CHANGES TO THE MONTE VISTA ECOSYSTEM

SETTLEMENT AND LAND USE CHANGES

Native people apparently first occupied the SLV 10,000 to 12,000 years before the present (BP) (e.g., Jodry et al. 1989). These people had a highly mobile lifestyle that depended largely on big game hunting. Initially, populations apparently were relatively small with localized and often seasonal settlements, many of which were along the Rio Grande and former lakes, rivers, and wetlands of the SLV where the availability of water, wildlife, and shelter was more predictable. For example, numerous archaeological sites occur in the headwater spring discharge area of Spring Creek on Monte Vista NWR (USFWS 2003). By about 2,000 BP, human populations in the SLV appear to have increased, small villages were established, and agriculture was developed along some waterways. Pueblo people were attracted to the SLV and, along with the Comanche, Utes, and other tribes, maintained some occupation of the region through the mid-1800s. Spanish explorers in 1540 found evidence that Pueblo people were diverting water from the Rio Grande in "acequias" or irrigation ditches (Jodry et al. 1989).

Spanish settlers first entered the SLV between 1630 and 1640 and several Spanish expeditions to the SLV occurred in the 17th and 18th centuries, although extensive settlement did not occur until the 1800s. An excellent summary of European settlement and history in the SLV is provided in Athearn (1975) and Simmons (1999 as excerpted from USFWS 2003). The following historical information is excerpted from these sources.

The historic territory of "New Mexico" was claimed for Spain in 1598 and Juan de Onate established a base camp near the confluence of the Rio Grande and Rio Chama. Shortly thereafter, hunting and exploratory expeditions into the SLV occurred. Bison were hunted in the valley at that time and native people were present (Fitzgerald et al. 1994). Sante Fe, New Mexico was established in 1610 and became the capital of Spain's Northern Province.

Conflicts between the Spanish and Pueblo and Ute people accelerated in the early- to mid-1600s. After expulsion of Spanish people in New Mexico in 1680, Spain retaliated in 1694 and Don Diego de Vargas reestablished control of Sante Fe. Later, Vargas traveled through and established camps in the SLV to hunt bison and elk. Many place names in the SLV came from early Spanish expeditions and people. By the mid-1700s, the Comanche gained power in the Rio Grande Valley and displaced the Ute who lived in the SLV. By the early-1700s, some mining had begun in the surrounding mountains, and during the mid- to late-1700s, the controlling government of New Mexico attempted to curtail Comanche raiding parties in the region, including the SLV. The Utes joined the Spanish in combating the Comanche and in 1786, the Comanche were defeated and signed a peace treaty with the Spanish.

From 1780 to the early-1800s, the Utes were the principal claimants to the SLV and Colorado mountains. Other tribes including the Navajo, Apache, Comanche, Kiowa, Arapaho, and Cheyenne also visited the SLV. Spanish and native people began to trap furs in the nearby mountains at this time and the fur trade expanded markedly after the U.S. gained control of much of the western U.S. via the Louisiana Purchase. Zebulon Pike was dispatched to explore the Rocky Mountain region in 1806. His party established a winter camp along the Conejos River, but was later detained by the Spanish. This was the last U. S. sponsored expedition into the SLV until 1848, when John Fremont

came through the valley in search of a route through the Rocky Mountains.

In 1821, revolution created the independent Republic of Mexico, which then became separated from Spain. At this time the former New Mexico territory became a free province and American and Mexican trappers regularly used the SLV as a resting and staging location. While the buffalo trade developed across the west in the 1830s, the SLV was less affected because it had few bison and the Utes diligently defended their hunting territory.

No permanent town-settlements occurred in the SLV until the 1800s. Hispanic settlement of the SLV began on Mexican land grants in the late-1840s and early-1850s, mainly Spanish missionaries and sheepmen (Buchanan 1970). Farmers soon learned that the floodplains of rivers and creeks were the only areas that could be cultivated and these areas also provided the most dependable forage for livestock, which dominated the economy of the area at the time (Holmes 1903). By the late 1840s, scattered settlements were present throughout the SLV. In 1846, war occurred between Mexico and the U.S., which culminated in the Treaty of Guadalupe-Hildalgo in 1848 that ceded control of Colorado and other western areas to the U.S. After the U.S. occupied the southwestern region, a network of army posts was established with settlement, farming, and ranching expanding rapidly in the late 1850s. The Homestead Act of 1862 and the arrival of roads and railroads in the 1860s and 1870s facilitated substantial population growth. During the 1860s a series of roads were built in the SLV to facilitate travel north from Fort Garland. In 1879 a narrow gauge rail line was constructed to Alamosa, Colorado and agricultural goods were shipped to Denver, Colorado and other eastern cities. By the late-1800s sheep and cattle grazing were extensive in the Valley and valley farms were producing large quantities of potatoes, hay, and peas.

Following major expansion of settlement into the SLV in the mid-1800s, farmers decided that irrigation was necessary if valley agricultural commerce was to survive. The history of efforts to develop means to irrigate SLV lands for agricultural production is extensive and is a classic example of efforts (that occurred repeatedly throughout the western U.S. where water is limited) to acquire, divert, and use limited surface and groundwater (Siebenthal 1910, Follansbee et al. 1915, Brown 1928, Powell 1958, Buchanan 1970, Emery et al. 1973, Athearn 1975, Hanna and Harmon 1989, Leonard and Watts 1989, BLM 1991, Ellis et al. 1993, Emery 1996, Jodry and Stanford 1996, McGowan and Plazak 1996, Wilkins 1998). This report does not attempt to chronicle the complex water developments, laws and regulations, and past and current attempts to plan and manage irrigation water supplies and diversions throughout the SLV. The following is a brief account of some of the major events that ultimately affected water supplies, movement, and uses on Monte Vista NWR based on the above references.

The first ditch to move water from local rivers to the interior of the SLV was the San Luis Peoples Ditch constructed in 1852. The first large ditch to move water from the Rio Grande, the Silvia Ditch, was constructed in 1866 (Holmes 1903). The "Ditch Boom" hit the SLV in the 1880s when many British and eastern investors sponsored construction of canals to provide irrigation water to agricultural areas in the SLV. The largest investments came from the Travelers Insurance Company of Connecticut, which financed the building of the Monte Vista and Travelers canals that diverted water from the Rio Grande to the SLV including areas now part of Monte Vista NWR. Other major canals also subsequently were built in the 1880s, such as the Empire Canal through Monte Vista NWR, which transformed the valley floor into a major agricultural production region.

Agricultural production in the SLV was enhanced by drilling thousands of wells into both the shallow unconfined and the deeper confined aquifers starting in the late-1800s. Water flows from wells drilled into the unconfined aquifer are subject to annual variation related to fluctuating recharge rates from infiltration of local precipitation and runoff, whereas flows from wells drilled into the confined aquifer are artesian and are buffered from climatic conditions. Recharge of the unconfined aquifer may be artificially increased by the addition of groundwater resources applied for irrigation. By 1980 about 2,300 pumped wells existed in the unconfined aquifer in the SLV (Emery 1996). Artesian water under the SLV was discovered about 1887 and within four years about 2,000 flowing wells had been developed (Emery 1996). By 1904 more than 3,200 artesian wells had been dug and by 1916 about 5,000 artesian wells were present and flowing in the SLV. By 1970 that number had increased to over 7,000 wells. Well pumping typically causes the unconfined aquifer to be seasonally lowered; the last time this aquifer was at or near capacity was the mid-1980s and the mid-1990s. Pumping

from the confined aquifer has continually depleted the aquifer storage and it has not been at capacity since the early-1950s www.waterinfo.org/taxonomy/term/1620). At Monte Vista NWR, many areas of the former salt desert shrub lands on the higher elevation alluvial fan surface near creek channels was converted to annually irrigated wet meadows for livestock grazing and production of hay and cropland via extensive networks of irrigation infrastructure built in the late-1800s and early-1900s. Much of this early water-control infrastructure remains present on Monte Vista NWR.

The substantial diversion of water from the Rio Grande in the SLV in the late-1800s led to an "embargo" in 1896 and the Rio Grande Convention Treaty of 1906 between the U. S. and Mexico. The "embargo" ordered by the U.S. Secretary of the Interior prevented further irrigation development of any magnitude in the Rio Grande Basin of Colorado and New Mexico by suspending rights-of-way across public lands for use of Rio Grande water; the embargo was not lifted until 1925. Under terms of the Treaty of 1906, the U.S. guaranteed an annual water delivery in perpetuity of 60,000 acre-feet of water in the Rio Grande at the head of the Mexican Canal near El Paso, Texas. In 1929, a temporary compact for water use and delivery in the Rio Grande was ratified by Colorado, New Mexico, and Texas and in 1938-39 these states ratified the Rio Grande Interstate Compact, which provides for apportionment between states of the water of the Upper Rio Grande Basin on the basis of specified indices of flow at key gauging stations. This Compact greatly influenced diversion of water from the Rio Grande in the SLV and subsequent development of surface and groundwater infrastructure that has affected Monte Vista NWR (Ellis et al. 1993).

In addition to diversion of Rio Grande water and drilling of groundwater wells, other water-control infrastructure in the SLV captured and diverted groundwater discharge and drainage. Two major groundwater conveyance ditches, the Bowen and Parma Drains were dug in the early-1900s, both of which carry water through Monte Vista NWR (Fig. 19). Groundwater pumping and diversion of groundwater discharge ultimately caused many discharge areas, such as the Spring Creek Spring, to dry up and discontinue seasonal flows (USFWS 2003).

As early as the late-1800s, farmers in the SLV began noticing increases in soil salinity, or "alkali" as it was commonly known, in some upland areas (mostly former salt desert shrub community sites) away from the Rio Grande that were sub-irrigated for production of hay, pasture, and cropland (Holmes 1903). Buildup of alkali was most common in areas that formerly had been in salt desert shrub; soils in these areas were locally known as "adobe" and covered with "chico brush" (greasewood). Technically, the soils in these former salt desert shrub areas were initially defined as San Luis sandy loam (Holmes 1903). Saline soils with high carbonate levels are common in the salt desert shrub areas and when irrigated for prolonged periods during the growing season, waters take up small amounts of soluble salts and through capillarity moved salts to soil surfaces. Historically soil areas highly susceptible to this alkali condition were south and east of Monte Vista near the current Monte Vista NWR (Holmes 1903) while areas immediately along the Rio Grande and near the foothills around the SLV were less affected.

CONTEMPORARY HYDROLOGIC AND VEGETATION COMMUNITY CHANGES

Immediately prior to refuge establishment in 1952, the Monte Vista area was predominantly pasture/hay and cropland. Many areas of native salt desert shrub habitat near Spring, Rock, and Cat Creeks had been converted to irrigated pasture and hay land and numerous small levees, water diversion control structures, and ditches had been constructed to facilitate irrigation (Fig. 18a). The original development plan for Monte Vista NWR proposed considerable expansion of existing dikes, ditches, drains, water-control structures, and roads to increase the diversion of water from the Monte Vista and Empire Canals (and other smaller drain canals) to enhance existing, and create new, irrigated meadows and wetland ponds (USFWS 1962). The subsequent development of this extensive water diversion and storage infrastructure subdivided the refuge into many water management "sub-units", with a general intent of maximizing the amount of refuge land that could be flooded or seasonally irrigated to benefit wetland-dependent wildlife, primarily waterfowl. These early water diversion and irrigation developments generally were designed and constructed irrespective of soil type or historical vegetation community types (USFWS 1962). Following the first refuge water-control developments, additional

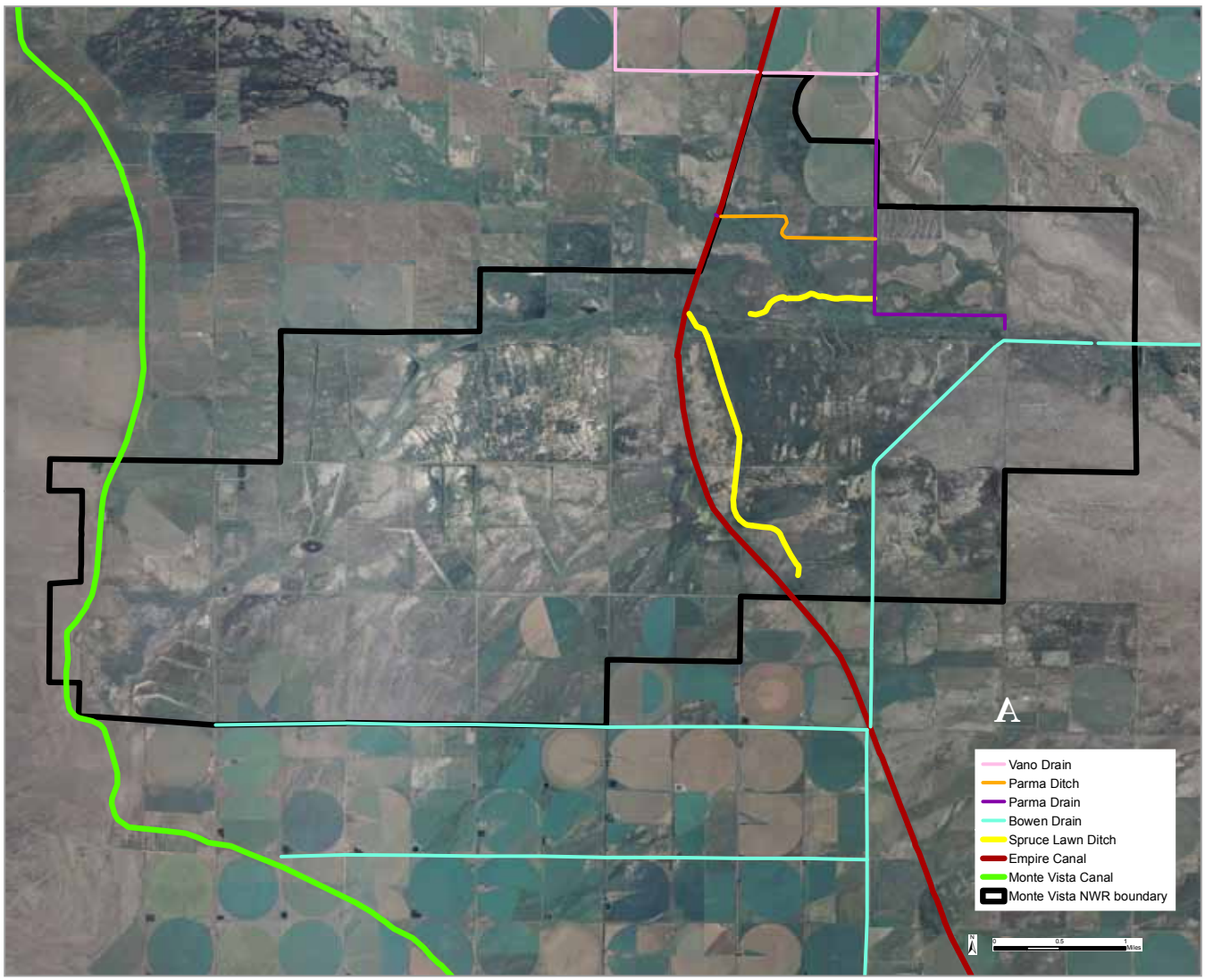
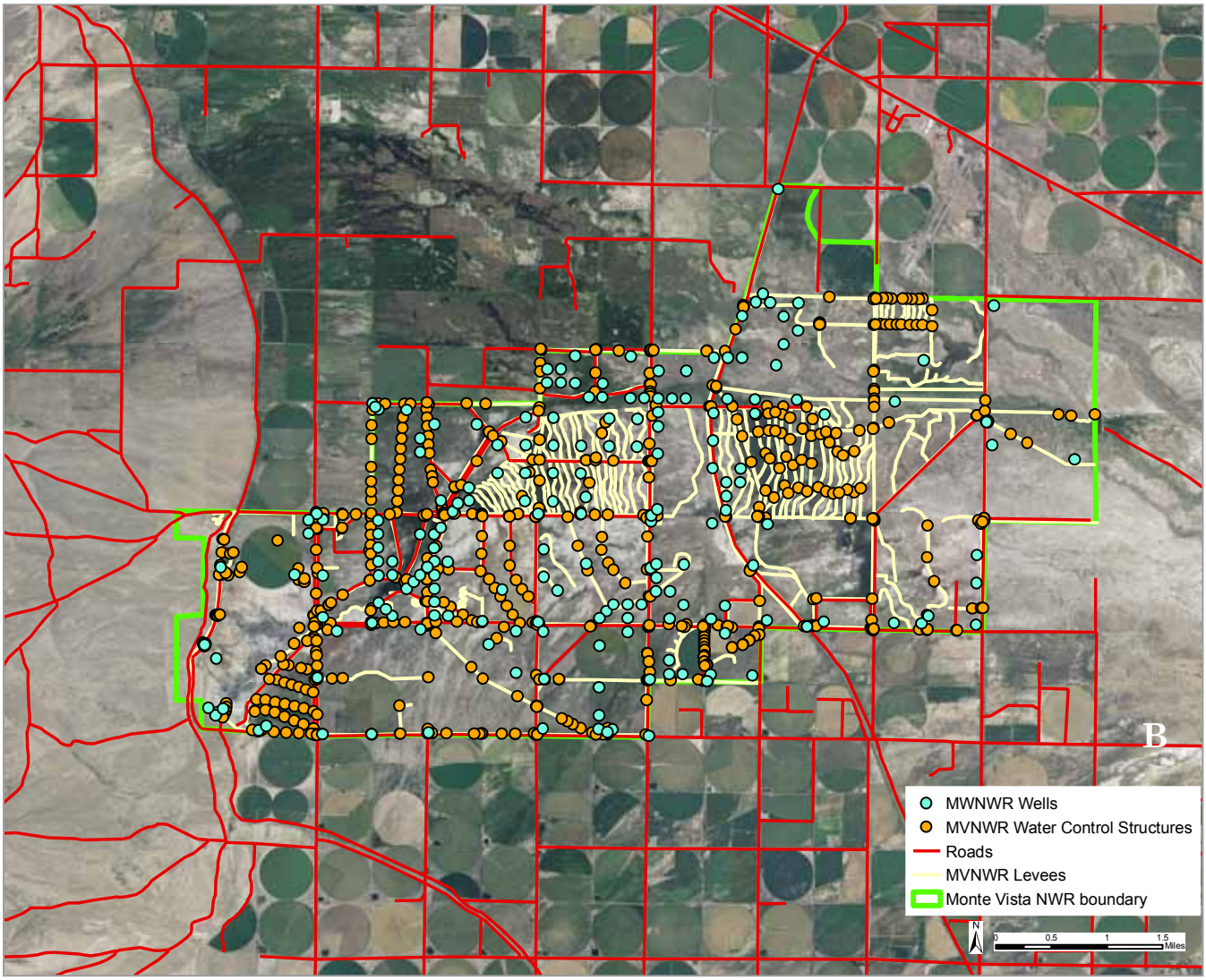


Figure 19. Location of: a) major ditches and drains and b) wells, water-control structures, levees, and roads on Monte Vista

levees, dikes, and water-control structures have been constructed and have created about 80 distinct irrigated wetland sub-units and more permanently flooded artificial diked "ponds", such as Parker Pond, along canals and drain ditches (Fig. 19).

The development of extensive networks of water diversion and conveyance ditches and canals, levees/dikes, and water-control structures on Monte Vista NWR have continued from the initial developments in the 1960s to the present time with a substantial increase in sub-compartmentalization of management units occurring during the mid-1990s to the mid-2000s (USFWS refuge annual narratives). Certain units on Monte Vista NWR have been extensively developed and compartmentalized by relatively large angle-dikes (e.g., Units 6, 10, 15, 16, 19), closely-spaced contour levees (Units 7 and 9), and conveyance ditches (Units 15, 16, 6, 8, 10) (Fig. 20). Many of these water-diversion/control developments have effectively blocked, diverted, and significantly modified former natural surface water flow pathways and patterns and attempted to create meadow and wetland habitats in areas that were formerly salt desert shrub habitat. For example, the four large angle-dikes constructed in Unit 19 intercept the natural historical drainage pathway of Spring Creek by diverting and impounding water in four small and closely spaced sub-units, and modifying and reducing Spring Creek flows further downstream. Modification of natural surface flow pathways occurs throughout the Spring and Rock Creek drainage corridors in Units 1-11, 14, and 15 and within the smaller formerly intermittent flow corridor of Cat Creek in Units 16, 17, and 22.



National Wildlife Refuge.

In the early-1950s, all of the wells on Monte Vista NWR were free-flowing from artesian pressure in the deeper confined aquifer and Spring Creek was still discharging groundwater (Striffler 2012). However, by the 1970s, the Spring Creek groundwater discharge point "head" stopped flowing and the number of free-flowing artesian wells on the refuge declined greatly. In the early-1970s, the Colorado State Engineer placed a moratorium on new wells drilled into the confined aquifer in the SLV. Since 1981, no well construction permits for new water appropriations, other than exempt domestic wells, have been issued in the SLV. Currently, during summer months almost all artesian wells on Monte Vista NWR cease flowing when maximum groundwater pumping occurs on and off the refuge for irrigation purposes (U.S. Bureau of Reclamation 1995).

In the mid-1980s, efforts began to recharge groundwater in the SLV. Currently, from November to January, six major irrigation companies divert and hold Rio Grande water in their canals to assist groundwater recharge. These winter diversions and recharges occur only if river water is not needed to meet the 1939 Rio Grande Compact obligations. The Monte Vista and Empire Canals are two of the irrigation canals used for the recharge program and certain areas on the refuge receive this winter recharge water if available (USFWS 2003, Striffler 2012).

Currently, Monte Vista NWR has 254 wells that historically provided at least some water to the refuge. Water from these wells is adjudicated for irrigation, wildlife, domestic, and stock water purposes (Striffler 2012). Of the 254 wells, 206 are small artesian wells that flow seasonally at rates

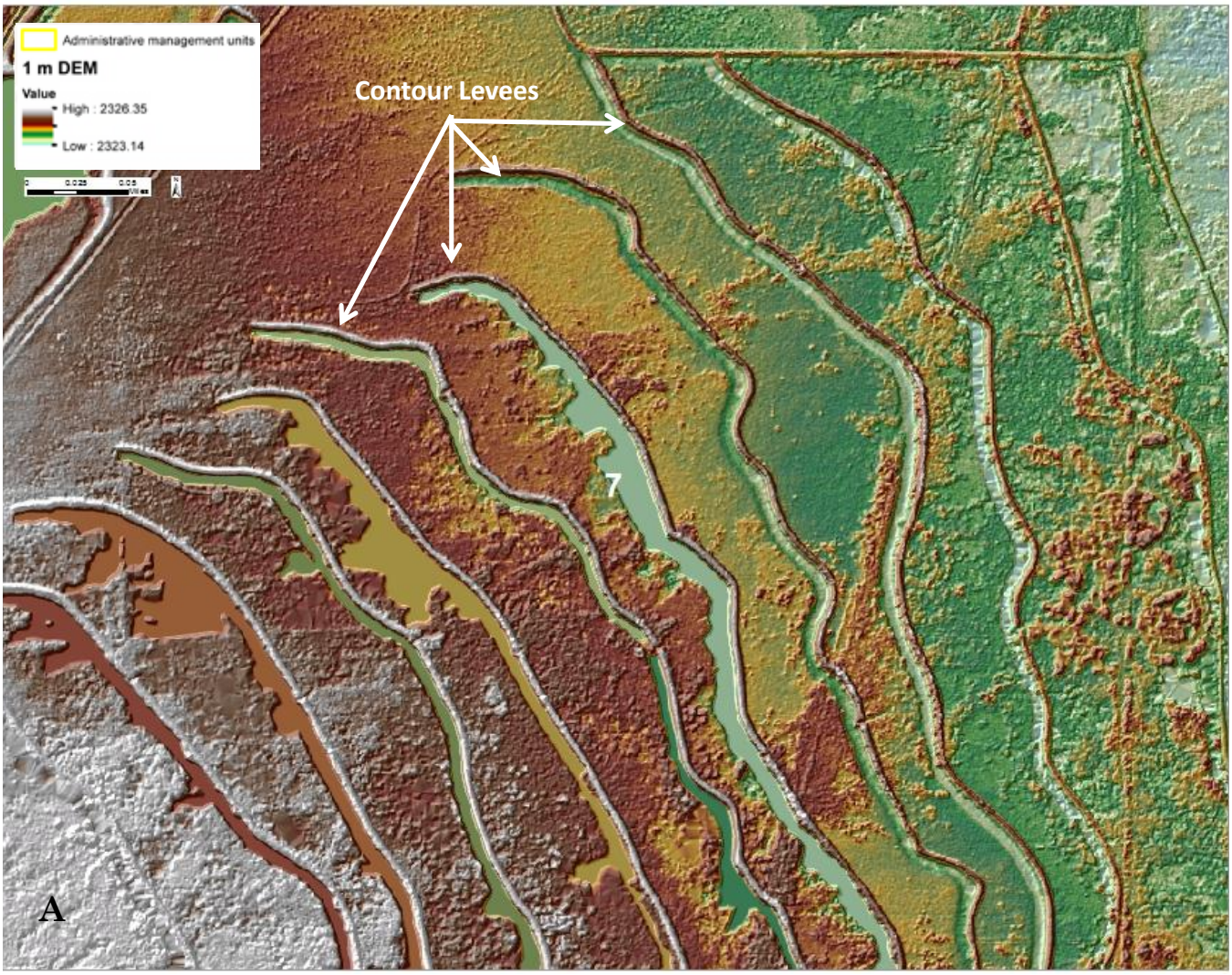


Figure 20. LiDAR DEM background showing: a) Unit 7, close-spaced contour levees, b) Units 15 and 16, angle-dikes, and c) Unit 10, conveyance channels on Monte Vista NWR.

< 50 gallons/minute (gpm). Eleven artesian wells are identified as flowing > 50 gpm but are listed as inactive and are no longer used. Three other larger artesian wells are adjudicated for an average flow of about 1,800 gallons/minute. Monte Vista NWR also has 21 large pumped wells with an average adjudicated flow of about 1,700 gpm.

Water availability and management at Monte Vista NWR is heavily controlled by SLV-wide water diversion infrastructure and associated Rio Grande Compact and water rights law. Monte Vista NWR receives an annual average of about 8,500 acre-feet of irrigation water from the Rio Grande primarily through the Empire and Monte Vista canals and water draining from neighboring private lands into several drainage ditches (e.g., Parma, Bowen, and Vano drains, etc., Fig. 19). As mentioned previously, the water delivery and diversion to the more than 80 wetland management sub-units on Monte Vista NWR is achieved using the complex infrastructure that includes more than 30 major and 100 minor dikes, over 400 water-control structures ranging from road culverts to larger creek dams and diversion points, and 61 miles of ditches (Fig. 19). Currently, the capability exists to seasonally irrigate and control water on more than 80% of the land surface on Monte Vista NWR (Striffler 2012).

The quality of water entering Monte Vista NWR could be potentially contaminated from inputs via the Rio Grande, subsurface groundwater, and drainage ditches (Striffler 2012). In general elemental contamination of water entering Monte Vista NWR is not high although drainage ditches contain the poorest water quality among water sources in the SLV (Archuleta 1992, Anderholm 1996). Copper and zinc in ditch waters exceed

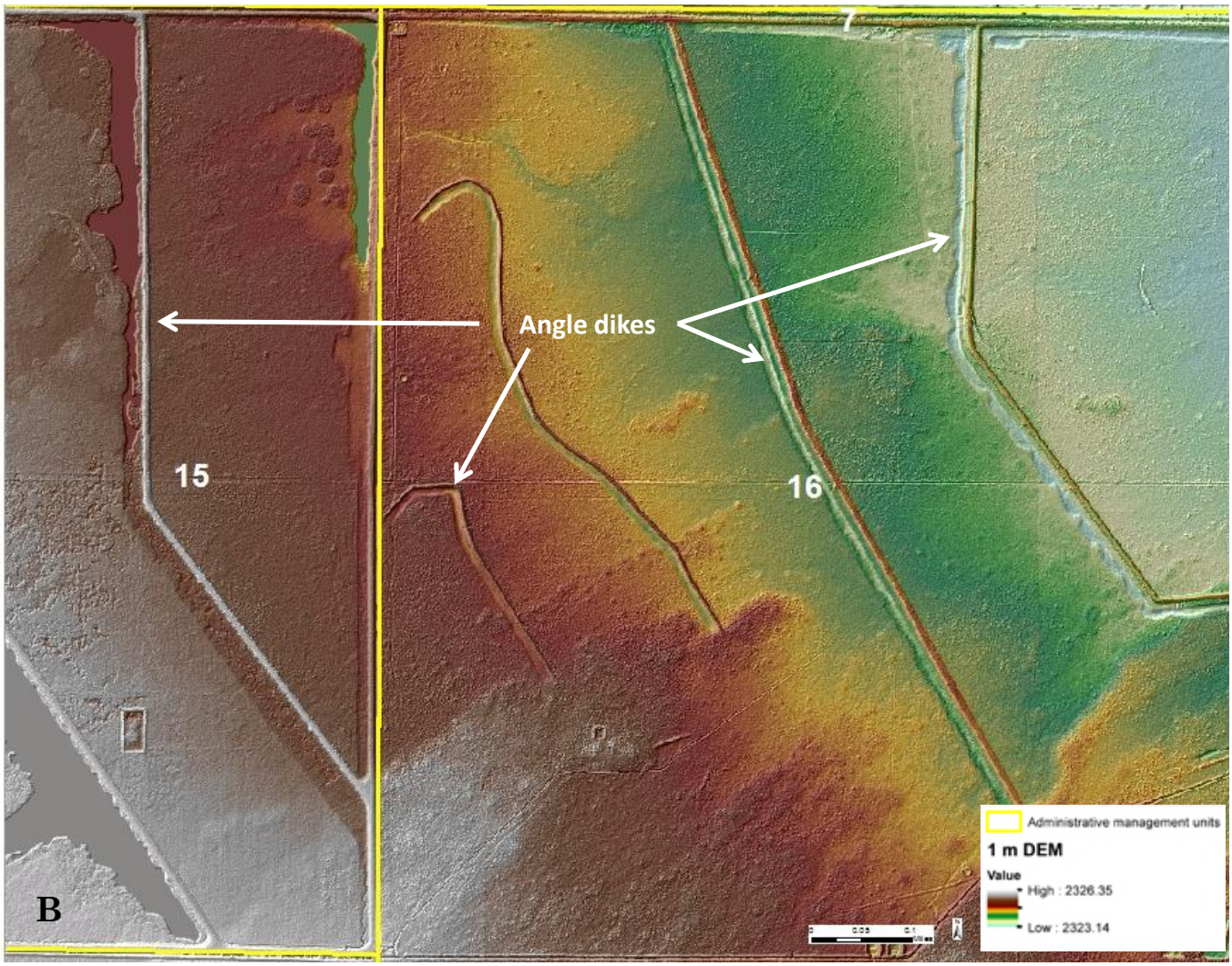


Figure 20, (continued). LiDAR DEM background showing: a) Unit 7, close-spaced contour levees, b) Units 15 and 16, angle-dikes, and c) Unit 10, conveyance channels on Monte Vista NWR.

aquatic life standards for the Rio Grande Basin. Mean concentrations of beryllium cobalt, iron, and manganese can exceed sediment guidelines and mean boron concentration has exceeded dietary levels for waterbirds.

Early in the development of Monte Vista NWR, over 100 small (1/4- to one-acre) "ponds" were created by constructing ring-dikes around artesian wells that were present when the property was purchased by the USFWS (Fig. 21). These ponds were intended to capture and hold artesian well water and provide small wetlands for waterfowl and other local wildlife species. Many of these ponds were not capable of holding water for more than short periods, because of low artesian flow and porous soils. The soil salinity of some pond sites also was high. Currently, many of these ponds are dysfunctional. Additionally, over time more than 100 islands were built in wetland units for nesting waterbirds and ducks. As some small artesian wells quit discharging water, other deeper and bigger wells were drilled.

Annual narratives for Monte Vista chronicle the many water and habitat management activities on the refuge through 1994 (Table 6). Management on the refuge is designated by 24 major management or "administrative" units (Fig. 12) and since the early-1960s, management has focused on providing habitat for breeding ducks (USFWS 2003), which includes early annual flooding, planting and maintaining dense nesting cover, and some predator control (Schroeder et al. 1976, Gilbert et al. 1996, USFWS 2003). This management emphasis was fostered by the attraction of high numbers and densities of breeding dabbling ducks to flooded wetlands on the refuge (Gilbert et al. 1996). Long-term studies

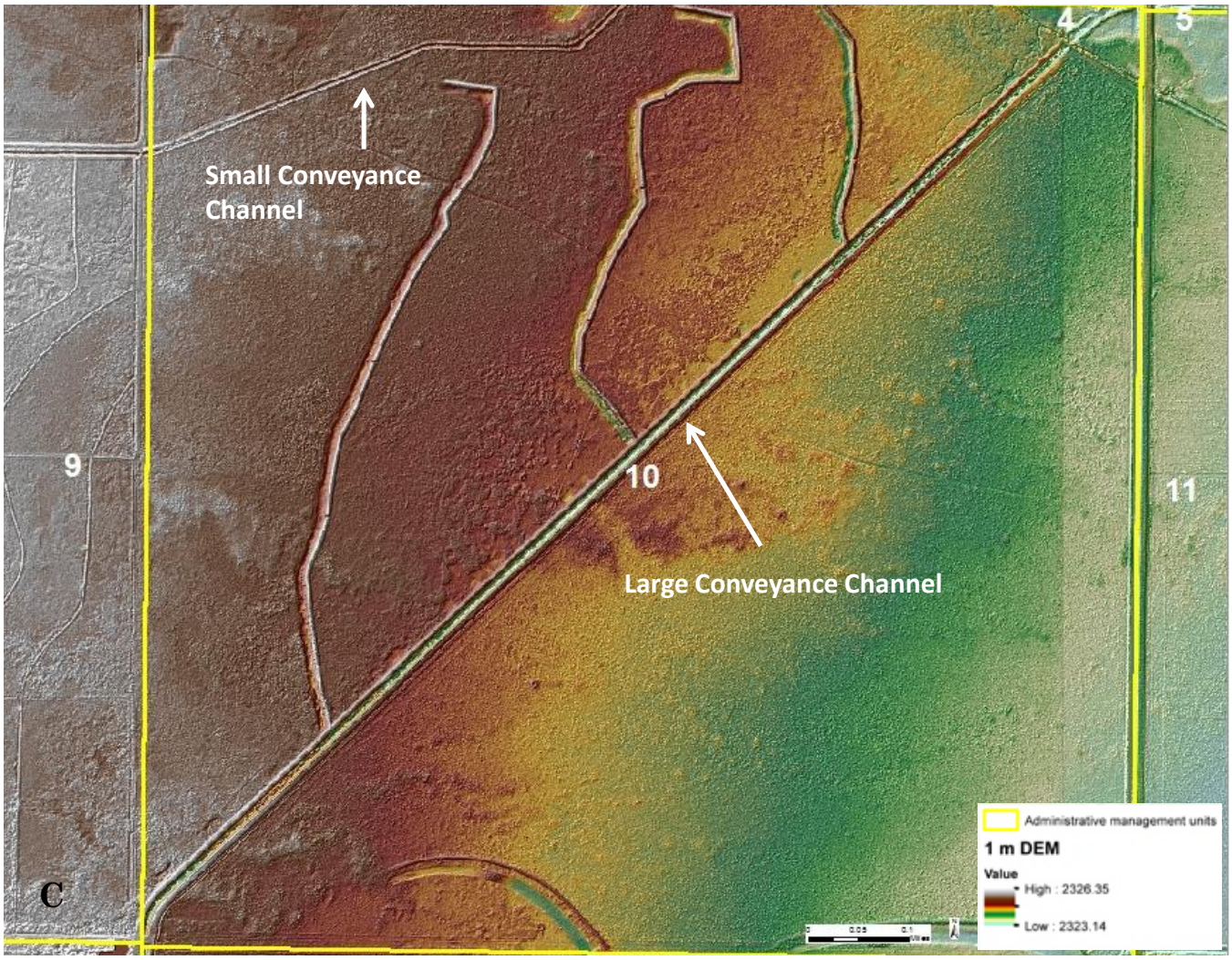


Figure 20, (continued). LiDAR DEM background showing: a) Unit 7, close-spaced contour levees, b) Units 15 and 16, angle-dikes, and c) Unit 10, conveyance channels on Monte Vista NWR.

of nesting ducks on the refuge indicated generally good nesting success and recruitment of young from the refuge into the 1990s.

Water management on Monte Vista NWR has been generally consistent over the past 30+ years (refuge annual narratives). The following paragraphs describe the typical water diversion and management efforts on the refuge to provide seasonal habitats and resources for wetland-dependent wildlife, especially waterfowl (taken from Striffler 2012). This description generalizes patterns and how annual differences occur for the specific location and timing/duration of water diversion and storage.

Groundwater is pumped (also including some artesian well flow) or diverted from the Parma Drain into about 2,000 acres of wetland units in February and March (Fig. 22a). This water provides roosting and loafing habitat for sandhill cranes and waterfowl, foraging and pair habitat for breeding waterbirds, and irrigation of nesting cover, mainly Baltic rush. During April through mid June, over 5,000 acres of wetland units, especially Units 1, 2, 3, 4, 6, 7, 9, 10, and 18, are flooded using surface water diverted from the Rio Grande through the Empire and Monte Vista canals (Fig. 22b). This water is moved to various units via lateral diversion ditches and water-control structures. Groundwater wells supplement the diverted Rio Grande water during dry years. This water management provides nesting and foraging habitat for breeding ducks and waterbirds and irrigation of nesting cover. From mid-June to August, over 1,300 acres of management units 1, 2, 4, 7, 11, 14, 15, and 18 are shallowly inundated similar to water diversions and movements in April and May (Fig. 22c) primarily to

Figure 21. Photograph of a ring-dike around an artesian well on Monte Vista National Wildlife Refuge.

provide nesting and brood rearing habitat. During September and October about 2,000 acres in units 8, 17, 19, and 20 are flooded using groundwater from wells (Fig. 22d) to provide additional brood habitat; loafing, roosting, and foraging habitat for fall migrant cranes, waterbirds, and waterfowl; and some hunting opportunity. In addition, groundwater recharge water is sometimes available from the Monte Vista and Empire Canals. Water in the Monte Vista Canal is directed to Unit 19 and if any excess water is available it is diverted into Spring Creek for flooding Unit 7. Available water in the Empire Canal is diverted into Units 9 and 10 and other northern areas.

Total annual water diverted onto the refuge has varied from less than 10,000 to more than 25,000 acre-feet from 1980 to the present (Fig. 23). Much of the annual variation in refuge water diversion relates to the amount of surface water available that can be diverted from the Rio Grande, which is influenced by annual precipitation and discharge in the upstream watershed. The USFWS acquired groundwater rights and rights to use water from the Rio Grande when refuge lands were acquired. The USFWS also subsequently established rights under Colorado water law to use groundwater. Groundwater wells supply on average about 8,200 acre-feet of water/year and about 8,500 acre-feet of Rio Grande water is used on average each year although use of this river water has varied from none in 2002 to over 30,000 acre-feet in 1992 (Fig. 23). Total water use reached a peak of about 38,000 acre-feet in 1992 and a low of 5,333 acre-feet in 1977. Generally, water availability and use on the refuge follows an alternating high and low pattern of regional precipitation that spans about 25 years (see earlier section on historical climate patterns).

In addition to the extensive artificial management of water on Monte Vista NWR, other habitat management has included: 1) physical manipulation of vegetation using land leveling, brush hogging, grazing, burning, tillage, and chemical treatments; 2) small grain production for sandhill crane and other wildlife use; and 3) control of invasive plant species (USFWS 2003, Table 6). Cattle grazing occurred on Monte Vista NWR from establishment until 1994 when a federal court ruling postponed grazing on the refuge and the USFWS initiated a five-year study to assess the effectiveness of different habitat management tech-

Table 6. Summary of water developments and management of Monte Vista NWR 1953-1994, taken from refuge annual narratives.

Year	Unit	Development Activities
1952		Monte Vista National Wildlife Refuge is established
1953	Sheridan Tract	80 ac cleared of brush, disced, floated and staked for leveling; chiseled down to 30"
	Rodman Tract	36 ac disced
	Sheridan Tract	3.5 ac fenced for goose pen
	Sheridan and Todman Tracts	8 to 10 miles of drain put in with 3 crossing and checks
	Sheridan Tract	Water control structures placed in north and south ditches
	Sheridan and Todman Tracts	7 ponds constructed around artesian wells
1954	Sheridan Tract	North and South ditches extended
	Sheridan and Rodman Tracts	Checks, weirs, dividing boxes and crossings added to ditches
	Unit 13	Chisled, disced, and planed for future planting
	Unit 1	New takeout on the Monte Vista Canal installed
	Across units	107 small ponds built around artesian wells; 4 of them are 15 ac while the others are 1/4 to 1 ac in size
1955	Across units	200 pond banks were planted with grasses
	Sheridan Tract	34 islands were created in upper Spring Creek
	Unit 7	11 irrigation structures installed
	Unit 13	160 acres was leveled
	Unit 4	Unit plowed
	Unit 1	60 ac cleared of brush
	Across units	35 new ponds
1956	Unit 22	1400' of drain installed
	Units 22, 23, and 3	200 ac harrowed, land planed, plowed, and planted
	Units 25, 26, and 29	5 new ponds developed
	Unit 24	2 contour levees and 2 water control structures installed
	Unit 20	One large pond and two small one acre ponds developed
	Unit 19	One 4 ac pond developed
1958	Units 20, 22-5	Drain ditches completed
	Unit 23	63 ac leveled and landplaned
	Unit 22	39 ac leveled and landplaned
	Unit 30	Initiated pond development and dike construction
1959	Unit 2G	2 contour levees, each 1.5 miles long; another 3 of 0.75 miles long
	Unit 6g and 6h	A 0.75 mile levee constructed between the two units
	Across units	9 24" control gates installed on ponds
1960	Across units	30 miles of small ditches reworked and cleaned
	Unit 3g	One mile of drain completed
	Unit 2f	100 ac cleared of brush for future farmland
1961	Across units	48 miles of ditches reworked and cleaned
	Unit 26	2 miles of raised head ditch constructed
	Unit 2f	107 ac leveled, 80 tons of manure spread over it, 50 ac disced to maintain brush control, 82 ac deep plowed and chiseled
	Unit 2	2 new goose pens constructed
	Unit 9f	Brush removed from 20 ac of land, half of unit plowed
1962	Across units	68 miles of ditches cleaned and reworked
	Unit 13	28 6" water control structures installed
	Unit 22	40 ac was brush hogged to start land leveleing
	Units 6 and 14	New ponds completed
	Unit 19	Development of this unit including 11.4 miles of levees and installation of structures

Table 6. continued

Year	Unit	Development Activities
	Unit 6	Development of this unit including 4.4 miles of levees and installation of structures
	Unit 14	Development of this unit including 1.55 miles of levees and installation of structures, 1.14 miles of roadway, 44 ac of land leveled with 22 ac of it chiseled
	Unit 22	Development of this unit including 40 ac land leveled and 110 ac deep chiseled
1963	Across units	100 miles of ditches cleaned
	Unit 15g	New head ditch installed
	Units 13f-6, 14f-1, and 13f-7	Leveling, landplaning, and deep chiseling
1964	Units 16, 21, and 22	Small ponds developed for watering cattle
	Across units	85 miles of ditches cleaned
1965	Unit 13	A new reservoir of 12 ac/ft capacity constructed for temporary storage of irrigation water
	Unit 6	Parshall flume installed in lateral 3
1966	Unit 15	New and extension levees completed
	Unit 16	New and extension levees initiated but not completed
1967	Unit 18	Constructed 1.25 miles of drain ditch around 80 ac field for farmland
1968	Unit 4	2 way water control structured installed to distribute water from Parma drain
	Unit 19	Goose pen area completely redone
	Unit 13 reservoir	Land leveling with removal of 12,600 cubic yards of dirt; clay and silt form unit 19 were spread over the interior of the reservoir for sealing
1969	Unit 23f-1	Land leveling, deep chiseling, discing, and land planing of 45 ac
1971	Unit 18f-1	Leveling, disking, land-planing, and deep chiseling
1980	Units 1 and 7	Levees constructed along the east side
	Noll property and Unit 10	2 contour levees, north and south, were completed in the newly acquired parcel and tailed out into unit 10
1984	Unit 16	Development of this unit including contour levees and 9 water-control structures
1990	Unit 15	moist soil vegetation management applied for first time on a pond
1991	Unit 24	moist soil vegetation management applied for first time on the Barclay pond

niques, which included grazing (Diebboll 1999). Concerns about grazing were in part derived from a long-term study of dabbling duck nesting on the refuge that indicated nest density was negatively affected by grazing (Gilbert et al. 1996) although many other factors such as vegetation characteristics, hydrology, and location were never considered. After the conclusion of the studies grazing was discontinued on the refuge (Table 6, USFWS 2003) until the late-2000's. Over time burning has become infrequent.

The extensive development of wetland management infrastructure before and after refuge establishment, the relatively consistent annual water regime management (flooding) among management units, and clearing of shrubland for croplands greatly altered the vegetation community/habitat composition on Monte Vista NWR since its establishment. Major modifications/degradations included a major reduction in the extent and composition of salt desert shrub habitat and a shift in remnant shrubland community composition toward the invasive weed, tall whitetop, and wetland vegetation, especially baltic rush (comparison of habitat areas on Fig. 16 vs. Fig. 24). Currently about 24% of the refuge is in salt desert shrub habitat, which

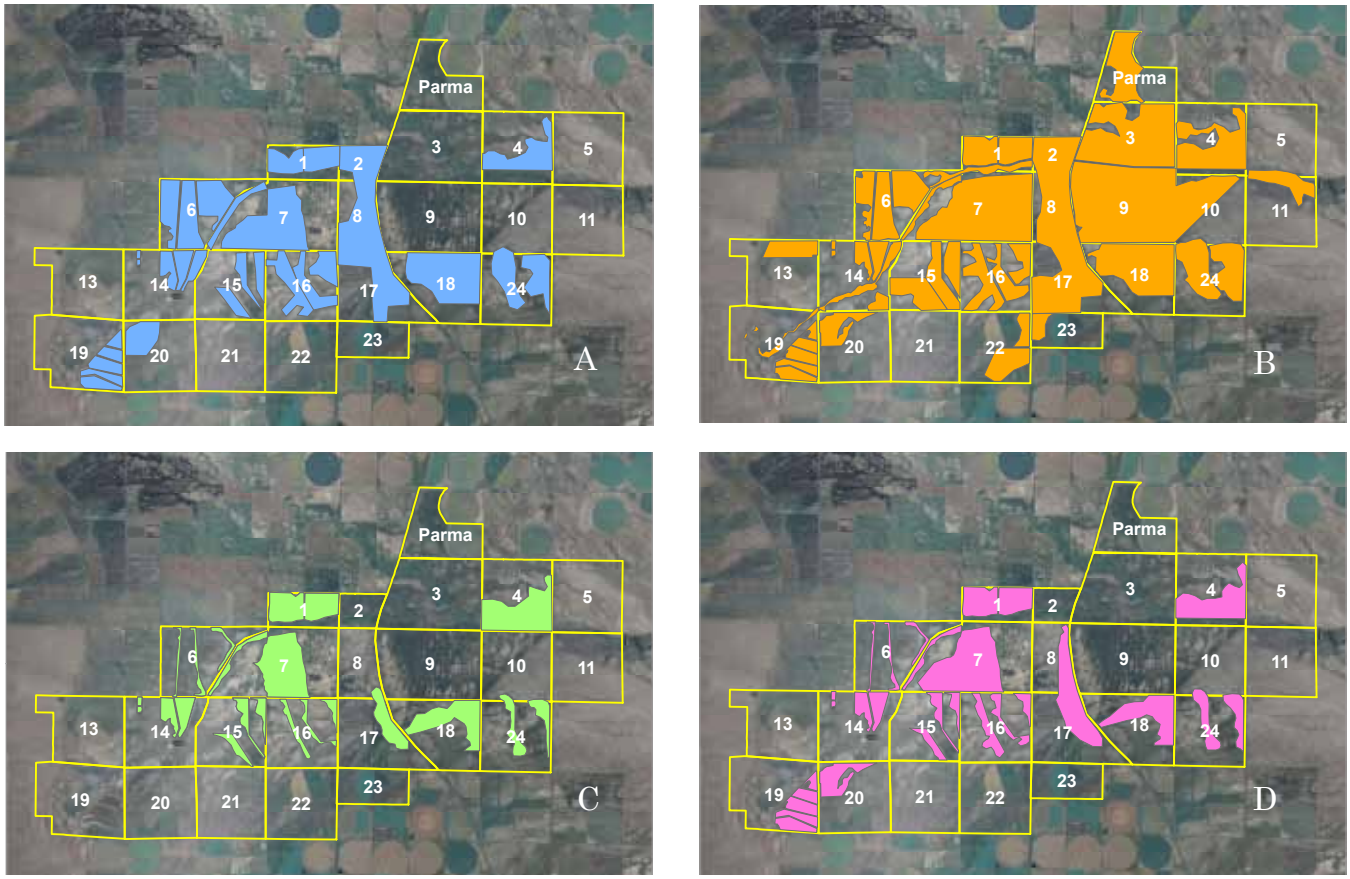


Figure 22. Water management strategies for Monte Vista National Wildlife Refuge: a) Feb-Mar, b) April to mid-June, c) mid-June to August, and d) Sept-Oct (modified from Striffler 2012).

when compared to the potential historic vegetation identifies a decrease of about 75% of this community type over time. National Wetland Inventory maps of the refuge prepared in the 1980s demonstrate the large areas of artificially managed seasonal and semi-permanent wetland units that represent converted salt desert shrub and creek corridor natural seasonal wetlands (Fig. 23). Most artificial wetlands mapped on Monte Vista are a "wet meadow" category that now is primarily composed of baltic rush and tall whitetop (Figs. 24-27). The area immediately south of Unit 9 is an example of where former shrubland has been converted to artificially irrigated wetland and the site is now invaded by tall whitetop. This site has Arena soils series, which typically supports salt desert shrub and saltgrass habitats (Fig. 27). In other areas, including those that have Hooper soils indicative of former shrub lands, whitetop also is extensive.

The extensive spread of tall whitetop on Monte Vista NWR is closely associated with the disturbance of soils and changes in hydrology caused by artificial irrigation and diversion of water to former shrublands. Although initially spread through the ditch system, native shrub vegetation communities were converted to wetter states through prolonged seasonally flooded hydrologic regimes, which allowed tall whitetop to out-compete natives (Gardner 2002). About 80%+ of the tall whitetop present on Monte Vista NWR is associated with levees, ditches, within a short distance of them, or has continued to spread out from these initially colonized areas (Fig. 27). Common areas for tall whitetop to initially germinate include transition areas from one vegetation community to another such as small elevation changes between wet meadow and salt desert shrub (Gardner 2002). Germination of tall whitetop seeds have been documented under a wide range of temperatures with only very cold or highly constant temperatures preventing growth (Miller et al 1986). Therefore, the wide range of diurnal temperatures which occur in the SLV are perfect for establishment of this species. Studies have shown that this weed may over time

alter local soil characteristics such as chemistry and structure. Tall whitetop is capable of taking sodium out of the soil profile and depositing it on the surface, thereby preventing germination of salt-intolerant species (Blank and Young 1997). Monotypic stands prevent light penetration to the surface further restricting competition from native species. Of note are Units 5, 10, and 11 south of the Bowen Drain, which have retained relatively intact greasewood shrublands that have not been converted to artificial seasonal wetlands and are not

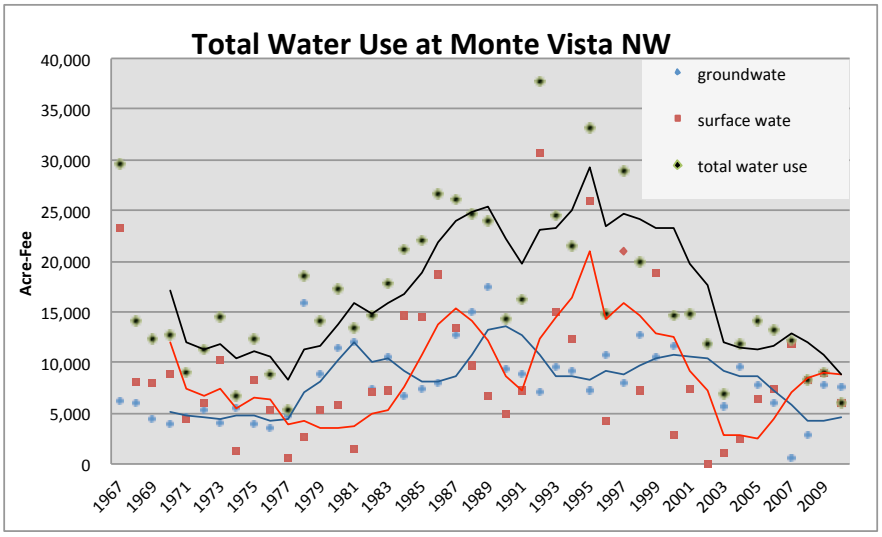


Figure 23. Total water use at Monte Vista National Wildlife Refuge 1967-2009 (from Striffler 2012).

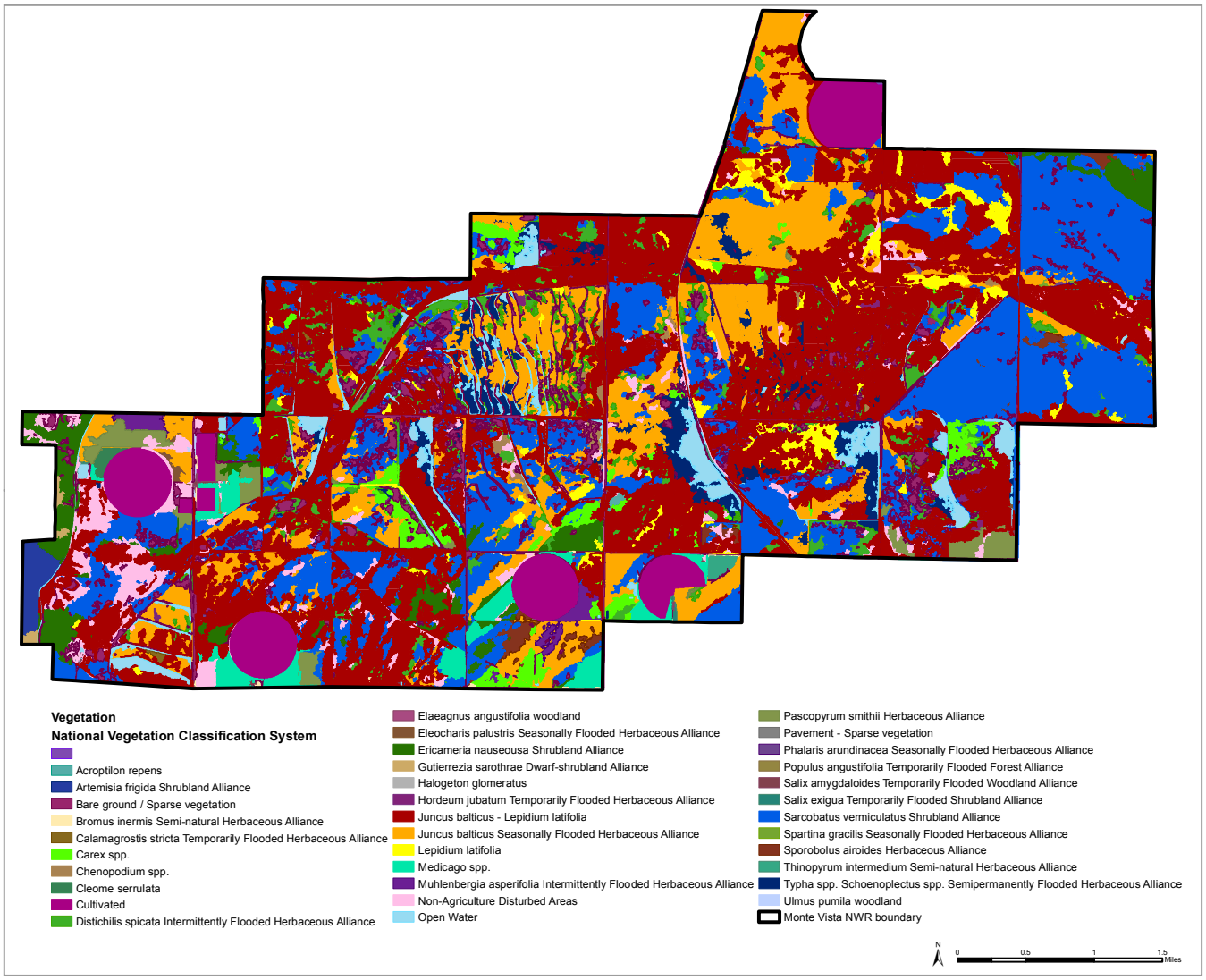


Figure 24. 2005 National vegetation classification system map of vegetation alliances on Monte Vista National Wildlife Refuge.

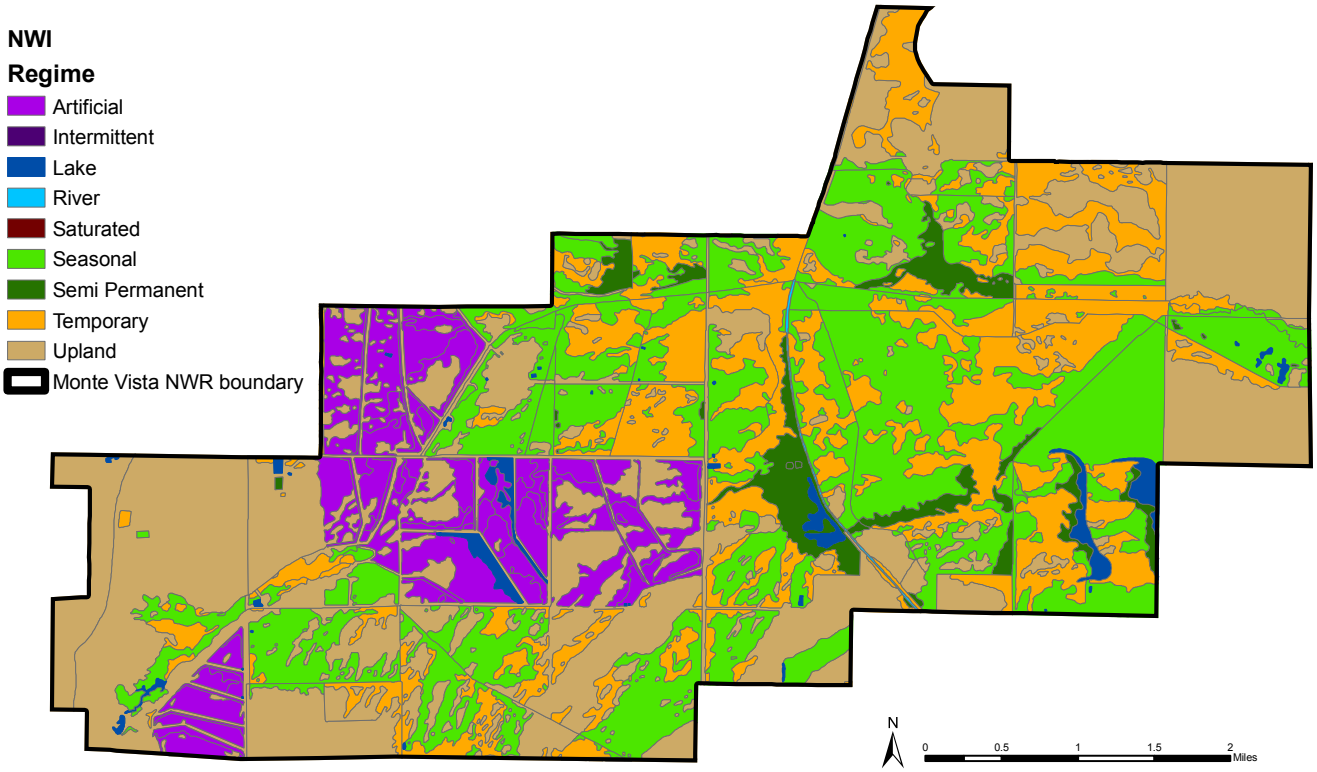


Figure 25. National wetland inventory of wetland classification types on Monte Vista National Wildlife Refuge.

invaded by tall whitetop. The presence of more intact shrub habitat in these units supports the conclusion that changes in hydrologic regime have helped establish tall whitetop in many areas that were formerly shrublands. Refuge management has attempted to limit the spread of invasive plant species, especially tall whitetop, using repeated mowing, herbicide application, and targeted grazing using sheep in some areas (USFWS 2003).

Several invasive species in addition to tall whitetop, including Canada thistle (*Cirsium arvense*), hoary cress (*Cardaria draba*), and knapweeds (*Centaurea* spp. and *Acropitilon repens*) are now widely distributed on the refuge and control of these species has been conducted with various chemical and physical treatments. These species are dispersed via irrigation ditches or equipment and commonly germinate in disturbed areas on a variety of soil types. However, they may occur in slightly different habitats as knapweeds typically exist in dryer areas whereas Canada thistle and hoary cress can survive in a wider range of moisture regimes. Canada thistle seeds may be viable in the soil for up to 20 years and has an extensive and often deep root structure that requires a combination of treatments for control. Mowing and grazing has proven effective in reducing the extent of this weed (Clark 2000). In more permanent water areas, cattail has developed relatively monotypic stands, which have been controlled by mechanical and water management. The combination of increased spring and summer irrigation flooding followed by rapid drying and high ET has elevated soil salinity levels and caused the spread of saltgrass.

After Monte Vista NWR was established, the refuge farmed about 900 acres to provide small grains to wintering waterfowl, cranes, upland birds, and deer (USFWS 2003). By the early 2000s, this farm acreage had declined to about 500 acres planted in rotations of small grains, alfalfa, and fallow. The alfalfa haying was used to increase soil fertility through nitrogen fixation, increase organic matter content, and to control invasive weeds. Most of the cropland and alfalfa lands are irrigated with center-pivot sprinkler systems in the Parma Unit and in Units 13, 20, 22, and 23 as opposed to flood irrigation methods used in meadows and wetlands. Lands removed from crop production were planted to perennial grasses and legumes.

Monte Vista NWR contains relatively abundant populations of the globally imperiled slender spider flower (*Cleome multicaulis*), which

Figure 26. General location of tall whitetop and baltic rush on Monte Vista National Wildlife Refuge.

occurs on moist alkaline soils found in the transition areas located between wet meadows and salt desert shrub communities (Rocchio et al. 2000). Giant bur-reed (*Sparganium eurycarpum*), a state imperiled species also is found on Monte Vista NWR. This plant is a persistent emergent found in wetlands with semi-permanent water regimes. Several animal species of concern are present on Monte Vista NWR, including the bald eagle (*Haliaeetus leuceocephalus*), American bittern (*Botaurus lentiginosus*), black tern (*Childonias niger*), burrowing owl (*Athene cunicularia*), ferruginous hawk (*Buteo regalis*), and white-faced ibis (*Plegadis chihi*). Population trends for bald eagle (Fig. 28), white-faced ibis (Fig. 29), duck broods (Fig. 30), and sandhill crane (Fig. 31) indicate annually variable numbers. Generally white-faced ibis and sandhill crane numbers on the refuge have increased over time, while numbers of wintering waterfowl and eagles have decreased (USFWS 2003).

Relatively large numbers of breeding dabbling ducks were attracted to Monte Vista NWR to nest after extensive wetland development and management for spring-summer flooding of these sites began in the early-1960s. Consequently, the refuge became an important contributor to local and regional waterfowl populations (Szymczak 1986, Gilbert et al. 1996). The artificial and enhanced wetlands and wet meadows also attracted and supported relatively large populations of many other waterbirds, such as sandhill cranes, ibis, egrets, and shorebirds (D'Errico 2006). Populations of some of these species, such as sandhill cranes, became trademarks of the refuge along with breeding ducks. Refuge wetlands and meadows also formerly supported relatively large populations of waterfowl in winter and waterfowl hunting harvest

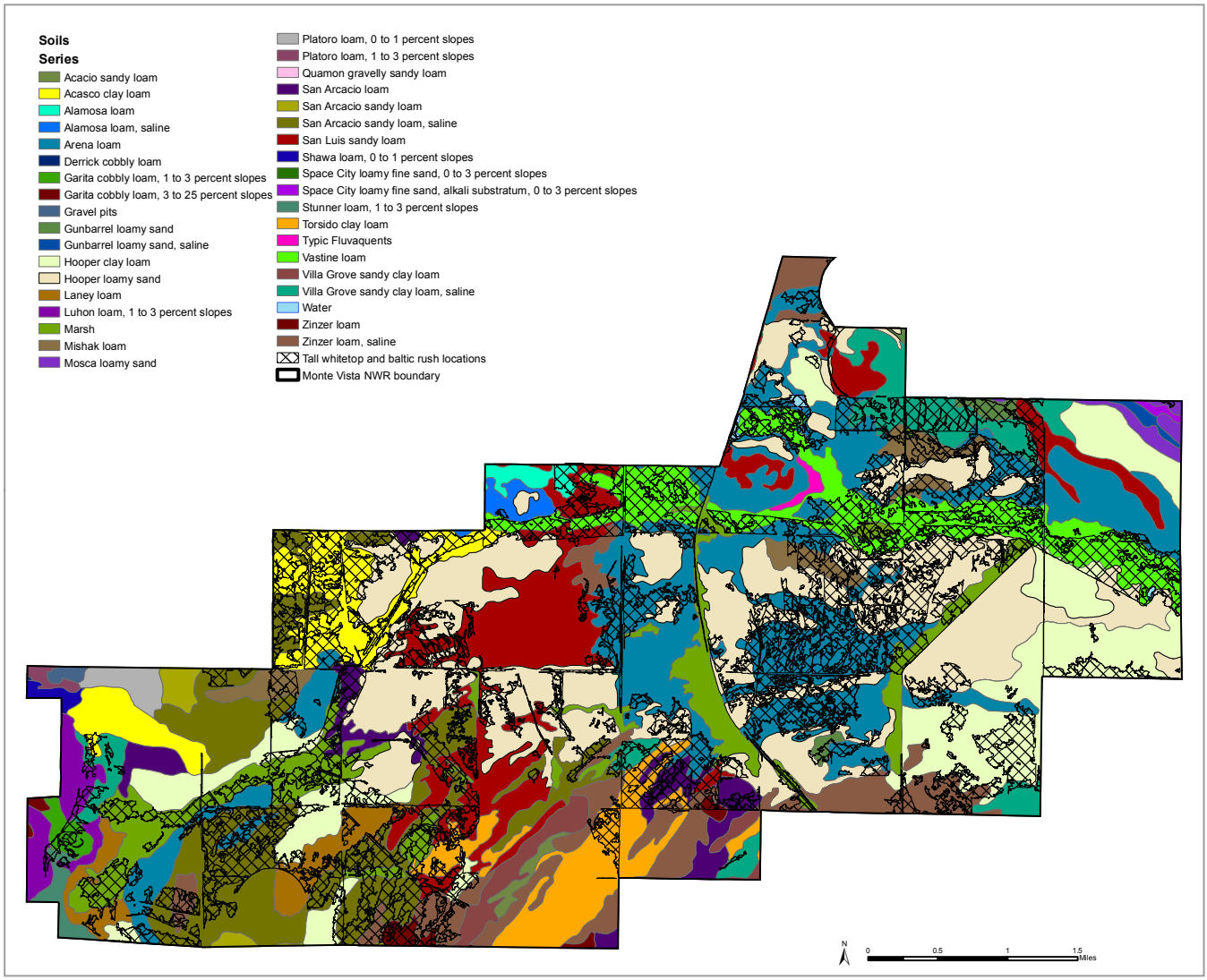


Figure 27. Location of tall whitetop and baltic rush on Monte Vista National Wildlife Refuge in relationship to soil type.

in the SLV traditionally has been among the highest in Colorado, mainly supported by locally produced ducks (Szymczak 1986). In some years, avian cholera outbreaks on the refuge have killed up to 6,500 ducks (USFWS 2003). Duck production on the refuge has averaged about 15,000 fledglings, but annual numbers fluctuate greatly depending on the amount of water available on the refuge and the overall wetness of the previous winter in the Rio Grande watershed.

It is generally believed that wetland-associated animal species, especially waterbirds, have increased on Monte Vista NWR compared to pre-irrigation and pre-wetland development periods (USFWS 2003). Several species of shorebirds, wading birds, and over-water nesters such as grebes commonly nest on the refuge. In contrast to waterbirds, populations of other animals that are associated with salt desert shrub likely have declined as this habitat was converted to irrigated meadow and seasonally flooded wetland units. In particular species such as burrowing owl, Gunnison's prairie dog (*Cynomys gunnisoni.*), raptors, plateau lizard (*Sceloprous tristichus*), and shrub and grassland birds now are rare, reduced in number and distribution, or are absent (USFWS 2003).

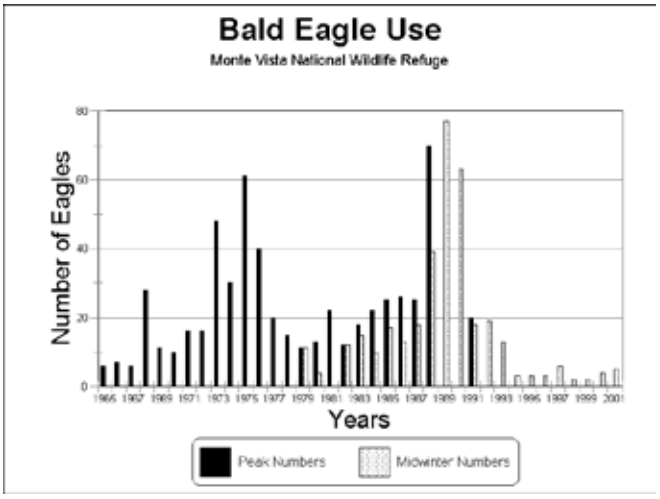


Figure 28. Number of bald eagles on Monte Vista National Wildlife Refuge, 1965-2001 (from USFWS 2003).

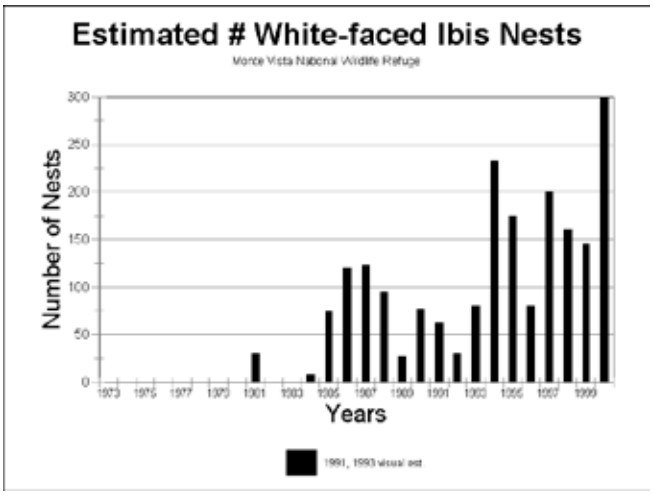


Figure 29. Estimated number of white-faced ibis nests on Monte Vista National Wildlife Refuge, 1973-2000 (from USFWS 2003).

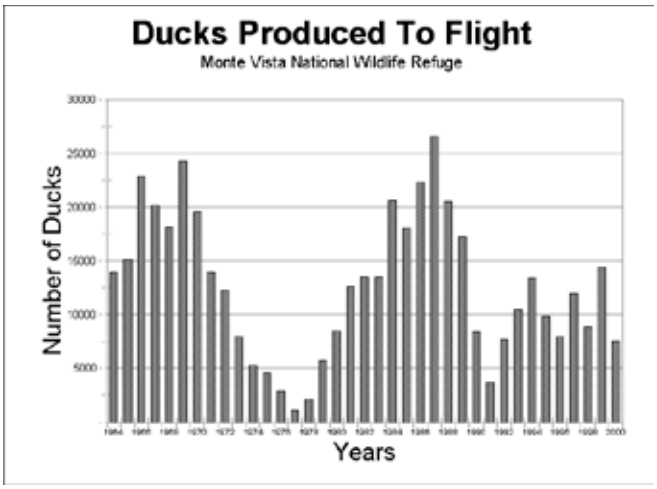


Figure 30. Estimated number of ducks produced to flight stage on Monte Vista National Wildlife Refuge, 1964-2000 (from USFWS 2003).

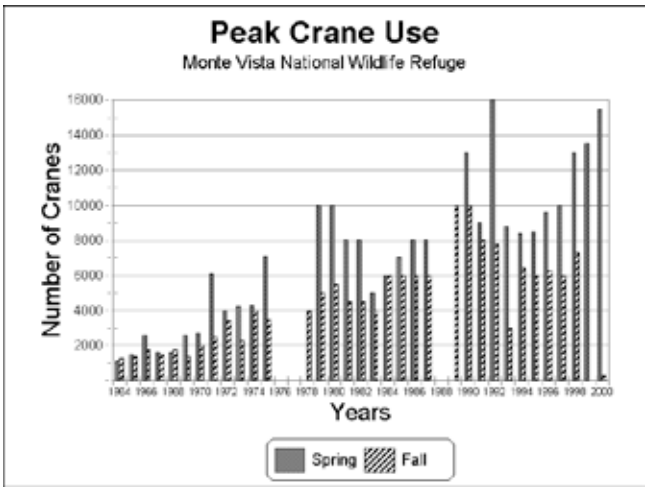


Figure 31. Peak numbers of sandhill crane on Monte Vista National Wildlife Refuge, 1964-2000 (from USFWS 2003).