AN EVALUATION OF
ECOSYSTEM RESTORATION AND MANAGEMENT OPTIONS FOR
COKEVILLE MEADOWS NATIONAL WILDLIFE REFUGE

PREPARED FOR:

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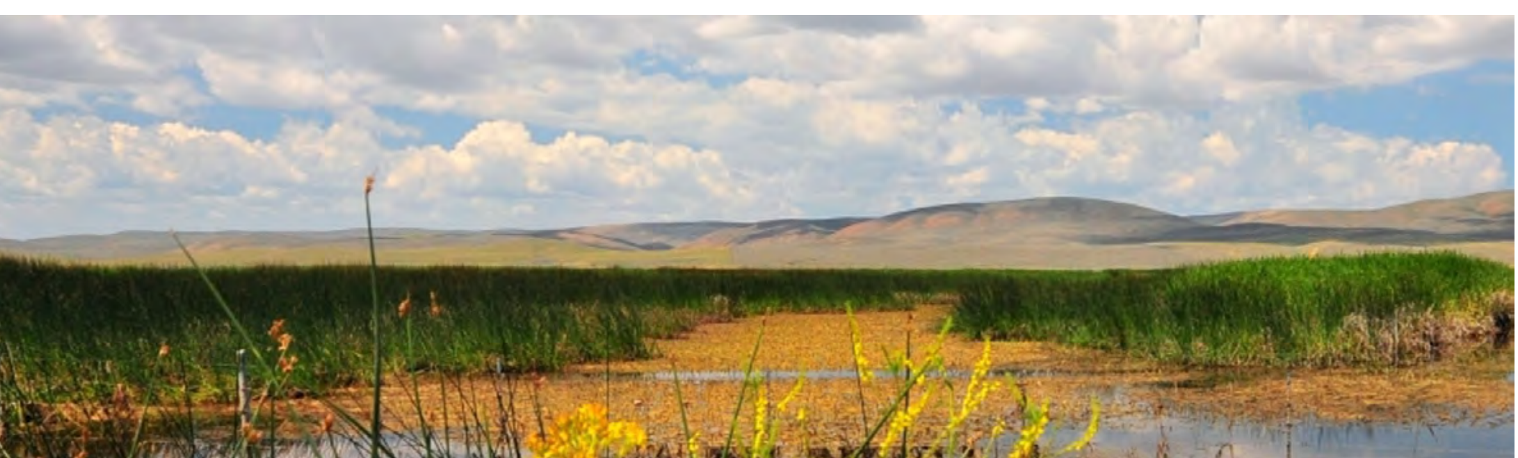

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EXECUTIVE SUMMARY

Cokeville Meadows National Wildlife Refuge (NWR) is a relatively new refuge authorized to contain 26,657 acres within an approved boundary in Lincoln County, Wyoming. Current NWR lands include 6,466 acres owned in fee title by the U.S. Fish and Wildlife Service (USFWS), 1,672 acres protected with conservation easements, 758 acres in Farmers Home Administration lands, and a 363 acre State of Wyoming land lease. The Bear River and its floodplain are the primary features on Cokeville Meadows NWR; edges of the floodplain grade into upland bluffs and alluvial fans. Water in the Bear River is seasonally impounded in areas upstream and in Cokeville Meadows NWR and is diverted into floodplain meadows and grasslands through a system of ditches, dikes, and water-control structures. Water diversions and infrastructure, roads, rail beds, and altered land uses have changed vegetation communities and topography on the refuge.

In 2009, a Comprehensive Conservation Plan (CCP) was initiated for Cokeville Meadows. This CCP is being facilitated by an evaluation of ecosystem restoration and management options using Hydrogeomorphic Methodology (HGM). This report provides this HGM evaluation with the following objectives:

1. Identify the pre-European settlement ecosystem condition and ecological processes in the Bear River Valley near Cokeville Meadows NWR.

2. Evaluate changes in the Cokeville Meadows NWR ecosystem from the Presettlement period with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.

3. Identify restoration and management options and ecological attributes needed to successfully restore specific habitats and conditions within the Cokeville Meadows NWR region.

The contemporary geomorphic surfaces at Cokeville Meadows NWR are primarily one to two mile wide Holocene alluvial deposits from the Bear River flanked by younger-age alluvial fans and low terraces. Numerous abandoned Bear River channels occur in the floodplain in the form of oxbows and floodplain wetland depressions. Soils at Cokeville Meadows include alluvial silt loams overlying alluvial sand and gravel, cobble silt and sandy loam soils on alluvial fans and terraces, and mixed parent material soils on the foothills. Elevations on the refuge range from about 6,500 feet on south end bluffs to 6,170 feet on the north end floodplains.

The climate of the Cokeville Meadows region is semi-arid, midcontinental. Average annual precipitation is about 12 inches; about 38% of annual precipitation occurs as rainfall from April to June. The frost-free growing season is only 60-70 days each year. Evapotranspiration rates are high and the occurrence of natural free-standing surface water is scare from summer through winter.

Historically, the Bear River had a strongly unimodal discharge/river stage pattern with peak discharges above 400 cubic-feet/second (cfs) in June and relatively low sustained discharges near 100 cfs from August through February. Water from the Bear River begins to enter many off-channel oxbows and floodplain depressions at about 300 cfs and much of the floodplain is inundated at discharges of > 1,000 cfs. Consequently, historic backwater flooding from the Bear River into floodplains typically occurred for relatively short time periods from late May to mid June in most years. In addition to the strong seasonal pattern of river discharge and flooding, long term data suggest alternating patterns of peak and low discharges about every 12 to 15 years. During the ca. 60 year period of record on the Bear River below Pixley Dam, the river exceeded 1,500 cfs in 9 years and annual peaks were below 500 cfs in 15 years.

Historic vegetation communities at Cokeville Meadows NWR included: 1) narrow riparian/riverfront forest corridors along the Bear River, 2) semipermanently flooded floodplain wetland depressions, 3) wet meadow sedge and grassland communities, and 4) upland sagebrush/grassland communities. A HGM matrix of relationships of these plant communities to geomorphic surface, soils, hydrology, and elevation was developed to map potential distribution of historic communities on Cokeville Meadows. Generally historic communities were distributed as relatively parallel bands as water-elevation gradients moved from the Bear River upslope to valley terraces and alluvial fans. Persistent emergent wetland communities were imbedded within floodplains in abandoned channels and depressions. The suite of vegetation communities historically provided important resources for diverse populations of animals. Migratory birds, both terrestrial and wetland species, were especially abundant in the floodplain ecosystem; most were seasonal visitors, but in wet years many waterbirds bred in the region.

This study obtained information, where available, on contemporary: 1) physical features, 2) land use and management, 3) hydrology, 4) vegetation communities, and 5) fish and wildlife populations of Cokeville Meadows NWR and the surrounding region. Native people apparently occupied the region at various times over the past 10,000 to 12,000 years, but European settlement did not become widespread until the mid 1800s. Sparse human populations, limited growing seasons, and little transportation and economic infrastructure limited ecosystem changes to the area until the mid 1900s, except for early diversions of water for human and livestock use, eventual extensive grazing, and rail/road construction. Most water diversion structures were built in the 1930s and 1940s to move water from the Bear River onto meadow and grassland areas in the floodplain to enhance forage and hay production during summer. Typically, the low-level Pixley and B-Q dams on the Bear River near Cokeville Meadows NWR were closed in spring to divert water into contour distribution ditches that branched from the diversion site to meadow fields. Irrigation companies operated and maintained water delivery systems and infrastructure. Water from the Smith's Fork River also was diverted into the Cokeville Meadows region via the Covey Canal. At the end of the irrigation season (about mid July), water is drained from meadows to allow drying and subsequent haying and then summer/fall grazing.

A set of seniority rights govern water use in the Bear River Valley during limited water periods. All water management and uses in the Bear River Basin are governed by the Bear River Compact, which determines water rights and obligations in Wyoming, Utah, and Idaho. Currently, 50 separate water rights are present on Cokeville Meadows NWR lands. Over 100 groundwater wells have been drilled in the Bear River Valley in the Cokeville Meadows region and they supply water for agriculture and urban uses. Ten of these wells are on existing NWR lands.

Current land use in the NWR acquisition boundary is dominated by shallowly flooded wet meadow habitats in the floodplain and sagebrush-grassland habitats on alluvial fans and upland terraces. Nearly 4,000 acres of terrace and alluvial fan areas have been converted to irrigated cropland and alfalfa fields. About 1,200 acres in the NWR boundary are in deeper wetland depressions and abandoned channel areas. The more consistent and prolonged spring/summer flooding on Cokeville Meadows NWR has shifted grass and wetland species to slightly wetter and fresher types. Creeping foxtail has expanded to dominate meadow communities. Cattail and bulrush now dominate deeper floodplain depressions and ditch/canal edges. Several noxious and invasive plants have become established on the refuge including Canada thistle, whitetop, musk thistle, and Russian knapweed.

Since Cokeville Meadows NWR was authorized in 1989 by an act of the Wyoming Legislature, the refuge has expanded through acquisition, easement, and land transfer. The purposes of the refuge are: 1) conservation of wetlands to meet obligations of migratory bird treaties and conventions, 2) conservation of Western Intermountain ecosystems, and 3) sustaining migratory bird populations. Management and development on the refuge began in the early 1990s and has included partial impoundment of floodplain sites for waterfowl production; enhancement of foraging areas for migratory waterfowl, sandhill cranes, eagles and raptors, songbirds, and shorebirds; providing nesting habitat for waterbirds; protecting roost sites for bald eagles; and protecting and enhancing lek sites for sage grouse. Existing irrigated hay and pastureland has been mostly maintained on the refuge, although some small areas were originally converted to dense nesting cover for waterfowl. About 50% of hayable meadows are hayed by adjacent landowners under permit. Invasive and noxious weeds also are controlled by permittees.

Little quantitative information is available to assess changes in presence, abundance, and distribution of animal species over time in the Cokeville Meadows NWR region. Use and production by some waterbird species may have increased as more annually consistent and prolonged water regimes have occurred because of annual water diversions. However, reduction in long-term dynamics of flooding may be decreasing wetland productivity and diversity of both plant and animal species. The effects of changes in wet meadow vegetation, including a now dominated creeping foxtail community, on animal populations are unknown. Total number of sage grouse lek sites on the refuge has not changed, but some individual lek sites have been abandoned. Populations of some mammal species have changed from historic periods and few native fish remain in the Bear River or its tributaries.

The major ecosystem changes and issues that affect future management and restoration of habitats on Cokeville Meadows NWR include: 1) maintaining and complying with adjudicated water rights and irrigation/drainage constraints with neighbor land holdings that control water flow and delivery pathways onto, and across refuge lands, 2) disjunctive land ownership, 3) presence and expansion of invasive and introduced plant species, 4) altered water flow and seasonal flooding regimes, 5) altered vegetation communities, and 6) public expectations for continued agricultural uses and expansion of lands and public access. Based on the HGM context of this study, future management of Cokeville Meadows should seek to:

1. Maintain the physical and hydrological character of the Bear River and its floodplain in the refuge boundary.

2. Restore natural topography, water regimes, and physical integrity of surface water flow patterns in and across the Bear River floodplain and adjacent terraces and alluvial fans.

3. Restore and maintain the diversity, composition, distribution, and regenerating mechanisms of native vegetation communities in relation to topographic and geomorphic landscape position.

Specific recommendations for each of these primary ecosystem goals include:

Goal #1. *Bear River floodplain physical and hydrological character*

- Protect and restore, where possible, the physical and hydrological integrity of the Bear River and major tributary channels and their water flows, especially the large spring pulse of water in these rivers and streams that originates from snowmelt and spring precipitation.

- Protect the natural heterogeneous topography of the floodplain including the unique geologic/soil characteristics of abandoned channels and river meander scars, floodplain drainages, alluvial fans, and older geologic-age higher elevation terraces.

- Maintain a low human presence in, and disturbance of, floodplain/terrace plant and animal communities.

- Protect alluvial aquifers and the delicate soil-mineral balances throughout the floodplain and its adjoining alluvial fans and terraces.

Goal #2. *Topography, Water Regimes, Water Flow Patterns*

- Restore natural topography and reconnect natural water flow patterns and pathways where possible.

- Manage wetland impoundments (that are retained) and natural floodplain depressions for more natural seasonal and long-term water regimes.

Goal #3. *Natural Vegetation Communities*

- Restore distribution of plant communities to appropriate sites based on HGM-predicted geomorphology, soil, topography, and hydrology features.

- Improve conditions to increase the distribution and historic composition of native Wet Meadow habitats.

- Reduce the area of more permanently flooded wetlands and persistent emergent vegetation.

- Actively control invasive and noxious plant species

Future management of Cokeville Meadows NWR should include regular monitoring and directed studies to delineate refuge features and communities and to determine how ecosystem structure and function are changing, regardless of whether restoration and management options indentified in this report are implemented. Ultimately, the success in restoring and sustaining communities and ecosystem functions/values at Cokeville Meadows NWR will depend on how well the physical and hydrologic integrity of the Bear River is protected and how key ecological processes and events, especially the short pulsed duration spring flooding, can be restored or emulated by management actions. Critical information and monitoring needs include: 1) obtaining key baseline soil, topography, plant and animal data; 2) annual monitoring of water use and flow patterns; 3) long-term changes in vegetation and animal communities.

Karen Kyle

INTRODUCTION

Cokeville Meadows National Wildlife Refuge (NWR) is a relatively new refuge authorized to contain 26,657 acres within an approved refuge boundary in Lincoln County, Wyoming (Fig. 1). Current NWR lands include 6,466 acres owned in fee title by the U.S. Fish and Wildlife Service (USFWS), 1,672 acres protected with conservation easements, 758 acres in Farmers Home Administration (FmHA) lands, and a 363 acre State of Wyoming land lease for a total of 9,259 acres. Cokeville Meadows NWR lies within the Bear River Valley and historically contained diverse floodplain and upland habitats that supported large numbers of breeding and migrating waterbirds and Neotropical migrant songbirds, wetland and upland associated mammals, endemic amphibian and reptile species, and a few native western riverine fish species.

The Bear River and its floodplain are the primary ecological features on Cokeville Meadows NWR. The Bear River originates in the Unita Mountains in Utah and flows northward into Wyoming and through the Cokeville Meadows NWR reach. Water in the Bear River now is seasonally impounded in some areas immediately upstream and in Cokeville Meadows NWR and is diverted into floodplain meadows and grasslands through a system of ditches, dikes, and water-control structures. Other water diversions occur from major tributaries to the Bear River, especially the Smith's Fork River. This diversion of river waters floods wetland depressions, irrigates meadows and supports extensive haying and grazing of the floodplain, and provides irrigation of cropland and tame grass fields such as alfalfa within the refuge acquisition boundary. Numerous small levees are present along sections of the Bear River and within the river floodplain to facilitate irrigation. Other levees have been intentionally constructed to create seasonal wetland impoundments. Many roads and ditches cross the floodplain.

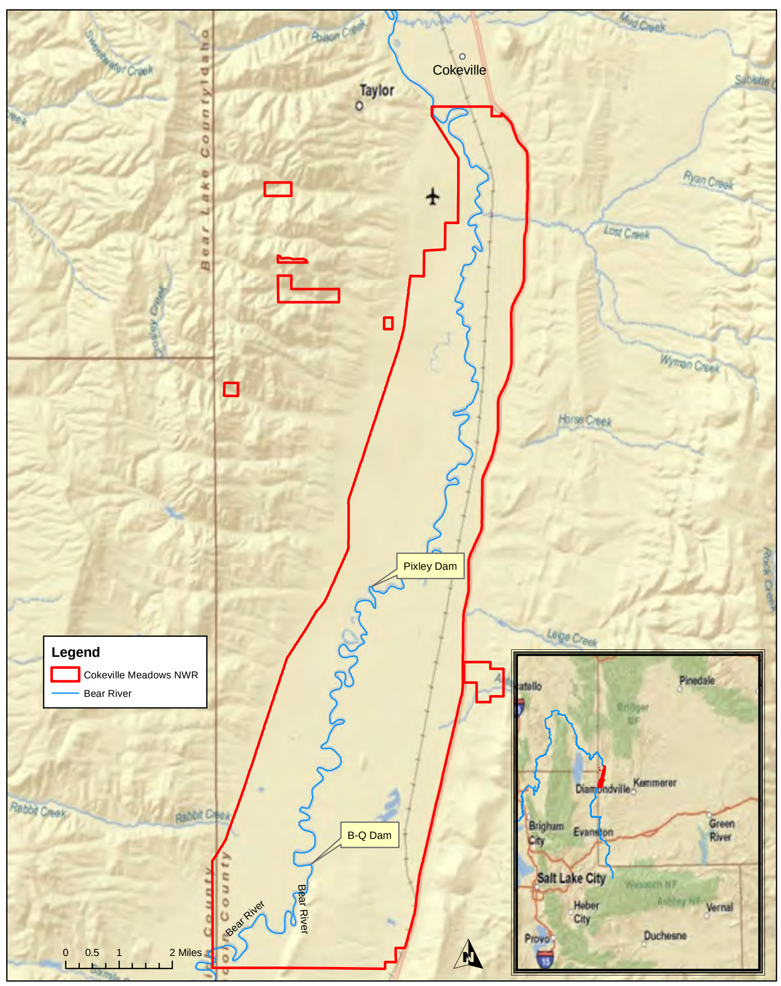


Figure 1. General location of the approved acquisition boundary for Cokeville Meadows NWR, WY.

The eastern boundary of the refuge has the greatest impacts from transportation where U.S. Highway 30 and a railroad grade transect the coalescing alluvial fans. Collectively, these physical structures have altered the hydrology of the Bear River and its floodplain, and along with many decades of haying and grazing, have contributed to changed vegetation communities in the system. Several introduced and invasive plant species are present on and adjacent to refuge lands.

In 2009, the USFWS initiated a Comprehensive Conservation Plan (CCP) for Cokeville Meadows NWR. The CCP process seeks to articulate the management direction for the refuge for the next 15 years and it develops goals, objectives, and strategies to define the role of the refuge and its contribution to the regional landscape in which it sets, and the overall mission of the NWR system. At Cokeville Meadows, the CCP is being facilitated by an evaluation of ecosystem restoration and management options using Hydrogeomorphic Methodology (HGM). HGM analyzes historic and current information about: 1) geology and geomorphology, 2) soils, 3) topography and elevation, 4) hydrologic condition and flood frequency, 5) aerial photographs and cartography maps, 6) land cover and vegetation communities, 7) key plant and animal species, and 8) physical anthropogenic features of the Cokeville ecosystem. HGM now is commonly used to evaluate ecosystems on NWR's (e.g., Heitmeyer and Fredrickson 2005, Heitmeyer et al. 2006, Heitmeyer and Westphall 2007, Heitmeyer et al. 2009) and provides a context to understand the physical and biological formation, features, and ecological processes of lands within the NWR and surrounding region. This historical assessment then provides the foundation, or baseline condition, to determine what changes have occurred in the abiotic and biotic attributes of the ecosystem and how these changes have affected ecosystem structure and function. Ultimately, HGM helps define the capability of the area to provide key ecosystem functions and values and identifies options that can help to restore and sustain fundamental ecological processes and resources.

This report provides HGM analyses for Cokeville Meadows NWR with the following objectives:

1. Identify the pre-European settlement (hereafter Presettlement) ecosystem condition and ecological processes in the Bear River Valley near Cokeville Meadows NWR.

2. Evaluate changes in the Cokeville Meadows NWR ecosystem from the Presettlement period with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.

3. Identify restoration and management options and ecological attributes needed to successfully restore specific habitats and conditions within the Cokeville Meadows NWR region.

Karen Kyle

THE HISTORIC COKEVILLE MEADOWS ECOSYSTEM

GEOLOGY

Cokeville Meadows NWR is located in the Bear River Valley in southwestern Wyoming (Fig. 1). The head waters of the Bear River are in the Uinta Mountains in northern Utah (Laabs et al. 2007). The river flows northward into southwestern Wyoming and passes near Evanston before looping back into Utah. As the river continues northward it crosses back into Wyoming just north of US Highway 30, southwest of the town of Cokeville, WY. The southern boundary of the Cokeville Meadows NWR acquisition boundary is near the site where Bear River reenters Wyoming. After leaving the northern Cokeville Meadows NWR acquisition boundary, the Bear River loops into Idaho near Border, WY and then descends southward into Utah. It then flows generally south and westward near Logan, UT and eventually enters Bear River Migratory Bird Refuge and the Great Salt Lake west of Brigham City, UT. The longitudinal profile of the river is steep near its headwaters but flattens quickly as it reaches the Wyoming border near Evanston. At Cokeville Meadows NWR, the river gradient is about 2 feet/mile. The uplands to the east of the Bear River Valley constitute the divide between the Great Salt Lake and Green River watersheds/basins. The uplands to the west of the Bear River Valley are the divide between the circuitous drainage of the Bear River and the direct drainage into the Great Salt Lake.

The Bear River Valley reaches its maximum width (about 3 miles) just north of the south border of Wyoming. Then the valley narrows to < ¼-mile wide at Myers Narrows, about nine miles south of Evanston and then to < 100 yards wide at The Narrows, north of Evanston. The Bear River Valley rewidens to about 2 miles at Cokeville Meadows NWR and then narrows again just north of the town of Cokeville, WY, where it is < ¼-mile wide.

Southwestern Wyoming, west of the Green River Basin, is characterized by north-trending mountain ranges, ridges, and valleys that represent diverse geological formations (Veatch 1907). Collectively, the area under Cokeville Meadows NWR

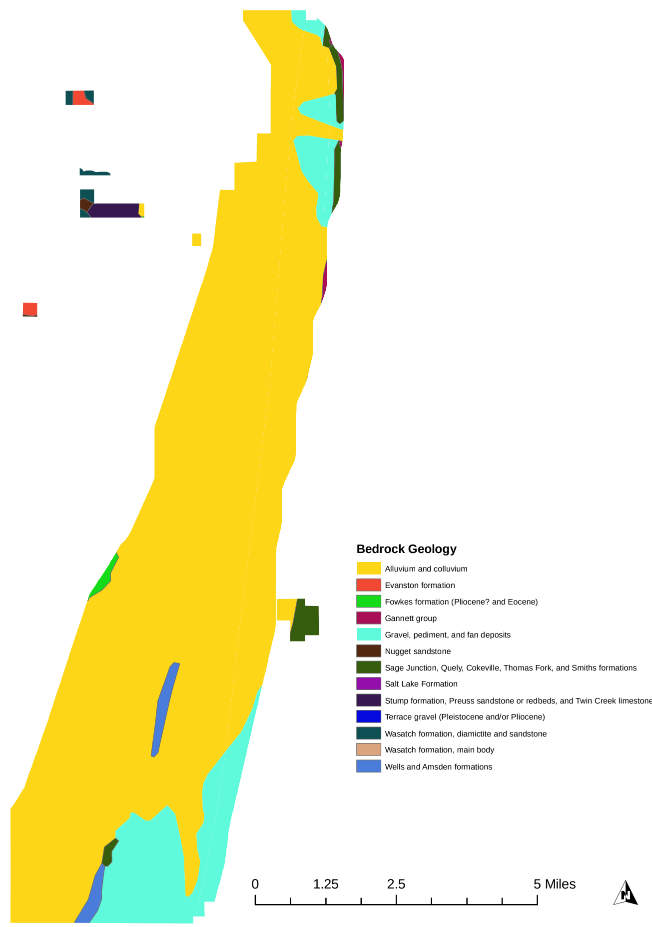


Figure 2. Bedrock geological surfaces of the Cokeville Meadows region.

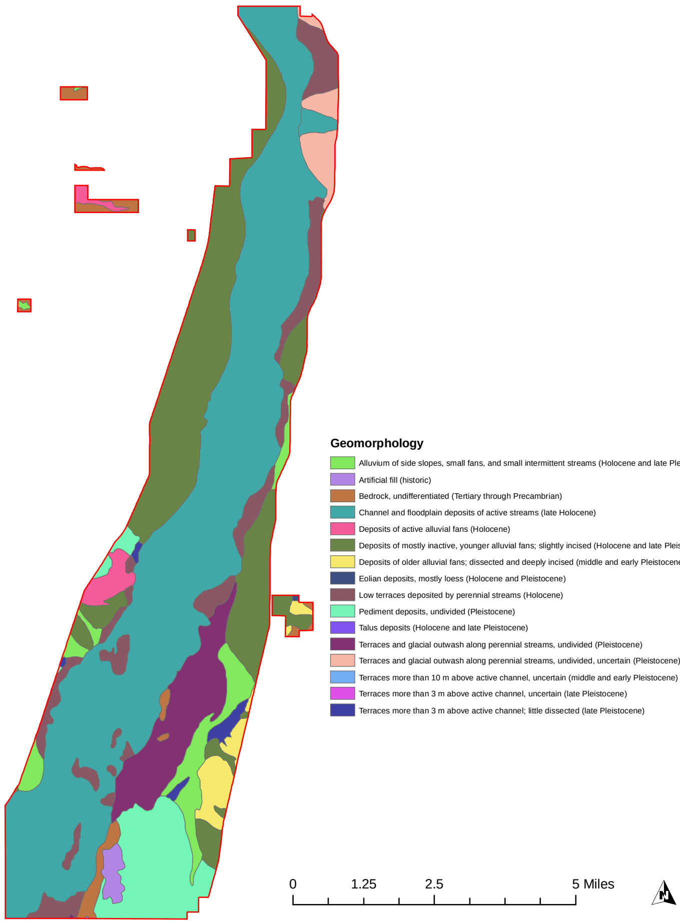


Figure 3. Surficial geomorphology of the Cokeville Meadows region.

includes complex folded and eastward-thrust rocks of Paleozoic, Mesozoic, and early Tertiary age (Appendix A provides a geological time scale) overlain by only slightly deformed later Tertiary and Quaternary sediments (Fig. 2). The north-south belt of mountains and overthrust faults is known as the "Overthrust Belt" Geologic Province of western Wyoming, southeastern Idaho, and northeastern Utah (Blackstone 1977). The Overthrust Belt is part of an extensive belt of folding and faulting that runs north-south from Canada to Mexico, also known as the Cordilleran Fold Belt (Ver Ploeg and DeBruin 1982). The Overthrust Belt contains numerous inactive north-south trending thrust faults, one of which, the Crawford Thrust, reaches the surface within the Cokeville Meadows NWR boundary and dips west under the refuge. Several high-angle thrusts occur in the subsurface on and near the refuge (Lines and Glass 1975, Rubey et al. 1980). The Laramide orogeny that produced the folding and faulting began during Cretaceous time and may have lasted into Eocene time. The most seismically-active fault system in the area is the Rock Creek fault, approximately 15 miles east of Cokeville.

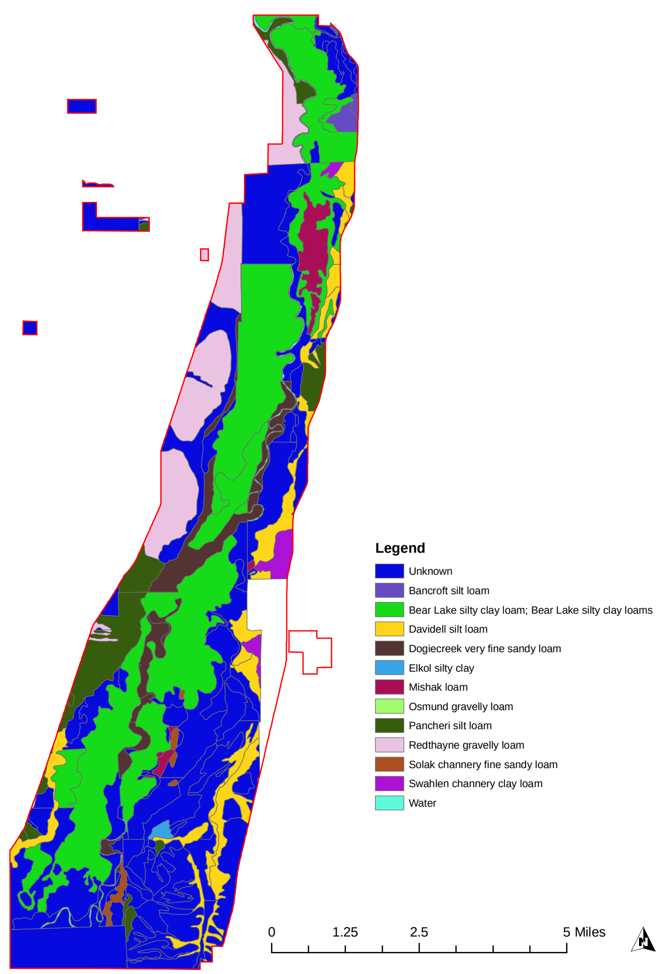
All geologic strata in the Cokeville Meadows NWR region that was deposited during the Cretaceous period resulted from alternating advance and retreat of seas (Bradley 1936). After retreat of the last sea, erosion and deposition of continental sediment formed the current surface landscape at Cokeville. During one of the last erosion cycles, the present Bear River developed along the line of least resistance in the area, presumably an uplifted and faulted zone (Laabs et al. 2007). Continued erosional down-cutting by the river formed a channel a few miles wide that cut into older deposits along the apex of the uplift. The valley of the Bear River follows approximately the north-south trend of the geologic structures and its width is closely related to the lithology of the rocks where the original bedrock-floored valley was cut (Reheis et al. 2009). Succession cycles of erosion and deposition filled the Bear River valley with thick alluvium consisting of weakly cemented clay, silt, sand, and gravel (Reheis 2005). These deposits represent accumulation of detrital material derived from upstream geologic formations. As the present valley became filled, outwash from adjacent hills accumulated along the margin of the floodplain, forming alluvial fans consisting of locally derived sand and gravel. On the west side of Cokeville, these deposits are relatively thick and overlie river alluvium in some areas. In T22N, R120W of the refuge, some outcrops of older rock including the Wells Formation are at the surface (Fig. 2).

The contemporary geomorphologic surfaces at Cokeville Meadows NWR (Reheis 2005) are primarily one to two mile wide Holocene alluvial deposits from the Bear River flanked by younger-age alluvial fans and low terraces (Fig. 3). The alluvial fill exceeds 185 feet thickness in some areas of the Bear River Valley near Cokeville Meadows NWR (Robinove and Berry 1963). Alluvial fan deposits, which extend about two-thirds up the Bear River Valley in the Cokeville Meadows region, reach a thickness of 75 feet locally. Natural levees occur adjacent to larger perennial tributary streams and some older, partly buried or scoured, natural levees are present next to former abandoned channels of the Bear River. Other important geomorphic surfaces on Cokeville Meadows NWR include active alluvial fans on the west side of the valley, older Pleistocene terraces and glacial outwash on the southeast side of the valley, Pleistocene pediment deposits, alluvium of side slopes and small intermittent streams, and older terraces and alluvial fans. Drainage within the area is through numerous streams/creeks that flow directly into the Bear River or that infiltrates into alluvial fans and terrace deposits adjacent to the river floodplain.

SOILS

Soil mapping for the Cokeville Meadows NWR region of Lincoln County, Wyoming is incomplete and contemporary detailed soil maps for the NWR are not available. Soil maps from the Bear River Valley immediately upstream of Cokeville Meadows in Rich County, Utah and a preliminary interim soil map prepared by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) for the Bear River Valley in Lincoln County, Wyoming provide general description of soil types and their distribution (Figs. 4, 5). Apparently, about 12 major soil types/groups are present on, or adjacent to, Cokeville Meadows NWR (Fig. 4). The arrangement of soils on the NWR is complex and reflects the numerous channel migration events across this floodplain, introduction of mixed-erosion sediments from surrounding Quaternary and Tertiary terraces, and alluvial deposition of Bear River Valley parent materials. Most soils on the NWR are shallow, with thin veneers of loam, silt and clay overlying deeper sands and gravels.

Soils at Cokeville Meadows NWR can generally be categorized in three general groups. The largest geomorphic soil group occupies floodplains and low terraces and is of the Calciaquoll-Cryaquoll-Riverwash Association. This soil group is characterized by nearly level to strongly sloping (0-15% slopes) soils that are generally deep, variable in texture, and derived from alluvium. Test borings and wells indicate the maximum thickness of the alluvium including thin veneers of silt loams and underlying alluvial sands and gravel is about 150 feet thick (Robinove and Berry 1963). Silts that overlay gravel typically are < 6 feet below the surface. Wader loam comprise most soils immediately adjacent to the currently actively Bear River channel and Dogiecreek sandy loam occupies natural levees along the Bear River channel. Floodplain soils that overly former meander belts of the Bear River include Bear Lake silt loam, and Berenicteon silt loam. Abandoned channels and other meander belt depression in the Bear River floodplain have clay or silt-clay soils overlying sands and gravels of former river channel bottoms. The second soil group at Cokeville Meadows NWR occurs on alluvial fans and high terraces on the edges of the Bear River floodplain. These soils are found on nearly level to moderately steep slopes (0-30% slopes) and are generally well drained gravelly and cobble silty and sandy loams such as Nevka loam and Duckree gravelly loam. Alluvial fan deposits may reach a thickness of 75 feet locally. The third soil group is present on the foothills of the Overthrust Belt and is of the Calciorthrid-Haploxeroll-Torriothent Association. Geologic over-thrusting and resulting mixed parent materials have produced variable soil textures and complex soil/landform relationships.



. Soil map of the Cokeville Meadows region based on interim NRCS mapping. (incomplete)

Figure 4. Soil map of the Cokeville Meadows NWR based on interim NRCS mapping (incomplete).

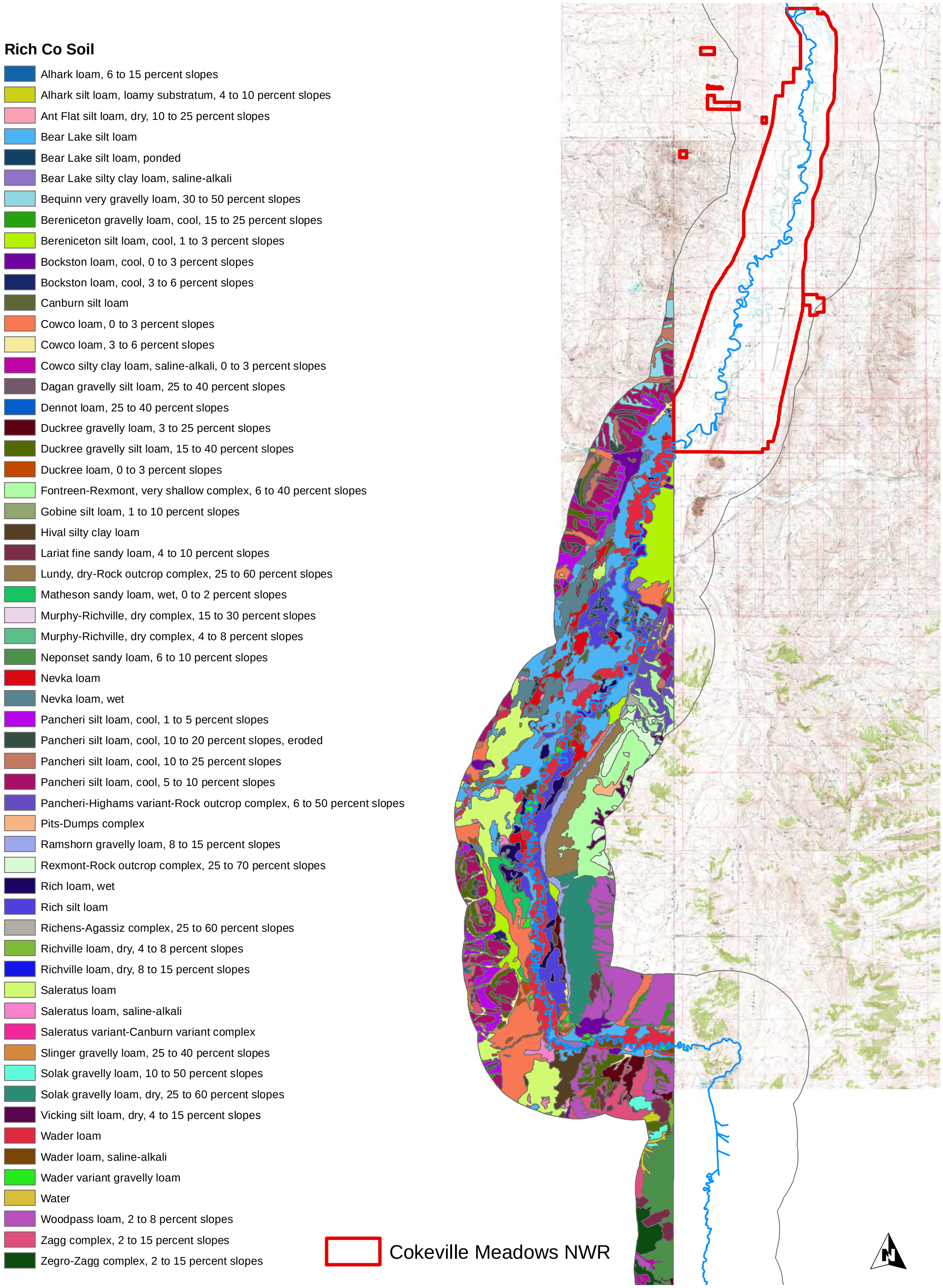


Figure 5. Rich County, Utah soils within 2 km of Bear River.

TOPOGRAPHY AND ELEVATION

Elevations on Cokeville NWR range from about 6,500 feet above mean sea level (amsl) on the bluffs at the south end to about 6,170 feet in floodplains on the north end where the Bear River exits the refuge (Fig. 6). Topographic heterogeneity on the refuge is related to historic Bear River channel and tributary channel migrations, minor within-floodplain channels, floodplain scouring, and alluvial deposition. Significant topographic features include the numerous abandoned channels of the Bear River, old alluvial and glacial terraces, and alluvial fans (Fig. 7).

CLIMATE AND HYDROLOGY

The climate of the Cokeville Meadows region is semi-arid, midcontinental (USFWS 1992). Most precipitation falling in the region is of Pacific origin; average annual precipitation is about 12 inches, with ranges from 9 to 18 inches annually, and the area is dry most of the year. About 38% of precipitation occurs as rainfall from April to June (Fig. 8). In winter, gusty winds can produce blizzards and drifting snow. The frost-free season is only 60-70 days. Days generally are clear and sunny (about 250 days/year) and evaporation rates are high in summer. Monthly average relative humidity ranges from 35% in July to about 75% in December. Mean monthly pan evaporation rates have a seasonal total of 31.3 inches, which is nearly three times annual precipitation. Temperatures are often below 0° Fahrenheit in winter and can exceed 90° Fahrenheit in midsummer. Annual mean temperature is 38° Fahrenheit. The combined low precipitation, high evaporation, and high summer temperatures lead to scarce occurrence of natural

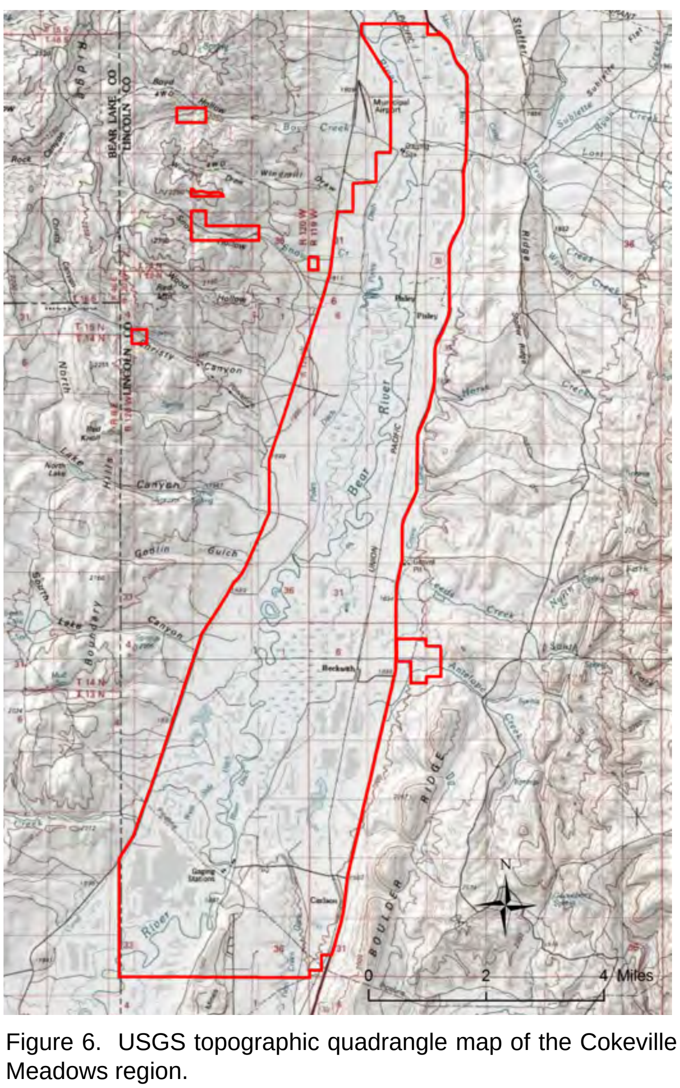


Figure 6. USGS topographic quadrangle map of the Cokeville Meadows region.

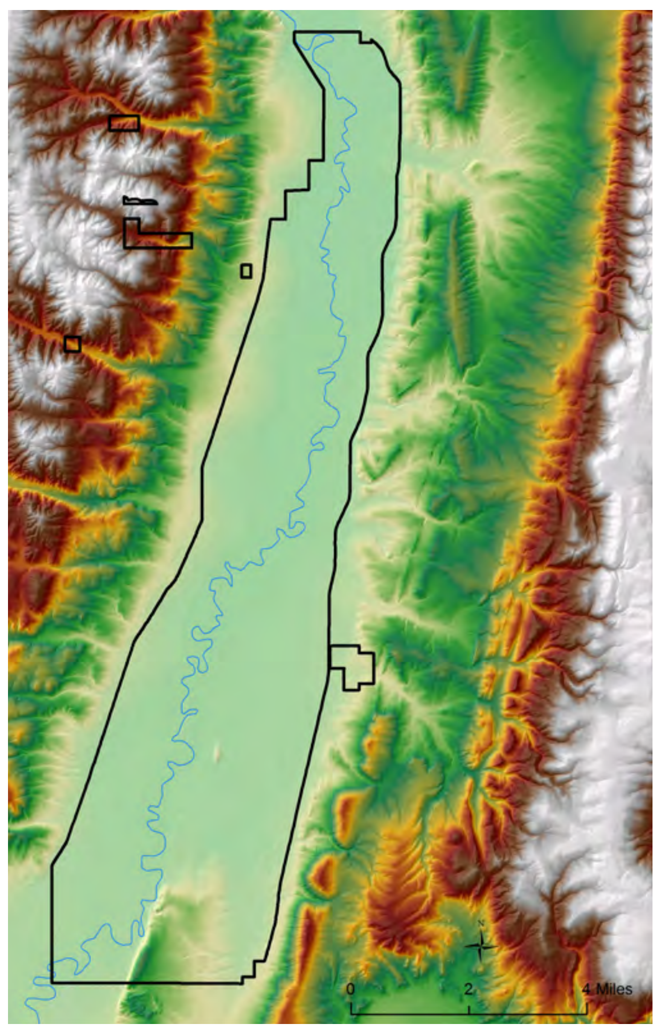


Figure 7. Shaded relief map of area surrounding Cokeville Meadows NWR. Elevations within the boundary range from 6,510 ft. on the south to about 6,165 ft. on the north.

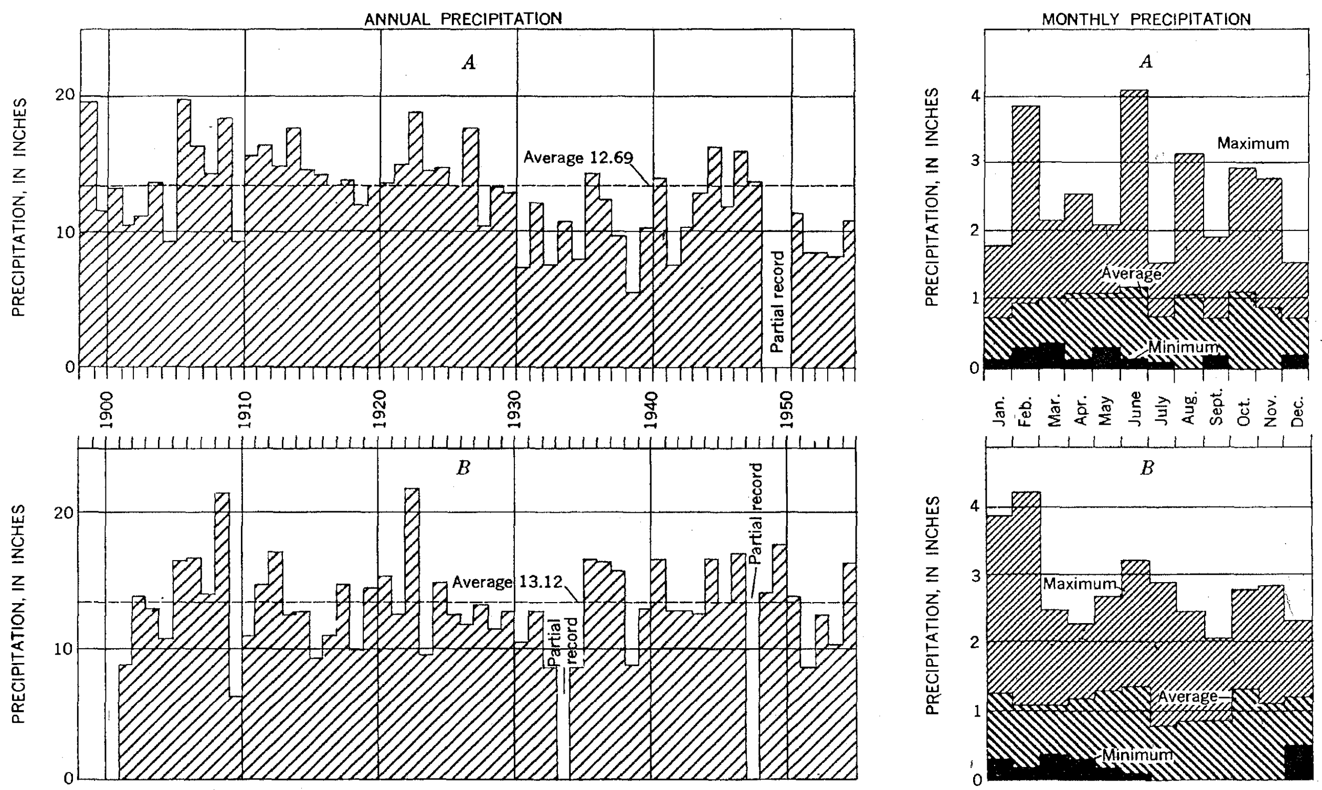


Figure 8. Mean annual precipitation and long-term trends for Cokeville, WY area (U. S. Weather Bureau).

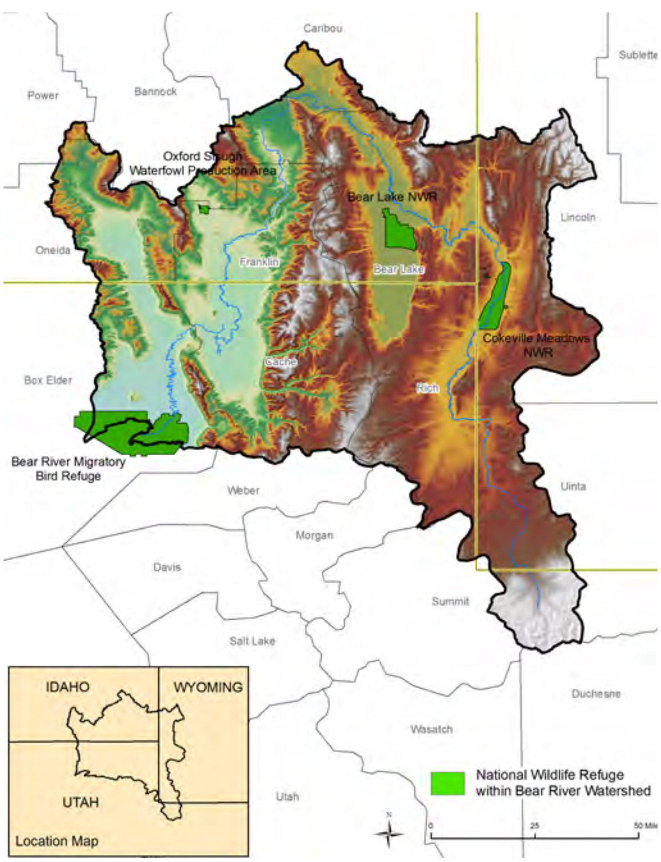


Figure 9. Shaded relief map of the Bear River Watershed.

free-standing surface water from summer through winter.

Cokeville Meadows NWR is within the Bear River Basin, which has a drainage area of about 4.8 million acres in three states (Fig. 9). Water flow into the Bear River comes from onsite regional precipitation, snowmelt, and groundwater discharge. Major tributaries to the Bear River near Cokeville Meadows NWR are the Smith's Fork River and Sublette, Twin, Spring, Brunner, Muddy, and Coral creeks. Water in the Bear River is fresh, but shallow depressions and larger lakes in the system can be highly saline. The Bear River at Cokeville Meadows NWR has little gradient, or fall, with the channel slope approximately 1.5-2.0 feet/mile. The flat relief and low stream gradient have caused the Bear River to frequently meander across the floodplain and has created many abandoned river channels and entrenched meanders. The majority of the acquisition boundary of Cokeville Meadows NWR is within the 100-year floodplain.

Historically, the Bear River had a strongly unimodal discharge/river stage pattern with peak discharges above 400 cubic-feet/second (cfs) in June and relatively sustained low discharges near 100 cfs from August through February (Fig. 10). Water from the Bear River begins to enter many off-channel oxbows and depressions at about 300 cfs, and much of the floodplain is inundated at discharges of > 1,000 cfs. Consequently, historic flow data suggest overbank and backwater flooding from the Bear River into the Cokeville Meadows floodplain ecosystem typically occurred for short time periods in late May through mid-June in most years. While being of short duration, this seasonal flooding recharged floodplain wetlands to their highest levels in spring and thereafter wetlands gradually dried from evapotranspiration to low maintenance levels in winter.

In addition to the strong seasonal pattern of river discharge, stage data from the Bear River below Pixley Dam, near Cokeville, WY indicate a long term pattern of peak discharges about every 12-15 years when the river exceeds 1,500 cfs (Fig. 11). In contrast, intervening dry years did not have river discharges > 500 cfs. During the ca. 60 year period of record below Pixley Dam, the Bear River exceeded 1,500 cfs in 9 years and was below 500 cfs in 15 years. This long term pattern of river discharge suggests a highly dynamic flooding environment for floodplain wetlands in the Cokeville Meadows NWR region, with occasional years when extensive overbank flooding punctuating more regularly occurring moderate flows and frequent dry years (Wyoming Water Development Commission 2001). The Central Division of the Bear River in Wyoming, where Cokeville Meadows NWR sets, has about 500,000 acre-feet of water flow in wet years, about 190,000 acre-feet in average years and essentially no flow in extreme dry years (Fig. 12). In average and wet years available water flow occurs during the non-irrigation season (August-March) on both the Smith's Fork and Bear River mainstem channels. The long-term alternating wet-dry pattern of water flow in the Bear River and related variable annual recharge of floodplain wetlands, probably caused long-term regularly fluctuating patterns of wetness-dryness in these wetlands at about 10-15 year intervals (Fig. 11).

Ground water in the Cokeville Meadows area is present in the Bear River Valley alluvium, alluvial fan deposits, and older geologic formations that underlie the area. The alluvial aquifer underlying the Cokeville Meadows NWR is bounded laterally and vertically by relatively impermeable shale (Glover 1990). This shale layer effectively prevents groundwater movement between the alluvial aquifer and other deeper formations. The potentiometric surface of the alluvial aquifer (Fig. 13) indicates that water enters the aquifer as underflow from the Bear River at the upstream part of Cokeville Meadows and then this water discharges downstream into the Bear River (Berry 1955). A second source of water recharge into the alluvium is leakage from tributary streams. Generally, groundwater levels in

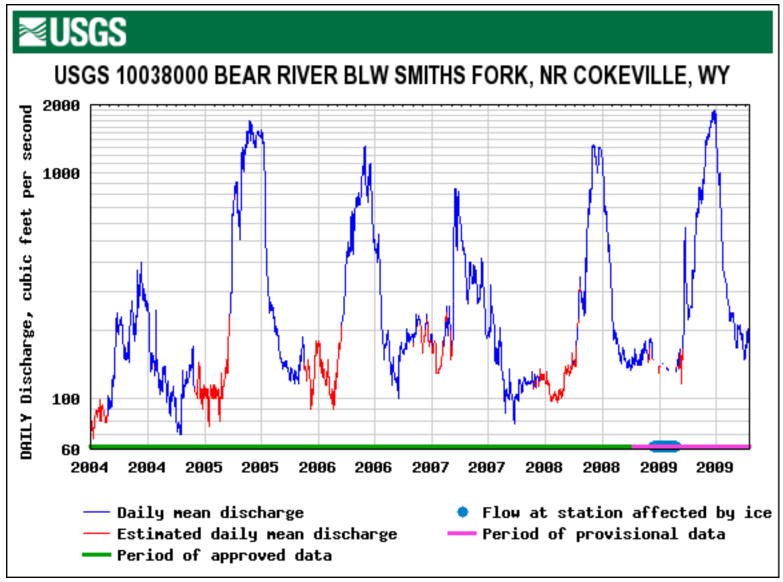


Figure 10. Mean daily discharge of Bear River near Cokeville, WY.

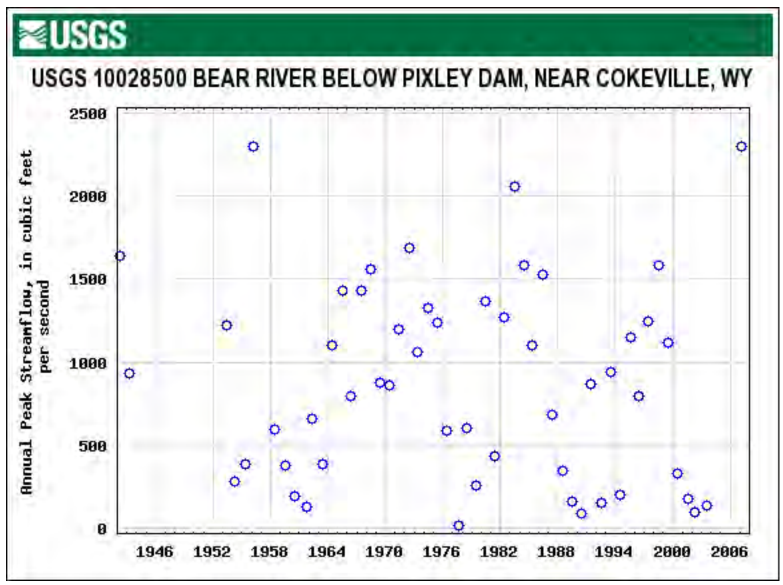


Figure 11. Peak annual discharge of Bear River at Pixley Dam near Cokeville, WY.

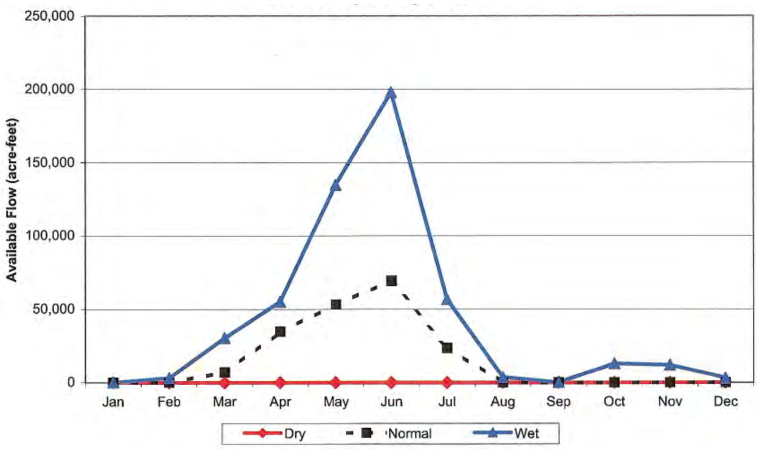


Figure 12. Available discharge in the Bear River in wet vs. dry years.

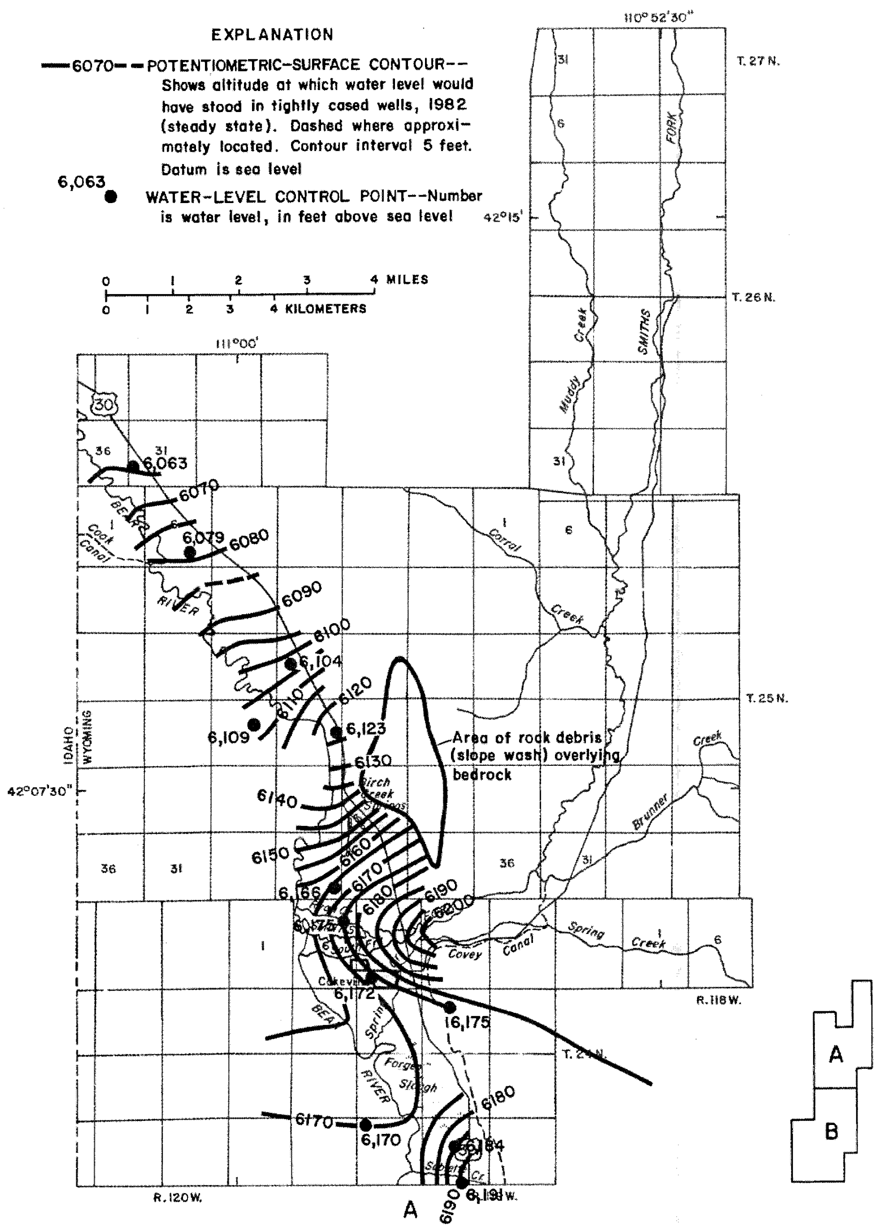


Figure 13. Potentiometric surface of groundwater.

the alluvium mirror seasonal precipitation and Bear River discharge patterns (Fig. 14). Alluvial fan deposits also yield large quantities of water where they overlie the alluvium, but the amount of groundwater gradually decreases away from the Bear River as the saturated thickness decreases (Berry 1955). The recharge for alluvial fans is derived mainly from infiltration of surface runoff. Older geologic formations that underlie the area include the Madison limestone, Amsden Formation, Tensleep sandstone, Bear River Formation and the Wasatch Formation that yield moderate quantities of groundwater to wells. Water from these formations generally is under artesian head and often moves to the land surface as low elevations dip from outcrop areas of these formations. Up to 100 gallons of water/minute occurs in artesian wells derived from the Madison limestone and Tensleep sandstone outcrops.

Evapotranspiration, primarily from willows (*Salix* sp.), persistent emergent wetland plants, and wet meadow grasses and sedges/rushes that obtain water directly from the water table, is a significant type of groundwater discharge during summer (Glover 1990). The amount of water that discharges as evapotranspiration depends on the consumptive-use requirements of various plant species and the depth to water. Evapotranspiration is higher when the water table is close to the land surface (such as in wetter years), but decreases as depth to groundwater increases. Essentially no evapotranspiration discharge of groundwater occurs to depths of greater than 10 feet.

Groundwater from the northern part of the Bear River Valley, including the Cokeville Meadows NWR area, is a calcium bicarbonate type, but constituents vary by geological source (Robinove and Berry 1963). Total mineral content of alluvial groundwater is 285-510 ppm dissolved solids (Table 1). Groundwater seepage from the Smith's Fork River influences local groundwater quality and apparently reduces local sodium and chloride levels. Generally, wells tapping alluvium up-gradient and away from return flow into the Bear River have water that is lower in dissolved solids and with lower sodium and chloride content than sites close to the river channel. Terrace deposits and alluvial fans contain magnesium-calcium bicarbonate type ground water with moderate amounts of sulfate. Deeper artesian groundwater contains predominantly sodium-calcium sulfate and bicarbonate types.

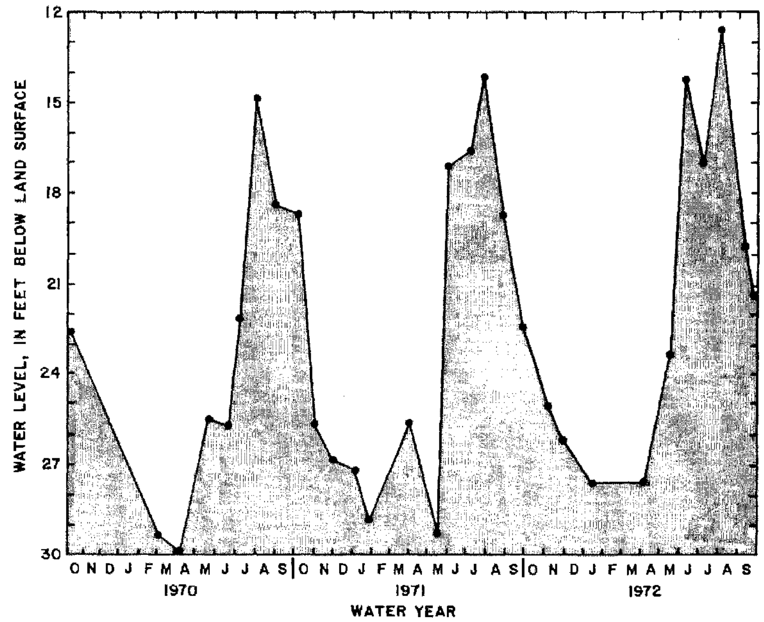


Figure 14. Water levels in wells near or on Cokeville NWR.

Surface water quality in the Bear River and floodplain wetlands reflects source of water and drainage in the area underlain by Precambrian metamorphic rocks on the north slopes of the Uinta Mountains of northeastern Utah and flows through the area underlain by Tertiary formations and through Tertiary and Cretaceous rocks in Wyoming. Seasonal fluctuations in discharge of the Bear River are accompanied by relatively minor changes in total mineral content of water; the effects of high flows in spring are mainly dilution of major constituents. Bear River water generally has a progressive increase in mineral content to the B-Q Dam and then a decrease in mineral content to Cokeville, WY (Table 1). Part of this latter decrease in mineral content apparently is due to the dilution effect of lower mineral water entering the Bear River from the Smith's Fork River (Robinove and Berry 1963).

LAND COVER AND VEGETATION COMMUNITIES

Cokeville Meadows is a riverine floodplain vegetation complex within the cold northern shrub steppe landscape of the Great Basin Floristic Province (Cronquist et al. 1972, West 1988, Welsh et al. 1993). Historic vegetation communities at Cokeville Meadows NWR included: 1) narrow riparian/riverfront-type forest corridors, 2) semi permanently flooded floodplain wetland depressions, 3) "wet meadow" sedge and grass communities, and 4) upland sagebrush/grassland communities (Nuttall 1834, Hironaka et al. 1983, Youngblood et al. 1985). Numerous accounts of vegetation within the Bear River Valley and adjacent uplands were made by early explorers and travelers (e.g., Nuttall 1834, Townsend 1839, Fremont 1845, Johnson and Winter 1846, Young 1899, Hafen and Hafen 1955).

Riparian communities historically were present along the Bear River, and some areas along major tributaries, and contained relatively narrow bands of early succession "riverfront" forest species, mainly black cottonwood (*Populus trichocarpa*) and willow (Youngblood et al. 1985). These wooded habitats were present on newly deposited and scoured sand-silt and gravelly soils on natural levee deposits near the active channel of the Bear and Smith's Fork rivers (Table 2). Consequently, soils in these areas are well drained but saturated for much of the year and usually have some surface flooding in most years (Auble et al. 2005). Riparian communities generally comprise < 1% of the total land area in the Wyoming Basin, but are among the productive communities in biomass of plants and animals and are essential habitats for meeting specific life history requirements of many species, especially Neotropical migrant songbirds (Nicholoff 2003). The extent and continuity of these riparian forest areas along the Bear River in the Cokeville Meadows NWR region in Presettlement times is unknown, but they probably were present in most river stretches (Fig. 15).

Low elevation abandoned channels of the Bear River (oxbows), floodplain depressions, and tributary off-channel areas contained wetland-obligate vegetation communities that graded from persistent robust

Table 1. Water quality data from Bear River.

[All values are expressed in or computed from equivalents per million]

Well	Geologic source	Percent of total cations			Percent of total anions			Total ions (epm)
		Ca	Mg	Na	HCO_3	SO_4	Cl-F-NO_3	
GROUND WATER								
Southern part								
13-120-25bb	Tertiary deposits	65	30	5	88	8	4	13.15
15-120- 8dd	Alluvium	42	29	29	71	16	13	17.75
21bdd	do	54	22	24	83	7	10	15.08
16-121-11ac	Terrace deposits and Tertiary deposits.	30	42	28	51	13	36	16.49
13bd	Alluvium	25	39	36	65	16	19	18.23
24ad	do	24	41	35	25	48	27	60.74
24bc	do	50	30	20	75	10	15	11.68
17-120- 6ac2		10	8	82	11	15	74	53.44
8db	Alluvium	22	38	40	62	9	29	21.51
19db	Tertiary deposits	23	64	13	68	18	14	22.35
32db	Alluvium and Tertiary deposits.	35	32	33	55	10	35	20.49
Northern part								
22-119- 5cc	Alluvium	46	29	25	52	22	26	18.34
23-119- 6ad	Alluvium and alluvial-fan deposits.	62	22	16	70	11	19	10.78
32bd	Alluvium	55	38	7	71	23	6	11.37
23-120-26ab	Nugget sandstone	29	24	47	42	48	10	27.83
24-119- 9bd	Terrace deposits	41	43	16	69	16	15	15.59
33ac	Slope wash	31	37	32	64	28	8	19.35
25-119-33dac	Alluvium	75	19	6	74	20	6	10.93

SURFACE WATER

Location	Date	Ca	Mg	Na	HCO_3	SO_4	Cl-F-NO_3	Total ions (epm)
Southern part								
Mill Creek, east branch	4-18-56			5	86	10	4	7.50
Mill Creek, west branch	4-18-56			4	90	7	3	8.81
Bear River above Sulphur Creek south of Evanston	4-18-56	64	29	7	89	7	4	6.71
Do	6-21-56	65	32	3	89	9	2	3.61
Do	9- 4-56			4	89	9	2	6.60
Yellow Creek, near mouth, west of Evanston	4-18-56			14	74	12	14	15.61
Bear River, 10 miles north of Evanston	4-17-56			12	77	14	9	10.32
Do	6-22-56	56	35	9	84	8	8	7.03
Do	9- 4-56			31	56	28	16	17.33
Northern part								
Bear River, at Beckwith Dam	4-13-56			22	66	18	16	15.54
Do	6-22-56	50	24	26	73	11	16	17.32
Do	9- 4-56			26	56	25	19	20.21
Sublette Creek, near mouth	4-13-56			12	66	25	9	14.75
Bear River, at Cokeville, above Smiths Fork	4-13-56	44	34	22	64	20	12	15.16
Do	6-22-56	35	38	27	67	16	17	15.89
Do	9- 3-56			19	59	27	14	16.10
Smiths Fork, at Cokeville	4-13-56			8	74	20	6	9.51

emergent plants such as cattail (*Typha latifolia)* and hardstem bulrush (*Schoenoplectus acutus*) in deeper elevations with more prolonged annual flooding to diverse annual and perennial sedges, rushes, and grasses in seasonally flooded depressions and margins of abandoned and minor channels that had semi-permanent and seasonal flooding regimes (Cronquist et al. 1972, see also Cowardin et al. 1979 and Hansen et al. 1995) Soils in these depressions typically have clay and silt-clay veneers over varied alluvial deposits (Table 2). Water levels and extent of flooding in these floodplain depressions were both seasonally and annually dynamic because of the ecological "driving" effect of annually variable precipitation, runoff, and flooding from the Bear River. Deeper water areas that had more permanent water regimes contained stands of submerged aquatic plants such as coontail (*Ceratophyllum demersum*), naiads (*Najas* sp.), pondweed (*Potamogeton* sp.), and marsh buttercup (*Ranunculus* aquatilis) and dense accumulations of algae. Semipermanently flooded wetland edges contained bands of persistent emergent vegetation such as cattail and hardstem bulrush. Seasonally flooded margins of these wetlands had mostly non-persistent emergent plants such as arrowhead (*Sagittaria latiifolia*), sedges, and rushes. In wet years with higher Bear River discharge, more area of floodplains likely was flooded at a deeper depth and stands of persistent emergent vegetation probably expanded from the margins to the interior of floodplain depressions (see e.g., van der Valk and Davis 1978, Van der Valk 1989). In contrast, during drier years, less water was present for shorter durations and more sedge-rush and less robust emergent vegetation probably was present. The National Wetland Inventory conducted in the late 1970s and early 1980s classified wetlands in the Cokeville Meadows area as 3% permanently flooded, 7% semi-permanently flooded, 21% temporarily flooded, 60% seasonally flooded, and ca. 10% intermittently flooded or saturated soils (Fig. 16, Table 3). These proportions may have been slightly different prior to developments in the area, and more area may have been seasonally or temporarily flooded during historic periods.

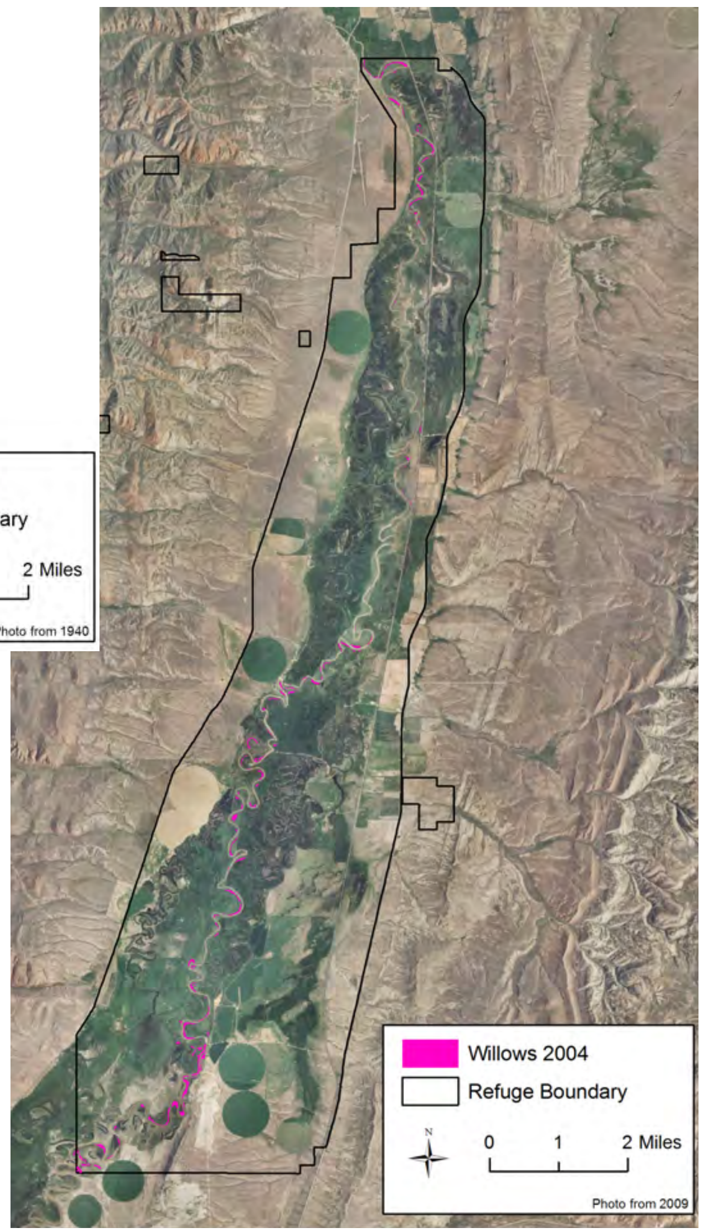
Table 2. Hydrogeomorphic (HGM) matrix of potential historic distribution of major vegetation/habitat types on Cokeville Meadows National Wildlife Refuge. Relationships were determined from historic land cover maps, aerial photographs, geomorphology maps (Reheis 2005), soil maps prepared by the USDA Natural Resource Conservation Service, hydrological data (various USGS, NOAA, and USFWS data from the Bear River and Cokeville Meadows floodplain areas), and various naturalist/botanical/explorer accounts and publications from the early and mid 1800s.

Habitat type	Geomorphic surface	Soil type	Flood frequency[a]
Riparian/Woodland	Natural levee	Gravelly, Sand-silt	A-SFE
Persistent Emergent	Abandoned channel, Tributary off-channel Depressions	Clay, silt-clay	A-PSMF
Meadow	Alluvial floodplain	Silt-loam	A-SF
Sagebrush-Grassland	Alluvial fans, terrace	well-drained Sandy loam, Erosional gravel	R

[a] A-SFE = annually flooded for seasonal periods, with extended soil saturation; A-PSMF = annually flooded with permanent or semipermanent water regimes; A-SF = annually flooded with short seasonal flooding in most years; R = rarely if ever flooded, but with seasonal surface sheetflow or groundwater infiltration.

The majority of the relatively flat higher elevations (i.e., non-depressional) within the Cokeville Meadows NWR floodplain region were covered with "wet meadow" vegetation that ranged from meadow foxtail (*Alopecurus partensis*), arrowhead, sedges, and rushes in lower elevation seasonally flooded areas to wheat grass (*Apropyron* sp.), saltgrass (*Distichlis stricta*) , basin wild rye (*Elymus cinereus*), and greasewood (*Sarcobatus vermiculatus*) in higher elevations on the edges of floodplains with intermittently flooded water regimes (Cronquist et al. 1972, Dorn 1986). Nuttall alkali grass (*Puccinellia airoides*), saltgrass, alkali sacaton (*Sporobolus airoides*), and alkali cordgrass (*Spartina* gracilis) and a few forbs generally were associated with greasewood communities because of the higher salinity levels of

Figure 15. Comparison of willow/riparian forest in 1940 vs. 2004.



these sites. Soils in meadow communities were predominantly silt-loam types (Table 2). This extensive meadow community at Cokeville Meadows NWR was sustained because of the high floodplain water table, a tendency for alkaline soils, and short duration pulses of river flooding that followed snow melt and rises in the Bear River in spring and early summer. Meadow vegetation way seasonally grazed by bison, elk, and mule deer and small rodents also consumed and processed meadow plants. Fire occasionally ranged through meadows. Collectively, herbivory and fire recycled nutrients in meadows and provided germination and regeneration sites for grass, sedge, and rush species.

Table 3. Summary of wetland types related to water permanence on the Cokeville Meadows National Wildlife Refuge acquisition boundary area in 1984 as determined by the U.S. Fish and Wildlife Service National Wetlands Inventory.

Wetland water regime	Acres	Percentage Total
Permanently flooded	738	3.0
Semipermanently flooded	1,704	7.0
Seasonally flooded	13,773	60.0
Temporarily flooded	4,748	21.0
Intermittently flooded	187	< 1.0
Saturated	1,918	8.0

Upland-type vegetation communities, dominated by shrub steppe communities, were present on the higher elevation alluvial fans and older terraces that adjoined the Bear River floodplain (Hironaka et al. 1983). Wyoming and big sagebrush (*Artemisia tridentate*) were the dominant species in these communities; other common species included thickspike wheatgrass (*Agropyron dasystachyum*), western wheatgrass (*Agropyron smithii*), needle and thread (*Stipa comate*), rabbit-brush (*Chrysothamnus nauseosus*), galletta grass (*Hilaria rigida*), bottlebrush squirreltail (*Sitanion* hystrix*)*, and bluegrasses (*Poa* sp.). Soils under these communities were loams or sandy loams and depth of soil and moisture penetration probably set the limits of plant distribution.

A HGM matrix of relationships of the above major plant communities to geomorphic surface, soils, hydrology and elevation (Table 2) was developed to map potential distribution of historic communities on Cokeville Meadows and the surrounding landscape (Fig. 17). Generally, historic communities were distributed as relatively parallel bands or zones as water-elevation gradients move from the Bear River upslope to valley terraces and alluvial fans. Persistent emergent wetland communities were imbedded within Holocene floodplains in abandoned channels and other depressions created by meandering of the ancestral Bear River.

KEY ANIMAL COMMUNITIES

The combined riverine, riparian forest, floodplain wetland, wet meadow, and upland habitats at Cokeville Meadows NWR historically provided important resources that supported annual cycle events for a wide diversity of animal species, and

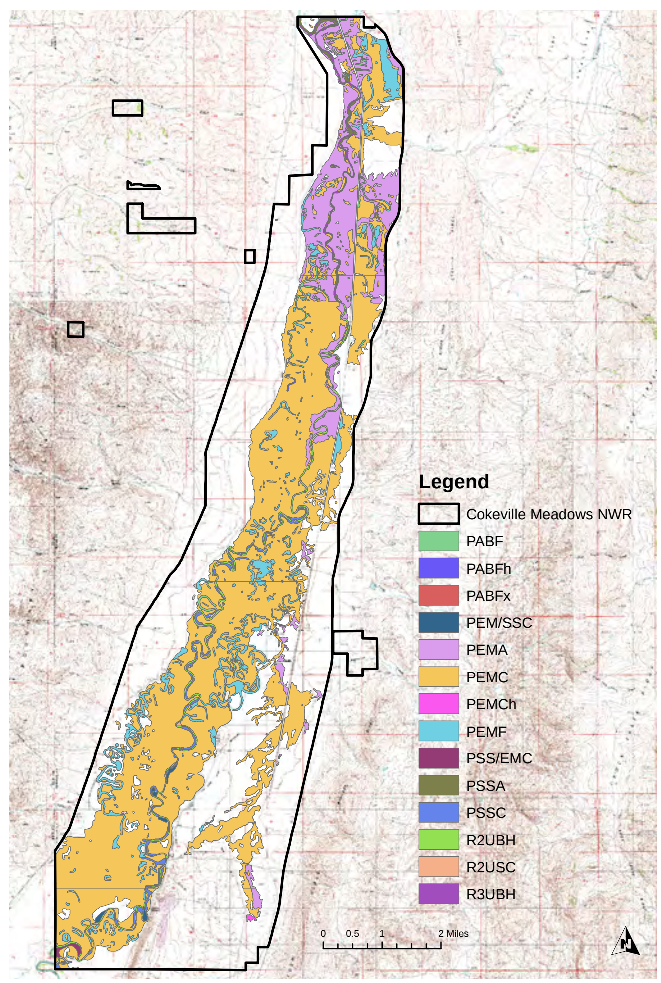


Figure 16. National Wetland Inventory data for Cokeville NWR, WY.

contributed to the sustainability of populations, throughout the Intermountain West region (USFWS 1992). Because of the short growing season and cold winters, most animal species that used the area were seasonal visitors from spring through fall (Laubhan and Fredrickson 1997). Migratory birds, both terrestrial and wetland species, were especially abundant in this floodplain system (Bellrose 1980, Jones et al. 2003, Nicholoff 2003). About 100 species of birds, including 65 species of waterbirds have been recorded at Cokeville Meadows NWR (USFWS 1992). The first nesting record of a least bittern (*Lxobrychus* exilis) in Wyoming occurred in the wetlands south of Cokeville in the late 1980s (Grove and Henry 1990). Key species groups include grebes, bitterns, herons, ibis, egrets, waterfowl, raptors, sandpipers, curlews, terns, flycatchers, swallows, chickadees, warblers, wrens, sparrows, and blackbirds. Over 30 species of waterbirds regularly breed in the region and many other species also nest in forest, wetland, and grassland areas; the most common species are dabbling and diving ducks, sandhill cranes (*Grus canadensis*), Canada geese (*Branta canadensis*), long-billed curlew (*Numenius americanus*), snowy egret (*Egretta caerulea*), black tern (*Sterna nigra*), great blue heron (*Ardea herodias*), American bittern (*Botaurus lentiginosus*), black-crowned night heron (*Nycticorax nycticorax*), white-faced ibis (*Plegadis chihi*), warblers, flycatchers, swallows, blackbirds, sparrows, and raptors. Bald eagles (*Haliaeetus leucocephalus*) commonly use the area in spring and fall, whooping cranes (*Grus Americana*) are occasional visitors during summer, and peregrine falcons (*Falco peregrines*) commonly stop in the area during migration.

Many mammal species historically were present in the Cokeville Meadows NWR region. The most common mammal species included marmots, chipmunks, northern pocket gopher (*Thomomys talpoides*), woodrat (*Neotoma cinera*), voles (*Microtus* sp.), silver-haired bat (*Lasionycteris noctivagans*), red squirrel (*Tamiasciurus hudsonicus*), striped skunk (*Mephitis mephitis*), mule deer (*Odocoileus hemionus*), pronghorn antelope (*Antilocarpa americana*) moose (*Alces alces*), and elk (*Cervus elaphus*) in upland and riparian areas and muskrat (*Ondatra zibethicus*), otter (*Lutra canadensis*), mink (*Mustela vison*), and raccoon (*Procyon lotor*) in wetland and riverine areas. The black-footed ferret (*Mustela nigripes*) historically ranged throughout the area (USFWS 1992).

Nearly 20 species of reptiles and amphibians apparently historically were present in the Cokeville Meadows NWR region (USFWS 1992). Northern leopard frogs (*Rana pipiens*), a species of concern,

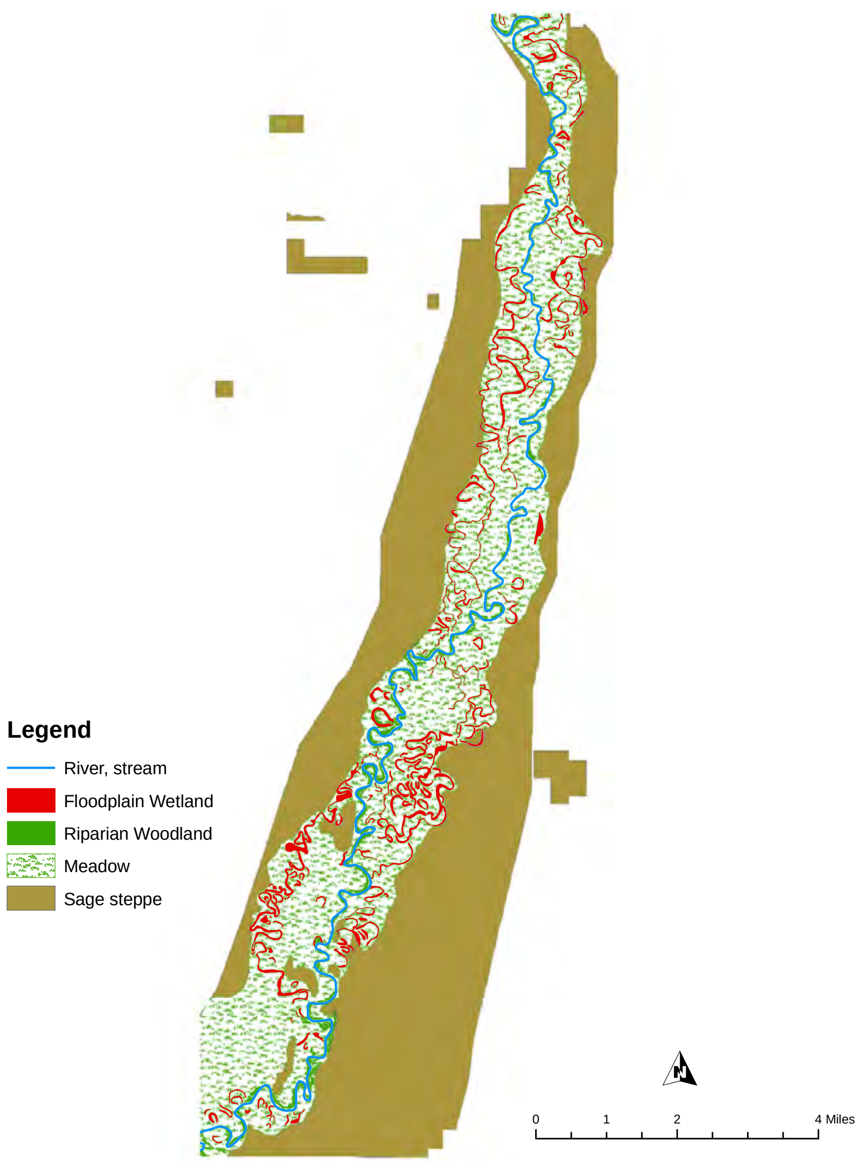


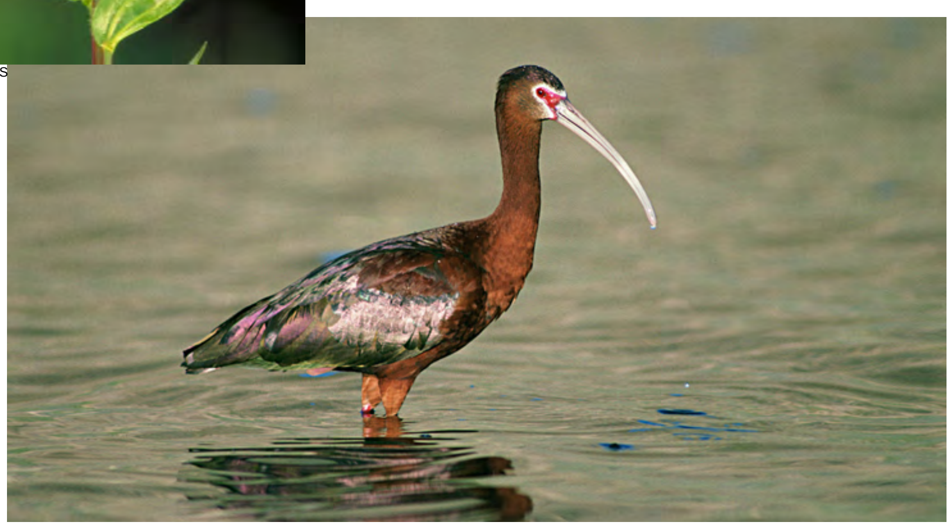
Figure 17. HGM map of potential historic community types.

are abundant in Cokeville Meadows wet meadows and wetlands. A small number of native fish were present in the Bear River and some species apparently moved into floodplain drainages, oxbows, and wetlands during high flow periods. These fish included the Bonneville cutthroat trout (*Oncorhynchus clarki Utah*), mountain whitefish (*Prosopium williansoni*), longnose sucker (*Catostomus catostomus*), longnose dace (*Rhinichthys cataractae*), speckled dace (*Rhinichthys osculus*), redside shiner (*Richardsonius baltcatus*), and mottled sculpin (*Cottus bairdii*).

Resources used by animal species within the Bear River floodplain were seasonally dynamic moderated by long-term climatic variation and river flow/flooding patterns. Most bird species exploited seasonal resources during migration and summer, and only a few species overwintered in the region (Laubhan and Fredrickson 1997). Cold winter temperatures froze most wetlands in the floodplain, but the river remained open throughout winter in most years and provided refuge, loafing, and some foraging resources for some species. Amphibians and reptiles timed annual emergence and life cycle events to coincide with spring thaw and flooding and availability of key arthropod and other prey species. Larger mammals often moved into the floodplain to escape cold and to find food and cover during winter and also used the area extensively in other seasons when nutritious grassland forage and carnivorous prey were present.

Thomas G. Barnes/USFWS

Ryan Hagerty/USFWS



Dave Menke/USFWS

Karen Kyle

Karen Kyle

CHANGES TO THE COKEVILLE MEADOWS NWR ECOSYSTEM

This study obtained information on contemporary: 1) physical features, 2) land use and management, 3) hydrology, 4) vegetation communities, and 5) fish and wildlife populations of Cokeville Meadows NWR and the surrounding region where it was available. This information chronicles the history of land and ecosystem changes at and near the refuge from the Presettlement period and provides perspective on when, how, and why alterations have occurred to ecological processes in the NWR and surrounding lands. Data on chronological changes in physical features and land use/management of the region are most available and complete (e.g., NWR annual narratives, sequential aerial photographs, etc.) while data documenting changes in fish and wildlife populations generally are limited.

SETTLEMENT AND LAND USE CHANGES

Native people apparently occupied the Cokeville Meadows region at various times over the past 10-12,000 years (Thompson and Pastor 1995). The "Shoshonean" Native American culture was present in the region up to the time of early exploration and occupancy of the area by European emigrants in the early to mid 1800s. The combined riverine and adjacent upland topography and diverse and seasonally productive plant and animal communities attracted historic people to the Bear River Valley. Considerable archeological evidence documents extensive settlement and seasonal camp sites in the Cokeville Meadows region (USFWS 1992). Early people in the region subsisted largely by hunting and gathering and probably had little influence on ecosystem processes or attributes other than to occasionally set fires in grasslands (Thompson and Pastor 1995).

The first European occupancy of the region began with Robert Stuart and the Astorians in 1812, followed by the Ashley explorations in 1823 (USFWS 1992). Early explorations and abundant furbearing mammals in the Bear River Valley led to expansion of trapping and enabled scattered settlements in the region were established from 1824 to 1840. Contemporary towns and river/reservoirs in southwestern Wyoming such as Bridger, Sublette, Fontanelle, La Barge, and Smith were named after early trappers (Haines 1996). From 1840 to 1869, larger numbers of European emigrants moved through the Bear Valley

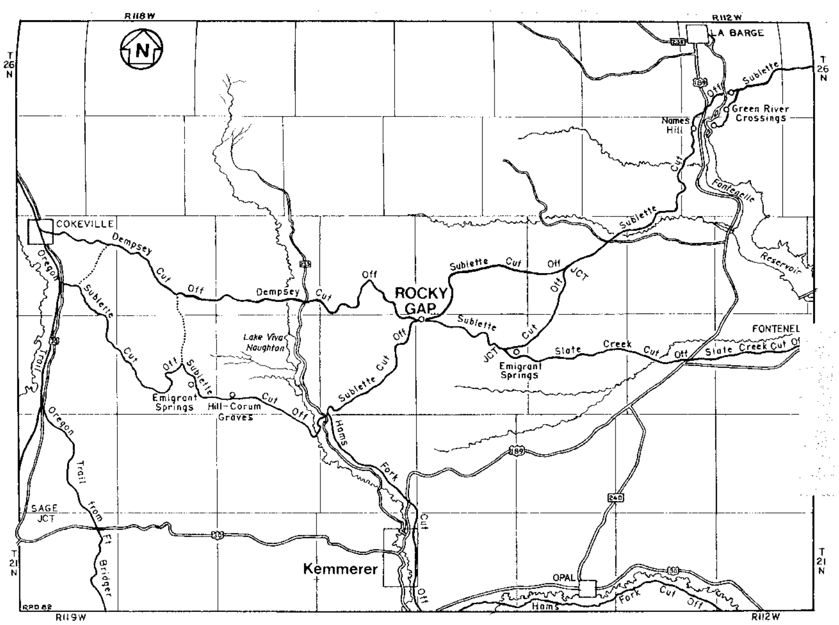


Figure 18. Map of Oregon Trail segments at and near Cokeville Meadows.

in westward migration to the Oregon Territory and the Pacific region along what became the Oregon Trail. Segments of the Oregon Trail pass through the acquisition boundary of Cokeville Meadows NWR (Fig. 18). The Oregon Trail entered what is now the south acquisition boundary adjacent to the Bear River and ran parallel to the river up to the present B-Q Dam. Then the trail continued north between the McFarland and Twin Creek irrigation ditches to near Big Knob. Then the trail turned northeast to a point along U.S. Highway 30 near Antelope Creek. A second major entry point of the Oregon Trail into the Bear River Valley was by way of the "Sublette Cutoff" (Fig. 18). This major shortcut to the main Oregon Trail entered the valley from the Ham's Fork River Plateau and either intersected the main Oregon Trail where Sublette Creek meets Highway 30 about three miles south of Cokeville or entered Cokeville directly from the east (Fig. 18).

In 1847, the first Mormon emigrants began moving into the region enroute to the Great Salt Lake region. Most emigrants during this time simply passed through the Bear River Valley and true settlements in the Bear River Valley did not begin until the completion of the transcontinental railroad in 1869. Subsequent settlement by Mormons' in the Bear River Valley established ranching in the area. The completion of the Oregon Shortline Railroad through the Bear River Valley near Cokeville, WY in 1882 permanently established occupancy in the region (Strack 2006). The town of Cokeville was established in 1874.

The settlement chronology of the Cokeville Meadows region suggests little ecological change from European human causes occurred in the region until the late 1800s. Even then the sparse human population, limited growing season, and small infrastructure apparently limited ecosystem changes to the area, except for early diversions of water for human and livestock use and eventually more extensive grazing (Young 1899, Veatch 1907). Lincoln County, WY, where Cokeville Meadows NWR is located, had fewer than 16,000 people by the late 1980s. Nearly 80% of Lincoln County currently is in public ownership, the largest percentage (nearly 50%) being owned by the U.S. Bureau of Land Management. Eventually, a network of road/highway and railroad lines transected the Cokeville region; U.S. Highway 30 forms the eastern boundary of the refuge. The region also has become laced with utility and pipeline corridors, including several lines within Cokeville Meadows NWR. The economy of the Cokeville area has historically been dominated by agricultural interests, mostly related to livestock production (Veatch 1907).

HYDROLOGICAL AND VEGETATION COMMUNITY CHANGES

The early development of the Cokeville Meadows NWR region included construction of transportation corridors along the edges of the Bear River Valley. Highways, roads, and railroads were developed in the region in the late 1800s and changed the way that water moved into floodplains from the east and west. These barriers to water movement eventually led to changes in topography and local erosion and sedimentation. Water and sediment changes altered the extensive coalescing alluvial fan system on the east side of the Bear River Valley near Cokeville Meadows NWR where the railroad and U.S. Highway 30 are located. Water entry into the floodplain now is restricted to specific locations that changed the pattern of water and sediment distribution compared to historic conditions.

The combination of irrigation development and land use changes beginning in the early 1900s greatly altered hydrology in the Bear River Valley and its floodplains. The most important of these changes was construction of a network of dams, ditches, small levees/dikes, and water-control structures that diverted Bear River (and tributary) flows into floodplain areas for agricultural and urban uses. The first major diversion of Bear River water near Cokeville Meadows NWR was construction of the Pixley Dam across the Bear River channel soon after water rights in Wyoming were adjudicated at the time of statehood. Most additional water diversion structures were constructed in the 1930s and 1940s to move water onto wet meadow/grassland habitats in the floodplain to enhance forage and hay production during summer. The last major dam development on the Bear River was a reconstruction of the B-Q Dam in 1968. Typically, the low-level dams on the Bear River allow local ranchers to divert water into contour distribution ditches that branch from the diversion site and overflow onto relatively flat floodplain grassland and meadow areas. By 1998 about 70% of land within the Cokeville Meadows NWR acquisition boundary was irrigated (Fig. 19). After water is moved to grassland and meadow areas, surface water gradually evaporates and lands dry so that hay can be harvested in late summer and early fall. Some irrigated areas also support cow-calf operations and pastureland.

Early diversion and delivery of irrigation water to individual ranchers required the formation of corporations to operate and maintain water delivery systems and infrastructure (Wyoming Water Development Commission 2001). Since territorial times, many irrigation companies and sub companies have been formed along the Bear River. Most of these companies are incorporated as nonprofit organizations and water is delivered on a rotational basis or to the user on demand. Water users in the Cokeville Meadows region depend on four principal points of diversion for their water supply. These are the Woodruff Narrows Reservoir, B-Q Dam, and Pixley Dam on the Bear River and the Covey Canal on the Smith's Fork River. Major diversion canals/ditches from the Bear River include, in a downstream order, the B-Q West Slough, McFarland Ditch, and B-Q Eastside Ditch above the B-Q Dam; Pixley Ditch above Pixley Dam, and the Cook Canal. The major diversion ditch on the Smith's Fork River is the Covey Canal. Currently, over 100 miles of ditches exist in the Bear River Valley in the vicinity of Cokeville Meadows NWR. Irrigation companies historically associated with these supply systems included the Woodruff Narrows Company, Beckwith-Quinn Canal Company, West Side Canal Company, Pixley Canal Company, Covey Canal Company, Mau Canal Company, and the Smith's Fork Irrigation District. The Beckwith-Quinn and Pixley Canal Companies no longer exist and the Mau and Covey Canal Companies are now incorporated into the Smith's Fork Irrigation District.

Over 100 groundwater wells have been drilled in the Bear River Valley in the Cokeville Meadows NWR region and they supply water for agricultural and urban uses (Fig. 19). Ten of these wells are located on Cokeville Meadows NWR lands. Pumping from the alluvial aquifer in the Cokeville Meadows area reduces flow in the Bear River (Franz 2005). In years when Bear River stream flow is below average, about 84% of water pumped from existing wells is derived from water that otherwise would have seeped in the Bear River. About 16% of this is directly used by floodplain wetland and meadow plants (Glover 1990). The largest reduction in Bear River flow caused by well extraction of groundwater occurs during August, which corresponds with the period of maximum pumping for alfalfa and small grain production. The amount of groundwater pumped is relatively small compared to total groundwater discharge into the Bear River, but undoubtedly has some effect on instream flow attributes of the Bear River in late summer. Simulation models of this

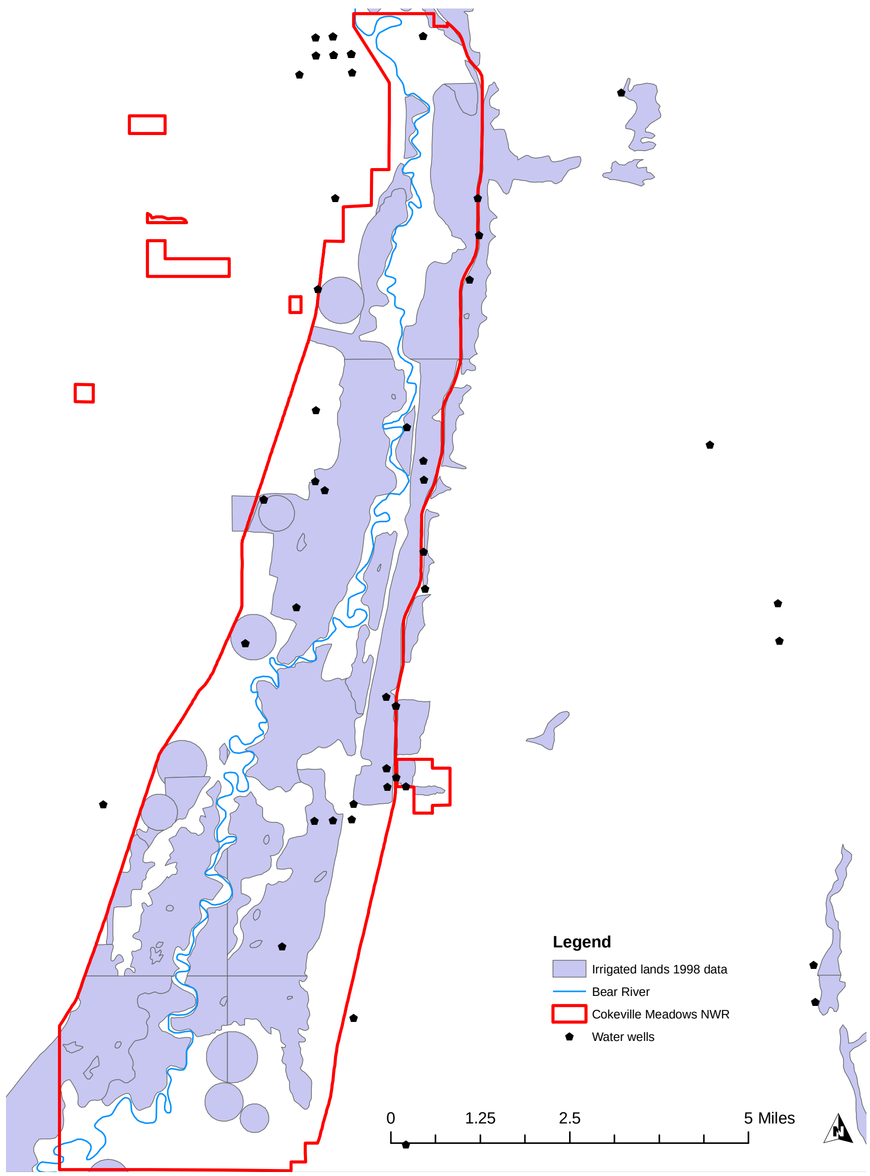


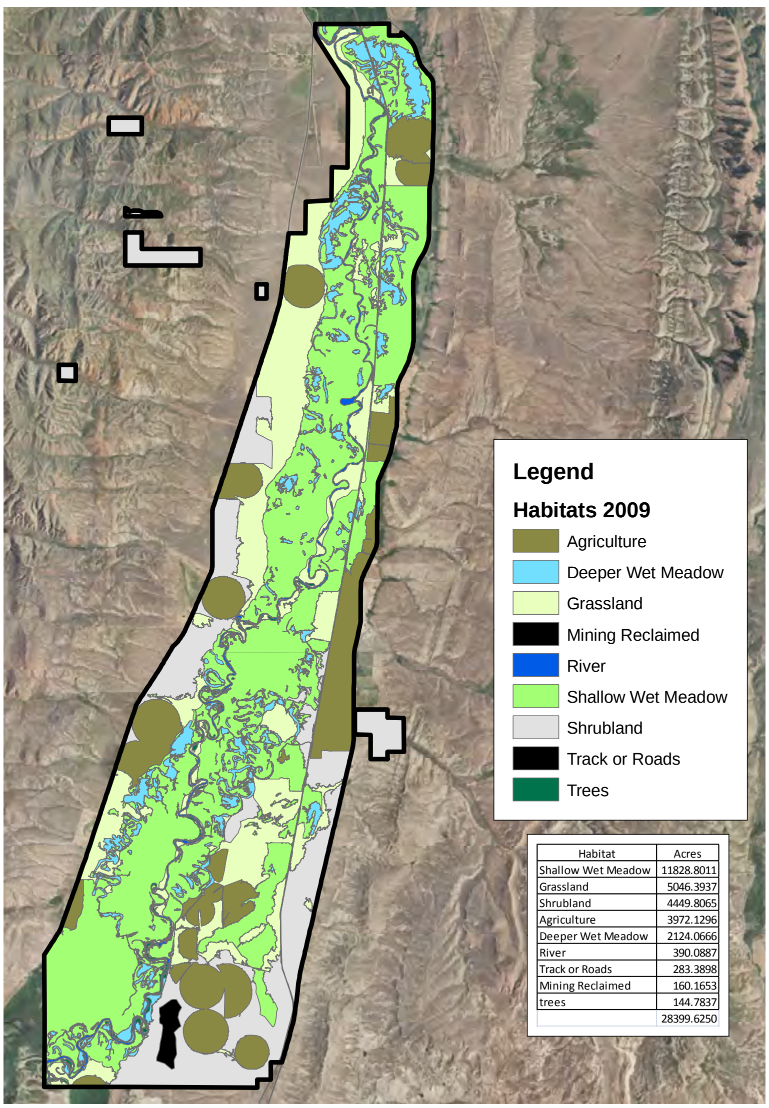
Figure 19. Location of irrigated lands and wells in the Cokeville Meadows region in 1998.

effect indicate that stream flow would be reduced by about 3.4 ft^3/second during August with carryover of about 0.5 ft^3/second to the following years irrigation season (Glover 1990).

In 1993, total water use in Lincoln County, Wyoming was about 405,000 Mgal (million gallons) (Ogle et al. 1996). Shallow ground water wells supplied most public-supply water for domestic, commercial, and industrial uses. Surface water supplied an estimated 153,000 Mgal of the total estimated 158,000 Mgal used for irrigation of hay, pasture, and crop lands. Livestock water use was only 203 Mgal and mining used about 153 Mgal (Ogle et al. 1993).

Floodplain topography and drainage systems, including depressions and abandoned channels in the Cokeville Meadows NWR area, have been altered by culvert and bridge crossings, railroad beds, and some channelization of tributaries. Overall, the fluvial system of the Bear River has been altered by historic land use changes throughout its watershed. These fluvial changes have caused altered ground and surface water hydrological regimes, increased sediment loading and coliform contamination of surface waters, and altered vegetation communities (e.g., Smith and Maderick 1993). The valleys and lower hill slopes near Cokeville Meadows NWR have been extensively grazed and farmed for several decades; higher elevation valleys and mountains also have been extensively grazed and are partly deforested.

Current land use in the Cokeville Meadows NWR acquisition boundary is dominated by shallowly flooded wet meadow habitats in the floodplain and sagebrush-grassland habitats on alluvial fans and upland terraces (Fig. 20). Nearly 4,000 acres of mostly terrace and alluvial fan areas have been converted to irrigated cropland and alfalfa fields. About 2,100 acres in the Cokeville Meadows NWR acquisition boundary are in deeper "wetland" depressions and abandoned channel areas in the floodplain.



Habitat	Acres
Shallow Wet Meadow	11828.8011
Grassland	5046.3937
Shrubland	4449.8065
Agriculture	3972.1296
Deeper Wet Meadow	2124.0666
River	390.0887
Track or Roads	283.3898
Mining Reclaimed	160.1653
trees	144.7837
	28399.6250

Figure 20. Map of habitat types present in 2009.

A set of "seniority rights" govern water use in the Bear River Valley during limited water periods; these being adjudicated at the time of Wyoming statehood. Other additional water rights have not been adjudicated, but are in good standing, including pumping of groundwater for irrigation, using center-pivot or roller irrigation structures. All water management and uses of water in the Bear River Basin are governed by the Bear River Compact, which determines water rights and obligations in Wyoming, Idaho, and Utah with respect to Bear River water (Jibson 1991). The original Compact was signed in 1958 and was amended by Congress in 1980. The Bear River Commission administers the Compact and water rights within each state are adjudicated and administered in accordance with state law subject to limitations in the Compact. In the 1980s proposals were advanced to construct water storage reservoirs on the Smith's Fork River, but these were not built because of inadequate economic benefits.

Currently, 50 separate water rights are present on Cokeville Meadows NWR lands. These water rights historically were present on lands acquired or now in NWR management (Appendix B). The earliest water rights on Cokeville Meadows NWR lands date to 1880 and provide use of Bear River water via the Pixley Irrigation Ditch.

Irrigation of meadows and other floodplain areas within the Cokeville Meadows NWR acquisition boundary is accomplished by inserting boards into the B-Q and Pixley water-control structures in early summer, both of which span the entire Bear River channel. Bear River water then backs up behind the structures and is diverted into irrigation ditches on both sides of the river. These ditches include larger distribution ditches that are 3-4 feet deep and several feet wide and small terminal ditches that may be only a foot or so deep. Select primary ditches, levees, and water-control structures along with other water management features on existing Cokeville Meadows NWR lands are shown in Fig. 21. Flow in the major ditches is monitored daily. At the end of the irrigation season, usually on 10 July, the boards are removed from the B-Q and Pixley dams and surface water drains back into canals and ditches (and back into the Bear River), infiltrates into the alluvial groundwater, or evaporates. Concurrently with removal of boards in the B-Q and Pixley dams, surface water is drained from fields and floodplain wetlands/depressions (including abandoned Bear River channels and oxbows) by removing dirt plugs or opening small water-control structures in individual fields/sites. Fields are allowed to dry until about 1 August when the wet meadow hay is cut and harvested. Only one cutting of hay is harvested due to the short growing season. In most years, over 70% of seasonally flooded acres become dry enough to harvest hay in late summer. The meadows typically then are used for pasture during late summer and fall. The only exception to this general irrigation pattern is continued irrigation of alfalfa until about 15 August each year. Some small grain crops that are grown on higher terrace and alluvial fan elevations are irrigated with ground water pumped into center pivot or roller-type irrigation systems.

Following the development of the irrigation water conveyance systems in the Cokeville Meadows NWR region, beginning in the early 1900s, the seasonal flooding of Cokeville Meadows NWR floodplain habitats became more consistent among years and was extended longer into summer than in historic times. Currently, irrigation flooding of meadows occurs from late April through early July in normal run-off years and the extent of seasonally flooded acres is increased to include almost all lands between

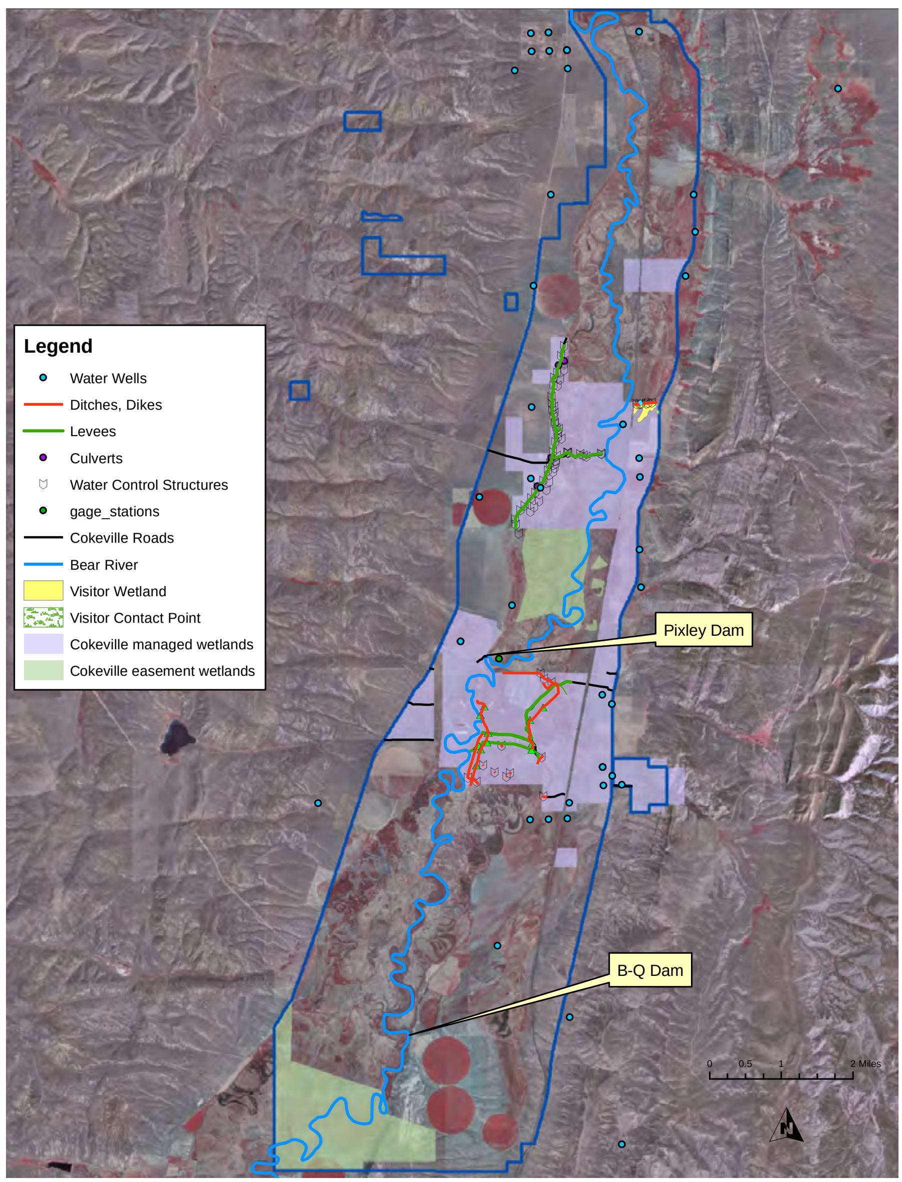


Figure 21. Location of primary water-control structures, ditches and dikes on Cokeville Meadows NWR and the location of managed and easement lands.

the conveyance system and the Bear River (Fig. 19). Consistently extending the period of surface flooding into summer months allowed encroachment of extensive stands of native perennial rushes and sedges into higher elevation meadow areas and also caused expansion of persistent emergent wetland plant species in floodplain depressions and along drainages. The more extensive and prolonged flooding also may have prevented the accumulation of surface alkalinity in some areas and shifted grass and wetland plant species to slightly fresher types. The high water table on the relatively flat floodplain prevented tillage and production of domestic grain crops, but simultaneously created ideal conditions for introduced grasses, especially creeping foxtail (*Alopecurus arundinaceus*) (NRCS 2007). Many canal systems have relatively low gradients and they hold water into the fall, and in some wet years, throughout the year. Therefore, the semipermanently flooded water conditions in canals and associated impounded areas or low depressions, such as abandoned Bear River channels, have become dominated by cattail and bulrush. In addition to more extended summer flooding regimes, the extensive annual haying and grazing in the last 100 years also may have changed the presence and distribution of native meadow and grass species at Cokeville Meadows and concurrently promoted expansion of introduced and invasive plant species.

Over time, several noxious invasive and poisonous plants have become established on or near Cokeville Meadows NWR. Death camas (*Camassia quamash*), tall larkspur (*Delphinium exalatum*), halogeton (*Halogeton glomeratus*), and locoweed (*Oxytropis* sp.) are major poisonous plants in the region. While few livestock deaths attributed to vegetation poisoning have been reported in the area, the potential for poisoning exists if the species are not controlled (USFWS 1992). Predominant invasive noxious plants in the region include Canada thistle (*Cirsium arvense*), whitetop (*Lepidium* draba), musk thistle (*Carduus nutans*), and Russian knapweed (*Cenaurea repens*).

ACQUISITION AND DEVELOPMENT OF COKEVILLE MEADOWS NWR

In February 1989, the State of Wyoming Legislature approved an act enabling the USFWS to acquire about 27,000 acres of land south of Cokeville for the establishment of Cokeville Meadows NWR (USFWS 1992). This Act included a set of conditions to regulate the acquisition process and subsequent management actions; the primary conditions were:

- Acquisition would be limited to 27,000 acres along the Bear River in Lincoln County, south of Cokeville, WY.
- Acquisition would be conducted on a willing seller-willing buyer basis and condemnation would not be used except in a mutually agreed upon title action. Land owners could reserve oil, gas, coal and other mineral rights together with rights of exploration and development.
- State-owned land could be purchased or leased as a refuge for migratory birds with oil, gas, coal and other mineral rights reserved to the state.
- Consent for refuge acquisition was conditional on executing agreements with the Wyoming State Engineer stating that the USFWS would agree to abide by state water law and the Bear River Compact in acquiring and exercising water rights; would not consider the enabling legislation as establishing a reserved water right; would not condemn rights for the NWR; and would address historic use practices.
- Consent for acquisition does not imply consent for development of the NWR.

Immediately after the above Act became effective, the USFWS began negotiation of agreements with the State of Wyoming on water rights and usage and Cokeville Meadows NWR subsequently was established in 1993. The refuge currently contains 9,259 acres in fee title (6,466 acres), conservation easements (1,672 acres), FmHA lands (758 acres), and a State of Wyoming land lease (363 acres). The enabling U.S. Congressional legislation for the refuge identified three purposes. These included: 1) the conservation of wetlands of the Nation to maintain public benefits and to fulfill international obligations of various migratory bird treaties and conventions, 2) Western Intermountain ecosystem conservation, and 3) migratory bird populations. The Environmental Impact Statement written for the refuge (USFWS 1992) identified constraints at the time and provided an evaluation of ecosystems to integrate multiple uses including conservation of fish and wildlife populations, livestock grazing and haying management, oil/gas/mineral development, recreation, and local community economics.

Cokeville Meadows NWR has authorization to expand to 26,657 acres; the balance from current NWR area is owned by multiple land owners (Fig. 22). The USFWS potentially could acquire over 20,000 acres with the remainder in easements and joint administration with other agencies/entities. Since development of the refuge began in the early 1990s, management of refuge lands has sought to partly impound some wetland areas for waterfowl production; create and enhance foraging habitats and areas for migratory waterfowl, sandhill cranes, eagles and raptors, songbirds, and shorebirds; provide nesting habitat for waterbirds; protect roosting sites for bald eagles; protect and enhance lek sites for sage grouse (*Centrocerus urophasianus*); and provide winter range for ungulates (Cokeville Meadows NWR, unpublished annual narratives).

Many wetland developments have occurred on the refuge including construction of levees, water-control structures, ditches, and dams. Recent construction activities have sought to improve irrigation systems, roads, and visitor access (Appendix C). The refuge is divided into various water management districts and includes about 5 miles of low elevation dikes and over 40 water-control structures. Typically, wetland developments have constructed infrastructure to divert Bear River water into floodplain depressions or flats and to partly impound these sites to prolong the duration of surface water during spring and summer. Impounded wetland areas often retain water until diversion of irrigation water into floodplain meadows is discontinued in July, and many deeper depression including oxbows may retain surface water throughout the year, at least in wet years. Certain impoundments have water-control structures to allow drainage or partial dewatering of the site either in late summer to allow some haying or grazing, or to manage vegetation for either seed producing annual/perennial plants or emergent species.

Existing irrigated hay land and pasture has been mostly maintained on Cokeville Meadows NWR since its establishment, although some small areas were originally to be converted to dense nesting cover for waterfowl (USFWS 1992). About 50% of hayable meadows are hayed by adjacent landowners under permit. Invasive and noxious weeds including Canada thistle, musk thistle, and Russian knapweed are controlled by permittees on the refuge. About 400 acres of small grains are grown on the refuge by permittee farmers and

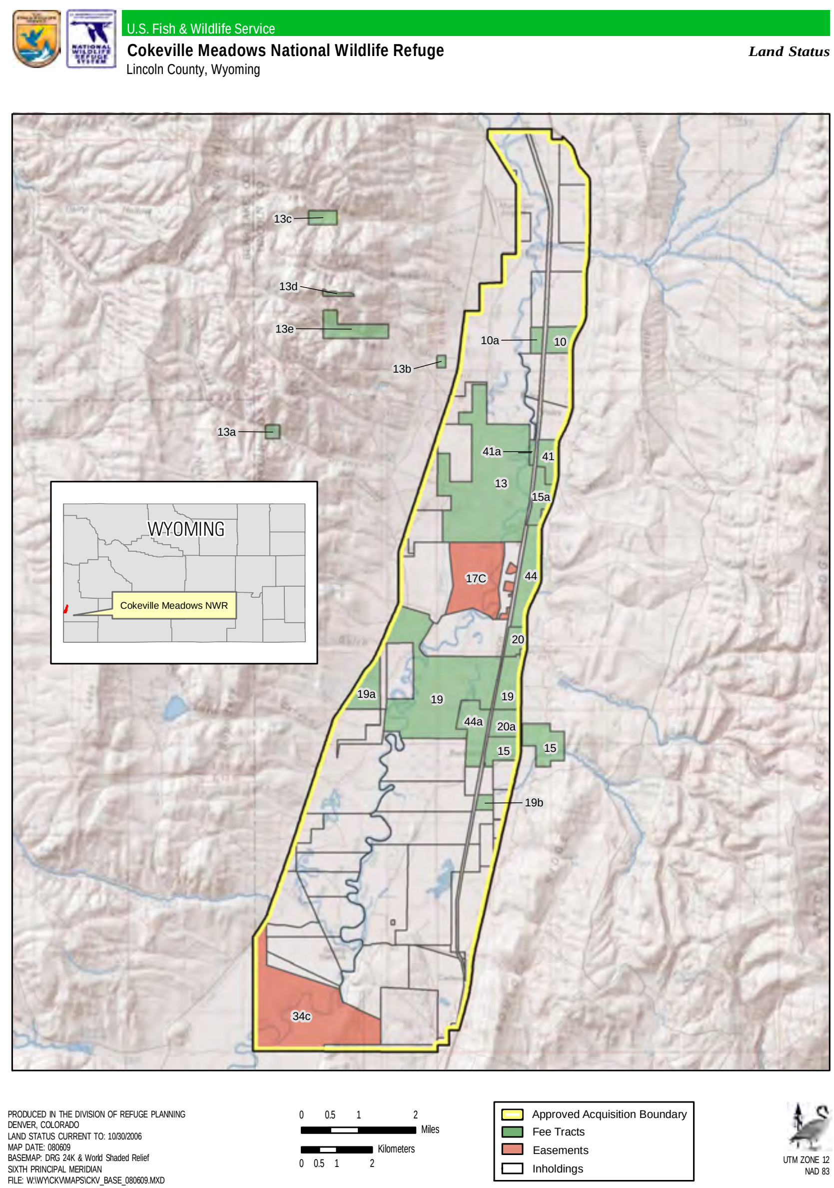


Figure 22. Ownership of lands at Cokeville Meadows NWR.

alfalfa and alfalfa/grass mixes are grown on about 1,400 acres.

ANIMAL POPULATIONS

Little quantitative information is available to assess changes in the presence, abundance, and distribution of animal species over time in the Cokeville Meadows region (e.g., USFWS 2007). Historically, the Bear River Valley, including the Cokeville Meadows NWR region, supported large numbers of waterfowl, waterbirds, and sandhill cranes, especially during spring migration periods (Drewein and Bizeau 1974, Bellrose 1980, USFWS 1992, Nicholoff 2003). In wet years many wetland-associated bird species nested in the region. Long-term trends in waterbird use of the region are unknown, but more annually consistent and prolonged water regimes in the Cokeville Meadows region, caused by annual diversion of river water onto floodplains to irrigate hay and pastureland may have increased use and production of some species over time, such as redhead (*Aythya americana*), canvasback (*Aythya valisineria*), black tern, black-crowned night heron, black-necked stilts (*Himantopus mexicanus*), and white-faced ibis. For example, production of redheads in the larger Bear River Valley during the 1970s and 1980s was among the highest of any western U.S. region in some years (Weller 1964, USFWS 1992). Breeding waterfowl surveys at Cokeville Meadows NWR in recent years have often counted a few thousand ducks and up to 1,100 Canada geese. Up to 500 sandhill cranes may be present on the refuge during migration periods, with up to 100 cranes attempting to nest on the refuge in some years (USFWS 1992, Subcommittee on Rocky Mountain Greater Sandhill Cranes 2007). Recent trends in waterfowl and crane numbers at Cokeville Meadows are difficult to assess given the lack of systematic surveys, but at least duck numbers appear to be lower than in previous periods. Mediated long-term dynamics of wetland flooding and drying regimes appear to have promoted denser, less diverse, wetland plant communities where nutrients are bound in emergent vegetation biomass and cover-open water interspersion is reduced. These vegetation changes generally reduce wetland productivity and waterfowl use/production. Intensive fall and spring grazing and high populations of some predator species such as red fox and striped skunk also may be depressing nest success and production (USFWS 1992). Cokeville Meadows is within the historic range of the trumpeter swan (*Cygnus columbianus*), but their occurrence now is rare. Other waterbirds are abundant on Cokeville Meadows NWR during spring and summer including several nesting species. Few counts of these breeders are made, but American bittern, long-billed curlew, black terns, white-faced ibis, snowy egret and black-crowned night herons commonly are present in more permanent water sites.

Little information is available on non-waterbird bird species, except for annual surveys of sage grouse leks. The total number of lek sites on the refuge has not changed in recent years, but some individual lek sites have been abandoned (USFWS 1992, Cokeville Meadows NWR, unpublished records). Abandoned sites usually are in sites with intensive grazing/haying and where native vegetation has shifted to more introduced or invasive species. Upland grassland and sagebrush habitats in the Cokeville Meadows region are degraded from past extensive grazing and some sites have been converted to small grain or alfalfa production. Likely, other animal species associated with these grassland and sage habitats have declined (Smith et al. 1984).

Populations of at least some mammal species have changed at Cokeville Meadows from historic periods. Species such as bison (*Bison bison*), wolf (*Canis lupus*), cougar (*Felis concolor*), and black-footed ferret formerly occurred in the region, but at present no known wild population of ferrets or bison occur in the region nor are sustained populations of wolf or cougar present. Regional populations of some ungulates, such as deer and elk, may be higher than in former times while others such as moose and pronghorn are lower. Likewise, populations of species such as red fox (*Vulpes fulva*), striped skunk, raccoon, muskrat, and beaver (*Castor canadensis*) likely are greater now than in Presettlement times, but other species including badger (*Taxidea taxus*), bats, and marmots (*Marmota* sp.) may have lower population sizes.

Few native fish remain in the Bear River or its tributaries. Currently many warm-water and introduced species such as sunfish are present in area rivers and streams. Non-native rainbow, brook, brown, and MacKinaw trout now are present in the Bear River. Bonneville cutthroat trout are present is suitable river habitat, but the pure strain native cutthroat trout has virtually disappeared downstream of Pixley Dam (USFWS 1992). Common carp (*Cyprinus* carpio) are present throughout the Bear River system, including deeper floodplain wetlands, and their presence has suppressed production and diversity of rooted aquatic vegetation and associated aquatic invertebrates. Few amphibians and reptiles are common in the region and no information is available to understand changes, if any, for these species.

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OPTIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

SUMMARY OF HGM INFORMATION

Information obtained during this study was sufficient to conduct an HGM evaluation of historic and contemporary ecological attributes of the Cokeville Meadows NWR ecosystem. Key summary data include:

1. Cokeville Meadows NWR currently is a small, relatively disjunct ownership, tract in the Bear River Valley of southwestern Wyoming.

2. This floodplain area at Cokeville Meadows was created by a laterally meandering Bear River system in a relatively narrow floodplain surrounded by terraces and alluvial fans that were formed mainly by erosion of adjacent mountains.

3. The geological/river hydrological setting of the refuge area created multiple abandoned channels and wide wet meadows within the floodplain.

4. Snowmelt and spring rains caused the Bear River to rise each spring/early summer and to flood many floodplain areas in most years.

5. Long-term climatic and river gauge data indicate alternating wet vs. dry years in the Cokeville Meadows region at about 12-15 year intervals. During wet years the spring/summer discharge in the Bear River was greater and caused more extensive and prolonged overbank flooding into floodplain habitats. Conversely, in dry years, little or no overbank flooding occurred along the Bear River and only short duration flooding of floodplain depressions occurred when higher river stages caused some backwater flooding into drainages.

6. The topography of Cokeville Meadows is heterogeneous and largely reflects the alluvial formation of the Bear River Valley.

7. Four major vegetation communities historically were present at Cokeville Meadows. These were a narrow band of riparian/riverfront forest in newly deposited coarse texture soils along the Bear River; semipermanently flooded emergent-type wetlands in deeper abandoned channels/oxbows of the Bear River; expansive wet meadows of sedge/rush/wet grassland species throughout much of the floodplain; and sagebrush-grassland communities on higher elevation older-age terraces and alluvial fans.

8. Habitats in the Bear River Valley, including the Cokeville Meadows area, provided abundant and diverse seasonal resources that were important to sustain populations of many animal species in the Intermountain West ecoregion. Most common species exploited seasonally available resources from spring through fall. Migratory birds were especially abundant in the region and over 30 waterbird species bred in the region, especially during wet years.

9. Native people occupied the Cokeville Meadows regions at various times over the past 10-12,000 years, but use was probably restricted to spring-fall periods and they had little impact on vegetation communities except for occasionally setting fires.

10. Permanent European occupation of the area did not occur until the mid- to late 1800s and sparse human populations; short growing seasons, and small infrastructure limited ecosystem changes to the area except for early diversions of water for human and livestock use and eventually more extensive grazing. Only about 16,000 people lived in Lincoln County, WY by the late 1980s.

11. Extensive water diversion and irrigation systems were constructed in the Bear River Valley near Cokeville Meadows NWR in the mid to late 1900s. Two larger dams within the Cokeville Meadows NWR acquisition boundary, the B-Q and Pixley Dams, were built across the Bear River and allowed local ranchers to divert water into distribution ditches and onto wet meadow and wetland depressions in the floodplain at Cokeville Meadows.

12. Many groundwater wells have been installed in the Bear River Valley near Cokeville Meadows and water from these wells supports hay production and some small grain crops. Pumping from these wells reduces groundwater discharge into the Bear River during July and August.

13. Floodplain topography and drainage systems, including floodplain depressions and abandoned channels, have been altered by levees, ditches, culvert and bridge crossings, water-control structures, and some channelization.

14. Currently, floodplain habitats at Cokeville Meadows are flooded more regularly and for longer periods than historically occurred, because of annual water diversions to irrigate hay/pasturelands.

15. Vegetation communities at Cokeville Meadows have shifted to wetter-type species including more extensive stands of persistent robust emergent species in deeper depressions, more sedges and rushes in meadows, and expansion of the introduced Garrison creeping foxtail across many floodplain areas.

16. Major invasive plant species now common on Cokeville Meadows include Canada thistle, whitetop, musk thistle, and Russian knapweed.

17. In February 1989, the State of Wyoming approved an act enabling the USFWS to potentially acquire about 27,000 acres south of the town of Cokeville, WY for the establishment of Cokeville Meadows NWR.

18. Currently, the refuge contains 9,259 acres in fee title (6,466 acres), conservation easements (1,672 acres), FmHA lands (758 acres), and a State of Wyoming land lease (363 acres).

19. Management efforts to date at Cokeville Meadows NWR mainly have been directed at impounding and diverting water to wetlands to increase waterfowl production and provide more predictable migration habitat; improving upland nesting habitat for ducks, providing foraging and nesting areas for sandhill cranes; enhancing roosting sites for bald eagles; protecting lek sites for sage grouse; improving winter range for ungulates; and providing riparian/wetland habitat for waterbirds, neotropical migrant birds, and some fish and mammals.

20. Wetland developments on the refuge have included constructing levees, water-control structures, and ditches. Typically, these developments have sought to divert higher water flows from the Bear River in spring and early summer into the impounded sites and then to hold the water through summer and/or fall.

21. Existing irrigation hay and pasture lands on the refuge have largely been maintained; about 50% of hayable meadows are hayed by adjacent landowners under permit.

GENERAL RECOMMENDATIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

This study is an attempt to evaluate restoration and management options that will protect, restore, and sustain natural ecosystem processes, functions, and values at Cokeville Meadows NWR. Cokeville Meadows NWR provides key resources to meet annual cycle requirements of many plant and animal species in the Rocky Mountain region of the western U.S., and the signature wet meadows of Cokeville

Meadows NWR are an especially critical component of this important habitat type, and its species assemblages, in the Rocky Mountain ecoregion. Cokeville Meadows is an important area that can provide opportunities for wildlife-dependent uses. These public uses are important values of the refuge, but they must be provided and managed within the context of more holistic regional landscape- and system-based management. This study does not address where, or if, the many sometimes competing uses of the refuge can be accommodated, but rather this report provides information to support The National Wildlife Refuge System Improvement Act of 1997, which seeks to ensure that the biological integrity, diversity, and environmental health of the (eco)system (in which a refuge sets) are maintained (USFWS 1999, Meretsky et al. 2006). Administrative policy that guides NWR goals includes mandates for: 1) comprehensive documentation of ecosystem attributes associated with biodiversity conservation, 2) assessment of each refuge's importance across landscape scales, and 3) recognition that restoration of historical processes is critical to achieve goals (Mertetsky et al. 2006). Most of the CCP's completed for NWR's to date have highlighted ecological restoration as a primary goal, and choose historic conditions (those prior to substantial human related changes to the landscape) as the benchmark condition (Meretsky et al. 2006). General USFWS policy, under the Improvement Act of 1997, directs managers to assess not only historic conditions, but also "opportunities and limitations to maintaining and restoring" such conditions. Furthermore, USFWS guidance documents for NWR management "favor management that restores or mimics natural ecosystem processes or functions to achieve refuge purpose(s) (USFWS 2001).

Given the above USFWS policies and mandates for management of NWR's, the basis for developing recommendations for Cokeville Meadows NWR is the HGM-approach used in this study. The HGM approach objectively seeks to understand: 1) how this ecosystem was created, 2) the fundamental physical and biological processes that historically "drove" and "sustained" the structure and functions of the system and its communities, and 3) what changes have occurred that have caused degradations and that might be reversed and restored to historic and functional conditions within a "new desired" environment. This HGM approach also evaluates the NWR within the context of appropriate regional and continental landscapes, and helps identify its "role" in meeting larger conservation goals and needs at different geographical scales. In many cases, restoration of functional ecosystems on NWR lands can help an individual refuge serve as a "core" of critical, sometimes limiting, resources than can complement and encourage restoration and management on adjacent and regional private and public lands.

Although many areas within the Bear River Valley on and near Cokeville Meadows NWR have been altered, much of the acquisition boundary area has retained historic vegetation community types and distribution. The primary ecological process that controlled this Bear River ecosystem was rising water levels in the Bear River in spring and early summer that seasonally inundated floodplain habitats in alternating wet vs. dry long-term patterns. The basic pattern of this spring-flood driven ecosystem remains present, but dams and diversion of water have created a more prolonged flooding pattern with less annually dynamic pulses of flood height and duration throughout the floodplain system than existed historically. Floodplain topography and hydrology in the Cokeville Meadows NWR acquisition boundary is most altered where extensive irrigation infrastructure has been constructed (e.g. dams, ditches, levees, water-control structures). Concurrently, vegetation in the NWR boundary is most changed from historic conditions where extensive irrigation, haying, and grazing have occurred over the last century. Further, the plant communities on the east side of the refuge are affected by U.S. Highway 30 and the railroad that travel north-south through the refuge. The specific effects of continual annual irrigation and long-term effects of constant grazing/haying are unknown, but collectively these factors seem to have shifted wet meadows to more introduced grasses and probably to more persistent emergent, sedge, and rush communities in lower elevations and depressions.

Major ecosystem changes and issues that affect future management and restoration of habitats on Cokeville Meadows NWR include:

- Maintaining and complying with adjudicated water rights and irrigation flow/drainage constraints with neighboring land holdings that control water flow delivery pathways and amounts of surface water that cross, and flood onto, NWR lands.

- Disjunctive land ownership with intervening private land holdings.

- Presence and some expansion of several invasive and/or introduced plant species, especially the current extensive coverage by creeping foxtail.

- Altered water flow regimes, and perhaps degraded water quality, in the Bear River and flood waters that flow on and through the floodplain.

- Altered vegetation communities throughout the refuge and conversion of native wet meadow plant communities to irrigated hay land.

- Public expectation for continued agricultural uses (haying, pasture, small grain production) on refuge lands, an expanded refuge acquisition, and greater public access.

Based on the HGM context of information obtained and analyzed in this study, we believe that future management of Cokeville Meadows NWR should seek to:

1. Maintain the physical and hydrological character of the Bear River and its floodplain in the Cokeville Meadows NWR acquisition boundary area.

2. Restore the natural topography, water regimes, and physical integrity of surface water flow patterns in and across the Bear River floodplain and adjacent terraces and alluvial fans.

3. Restore and maintain the diversity, composition, distribution, and regenerating mechanisms of native vegetation communities in relationship to topographic and geomorphic landscape position.

The following general recommendations are suggested to meet these ecosystem restoration and management goals for Cokeville Meadows NWR.

1. *Maintain the physical and hydrological character of the Bear River and its floodplain in the Cokeville Meadows NWR acquisition boundary area.*

Fortunately, most of the major physical features of the Bear River Valley, including the Cokeville Meadows NWR acquisition boundary area, have not been highly altered by large dams or channelization of the Bear River and its major tributaries; major bridges, rail beds and roads that cross the floodplain valley; land leveling; urban or residential developments; excavations on terraces and alluvial fans adjacent to the floodplain; or large mining operations. The most important alterations to physical attributes of the Cokeville Meadows ecosystem have been construction of the B-Q and Pixley dams on the Bear River, irrigation ditches and canals, and roads/rail beds on the edges of the floodplain. Most of these developments do not appear to have compromised the integrity or functioning of the ecosystem in irreversible ways. Nonetheless, it is important to protect the Cokeville Meadows NWR area from future landscape and hydrological development proposals that might significantly alter the physical and hydrological characteristics of this ecosystem. Collectively, completing the establishment of Cokeville Meadows NWR within its acquisition boundary and maintaining the integrity of the Bear River Valley is critically important within the context of larger Intermountain West and Great Basin conservation initiatives (e.g., USFWS 1992, Nachlinger et al. 2001).

2. *Restore the natural topography, water regimes, and physical integrity of surface water flow patterns in and across the Bear River floodplain and adjacent terraces and alluvial fans.*

The diversity and productivity of the Bear River Valley, including the Cokeville Meadows NWR acquisition boundary area, was created and sustained by a diverse geomorphic/topographic surface (that reflected historic migrations and scouring/deposition by the Bear River) that was seasonally "hydrated" by a strong seasonal pulse of water into the ecosystem each spring from flooding of the Bear River and its tributaries and surface and groundwater drainage/recharge from surrounding mountain/terrace slopes. The topographic and geomorphology/soil characteristics of the region created complex, and highly interconnected, mosaics of elevations and water flow pathways with site-specific hydrology that supported local vegetation communities and diverse resources that were used by many animal assemblages on Cokeville Meadows NWR. Unfortunately, considerable changes have occurred in topography and flow of water across the Bear River Valley because of water diversion from the Bear and Smith's Fork rivers, seasonally impounding water upstream of the B-Q and Pixley dams, over 100 miles of irrigation ditches and canals in and on the edge of the floodplain, low-level dams and berms along the Bear River and in floodplain depressions, numerous water-control structures, and some pumping of groundwater from over 100 wells in the region. Most of the water developments in the region have been intended to provide more sustained annual irrigation water to floodplain meadows to enhance hay production and pastures. Diversion of water for irrigation of hay and pasturelands in spring simulates natural flooding from the Bear River into the Cokeville Meadows floodplain but has reduced inter-annual variation of low vs. high flooding, prolonged annual flooding of meadows, and changed in-stream flows especially in late summer. Seasonal impoundment upstream of the B-Q and Pixley dams has caused higher prolonged water levels in summer and appears to have promoted steep-angle channel bank erosion in some places. The cumulative impacts of these hydrological changes on ecosystem structure, functions, and values are not known, however, plant communities have shifted to more water tolerant species and the many ecologically beneficial effects of periodic extreme drought or flooding have been reduced.

Some topographic/hydrologic developments on Cokeville Meadows NWR have been constructed by the USFWS to partly impound water in floodplain depressions to provide more consistent water areas with longer hydroperiods for breeding waterbirds, especially ducks. While this impoundment does provide more consistent wetland habitat during spring and summer, it reduces the natural dynamic variation in water regimes that ultimately is necessary to sustain long-term diversity and production of floodplain wetlands. These wetlands require periodic annual drying that alternates with more extensive flooding in wet years to recycle nutrients, provide germination surfaces to regenerate plant communities, and provide access to specific foods by certain animal groups in both wet and dry periods of the long-term cycle (e.g., van der Valk 1989). Further, all topographic alterations to the floodplain alter how and where river floodwater flows across lands and moves nutrients and resources. For example, historically high water in the Bear River occasionally overflowed banks and spread across floodplains in a "sheetflow" manner by first inundating depressions and then gradually moving onto higher elevations and then draining in a similar manner. Now, because of ditches, dams, etc., water usually is purposefully routed to specific areas where it may or may not overflow onto low elevations in a sheetflow manner. Likewise, drainage of floodwater from the floodplain usually is channeled through ditches and not back through natural lower elevation locations.

Generally, restoration of the physical and biotic diversity and productivity of the Cokeville Meadows ecosystem will require at least some restoration of natural topography, especially reconnecting natural water flow pathways in the floodplain. Further, the annually dynamic nature of historic spring flooding patterns should be restored, or emulated, where possible. This restoration of natural flooding patterns will mean that occasional dry, and conversely occasional very wet, conditions in floodplain depressions and meadows will occur. Reinstating this annually dynamic hydroperiod also will mean that waterbird production will be annually dynamic across years; with higher use and production in wet years and lower abundance and production in dry years. While waterbird production may be more irregular among years, restoring the natural hydrodynamics of the system ultimately will sustain the long-term diversity and production of the ecosystem, and thus its long-term carrying capacity for many animal species. Disjunct ownership of lands by the NWR and historical precedents and legal constraints of water use and water rights will make management for emulation of natural flooding dynamics difficult in many areas of the refuge acquisition boundary. However, emulation of more natural water regimes seems possible in some managed areas and may be possible to some larger geographic extent if NWR lands are expanded to the approved boundary, thus allowing more opportunity for restoration of natural topography, overbank flooding, and water movement/duration patterns.

3. *Restore and maintain the diversity, composition, distribution, and regenerating mechanisms of native vegetation communities in relationship to topographic and geomorphic landscape position.*

Four major vegetation communities historically were present in the Cokeville Meadows ecosystem and they were distributed along geomorphic, soil, topographic, and flood frequency gradients. HGM-based mapping of potential historic distribution of communities was somewhat constrained in this study by the lack of refined soil and topographic information. Nonetheless, the distribution of geomorphic surfaces and flood frequencies in various floodplain elevations described vegetation community distribution relatively well. Riparian/riverfront forest was present on natural levees with coarse material soils immediately adjacent to the Bear River and its major tributaries, while emergent-type wetland vegetation occurred in floodplain depressions, especially old river meander channels. Sagebrush-grassland communities occurred on alluvial fans and terraces along the edge of the floodplain. The largest community type at Cokeville Meadows was the namesake meadow habitat. If more refined soil and topographic information had been available, it might have been possible to map specific plant distribution in the meadows relative to slight variations in soil salinity and elevation. For example, more alkali species such as saltgrass and alkali sacaton historically occurred on more saline areas while more extensive rush and sedge species were present in slightly lower elevations in the meadow areas that flooded more regularly and for slightly longer duration. Future information on soils and elevations should help identify the distribution of specific historic plant assemblages in meadow areas.

Each vegetation community in the Bear River Valley provided important, usually seasonal, resources to a diverse animal community that used the area. And, each community was the result of distinctive seasonal flooding regimes caused by inter- and intra-annual dynamics of water flows and flooding of the Bear River and its major tributaries. The winter climate in the region is extreme and most animals using the area were seasonal visitors. More water/flooding, and thus available aquatic/wetland resources, occurred in spring and early summer than in other periods. For waterbirds, shallowly flooded habitats in most springs provided extremely important spring migration habitat and in wet years the extended summer water area provided important periodic breeding habitat. In contrast, less habitat and resources were available from late summer through the following spring except in wet years when higher, more prolonged floods, inundated floodplain wetlands for longer periods and carryover water into fall/winter was higher.

Based on the HGM model of potential Presettlement vegetation communities, the current distribution of major vegetation community types at Cokeville Meadows is not drastically altered from historic condition, but significant shifts have occurred in species composition of the communities. The primary changes from historic condition are:

1. Conversion of some habitats to agricultural crops or introduced hay lands.

2. Shifts in species composition in wetland and meadow communities.

3. Loss of much woody species in riparian corridors.

4. Expansion of emergent wetland species along ditches, canals, and drainages where surface water is present for longer periods.

Typically, ecosystem restoration strategies seek to restore elements of the diversity, composition, and natural distribution patterns of habitats in a region where they may have been altered (e.g., Heitmeyer 2007). At Cokeville Meadows, this restoration goal seems important to sustain plant and animal communities and to provide other related ecosystem functions and values such as nutrient and energy flow, carbon sequestration, water filtration and recharge, flood water storage, human uses, etc. As such, management actions at Cokeville Meadows NWR should attempt to protect, maintain, and restore (if need be) functional areas of all native habitat types that were present in the early 1900s prior to major changes in irrigation and land use. The appropriate distribution for each community is identified by the HGM matrix produced for this region in terms of geomorphic surface, soil and elevation to the extent that data allow, and hydrologic regime. In meadow habitats, extensive grazing/haying and diversion of irrigation water to floodplains appears to have gradually shifted plant species composition and distribution to wetter and more introduced species. The shift in meadow vegetation may not be highly detrimental if the new species provide similar resources to the historic communities, however, retaining the native community diversity and composition is a desirable goal to assure the historic attributes of the ecosystem, including those not fully understood at present, are retained.

Each community at Cokeville Meadows had important driving ecological processes, usually including some periodic disturbance event such as flood, drought, fire, herbivory, etc. A key to sustaining or restoring historic plant associations will be making sure the driving processes and disturbances are present. Consequently, future management should identify where basic processes are still present, and where they need to be restored. As such, some "deconstruction" of past infrastructural developments including physical works such as ditches, levees, water-control structures, etc. may be required. Clearly, certain changes may not be possible for the reasons mentioned in #2 above, however, other USFWS-controlled changes can be conducted. Likely, some conflicts in changing existing landscape features may occur among user groups, but management of Cokeville Meadows NWR ultimately should be based on restoring sustainable communities to meet resource/ecosystem goals.

SPECIFIC RECOMMENDATIONS FOR RESTORATION AND MANAGEMENT OPTIONS

Maintain the Physical and Hydrological Character of the Bear River System

The Bear River Valley ecosystem was created and sustained by geological and hydrological processes of the Bear River and its tributaries that largely still exist in their general physical/hydraulic form. It also is helpful that human presence in, and disturbance of, floodplain/terrace plant and animal communities at Cokeville Meadows NWR historically has been low. Changes to ecosystem features on the refuge have occurred and many issues cannot be controlled by the USFWS. Nonetheless, the USFWS has the opportunity to manage Cokeville Meadows NWR in an exemplary way that contributes to the overall sustainability and restoration of the Bear River Valley. The USFWS also can help promote stewardship and protection of other private and public lands in the Bear River Valley, especially those adjacent to Cokeville Meadows, which can help protect the integrity of this ecosystem. The following conservation actions seem important in this regard:

1. *Protect and restore, where possible, the physical and hydrological integrity of the Bear River and major tributary channels and their water flows, especially the large spring pulse of water in these rivers and streams that originates from snowmelt and spring precipitation.*

- Do not construct additional dams, levees, or channel-bank stabilization structures on the Bear River or its tributaries.

- Evaluate the need, and legal standing, for existing dams and water diversions structures on the Bear River and major tributaries.

- Remove and do not replace hard points or bank stabilization structures along the channel banks of the Bear River on Cokeville Meadows NWR unless they protect non-USFWS property or structures.

- Remove, or place wide spillways in mainstem levees along the Bear River and larger tributaries. Where old or existing levees have been breached or destroyed, do not rebuild them.

- Reconnect floodplain habitats with the Bear River to allow natural overbank and backwater flooding into and out of the floodplain.

- Maintain unimpeded physical and water-flow connection between tributaries and the main Bear River channel.

- Participate in Bear River watershed activities that help protect water quantity and quality in the Bear River.

- Complete acquisition and establishment of Cokeville Meadows NWR within its authorized boundary.

2. *Protect the natural heterogeneous topography of the floodplain including the unique geologic/soil characteristics of abandoned channels and river meander scars, floodplain drainages, alluvial fans, and older geologic-age higher elevation terraces.*

- Protect alluvial fans and terraces along the Bear River floodplain on Cokeville Meadows NWR from development, mining, and topographic alteration and develop private land programs to maintain natural topographic and geological features on similar private lands.

- Do not alter topography further in floodplain wetlands, natural drainages, and other floodplain/meadow lands.

- Reduce agricultural activities that may cause erosion, increased sediment loading, and alteration of topographic elevation/features.

3. *Maintain a low human presence in, and disturbance of, floodplain/terrace plant and animal communities.*

- Restrict residential/commercial developments on Cokeville Meadows NWR and work with county and state entities to maintain low human impacts on adjacent lands.

- Control public access to compatible uses and seasons.

- Evaluate ecosystem disturbances caused by widespread continued haying and grazing on Cokeville Meadows NWR lands.

4. *Protect alluvial aquifers and the delicate soil-mineral balances throughout the floodplain and its adjoining alluvial fans and terraces.*

- Further evaluate groundwater-surface water recharge and discharge distribution and capacities, with additional monitoring of effects of irrigation and wells on alluvial aquifer water quantity and quality.

- Maintain undisturbed vegetation on critical groundwater recharge and discharge sites including seeps and artesian well locations.

Restore Floodplain Topography, Water Regimes, and Water Flow Patterns

Restoration of historic ecological communities and processes at Cokeville Meadows NWR will require at least some restoration of natural topography, water flow patterns, and flooding/drainage regimes. Many past irrigation infrastructural developments and some NWR wetland impoundment projects have altered these important ecosystem attributes and all existing alterations should be carefully evaluated to determine their purpose, efficiency, and interactions with regional water rights and water use needs and history. The Bear River ecosystem is semi-arid and water regimes historically were dominated by increased precipitation and snowmelt in spring that caused higher river flows and flooding followed quickly by drying through summer and fall to low levels in winter and early spring. Superimposed on this strong seasonal water regime were long-term patterns of occasional high flow and flood events and alternating low flow, more droughty conditions on ca. 15-year recurrence intervals. Since the development of extensive water diversions and irrigations systems in the Bear River Valley near Cokeville Meadows, water regimes in floodplain areas, especially meadows and depression wetlands have been more annually consistent, prolonged, and generally wetter than during historical periods. Likewise, management of wetlands (through levees, ditches, and water-control structures) on Cokeville Meadows NWR lands also have tended to provide longer duration and more regular flooding of these areas and has greatly reduced annual flooding-drying dynamics. A return to more historic seasonal and long-term patterns of flooding in this ecosystem will be difficult across wide areas because of the disjunctive ownership of lands, past irrigation history and water rights, and the extensive irrigation infrastructure. Nonetheless, some changes seem possible for specific areas on Cokeville Meadows and include:

1. *Restore natural topography and reconnect natural water flow patterns and pathways where possible.*

- Remove and/or breach spoil material berms and levees along the Bear River and major natural drainages.

- Improve water flow into and through historic floodplain wetland depressions including abandoned channels by removing obstructions, levees, and dams in and across these drainages and depressions.

- Restore at least some natural topography in wetland impoundments, crop and hay fields that may be restored to native vegetation, and terraces and remove islands or other deposition sites in wetlands.

- Evaluate all levees, roads, ditches, and water-control structures to determine if they are necessary, or are detrimental, to water management or restoration of natural water flows and regimes. Remove unnecessary levees and roads and/or construct spillway breaches in drainages.

- Do not construct additional wetland impoundments, roads, levees, or other water-control structures that alter water flow into and across the floodplain.

- Remove roads, berms, and ditches that disrupt natural surface water sheetflow or groundwater discharge and seepage across and from alluvial fans and terraces.

2. *Manage wetland impoundments (that are retained) and natural floodplain depressions for more natural seasonal and long-term water regimes.*

- Manage water regimes in all wetlands for a more natural seasonally and annually dynamic water regime that emulates natural increases in distribution and depth of water in spring followed by drying in summer and fall.

- Emulate long-term patterns of drier wetland regimes in floodplain wetlands in most years including periodic complete drying of shallower depressions in some years and occasionally flooding all basins for more prolonged periods throughout summer and fall in some years.

Restore Natural Vegetation Communities

The current types and distribution of major vegetation communities are similar to historic conditions, but some changes have occurred in species composition of communities. The primary changes are increases in introduced grasses in meadows and sagebrush habitats; loss of willow and cottonwood in riparian corridors; and the presence of more water tolerant sedge, rush, and persistent robust emergent species in floodplain depressions and low elevation meadow areas. The native mixture of vegetation communities present in the Bear River Valley, including the Cokeville Meadows NWR acquisition boundary area, provided critical resources to many animal species and populations in the Intermountain West. Maintaining and restoring, where necessary, the distribution and types of historic habitats is important to the long term capability of the Bear River ecosystem, and entire Intermountain West, to support endemic communities and system functions and values. Fortunately, at Cokeville Meadows NWR, less restoration of native communities is needed compared to other highly degraded and altered areas (e.g., Heitmeyer et al. 2010). Major ecosystem changes appear to be the loss of the woody component of riparian corridors and the potential aggressive expansion of certain introduced cultivars, e.g., creeping foxtail, and invasive species. A detailed vegetation inventory of all lands in the Cokeville Meadows acquisition boundary is needed as is careful monitoring to identify changes in species and potential key resources for animal species.

Restoration of native communities seems possible and is desirable for some areas on Cokeville Meadows NWR, including sites that have been converted from native habitats or are in more highly altered locations. Specific actions to assist this restoration include:

1. *Restore distribution of plant communities to appropriate sites based on HGM-predicted geomorphology, soil, topography, and hydrology features identified in Figure 17.*

- Sustain Riparian Forest corridors along the Bear River and larger tributaries including the Smith's Fork River on newly deposited/scoured coarse material surfaces. Attempts should be made to encourage and/or reintroduce willow and cottonwood in these sites, including protection of these river corridors from extensive grazing.

- Sustain diverse wetland plant assemblages in floodplain depressions and reduce robust emergent coverage by restoring more natural water regimes.

- Maintain the large meadow community in the Bear River floodplain and encourage conversion of areas that have been converted to introduced grasses or cropland to revert to more native species mixes.

- Sustain sagebrush-grassland communities on alluvial fans and terraces.

2. *Improve conditions to increase the distribution and historic composition of native Meadow habitats.*

- Restore certain meadow areas currently in alfalfa or grain production to native meadow species.

- Restore seasonal and annual dynamics of historic water regimes in meadow communities where possible.

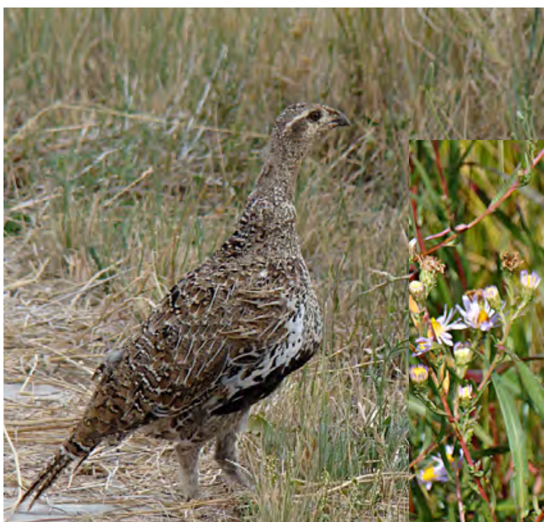
- Evaluate the extent of permittee haying and grazing in meadow areas on the refuge and possibly restore some areas to native species composition and more natural disturbance mechanisms by removing haying/grazing in some or all years and include fire and irregular herbivory/grazing.

3. *Reduce the area of more permanently flooded wetlands and robust emergent vegetation.*

- Reduce or modify impoundment structures in floodplain depressions.
- Remove levees, ditches, and water-control-structures from all higher elevations within floodplains, alluvial fans, and terraces where possible.
- Change water management in retained impoundments to more natural seasonal and long-term water regimes.

4. *Actively control invasive and noxious plant species.*

- Actively control invasive and noxious plant species using appropriate chemical, mechanical, and biological methods.



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MONITORING AND EVALUATION

Several important data sets (including soil and elevation maps, vegetation inventories, and surveys of animal population), used in the HGM evaluation for Cokeville Meadows were somewhat dated, incomplete, or measured at relatively large spatial scales. As these data become more contemporary and comprehensive, certain analyses and mapping developed in this study should be refined. Future management of Cokeville Meadows NWR should include regular monitoring and directed studies to determine how ecosystem structure and function are changing, regardless of whether restoration and management options identified in this report are undertaken. Ultimately, the success in restoring and sustaining communities and ecosystem functions/values at Cokeville Meadows NWR will depend on how well the physical and hydrological integrity of the Bear River Valley is protected and how key ecological processes and events, especially pulsed short duration spring flooding, can be restored or emulated by management actions. Uncertainty exists about the ability to make some system changes because of boundary, water rights and historical uses, and land uses in the larger Bear River watershed, especially upstream from the refuge. Also, techniques for controlling or reducing introduced plant species, such as creeping foxtail, are not entirely known.

Whatever future management actions occur on Cokeville Meadows NWR, activities should be done in an adaptive management framework where: 1) predictions about community response and water issues are made (e.g., reduced occurrence of robust emergent species and possibly creeping foxtail) relative to specific management actions (e.g., restoring long-term alternating drying vs. prolonged flooding in floodplain depressions) and then 2) follow-up monitoring is conducted to evaluate ecosystem responses to the action. Critical information and monitoring needs for Cokeville Meadows NWR are identified below:

KEY BASELINE ECOSYSTEM DATA

Important site- and regionally-specific data that are needed for the Cokeville Meadows region include:

- Detailed soils mapping and description, especially within the alluvial floodplain areas.
- More refined topographic information, preferably to < 1 foot accuracy.
- Comprehensive inventory and mapping of all vegetation, including invasive and noxious species.
- Comprehensive surveys of key animal species that represent major taxa, species of concern or management emphasis, and primary trophic levels.

RESTORING NATURAL WATER REGIMES AND WATER FLOW PATTERNS

This report suggests several physical and management changes to help restore some more natural topography, water flow, and flooding dynamics in floodplain habitats. Most changes involve restoring at least some more natural water flow through natural drainages and tributaries and across floodplain meadows in a sheetflow manner and to manage depressions and impounded sites for more seasonally- and annually-dynamic flooding and drying regimes.

The following monitoring will be important to understand effects of these changes if implemented:

- Annual monitoring of water use for refuge areas including source, delivery mechanism or infrastructure, extent and duration of flooding/drying, and relationships with non-refuge water and land uses. These data will also document how existing water rights are used and maintained.

- Documentation of how water moves across floodplain areas including interactions with non-refuge lands.

- Evaluation of surface and groundwater interactions and flow across and through alluvial fans and terraces onto floodplain areas and eventual discharge into the Bear River.

- Periodic monitoring of water quality in all drainage and floodplain areas.

LONG TERM CHANGES IN VEGETATION AND ANIMAL COMMUNITIES

As stated, comprehensive baseline data on historic, and even current, plant and animal communities for Cokeville Meadows NWR is sparse. In addition to determining current distribution and dynamics of species, long term survey/monitoring programs are needed to understand changes over time and in relation to management activities (e.g., USFWS 2007). Important survey/monitoring programs are needed for:

- Distribution and composition of major plant communities including expansion or contraction rates of introduced and invasive species.

- Survival, growth, and regeneration rates of willow and cottonwood in riparian forest corridors.

- Abundance, chronology of use, survival, and reproduction of key waterbird and neotropical migrant songbirds such as dabbling ducks, sandhill crane, American bittern, etc.

- Occurrence and abundance of ungulates.

- Occurrence and abundance of amphibians, reptiles, and fish.

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APPENDICES

A - C

Karen Kyle

APPENDIX A
North American Glacial Episodes and General Geologic Time Scale

Geologic Period	Geologic Epoch	Sub-Division	O Isotope Stage [2]	Years (BP)
	Holocene		(1)	0 to 10-12 ka*
		Late Wisconsin	(2)	10-12 to 28 ka
		Middle Wisconsin	(3, 4)	28 to 71 ka
	Late Pleistocene	Early Wisconsin	(5a - 5d)	71 to 115 ka
QUATERNARY		*Late Sangamon* Sangamon	(5e)	115 to128 ka
	Pleistocene	Late – Mid Pleistocene *(Illinoian)*	(6 - 8)	128 to 300 ka
	Middle Pleistocene	Middle – Mid Pleistocene	(9 - 15)	300 to 620 ka
		Early – Mid Pleistocene	(16 - 19)	620 to 770 ka
	Early Pleistocene			770 ka to 1.64 Ma**
TERTIARY	**Pliocene**			1.64 to 5.2 Ma
	Miocene			5.2 to 23.3 Ma
	Oligocene			23.3 to 35.4 Ma
	Eocene			35.4 to 56.5 Ma
	Paleocene			56.5 to 65.0 Ma
CRETACEOUS	*Late Cretaceous*			65.0 to 97.0 Ma
	Early Cretaceous			97.0 to 145.6 Ma
JURASSIC				145.6 to 208.8 Ma
TRIASSIC				208.8 to ≈ 243.0 Ma
PERMIAN				≈ 243.0 to 290.0 Ma
PENNSYLVANIAN				290.0 Ma to 322.8 Ma
MISSISSIPPIAN				322.8 to 362.5 Ma
DEVONIAN				362.5 to 408.5 Ma
SILURIAN				408.5 to 439.0 Ma
ORDIVICIAN				439.0 to 510.0 Ma
CAMBRIAN				510.0 to ≈ 570.0 Ma
PRECAMBRIAN				> ≈ 570.0 Ma

* ka = x 1,000; ** Ma = x 1,000,000

≈ = "approximately"

[1] Modified from Morrison, 1991; Sibrava, et al., 1986; and Harland, et al., 1990.

[2] Oxygen isotope.

APPENDIX B

Water Rights on Cokeville Meadows NWR

Former Owner	Tract	Right No.	Priority	Source	Name	Use	(cfs)	(gpm)
Richard Cornia	15,a	permit 12453	6/1/14	Antelope Creek	Ellen Reservoir	i	1.22	
Richard Cornia	15,a	permit 98366	9/7/93	Groundwater	Beckwith #1	i		
Richard Cornia	15,a	permit 113469	12/17/98	Groundwater	Beckwith #1 Enl	i	0	0
Richard Cornia	15,a	U.W. 15161	8/14/72	Groundwater	Corina Well #1	s,c		25
Richard Cornia	15,a	U.W. 42138	4/8/77	Groundwater	Corina Well #3	i		
Richard Cornia	15,a	permit 113469	12/17/98	Groundwater	Beckwith #1 Enl	i		
Richard Cornia	15,a	permit 9120	6/9/09	Smith's Fork	Covey Canal	l,d		
Richard Cornia	15,a	permit 9120	6/9/09	Smith's Fork	Covey Canal	i	0.29	
Richard Cornia	15,a	permit 9120	6/9/09	Smith's Fork	Covey Canal	i	0.69	
Leo Cornia	41,a	U.W. 15162	8/14/72	Groundwater	Corina Well #2	i		
Leo Cornia	41,a	permit 295E	5/31/1897	Smith's Fork	Mau Canal Enl	s,d	7.34	
Leo Cornia	41,a	permit 9120	6/9/09	Smith's Fork	Covey Canal	l,d	2.2	
Buckley	20a,30		4/18/25	Antelope Creek	Tanner Supply Ditch	i	0.38	
Buckley	20a,30	U.W. 74218	11/9/84	Groundwater	Buckley Well #4 Enl	i		
Buckley	20a,30	U.W. 59625	7/1/82	Groundwater	Buckley Well #3	d,s		25
Buckley	20a,30	U.W. 60689	2/8/82	Groundwater	Buckley Well #4	i		
Buckley	20a,30	permit 9120 proof 23297	6/9/09	Smith's Fork	Covey Canal	i	0.1	
Buckley	20a,30	permit 9120 proof 23412	6/9/09	Smith's Fork	Covey Canal	i	0.88	
Buckley	20a,30	permit 9120	6/9/09	Smith's Fork	Covey Canal	i	0.75	
Buckley	20a,30	permit 9120 proof 20756	6/9/09	Smith's Fork	Covey Canal	i	4.81	
Buckley	20a,30	permit 9120 proof 15155	6/9/09	Smith's Fork	Covey Canal	i	1.14	
Thornock	19,a-c	terr 8617	5/31/1878	Bear River	BQ-Dam East Ditch	i	8.93	
Thornock	19,a-c	terr 8619	12/31/1879	Bear River	Pixley Dam	i	2.3	
Thornock	19,a-c	terr 8621	12/31/1880	Bear River	Pixley Irrigation Ditch	i	0.43	
Thornock	19,a-c	terr 8634	12/31/1881	Bear River	Pixley Irrigation Ditch	i	2.37	
Thornock	19,a-c	USA does not hold water right but uses shares managed by water-right owner	5/31/1878	Beckwith Quinn Canal Co	BQ-Dam East			
Thornock	19,a-c	USA does not hold water right but uses shares managed by water-right owner	5/31/1878	Beckwith Quinn Canal Co	BQ-Dam East			
Thornock	19,a-c	U.W. 275	7/27/59	Groundwater	Thornock Bros #1	i		
Thornock	19,a-c	U.W. 57459	4/14/81	Groundwater	Thornock Well #3	l,s		
Thornock	19,a-c	U.W. 73966	6/9/82	Groundwater	Thornock Well #3 Enl			
Thornock	19,a-c	permit 3264, Proof 8722	6/12/01	McFarland Ditch	Ditch	i	1.14	
Thornock	19,a-c	terr 8833	12/31/1881	Spring Creek	North Lake Ditch	i	0.29	
Thornock	19,a-c	permit 9120 Proof 16241	6/9/09	Smith's Fork	Covey Canal	i	5.49	
Thornock	19,a-c	permit 9120 Proof 23412	6/9/09	Smith's Fork	Covey Canal	i	0.08	
Thornock	19,a-c	terr 8918	12/18/08	Sucker Springs		s,d		
Bartlett	44a	terr	5/31/1878	Bear River	BQ Dam East Ditch	i	0.68	
Bartlett	44a	terr	12/31/1881	Bear River	Pixley Ditch	i	0.29	
Bartlett	44a	U.W. 41237	7/20/77	Groundwater	Bartek #1 Well	i		
Bartlett	44a	permit 9120	6/9/09	Smith's Fork	Covey Canal	l,d	4.97	
Etcheverry Sheep Co.		permit 1761E	8/3/07	Bear River	Pixley Ditch Enl	i	0.08	
Etcheverry Sheep Co.		terr	12/31/1880	Bear River	Pixley Irrigation Ditch	i	2.35	
Etcheverry Sheep Co.		terr	12/31/1881	Bear River	Pixley Irrigation Ditch	i	0.58	
Etcheverry Sheep Co.		terr	12/31/1880	Bear River	Pixley Irrigation Ditch	i	11	
Etcheverry Sheep Co.		U.W. 308	7/24/59	Groundwater	Etcheverry Well #1	i		
Etcheverry Sheep Co.		permit 295E	5/31/1887	Smith's Fork	Mau Canal Enl	s,d		
Etcheverry Sheep Co.		USA does not hold water right but uses shares managed by water-right owner		Woodruff Narrows Reservoir	Woodruff Narrows Ditch			
Dimond	10,a	permit 2066E	3/8/09	Pine Creek	Mau Canal Enl	i		
Dimond	10,a	permit 9120	6/9/09	Smith's Fork	Covey Canal	l,d		
Dimond	10,a	permit 2065E	3/6/09	Smith's Fork	Mau Canal Enl	l,d		

APPENDIX C

Documentation of construction projects on Cokeville Meadows NWR 2003-2009.

Cokeville Meadows National Wildlife Refuge
Improvements by Year
K. Kirk
9/15/09

Etcheverry Project (2003,04,05)

The first improvements to the Refuge occurred on the Etcheverry Tract(13). During these three years work was done to improve the irrigation system and make dikes more accessible to Refuge staff. 3.5 miles of existing dike was improved and 28 board-stop structures were installed to more efficiently move water out of the Pixley ditch and to move water through a cross dike that divides the unit. A structure was added to let water flow back out to the river in high water years to avoid overtopping the dike that divides the unit. Two crossings were replaced and one crossing was added to better aid travel throughout the unit for Refuge employees and to try to discourage cattle from walking through the ditch.

Thornock and South Bartlett Project (2005,06,07)

The Thornock(19) and South Bartlett(44a) tract improvements began in 2005. Over the next 3 years a little over 2 miles of existing dike was improved within the two units and 17 board-stop structures were added or replaced to better irrigate the lands and create seasonal wetlands for migrating and nesting waterfowl, waterbirds, and shorebirds.

APPENDIX C
Continued

Thornock Pivot (2006)

The Refuge was able to replace a center pivot irrigation system that was purchased with the land sale of tract 19. It is placed on a 1200 gpm ground water well. This land is currently used to grow alfalfa. Irrigation starts in late May to early June and lasts until late August.

North Cornia or Netherly Slough Pullout (2006 - 2008)

A visitor contact area was added in 2006 on the North Cornia tract (41). An informational kiosk and large parking lot were constructed as well as a small paved walking trail and benches overlooking the slough.

In 2008 improvements were done to the dike along the south side of the Mau Canal as it runs through tract 41 and board-stop structures were added to let water flow through the wetland unit. Two structures were also added to the north side of the Mau Canal for private use. The length of the ditch/levee that was improved is approxametly 1/3 of a mile. Two 15 inch structures were added to fill and drain the wetland. Two 46 inch crossings where added in the ditch and two 24 inch structures were added to irrigate the private land to the north. These improvements greatly increased the visibility of wildlife for the contact station.

APPENDIX C
Continued

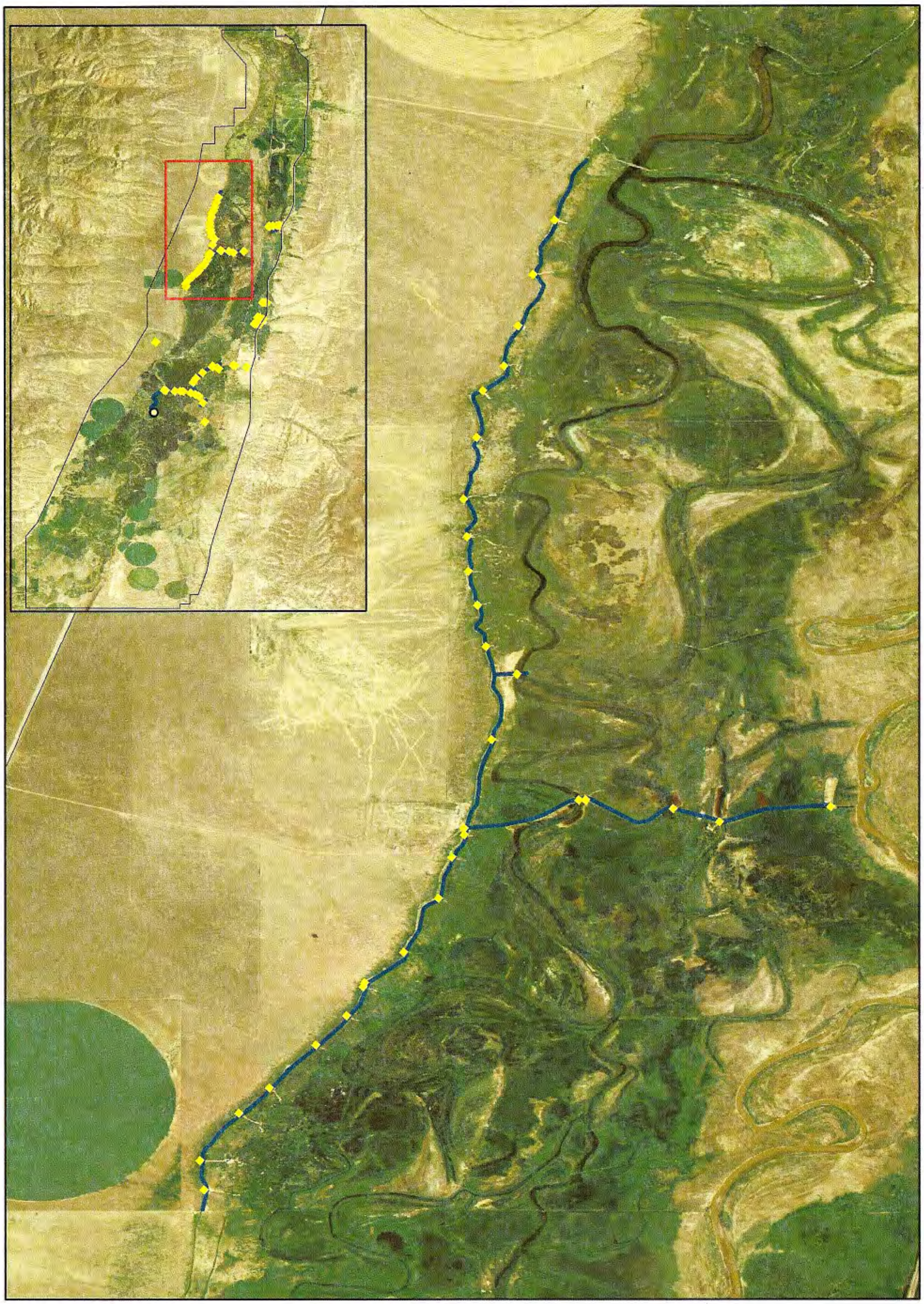
Thornock Project Continued 2009

This year the Refuge improved ¾ of a mile of the Beckwith and Quinn (BQ) dike that runs along the Bear River on the Thornock tract (19). The new dike has a 12 foot width at the top and no structures were added to it. Adjacent to the south end of the work on the Refuge an additional dike that runs to the east was connected. Two 36 inch structures and one open pipe (crossing) was added to that dike to help back water up onto private land before it flows onto the Refuge. Plans to continue working south on private land are slated for 2010.

Karen Kyle

APPENDIX C
Continued

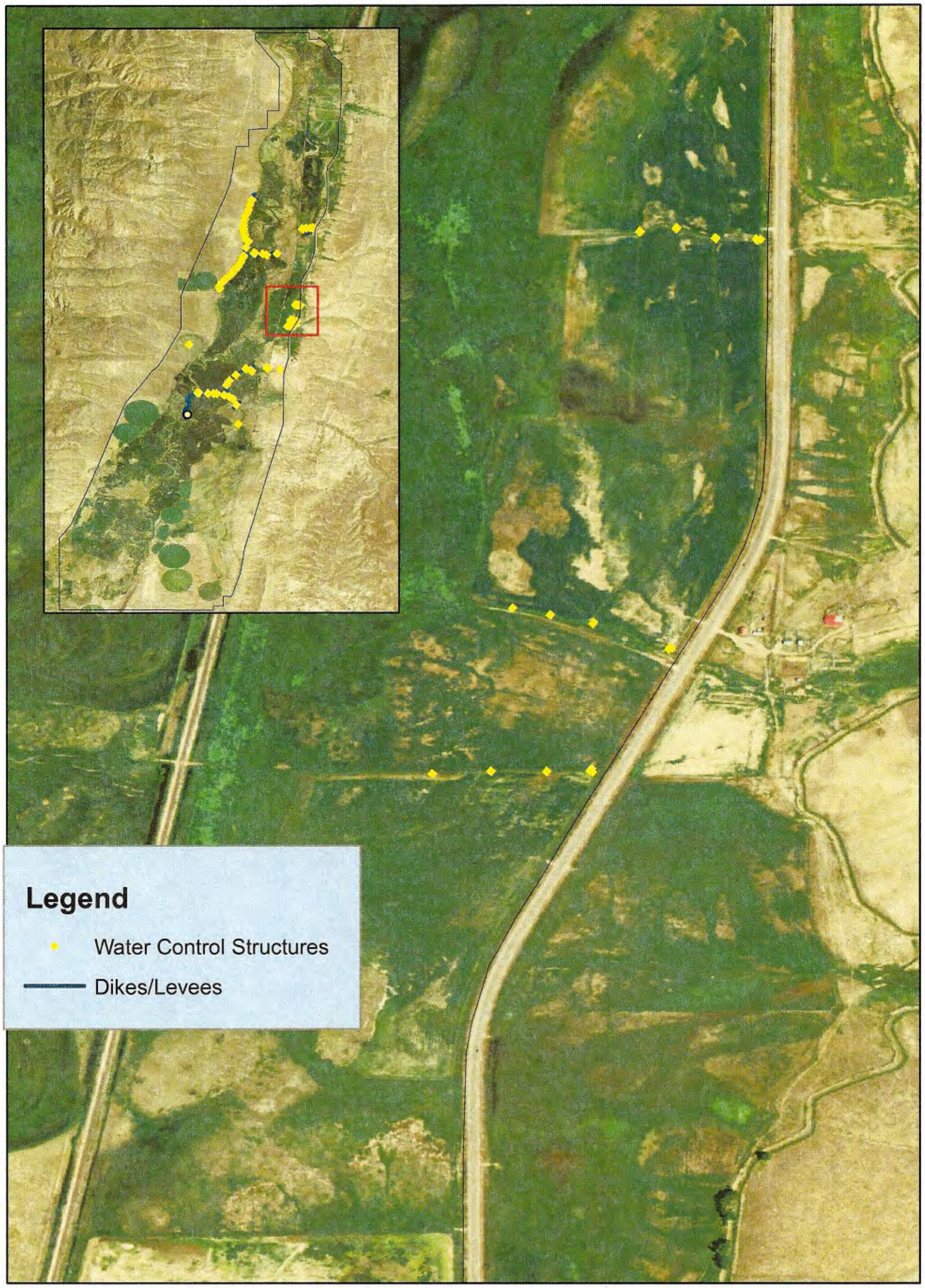
Cokeville Meadows Improvements Etcheverry Tract 2003, 2004, 2005



APPENDIX C

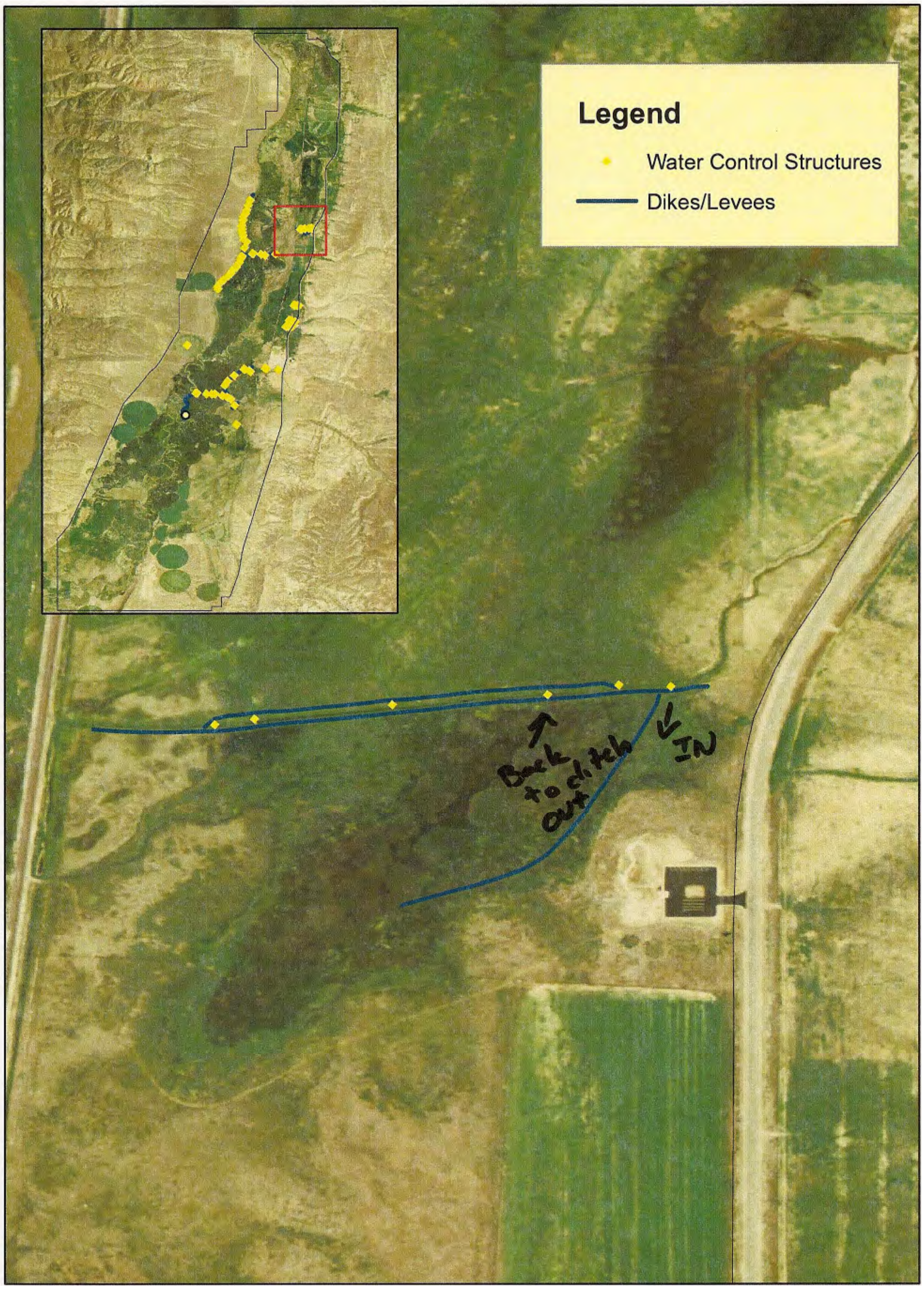
Continued

Cokeville Meadows Improvements Bartlett Tract
Installed structures on existing ditches 2009



APPENDIX C
Continued

Cokeville Meadows Improvements North Cornia Tract Parking lot and Trail 2006, Wetland and Ditch Creation/Restoration 2008



APPENDIX C
Continued

Cokeville Meadows Improvements Thornock & S. Bartlett
2005, 2006, 2007 and 2009