000[f]	CBSG		NA
Fluoride	2,000	CBSG		NA
Sulfate	250,000[g]	CBSG		NA
			Total[h]	8.8×10^{-5}

Table 7.1 (continued)

The following chemical have ARARs that were adjusted downward to reduce overall risk: arsenic benzene, chlorobenzene, 1,3-dichlorobenzene, trichloroethylene, and xylene.

CBSG	Colorado Basic Standards for Groundwater
CPMS	4-chlorophemylmethyl sulfide
CPMSO	4-chlorophenylmethyl sulfoxide
$CPMSO_2$	4-chlorophenylmethyl sulfone
CSRG	Containment system remediation goal
DBCP	Dibromochloropropane
DCPD	Dicyclopentadiene
DDE	2,2-bis(p-chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP	Diisopropylmethyl phosphonate
HBC	Health-based criteria
MCL	Maximum containment level
NA	Not applicable
NDMA	N-nitrosodimethylamine
PQL	Practical quantitation limit
$\mu g/l$	Micrograms per liter

a. Practical quantitation limit; presented only when the PQL is greater than the CSRG.
b. Based on the CSRG.
c. PQL listed in the CBSG standards
d. PQL attainable by the U.S. Army
e. The remediation goal for NDMA was established at 0.007 parts per trillion (ppt) in the Conceptual Remedy Agreement. The current PQL readily available is 0.033 ppt. The estimated risk associated with NDMA is based on a 70-year residential exposure duration.
f. Inorganic standard for chloride will be met by natural attenuation consistent with the onpost remedial action.
g. Inorganic standard for sulfate may be the natural background concentration, which will be established and met by natural attenuation consistent with onpost remedial action.
h. Because of the variability in contaminant distribution and concentration, the maximum risk associated with the groundwater cleanup concentrations is not expected to occur at any one location.

Table 7.2: Containment System Remediation Goals for the North Boundary Containment System

Analyte	CSRG (μg/l)	Source	PQL[a]	Rural Residential Hypothetical Cancer Risk[b]
1,2-Dichloroethane	0.4	CBSG	1.0[c]	9.1×10^{-7}
1,2-Dichloroethylene	70	CBSG		NA
1,4-Oxathiane	160	HBC		NA
Aldrin	0.002	CBSG	0.05[d]	4.0×10^{-7}
Atrazine	3	MCL, CBSG		NA
Benzene	3	HBC		2.0×10^{-6}
Carbon tetrachloride	0.3	CBSG	0.99[d]	7.9×10^{-7}
Chloroform	6	CBSG		6.4×10^{-6}
CPMS	30	HBC		NA
CPMSO	36	HBC		NA
CPMSO2	36	HBC		NA
DBCP	0.2	MCL, CBSG		3.8×10^{-6}
DCPD	46	HBC		NA
Dieldrin	0.002	CBSG	0.05[d]	1.2×10^{-6}
DIMP	8	CBSG		NA
Dithiane	18	HBC		NA
Endrin	0.2	CBSG		NA
Isodrin	0.06	HBC		NA
Malathion	100	HBC		NA
Methylene chloride	5.0	MCL, CBSG		NA
NDMA	0.007	(e)	0.033	1.0×10^{-5}
Tetrachloroethylene	5	MCL, CBSG		4.0×10^{-6}
Toluene	1,000	MCL, CBSG		NA
Trichloroethylene	3	HBC		9.9×10^{-7}
Xylenes	1,000	HBC		NA
Arsenic	2.35	HBC		5.6×10^{-5}
Chloride	250,000[f]	CBSG		NA
Fluoride	2,000	CBSG		NA
Sulfate	250,000[g]	CBSG		NA
			Total[h]	8.0×10^{-5}

Methylene chloride is a common laboratory contaminant and analytical anomalies are anticipated during compliance monitoring.

The following chemical have ARARs that were adjusted downward to reduce overall risk: arsenic benzene, chlorobenzene, trichloroethylene, and xylene.

Table 7.2 (continued)

CBSG	Colorado Basic Standards for Groundwater
CPMS	4-chlorophenylmethyl sulfide
CPMSO	4-chlorophenylmethyl sulfoxide
$CPMSO_2$	4-chlorophenylmethyl sulfone
CSRG	Containment system remediation goal
DBCP	Dibromochloropropane
DCPD	Dicyclopentadiene
DIMP	Diisopropylmethyl phosphonate
HBC	Health-based criteria
MCL	Maximum containment level
NA	Not applicable
NDMA	N-nitrosodimethylamine
PQL	Practical quantitation limit
μg/l	Micrograms per liter

a. Practical quantitation limit; presented only when the PQL is greater than the CSRG.
b. Based on the CSRG
c. PQL listed in the CBSG standards
d. PQL attainable by the U.S. Army
e. The remediation goal for NDMA was established at 0.007 parts per trillion (ppt) in the Conceptual Remedy Agreement. The current PQL readily available is 0.033 ppt. The estimated risk associated with NDMA is based on a 70-year residential exposure duration.
f. Inorganic standard for chloride will be met by natural attenuation consistent with the onpost remedial action.
g. Inorganic standard for sulfate may be the natural background concentration, which will be established and met by natural attenuation consistent with onpost remedial action.
h. Because of the variability in contaminant distribution and concentration, the maximum risk associated with the groundwater cleanup concentrations is not expected to occur at any one location.

Table 7.3: Containment System Remediation Goals for the Northwest Boundary Containment System

Analyte	CSRG (μg/l)	Source	PQL[a]	Rural Residential Hypothetical Cancer Risk[b]
Chloroform	6	CBSG		6.4×10^{-6}
DIMP	8	CBSG		NA
Dieldrin	0.002	CBSG	0.05[c]	1.2×10^{-6}
Endrin	0.2	CBSG		NA
Isodrin	0.06	HBC		NA
NDMA	0.007	(d)	0.033	1.0×10^{-5}
Trichloroethylene	3	HBC		9.9×10^{-7}
Arsenic	2.35	HBC		5.6×10^{-5}
Chloride	250,000[e]	CBSG		NA
Fluoride	2,000	CBSG		NA
Sulfate	250,000[f]	CBSG		NA
			Total[g]	7.5×10^{-5}

The following chemical have ARARs that were adjusted downward to reduce overall risk: arsenic and trichloroethene.

CBSG	Colorado Basic Standards for Groundwater
DIMP	Diisopropylmethyl phosphonate
HBC	Health-based criteria
MCL	Maximum containment level
NA	Not applicable
NDMA	N-nitrosodimethylamine
PQL	Practical quantitation limit
μg/l	Micrograms per liter

a. Practical quantitation limit; presented only when the PQL is greater than the CSRG.
b. Based on the CSRG
c PQL attainable by the U.S. Army
d. The remediation goal for NDMA was established at 0.007 parts per trillion (ppt) in the Conceptual Remedy Agreement. The current PQL readily available is 0.033 ppt. The estimated risk associated with NDMA is based on a 70-year residential exposure duration.
e. Inorganic standard for chloride will be met by natural attenuation consistent with the onpost remedial action.
f. Inorganic standard for sulfate may be the natural background concentration, which will be established and met by natural attenuation consistent with onpost remedial action.
g. Because of the variability in contaminant distribution and concentration, the maximum risk associated with the groundwater cleanup concentrations is not expected to occur at any one location.

Table 7.4: Groundwater Alternatives for the North and Northwest Plume Groups

Alternative*	Process Options	Paleochannel	Extractions Wells (total number)	Recharge Wells/Trenches (total number/ total length)	Flow Rate (gpm)	Remediation Timeframe (years)	Treatment Facility Location	Residuals Generated
North Plume Group								
N-1 No action	Monitoring site reviews	FC, N	None	None	N/A	Unknown	N/A	None
N-2 Continued operation of the NBCS with improvements as necessary	NBCS operation (soil-bentonite barrier, carbon adsorption)	FC, N	No additional	No additional	240	15 to 30+	NBCS	No additional
N-4 Offpost Intercept and Treatment System	Carbon adsorption NBCS operation	FC N	5 12	6 trenches/1500 feet	180 300	15 to 30	T2S, R67W, Sec. 14, NE 1/4 Sec.	Spent carbon
N-5 Expansion of the Offpost Intercept and Treatment System	Carbon adsorption NBCS operation	FC N	7 13	10 trenches/ 2700 feet 2 trenches/600 feet	240 330	10 to 20	T2S, R67W, Sec. 14, NE 1/4 Sec.	Spent carbon
Northwest Plume Group								
NW-1 No action	Monitoring site reviews	NW	None	None	N/A	Unknown	N/A	None
NW-2 Continued operation of the NWBCS with improvements as necessary	NWBCS operation	NW	No additional	No additional	850	3 to 8	NWBCS	No additional

FC First Creek
gpm Gallons per minute
N/A Not applicable
N Northern
NBCS North Boundary Containment System
NW Northwest
NWBCS Northwest Boundary Containment System

* All alternatives include groundwater monitoring and site reviews.

'21905 402010
1107121495 RO2

Table 8.1: Summary of the Detailed Analysis and Ranking of Groundwater Alternatives for the North Plume Group

Criteria	Alternative N-1 No Action	Alternative N-2 Continued Operation of the North Boundary Containment System With Improvements as Necessary	Alternative N-4 Offpost Intercept and Treatment System	Alternative N-5 Expansion 1 to Interim Response Action A
Overall protection of human health and the environment	This alternative would not provide protection of human health and the environment.	This alternative provides limited overall protection of human health and the environment by preventing migration of contaminants from RMA to the Offpost Study Area north of the NBCS. Potential risk associated with groundwater in the North Plume Group would decrease over time.	This alternative reduces potential risk and provides protection of both human health and the environment by remediating North Plume Group groundwater and groundwater migrating from RMA to the Offpost Study Area.	This alternative reduces potential risk and provides protection of both human health and the environment by remediating North Plume Group groundwater and groundwater migrating from RMA to the Offpost Study Area.
Compliance with ARARs	This alternative is not expected to achieve chemical-specific ARARs.	Chemical-specific ARARs would be attained in approximately 15 to 30-plus years, as estimated by groundwater modeling.	Chemical-specific ARARs would be attained in approximately 15 to 30 years, as estimated by groundwater modeling.	Chemical-specific ARARs would be attained in approximately 10 to 20 years, as estimated by groundwater modeling.
Long-term effectiveness and permanence	This alternative would not reduce the residual risk associated with groundwater exposure pathways.	This alternative would reduce residual risk associated with North Plume Group groundwater by preventing contaminant migration at the NBCS and continuing recharge of treated groundwater to flush contaminants in the North Plume Group.	This alternative would reduce residual risk associated with North Plume Group groundwater, through operation of the NBCS and the Offpost Intercept and Treatment System and improvements to both systems as necessary.	Through treatment, this alternative would reduce residual risk associated with North Plume Group groundwater through operation of the NBCS, the Offpost Intercept and Treatment System, and the Expansion 1 system.
Reduction of mobility, toxicity, or volume	This alternative would not employ any treatment process options and would not reduce toxicity, mobility, or volume of groundwater within the North Plume Group or groundwater migrating from RMA to the Offpost Study Area.	This alternative would reduce toxicity, mobility, and volume of groundwater migrating from RMA to the Offpost Study Area.	Through treatment, this alternative would reduce toxicity, mobility, and volume of groundwater within the North Plume Group and groundwater migrating from RMA to the Offpost Study Area.	Through treatment, this alternative would reduce the toxicity, mobility, and volume of groundwater within the North Plume Group and groundwater migrating from RMA to the Offpost Study Area.

Table 8.1 (continued)

Criteria	Alternative N-1 No Action	Alternative N-2 Continued Operation of the North Boundary Containment System With Improvements as Necessary	Alternative N-4 Offpost Intercept and Treatment System	Alternative N-5 Expansion 1 to Interim Response Action A
Short-term effectiveness	Because no remedial action would be performed, there would be no short-term impacts. There would be no implementation period.	There would be no short-term impacts because the NBCS is already operating. There would be no implementation period.	Community and workers were protected by adhering to standard health and safety practices. The implementation period is complete and the system is fully operational.	Community and workers would be protected during construction through adhering to standard health and safety practices. The implementation period would be approximately 14 months.
Implementability	Technical feasibility would be high. The administrative feasibility would be low.	This alternative is readily implementable. Technical and administrative feasibility would be high.	This alternative is readily implementable. Technical and administrative feasibility would be high.	This alternative is readily implementable. However, the construction would be conducted in two time periods due to the design phase for the expansion. Technical and administrative feasibility would be high.
Estimated cost	Total Capital Cost = $ -0- Total Long-term O&M Cost = $4.1 to 6.0 million Total Present Worth Cost = $4.1 to 6.0 million	Total Capital Cost = $ -0- Total Long-term O&M Cost = $30.6 to 32.5 million Total Present Worth Cost = $30.6 to 32.5 million	Total Capital Cost = $16.7 million Total Long-term O&M Cost = $39.8 to 46.4 million Total Present Worth Cost = $56.5 to 63.1 million	Total Capital Cost = $19.4 million Total Long-term O&M Cost = $36.9 to 43.6 million Total Present Worth Cost = $56.2 to 63 million

ARAR Applicable or relevant and appropriate requirement
NBCS North Boundary Containment System
O&M Operation and maintenance
RMA Rocky Mountain Arsenal

'21905 402010
1107121495 R02

Table 8.2: Summary of the Detailed Analysis and Ranking of Groundwater Alternatives for the Northwest Plume Group

Criteria	Alternative NW-1 No Action	Alternative NW-2 Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary
Overall Protection of Human Health and the Environment	This alternative would not provide protection of human health and the environment.	This alternative would provide protection of human health and the environment by preventing migration of contaminants from RMA to the Offpost Study Area north of the NWBCS. Potential risks associated with the Northwest Plume Group groundwater would be substantially reduced through continued operation of the NWBCS and improvements as necessary.
Compliance With ARARs	This alternative is not expected to achieve chemical-specific ARARs.	This alternative is expected to meet or exceed chemical-specific ARARs in approximately three to eight years, as estimated by groundwater modeling.
Long-term Effectiveness and Permanence	This alternative would not reduce the residual risk associated with potential groundwater exposure pathways.	This alternative would reduce residual risk associated with groundwater within the Northwest Plume Group through preventing contaminant migration at the NWBCS and recharging treated groundwater to flush contaminants in the Northwest Plume Group.
Reduction of Toxicity, Mobility, or Volume	This alternative would not employ any treatment process options and would not reduce the toxicity, mobility, or volume of groundwater within the Northwest Plume Group or groundwater migrating from RMA to the Offpost Study Area.	This alternative would reduce toxicity, mobility, and volume of groundwater migrating from RMA to the Offpost Study Area. Groundwater contaminant concentrations would be reduced within the Northwest Plume Group by flushing provided by recharge of treated water at the NWBCS.
Short-term Effectiveness	Because no remedial action would be performed, there would be no short-term impacts. There would be no implementation period.	There would be no short-term impacts. There would be no implementation period.
Implementability	The technical feasibility would be high. The administrative feasibility would be low.	This alternative is readily implementable. Technical and administrative feasibility would be high.
Estimated cost	Total Capital Cost = $ -0- Total Long-term O&M Cost = $0.6 to 1.3 million Total Present Worth Cost = $0.6 to 1.3 million	Total Capital Cost = $ -0- Total Long-term O&M Cost = $12.4 to 13.1 million Total Present Worth Cost = $12.4 to 13.1 million

Table 8.2 (continued)

ARAR Applicable or relevant and appropriate requirement
NWBCS Northwest Boundary Containment System
O&M Operation and maintenance
RMA Rocky Mountain Arsenal

'21905 402010
1107121495 RO2

Table 9.1: Estimated Costs of the Offpost Operable Unit Selected Remedy

Cost Component	Alternative N-4	Alternative NW-2[a]
Capital Costs		
Monitoring well system	$ 908,000	NA
Offpost Intercept and Treatment System extraction/recharge system	4,593,000	NA
Treatment facility	4,106,000	NA
Startup costs	341,000	NA
Indirect costs	6,715,000	NA
Total estimated capital costs	$ 16,663,000	$0
Annual Operation and Maintenance Costs		
Groundwater monitoring	$ 352,000	$ 134,000
Site reviews	150,000	150,000
North and northwest boundary system operations	1,724,000	769,000
Offpost Intercept and Treatment System facility O&M	522,000	NA
Offpost Intercept and Treatment System carbon replacement[b]		
0 to 3/5 years	817,000	NA
3/5 years to system shutdown	227,000	NA
Total estimated Annual O&M Costs		
0 to 3/5 years	$ 4,618,000	
3/5 years to system shutdown	$ 4,028,000	$ 1,053,000
	Nonconservative[c]	Conservative[c]
Total remedy costs	$ 68,911,000	$ 76,143,000

DIMP Diisopropylmethyl phosphonate
NA Not applicable
O&M Operation and maintenance

a. There are no capital costs for Alternative NW-2 because the remedial systems are currently operational.

b. The carbon usage rate is assumed to decrease over time as a result of expected decreases in influent DIMP concentration. The duration of time before a decrease in carbon usage rate is expected to occur within three to five years.

c. A range of total costs has been estimated on the basis of the range of expected remediation timeframes as estimated by the groundwater model results.

Table 10.1: Summary Evaluation of Chemical-specific and Other Applicable or Relevant and Appropriate Requirements for the Offpost Operable Unit

Standard, Requirement Criteria, or Limitation	Citation	Description	Applicable/ Relevant and Appropriate Requirement	Comment
Chemical-specific ARARs				
Safe Drinking Water Act	40 CFR Part 141	Establishes primary MCLs for public water-supply systems.	No/Yes	Groundwater in the vicinity of the site is being used or may be used as a source of water for public water system or private supply wells. Therefore, those primary MCLs that are more stringent than the Colorado Primary Drinking Water Regulations (because Colorado has primary enforcement authority) are relevant and appropriate.
	40 CFR Sections 141.50 and 141.51	Establishes MCLGs (nonenforceable health goals) for public water systems.	No/Yes	Groundwater in the vicinity of the site is being used or may be used as a source of water for a public water system or private supply wells. Therefore, in accordance with the NCP, nonzero MCLGs are considered to be relevant and appropriate.
Other ARARs				
Colorado Basic Standards for Groundwater; Colorado Basic Standards and Methodologies for Surface Water	5 CCR 1002-8 Section 3.11.0 et seq.; Section 3.1.0 et seq.	Establishes statewide standards for waters of the state.	Yes/No	State standards that are more stringent than federal standards are considered applicable.

Table 10.2: Summary Evaluation of Action-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Unit

Standard, Requirement Criteria, or Limitation	Citation	Description	Applicable/ Relevant and Appropriate Action-specific Requirement	Comment
Federal ARARs				
Safe Drinking Water Act	42 USC Sections 300h to 300h-7			
- Underground Injection Control Regulations	40 CFR Parts 144 to 147	Establishes standards for construction and operation of injection wells/trenches	Yes/No	Applicable if reinjection wells/trenches are used for discharge of treated water; relevant and appropriate if some other method of reinjection is used. Under the provisions of 40 CFR 144.13(L), EPA has determined that the reinjection wells/trenches used in conjunction with the barrier treatment system do not endanger underground sources of drinking water. The level of treatment prior to reinjection, offpost alternative water supplies, and other remedies are sufficient to meet the requirements of the UIC program.
Colorado Air Quality Standards	CRS Sections 25-7-101 to 25-7-806			
- Odor Emission Regulations	Colorado Air Quality Control Regulation No. 2	Sets limits on emission of odorous air contaminants	Yes/No	Applicable to remedial action for the Offpost OU.

ARAR Applicable or relevant and appropriate requirement
CFR Code of Federal Regulations
CRS Colorado Revised Statues
OU Operable unit
EPA U.S. Environmental Protection Agency
UIC
USC United States Code
VOC Volatile organic compound

Table 10.3: Summary Evaluation of Location-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Unit

Standard, Requirement Criteria, or Limitation	Citation	Description	Applicable/ Relevant and Appropriate Location-specific Requirements	Comment
Federal ARARs				
Executive Order 11988 - Flood Plain Management	40 CFR Part 6, Appendix A	Directs federal agencies to avoid long- or short-term impacts associated with occupancy and modification of a floodplain.	Yes/No	Requires a 500-year floodplain to be identified and considered in scoping any remedial actions.
Executive Order 11990	40 CFR Part 6, Appendix A	Minimizes the destruction, loss, or degradation of wetlands.	Yes/No	Requirements associated with this order would be applicable to any remedial actions that could affect the existing wetlands.

ARAR Applicable or relevant and appropriate requirement
CFR Code of Federal Regulations

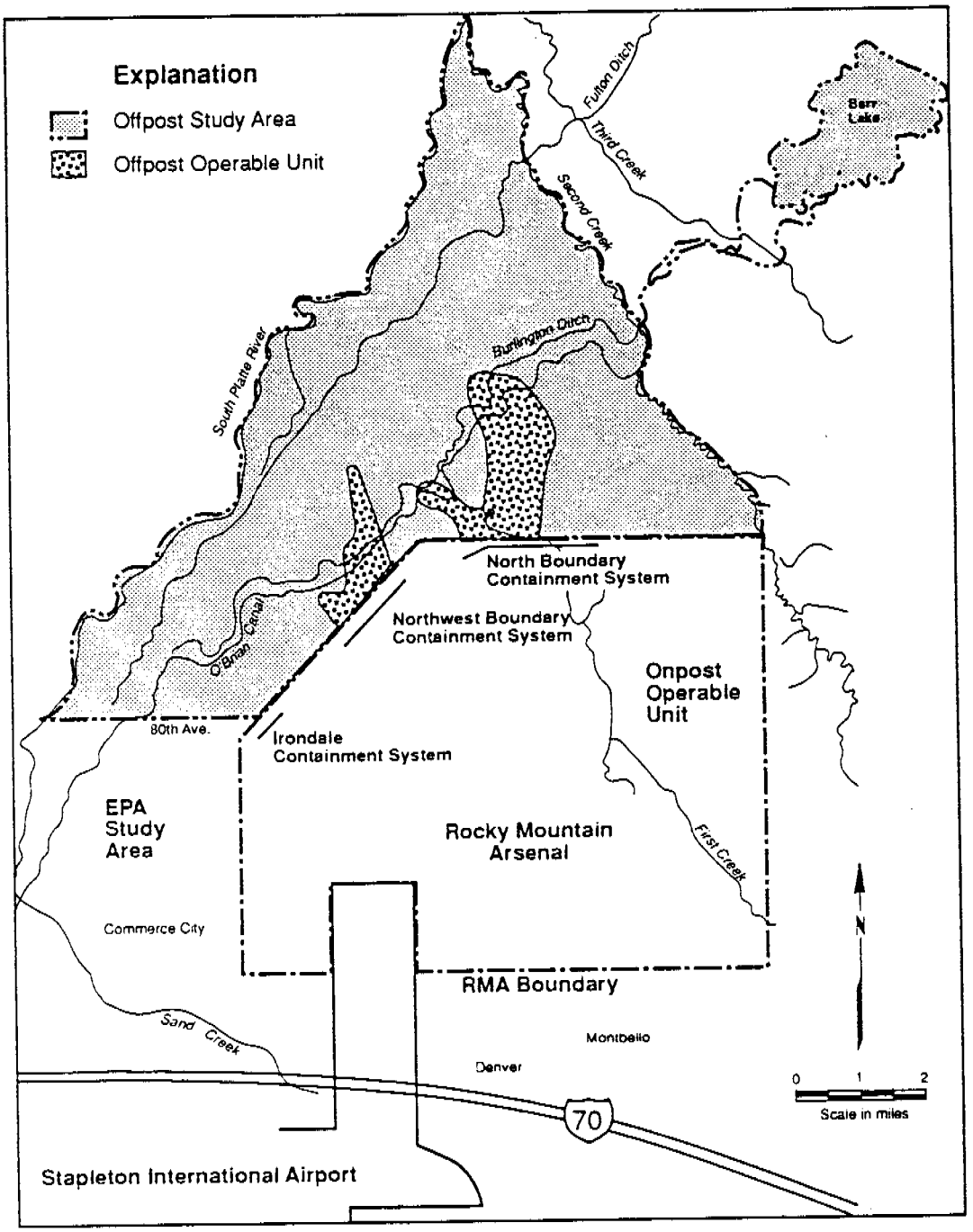


Figure 1.1

Rocky Mountain Arsenal Operable Units and Offpost Study Area

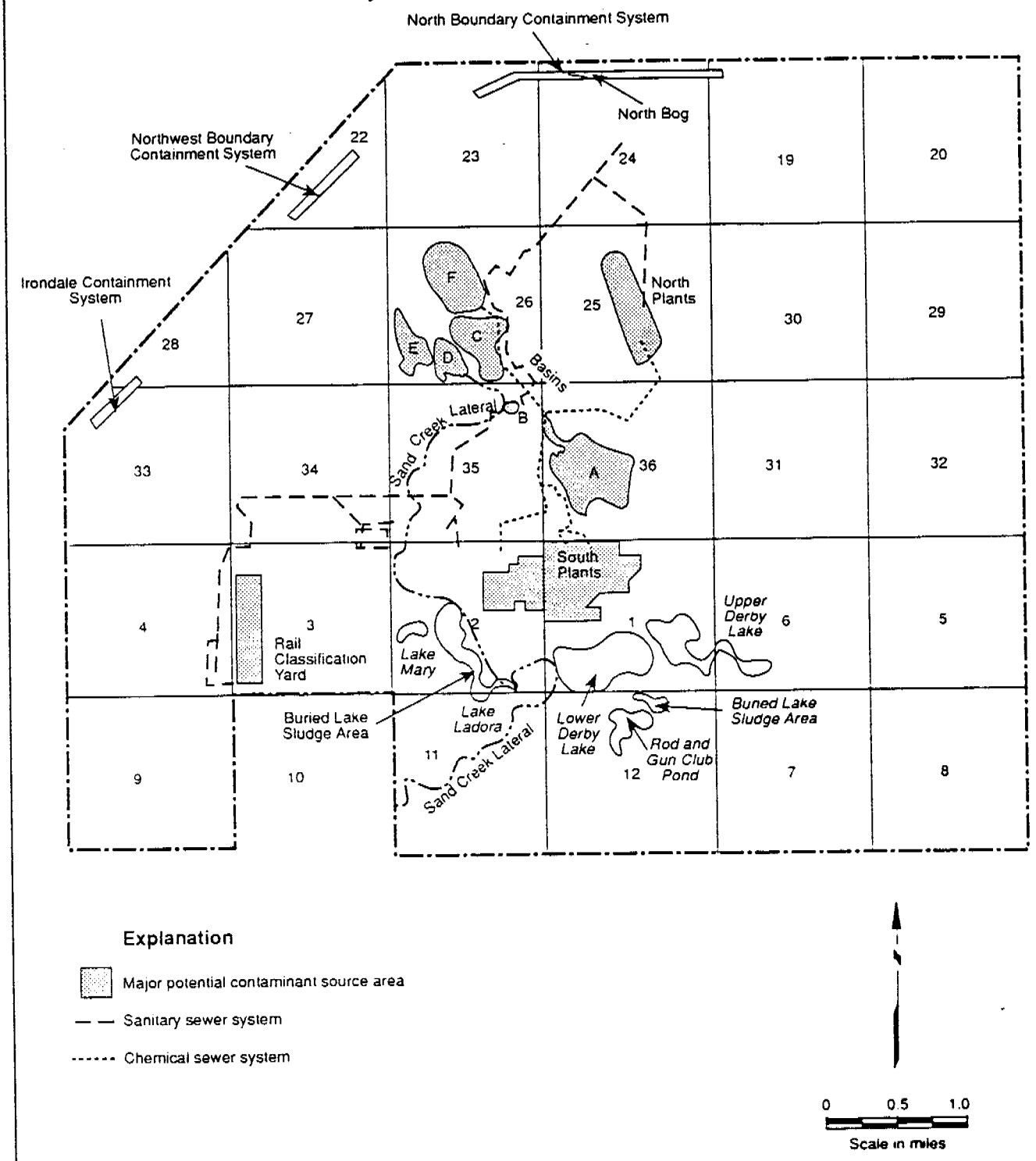
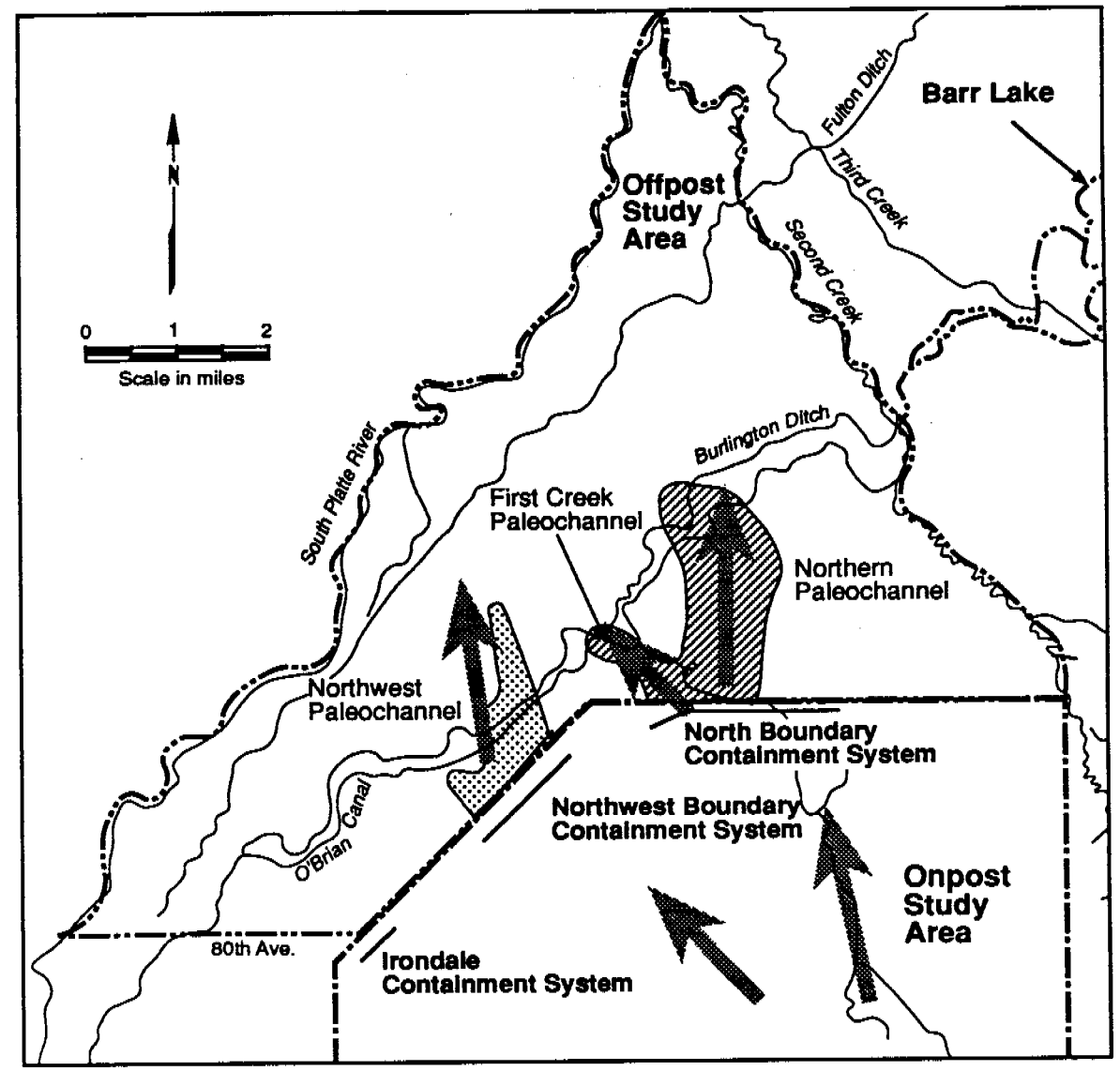


Figure 2.1

Locations of Contaminant Source Areas



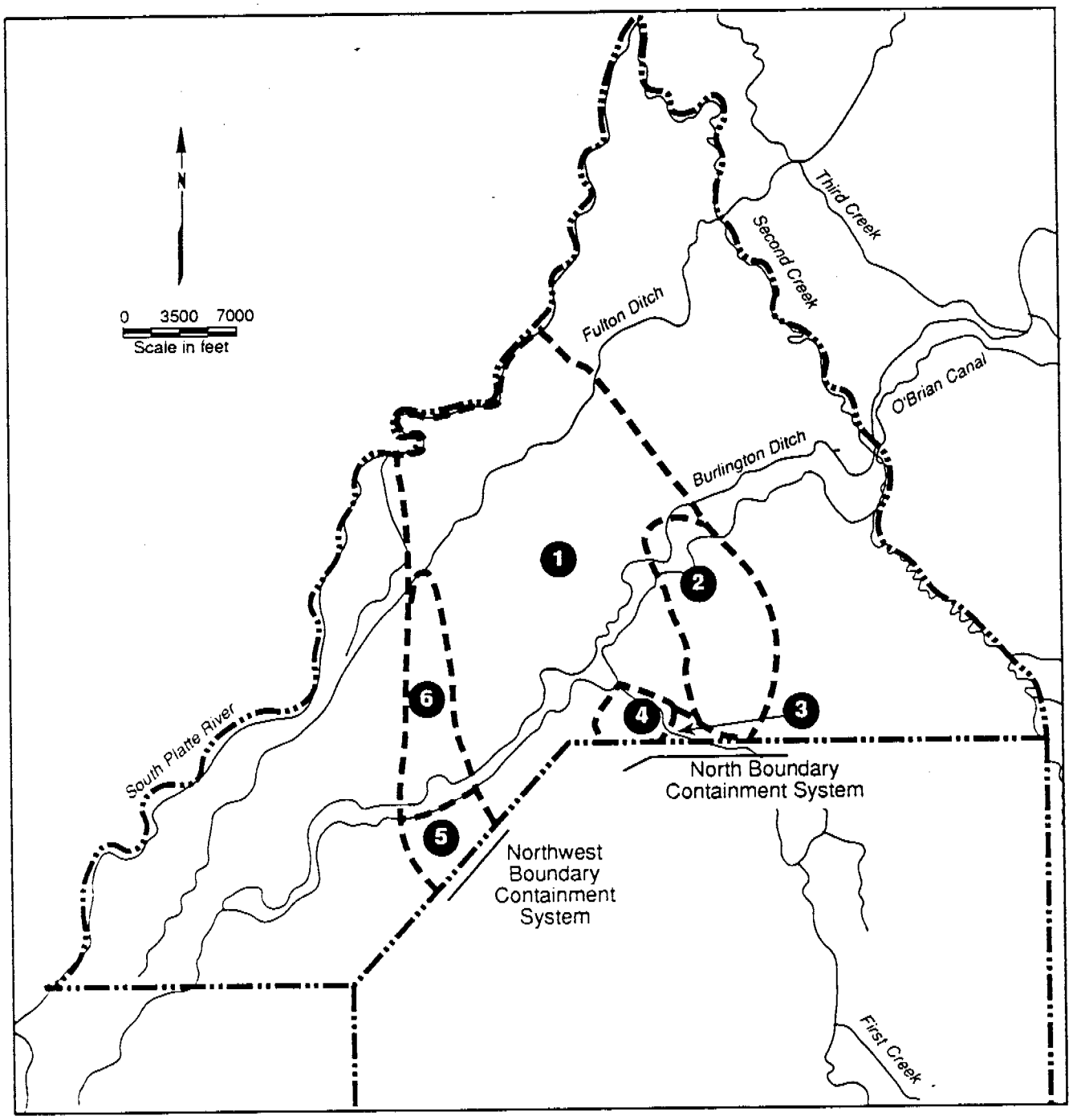
Explanation

Groundwater flow direction

Northwest plume group

North plume group

Figure 5.1
Contaminant Migration Pathways

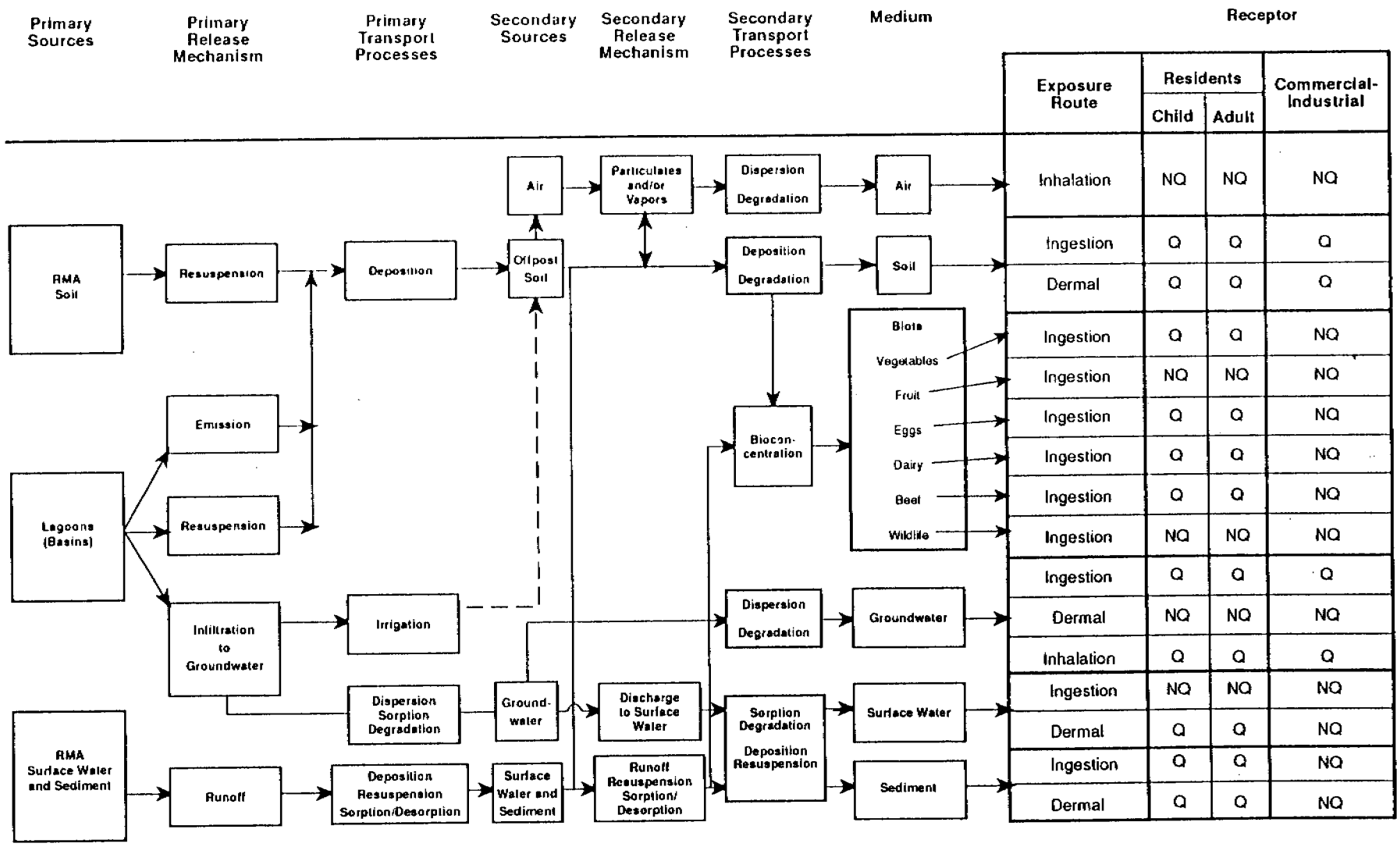


Explanation

Zone 1	Rural residential land use
Zone 2	Rural residential land use
Zone 3	Urban residential land use
Zone 4	Urban residential land use
Zone 5	Commercial and industrial land use
Zone 6	Rural residential land use
	Offpost study area boundary

Figure 6.1

Offpost Study Area Exposure Assessment Zones



Exposure Route	Residents		Commercial-Industrial
	Child	Adult	
Inhalation	NQ	NQ	NQ
Ingestion	Q	Q	Q
Dermal	Q	Q	Q
Ingestion	Q	Q	NQ
Ingestion	NQ	NQ	NQ
Ingestion	Q	Q	NQ
Ingestion	Q	Q	NQ
Ingestion	Q	Q	NQ
Ingestion	NQ	NQ	NQ
Ingestion	Q	Q	Q
Dermal	NQ	NQ	NQ
Inhalation	Q	Q	Q
Ingestion	NQ	NQ	NQ
Dermal	Q	Q	NQ
Ingestion	Q	Q	NQ
Dermal	Q	Q	NQ

EXPLANATION

Q Quantified

NQ Not quantified

Figure 6.2

Site Conceptual Model Offpost Study Area

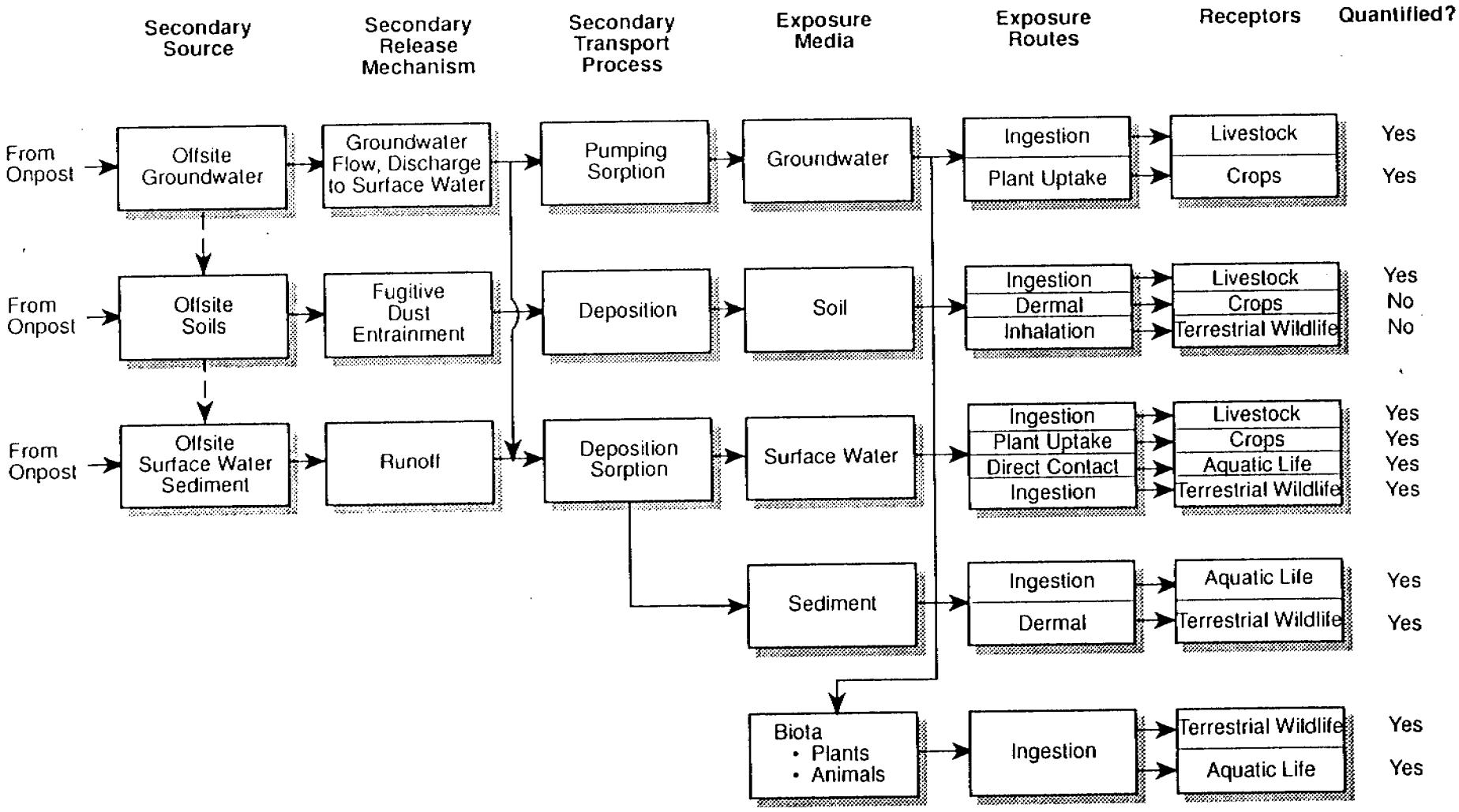
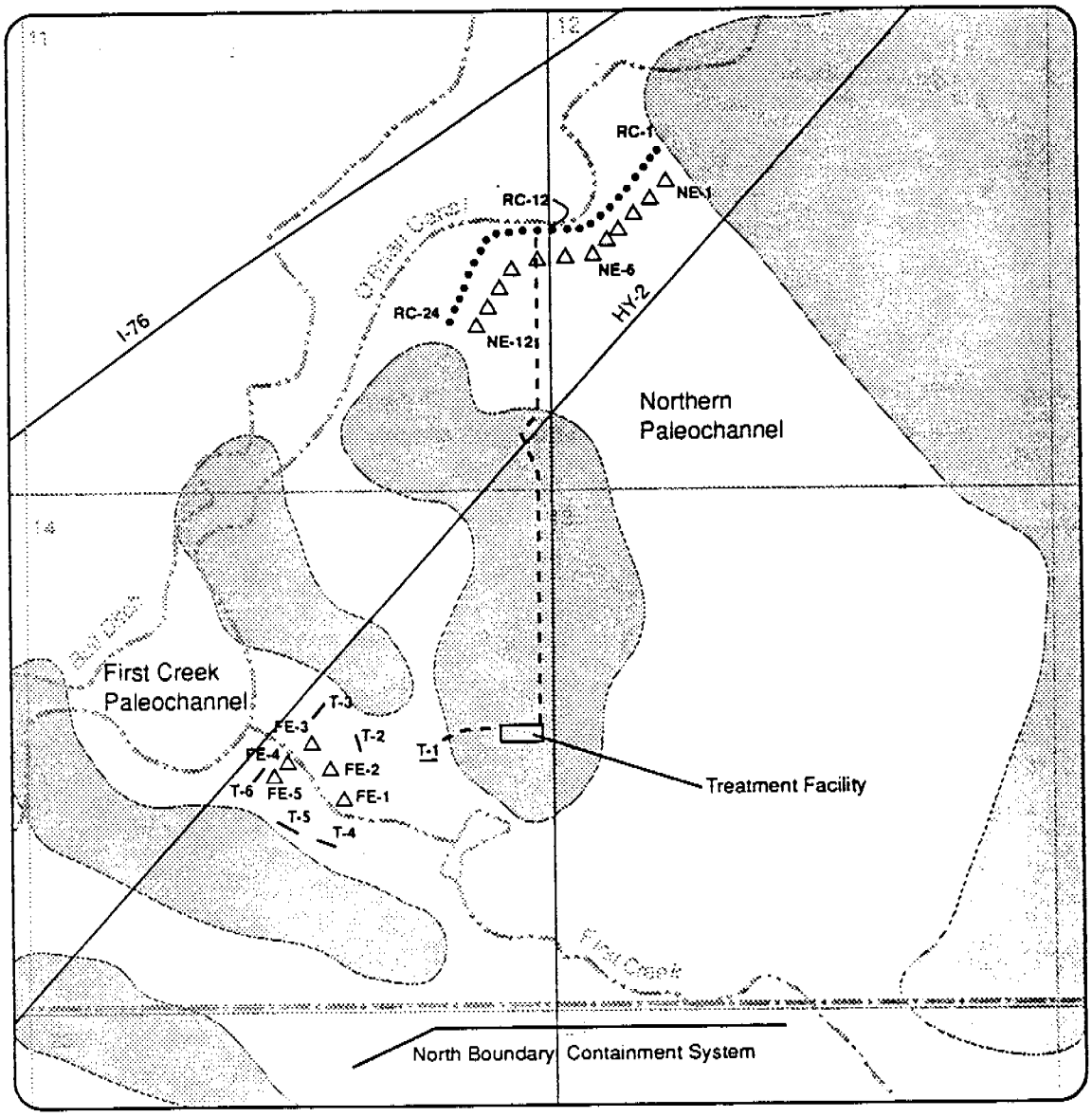


Figure 6.3

Ecological Site Conceptual Model
for the Offpost Study Area



Explanation

- △ Offpost Intercept and Treatment System extraction well
- • Offpost Intercept and Treatment System recharge well
- \ Offpost Intercept and Treatment System recharge trench
- – – Pipeline
- ▭ Unsaturated alluvium

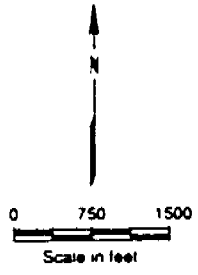
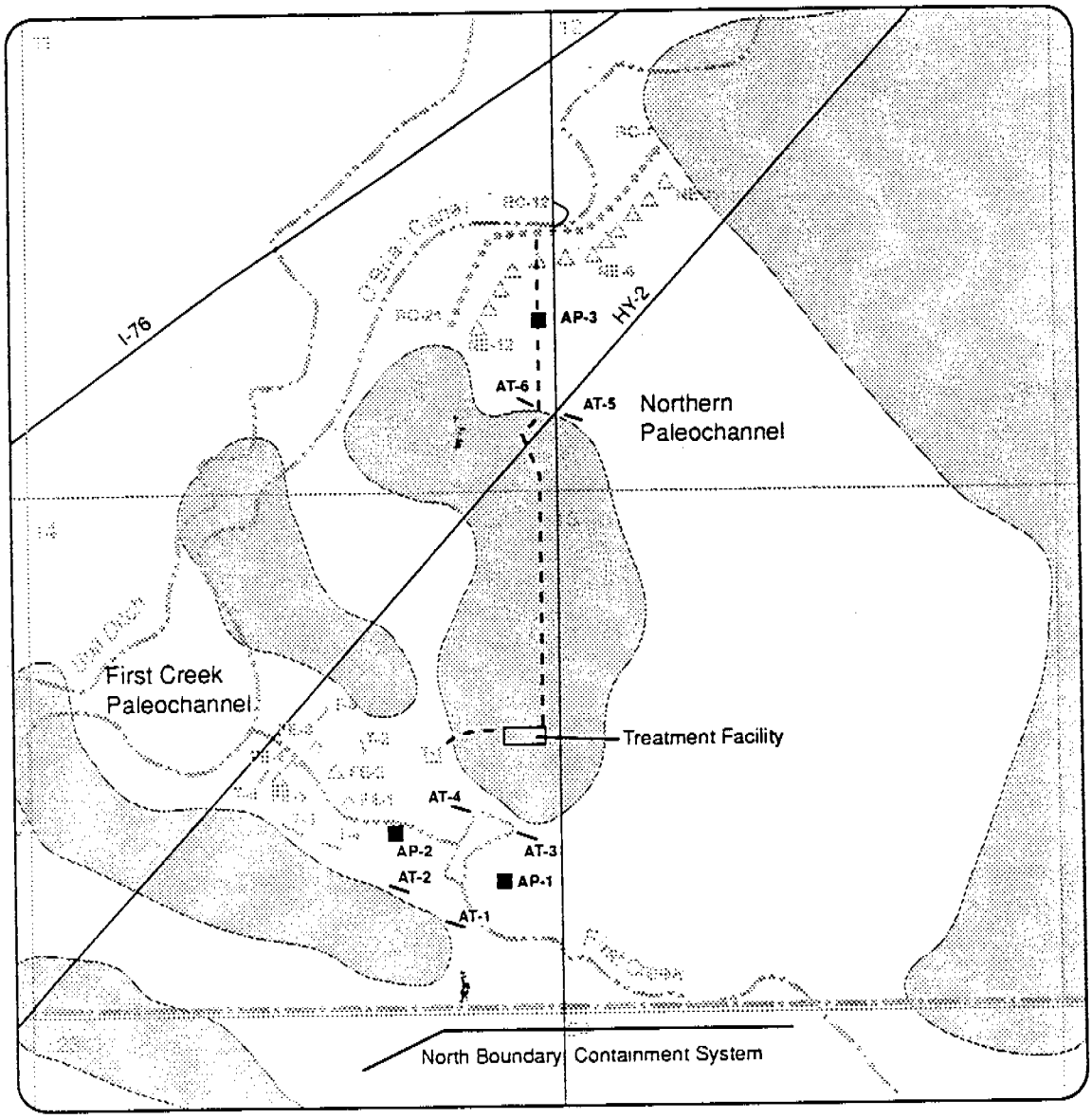


Figure 7.1

Alternative N-4 Remedial System Components



Explanation

- Additional extraction well under Alternative N-5
- Additonal recharge trench under Alternative N-5
- Offpost Intercept and Treatment System extraction well
- Offpost Intercept and Treatment System recharge well
- Offpost Intercept and Treatment System recharge trench
- Pipeline
- Unsaturated alluvium

N

0 750 1500

Scale in feet

Figure 7.2

Alternative N-5 Remedial System Components

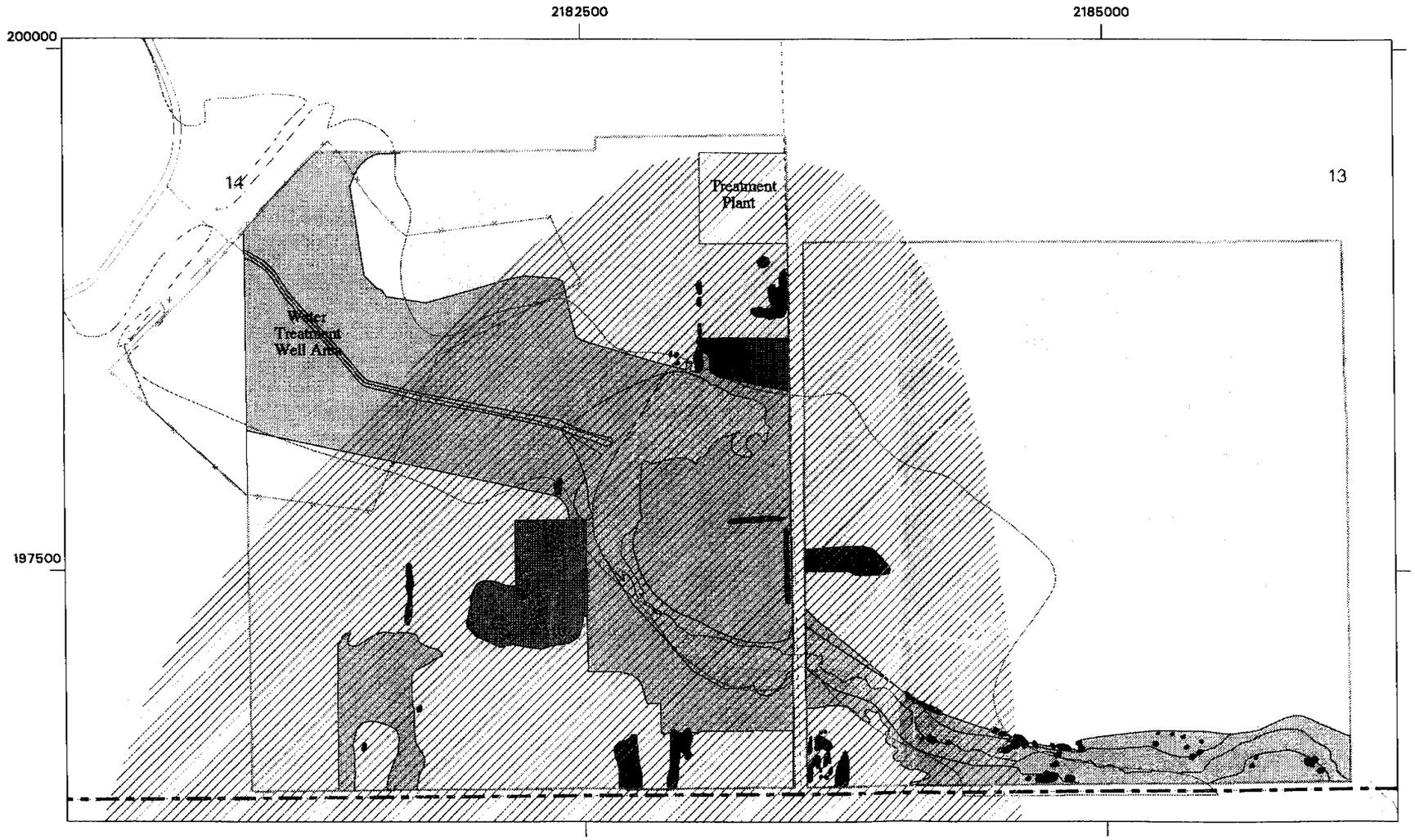


Figure 9.1
Offpost Area of Revegetation

SHELL OFFPOST PROPERTIES

VEGETATION CLASSIFICATION with 1995 ESTIMATED SURFACE SOIL DIELDRIN DISTRIBUTION

- Arsenal Boundary
- Native Perennial Grassland
- Wetland
- Tree Grove
- Seeded Area
- Homestead Site
- Seeded Barrow Area
- Seeded Fill Area
- Unclassified
- Shell Properties
- Dieldrin >= .04 ug/g (1995)

Acreage Breakdown

Area of Offpost Plume (On Shell Property)	193.87 Acres
Area of Offpost Plume (Not on Shell Property)	21.24 Acres
PLOWABLE AREA (On Shell Property)	167.69 ACRES

Includes:
- Seeded Area 110.04
- Seeded Barrow Area 5.98
- Seeded Fill Area 2.24
- Native Perennial Grassland 49.43

Other Areas:
- Tree Groves 4.76
- Wetlands 16.07
- Homestead Site 1.25
- Treatment Plant 4.10

From: "Dieldrin in Surficial Soils",DPA, May 30, 1995.
RMA Environmental Database, Dieldrin contour data from Foster Wheeler & DPA (1995).

MORRISON KNUDSEN CORPORATION
Environmental Services Division

-N-

SCALE 1 : 7,000

0 500 1000 FEET

December 01, 1995