1 THE SITE AND ITS CONTEXT

The environmental message of the Rocky Mountain Arsenal National Wildlife Refuge grows out of what has occurred on this site through history, and what it is becoming through restoration. For this reason, an understanding of the history of the site and its context—biological, cultural, and legislative—is crucial for planning and caring for the Refuge.

CULTURAL HISTORY

Stone flakes from spearheads and knives, fire-cracked rocks used for cooking, hammer and grinding stones dating between 3,500 B.C. and 1,000 A.D. are some of the evidence of prehistoric activities near the northern boundary of the Refuge. Even earlier, nomadic hunter-gatherers who migrated to North America between 40,000 and 12,000 B.C. camped at Henderson Hill. By the early 1500s, Apache tribes occupied the area, followed by the Comanches, Utes, Arapahoes, and Northern Cheyennes.

Eventually, ranchers, farmers, and homesteaders displaced Native American populations. From the mid-1800s, prairie settlers grazed cattle and raised crops such as corn and wheat. By the 1930s, approximately 200 families lived on the Refuge site. (See Figure 1.1.) Farmers played a major role in changing the landscape—and encouraging wildlife—by building ditches and lakes and introducing water.

Figure 1.1 The Egli Family lived and farmed on the site of the future Rocky Mountain Arsenal National Wildlife Refuge. (Photo courtesy of Egli Family.)

The outbreak of World War II radically changed the lives on these seemingly remote farms and ranches and the priorities of the whole country. Although there was controversy about the country entering into the war, once that decision was made, the nation was committed to victory. The Rocky Mountain Arsenal was built as a part of that commitment. Farmers and ranchers living on the site were asked to sacrifice their homes and farms for the sake of the war. Most of the residents cooperated as their contribution to the war effort. Construction of the Arsenal began June 1942.

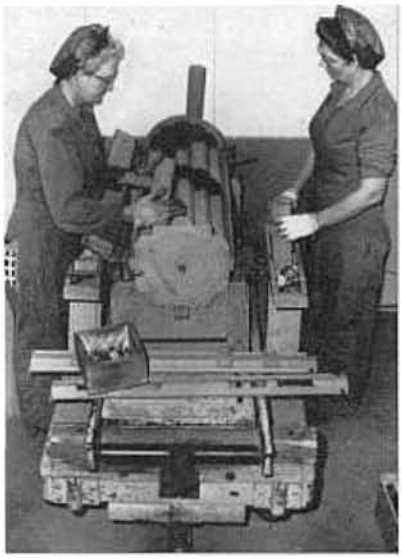


Figure 1.2 Workers place "goop" incendiary bombs in bomb clusters (Denver Post, 1952).

1942-Present

The United States had made only limited use of chemical weapons in combat. But, beginning in the 1920s and continuing until the recently concluded arms race, the possible deployment of these weapons by others forced the United States to engage in significant research and development programs for chemical weapons.

The concept of deterrent chemical weapons has been integral to America's overall military strategy throughout this century, but especially during the recent past. The United States produced massive quantities of a lethal nerve agent (German Brown), matched it with an effective delivery system, and advised the former Soviet Union that it had this capability. The Rocky Mountain Arsenal—as the only production source for this gas outside of the Soviet Union—had a significant role in national defense during the Cold War years.

When the United States entered World War II in late 1941, there was only one U.S. facility capable of manufacturing chemical agents. The need for additional arsenals had been recognized for some time and by 1942, facilities were under construction at Pine Bluff, Arkansas; Huntsville, Alabama; and Commerce City, Colorado. The site near Denver was selected because it could not easily be reached by enemy bombers, the necessary land—20,000 acres—was readily available, and it had easy access to railroads, power, and water.

Construction of the Rocky Mountain Arsenal was carried out at a feverish pace until completion on August 15, 1943. Costs totaled approximately $50 million.

There were two major chemical agents manufactured at the Arsenal during World War II: mustard gas and Lewisite. Chlorine gas was also manufactured because it was used in making both mustard gas and Lewisite. All of the process intermediates and additives, including acetylene, thionyl chloride, arsenic trichloride, sulfur monochloride, and mercuric chloride were also produced at the Arsenal.

Neither Lewisite nor mustard gas was used by the United States during World War II. But, the Germans knew of the American ability to use these agents. Crude mustard was a mixture of

The historical discussion here is drawn largely from *An Interpretive Plan for the Rocky Mountain Arsenal National Wildlife Refuge* by the National Park Service, 1995.

approximately 70 percent dichloroethyl sulfide and 30 percent sulphur and other sulfur compounds.

In addition to producing chemical agents during the war years, the Arsenal also produced and filled incendiary bombs, used with enormous effect against both Germany and Japan (Figure 1.2). The bombs were filled with napalm gel, white phosphorous, and phosgene. On March 9 and 10, 1945, U.S. forces dropped more than 1,500 tons of these weapons—all produced at the Arsenal—on Tokyo. The resulting firestorm devastated much of the city. By the end of the war, the Arsenal had produced more than 100,000 tons of incendiary bombs.

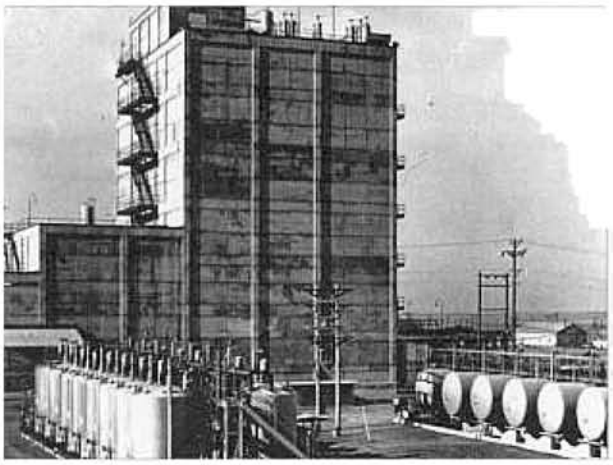


Figure 1.3 The North Plants nerve gas facility was in production from 1953 through 1969 (Denver Post, 1954).

The Chemical Warfare Service (CWS) faced a difficult decision when the war ended. The CWS recognized that the reduced need for chemical agents and incendiary bombs would result in a vastly reduced budget. Alternatives, including "mothballing" the Arsenal, were discussed, but the CWS finally decided that it would be best to lease the facility to commercial operators who could provide maintenance and improvements. This option would allow the facilities to remain in operating condition in the event of another national emergency, in which case the plant could be reclaimed by the U.S. Government.

Shell Oil Company was the major commercial operator at the Arsenal's South Plants. Shell assumed the existing lease from Julius Hyman and Company in 1952 and produced agricultural chemicals, including pesticides, until 1982.

Cold War tensions, exacerbated by the North Korean invasion of South Korea, resulted in the Arsenal being reactivated. During the conflict, white phosphorous-filled bombs, artillery shells with distilled mustard, and incendiary cluster bombs were manufactured. Of greater significance, though, was the decision to begin manufacturing at the Arsenal a highly toxic chemical product, known generically as nerve agent.

Through interviews with German military and scientific personnel, the U.S. Army learned that the Germans had discovered a five-step process for producing nerve agent during World War II. Even more ominous, the Soviet Union also had the German technology and had operating plants.

In response, the U.S. Government had the Vitro Corporation design and build a nerve agent manufacturing plant at the Arsenal. The facility, known as North Plants, consisted of 103 structures situated on a 90-acre complex. It started production in 1953 and continued intermittently until 1969 (Figure 1.3). (During this same period, Shell continued their manufacture of pesticides at the South Plants.)

The safe disposal of chemical agents and the destruction of munitions filled with these products was another aspect of the Arsenal's mission. This work started in the 1950s, but accelerated considerably following a 1968 Presidential Directive

mandating the destruction of obsolete chemical weapons. The Arsenal was chosen as the site for demilitarization of obsolete nerve and mustard gases, partly because of the expertise in the demilitarization operations already developed by Denver personnel, and partly because of the superior facilities located at North Plants. Under "Project Eagle," destruction of bulk mustard gas started in 1971. Following four years of research and development, the Arsenal began a three-year demilitarization program.

The Rocky Mountain Arsenal also contributed to the space program. Between 1961 and 1982, the rocket fuel known as "Aerozine-50" was produced. The U.S. Air Force used this product to fuel Titan missiles, and NASA used it in the U.S. Space Program.

Figure 1.4 While an environmental cleanup agreement was being negotiated, a number of interim cleanup activities resolved some of the most urgent contamination problems.

The waste products from chemical manufacturing at the Arsenal were allowed to drain into natural basins. In 1956 the Army constructed its first lined basin—Basin F—primarily for the liquid wastes from nerve gas production.

Concern about contaminated ground water migrating to adjacent community water systems intensified over the decades and by the 1970s the Colorado Health Department ordered the Army and Shell to stop polluting the water. By the early 1980s, the principals—including the Department of the Army, the Environmental Protection Agency, the State of Colorado, and Shell Oil Company—found their differences irreconcilable and filed suit against each other in Federal district court. In 1988, an interim Consent Decree was signed by all parties, except the State of Colorado, which defined their roles in the cleanup as well as apportioning costs. Besides controlling ground water migration and collecting and analyzing data, a cleanup strategy was selected for Basin F.

In 1995, all of the parties with a say in cleaning up the Arsenal reached a consensus on a solution for remediation. That plan has been presented to the public and a Record of Decision will be issued to announce the selection of final remedial alternatives. Components of the plans include:

- Continued operation of the groundwater treatment systems that are currently in place cleaning groundwater.
- Demolishing and disposing on-site of existing buildings with no future use.
- Placing some structural debris as fill in Basin A.
- Excavating, landfilling, capping, containing, or solidifying some soils, depending on location and quality.
- Constructing a wildlife barrier over selected sites to prevent burrowing animals from penetrating the caps.

The Rocky Mountain Arsenal is internationally significant for its role in weapons technology, particularly as the only manufacturing facility for German Brown nerve agent outside of the former Soviet Union. Its designation as a Superfund site, and the innovative technology developed there in response to the unique cleanup problems has influenced the discussion of hazardous materials and their impact on communities on a national level as well.

LEGISLATIVE FRAMEWORK

The construction and operation of the Arsenal and its security measures over a 40-year period provided a safe haven for a variety of wildlife on the edge of a major metropolitan area. The importance of this was recognized in the early 1990s. Once cleanup has been completed, the current 17,000 acres will be managed by the U.S. Fish and Wildlife Service as a wildlife refuge, in accordance with the Rocky Mountain Arsenal National Wildlife Refuge Act of 1992.

The Refuge Act of 1992 specifies eight purposes for which the Refuge is being established. (See Table 1.1.) The second purpose pertains primarily to bald eagles which winter at the Arsenal. It also includes ferruginous hawks and swift fox, which are candidate species. Conserving and enhancing naturally occurring species (purpose 6), as well as conserving and enhancing those other—non-native—species attracted to the site because water and vegetation were introduced, are equally important (purposes 1 and 7).

National wildlife refuges are the only federal lands managed primarily to provide habitat for the many diverse species of wildlife. Although land management for the benefit of wildlife is a function common to all refuges, individual refuges have been established under many different authorities and funding sources and for a variety of purposes. The purposes for establishing a particular refuge are specified in the authorizing document for that refuge. Each refuge has one or more primary purposes. These purposes guide the establishment, design, and management of the refuge.

The Service's efforts to manage a national wildlife refuge and determine which uses are permitted at a specific location are guided by each

Table 1.1. The Rocky Mountain Arsenal National Wildlife Refuge Act of 1992 specifies eight purposes for which the Refuge is being established:

1. *To conserve and enhance populations of fish, wildlife, and plants within the Refuge, including populations of waterfowl, raptors, passerines [songbirds], and marsh and water birds.*

2. *To conserve species listed as threatened or endangered under the Endangered Species Act and species that are candidates for such listing.*

3. *To provide maximum fish-and-wildlife-oriented public uses at levels compatible with the conservation and enhancement of wildlife and wildlife habitat.*

4. *To provide opportunities for compatible scientific research.*

5. *To provide opportunities for compatible environmental and land use education.*

6. *To conserve and enhance the land and water of the Refuge in a manner that will conserve and enhance the natural diversity of fish, wildlife, plants, and their habitats.*

7. *To protect and enhance the quality of aquatic habitat within the Refuge.*

8. *To fulfill international treaty obligations of the United States with respect to fish and wildlife and their habitats.*

refuge's specific purposes and three broadly applicable laws—the Refuge Recreation Act of 1962, the National Wildlife Refuge System Administration Act of 1966, and the Endangered Species Act of 1973. Other laws and authorities considered in approving the use of refuge lands for various activities include the Wilderness Act of 1964, the Migratory Bird Treaty Act of 1918, the National Environmental Policy Act of 1969, the National Historic Preservation Act of 1966, Executive Order 11988 (Flood Plain Management), Executive Order 11990 (Protection of Wetlands), and Executive Order of 1994 (Environmental Justice).

The broad goals of the National Wildlife Refuge System also form part of the framework for planning each refuge. These goals are to:

- Preserve, restore, and enhance in their natural ecosystems (when practicable) all species of animals and plants that are endangered or threatened with becoming endangered;
- Perpetuate the migratory bird resource;
- Preserve a natural diversity and abundance of fauna and flora on refuge lands; and
- Provide an understanding and appreciation of fish and wildlife ecology and man's role in his environment and to provide refuge visitors with high quality, safe, wholesome, and enjoyable recreational experiences oriented toward wildlife to the extent these activities are compatible with the purposes for which the refuge was established (Figure 1.5).

Figure 1.5 One of the goals of the National Wildlife Refuge System is to provide visitors with high quality, safe, wholesome, and enjoyable recreational and educational experiences oriented toward wildlife.

Refuge Recreation Act

The Refuge Recreation Act of 1962 (16 U.S.C. 460 *et seq.*) was enacted in response to the growing public use of refuges. The Act was the first to establish the "compatibility" standard for use of refuge lands. This Act requires that any recreational use of refuge lands be compatible with the primary purpose(s) for which a refuge was established and not inconsistent with other previously authorized operations or the primary objectives of the area. The Act further requires the Secretary of the Interior to determine that sufficient funds are available to manage these recreational activities before a particular use is permitted.

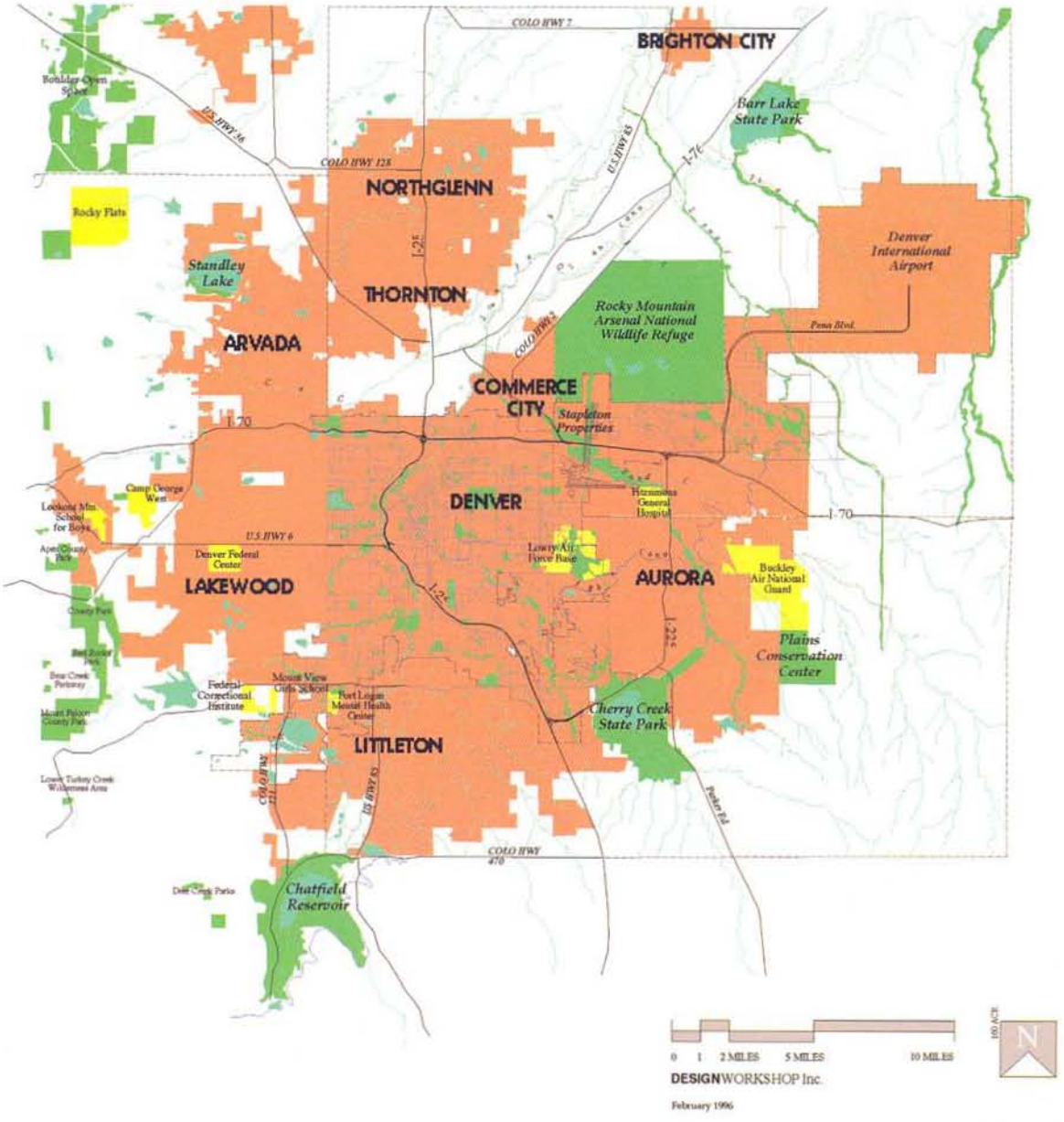
National Wildlife Refuge System Administration Act

The National Wildlife Refuge System Administration Act of 1966, as amended (16 U.S.C. 668dd *et seq.*), defined the Refuge System as it is known today. The act consolidated the various categories of lands administered by the Secretary of the Interior through the Service for the conservation of fish and wildlife into a single National Wildlife Refuge System. This consolidation brought together wildlife refuges, areas for the protection and conservation of fish and wildlife threatened with extinction, wildlife ranges, game ranges, wildlife management areas, and waterfowl production areas.

Urban Development
State/Federal Institution
Open Space/Parks

REGIONAL LOCATION
(Map 1.1)

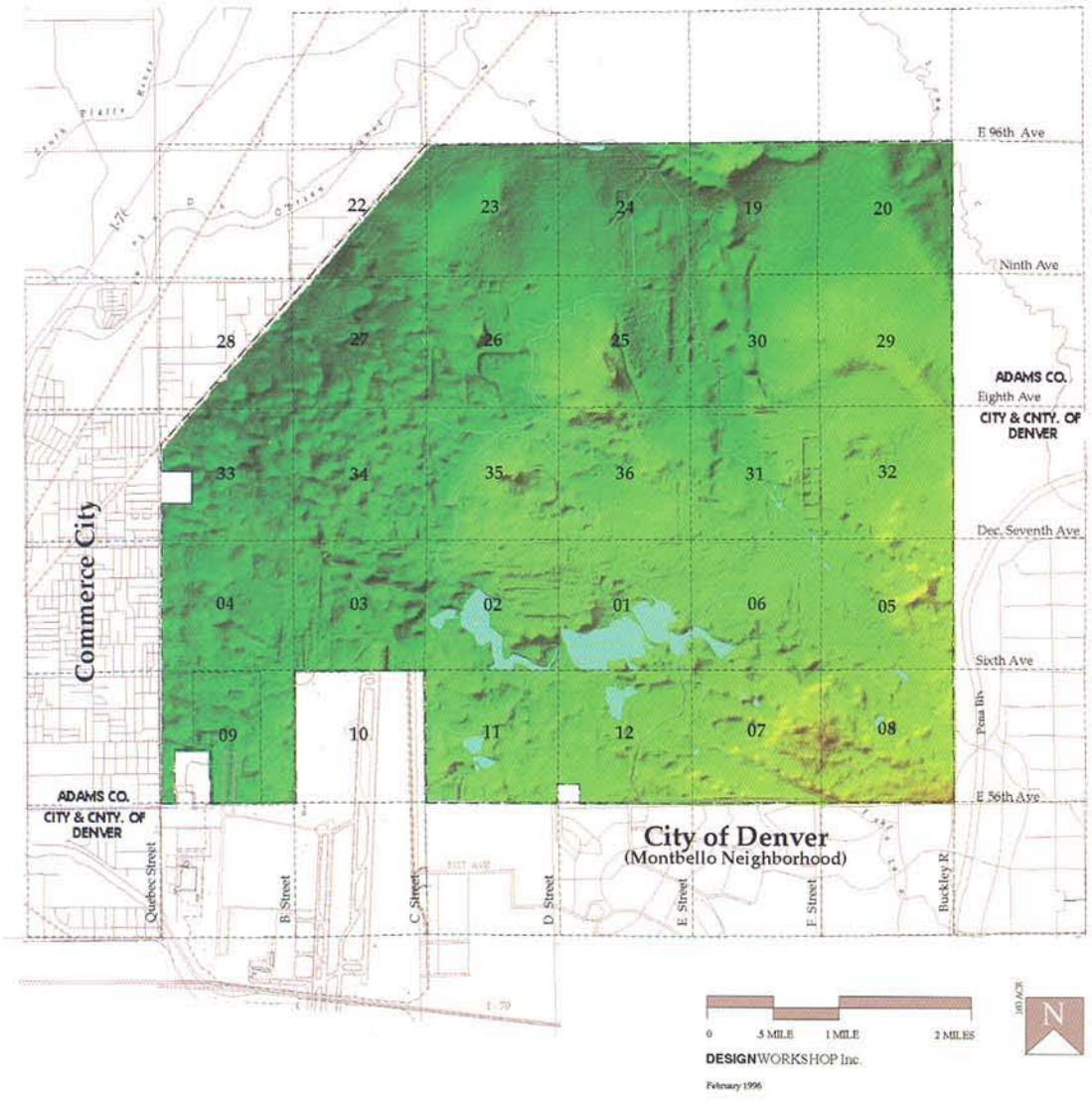
Source:
Design Workshop, *Denver Parks Study*, 1993



Highest Elevation
Lowest Elevation

BASE MAP
(Map 1.2)

Source:
GIS Elevation Map from 2 foot contours, Orthophoto mapping by Geonex Delta Aerial Surveys, June 1989.



The Refuge Administration Act reinforced and expanded the compatibility standard. It authorized the Secretary of the Interior to "permit the use of any area within the System for any purpose including, but not limited to, hunting, fishing, public recreation and accommodations, and access whenever he or she determines that such uses are

Figure 1.6 The Endangered Species Act of 1973 directs the Service to emphasize endangered and threatened species, such as this bald eagle.

compatible with the major purposes for which such areas were established."

Endangered Species Act

The Endangered Species Act of 1973, as amended, directs the Service to emphasize endangered and threatened species (Figure 1.6), in both acquiring and operating all refuges. Under the Act, the protection, enhancement and recovery of endangered and threatened species are to receive priority consideration in managing national wildlife refuges.

Environmental Justice

In 1994, President Clinton signed an executive order requiring federal agencies to address the effects of federal actions on minority and low-income populations. The Rocky Mountain Arsenal National Wildlife Refuge is urban, with potential users coming primarily from the Denver metro area, portions of which consist of minority and low-income populations.

PHYSICAL ENVIRONMENT

Geology and Soils

The Refuge is located in the Denver Basin, which is a north-south fold in the regional geology that extends along the Front Range from Cheyenne, Wyoming to Colorado Springs, Colorado (See Map 1.1 Regional Context). Surface geologic deposits consist primarily of unconsolidated river sediments (alluvium) deposited by the South Platte River system and covered partially by wind blown (eolian) sediments. The uppermost bedrock layer is called the Denver formation. This layer was originally 900 feet thick, but has eroded completely at nearby South Platte River areas, and is 500 feet thick at the southeast corner of the Refuge (Morrison-Knudsen 1988). The Denver formation is composed of stratified layers of clay, sandstone, shale, siltstone, and coal. Below the Denver formation are numerous sedimentary geologic strata such as sandstones and shales. The Pierre shale formation is found at depths of 1,200 to 1,700 feet below the surface. This formation is about 6,200 feet thick.

Surface topography resulted from river and stream erosion associated with the South Platte River and its tributaries (Map 1.2 Base Map). The land shape varies from almost level to gently rolling with slopes typically less than 3 percent and terrace escarpments with slopes up to 10 percent. Wind-deposited material is thickest in the

south and southwest sections of the Refuge (Walsh 1991). Elevation ranges from 5,138 feet along the northwest boundary to 5,250 feet at southeastern boundary. Rattlesnake Hill and Henderson Hill are prominent high points located in the central and northeastern portions of the Refuge (respectively).

Soils developed from both wind- and water-deposited material (Map 1.3 Soil Series). Soils formed from water transported material are derived from shales, sandstone, and granite.

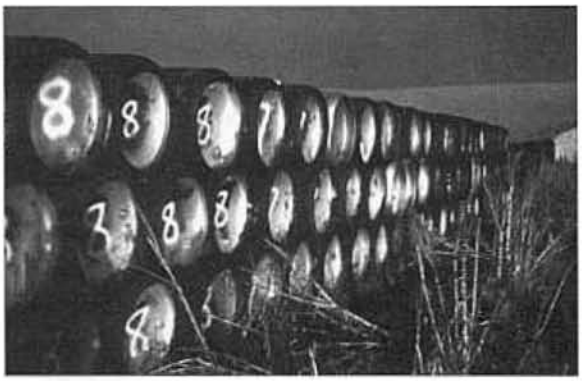


Figure 1.7 Most areas of soil contamination are found in the center of the Refuge and are currently the focus of cleanup operations.

These soils are generally of clay to loam texture, although cobbly material occurs on hills in the northern portion of the Refuge (Walsh 1991). Soils developed in wind deposited material are typically sandy in texture. Throughout the Refuge, soils formed under grassland vegetation are typically dark colored with high organic matter content.

Bresser is the most common soil series on the Refuge. These soils occur on sandy wind deposited plains in the southwestern and southern portions of the Refuge. Bresser soils are deep and well-drained with medium to coarse textures. Weld series soils also occur extensively in the northeastern portion of the Refuge. These soils are formed from alluvial and wind deposited material and have fine to medium textures. Ascalon soils are found on old alluvial terraces, escarpments and eolian plains in the central and northern areas of the Refuge. Satanta soils are similar to Ascalon but are finer textured. The well-drained Nunn soils are found in moderate distribution over the north and east portions of the Refuge. The coarse sandy textured Truckton soils are found to a limited extent in the south and west portions of the Refuge; they are highly susceptible to wind erosion. Aquic Haplustolls are deep, poorly drained soils occurring primarily along First Creek (Walsh 1991).

Disturbed areas on the Refuge include borrow pits, sedimentation and effluent basins, and fill areas. Areas of soil contamination occur in the central portion of the Refuge and are currently the focus of cleanup operations (Figure 1.7).

Refuge soils are subject to wind and water erosion. The Nunn and Satanta soils are the most susceptible to water erosion. Truckton, Bresser, and Ascalon soils have the greatest potential for wind erosion when vegetation is removed. Revegetation potential is moderate for most soils on the Refuge, although some soils may have revegetation limitations due to slope, water holding capacity, or depth.

Water Resources

Surface Water Hydrology

The Refuge is within several drainage basins that are tributary to the South Platte River, which is located less than two miles northwest of the Refuge (Map 1.4). These basins include Irondale

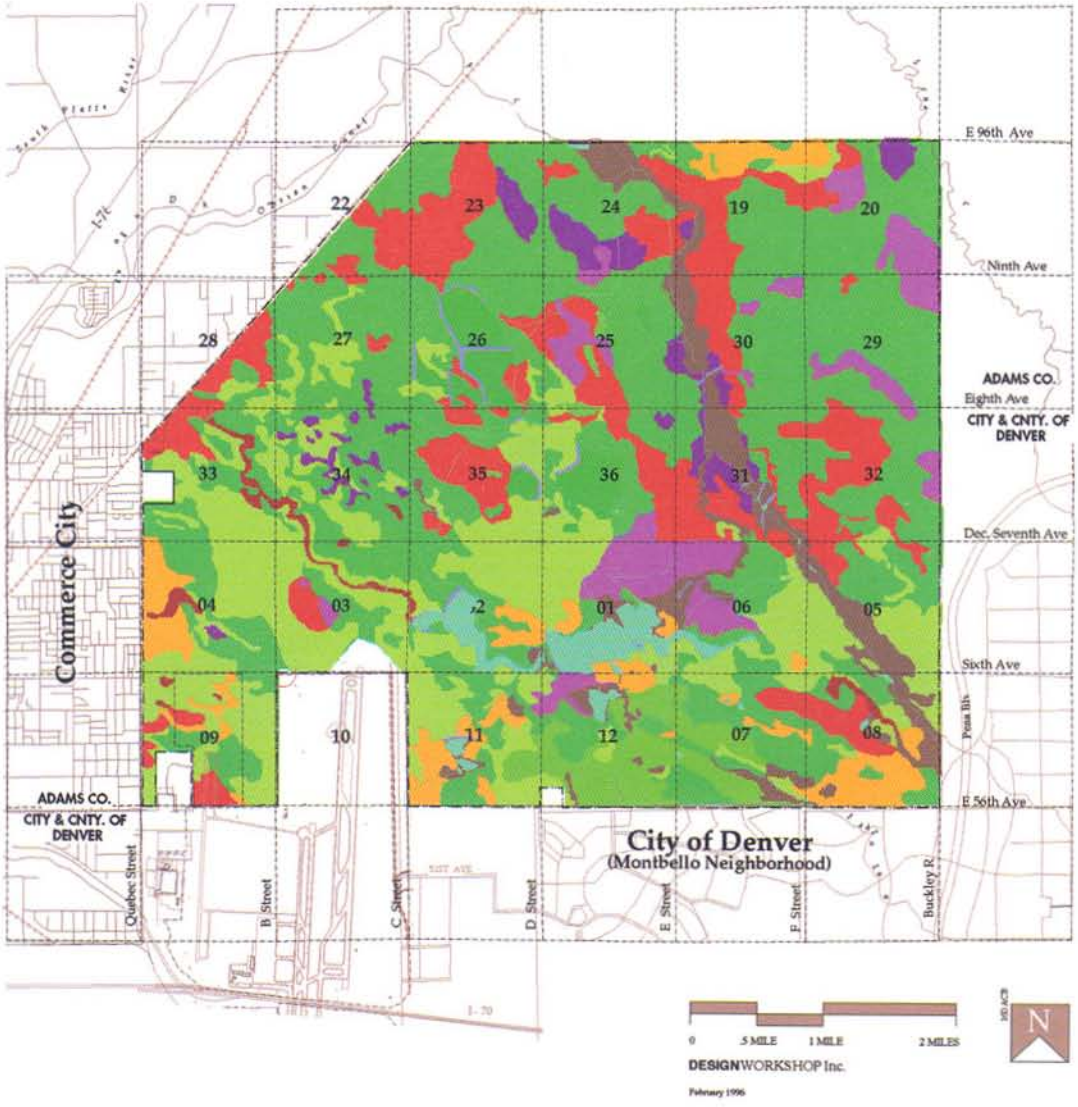
SOIL SERIES
(Map 1.3)

Ascalon Sandy Loam	As
Bresser Sandy Loam	Br
Bresser-Satanta Sandy Loam	Bs
Nunn Clay Loam	Nu
Satanta Loam	Sa
Weld Loam	We
Truckton Loamy Sand	Tr
Petrocalcic Paleustolls	Ca
Aquic Haplustolls	Fa
Typic Haplustolls	Th

Water
Basins
Dams/Dikes

Railroads
Streams
Section Lines
Refuge Boundary

Source: Morrison Knudsen Corp.



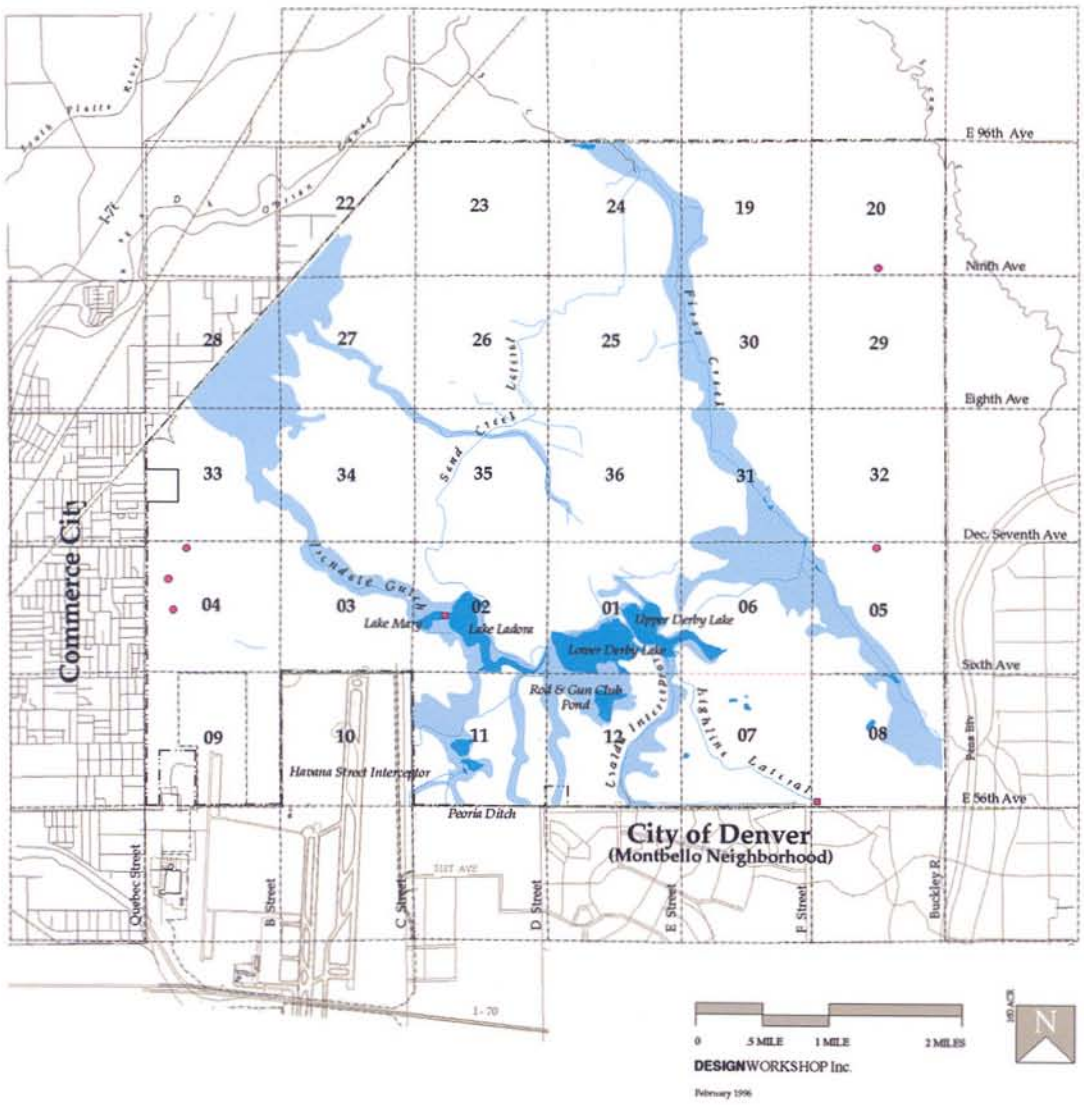
WATER RESOURCES
(Map 1.4)

100 Year Floodplain
Lakes, Ponds, Wetlands

Wells
Siphons

Streams & Ditches
Section Lines
Refuge Boundary

Source:
Digitized from figure RISR A1.5-2 in final, remedial investigation Summary Report, Appendix A



DESIGNWORKSHOP Inc.

February 1996

Gulch, First Creek, Second Creek, and several small areas that originally drained directly into the South Platte River. Due to human alterations, some of these last areas now are tributary to either Irondale Gulch or First Creek. The Irondale Gulch and First Creek basins cover more than 91 percent of the total Refuge area.

At the Refuge, water flows primarily through a network of ditches and lakes. Flows within the drainage basins of the Refuge have been greatly modified by the construction of a number of diversions (laterals) and drainage channels (interceptors). Two of the more distinct drainage features, the Sand Creek lateral and the Upper Derby Lake overflow, can transport water from Irondale Gulch to the adjacent First Creek basin.

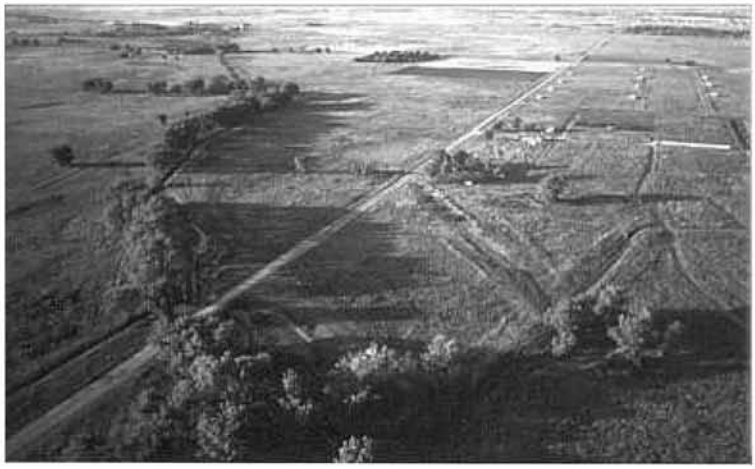


Figure 1.8 Within the Refuge, First Creek flows northwesterly for about 5.5 miles in a relatively straight channel. Headcutting of the streambed is occurring in some areas because the channel has been straightened.

Surface water originates from direct precipitation, runoff, inflow from drainage basins to the south and southeast, and ground water. All surface flows are intermittent, with streamflow occurring as a result of runoff, released or diverted flow, or direct precipitation. Localized flooding occurs from thunderstorms that produce high intensity rainfall. For drainages without diversions and inflows from controlled releases, highest monthly flows occur in late spring to early summer and lowest flows occur in winter. Daily and monthly streamflows vary widely. A large proportion of surface flow onto the Refuge is lost due to ground water seepage, evaporation and vegetation transpiration.

Prior to 1942, most of what is now the Refuge was used for agricultural purposes. Ditches and reservoirs were built to transport and store irrigation water. When the Arsenal was established by the Army, additional water impoundments were constructed and water was used primarily for industrial purposes. Irrigation and process water supplies were obtained from the Highline Canal, from which the lakes were filled. Surface water is currently used for cleanup and remediation of contaminated areas and for Refuge purposes, such as wildlife management and fishing. Expanding land development upstream of the Refuge for residential, commercial, and industrial purposes has increased runoff onto the Refuge.

The Irondale Gulch drainage basin encompasses the largest area of the watersheds on the Refuge. The majority of the basin is upstream of the Refuge and contains industrial and residential development. Generally, most of the basin is not channelized, although storm runoff channels have been constructed in developed areas south of the Refuge to direct flow onto the Refuge. Within the Refuge, the drainage basin contains four lakes (Upper and Lower Derby, Ladora and Mary), two ponds (Havana, and Rod and Gun Club), four drainage interceptors (Uvalda, Peoria, Havana

and Randolph Tributary), two laterals (Sand Creek and Highline), and several wetlands, as well as numerous smaller natural drainage conduits and manmade ditches. Six collection basins (Basins A, B, C, D, E, and former Basin F) are located in the portion of the Refuge that originally drained directly into the South Platte River.

The First Creek drainage basin (Figure 1.8) is long and narrow, with much of its area located upstream of the Refuge. Most of the basin is undeveloped. Within the Refuge, the creek flows northwesterly for about 5.5 miles in a relatively straight channel, with a slope of about 0.5 percent. Headcutting of the streambed is occurring in some areas due to manmade channel straightening. Surface flow is intermittent and averages approximately 900 acre-feet per year. Some parts of the creek flow most of the time and some rarely. Continuous surface flow occurs after major storm events. First Creek fluctuates between gaining water from ground water and losing water to ground water. For First Creek, however, ground water is the major source of water supply (Stollar and Associates 1990). Until recently, the Highline Canal has also been a source of supply to First Creek, as are several other ditches and channels on the Refuge.

Other small drainage basins within the Refuge include: the Second Creek drainage basin, which crosses the Refuge at its very northeast corner; and the southwestern and northwestern corners of the Refuge, which drain directly into the South Platte River. The Second Creek basin is mostly undeveloped. The creek is intermittent and has a well-defined channel.

The southwestern corner encompasses most of Stapleton Airport north of Interstate 70, all of Section 9 and portions of Sections 3 and 4 of the Refuge. Due to the sandy soils and sparse development, there is little, if any, surface runoff from this basin.

The northwestern drainage basin does not contain a distinct channel and is characterized by a large number of natural depressions, including Basins A-F. This basin on the Refuge is largely undeveloped, and confined by the Burlington Northern railroad embankment. No surface water discharges from this basin.

Upper Derby Lake, which can receive inflow from the Highline Canal and the Uvalda Interceptor, covers 83 acres at its full storage capacity of 460 acre-feet of water. Upper Derby Lake (Figure 1.9) is currently empty pending cleanup. Lower Derby Lake can receive inflow directly from the same sources or from Upper Derby; its normal pool storage volume is 550 acre-feet with a surface area of 73 acres.

Lake Ladora receives water primarily from Lower Derby Lake and secondarily from Havana Pond. The western tier wells also deliver water to Lake Ladora. These wells are located on the western side of the Refuge within the 815 acres of the Arsenal to be auctioned. A permanent easement would grant continued use of these wells as a supplemental water supply for Lake Ladora. Its storage capacity is 400 acre-feet, with a surface area of 48 acres. Lake Mary is located directly west of Lake Ladora. It receives a regulated water supply from wells, Lake Ladora, and a potable water storage tank. Lake surface area is 9 acres at a normal pool storage volume of 60 acre-feet. These lakes were all constructed for various purposes. Rod and Gun Club Pond was excavated in a natural topographic depression south of Lower Derby Lake (Stollar and Associates 1990). The pond receives runoff within its small basin and overflow from Lower Derby Lake and the Uvalda Interceptor. The pond covers an area of about 4.9

Figure 1.9 Upper Derby Lake (foreground) is currently empty, while Lower Derby (background) is filled.

acres when full and has a volume of about 15 acre-feet. There is a large marshy area around the pond.

Six basins used for the retention of process water, waste water, or storm runoff were constructed during operation of the Arsenal. These basins are natural topographic depressions that have been supplemented by berms and other structures. Basin A is the largest of these collection basins (240 acres). It was used for many years to store liquid process wastes. Most runoff collects in low areas and causes local ponding. Basin F, which was a primary disposal site for liquid and chemical wastes for many years, has been recontoured and no longer captures surface runoff.

Surface and ground water flows are connected at the Refuge. Within the First Creek drainage, surface water typically discharges to ground water at the south boundary, while at the north boundary and beyond, ground water discharges to First Creek. In general, ground water discharges to the lakes at their east to southeast sides and is recharged by the lakes to the north and northwest sides. Ground water is the main water source for Rod and Gun Club Pond. A net discharge of ground water to surface water occurs at Lake Ladora, and Lake Mary to Upper Derby Lake when dry. A net loss to ground water occurs in First Creek, Lower Derby Lake, Upper Derby Lake (when filled), Havana Pond, and the Uvalda Interceptor (Stollar and Associates 1990).

Ground Water Hydrology

The Refuge is within the Denver ground water basin. Surficial stream and wind deposited soil contain water, as do several bedrock aquifers. Unconsolidated deposits cover nearly all of the Refuge and are underlain by the sedimentary Denver formation. Shallow ground water flow occurs primarily in the unconsolidated deposits, but also in the weathered outer layer of the Denver formation. The thickness of the shallow aquifer varies from less than 20 feet under the disposal basins and South Plants area (where a bedrock mound rises close to the surface) to 70 feet in bedrock valleys in which unconsolidated materials have been deposited. Water levels range from less than 5 feet below ground surface in the area of the lakes, Basin A, and First Creek to more than 60 feet on the west side of the Refuge. Ground water level fluctuations are generally less than 2 feet. Ground water flows to the north and northwest.

Previous human activities and cleanup operations have altered the water table and flow direction in local areas. These changes include the

boundary containment and treatment systems, recharge from surface water impoundments, and depression due to well pumping. A ground water mound underlying South Plants creates flow in every direction away from the area. Ground water flows to the west beneath at least two of the lakes. The shallow aquifer is recharged from precipitation and surface water and discharges to surface water (principally to the South Platte River). It is also recharged from and discharges to the Denver Formation aquifer.

The Denver Formation aquifer is separated from the shallow alluvial flow system by relatively impermeable shale or claystone. The Denver Formation, 200 to 500 feet thick under the Refuge, contains water-bearing layers of sandstone and siltstone in poorly defined, irregular, interconnected beds that range in thickness from a few inches to 50 feet. Ground water flow in the Denver Formation is toward the northwest. A small amount of recharge occurs from the overly unconfined aquifer and from bedrock outcrops, which occur in only a few locations. Discharge from the Denver Formation occurs by lateral flow into the unconfined aquifer and by leakage to the underlying Arapahoe bedrock aquifer.

Surface Water Quality

Both off-site and on-site sources of contamination have adversely affected the surface water quality on the Refuge. Chemical constituents can be introduced into a channel or lake in either dissolved and/or particulate form via runoff, discharge from poor quality ground water or windblown deposition of particulates directly into the water. Inorganic constituents may be naturally occurring or from manmade sources, while organic constituents are from manmade sources, such as runoff from developed areas or past industrial manufacturing of chemical compounds at the Arsenal.

In the Irondale Gulch basin south of the South Plants area, surface water is the principal migration pathway for pesticides and other organic compounds, as well as arsenic, mercury, cyanide, and trace metals. Some organic compounds were also detected in ditches entering the Refuge from residential and industrial areas to the south and in ditches originating in the South Plants area. Other compounds are likely to have both off-site and on-site sources, while some are likely to be only from past activities at the Arsenal. Compounds detected in ditch sediments were similar to those in surface water, except that heavier trace metals were found.

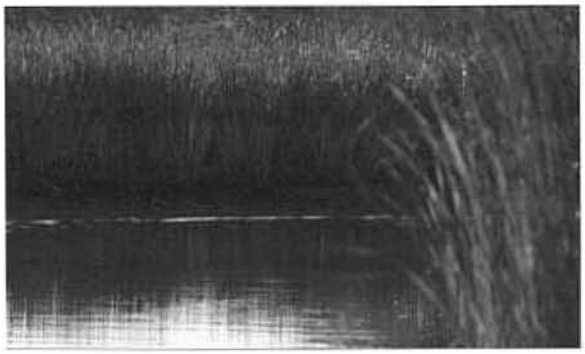


Figure 1.10 Water quality of the major lakes and ponds is typically quite high, with only isolated organic and trace inorganic compounds detected in the water and lake bottom sediments.

In contrast to stormwater flowing onto the Refuge, water in Refuge lakes and ditches in the Irondale Gulch basin generally have low concentrations of organic and inorganic compounds. The water quality of the major lakes and ponds on the Refuge is typically quite high, with only isolated organic and trace inorganic detections in the water and lake bottom sediments (Figure 1.10). It may be that dilution, settling, and infiltration of

constituents are responsible for the relative absence of pollutants downstream of the stormwater inflows to the Refuge. The high alkalinity of the surface water also may act to effectively remove toxic heavy metals.

Classes of compounds detected in surface water in the South Plants area include many types of organic compounds, some of which are pesticides and nerve-gas related compounds. Trace metals detected in this area are generally higher in concentration than near the southern boundary, indicating an on-site source. Surface water is a significant transport mechanism for contaminants in this area.

Lands east of First Creek on the Refuge exhibit minimal contamination of surface water. First Creek, however, has detectable levels of organic compounds throughout its length on the Refuge and north of the Refuge. It also has elevated concentrations of calcium, magnesium, potassium, sodium, chloride, fluoride, sulfate, nitrate, and arsenic. Sources of arsenic may include the Refuge sewage treatment plant and off-site sources. Organic compounds and metals also have been detected in stream bottom sediments. Sediment contamination does not appear to be directly related to surface water contamination. Some organic compounds are entering First Creek from sources upstream of the Refuge; however, some were also manufactured at the Arsenal.

Surface water samples collected from Basin A have consistently contained organic compounds, pesticides, and arsenic. Elevated concentrations of sodium, fluoride, mercury, calcium, and cadmium have also been detected. Sediments in Basin A also are contaminated with organic compounds and heavier trace metals. The South Plants area is the principal source of contamination to this as chemical wastes were discharged into Basin A. Surface water flowing north from the South Plants area contains high concentrations of many organic compounds and arsenic. Trace metals detected in the water and sediments in Basin A are higher in concentration than at the south boundary of the Refuge, indicating Arsenal activities were the likely source. Water in the collection basins generally does not exit the Refuge as surface flow.

In the Sand Creek basin outside the Refuge, one pesticide compound occasionally has been detected in surface water. No other organic or inorganic compounds have been detected within the basin.

Ground Water Quality

The largest areas of contaminated ground water are in the north, central, and western parts of the Refuge and occur as spatially distinct contaminant plumes. The plumes contain one or more contaminants migrating together through the shallow aquifer. Migration has resulted in the merging of contaminant plumes from individual source areas.

A zone of high level contamination exists within the shallow ground water flow system from the South Plants area through Basins A, C, and F to the north boundary containment system. High concentrations also occur from South Plants north to Basin A and south towards Lower Derby Lake. Other contaminated areas include the North Plants area and the western part of the Refuge. These plumes contain elevated concentrations of various organic compounds, such as pesticides and hydrocarbons, as well as inorganics such as arsenic, mercury, trace metals, chloride, and fluoride.

One plume extends from the South Plants tank farm to Lake Ladora and Lower Derby Lake. This plume is driven by a ground water mound under

South Plants and is inhibited from migrating by maintaining the lakes at the approximate level of the local water table. Control of these lake levels also drives other ground water contaminant plumes toward the boundary containment systems for treatment.

Distinct contaminant plumes have not been identified in the bedrock aquifers at the Refuge, but detections in bedrock water indicate that vertical migration pathways exist between shallow ground water and deeper water. Sources of ground water contamination include contaminated surface water and waste water, chemical sewer leakage and contributions from solid waste burial sites. At the north and northwest boundaries of the Refuge, contaminated shallow ground water is being removed, treated, and returned to the flow system downgradient of the boundaries. Ground water intercept-and-treat systems also are located at Basin A, Basin F, and at the Rail Classification Yard and Motor Pool within the Refuge.

Climate and Air Quality

Climate at the Refuge is considered semi-arid, with low relative humidity, intense sunshine, and wide variations in seasonal and daily temperatures. The average high temperature in January is 43°F and the average low is 16°F. Highest temperatures occur in July with an average high of 88°F and average minimum temperatures of 59°F. Precipitation generally ranges from 12 to 16 inches annually, with 80 percent occurring between April and September. May is the wettest month and averages 2.5 inches. January is the driest month with an average of 0.5 inches.

Winds follow a daily pattern of flowing from the south at night and from the north during the day. Wind speeds at the Refuge average 8.7 miles per hour. Strong winds are common throughout the year, but March and April are the windiest months with the greatest potential for dust storms (Woodward Clyde 1992).

The Denver metropolitan area experiences chronic carbon monoxide, ozone, and particulate matter air pollution as well as visibility problems. Major sources of pollutants are thought to come from motor vehicles, industry, wood burning, and agricultural operations. Climatic and topographic conditions also contribute to air quality problems in the region. Denver's high elevation and abundance of cloud free days are conducive to production of ozone. Temperature inversions prevent atmospheric mixing and results in the accumulation of pollutants. Stable atmospheric conditions that are favorable for accumulation of pollutants occur throughout the year, but primarily in the winter. The Refuge is located in a non-attainment area for ozone, carbon monoxide, and extremely fine particulates (PM-10). Non-attainment indicates that the state standards for pollutants are not being met.

Air quality on the Refuge has been monitored since 1988 to determine ambient air quality levels and potential air pollution from cleanup activities (Woodward Clyde 1992). Monitoring of criteria pollutants–sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone–indicates air quality at the Refuge is generally better than most Denver area sites. Through 1991, there had been no violation of applicable air quality standards at the Refuge. The plume of urban air pollutants occurs primarily within the South Platte River drainage basin (City of Denver 1988). The Refuge is located on the periphery of the most polluted area. Periods of increased air pollutants at the Refuge are generally attributable to Denver metropolitan sources.

There are two primary sources of total suspended particles (fine dust particles): particulates from the Denver metro area and remedial cleanup actions that generate dust (Woodward Clyde 1992). The contribution from remediation activities is generally localized and short-term. Particulate levels on the northern and eastern boundaries of the Refuge are well below Denver's and similar to rural conditions. The concentration of PM-10 particulates (extremely fine dust particles) at the Refuge are related to dry windy conditions, and from sources in metro Denver. Current remediation and construction activities at the Refuge do not contribute substantially to PM-10 concentrations.

Air quality monitoring for metals, organic compounds, and pesticides also has been conducted at the Refuge (Woodward Clyde 1992). Maximum metal concentrations typically occur during windy periods when particulate concentrations are high. Remediation activities are believed to contribute to metal concentrations. The presence of organic compounds at the Refuge appears to be related mostly to off-site sources, although remediation activities also may be a source. The primary source of pesticides is believed to be agricultural sources north of the Refuge, although cleanup activities also appear to have contributed to pesticide concentrations.

Noise

The Refuge is located on the northeastern edge of the Denver metropolitan area. Noise levels at the Refuge vary widely with location. Noise on the western and southern perimeter of the Refuge is dominated by sounds from commercial development, traffic, and residential areas. Historically, Stapleton Airport generated very high noise levels in the southern and western portion of the Refuge from adjacent take-off runways. Relocation of the airport to the new Denver International Airport (DIA) east of the Refuge has reduced noise levels greatly in the western portions of the Refuge. Noise contours of up to 60 decibels from one DIA runway extends into a small portion of the eastern side of the Refuge (City of Denver 1988). Noise levels on the eastern side of the Refuge have increased with local and DIA vehicle traffic on Buckley Road and Peña Boulevard. The northern boundary of the Refuge is primarily agricultural land, with traffic from 96th Avenue being the primary noise source.

Noise levels within the interior of the Refuge are very similar to rural conditions, except for aircraft noise. Traffic within the Refuge is restricted, and there is limited public vehicle access. Remediation activities that involve the use of heavy equipment results in elevated noise levels during periods of operation. Noise sources within the Refuge generally are concentrated to specific areas of activity at buildings, cleanup operations, and along roadways. Many areas within the Refuge have very low background noise levels with a minimum of human activities or disturbance.

BIOLOGICAL ENVIRONMENT

Vegetation

Most of the vegetation on the Refuge (Map 1.5) has been altered by human activities. Agricultural practices, industrial activities, cleanup operations, and current wildlife management operations all have played a role in creating the existing compo-

sition of Refuge vegetation. There are, however, small areas of remnant native vegetation.

The Refuge occurs within the western edge of the High Plains that extend through the midwest U.S. Prior to settlement, the area was covered by warm-season, shortgrass prairie vegetation. Blue grama and buffalo grass were dominant perennial grasses in the predevelopment ecosystem. These species were well adapted to the semi-arid environment and periods of drought. In moister sites, green needle grass, side-oats grama, little bluestem, and Sandberg bluegrass were likely common. Sandy soils developed in wind blown sediments and historically supported sand sagebrush, needle-and-thread grass, sand dropseed, prairie sandreed, sand bluestem, switchgrass, and Indian ricegrass. Bottomlands often supported stands of switchgrass and big bluestem. Perennial forbs common prior to development varied with soil and topographic position, and included American vetch, prairie clover, silvery lupine, prairie cone flower, prairie aster, and evening primrose. Annual native forbs may have included plantain, prairie pepper grass, western ragweed, and narrowleaf goosefoot (Morrison-Knudsen 1989a).

Before establishment of the Rocky Mountain Arsenal in 1942, much of the native vegetation had been removed. Historical data from 1937 indicates non-irrigated dryland farms covered much of the Refuge area (Morrison-Knudsen 1989a). Irrigated cropland occurred on approximately 2,000 acres in the northern and western sections of the Refuge. Although native grassland and shrubland occurred in scattered locations throughout the Refuge in 1937, most of the native vegetation had been disturbed before industrial activities.

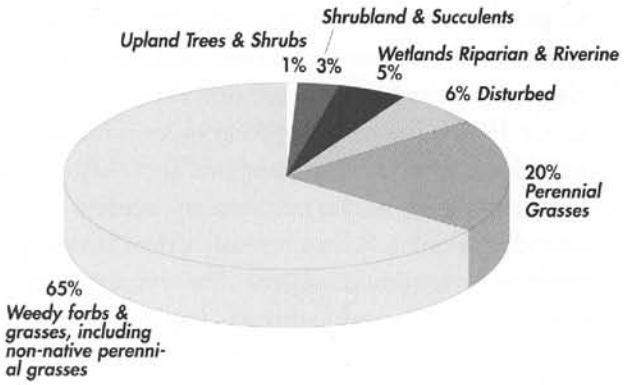


Figure 1.17 Current vegetation types at the Rocky Mountain Arsenal National Wildlife Refuge.

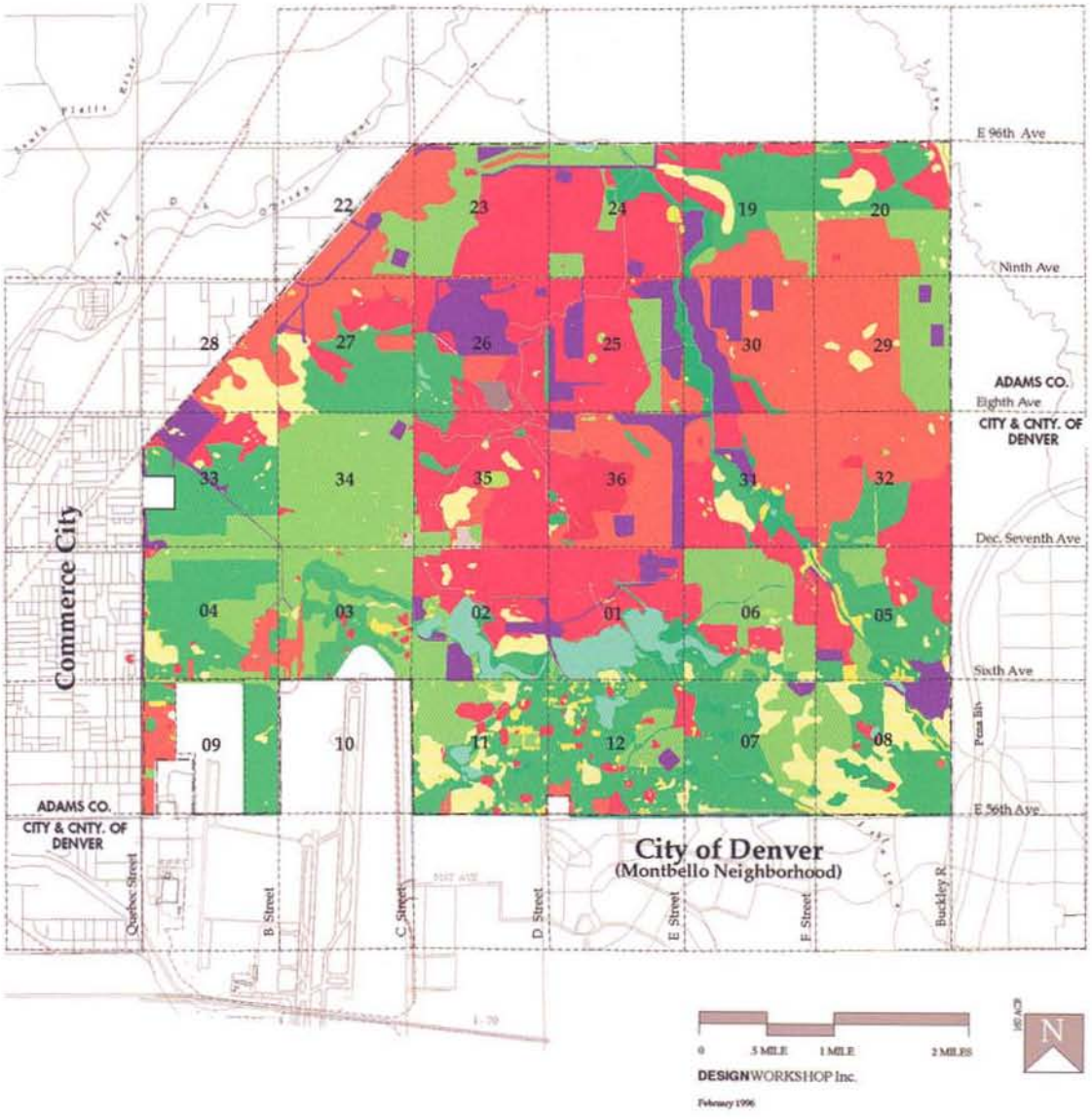
Historically, native trees were found primarily along drainages, with additional plantings of non-native and native trees around homesteads. Riparian trees before settlement included plains cottonwood, peachleaf willow, and occasional boxelders and hackberries. The wettest sites were dominated by cattails and bulrushes. Understory vegetation in the riparian plant communities contained choke cherry, golden currant, wild plum, hawthorn, yellow Indian grass, and slender wheatgrass. Native shrubs historically occurring on the Refuge were fringed sage, sand sage, rabbitbrush, broom snakeweed, and winterfat. Saline bottomland areas contained alkali sacaton, inland salt grass, and western wheatgrass (Morrison Knudsen 1989a).

There are six primary vegetation types currently found on the Refuge (Figures 1.11 - 1.16). They are weedy forbs and grasses; native perennial grasses; wetlands, riparian and riverine; shrubland and succulents; upland trees and shrubs; and remnant vegetation. Their percentages of cover are shown in Figure 1.17.

VEGETATION
(Map 1.5)

- Unclassified
- Research
- Bare
- Alfalfa/Sweetclover
- Cereal Rye
- Cobble Soil Veg
- Seeded Area
- Lawn Area
- Tree Grove
- Wetlands
- Locust Thicket
- Crested Wheatgrass
- Shrublands/Succulents
- Native Perennial Grasses
- Cheatgrass/Weedy Forb
- Weedy Forb
- Water
- Railroads
- Streams
- Section Lines
- Refuge Boundary

Source:
Interpreted from Vegetation Classification from 1:2400 Aerial photographs dated 1989-1992 and Morrison Knudsen



VEGETATION DISTRIBUTION
(Map 1.6)

- Weedy Forbs & Grasses
- Native Perennial Grasses
- Major Disturbed Areas
- Lacustrine
- Wetlands
- Riparian / Riverine
- Shrubland/Succulents
- Upland Trees
- Streams
- Section Lines
- Refuge Boundary

Source:
Interpreted from Vegetation Classification from 1:2400 Aerial photographs dated 1989-1992, Morrison Knudsen Corp.

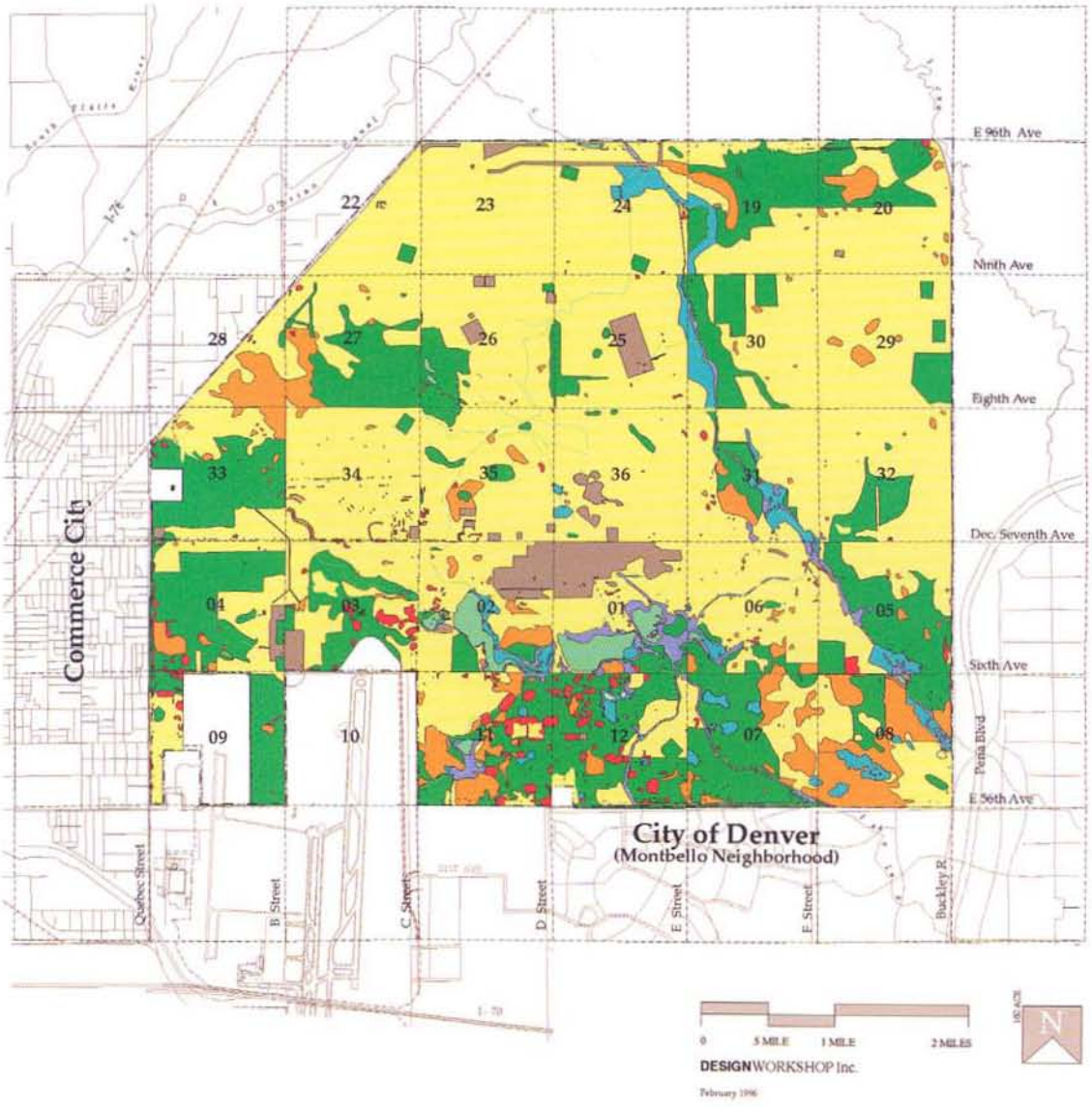


Figure **1.11** Perennial Grasses

Figure **1.12** Shrublands and succulents

Figure **1.13** Remnant Vegetation Areas

Figure **1.14** Wetland, Riparian, and Riverine Plant Communities

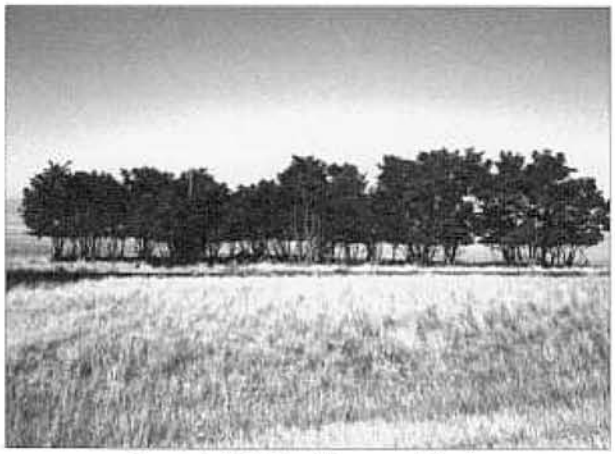


Figure **1.15** Upland Trees and Shrubs

Figure **1.16** Weedy Forbs and Grasses

Weedy Forbs and Grasses

The weedy forb and grass vegetation type is the most widespread. Morrison-Knudsen (1989a) mapped four different types of weedy vegetation:

Weedy Forbs.

The weedy forb type is the most common vegetation type on the northern two-thirds of the Refuge. This vegetation type was established following land disturbing activities, and may be perpetuated by prairie dogs that selectively graze perennial grasses (Morrison-Knudsen 1989a). This type is dominated by annual and biennial forbs and is found on 16 percent of the Refuge. Common species include cheatgrass, summer cypress (kochia), field bindweed, prickly lettuce, and tansy mustard. Areas mapped as weedy forb include a few native forbs and grasses such as scarlet globemallow, sunflower, and red three-awn. There are very few woody or succulent plants found in this vegetation type.

Cheatgrass and Weedy Forb.

This is the most extensive vegetation type, with about 20 percent of the Refuge supporting a mixture of cheatgrass and weedy forbs. Cheatgrass represents about two-thirds of the plant cover in this type. Principal weedy forbs include field bindweed, musk thistle, and prickly lettuce. Cheatgrass has become established throughout the Refuge.

Cheatgrass/Perennial Grass.

This type represents a mixture of annual and perennial grasses and occurred on 10 percent of the Refuge by 1989. Cheatgrass was the dominant vegetation cover (58 percent), followed by perennial grasses (28 percent). Common native perennial grasses included sand dropseed, red three-awn, and needle-and-thread grass. This type represents areas where native grasses have not been completely replaced by weedy species. These areas may be in successional transition to native perennial grasses (Morrison-Knudsen 1989a).

Crested Wheatgrass.

Crested wheatgrass is not considered a weedy species. It is an introduced species imported from Eurasia for erosion control. This species was planted in various locations on the Refuge throughout the years to reclaim disturbed areas. Currently, crested wheatgrass covers 19 percent of the Refuge. This species often occurs in relatively pure stands, but other species found in this unit include cheatgrass, sand dropseed, and field bindweed. Yucca and prickly pear cactus also occur to a limited extent in this type. Stands of crested wheatgrass typically are replaced by native perennial grasses over time (Morrison-Knudsen 1989a).

Perennial Grasses

Native perennial grasses are scattered throughout the Refuge. About 20 percent of the Refuge is covered by this type in stands from less than a tenth of an acre to about 500 acres. Native grass cover averaged 57 percent in 1989, with weedy vegetation (mostly cheatgrass) providing the rest of the cover. Perennial grasslands are remnants of the original grasslands that have survived or escaped disturbance from farming, grazing, and industrial activities.

Composition of the native grassland communities varies with soil, topographic position, and previous disturbance. Blue grama and buffalo grass occur on loamy soils in the northern and west-central portions of the Refuge. On coarser

textured soils of this type, needle-and-thread grass, sand dropseed, and red three-awn are present. Western wheatgrass occurs on finer textured soils in east-central and northern areas. Sandy wind deposited soils support stands dominated by sand dropseed, and needle-and-thread grass, although prairie sandreed, sand bluestem, and Indian ricegrass also are present.

Bottomlands along First Creek support several native perennial grasses including western wheatgrass, slender wheatgrass, and Canada wild rye. Numerous weedy species are also found in these moist locations. There are several small cobbly areas on hills in the central and northern areas of the Refuge that support stands of native grasses such as side-oats grama, ring muhly, and Sandberg bluegrass.

Woody and succulent plants also occur in varying densities in perennial grasslands. Prickly pear cactus was the most common followed by bushy eriogonum.

Shrubland and Succulents

Several shrub or succulent dominated communities are found on the Refuge. These communities occur primarily in association with various grassland types. Shrubland and succulents represent about 3 percent of the vegetation types on the Refuge.

Sand Sagebrush.

Sand sagebrush occurs on sandy upland sites in the southern portion of the Refuge. Needle-and-thread grass and prairie sandreed are the most common native grasses in this type, while cheatgrass is the most abundant weedy grass. Areas of sand sagebrush possibly escaped plowing due to the unsuitability of the soils for farming.

Rubber Rabbitbrush.

Rabbitbrush occurs on scattered upland hills in the eastern and southern parts of the Refuge. Only about 0.3 percent of the Refuge is covered in this vegetation type. Associated herbaceous vegetation is primarily cheatgrass and several perennial grass species, including sand dropseed and red three-awn. It is likely these areas were established as a result of overgrazing.

Yucca Grassland.

Yuccas do not occur as a community by themselves, but in association with mixed grassland vegetation. This type is found in the northwestern and south-central areas of the Refuge. Common associated vegetation includes cheatgrass, needle-and-thread grass, red three-awn, sand dropseed, and blue grama. Yuccas are most common on sandy shallow soils along low ridges.

Locust Thickets.

New Mexico locust thickets are found on about 0.5 percent of the Refuge and are most common in the southern portion. Locusts form dense thickets with 88 percent cover and an understory of cheatgrass. Locust stands probably were planted as windbreaks or for game cover.

Wetland, Riparian and Riverine Plant Communities

Riparian plant communities occur on approximately 5 percent of the Refuge. Streams and bottomland areas where moister conditions exist provide habitat capable of sustaining varied plant communities.

Cottonwood-Willows.

Plains cottonwood and peachleaf willow are the principal tree species occurring along

drainages, canals and reservoirs. This community was found on the Refuge prior to settlement, but has expanded due to additional water features. This vegetation type is most developed along the First Creek drainage. Understory species are currently dominated by smooth brome, with a subdominant presence of cheatgrass, slender wheatgrass, Canada wild rye, and Kentucky bluegrass.

Bottomland Meadow.

Bottomland meadows are found in moist soils near drainages, reservoirs and canals. Species composition varies widely between locations, with weedy forbs the most common. Representative species include barnyard grass, lady's thumb, horseweed, prickly lettuce, and showy milkweed. Canada thistle, a noxious weed, is present at nearly all sites. Disturbance to these areas eliminated native grasslands, which likely were dominated by big bluestem, and slender and western wheatgrass.

Cattail Marsh.

Cattail areas typically occur in almost pure stands in the wettest locations along streams, ditches and reservoirs. An increase in water features on the Refuge likely has increased the presence of this vegetation type.

Upland Trees and Shrubs

There are a variety of ornamental trees and shrubs scattered throughout the Refuge. The majority of these are found in the southern half, where it was planted near homesteads and as windbreaks. Common species include Siberian and American elm, Russian olive, Rocky Mountain juniper, green ash, and various fruit trees.

Remnant Vegetation Areas

Several plant communities of special interest were identified in investigations conducted in association with cleanup operations (Morrison-Knudsen 1989a). These areas of remnant native vegetation are considered important due to their excellent condition, unique characteristics, or rarity. Areas of highest priority for protection and preservation include:

- Sand prairie grassland–This plant community is rare regionally and statewide. Sand bluestem, prairie sandreed, and bush morning-glory are the key species distinguishing this site.
- Shortgrass prairie grassland–This 200-acre native prairie is dominated by blue grama, needle-and-thread grass, and buffalo grass. This site provides a seed source for revegetation of other sites and important wildlife habitat.
- Sand sagebrush shrubland–Several areas of sand sagebrush are found in the central and southeast parts of the Refuge. Other vegetation found in this type includes ball and hedgehog cactus, blue grama, and prairie sandreed.
- Gravel breaks–Remnants of a South Platte River terrace such as those found on Rattlesnake Hill support species found at no other location on the Refuge. Vegetation on these cobbly sites includes Fendler three-awn, side-oats grama, Sandberg bluegrass, yellow violet, salt and pepper, and broom snakeweed.
- Mature cottonwoods–The large mature cottonwoods found along First Creek provide excellent nesting and roosting habitat for raptors and a variety of migratory birds, and serve as cover for deer and most other mammals.

Figure 1.18 Before settlement, the plains ecosystem provided habitat for a variety of species such as fox (above) and badger (below) that are now rarely seen.

Wildlife and Fisheries

The Refuge supports a variety of wildlife and fish species common to the presettlement plains ecosystem (Figure 1.18), as well as several introduced or exotic species that were not historically present. There are also several species that are native to the plains ecosystem that no longer occur on the Refuge. Several of these species are being considered for reintroduction.

Wildlife Populations

There are a number of wildlife species that are more common on the Refuge than other regional habitats. The most abundant include mule and white-tailed deer, coyotes, prairie dogs, bald eagles, ferruginous hawks, and burrowing owls. Deer populations have increased due to a variety of factors including the perimeter fence, the abundance of weedy forbs, suitable cover, relatively low human disturbance, and the absence of hunting. Ferruginous hawks and bald eagles benefit from the large population of prairie dogs and favorable habitat. Coyotes also benefit from numerous prairie dogs and other small mammals. Burrowing owls take advantage of prairie dog burrows for nesting. Ring-necked pheasants have thrived in grassland habitats in the absence of hunting, although pheasant populations often experience population fluctuations periodically. Western meadow larks, grasshopper sparrows, vesper sparrows, and horned larks also are more common on the Refuge than similar off-site habitat.

Important areas of habitat for selected species as may be seen on Map 1.7 Wildlife Habitat-Winter and Map 1.8 Wildlife Habitat-Spring, Summer, Fall.

Before settlement, the plains ecosystem provided habitat for a variety of species including bison, pronghorn antelope, prairie dogs, coyotes, foxes, badgers, and rabbits. It also provided habitat for a variety of small mammals, birds, reptiles, and amphibians. Conversion of the native grasslands to agricultural lands and subsequent industrial development followed by invasion of non-native plant species has resulted in a substantial shift in the composition of wildlife species, numbers and distribution.

Following cleanup, the Refuge will be the largest contiguous block of undeveloped land within the Denver metropolitan area. The Refuge currently supports a significant concentration of

prairie dogs, bald eagles, burrowing owls, and other raptors (hawks, falcons, owls, and eagles) along the Front Range. In addition, the Refuge provides a significant source of habitat for a substantial population of deer, migratory birds, and small mammals.

The importance of the Refuge to the region, particularly for migratory bird species, will continue to increase with development along the Front Range in the Denver metropolitan area. The Refuge's large, 27-square mile area supports species and communities associated with the once expansive plains grasslands that have been long in decline due to agricultural and urban development (Map 1.6 Vegetation Distribution). Many of the remaining areas of native grassland or undeveloped land have been fragmented by cropland, roads, housing, and commercial development. The diversity of habitat found on the Refuge provides a unique setting for maintaining, and establishing wildlife native to the region.

Figure 1.19 Great Blue heron are among the many bird species attracted to the Refuge.

Mammals

Deer are the most noticeable wildlife found on the Refuge. Two deer species are present–mule deer and white-tailed deer. Mule deer are the most common with a current population estimated at 530 animals. These deer are found throughout the Refuge. Mule deer populations have increased rapidly from a density of 8 per square mile in 1986 and 1987, to a 1995 population of 20 per square mile. The current density is higher than typical for most prairie habitats, and is due primarily to Refuge fencing in 1990. White-tailed deer are found typically in riparian and wooded areas with greater cover, such as along First Creek and the South Lakes area. Their current population is estimated at 200, up from the 1986-87 census of 56 (Morrison-Knudsen 1989b).

Other mammals also are found on the Refuge. Desert cottontail rabbits, the most abundant rabbits, usually are found in association with prairie dogs. Eastern cottontails generally are found in riparian areas or thickets. Black-tailed jack rabbits are common in the southwest portion of the Refuge (Jones et al. 1994). Plains pocket gophers are found throughout most of the Refuge, although they typically avoid prairie dog towns and areas of crested wheatgrass. The thirteen-lined ground squirrel is the most common ground squirrel. The spotted ground squirrel occurs where sandy soils exist in the western portion of the Refuge. A few fox squirrels inhabit woody riparian areas and upland tree groves. Muskrats are found at all lakes and ponds. No beavers have been found on the Refuge, although there is some evidence indicating beaver were once present.

Other small mammals found on the Refuge include deer mice, western harvest mice, prairie vole, silky pocket mice, and plains pocket mice (Boone and Preston 1994). The northern grasshopper mouse prefers native grasslands and yucca stands. Ord's kangaroo rat can be found in yucca dominated plant communities. Prairie and meadow voles favor areas with developed grass

and forb cover, and are an important part of the prey base.

Birds

Birds found on the Refuge include year-round residents, nesting species, and seasonal migrants. The most conspicuous of the grassland songbirds are the horned lark, western meadow lark, grasshopper sparrow, and lark bunting (Preston et al. 1994). Horned larks prefer areas of sparse vegetation such as prairie dog towns, while the western meadow lark is found in taller herbaceous vegetation. Various sparrows, such as the vesper sparrow, Cassin's sparrow, Brewer's sparrow, and lark sparrow, nest in grassland habitat (Preston et al. 1994). Grassland migrant species include various swifts, swallows, and sparrows.

Figure 1.20 Burrowing owls are the most numerous of the owls found at the Refuge.

Deciduous trees near buildings or old homesteads provide nest sites for northern flickers, western kingbirds, black-billed magpies, American robins, common grackles, European starlings, northern orioles, yellow warblers, and a variety of other species. Riparian woodlands that contain denser and more varied plant communities also support a similar composition of tree nesting birds. Riparian areas also attract spring migrants such as red-headed woodpeckers, dusky and willow flycatchers, and various thrushes, sparrows, and warblers. Cattail marshes bordering lakes, ponds, ditches, and streams provide valuable nesting habitat for red-winged blackbirds and common yellowthroats. Important migratory bird nesting habitat is concentrated along First Creek, area lakes, and in areas of wooded and shrubby vegetation.

Lakes, ponds, and streams on the Refuge provide a variety of habitat for waterfowl and shorebirds. The Refuge supports more waterbirds than historically occurred, since most of the lakes, ponds and associated wetlands were created following settlement. Canada geese are probably the most common waterbird found on the lakes. A variety of ducks are found on Refuge lakes during the spring and fall including mallards, northern pintails, gadwalls, American wigeons, teals, and many other species. Diving ducks that frequent lakes include canvasbacks, redheads, common goldeneyes, and buffleheads. Lake Ladora currently supports the highest waterfowl use.

Great blue herons are most frequently found near aquatic sites (Figure 1.19). Black-crowned night herons are also active around lakes and wetland sites. There are a number of shorebirds common at lake shores during the spring and fall including killdeer, American avocet, willet, greater yellowlegs, several sandpipers, and numerous others (Morrison-Knudsen 1989b). Herring and ring-billed gulls are the most common gulls found on the Refuge. American white pelicans have been observed on all Refuge lakes.

Ring-necked pheasants, a non-native species, were introduced to the Refuge for hunting during the 1960s and are still abundant. Mourning doves are common seasonally.

There are 16 species of raptors known to use the Refuge. Ferruginous hawks are winter

Figure 1.21 Yellow bellied Racer is one of the species of snakes found at the Refuge along with frogs, toads, and salamanders.

migrants that hunt in the open grassland habitats on the Refuge. Cooper's and sharp-shinned hawks are seasonal migrants that favor wooded areas, but no nests have been found to date. The Refuge also provides suitable habitat for American kestrels and prairie falcons that feed on small mammals and insects. Red-tailed hawks, Swainson's hawks, and northern harriers are seasonally common and all nest on the Refuge. Rough-legged hawks are found in open grassland habitat during the winter months.

There are five owl species found on the Refuge, the most numerous of which is the burrowing owl. Burrowing owls make use of abandoned prairie dog burrows for nesting (Figure 1.20). Great horned owls and long-eared owls also nest on the Refuge. Although uncommon, eastern screech owls use wooded habitat, and short-eared owls have been observed during migration.

Bald eagles winter on the Refuge primarily from November to March. Bald eagles roost in the large cottonwood trees on First Creek and feed primarily on prairie dogs and jack rabbits (USFWS 1992). The Service has established a bald eagle management area to restrict access to important eagle habitat during winter use periods.

Reptiles and Amphibians

Bullsnakes are the most common reptiles found on the Refuge (Figure 1.21). Relatively uncommon, the western hognose is found in sandy areas. Garter snakes can be found near water. Prairie rattlesnakes are present and very common. Only a few lizard species have been observed including lesser earless lizard, short-horned lizard, and many-lined skink.

The most abundant amphibian is the striped chorus frog, which breeds in shallow wet areas. The northern leopard frog and bullfrog occur primarily at Refuge lakes. Toads known to exist in the vicinity of water sources include the Plains spadefoot toad and Woodhouse's toad. Tiger salamander larvae are found in most wetland areas across the Refuge, whereas adults use mammal burrows.

Fish

Ladora, Mary, and Lower Derby lakes provide a source of water that supports viable fish populations. Bluegill, channel catfish, northern pike, and largemouth bass are the principal species. The Service currently manages these lakes for a catch and release fishery program. First Creek and other small ponds contain small fish populations such as fathead minnows. Mosquito fish are stocked annually in wetlands in the southern area of the Refuge to assist in control of mosquito larvae.

Threatened, Endangered, and Candidate Species

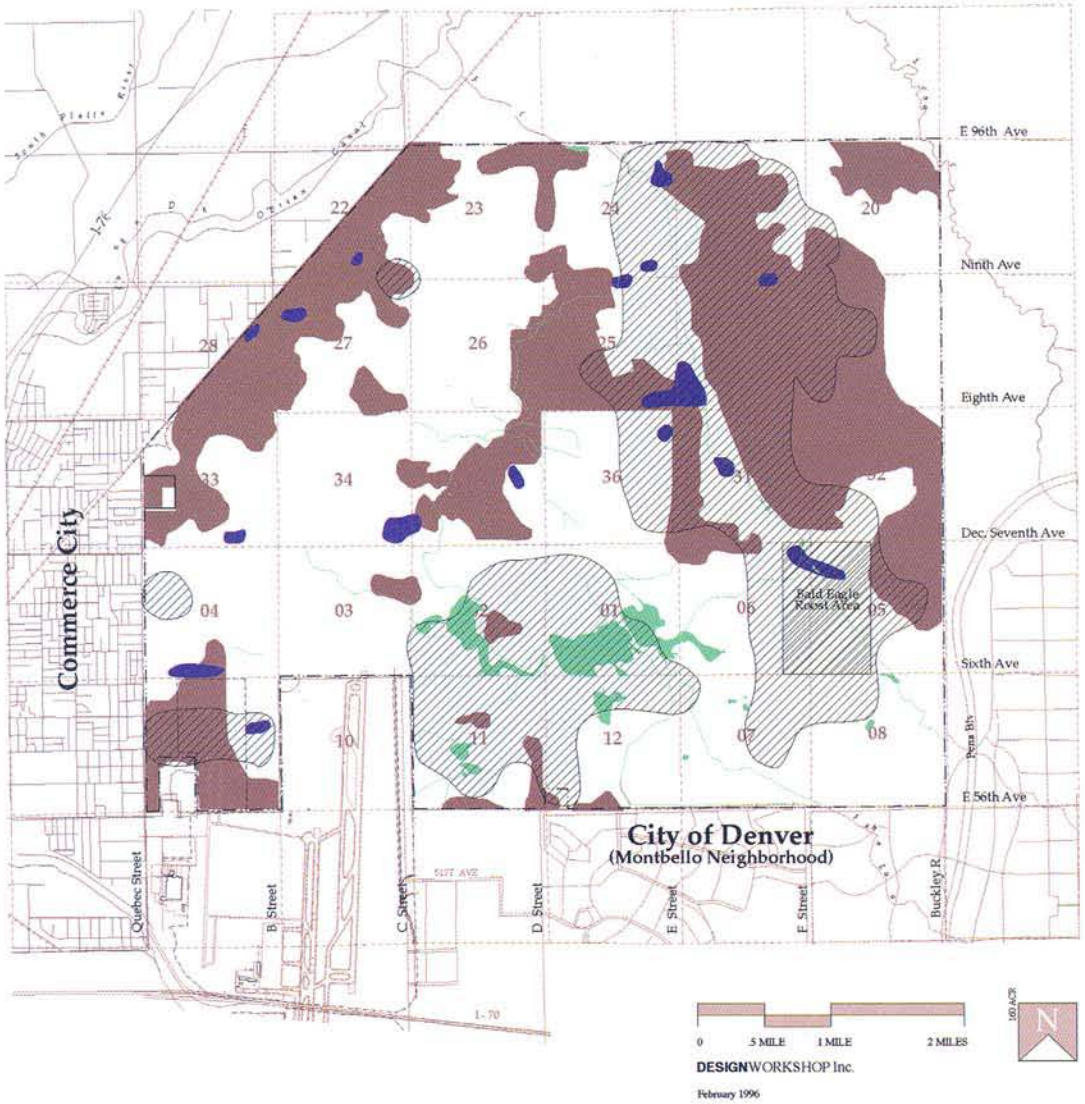
The Refuge provides habitat for several federally listed threatened, endangered and candidate plant and animal species. Candidate species are

SELECTED WILDLIFE HABITATS — WINTER *(Map 1.7)*

- Prairie Dog Colonies
- Ferruginous Hawk Winter Roost Sites
- Principal Roosting and Loafing Eagle Habitat
- Lakes

- Streams
- Section Lines
- Refuge Boundary

Source: U.S. Fish & Wildlife Service and Rocky Mountain Arsenal National Wildlife Area surveys
Note: The entire Refuge provides important foraging habitat for bald eagles and habitat for many other wildlife species and is important both on a local and regional basis.



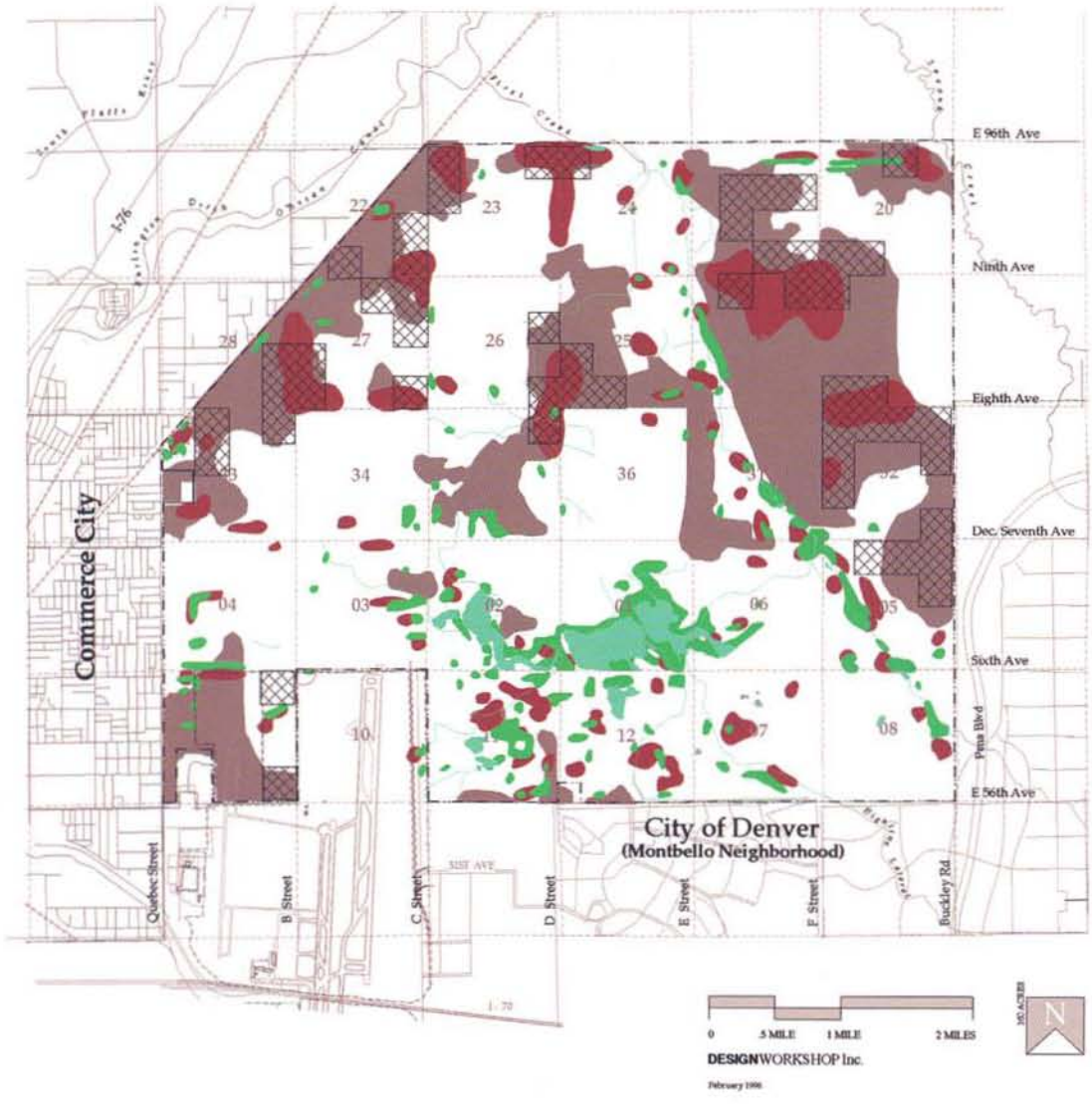
DESIGNWORKSHOP Inc.
February 1996

SELECTED WILDLIFE HABITATS — SPRING, SUMMER, FALL *(Map 1.8)*

- Prairie Dog Colonies
- Migratory Bird Nesting Habitat
- Raptor Nest Areas
- Known Burrowing Owl Nest Areas
- Lakes

- Streams
- Section Lines
- Refuge Boundary

Source: U.S. Fish & Wildlife Service and Rocky Mountain Arsenal National Wildlife Area surveys
Note: The entire Refuge provides important habitat to many wildlife species and is important both on a local and regional basis.



those for which insufficient information is currently available for listing as threatened or endangered. Some species inhabit the Refuge on a regular or seasonal basis while others are migrants that are infrequently sighted on the Refuge.

Bald Eagle

The bald eagle was recently downlisted from endangered to threatened status in the majority of the contiguous U.S., including Colorado, due to nationwide recovery efforts. The decline of the bald eagle was attributed primarily to the use of organochlorine pesticides, that caused egg shell thinning and subsequent nesting failure. Additional factors such as loss of habitat, habitat electrocution, powerline collisions, and other human disturbances also contributed to the decrease in eagle populations.

A winter bald eagle communal roost was first discovered at the Refuge in 1986. Bald eagles annually use the cottonwood trees along First Creek between October and April as a winter communal roost. Bald eagles at the Refuge prey on prairie dogs and other small mammals. The Service has implemented measures to restore prairie dog populations from a sylvatic plague outbreak that decimated populations in 1988. A 7000 acre Bald Eagle Management Area was also established on the Refuge to protect high eagle use areas during critical times of the year. An Eagle Watch blind was established on the east side of the Refuge to allow public viewing of the eagles on their evening roost without disturbing them.

American peregrine falcon

The American peregrine falcon is listed as an endangered species throughout its range. Pesticide use is thought to have led to the decline of this species. Peregrines typically nest on ledges close to water near readily available sources of avian prey. The closest suitable nesting habitat for peregrines near the Refuge is located along the Front Range foothills, 25 miles to the west. Peregrines have also been introduced in the downtown Denver area in efforts to establish an urban population. Peregrines have been observed at the Refuge on several occasions.

Eskimo curlew

The Eskimo curlew is a wide ranging bird species that favors open grassy meadows. Habitat fragmentation, loss of prey populations of grasshoppers and commercial hunting are thought to have led to their decline. The endangered Eskimo curlew has never been sighted on the Refuge, and has not been sighted in Colorado since 1965. It could potentially occur on the Refuge, however habitat to the north along the South Platte River is likely to be more suitable.

The Ute ladies'-tresses orchid

The Ute ladies'-tresses orchid is a threatened plant species found along streams, in wetlands, and in other moist habitats along Colorado's Front Range and plains areas in elevations below 6,500 feet. The Refuge contains habitat suitable for the orchid, but surveys of the Refuge have not located any populations of this species.

Platte River Species

Water use on the Refuge will result in depletions to the Platte River system. Several threatened and endangered species, such as whooping crane, piping plover, and least tern in central Nebraska, may be affected by reductions in Platte River streamflow.

Candidate Species

The following species are candidates for federal listing:

- Preble's meadow jumping mouse–The Preble's meadow jumping mouse prefers dense willow and grass riparian vegetation. Although this type of habitat is present on the Refuge, no specimens have been recorded.
- Swift fox–The swift fox prefers shortgrass prairie habitat. They prey on a variety of small birds and mammals. Suitable habitat and a potential prey base are found on the Refuge, however it is uncertain whether the swift fox is present.
- Ferruginous hawk–The ferruginous hawk is native to open grassland habitat. Conversion of grasslands to agriculture, loss of nesting sites, and reduction in prey base have led to its decline. A large number of ferruginous hawks are attracted to the Refuge each winter by the abundance of prairie dogs and rabbits.
- Baird's sparrow–Baird's sparrow is a migrant visitor to the native grassland prairie of the Refuge. Its decline is attributed to the loss of open grassland prairie habitat.
- Black tern–The black tern typically nests along lake shores and marshes and feeds on small fish. The Refuge contains suitable habitat for the black tern, but it has only been observed as an uncommon migrant.
- Mountain plover–The mountain plover prefers dry upland plains and prairies. It feeds primarily on grasshoppers. The extensive prairie dog towns at the Refuge provide excellent habitat for the plover. Although the mountain plover has been observed on the Refuge, no nesting activity has been documented.
- White-faced ibis–The white faced ibis, a long-legged, wading bird, is found in association with lakes, rivers and wetlands. The Refuge does not provide optimal nesting or foraging habitat for the ibis, but it is recorded as a casual visitor.
- Regal fritillary butterfly–This species prefers wet or moist meadows. Larvae feed on the leaves of Viola, which are not common on the Refuge. No regal fritillary butterflies have been recorded on the Refuge.
- Colorado butterfly weed–The Colorado butterfly weed prefers moist prairie meadows. The Refuge contains suitable habitat, but there have been no documented occurrences of the butterfly weed.

SOCIAL AND ECONOMIC ENVIRONMENT

Land Use

The Refuge is located in Adams County, Colorado, in the northeastern portion of the six-county Denver metropolitan area. The Refuge's 17,000 acres accounts for about 2 percent of the 764,200 acres in Adams County. (See Map 1.1 Regional context.)

Land use surrounding the Refuge varies considerably. The site of the former Stapleton International Airport adjoins the Refuge on the southwest. The Refuge is adjoined by residential and commercial development on the southeast, agricultural land on the north and east, and industrial development on the southwest, northwest and west. The Burlington Northern Railroad corridor parallels Highway 2 and Interstate 76 along the northwest boundary of the Refuge. This area is characterized mostly by industrial development, and is expected to continue to attract industry.

Adams County consists of 9 cities: Aurora, Bennett, Brighton, Broomfield, Commerce City, Federal Heights, Northglenn, Thornton, and Westminster. Bennett, Commerce City, Federal Heights, Northglenn, and Thornton are located entirely in Adams County. Unincorporated Adams County consists mostly of rural residential land use (52 percent). Other types of development in unincorporated Adams County include single-family and multi-family residential (15 percent), industrial (19 percent), commercial (2 percent), and planned unit developments (12 percent). Large tracts of designated open space in Adams County include Barr Lake State Park and Recreation Area northwest of the Refuge, and Adams County Regional Park north of the Refuge. Other regional recreation areas in the Denver metropolitan area include state parks at Cherry Creek and Chatfield Reservoirs and Roxborough State Park, and the Denver and Boulder Mountain Parks Systems.

Future land use around the Refuge is designated by Adams County, the City and County of Denver, and Commerce City (Map 1.9 Regional Flows). Development of the Gateway area surrounding the Denver International Airport and redevelopment of the former site of Stapleton Airport is under the jurisdiction of the City and County of Denver. Agricultural land north and northwest of the Refuge is designated for residential development, with open space areas designated along First and Second Creeks.

The land adjoining Section 29 east of the Refuge is designated for development of offices and businesses specializing in distribution. South and east of the Peña Boulevard and Buckley Road corridor is part of the planned site of Gateway. Most of this area is designated mixed use, including offices, hotels, and retail uses. Residential development is planned south of Sections 7 and 8 and east of Section 8 beyond Peña Boulevard. The Montbello Neighborhood is located south of the Refuge in the City and County of Denver.

Utility corridors in the Refuge exist for potable and non-potable water, operational and non-operational sewer, electrical, contaminant waste, gas, and fiber optics. Primary utility corridors are located along East 56th Avenue; December Seventh Avenue, especially in the area of South Plants; portions of Ninth Avenue and Highway 2; and portions of Section 25 especially in the area of North Plants. A primary electrical corridor is located along Buckley Road north of Sixth Avenue to 96th Avenue, and along East 96th Avenue from Buckley Road to E Street.

Some areas of the Refuge would be transferred to other owners or converted to other uses. Under the law establishing the Refuge, a strip of land up to 100 feet wide could be used to widen 56th Avenue on the south side, 96th Avenue on the north side, and Colorado Highway 2 on the northwest side of the Refuge. The Refuge boundary on the southwest and west sides would be modified by the sale of 815 acres. The proceeds from the sale of this land, as specified in the Refuge Act, will be used to help build the Visitor Learning Center. The Service will use these opportunities to modify the existing fencing. Fencing would be set back from its current location to accommodate the new Refuge boundary.

Socioeconomics

The socioeconomic study area includes two regions. Adams County, where the Refuge is located, is the primary study area. The Denver metro area is the secondary study area. The Adams County economy is integrated into the larger and more complex Denver metro area economy.

Adams County is one of six counties in the Denver metro area. Population in the metro area was 1,715,300 in 1992. Population is expected to grow to 2,612,200 by 2015. In 1992, Adams County had a total population of 281,700, which ranked fifth in the state. Population in Adams County has shown small annual increases from 1983 to 1992; the total increase for this period was 8 percent. It is expected to grow to 408,400 by 2015.

Adams County includes 9 cities and has a land area of 1,194 square miles. About 78 percent of the population in the county resides in incorporated areas. Development patterns vary significantly across the county. Some areas are highly urbanized or industrialized, while others are commercial, suburban, or agricultural. Population densities also vary. The most concentrated population densities are in Commerce City, Thornton and Northglenn. Population is more dispersed around Bennett and Brighton. Average household size is 2.68 persons. There are about 230 persons per square mile in Adams County.

Commerce City adjoins (or will adjoin) the Refuge on the north, west, and northeast. By agreement with surrounding jurisdictions, the city may expand into areas north and east of the Refuge. Major highways, arterials, and railroads make Commerce City a central transportation and distribution hub. Transportation is the city's growth industry. During the last few years, truck terminals, air freight handlers, mail handlers, and local truckers and distributors have located in Commerce City. It is also home to a high concentration of industry. Even with growth in transportation and industry, nearly half of the business in Commerce City are services and retail trade. The majority of land in Commerce City is used for public roads, infrastructure and industry. Residential uses account for 23 percent and commercial uses account for 5 percent.

Median household income in Commerce City is $22,916, about 70 percent of median household income in Adams County. Unemployment was 6.8 percent in 1994. From 1980 to 1990, population in Commerce City increased 1.4 percent, significantly less than the 7.8 percent increase in Adams County during the same period.

Colorado tourism

A major factor in the Refuge's future attendance will be its attractiveness to Colorado tourists. Colorado has a large and complex tourism industry with significant seasonal fluctuations. There are very little reliable data on Colorado tourism activity, particularly since the demise of the Colorado Tourism Board. In past studies, BBC Research and Consulting has estimated the total number of out-of-state, discretionary tourists at about 7.0 million individuals per year. Approximately 60 percent of these visitors pass through the Denver metropolitan area on their way to mountain resorts and other destinations. Research by the Denver Convention and Visitors Bureau indicates that Denver's local tourist market (visitors with Denver as a destination) is comprised principally of persons visiting friends and relatives and those persons visiting Denver for multiple purposes, such as shopping, medical care, or specific events.

Although Colorado enjoys a sizable tourism industry, and a market predisposed to nature and wildlife attractions, the Refuge still faces difficult challenges in penetrating this market. Most of the Colorado tourism market passes through Denver on its way to the more dramatic natural attractions of the Rocky Mountains. Enticing visitors to

stop at what is largely a plains exhibit, while in sight of the mountains, will be difficult.

Denver also has a well used and strongly supported system of arts and cultural attractions. Attendance at the Denver Natural History Museum and the Denver Zoo, approximately 1.8 and 1.5 million per year respectively, provides some indication of the area's ability to support wildlife or nature-related exhibits and attractions. Currently the Refuge ranks third behind Rocky Mountain National Park and the Denver Zoo as a destination for wildlife viewing. It should be noted that museum attendance figures can be skewed by one time major attractions, such as the King Tut exhibit or similar promotions. Multiple use by members is also a factor that adds uncertainty to attendance figures.

Current Public Use on and near the Refuge

Outdoor activities and the use of natural areas for recreation are important aspects of the quality of life that the Denver metropolitan area offers. Public use programs at the Refuge give the public the chance to learn about its history, wildlife, and cleanup activities. These programs include wildlife tours, environmental education, presentations, special events, the Eagle Watch, interpretive activities, nature walks, and fishing and scout programs. Public participation programs occur on and off the Refuge. In 1994, nearly 49,000 people participated in these programs. A large portion of the public participation programs is devoted to programs involving school children. In 1994, almost 15,000 students participated in environmental education programs on the Refuge.

An average of 4,075 visitors came to the Refuge each month in 1994. About 1,425 of these visitors participated in environmental education. Many of these participants were students and teachers. Another 1,140 visitors participated in wildlife tours and eagle watching. Visitors also participated in interpretive programs and nature walks, presentations, scout programs, and special events.

Current recreational activities on the Refuge include bird watching, eagle watching, and fishing. Annually, 700 permits are issued for catch-and-release fishing. From 1990 to 1994, participation in environmental education programs, interpretive programs, and nature walks increased significantly. Other programs that gained popularity included fishing and presentations.

Currently, there are eight full-time positions associated with public use of the Refuge. These positions are funded by the Army. As the Service assumes full responsibility for the management and operations of the Refuge, it will be required to fund all staffing. Volunteers contribute to the staff requirements necessary to offer current public participation programs. In 1994, volunteers contributed the equivalent of more than three full-time positions. The Rocky Mountain Arsenal Wildlife Society was established in 1995 to assist the Refuge by supplying volunteers and other resources.

The Emerald Strands Plan (Adams County, et. al. 1990) is a cooperative park, open space, and trail Plan for the area surrounding the new Denver International Airport. The plan focuses on future development in order to provide links with other metropolitan-area trails and open spaces and creates a system allowing people to move about the area on a series of trail loops designed for pedestrians, bicyclists, and equestrians.

Open space corridors and trails are recommended throughout the area, in response to all stream corridors, which have been identified as

open space. However, not all stream corridors will have trails. Off-street trails have been recommended to provide a link with the Rocky Mountain Arsenal National Wildlife Refuge. Three areas of focus proposed to provide connection with the Arsenal are the Highline Canal and Lateral, First Creek, Second Creek, and a corridor in relation to the proposed E-470.

In addition, Commerce City has studied open space trail connections and has identified several on-street connections to an off-street trail, running parallel to Quebec, adjacent to the Refuge.

In Montbello, perimeter streets now have separated bike paths: Peoria Street, Chambers Road, and 56th Avenue. Montbello has explored developing an on-street bikeway system within the Montbello neighborhood to connect residential small areas, schools, parks, recreation facilities, and off-street bicycle trails. In Green Valley, bike paths are not yet developed. The Highline Canal and First Creek open space are proposed locations for a new off-street bike trails.

Transportation

The main freeways that provide significant regional connections for the Refuge are I-70, I-270, the proposed E-470, and Peña Boulevard. Proposed development on these roads calls for an increased number of lanes and thus increased transportation capacity.

Table 1.2 Attendance at Selected Recreation Opportunities

Recreation Area	1993 Attendance	1994 Attendance	1993-1994 Attendance	Visitation as % of CMSA population *(1)*
Denver Recreation Area Opportunities				
Barr Lake State Park *(2)*	125,773	113,956	-9.40%	5.46%
Chatfield Reservoir *(3)*	na	1,500,000	na	71.80%
Cherry Creek State Park	1,200,000	1,400,000	16.67%	67.02%
Lookout Mountain Nature Center	15,500	na	na	0.74%
Roxborough State Park *(3)*	na	100,000	na	4.79%
National Parks				
Rocky Mountain National Park	3,050,000	3,000,000	-1.50%	na
Grand Teton	2,595,000	2,800,000	7.90%	na
Mesa Verde	535,670	553,520	3.33%	na
Yellowstone	2,330,000	2,480,000	6.44%	na

Source: Site interviews conducted by BBC Research and Consulting.
(1) Based on U.S. Bureau of the Census, 1990 Census of Population and Housing, Supplementary Reports, Metropolitan Areas as defined by Office of Management and Budget, June 30, 1993, as reported in the Statistical Abstract of the United States, 1994.
Reported population for Denver-Boulder-Greeley CMSA
(2) Through June 30 only, for both years
(3) Estimate

• I-70 is located south of the Refuge running east-west through Stapleton. This freeway is an important connector between the plains and the mountains. It is an important regional transportation corridor to Denver International Airport and is slated to increase in size from 6 lanes to 10-12 lanes of traffic. I-270 connects US 85 and I-70 southwest of the Refuge. The freeway directs traffic through Commerce City and is proposed to increase from 6 lanes to 10-12 lanes.

• E-470 is a proposed beltway running along the eastern edge of the metropolitan area from the intersection of I-25 and C-470 in the south to approximately I-25 and 120th Avenue in the north. E-470 is a proposed 6 lane freeway that would serve as a major north/south access road to and from the new airport, connecting I-25, I-76, and I-70 with an interchange at Peña Boulevard.

• The construction of Peña Boulevard between I-70 and the new airport has greatly increased traffic along the Refuge's eastern boundary. An interchange at 56th Avenue has a prominent informational sign advertising the Refuge.

The roads immediately bordering the Refuge are Quebec Street, 96th Avenue, 56th Avenue, and Buckley Road. Each of these, except Buckley Road, are principal arterials that make important connections with Denver International Airport.

• Quebec Street borders the west boundary of the Refuge. Quebec's proposed future development will result in realignment to the east, an increase from 4 lanes of traffic to 6 lanes, and improved interchanges between I-70 and I-270.

• Bordering the northern boundary of the Arsenal is 96th Avenue, which is to be extended east of Buckley Road to an interchange at E-470. The existing 96th west of Buckley will increase from 2 to 4 lanes of traffic.

• 56th Avenue bordering the Refuge's southern boundary has recently been completed from Peña Boulevard to Quebec Street. Plans call for it eventually to be widened to 4 lanes.

• Buckley Road, on the eastern border of the Refuge, is a gravel road that the Service proposes closing from the Eagle Watch north to 96th Avenue.

LANDSCAPE STRUCTURE AND ZONES

A landscape ecological view

If you look in the right direction when landing or taking off from Denver International Airport, you can get a fascinating aerial view of the Refuge (Figure 1.22). Included in that vista are many distinct patterns, some natural and some the work of human hands. Most visible are the stands of large trees, either in lines along First Creek, the lakes, ditches, and canals or in other, more regular shapes where people have planted them. The manufacturing plants, other buildings, utilities, and roads also make strong marks. Other patterns are obvious on the surface of the ground, where vegetation and soils have been disturbed for one purpose or another.

Not only do these patterns reveal many stories about past uses of the site, they also hint at ecological function. Thickets of New Mexico locust and other patches of vegetation, for example, provide important habitat. The large cottonwoods and other vegetation along First Creek provide roosts for bald eagles and function as movement corridors for some birds and small mammals.

Understanding the relationships between landscape forms, like patch and corridors, and eco-

logical functioning helps plan more effectively. For example, knowing that deer or small mammals are using a thicket or a lake edge for cover and feeding means that roads or trails should either be kept out or be very carefully planned.

Regional patterns

Looking at these same landscape patterns as they relate to the larger region, it becomes clear that many of the patterns extend well beyond the Refuge's boundaries (Map 1.9 Regional Flows). First Creek and its considerable riparian vegetation continue from upstream right through the Refuge fence. Areas of grasses or forbs extend off site to the north.

Even with the Refuge's extensive size, it is not an island. It is tied into its region ecologically and many other ways. One of the challenges of planning and managing the Refuge is recognizing and working with these regional connections and relationships. It is a mistake to believe that Refuge boundaries or even a fence separates the Refuge from its environs. (Refuge biologists note that the existing boundary fence stops few species other than deer and people. All others either dig under or fly over the fence.)

Figure **1.22** From the air, there are many fascinating patterns to read on the surface of the Refuge.

Zones

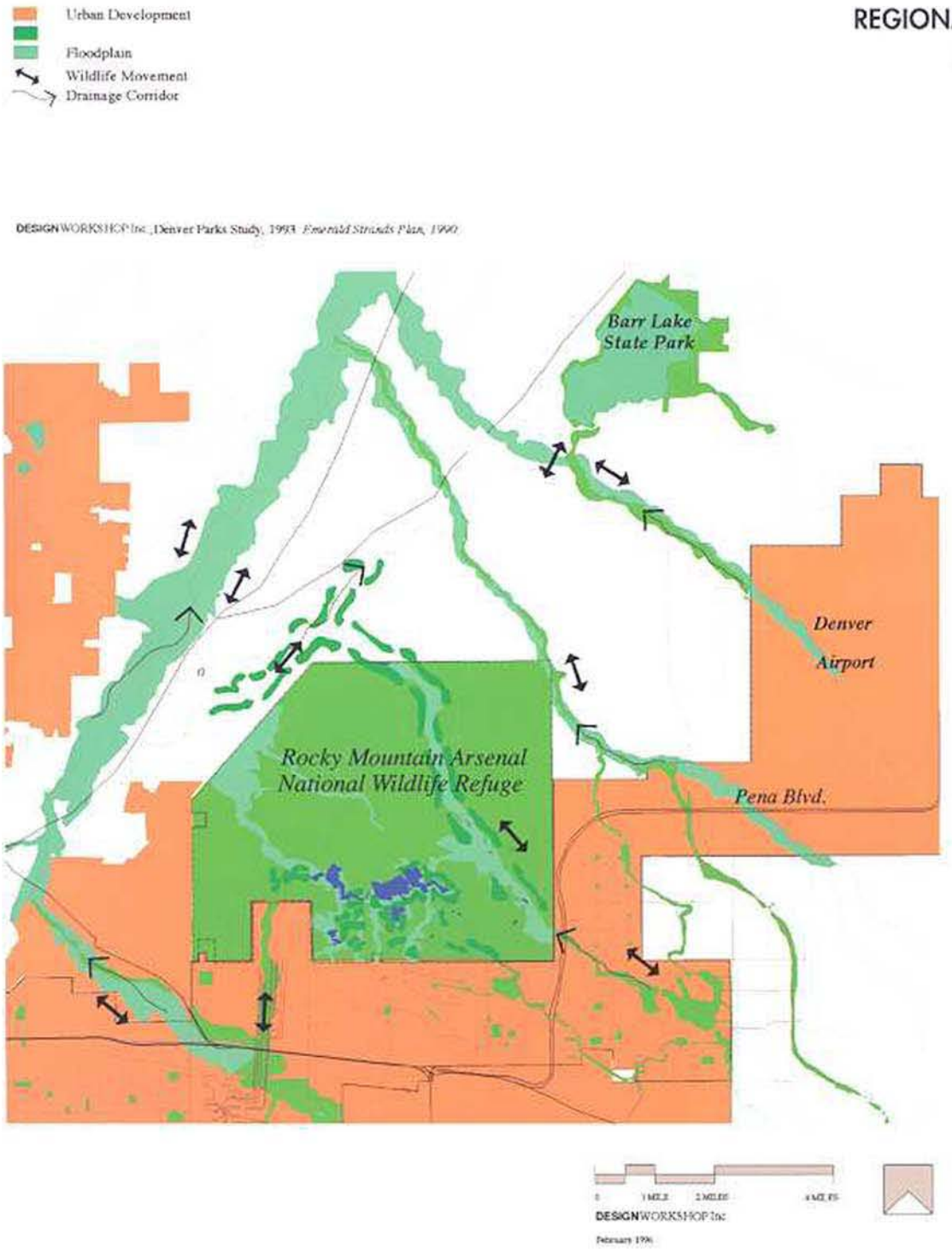
Early in the planning process a zone management concept was identified for the Refuge. The Refuge was divided into three planning and management zones based on a combination of current habitat types, historical disturbance, likely levels of public use, and anticipated cleanup activities (Map 1.10 Planning Zones).

The northern zone has the least trees and shrubs and will see the majority of cleanup activities. Cleanup will alter the area considerably, but will provide an opportunity to re-establish native prairie vegetation that has long been displaced.

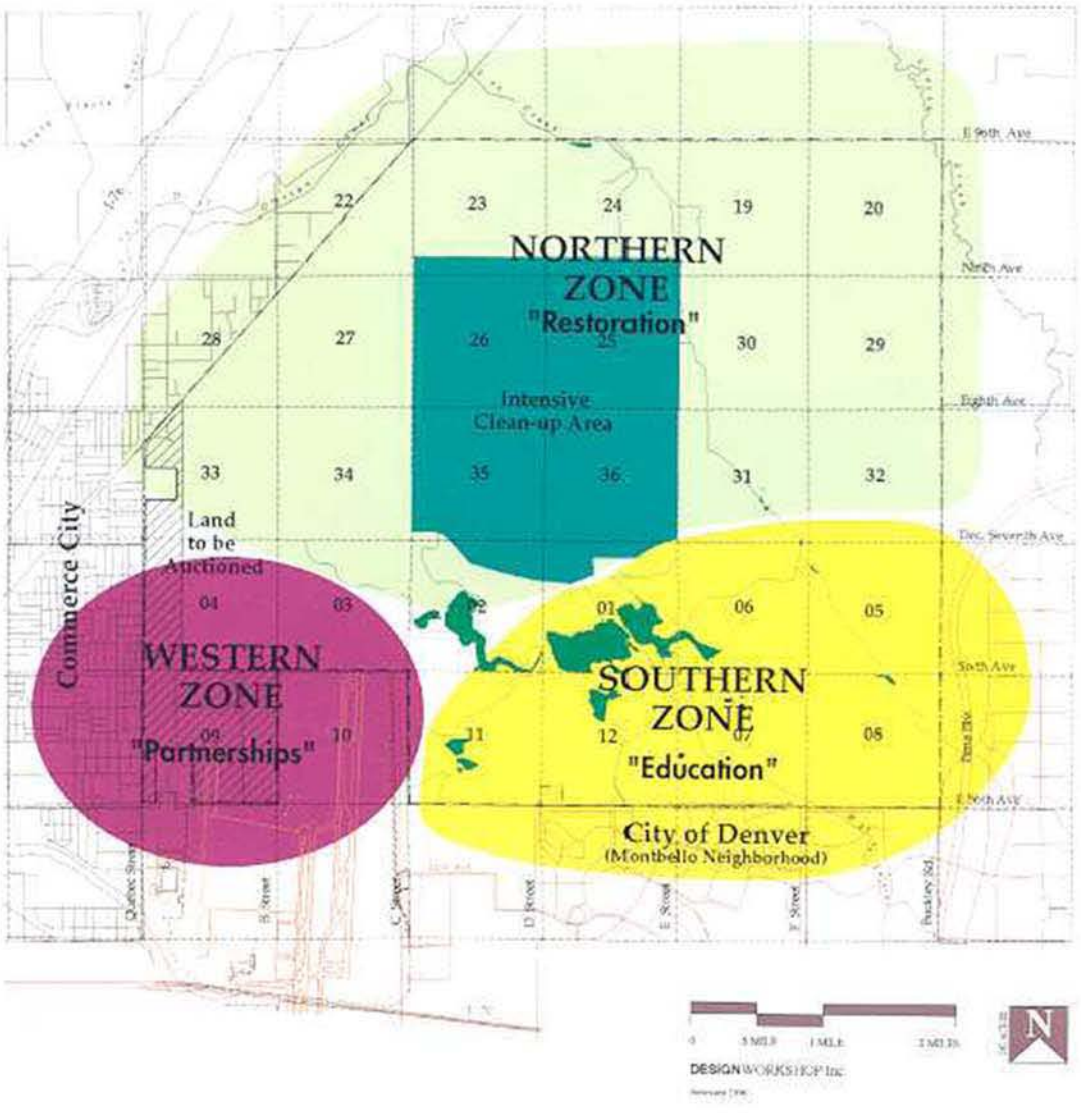
The southern zone has many lakes and ditches and related vegetation. Little cleanup activity will take place here. Because of its rich diversity of habitat, wildlife viewing is particularly rewarding in the southern zone. To be sustained, the southern zone will need greater habitat and wildlife management inputs because it is an artificial, even a cultural, system.

The western zone is a product of economic and political reality. It includes the southwestern corner of the Refuge, adjacent lands that will be auctioned off by the U.S. Government, and the northern end of the former Stapleton International Airport. Because this zone is in the general direction of the center of the metropolitan area, it is a logical gateway to the Refuge. Because these lands are undergoing dramatic transitions in use, the opportunity exists to plan them together to

REGIONAL FLOWS
(Map 1.9)



PLANNING ZONES
(Map 1.10)



achieve a coordinated result. This zone also is an acknowledgement that the Service wants and needs the participation and cooperation of the larger community if the Refuge is to succeed.

Both the perimeter greenbelt (that will surround the Refuge on the outside of the fence) and the western zone have the potential for accommodating higher public use than other parts of the Refuge because habitat is less sensitive in these places. In addition, because of the cleanup work and the distinct differences between the northern and southern portions of the Refuge, potential uses and user groups can be divided between these northern and southern zones.

Visual Resources

The Refuge is located on the edge of a major urban area; with Commerce City to the immediate west, the City of Denver to the south; Denver International Airport and the future Gateway development to the east; and to the north is agricultural land. The most striking views are westward to the Front Range with the Denver skyline in the foreground (Figure 1.23). The site has experienced considerable changes during its conversion from prairie to agriculture prior to the 1940s, and subsequent to that in its role as a military arsenal and a site for the production of agricultural chemicals. As a Superfund cleanup site, it will experience further disruption over the next several decades. The visual resources have been affected by these past uses. Visual resources range from fragments of undisturbed landforms and vegetation cover that have existed since presettlement days, to the creation of storage lakes for irrigation purposes, to regraded areas, to cleanup landfills and capped sites.

The southern zone is the most culturally affected landscape, with lakes, wetlands, canals, ditches and detention basins providing water for woody riparian vegetation, and old homestead sites with remnant upland trees. Roads and tracks that serviced this agricultural landscape remain, along with utility poles, powerlines and railroad lines. This is a highly modified landscape, with little original native vegetation remaining. The overall appearance is of a more intimate, partially treed landscape amid grassland, with a lushness less typical than would be expected in adjacent rural areas.

The northern zone has been less obviously disturbed by agriculture, although it was severely affected as a result of weapons and agricultural chemical manufacturing. This cleanup zone will be most affected by future work. However, it retains an open, prairie-like feel, interrupted by only the occasional grouping of upland trees associated with old homesteads, and by a line of riparian vegetation along First Creek. Its gently undulating nature with the higher ground to the east precludes long views eastward, except at high points, and provides a panorama of the Front Range.

Figure 1.23 From the Refuge there are many opportunities for dramatic views of the Denver skyline with the Front Range as a backdrop.

Some of the manmade structures, such as the Army's headquarters, homesteads, warehouses, bunkers, the perimeter fence, the boundary ground water containment system and some utilities may remain (Figure 1.24). These add to the visual diversity. In addition, many of the manmade topographic features including, road and railroad profiles, cleanup mounds, bunkers, ditches and dikes, and a large number of miscellaneous "gouges" and "lumps" in the landscape will remain.

The dominant landmark from most points within the Refuge is the Front Range. The Denver skyline is silhouetted against that backdrop. A number of silos and stacks in Commerce City are visible from the Refuge. The blue Post Office Bulk Mail Facility dominates the foreground in the southwest corner of the Refuge. From Henderson Hill, it is possible to see Denver International Airport and, from the southeast edge of the Refuge, Peña Boulevard leading to the airport. Both Commerce City and the Montbello neighborhood with their low rooflines are visible when close to the Refuge perimeter.

Figure 1.24 Most of the structures built on the site, such as this water tower, will be removed either because they are contaminated or the earth under them is.