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 1×10^{-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 ground water, 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 $\mu g/l$.

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.