
Executive Summary

The Rocky Mountain Arsenal (the Arsenal) is a federally-owned facility in Adams County, Colorado, just northeast of the Denver metropolitan area and southwest of Denver International Airport (Figure S.1). In 1942, the U.S. Department of Army (Army) purchased this 27 square-mile property for the manufacture of chemical warfare agents and incendiary munitions. Agents and munitions included rockets and projectiles containing blister agents (e.g., mustard gas), lewisite, phosgene bombs, incendiary bombs, napalm, and later, Sarin nerve agent. The Army also used the Arsenal for “demilitarization” of nerve agents and bombs into the 1980s. Manufacturing byproducts, unexploded munitions, and other wastes were stored on-site.

After World War II, the Army leased portions of the site to private industry, primarily Shell Oil Company (Shell). Shell manufactured pesticides, insecticides, herbicides, and other chemicals at the Arsenal from 1952 to 1982. Wastes from both Shell and Army manufacturing were transported through chemical sewers to on-site trenches and waste disposal basins (Figure S.2). Millions of pounds of chemical weapon and pesticide manufacturing wastes were disposed in these waste areas between 1942 and 1982.

The Environmental Protection Agency (EPA) listed the Arsenal on the Superfund National Priorities List (NPL) in the 1980s, thus recognizing the Arsenal as one of the most contaminated sites in the country and making it a priority for cleanup. The final environmental remediation plans were finalized in 1995 and 1996. At that time, the Army anticipated completion of remediation, excluding ongoing treatment of groundwater, by 2011. That estimate has now been revised to 2010.

The Superfund cleanup program addresses threats to human health and the environment. The same federal law that established this cleanup program also included provisions for recovery of natural resource damages (NRDs). Thus, in addition to those cleanup activities, the Colorado Natural Resource Trustees have initiated a natural resource damage assessment (NRDA) at the Arsenal. The goals of NRDs claims are to restore the environment to the state it would have been in had the pollution not occurred, and to compensate the public for the interim losses of public trust natural resources up to the time that such restoration is complete. Restoration can be accomplished by directly restoring the injured resource, or by rehabilitating, replacing, or acquiring equivalent resources.

The Arsenal Records of Decision (RODs) require continued operation of existing groundwater containment, extraction, and treatment systems, as well as installation of additional extraction systems and upgrades to existing systems. Hazardous substances continue to migrate to groundwater from contaminated subsurface soils, and thus groundwater at the Arsenal will not be clean for the foreseeable future.

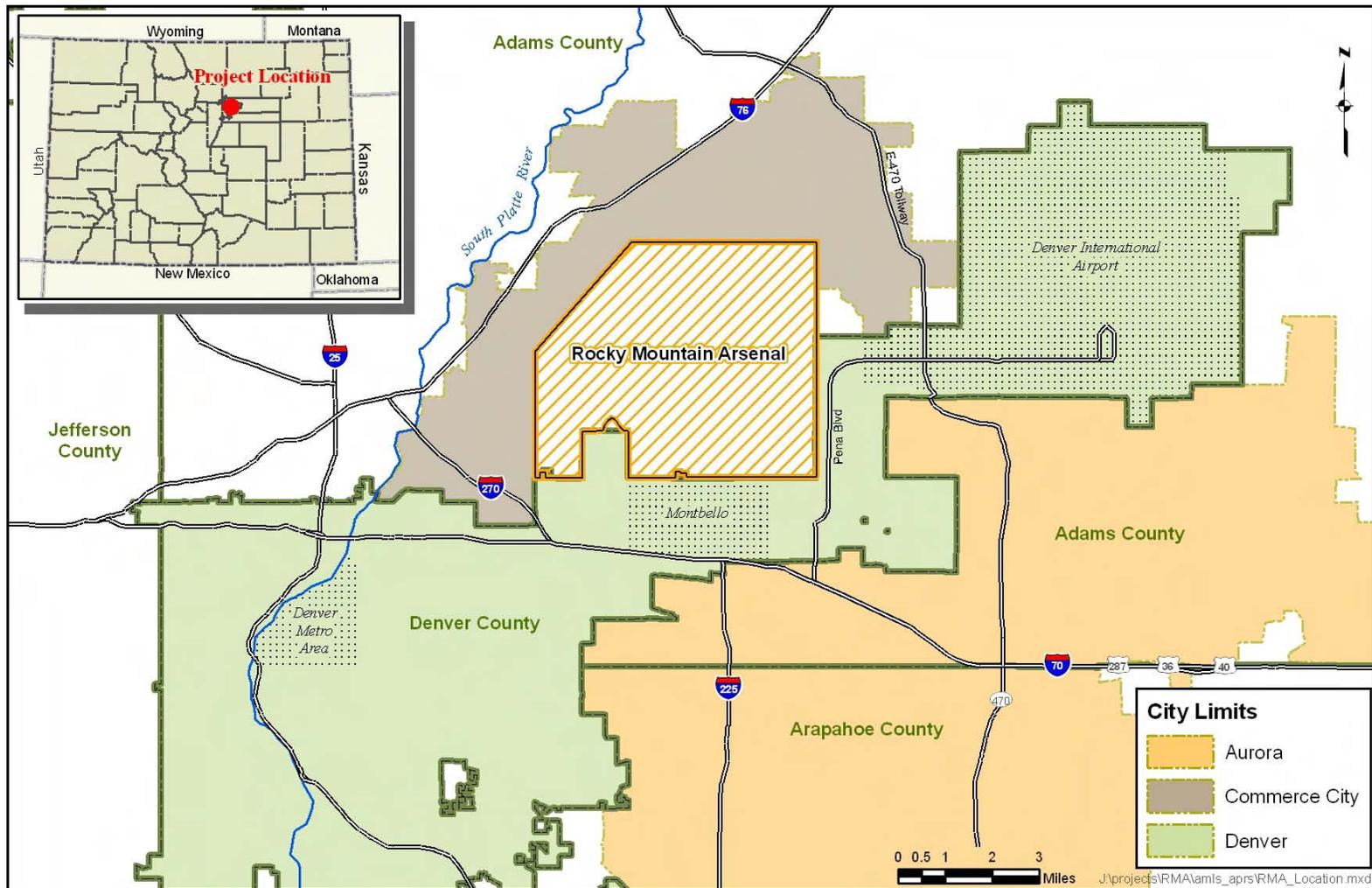


Figure S.1. General location of the Rocky Mountain Arsenal in the Denver area.

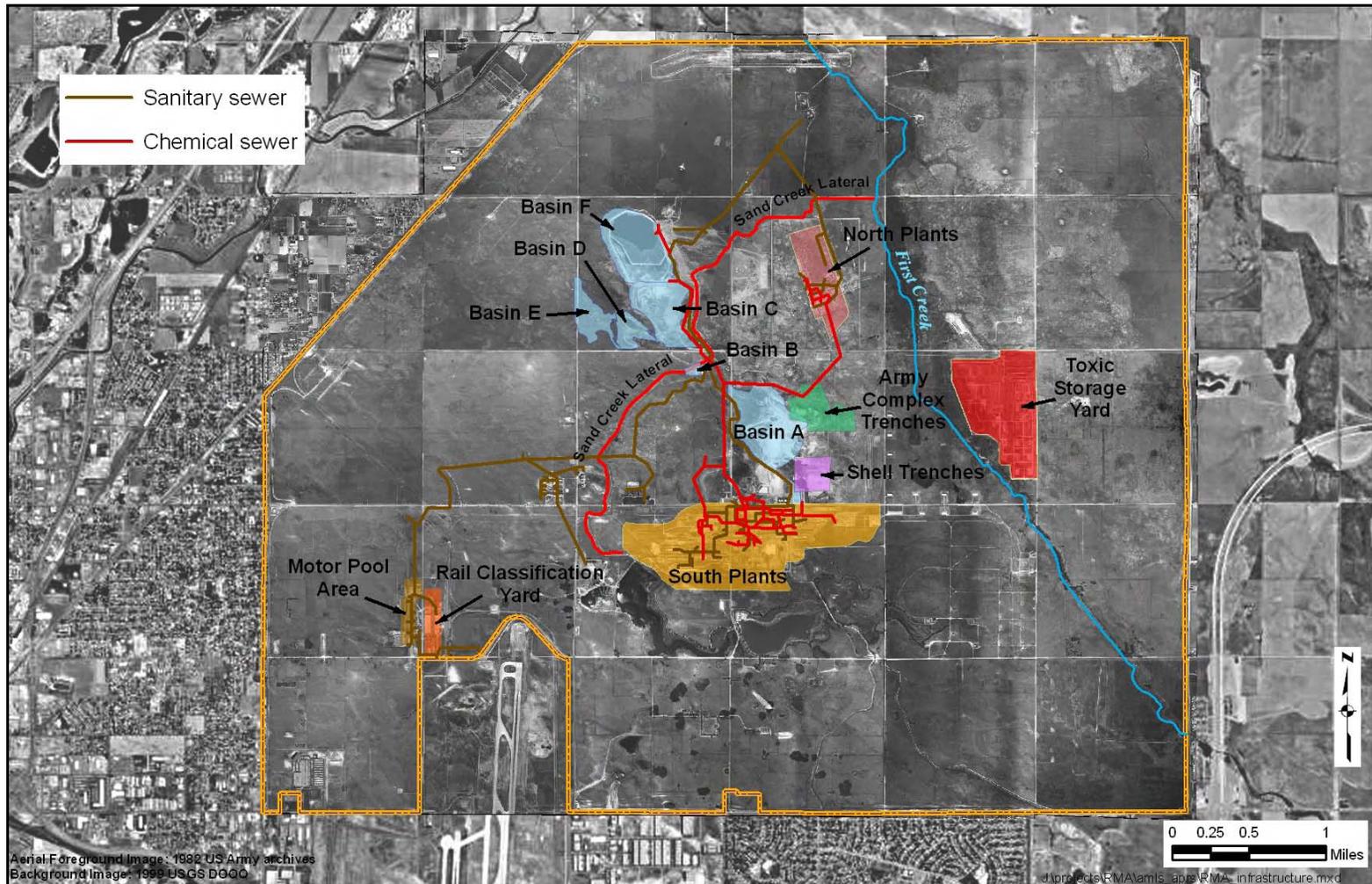


Figure S.2. Manufacturing, storage, waste transit, and waste disposal sites at the Arsenal.

The purpose of this Assessment Plan is to document the State Trustees' basis for conducting a damage assessment, and to set forth the proposed approaches for quantifying harm ("injuries") to natural resources and calculating damages associated with those injuries. The Assessment Plan enables the Trustees to ensure that the NRDA will be completed in a planned and systematic manner and at a reasonable cost. The Plan informs the Army, Shell, and the public of the proposed assessment methods so that stakeholders can participate in the assessment process.

The State Trustees plan to seek recovery for both the costs of restoring injured resources to baseline conditions (i.e., conditions that would have been present absent the releases of hazardous substances), and for compensatory damages to account for lost services in the past, present, and future until the natural resources have been restored to baseline.

The State's NRD calculations will take into account the benefits of the remedial actions at the Arsenal. For resources where the remedial actions will return or have returned resources to baseline conditions, the State's damage calculations will include the period from the onset of injury (or 1981) until baseline conditions are (or were) achieved.

Response actions

The Army and Shell addressed the contamination at the Arsenal through a series of response actions beginning with the installation of groundwater extraction and treatment systems on the boundaries of the facility in the early 1980s. In the mid-1980s, the Army and Shell implemented interim response actions (IRAs) to address known significant sources of contamination and to protect against immediate threats to human health and the environment. The most extensive IRA was the closure of Basin F (Figure S.2), where the Army removed and incinerated nearly 11 million gallons of liquid chemical waste and transferred over 500,000 cubic yards of contaminated soils and sludge to a temporary waste pile. Noxious odors from the excavation and air-drying of the sludges entered nearby neighborhoods. After approximately six months of failing to control the emissions, the Army abandoned the sludge removal and capped the remaining materials in place.

The selected remedies to address human health and the environment put forth in the On-Post and Off-Post RODs included the construction of a lined hazardous waste landfill and re-construction of Basin A (Figure S.2) as a landfill. The hazardous waste landfill received contaminated soils and sludges posing an unacceptable risk to human health, and Basin A received contaminated soils and sludges that did not exceed human health risk thresholds but did pose a risk to biota. Millions of cubic yards of soils have been transported to these repositories; excavation and transport of Basin F soils and sludges are scheduled for completion in 2008. However, in many locations, only the upper five to ten feet of soils were remediated, leaving large quantities of hazardous substances buried in deeper soils.

After excavation of contaminated soils, hundreds of acres at the Arsenal were capped, covered with clean soil, and revegetated, thereby reducing risks to human health and the environment and benefiting injured natural resources. Once appropriate response actions were completed, portions of the Arsenal were deleted from the NPL. Thus far, over 900 acres were removed from the NPL and sold to Commerce City, and over 12,000 acres were removed from the NPL and transferred to the U.S. Fish and Wildlife Service to be part of the National Wildlife Refuge system. Areas such as waste disposal trenches, landfills, and areas with groundwater treatment systems will remain in the Army's possession.

While response actions address threats to human health and the environment, the State Trustees must calculate the cost of restoring injured resources to baseline conditions, and quantify interim losses up to the time that restoration is complete and baseline conditions are achieved. The State Trustees anticipate using existing data to determine and quantify injuries to groundwater, wildlife and its supporting ecosystems, and air resources.

Groundwater injuries and damages

Hazardous substance releases at the Arsenal have resulted in extensive plumes of contaminated groundwater under the Arsenal property and north of the Arsenal towards the South Platte River (Figure S.3). In addition, the Army placed institutional controls preventing the use of the groundwater as a drinking water source on all groundwater under the Arsenal, and preventing any use of shallow groundwater underlying 350 acres of Shell property north of the Arsenal until that groundwater is clean.

To assess lost groundwater services over time, the State Trustees will:

- ▶ Calculate the spatial extent of the groundwater plume containing hazardous substance concentrations in excess of State or federal groundwater standards
- ▶ Determine the extent to which hazardous substances have been released to groundwater in deep aquifers underlying the Arsenal, including the Denver, Upper Arapahoe, Lower Arapahoe, and Laramie – Fox Hills Formations
- ▶ Determine the volume of groundwater in each of the deep aquifers that is inaccessible for use as a drinking water supply because of institutional controls
- ▶ Determine the annual safe yield of shallow alluvial groundwater underlying the Arsenal that is inaccessible as a drinking water supply because of institutional controls, as well as the annual safe yield inaccessible for any purpose because of hazardous substance concentrations.

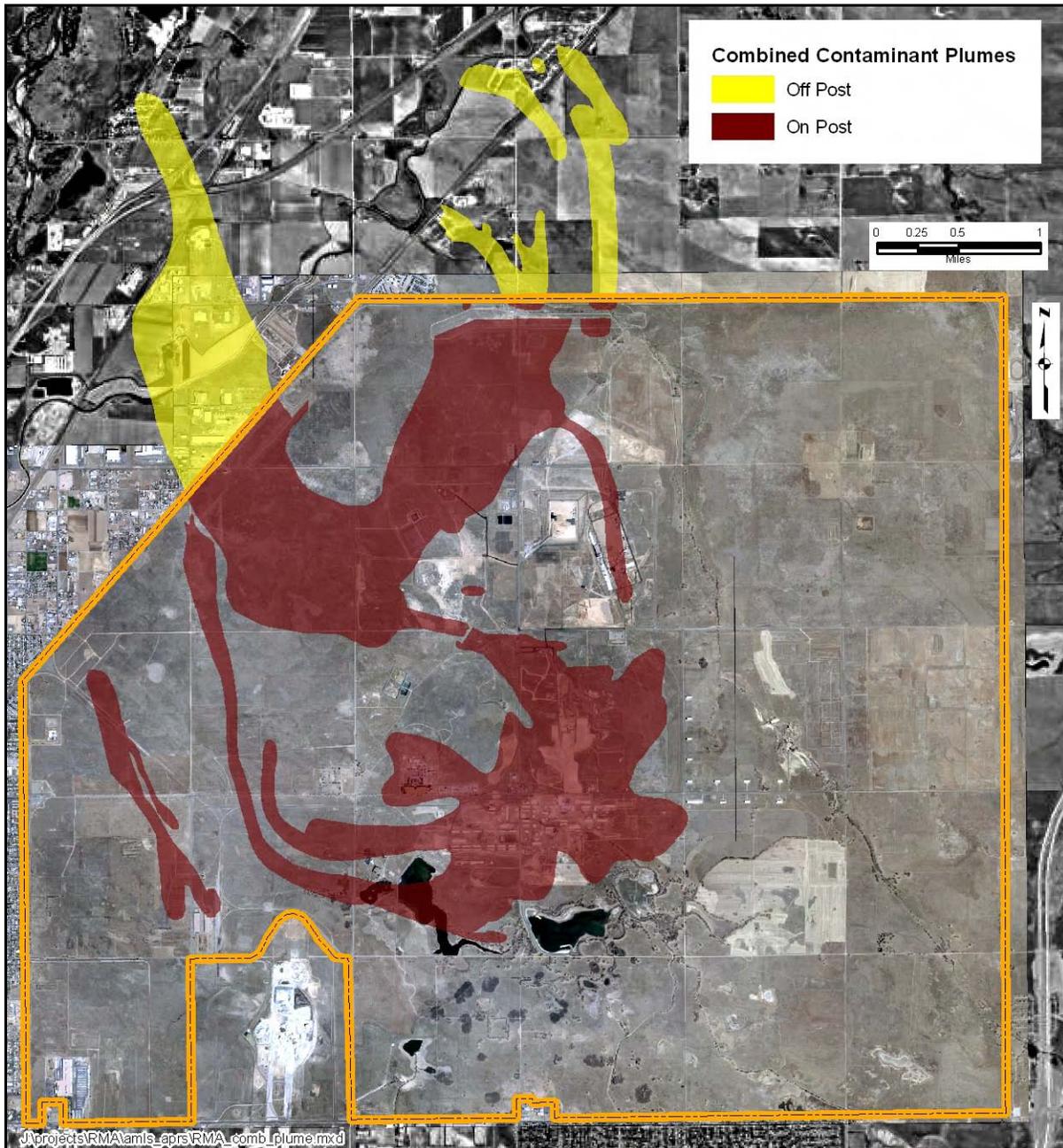


Figure S.3. Estimated extent of a combined contaminant plume (trichloroethylene, benzene, chloroform, dibromochloropropane, and dieldrin) in the shallow alluvial aquifer (1994).

The assessment of groundwater injury will rely primarily on existing data within the Rocky Mountain Arsenal Environmental Database. To determine the spatial extent of groundwater injuries over time, the State Trustees may perform the following additional work as part of the assessment:

- ▶ Develop a flow and transport model using MODFLOW/MT3D or MODFLOW-SURFACT to estimate the spatial extent of groundwater injury in the past, present and future
- ▶ Develop a hazardous substance plume degradation/decay model to estimate the future spatial extent of groundwater injury
- ▶ Evaluate contaminated groundwater in the weathered upper Denver Formation as well as in deeper groundwater formations
- ▶ Further identify past and existing uses of groundwater at and downgradient of the Arsenal.

NRDA regulations specify that the highest-and-best use of an injured resource should be used to calculate damages. In the Denver metropolitan area, municipal water supply qualifies as the highest and best use for groundwater. Thus, the State has incurred lost use damages to groundwater both directly, because of the plume of hazardous substances in groundwater, and indirectly, because the hazardous substances resulted in institutional controls preventing the use of the Arsenal groundwater as a municipal water supply.

Many municipal water suppliers in the Denver metropolitan area use shallow alluvial groundwater tributary to the South Platte River as a water source. When easily accessible water supplies such as the shallow South Platte River groundwater are not available, municipalities spend millions of dollars to transport water tens or even hundreds of miles from distant water sources to the end-user. Preliminary evidence thus suggests that clean alluvial groundwater under the Arsenal would be a practical municipal water source.

Shallow groundwater at the Arsenal is tributary to the South Platte River. To access this water (absent hazardous substances and institutional controls), a user would be required to have an approved augmentation plan demonstrating that senior water rights holders in the South Platte River basin would not be harmed as a result of pumping. Most alluvial groundwater pumped in the Arsenal area is either used in households and then released to the South Platte River via wastewater treatment plant effluent, or is used for irrigation, with a portion percolating back to shallow groundwater. Most municipal suppliers use wastewater effluent as well as rights to more polluted water sources such as ditches to provide augmentation when necessary to offset pumping of clean groundwater. Thus, it is likely that, absent the releases of hazardous substances and subsequent

enactment of institutional controls, the Arsenal groundwater would have been an attractive and usable municipal water source.

The State Trustees will use a combination of approaches to assess damages to injured groundwater at the Arsenal. These approaches will account for both the cost of restoration and the compensable value of the interim loss. Compensable value is the value of lost direct public use of the services, plus lost non-use values such as existence and bequest values. The State Trustees anticipate using the following approaches for estimating damages:

- ▶ Market price methods
- ▶ Resource equivalency methods
- ▶ Total value/restoration scaling methods.

Water resources, including groundwater, are traded in a reasonably competitive market in the Denver metropolitan area. Initial evaluation of data suggests that sufficient information is available to form an accurate representation of the willingness to pay for water for at least the past 15 years in the Front Range area of Colorado. This can provide a basis on which to value contaminated groundwater damages from the Arsenal.

To develop market prices for groundwater in the Arsenal region, the State Trustees will use observed market data, including associated variables, to establish appropriate market prices for which water would sell in the Front Range region at a given date. The sale price of water will then be used to calculate the annual diminished value of injured resources. If necessary, market prices for any dates after those available in the collected transactions will be based on statistical forecasts using projections of variables that help explain changes in water prices, such as urbanization and development in the region.

The State Trustees also intend to use restoration-based equivalency approaches to assess damages. This includes resource equivalency analysis (REA), in which the State Trustees first quantify injuries in terms of lost groundwater services, then scale restoration projects such that they provide the equivalent amount of groundwater service gain. The State expects to use this “service-to-service” scaling method because restoration alternatives are available that provide similar types and quality of services as those lost. Projects that restore groundwater services may include:

- ▶ Water quality protection and improvement programs
- ▶ Water reuse programs
- ▶ Water conservation programs
- ▶ Water recharge programs.

Restoration projects will be scaled to compensate for both interim losses and restoration that is required to return injured resources to baseline conditions. The State will then estimate the cost of the projects based on preliminary project designs – full engineering designs are not feasible or appropriate to develop during the assessment process.

Finally, in addition to service-to-service scaling, the State may use a value-to-value scaling approach to assess the total value equivalency (TVE) of groundwater damages. Using this approach, the State Trustees will conduct a survey with stated-choice questions to determine public preferences for various types of restoration alternatives. This will aid the State Trustees in evaluating the benefits of restoration alternatives and provide additional input into the selection of alternatives. In addition, the study will provide value-based, as opposed to service-based, methods to determine the appropriate scale of potential restoration actions.

Anticipated activities to assess groundwater damages by TVE include:

- ▶ Developing restoration options to offset groundwater injuries at the Arsenal
- ▶ Conducting qualitative survey research such as focus groups and structured individual interviews to aid in the development of the TVE survey
- ▶ Developing the survey instrument, including peer review of the survey and the implementation process
- ▶ Administering the survey to a relevant segment of the population
- ▶ Analyzing and reporting the data.

Using the TVE approach, groundwater damages will be based on both lost active use values and lost passive use values.

Wildlife injuries and damages

Prior to implementation of the cleanup, much of the wildlife habitat at the Arsenal was contaminated with elevated concentrations of hazardous substances, resulting in widespread wildlife mortality. Contaminants found in soils, surface water, and sediments included the toxic pesticides aldrin, dibenzochloropropane, dieldrin, endrin, and isodrin. Prior to remediation, aldrin and dieldrin were detected in surface soils across much of the Arsenal property (Figure S.4). Most soils in the central processing and disposal areas (see Figure S.2) contained pesticide concentrations exceeding ecological risk thresholds. As a result, approximately 1.5 million cubic yards of contaminated soils were excavated and landfilled as part of the implemented remedy at the Arsenal.

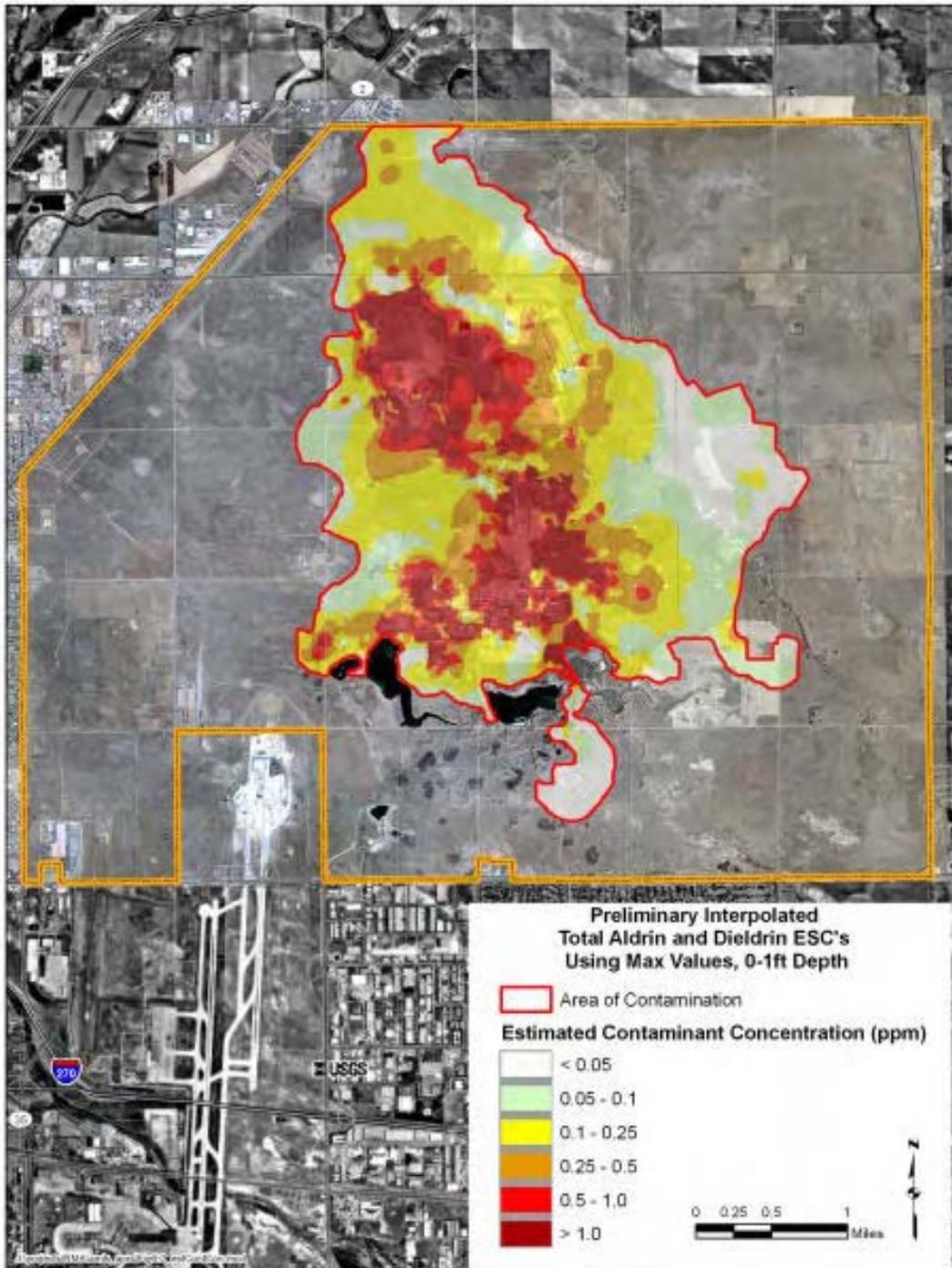


Figure S.4. Organochlorine pesticides such as aldrin and dieldrin were widespread in Arsenal soils before remediation.

To determine and quantify injuries to biota as a result of these hazardous substance releases, the State Trustees will employ multiple methods, including:

- ▶ Identifying Food and Drug Administration (FDA) action level exceedences and/or State and federal consumption advisories. Existing data indicate some exceedences of FDA action levels in Arsenal biota. Consumption of fish caught in Arsenal lakes has been banned since 1984. The 1989 Federal Facility Agreement banned consumption of all Arsenal wildlife.
- ▶ Compiling evidence of wildlife mortality. Existing documents describe thousands of bird and mammal carcasses found at the Arsenal, including over 1,800 waterfowl carcasses in Basin F alone between 1981 and 1988.
- ▶ Developing food web models to estimate injuries to biota. Toxicology studies can be used to determine oral doses of contaminants that cause adverse effects to biota. Food web models will allow estimates of toxic doses of contaminants in wildlife based on contaminant concentrations in soils. Injury thresholds in soils will be developed using these food web models.
- ▶ Estimating injuries that have occurred as a result of response actions. Response actions at the site have resulted in harm to wildlife habitat by heavy machinery, intentional eradication of prairie dogs, and reduction in burrowing animal habitat resulting from constructed biota barriers.

As part of this assessment, the State Trustees will compile existing data from Arsenal documents and from the Rocky Mountain Arsenal Environmental Database. Food web models developed during the Superfund remedial investigation will be updated as appropriate to reflect current scientific understanding. The State Trustees may undertake the following additional work to determine and quantify injuries and damages to biological resources:

- ▶ Revise and update bioaccumulation and dietary toxicity models
- ▶ Address the additive toxicity of organochlorine pesticides such as aldrin and dieldrin
- ▶ Assess injuries to biological resources from exposure to metalloids such as arsenic
- ▶ Assess injuries to biological resources associated with perennial and intermittent surface water and associated sediments
- ▶ Assess injuries to reptiles, amphibians, fish, and bats.

The State Trustees will quantify the spatial and temporal extent of injuries to biological resources and their supporting habitat. Damages will be assessed based on the cost to restore equivalent resources over space and time. The State Trustees will use habitat equivalency analysis or REA to first quantify injuries in terms of lost habitat or lost resource services, then scale restoration projects such that they provide the equivalent amount of habitat or resource service gain.

The State will consider restoration projects from existing regional restoration plans (e.g., from the Northeast Greenway Corridor project) and solicit proposals from State agencies such as the Division of Wildlife, interested nonprofit organizations, and the general public when identifying a list of potential restoration projects. Such projects would benefit the resources that have been injured at the Arsenal. Specific types of restoration projects may include:

- ▶ Preservation of existing habitats at risk to development
- ▶ Restoration and enhancement of existing degraded habitats
- ▶ Preservation of protective buffers for core areas of high wildlife value.

After determining the required size of proposed restoration projects, the State will estimate the cost to implement these projects. Costs will be based on preliminary project designs. Total cost estimates will include project design, implementation, monitoring, continued operation and maintenance, contingencies, Trustee oversight, and adaptive management.

Air injuries and damages

Depending on availability of data, the State Trustees plan to evaluate injuries to air resources incurred during the Basin F IRA in 1988 and 1989. Attempts to excavate and air-dry Basin F sludges released noxious odors to surrounding communities. From the summer of 1988 through the spring of 1989, the Army received 200 odor complaints from nearby citizens. Many people reported adverse effects such as headaches, burning and watering eyes, nausea, and vomiting. Local residents reported that they avoided the outdoors and shut their windows, regardless of the weather. The foul odors and adverse health effects constituted an injury to the State's air resources.

Injuries to air resources will be quantified in terms of lost air services. A REA-type service-to-service scaling approach may be evaluated to quantify damages to air resources. Under this approach, the State would identify air restoration projects that could provide the equivalent of the air resource services lost as a result of the Basin F IRA.

Availability and public comment

The Assessment Plan will be available for public comment for 30 days following publication of a notice of availability in newspapers of statewide circulation. It can be accessed at <http://www.cdphe.state.co.us/hm/rma.htm>. An extension to the public comment period may be granted if requested and found to be reasonable and appropriate. Questions can be directed to vicky.peters@state.co.us or 303-866-5068; or jeff.edson@state.co.us or 303-692-3388. Comments can also be sent to:

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The Assessment Plan may be modified in the future. If a significant modification is made, the revised Plan will be provided to the public for comment.