Rainwater Basin Joint Venture Waterfowl Plan

A regional contribution to the

North American Waterfowl Management Plan

and the

Rainwater Basin Joint Venture Implementation Plan

By the Rainwater Basin Joint Venture

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Executive Summary

The Rainwater Basin Joint Venture partnership (RWBJV) was formed in 1992. The initial focus of the RWBJV was the Rainwater Basin wetland complex (RWB). This complex contains a high density of playa wetlands and is the focal point of spring migration for waterfowl in the Central Flyway. Thus, conservation actions during the initial years were focused on protecting, restoring, and enhancing wetlands to support migrating waterfowl. The RWBJV Management Board embraced the 1999 North American Bird Conservation Initiative and expanded the partnership's geographic and conservation focus. The expanded RWBJV Administrative Area included the portions of Bird Conservation Regions 11 (Prairie Pothole Region) and 19 (Central Mixed-grass Prairies) that lie within Nebraska.

To help guide waterfowl conservation, the RWBJV has developed benchmarks for the breeding and non-breeding (migration) phases of the annual life cycle. The RWBJV developed a bioenergetics model for the non-breeding period that incorporates the foraging needs of waterfowl using the RWB during spring migration. This model incorporates species-specific use estimates, residency time, basal metabolic rates, and forage selection to estimate the foraging resources needed by waterfowl during this period.

Based on an energetics approach, the RWBJV has estimated that the RWB will need to provide 4.4 billion kcals of wetland-derived foraging resources. It is estimated that this will require approximately 62,500 acres of functioning wetland habitat. Four strategies were developed to make these goals attainable within the RWB. Goals and strategies were outlined for public lands, private lands enrolled in long-term conservation programs, private lands in short-term conservation agreements, and non-program wetland acres.

The public lands strategy has a goal to acquire 7,990 additional wetlands acres. Acquisition will be voluntary and focused on "roundouts", or the privately owned portions of wetlands currently in split (public and private) ownership. At goal, public lands will provide approximately 55% of the foraging resources. For the private lands in long-term conservation programs, the goal is to enroll an additional 9,200 wetland acres over the next 20 years. At goal, these long-term conservation program lands will provide 25% of the foraging resources needed by spring-migrating waterfowl. The short-term conservation program goal outlines enrolling 7,250 acres under revolving 10-year agreements and would provide 10% of the foraging resources. Finally, the non-program lands will contribute approximately 10% of foraging resources. In addition to acreage goals, watershed and vegetation composition benchmarks were also outlined. When these strategies are implemented, the RWB should be able to provide sufficient habitat to support waterfowl during spring migration.

The RWBJV Administrative Area supports several hundred thousand breeding waterfowl, primarily in Nebraska's Sandhills. The partners are continuing to initiate and conduct research and monitoring projects to understand what specific areas within this expansive landscape are most important to breeding waterfowl. Initial focus will be on those regions with a high density of wetlands in this grassland system. Future implementation will focus on conservation projects that provide preferred habitat for breeding waterfowl and are economically viable and compatible with cattle production, the major agriculture practice in the Sandhills.

Research and monitoring activities will help the RWBJV refine conservation benchmarks. The

primary focus in the RWB will be on monitoring the impacts of management to promote desired vegetation communities, evaluating the foraging resources available from different vegetation communities under different management and ownership, and developing a survey protocol to refine waterfowl use estimates. In the Sandhills, the RWBJV will initiate or assist in the development of surveys or research projects that can be used to determine settling patterns of breeding waterfowl and determine limiting factors of waterfowl recruitment. These assessments will assist the RWBJV in understanding which landscapes (wetlands and grasslands) are the most important for breeding waterfowl and will help guide future conservation activities.

Introduction

The development of this waterfowl habitat conservation plan for the Rainwater Basin Joint Venture partnership (hereinafter, RWBJV) was completed to complement the actions taken at the national and international level. The North American Waterfowl Management Plan ([NAWMP] U.S. Fish and Wildlife Service and Canadian Wildlife Service 1986) was drafted in response to the decline in continental breeding duck populations. Between 1970 and 1985, the average annual population dropped for almost all species. Three species showing the most significant declines were Northern Pintail (>50%), Mallard (37%) and Blue-winged Teal (29%).

NAWMP became the framework to guide conservation of waterfowl habitats across North America. It promoted a change in conservation actions through the establishment of joint ventures. The joint ventures were collaborative partnerships of non-governmental organizations, public agencies and individuals. The initial role of joint ventures was to guide waterfowl conservation in areas of prominent waterfowl habitat. Over time, joint ventures have expanded their focus to promote conservation of avian species described in the four national bird conservation initiatives, although waterfowl remain a priority for most joint ventures.

Since 1986, NAWMP has been revised to provide better population targets, identify priority landscapes, and describe overarching habitat requirements to support waterfowl populations at target levels. Within Nebraska, three areas of major concern were identified in the most recent update to NAWMP: the Rainwater Basin Wetland Complex (RWB), Central Platte River, and Sandhills (NAWMP 2012). The Central Platte River was added as a priority area as part of this recent revision.

NAWMP encouraged joint ventures to develop waterfowl plans that, when implemented, would support their portion of the national population objectives. This waterfowl plan was completed to complement actions taken at the national and international level and to provide direction, guidance, and strategies as to how the RWBJV would contribute to meeting national population objectives.

In 1992, the RWBJV was formed. Its initial focus was on waterfowl habitat within the RWB. In 2001, in response to a national call for joint ventures to extend conservation work to all species of birds, the RWBJV partnership began to take steps to expand its administrative boundary and mission to include the portions of Bird Conservation Regions 11 and 19 that lie within Nebraska.

Although the administrative boundary has expanded, the name of the RWBJV remains the same. The need to retain the name outweighs the confusion it may pose to those unfamiliar with the organization or the geography of Nebraska. Within this document, “RWBJV” is used to reference the partnership, “RWBJV Administrative Area” describes the geographic area administered by the partnership (Figure 1), and the 21-county area that was the impetus for the creation of the RWBJV is designated as the “RWB” (Figure 1). Every attempt will be made to make it clear to the reader which form is being addressed.

The RWBJV Administrative Area

Approximately 90% of the RWBJV Administrative Area is in Bird Conservation Region 19 (BCR19), the Central Mixed-grass Prairies Region, while 10% is in BCR 11, the Prairie Pothole Region, (North American Bird Conservation Initiative 1999). The area of BCR 11 that is administered by the RWBJV is at the southern edge of the Prairie Pothole Region. This area has no true prairie pothole wetlands, and the landscape is dominated by land uses and habitats characteristic of BCR 19. In Nebraska, BCR 11 is dominated by row-crop agriculture, while the wetlands and grasslands generally are confined to the drainages of the Missouri and Niobrara rivers (Bishop et al. 2009, Bishop et al. 2011). To define the RWBJV Administrative Area, all of BCRs 11 and 19 in Nebraska were therefore combined into a single unit.

The RWBJV Administrative Area is part of the Great Plains, a region known for its wide variations in temperature and precipitation. West of the 100th meridian, evaporation and transpiration exceed precipitation, commonly drying up wetlands even in wetter years. Precipitation occurs sporadically, which results in variable amounts of water in wetland systems. In some years, precipitation and snow melt may come early and be abundant enough to fill most palustrine wetlands and sustain flows in riverine wetlands. In other years, the greatest precipitation occurs as a result of summer thunderstorms. This temporal variation of precipitation alters the phenology, species composition, and structure of the wetland vegetation communities.

A wide variety of human alterations that impact the palustrine and riverine wetlands are found in the RWBJV Administrative Area. Modifications include water concentration pits, land leveling, culturally accelerated sedimentation, road ditches, drainage ditches, invasive species, stream channelization and degradation, dams, diversions, water withdrawals, and other watershed modifications. These modifications directly impact wetland numbers, size, and function (LaGrange 2005; LaGrange et al. 2011).

Grasslands dominated by mixed-grass, tallgrass, and sandhill prairie communities once occupied a majority of the RWBJV Administrative Area. Outside of the Sandhills, many of these grasslands have been converted to row-crop agriculture. The grasslands that remain today are generally associated with the region’s riverine systems or lands not suitable for row-crop agriculture due to the potential for wind and/or water erosion. The remaining grasslands are often integrated into agricultural operations for grazing or haying, which, depending on timing and intensity, can significantly impact the habitat values these lands provide to wildlife.

Woodlands are generally confined to the drainages of the major river systems found in the RWBJV Administrative Area. Along the Loup, Missouri, Platte, and Republican rivers, the woodlands are generally composed of deciduous species. Russian olive and eastern red cedar are the primary invasive species impacting these woodlands. Along the Niobrara River there is a greater diversity of species, including both deciduous and coniferous woodlands. Invasion by eastern red cedar is a major threat to these communities as well.

Geographic Focus Areas in the RWBJV Administrative Area

For planning purposes the RWBJV Administrative Area is divided, based on landscape characteristics, into eight Geographic Focus Areas (Figure 1): 1) Central Loess Hills, 2) Central and North Platte River, 3) Missouri River, 4) Northeast Prairies/Elkhorn River, 5) Rainwater

Basin 6) Republican River/Blue River Drainages and Loess Canyons, 7) Sandhills, and 8) Verdigris – Bazile Creek Drainages (Figure 1).

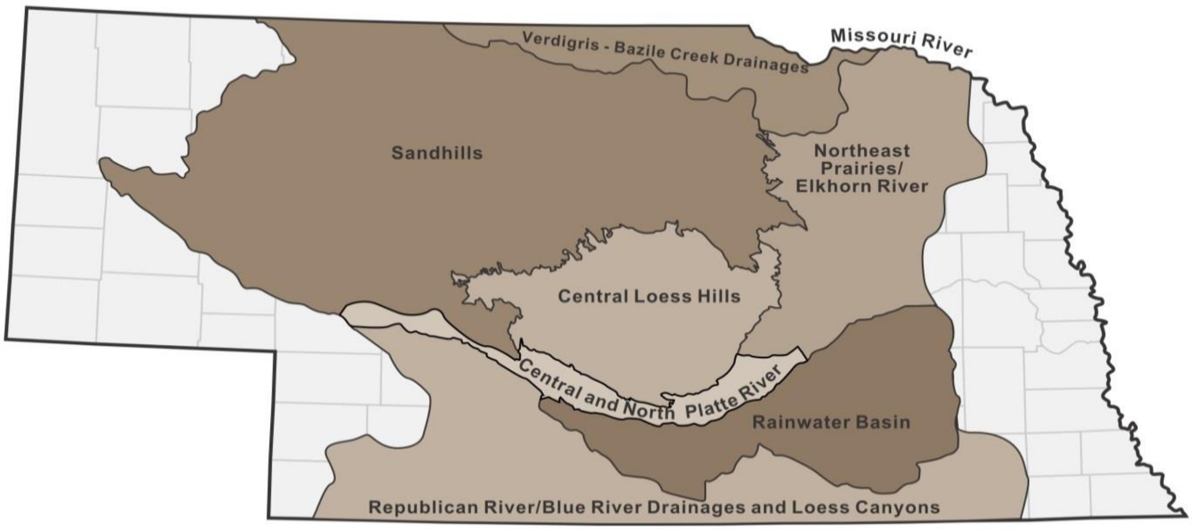

Figure 1. Geographic Focus Areas in the RWBJV Administrative Area.

In order for states to receive federal funds through the Wildlife Conservation and Restoration Program and the State Wildlife Grants Program, Congress charged each state to develop a State Wildlife Action Plan. Nebraska's plan is the *Nebraska Natural Legacy Project* (Schneider et al. 2011), which was developed as a state-wide plan to direct and focus the actions of conservation partners in Nebraska. To provide geographic focus, biologically unique landscapes (BULs) were identified, including 23 located within the RWBJV Administrative Area. These geographic areas were determined to have the highest probability of meeting the criteria of representing the various habitats within the state, and keeping common species common, while not overlooking pockets of habitat that support at-risk species. The 23 BULs in the RWBJV Administrative Area are:

Calamus River	Elkhorn Confluence	Middle Niobrara	Sandstone Prairies
Central Loess Hills	Keya Paha	North Loup River	Snake River
Central Platte River	Loess Canyons	Panhandle Prairies	Southeast Prairies
Cherry County Wetlands	Lower Loup River	Platte Confluence	Verdigris-Bazile
Dismal River Headwaters	Lower Niobrara River	Rainwater Basin	
Elkhorn River Headwaters	Middle Loup River	Sandhills Alkaline Lakes	

The RWBJV Administrative Area encompasses approximately 35 million acres and contains over 2.3 million acres of wetland habitats and over 20 million acres of grasslands (Table 1). Wetlands comprise nearly 7% of the RWBJV Administrative Area, while grasslands cover approximately 60% of the landscape (Table 1). Each Geographic Focus Area contains a variety of wetland, grassland, and woodland habitats. Over half of the wetlands found within the RWBJV Administrative Area are located in the Sandhills, with a majority of these acres being classified as sub-irrigated wet meadows (palustrine wetlands). The RWB Geographic Focus Area contains the highest density of playa wetlands (palustrine wetlands), followed by the

Central Loess Hills (Central Table Playa Complex), Northeast Prairies/Elkhorn River (Todd Valley Wetland Complex), and Republican River/Blue River Drainages and Loess Canyons (Southwest Playa Wetland Complex). The Republican River/Blue River Drainages and Loess Canyons GFA contains the most human-made wetland features (reservoirs, stock dams, and irrigation reuse pits (Table 1). Outside of the Sandhills, grasslands are generally confined to the floodplains of the major river systems or on environmentally sensitive lands. The primary Geographic Focus Areas with significant grasslands are the Central Loess Hills, Northeast Prairies/Elkhorn River, Republican River/Blue River Drainages and Loess Canyons, Sandhills, and Verdigris - Bazile Creek Drainages. (Table 1).

Table 1. Wetland and grassland acres and their distribution by Geographic Focus Area (Bishop et al. 2011).

Geographic Focus Area	Geographic Focus Area (Acres)	Total Wetland (Acres)	Lakes & Reservoirs (Acres)	Palustrine Wetlands (Acres)	Riverine Wetlands (Acres)	Lacustrine Wetlands (Acres)	Grassland (Acres)
Central Loess Hills	3,598,453	169,185	20,504	12,473	136,209	0	2,166,456
Central and North Platte River	1,035,879	107,514	6,597	1,590	99,327	0	160,448
Missouri River	77,852	40,858	12,309	7,714	20,835	0	6,279
Northeast Prairies/ Elkhorn River	4,792,660	339,339	19,676	16,774	302,889	0	1,320,359
Rainwater Basin	3,830,130	120,852	25,703	44,198	50,950	0	677,965
Republican River/Blue River Drainages and Loess Canyons	5,826,800	226,427	60,937	5,437	160,054	0	3,140,230
Sandhills	13,587,519	1,253,724	25,719	1,120,700	22,331	84,974	11,535,386
Verdigris – Bazile Creek Drainages	2,004,581	91,833	7,766	4,770	79,297	0	1,383,183
Total	**34,753,873**	**2,349,733**	**179,212**	**1,213,656**	**871,891**	**84,974**	**20,390,306**

Central Loess Hills

The Central Loess Hills Geographic Focus Area, located in the center of the RWBJV Administrative Area, contains rolling to steep loess hills dissected by the valleys of the Loup rivers. Ridge tops (tables) are nearly level to gently sloping and covered with loess soils. Scattered across these table lands are numerous playa wetlands referred to as the Central Table

Playas (LaGrange 2005). Based on hydric soil mapping units (polygons) and depressional wetland points defined in the Soil Survey Geographic Database (SSURGO), as well as the palustrine wetlands delineated in the National Wetlands Inventory (NWI; Cowardin et al. 1979), it is estimated that there were once over 6,300 playas covering more than 18,000 acres. Based on an assessment of aerial photography completed in 2010, just over half of the playas (3,470 individual wetland footprints) continue to demonstrate some level of function, such as ponding water or growing hydric vegetation (Bishop et al. 2011). These playa wetlands are generally smaller than the playas found in the RWB and are characterized by seasonal and temporary water regimes.

The steep, erodible side slopes of the Central Loess Hills drop off into the broad floodplains of the Loup rivers. The Central Loess Hills GFA contains the lower reaches of the Middle Loup, North Loup, and South Loup rivers, all of which are spring-fed and originate in the Sandhills. These broad and shallow sand-bed rivers maintain relatively constant year-round stream flow. Sandbars and shallow side channels are typical features within and adjacent to the active river channels.

Based on a 2011 habitat assessment, the Central Loess Hills GFA contains approximately 12,500 acres of palustrine wetlands, 136,000 acres of wet meadows and other riverine wetlands, and approximately 2.2 million acres of grasslands (Table 1). The playa wetlands found in this GFA provide important migration stopover habitat for the endangered Whooping Crane (Austin and Richert 2001), as well as numerous other species of migratory waterbirds (e.g., waterfowl, shorebirds, and wading birds). The riverine wetlands associated with the Loup rivers provide breeding habitat for the threatened Northern Great Plains population of Piping Plovers and endangered Interior population of Least Terns. The wet meadows and associated grasslands found in the Central Loess Hills currently support an estimated 875,000 grassland nesting birds (RWBJV 2013*a*).

Row-crop agriculture and ranching are dominant land uses in the Central Loess Hills. Row-crop agriculture is generally confined to the river valleys and areas of limited topographic relief. Crops generally include alfalfa, corn, milo, soybeans, and wheat. Most of the steep, more erodible slopes remain as native grasslands dominated by mixed-grass prairie communities. Higher commodity prices and the guaranteed income provided by the Federal Crop Insurance Program have contributed to the conversion of environmentally sensitive grasslands and wetlands to row-crop agriculture. This conversion has reduced the quantity and distribution of grassland, wetland, and wet-meadow habitats found throughout the Central Loess Hills. The encroachment of undesirable plant species (i.e., eastern red cedar, Russian olive, smooth brome, etc.) has occurred on thousands of acres of native habitats. Fire suppression is believed to be a major factor that has contributed to the expansion of invasive species throughout this GFA.

Central and North Platte River

The Central Platte River is a 90-mile segment of the Platte River, extending from Lexington, Nebraska to Chapman, Nebraska. Historically, the Platte River was a wide, shallow river with multiple channels that meandered across an expansive floodplain. Large, scouring floods regularly set back vegetation succession and maintained a diversity of habitats across the floodplain. Following European settlement, the Platte River was extensively regulated, and the flood pulses and river flows that once shaped the ecosystem were greatly reduced. As a result, the areas of active floodplain and associated wet meadows were reduced, the river channels narrowed and deepened, and extensive riparian forests became established on islands and along river banks. For example, a comparison of average annual discharge levels at the city of North Platte, Nebraska, before1930 and after 1930, shows a 70% reduction in river flows (U.S. Fish and Wildlife Service 1981). At the same monitoring location, the channel width narrowed from nearly 2,950 ft. to less than 330 ft. between 1870 and 1970. Similarly, the average channel width near Overton, Nebraska, declined from 4,800 ft. in 1865 to 740 ft. in 1998 (Murphy et al. 2004). Sidle et al. (1989) reported that 60% to 80% of the open riverine/sandbar habitat and 55% of wet meadow habitat had been lost in this reach of the Platte River due to agricultural conversion, development, and hydrologic changes.

Despite the highly altered nature of this system, the combination of broad, braided river channels, adjacent wet meadows, and abundant food supplies continues to attract millions of wetland-dependent migratory birds each year. The 60,000 acres of palustrine and riverine wetlands and over 140,000 acres of grassland that occur along the Central Platte River (Table 1) continue to provide necessary roosting, loafing, and foraging habitat for millions of migratory birds. These habitats are used by the endangered Whooping Crane (USFWS 1978) and approximately 90% of the world's Sandhill Crane population, and provide migration and wintering habitat for millions of waterfowl, migration habitat for a myriad of waterbirds, and non-breeding habitat for numerous shorebirds. In addition, the Central Platte River provides breeding habitat for the threatened Northern Great Plains population of Piping Plovers and the endangered Interior Least Tern, and for an estimated 160,000 priority grassland nesting birds (Rainwater Basin Joint Venture 2013*a*).

Today, the Central Platte River Valley is intensely cultivated. Based on the 2009 United States Department of Agriculture (USDA) Cropland Data Layer, over 60% of the historic floodplain is planted to corn, soybeans, or alfalfa (USDA 2009). In 2004, due to the diversion of water for irrigation, much of the Platte River was declared over-appropriated by the Nebraska Department of Natural Resources (DNR). This designation required new groundwater and surface water depletions to be offset, with the intent of managing the system in a sustainable manner. Although cropland conversion has slowed, gravel mining and residential and commercial development continue to result in the loss of riverine and wet-meadow habitats. Invasive plant species also continue to degrade in-channel habitats and adjacent wet meadows. Primary threats include: eastern red cedar, Kentucky bluegrass, *Phragmites*, purple loosestrife, reed canary grass, and smooth brome.

The North Platte River is one of the two tributaries that form the Platte River. The North Platte River originates in Colorado and flows through Wyoming before entering Nebraska. The stretch of the North Platte River within the Central and North Platte River GFA is located approximately 60 miles upstream from the river stretch designated as the Central Platte River. This stretch of river has a high density of palustrine and riverine wetland habitats, including approximately 36,000 acres of wet meadows and 16,000 acres of grasslands dominated by mixed-grass prairie species (Bishop et al. 2011).

The wetland and grassland habitats in this 80-mile stretch of river from Lewellen, Nebraska to North Platte, Nebraska have also been negatively impacted by the extensive regulation of North Platte River flows since European settlement. It is estimated that 25% of the historic wet meadows have been converted to row-crop agriculture (LaGrange 2005). The altered flow regimes have resulted in an increase of scrub-shrub and forested wetlands at the expense of riverine and emergent wetlands (LaGrange 2005).

Despite the negative impacts of land-use conversion and altered flow regimes, this stretch of river contains a diverse mix of riverine and marsh-like wetlands within the historic floodplain and river channel. Approximately 80% of the wetlands are either temporary or seasonal in nature (LaGrange 2005). This area is extremely important to the portion of the mid-continent population of Sandhill Cranes (approximately 56,000 individuals) that do not stage in the Central Platte River valley (Krapu et al. 2011).

Although the conversion of grasslands and wet meadows to row-crop agriculture has slowed as a result of the moratorium on new irrigated acres, these habitats continue to be converted for gravel mining operations and urban/suburban/commercial development. Wet meadows and grasslands in the North Platte River valley are also being invaded by eastern red cedar, Kentucky bluegrass, *Phragmites*, purple loosestrife, reed canary grass, Russian olive, and smooth brome.

Missouri River

The Missouri River Geographic Focus Area forms the northeast boundary of the RWBJV Administrative Area. This 125-mile stretch of river, between Ponca, Nebraska and Spencer Nebraska, is the southernmost unchannelized portion of the Missouri River. Because this portion of the river remains unchannelized, the active channel and associated floodplain contain a myriad of riverine and palustrine wetlands.

Prior to the 1930s, the Missouri was an unmanaged, natural river that supported a tremendous number and diversity of fish and wildlife. The river occupied a sandy channel and flowed between erodible banks, from 1,500 feet to over one mile apart, with braided, sinuous channels twisting among sheltered backwaters, sloughs, chutes, oxbows, gravel bars, sandbars, mudflats, snags, alluvial islands, deep pools, marshland, and shallow-water areas (U.S. Fish and Wildlife Service 1980). The character of the Missouri was drastically altered between 1930 and 1970 as channelization and main-stem dams narrowed and deepened the river channel, and associated floodplain wetlands disappeared. The six main-stem dams in the Dakotas, Montana, and Nebraska have changed water quality, quantity, and timing throughout the Missouri River system (LaGrange 2005). The controlled release of water from the upstream dams has reduced the flood pulse that was a key factor in maintaining the in-channel habitat and adjacent floodplain wetlands. Although the stretch of river within the Geographic Focus Area is not channelized, it is still negatively impacted by the upstream dams. Reduced sediment loads negatively influence channel morphology, while controlled releases from upstream dams reduce scouring and in-channel habitat maintenance (LaGrange 2005). Many of the off-channel wetlands historically associated with this system have been altered to increase row-crop agriculture. Today 18,000 acres, or 25% of the landscape, are under row-crop agriculture production (USDA 2009).

Based on a 2011 habitat assessment, the Missouri River GFA contains approximately 28,500 acres of palustrine and riverine wetlands, and just over 6,000 acres of grassland (Table 1). Despite the numerous alterations to the system, these wetlands still provide vital stopover habitat for numerous migratory waterfowl and shorebirds, as well as breeding habitat for the threatened Northern Great Plains population of Piping Plovers and the endangered Interior Least Tern.

The greatest threat to the unchannelized portion of the Missouri River is riverbed degradation (LaGrange 2005). Other key threats include residential/agricultural/commercial development, transportation, water pollution, water development projects, stream bank stabilization, drainage, and filling (LaGrange 2005). Projects associated with each of these threats have both direct and indirect impacts that cumulatively impair river functions by isolating the floodplain from the river and reducing the natural dynamics. Invasive vegetation also threatens habitat for migrating waterfowl, shorebirds, and other wetland-dependent species. Purple loosestrife and *Phragmites* have become established throughout this stretch of the Missouri River, including the confluence of the Niobrara River. Expansion of these species into the backwaters of Lewis and Clark Lake and the Niobrara and Missouri rivers is a threat to native plants and habitat.

Northeast Prairies/Elkhorn River

The Northeast Prairies/Elkhorn River Geographic Focus Area is located in the northeastern portion of the RWBJV Administrative Area. The GFA is intensely farmed and has a higher human population density than other geographic focus areas in the RWBJV Administrative Area, creating a fragmented landscape. At one time, the uplands were dominated by grasslands with a diverse assemblage of tallgrass and mixed-grass prairie species (Schneider et al. 2011). Some localized regions in this GFA contained a high density of playa wetlands. The playa wetland complex associated with this GFA is described as the Todd Valley Playa Wetland Complex (LaGrange 2005).

Today the mesic floodplains and steeper drainages associated with the Elkhorn River contain savannahs, woodlands, and densely forested habitats. Remnant tallgrass prairies are scattered across this region. The remaining playa wetlands contain a diverse mix of early successional wetland vegetation communities.

Despite the intensive row-crop and agricultural/urban/suburban development, this Geographic Focus Area contains significant grassland and wetland acres. Approximately 320,000 acres of palustrine and riverine wetlands and over 1.3 million acres of grassland occur throughout the Northeast Prairies/Elkhorn River GFA (Table 1). This landscape provides breeding habitat for numerous grassland nesting birds, while the Elkhorn River provides breeding habitat for the threatened Northern Great Plains population of Piping Plovers and the endangered Interior Least Tern. The Elkhorn River and Todd Valley wetlands provide secondary habitat for migrating wetland-dependent species (shorebirds, waterbirds, and waterfowl).

As with most of eastern Nebraska, this region is intensely cultivated. Nearly all of the grasslands have been converted, and many of the embedded playa wetlands drained to promote row-crop agriculture. Based on the 2009 USDA Cropland Data Layer, 55% of this landscape is cultivated to corn, soybeans, or alfalfa (USDA 2009, Bishop et al. 2011). Nearly 10% of the grassland cover has been re-established through the Conservation Reserve Program (CRP). Although many of these acres were not planted exclusively to native species, the acres complement the native tallgrass remnants scattered throughout the region. A majority of the CRP contracts are expiring, and current high commodity prices, plus the safety net provided by the Federal Crop Insurance Program, are accelerating conversion of these acres back to row-crop agriculture.

Invasive plant species, such as eastern red cedar, Kentucky bluegrass, *Phragmites*, purple loosestrife, reed canary grass, and smooth brome, continue to degrade wet meadows and adjacent mesic floodplains in this region. The loss of grasslands in the region has resulted in higher stocking rates and a shift to year-long grazing regimes. The transitions in grazing practices, as well as fire suppression, are believed to be a major factor contributing to the encroachment of undesirable plant species (i.e., Kentucky bluegrass, eastern red cedar, and smooth brome, etc.).

Rainwater Basin

The RWB encompasses 6,150 square miles, including parts of 21 counties in the south-central portion of the RWBJV Administrative Area. Condra (1939) identified this landscape as the Loess Plains Region of Nebraska. This region has expansive rolling loess plains formed by deep deposits of wind-blown silt with a high density of clay-pan playa wetlands. Overland runoff from intense summer storms and melting winter snowfall fill these playa wetlands.

Analysis of the historic soil surveys (1910 – 1917), NWI (1980 – 1982), and SSURGO data (1961 – 2004) indicates that playa wetlands were once a prominent feature of this landscape. Combined, these datasets identified approximately 11,000 individual playa wetlands (204,000 acres) that were historically part of the landscape. It has been estimated that there were over 1,000 semi-permanent and seasonal wetlands, which covered over 70,000 acres, and more than 10,000 temporary wetlands that accounted for an additional 134,000 acres.

A Nebraska Game and Parks Commission (NGPC) breeding waterfowl habitat survey (McMurtrey et al. 1972) used the historic soil surveys as a reference to evaluate the distribution of remaining wetlands. McMurtrey et al. (1972) reported that 82% of the major wetlands had been converted to agriculture, removing approximately 63% of the total wetland acres from the landscape. The fast-paced degradation continued, and by 1985 only 10% of the surveyed wetlands remained. The remaining wetlands represented only 22% of the original surveyed acres, and virtually all were hydrologically impaired (Schildman and Hurt 1984). Due to the extensive wetland loss and continued degradation, RWB wetlands were given a Priority 1 ranking, the most imperiled status, in the Nebraska Wetlands Priority Plan (Gersib 1991).

Land use in the RWB is dominated by row-crop agriculture (70% of the acres), predominantly in a corn and soybean rotation. Grassland habitats make up approximately 20% of the region, while 3% of the area is covered by savannahs, woodlands, and forest communities that are confined to the steeper drainages associated with the Republican and Blue river systems. Riverine wetlands associated with these systems comprise about 2% of the landscape. Of the historic 204,000 RWB wetland acres, roughly 40,000 acres remain, or about 17% of the historic distribution. Today, playa wetlands in the RWB make up less than 1% of the total landscape (Bishop and Vrtiska 2008; Bishop et al. 2011).

Approximately 44,000 acres of palustrine wetlands, 51,000 acres of riverine wetlands, and 678,000 acres of grassland presently occur throughout the RWB Geographic Focus Area (Table 1). Despite the extensive wetland loss, this region still hosts one of the greatest wildlife migration spectacles on earth. During spring migration the RWB provides roosting, loafing, and foraging habitat for millions of migratory waterfowl and other wetland-dependent species. The RWB provides essential staging habitat for an estimated 8.6 million waterfowl (Appendix A) and nearly 600,000 shorebirds (RWBJV 2013*b*), as well as vital stopover habitat for the endangered Whooping Crane.

Over the years, a variety of wetland rules and laws have helped to significantly reduce active wetland drainage; however, wetland function across the landscape continues to decline as a result of intentional human activity, such as active drainage, and through ecological processes, including natural and culturally accelerated sedimentation (LaGrange et al. 2011). In addition, wetland modifications, including water concentration/irrigation reuse pits, land leveling, culturally accelerated sediment, and drainage ditches, directly impact the wetlands or limit the amount of runoff reaching the wetlands. Furthermore, the combination of sedimentation and altered watershed hydrology leads to conditions that promote invasive species. Depending on the water regime and duration of saturated conditions, primary threats include reed canary grass, hybrid cattail (Grace and Harrison 1986), and river bulrush (Kaul et al. 2006, Rolfsmeier and Steinauer 2010).

Republican River/Blue River Drainages and Loess Canyons

The Republican River/Blue River Drainages and Loess Canyons GFA lies along the southern boundary of the RWBJV Administrative Area. A limited surface and groundwater supply differentiates the region from other GFAs in the RWBJV Administrative Area. As a result, a significant proportion of the cropland is cultivated with dry-land farming practices. Despite the limited ground- and surface-water resources, significant irrigation development occurred in the Republican River drainage through 2004. The unsustainable irrigation development ultimately led the Nebraska DNR to designate the Republican River drainage as an over-appropriated river basin. This designation led to a combination of restrictions on new acres developed for irrigation and on irrigation water allocations. The Blue River basins are defined by the drainage area of the Big and Little Blue rivers. At this time, the Blue river basins have no limitations on groundwater development, but triggers are in place should further groundwater depletions occur.

In the western portion of this region, there are numerous playa wetlands that are part of the Southwest Playa complex (LaGrange 2005). These freshwater wetlands receive water from runoff and are small (mostly less than 5 acres), temporarily and seasonally flooded wetlands. Most have no natural outlet for water. In most years, these wetlands dry up early enough in the growing season to be farmed. Southwest Playa wetlands are similar to RWB wetlands farther east, except that the RWB complex receives greater rainfall, and the wetlands there tend to be larger (LaGrange 2005).

The topography and soils of this Geographic Focus Area vary from steep hills and canyons with highly erodible soils in the west, to relatively flat and highly productive plains, rolling hills, and breaks in the east. Stream flows vary and are dependent on precipitation. Grasslands are dominated by mixed-grass prairie communities, with tallgrass prairies occurring along the eastern boundary. Fire suppression and year-long grazing regimes are believed to be major factors contributing to the establishment of invasive species in many of the grasslands in this GFA.

Approximately 5,000 acres of palustrine wetlands, 160,000 acres of riverine wetlands, 61,000 acres of lakes and reservoirs, and 3.1 million acres of grassland occur throughout the Republican River/Blue River Drainages and Loess Canyons Geographic Focus Area (Table 1). With the exception of Harlan County Reservoir, a 16,000 acre flood-control reservoir, water bodies are typically associated with small watershed impoundments created for flood control, grade stabilization, and livestock water. These man-made wetland features (reservoirs and stock ponds) provide migration, and at times wintering, habitat for waterfowl, as well as stopover habitat for numerous species of shorebirds. The grasslands in this GFA provide breeding habitat for an estimated 1.5 million grassland nesting birds (RWBJV 2013*a*).

Habitat loss from grassland conversion and wetland drainage for row-crop agriculture has occurred to varying degrees throughout this Geographic Focus Area. Row-crop agriculture development has been slower in the Republican River Basin, primarily due to a limited groundwater aquifer and moratoriums on irrigation development. Invasive species continue to threaten habitat quality of both wetlands and uplands in the Geographic Focus Area. *Phragmites*, purple loosestrife, and reed canary grass have played a role in reducing habitat, constricting river channel widths, and depleting surface water flows.

Sandhills

The Sandhills are a 19,300-square-mile sand dune formation located in north-central Nebraska. Although located in a semi-arid climate, the Sandhills contain an abundance of lakes, wetlands, wet meadows, and spring-fed streams scattered across the largest contiguous grass-stabilized dune system in North America (Schneider et al. 2011).

Between the dune formations are long, gently sloping valleys containing spring-fed meandering streams, lakes, wetlands, and wet meadows. Groundwater recharge is the prominent characteristic of the sands, creating a vast aquifer that stores 700-800 million acre-feet of groundwater (Keech and Bentall 1971). This volume represents twice the volume of Lake Erie. Most of the area's lakes, wetlands, and streams are sustained by groundwater discharge from adjoining dunes. About 90 percent of the stream flow (2.4 million acre-feet) comes from groundwater discharge (Bentall 1990). The Niobrara River flows along the Sandhills' northern border, and the North Platte and Platte rivers flow along part of the southern boundary. The Calamus, Cedar, Dismal, Elkhorn, and Loup rivers originate within the Sandhills.

Approximately 1.1 million acres of palustrine and riverine wetlands, 85,000 acres of lacustrine wetlands, and over 11.5 million acres of grassland occur throughout the Sandhills GFA (Table 1). The mosaic of wetlands and grasslands was identified by Bellrose (1980) as the most significant waterfowl nesting habitat outside of the Prairie Pothole Region. Vrtiska and Powell (2011) estimated that 275,000 waterfowl annually nest in the Sandhills. The larger Sandhills lakes provide nesting habitat for a majority of the High Plains flock of Trumpeter Swans (Grosse et al. 2012). The wet meadows and grasslands provide vital nesting habitat for an estimated 4 million grassland birds (RWBJV 2013*a*). A significant proportion of the estimated 400,000 breeding shorebirds found in the RWBJV Administrative Area occur in the Sandhills (RWBJV 2013*b*). Nearly all of the nesting waterbirds in the RWBJV Administrative Area occur in the Sandhills (RWBJV 2013*c*).

Wetland loss in the Sandhills has occurred primarily through draining by surface ditches, beginning as early as 1900 (U.S. Fish and Wildlife Service 1960, McMurtrey et al. 1972, LaGrange 2005). With the introduction of center-pivot irrigation systems to the Sandhills in the early 1970s, land leveling/shaping and local water-table declines resulted in extensive wetland losses in some areas. While quantifiable data are not available for the Sandhills, estimates of wetland acres drained range from 15% (McMurtrey et al. 1972) to 46% (U.S. Fish and Wildlife Service 1986). Sandhills wetlands were given a Priority 1 ranking, the most imperiled status, in the Nebraska Wetlands Priority Plan, due to very extensive past losses (Gersib 1991). Sandhills wetlands continue to be threatened by drainage ditches, generally created to increase hay acreage. This drainage directly impacts the lake or wetland where the project occurs and also can lead to cumulative wetland loss, both downstream and upstream, as the channel becomes entrenched, lowering the water table, and causing lateral drainages that impact adjacent wetlands. Many smaller wetlands are also threatened by conversion from ranching to irrigated row-crop agriculture. Concentrated, large-scale irrigation development can result in long-term effects on wetland communities by lowering the groundwater table. Many of the lands originally developed for row-crop production have been planted back to grasslands. This was incentivized by the CRP program. However, CRP acres could be rapidly converted to row-crop agriculture. As CRP contracts expire, there are multiple factors that could influence conversion of these lands back to row-crop agriculture. For example, current commodity prices, land values, and cash rent remain at all-time highs, and the Federal Crop Insurance Program provides a source of guaranteed income for cultivation of these environmentally sensitive lands.

Verdigris-Bazile Creek Drainages

This landscape, located in the northern portion of the RWBJV Administrative Area, is defined by the watersheds of Verdigris and Bazile creeks, which originate in and flow through Cedar, Knox, Holt, and Antelope counties, emptying into the Niobrara and Missouri rivers in northeast Nebraska.

Topography is variable, resulting in a mosaic of cropland, grasslands, and woodlands. This Geographic Focus Area is located at the transition zone between the tallgrass and mixed-grass prairie ecoregions. As a result, the grasslands contain a diverse assemblage of tallgrass and mixed-grass prairie communities. Tallgrass prairie communities dominate the native grasslands along the eastern boundary, while species associated with mixed-grass prairie prevail in grasslands along the western boundary. Woodlands are generally confined to the drainages and bluffs associated with the major riverine systems (Verdigris Creek, Bazile Creek, Missouri River bluffs and breaks) (Schneider et al. 2011). These woodlands are dominated by deciduous species. The dominant cultivated crops in this region include corn, soybeans, and alfalfa (Bishop et al. 2009).

Approximately 4,800 acres of palustrine wetlands, 79,000 acres of riverine wetlands, 7,800 acres of lakes and reservoirs, and 1.4 million acres of grassland occur throughout the Verdigris-Bazile Creek Drainages GFA (Table 1). The CRP program has been utilized to re-establish grasslands on former row-crop acres with steeper topography and water erosion problems. Although many of these acres were not planted exclusively to native species, the re-established grassland acres complement the native tallgrass and mixed-grass remnants scattered throughout the region. It is estimated that this landscape provides nesting habitat for 600,000 grassland breeding birds (RWBJV 2013*a*). The Niobrara River provides breeding habitat for the threatened Piping Plover and endangered Interior Least Tern.

A majority of the CRP contracts are expiring, and current high commodity prices, plus the safety net provided by the Federal Crop Insurance Program, are accelerating conversion of these acres back to row-crop agriculture. Grassland conversion is also occurring as a result of current farm economics and farm policy. Fire suppression and year-long grazing regimes are suspected of creating conditions that allow eastern red cedars, Kentucky bluegrass, and smooth brome to invade grasslands. Eastern red cedars have also invaded the woodlands and forests associated with the Verdigris – Bazile Creek Drainages.

Continental Priority Waterfowl Species

The 2004 update of NAWMP assigned a continental priority for each species of waterfowl, based on socioeconomic importance and vulnerability to population decline (NAWMP 2004). The plan stepped down the priority rating to geographic regions called Waterfowl Conservation Regions (WCR), which were modifications of Bird Conservation Regions (NAWMP 2004). The modifications were made to delineate those landscapes that had similar priority waterfowl species and conservation needs. Conservation needs during breeding and non-breeding life cycles were prioritized for each species within each WCR.

About 90% of the RWBJV Administrative Area lies within WCR 19, while the 10%, located in the northeast portion of the RWBJV Administrative Area, falls in WCR 11 (Prairie Pothole Region). This small southern edge of the Prairie Pothole Region has no true prairie pothole wetlands and is of relatively low importance to breeding waterfowl. For this reason, the priority species identified for WCR 19 reflect the priority species for the RWBJV Administrative Area (Table 2).

WCR 19 was recognized by NAWMP as having high conservation needs for five species of waterfowl during the non-breeding (migration) portion of their life cycle. Those species are Mallard, Northern Pintail, Lesser Snow Goose (Western Central Flyway and mid-continent populations), Greater White-fronted Goose (mid-continent), and Canada Goose (Western Prairie/Great Plains populations). Other priority species within WCR 19 were listed as moderate or moderately low in priority for non-breeding conservation needs. NAWMP (2004) also identified WCR 19 as having a high importance and conservation need for the breeding populations of Canada Geese (Western Prairie/Great Plains populations) and Trumpeter Swans (High Plains Flock) (Table 2).

Priority Waterfowl Species for the RWBJV Administrative Area

At a more local level, not all priority species listed for WCR 19 are priority species within the RWBJV Administrative Area. The RWBJV used the Strategic Habitat Conservation (National Ecological Assessment Team 2006) framework to select a subset of priority species: Mallard, Northern Pintail, Greater White-fronted Goose, Lesser Snow Goose, and Trumpeter Swan. These five species were selected because of their national priority and because their habitat needs were likely to represent the full spectrum of roles that wetlands in the RWBJV Administrative Area play during both the non-breeding (Brennan 2006, Webb 2010a, Pearse et al. 2011a, 2011b) and breeding seasons (Grosse et al. 2012).

Spring migration brings millions of migratory waterfowl into the RWB, with Mallard and Northern Pintail being the two most abundant duck species. Greater White-fronted Goose and Lesser Snow Goose are the two most abundant goose species. The energy demand by this large congregation of birds is significant. A sensitivity analysis completed on the bioenergetics model suggested that Mallards and Northern Pintails would consume 60% of foraging resources during spring migration (Appendix A).

Table 2. Priority species identified by the North American Waterfowl Management Plan that are found in the Rainwater Basin Joint Venture Administrative Area, and their conservation priority within Waterfowl Conservation Region 19 (NAWMP 2004).

Species / Population	Continental Priority	Breeding Importance	Breeding Conservation Need	Nonbreeding Importance	Nonbreeding Conservation Need
Ducks					
Mallard	High	Moderate Low	Moderate	Moderate High	High
Northern Pintail	High	Moderate Low	Moderate	Moderate High	High
American Wigeon	Moderate High			Moderate Low	Moderate Low
Blue-winged Teal	Moderate High	Moderate Low	Moderate Low	Moderate Low	Moderate Low
Canvasback	Moderate High			Moderate Low	Moderate Low
Common Goldeneye	Moderate High			Moderate High	Moderate High
Redhead	Moderate High			Moderate Low	Moderate Low
Gadwall	Moderate	Moderate Low	Moderate Low	Moderate Low	Moderate Low
Green-winged Teal	Moderate			Moderate Low	Moderate Low
Northern Shoveler	Moderate	Moderate Low	Moderate Low	Moderate Low	Moderate Low
Ring-necked Duck	Moderate			Moderate Low	Moderate Low
Geese and Swans					
Canada Goose - Shortgrass Prairie	Moderate			Moderate Low	Moderate Low
Canada Goose - Tallgrass Prairie	Moderate Low			Moderate High	Moderate
Canada Goose - Western Prairie/Great Plains	Above Objective	High	High	High	High
Greater White-fronted Goose, Mid-continent	Moderate Low			High	High
Lesser Snow Goose - Western Central Flyway	Moderate			High	High
Lesser Snow Goose – Mid-continent	Above Objective			High	High
Ross's Goose	Above Objective			Moderate High	Moderate
Trumpeter Swan - Interior Population, High Plains Flock	Above Objective	High	High	High	High

Birds continuing their northward migration use the broader distribution of wetland complexes located throughout the RWBJV Administrative Area, including the Central Platte River, Central Table Playas, Missouri River, Sandhills, and Todd Valley Wetlands.

Trumpeter Swans, reintroduced into the Sandhills in the 1960s (Monnie 1966), have experienced an annual population growth of 4.2% since 1990 (Comeau and Vrtiska 2010), and the High Plains Flock continues to expand its breeding range in the Sandhills. Their affinity appears to be toward larger, more permanent wetlands located within wetland complexes (Grosse et al. 2012).

Population Objectives

Non-breeding Waterfowl Population Objectives

Spring waterfowl use within the RWB has been estimated from a combination of directed research projects and published reports (Bellrose 1980, Benning 1987, Gersib et al. 1989, Vrtiska and Sullivan 2009, Pearse et al. 2011*b*). It has been estimated that as much as 90% of the mid-continent population of Greater White-fronted Geese, approximately 50% of mid-continent Mallards, and 30% of the continental Northern Pintail breeding population use the area (Gersib et al. 1989). These percentages vary with annual changes in water and wetland conditions. Lesser Snow Goose numbers are estimated at 1.5-7.0 million (Vrtiska and Sullivan 2009). Waterfowl migrations during the fall appear to involve far lower numbers, with shorter stays over a more extended migration season.

If NAWMP population goals are reached, it is estimated that 8.6 million waterfowl will use the RWB wetland complex and adjacent Central Platte River during spring migration. Mallard and Northern Pintail numbers would reach approximately 4.2 million and 800,000, respectively. The balance of duck numbers would primarily consist of Blue-winged Teal, Green-winged Teal, Northern Shoveler, American Wigeon, and Gadwall. The Mid-continent Greater White-fronted Goose population would be over 500,000. It is expected that more than 400,000 Canada Geese (Great Plains, Western Prairie, and Tall Grass Prairie populations) and millions of Lesser Snow Geese and Ross's Geese will come through as well (Appendix A). Estimates of abundance for waterfowl in the Central Loess Hills, Central Table Playas, Northeast Prairies/Todd Valley, Republican River, and Verdigris-Bazile/Missouri River landscapes are unavailable. There is recognition of the interchange between the RWB and the Central Platte River during intense climatic events or periods of extreme drought, and this may occur to a lesser extent with these other landscapes.

Breeding Waterfowl Population Objectives

Bellrose (1980) identified Nebraska's Sandhills as the highest-quality duck production area south of the Prairie Pothole region. Aerial surveys have been conducted to estimate the number of breeding waterfowl in the Sandhills. Based on the detection probabilities derived from these surveys, it is estimated that under favorable conditions, 275,000 breeding ducks nest in the Sandhills (Vrtiska and Powell 2011). Species composition is approximately 34% Mallard, 27% Blue-winged Teal, 20% Gadwall, 14% Northern Shoveler, and 6% Northern Pintail (Vrtiska and Powell 2011). Fall flight estimates for the Great Plains population of Canada Geese exceeds 10,000 (LaGrange 2005).

The historic breeding range of the Trumpeter Swan once extended from the Bering Sea, across Canada to the Atlantic Coast, and into the midwestern United States (Banko 1960). Nesting occurred in the Sandhills, but by the early 1900s, few birds remained. Only three occurrences of nesting were recorded between 1912 and 1960 (Central Flyway Council 1982). Because these birds historically occurred in the Sandhills, and because much of the wetland habitat there was still intact, Trumpeter Swans were reintroduced at LaCreek National Wildlife Refuge between 1960 and 1962 (Monnie 1966).

Soon after reintroduction, Trumpeter Swans began to pioneer new wetland habitats throughout the Sandhills. The High Plains Flock of the Interior Population has experienced 4.2% population growth annually since 1990 (Comeau and Vrtiska 2010). In 2004, the High Plains Flock surpassed the management goal of 500 individuals during the mid-winter survey (Comeau-Kingfisher and Koerner 2005), and the population consisted of 524 birds, with 65 nesting pairs, in 2010 (Comeau and Vrtiska 2010). This exceeds the cooperative management plan goal of 500 birds and 50 nesting pairs (Comeau-Kingfisher and Koerner 2005). Most of the Trumpeter Swans use the Sandhills during both the breeding and non-breeding seasons.

Other landscapes in the RWBJV Administrative Area are limited in numbers of nesting waterfowl. Nesting is limited within the RWB, but in wet years some ducks nest in the area (Evans and Wolfe 1967). Evans and Wolfe (1967) noted five species of ducks nesting in the RWB, but changes in crop rotations and farming practices probably have decreased the amount of nesting by waterfowl in the region since their study. Some Mallards and Blue-winged Teal may nest in RWBJV Administrative Area, however the number of nesting individuals is insignificant compared to the proportion of the population nesting in the Prairie Potholes, Canadian Parkland, Arctic, and Boreal Forest. The wooded corridors along the rivers and creeks that bisect the geographic focus areas of the RWBJV Administrative Area provide nesting cavities for Wood Ducks and possibly Hooded Mergansers.

Wetland Habitat

Each of the geographic focus areas in the RWBJV Administrative Area contains a unique abundance, distribution, and diversity of wetland types. This diverse wetland composition influences the species and number of waterfowl each landscape can support. Playa wetlands (palustrine wetlands), like those found in the Central Loess Hills (Central Table Playas Wetland Complex), Northeast Prairies/Elkhorn River (Todd Valley Wetland Complex), Republican River/Blue River Drainages and Loess Canyons (Southwest Playas Wetland Complex), and RWB GFAs provide optimal foraging habitat for dabbling ducks during the non-breeding phase of the annual life cycle. Sandhills lakes (lacustrine wetlands) provide critical foraging and nesting habitat for Trumpeter Swans. The juxtaposition of wetlands and grasslands found in the Sandhills provides essential nesting habitat for a majority of the nesting waterfowl found in the RWBJV Administrative Area. Riverine wetlands associated with the Elkhorn (Northeast Prairies/Elkhorn River GFA), Loup (Central Loess Hills GFA), Missouri, and Platte (Central and North Platte River GFA) rivers provide some reliable stopover habitat, especially during periods of drought.

Non-breeding Waterfowl Habitat

The non-breeding portion of the Rainwater Basin Joint Venture Waterfowl Plan is based on the "Cross Seasonal Effects" hypothesis (Krapu 1981). The hypothesis suggests that suitable habitat conditions at mid-latitude staging areas are necessary to acquire sufficient nutrient reserves to complete migration, initiate nesting, and produce viable offspring. LaGrange and Dinsmore (1988) speculated that regions closer to the breeding grounds would be more important for nutrient acquisition by females preparing to nest. The RWB is probably the most significant non-breeding (migration) habitat within the RWBJV Administrative Area and arguably within the Central Flyway. Conservation work by the RWBJV in the RWB has focused, and will continue to focus, on habitat for migrating waterbirds. The challenge is to provide adequate ponded-water habitat, with access to natural forage, to support spring-migrating waterfowl.

In 2008, the RWBJV completed an updated NWI (Cowardin et al. 1979) in the RWB. That dataset was compared to the initial 1980 NWI inventory. A loss of 6,000 palustrine emergent wetland acres was documented, despite the 20,000 acres of conservation work completed in the region since the RWBJV was established. It has been speculated that most of the losses were a result of on-site wetland modifications completed prior to the 1985 Farm Bill "Swampbuster" provision, which limited wetland drainage by producers enrolled in USDA farm programs. However, high commodity crop prices also may have led to some wetland losses in more recent years.

NWI mapping also identified over 10,000 concentration pits within the RWB (Bishop and Vrtiska 2008). To manage irrigation water and comply with state and Natural Resources District rules, thousands of concentration pits (irrigation reuse pits) have been excavated throughout the RWB. These concentration pits are commonly located at the lowest elevation within a field, and irrigation runoff is pumped from the pit and re-applied at the upper end of the field. During the final irrigation of the growing season, the pits are often pumped dry, causing natural runoff from the following year's snowmelt and spring rains to be captured in the pits instead of reaching wetlands. It is estimated that the pits are capable of storing over 56,000 acre-feet of water region-wide (Bishop and Vrtiska 2008).

Wetland density and wetland area have been shown to positively influence waterfowl richness and abundance in the RWB during the non-breeding portion of the annual life cycle (Webb et al. 2010*a*). In periods of drought, limited water may concentrate birds, increasing the risk and potential severity of an epizootic disease outbreak (Blanchong et al. 2006) and may increase inter- and intraspecific competition for roosting, foraging, and loafing habitat (Webb et al. 2010*b*). Tidwell (2010) found that adult Mallard females that congregated in high-density wetland complexes acquired significantly more lipid reserves compared to those individuals that gathered on relatively isolated wetlands. In waterfowl, there appears to be a positive relationship between the amount of nutrient reserves acquired on migration areas and subsequent recruitment (Alisauskas 2002, Klaassen et al. 2006, Devries et al. 2008).

The close proximity between the RWB and the Central Platte River creates a macro wetland complex, with local bird movement between the two areas. Intense late-winter storms with sustained freezing temperatures are common during spring migration. These events often freeze RWB wetlands for short periods of time, forcing birds to migrate south or shift to the Platte River and surrounding habitats. During periods of extreme drought, limited playa wetland habitat is available in the RWB, and the Central Platte River provides critical secondary habitat (National Research Council of the National Academies 2005).

Although accurate numbers are unavailable, the Sandhills and other landscapes of the RWBJV Administrative Area do provide migration habitat, but to a lesser degree than the RWB and Central Platte River. It is speculated that only a small portion of the birds that use the RWB also use other wetland complexes in the RWBJV Administrative Area. Most birds appear to arrive directly to the RWB and then leave directly to the Prairie Pothole Region (Pearse et al. 2011b). Birds that do stop over in the Sandhills and other areas are more dispersed and do not congregate in the same density as in the RWB. Rivers and creeks in the Sandhills provide wintering habitat for Trumpeter Swans, and in warmer winters, Sandhills lakes may remain open and provide habitat.

Breeding Waterfowl Habitat

Life history characteristics and regional wetland conditions are important to the distribution of breeding waterfowl at relatively large scales (Johnson and Grier 1988). However, at smaller scales, other factors may influence waterfowl settling patterns (Johnson 1980). The distribution and abundance of wetlands, as well as the juxtaposition of different water regimes (semi-permanent, seasonal, temporary), has been shown to influence habitat selection by waterfowl on breeding grounds (Fairbairn and Dinsmore 2001, Naugle et al. 2001). Additionally, areas with relatively large intact expanses of grassland appear to maximize waterfowl nest success (Stephens et al. 2005).

Outside of the Sandhills, the lower wetland densities, seasonality of wetlands, and lack of grasslands limit the number of breeding ducks in the RWBJV Administrative Area. The extensive amount of intact grassland, higher wetland density, and the interspersion and greater number of semi-permanent wetlands provide good nesting and brood habitat for ducks, geese, and Trumpeter Swans in the Sandhills. Although the grassland landscape has remained relatively intact, wetland drainage continues, but at a slower pace compared to years before the "Swampbuster" provision of the 1985 Farm Bill. Recent spikes in commodity prices may have increased grassland conversion to cropland. The increased commodity prices also may have made it profitable for some producers to opt out of the U.S. Department of Agriculture's farm program. As a result, wetlands within these operations are not protected by the "Swampbuster" provision, and are subject to drainage and filling. The Clean Water Act may protect some of the wetlands from drainage, but many of the Sandhills wetlands are considered to be geographically isolated and may no longer be protected under the Clean Water Act.

The large expanse of wetlands and open grassland (95% of 12.8 million acres within the Sandhills; Schneider et al. 2011) is conducive to wind development. Development of large-scale wind farms could fragment the landscape and lead to increased nest predation and aversion to the area. The spread of invasive species will degrade nesting and wetland habitats. Smooth brome grass, Canada thistle, leafy spurge, eastern red cedar, hybrid cattail, *Phragmites*, and reed canary grass pose the greatest current threat.

Duck recruitment in the Sandhills is lower than what would be expected in such a large, intact grassland (Stephens et al. 2005), and nest predation appears to be the main limiting factor (Glup 1987, Walker et al. 2008). Cunningham (2011) also observed a higher-than-normal proportion of young Mallard hens nesting within the Sandhills, suggesting some of the low nest success may be attributed to inexperienced females.

Conservation Design

Non-breeding Waterfowl

At the most conceptual level, conservation success in the RWB means a sufficient distribution of local wetland complexes, with a good distribution of shallow water and an abundance of early-succession plant communities. To determine the number of wetland acres needed to support waterfowl using the RWB, the RWBJV developed a bioenergetics model, which allowed us to estimate the energetic needs of waterfowl during spring migration. The model incorporates bird-use days, species-specific energetic needs, and forage selection (Appendix A).

Population estimates were developed by calculating the number of individuals that would stop in the RWB if waterfowl populations were at the NAWMP population goals. Energetic requirements were derived by multiplying waterfowl populations by their estimated length of stay in the RWB, and their energetic requirements (Appendix A). The model projects that birds using the RWB during spring migration will require 15.6 billion kilo-calories (kcals) (Appendix A). Forage selection studies completed on various waterfowl species suggest that a proportion ranging from 30 to 80% of waterfowl diets should be wetland seeds and other plant material. When the calculations for each species are compiled, 4.4 billion of the 15.6 billion kcals need to be provided by wetland-derived seeds.

Geographic Information System (GIS) technology was used to delineate the distribution and abundance of contemporary vegetation communities, while energy production of each wetland vegetation community was based on estimates contained in the literature (Appendix A). The cumulative production capability of the wetlands was estimated to be 5.9 billion kcals if all wetland acres were ponded. Ponded, or available, water conditions vary annually across the RWB, and rarely are all wetlands in the region full. From 2004-2012, spring water conditions varied from 2,160 to 12,000 acres and provided 10-44% of the 4.4 billion kcals needed. To produce 4.4 billion kcals of natural food, increases would have to occur in the: 1) number of functioning wetland basins across the RWB, 2) ponding frequency or capability of existing wetlands during the spring, and 3) amount of wetland-derived seed resources in the wetlands.

Several GIS models and associated decision support tools were developed as part of this planning effort. Local and landscape features were evaluated to develop a wetland prioritization model to identify wetlands and landscapes in the RWB that had the greatest potential to provide quality habitat for migrating waterfowl (Bishop 2008). Variables in the model included wetland size, wetland density, proximity to human disturbance, and contribution to a wetland complex (Bishop 2008). Additional decision support tools have been developed from the initial prioritization model, including: 1) a watershed restoration prioritization that identified those concentration pits with the greatest impact on functional wetlands; 2) wetlands expected to have the highest value to Whooping Cranes; and 3) identification of priority wetland roundouts that should be acquired in fee title. Roundouts are the privately owned portions of wetlands in split (public and private) ownership. Roundout portions of wetlands often constrain management and prevent restoration of the entire wetland. For example, restoring the natural hydrology of the public portion of a wetland may not be possible if the privately owned roundout portion includes croplands.

Considering information from the wetland prioritization model and energetics model, four targets were identified (see below) to achieve one of the overarching objectives defined in the RWBJV Implementation Plan. It states: "*By 2030, improve, maintain, and protect natural wetlands—through a voluntary, cooperative approach—which are capable of meeting the energetic needs of spring-migrating waterfowl (approximately 4.4 billion kilocalories) under average weather conditions.*"

The figures used in each target and its associated strategies are not absolute, but represent one scenario that would allow the RWBJV to meet habitat objectives for waterfowl. Changes in policies, programs, public support, and funding can and will determine which conservation opportunities will arise. As one target is exceeded, other target numbers will be adjusted.

Central Platte River Conservation Targets and Strategies

Target 1. Support the restoration of sloughs that provide reliable habitat for wintering and migrating waterfowl.

Strategy A: Work with willing landowners to re-establish these wetland habitats that have been significantly degraded as a result of the altered hydro-regime.

Target 2. Work with partners to establish target flows necessary to maintain in-channel habitat conditions through scouring and other ecological processes, and provide reliable habitat for migrating waterfowl.

Strategy A: Provide technical resources necessary to complete geospatial analysis to quantify and map the habitat conditions under different flow regimes.

Strategy B: Provide technical resources necessary to quantify the impacts of different flow regimes on available in-channel habitat for waterfowl.

RWB Conservation Targets and Strategies

Target 1. By 2030, publicly owned wetlands will provide 55% of the total natural forage needed by waterfowl in the RWB (Table 3).

Strategy A: Increase public wetland acres from 18,814 to 26,800. Most of the newly acquired wetland acres will be "roundouts" to existing public wetlands. Roundouts also may increase the forage production on existing public wetlands.

Strategy B: Through management, maintain 80% of public wetland acres in early successional plant communities to optimize moist-soil seed production.

Strategy C: Increase ponding frequency under average moisture conditions from 17.7% to 45% (Table 4):

- Restore the natural hydrologic characteristics of each wetland to the greatest feasible degree.
- Increase the function of associated watersheds by reclaiming irrigation reuse pits and implementing other conservation practices.
- Provide additional supplemental water delivery by increasing the use of high-volume wells.
- Develop a long-term funding source to operate high-volume wells.

Strategy D: Increase the number of upland buffer acres from 13,268 to 17,793 through fee-title land acquisition or long-term easements.

Target 2. By 2030, long-term conservation wetlands will provide 25% of the total natural forage needed by waterfowl in the RWB (Table 3).

Strategy A: Increase the number of wetland acres from 3,448 to 12,687 through conservation easements or other long-term conservation programs.

Strategy B: Through management, maintain 75% of these wetland acres in early-succession plant communities.

Strategy C: Increase ponding frequency under average weather conditions to 45% (Table 4):

- Restore the natural hydrologic characteristics of each wetland to the greatest feasible degree.
- Increase the function of associated watersheds by reclaiming irrigation reuse pits and implementing other conservation practices.
- Provide additional supplemental water delivery by increasing the use of high-volume wells.
- Develop a long-term funding source to operate high-volume wells.

Strategy D: Increase the number of upland buffer acres from 2,899 to 7,245 through conservation easements or other long-term conservation programs.

Target 3. By 2030, wetlands enrolled in short-term conservation agreements of less than 30 years will provide 10% of the natural forage needed by waterfowl in the RWB (Table 3).

Strategy A: Increase the number of wetland acres enrolled in short-term conservation programs from 2,481 to 7,346.

Strategy B: Restore and maintain wetland plant communities at 60% early-successional state, 30% cropland (farmed), and 10% late-succession.

Strategy C: Restore wetland and watershed function so that ponding frequency reaches 33% under average weather conditions (Table 4).

Target 4. By 2030, wetlands in private ownership that are not in any conservation program will provide 10% of the total natural forage needed by waterfowl in the RWB (Table 3).

Strategy A: Through incentives and education, maintain wetland vegetation communities that are 30% early-successional state, 50% cropland (farmed), and 20% late-succession.

Strategy B: Restore watershed function to these wetlands so that they reach a 25% ponding frequency under average weather conditions (Table 4).

Strategy C: Encourage the development of short-term conservation programs that encourage the establishment of grassland buffers for these wetlands.

Table 3. Current and projected targets for wetland acres and kilocalories provided by natural plant communities for spring-migrating waterfowl in the Rainwater Basin region of Nebraska.

					2030 Goal			
Wetland Category	**Current # of Acres**		**Additional Acres Needed**		**Total Acres**		**Kcals Provided**	**% of Total Kcals**
	Wetland	Upland	Wetland	Upland	Wetland	Upland		
Public	18,814	13,268	7,990	4,525	26,804	17,793	2.47 billion	55
Private, Long-Term Conservation	3,448	2,898	9,239	4,346	12,687	7,245	1.1 billion	25
Private, Short-Term Conservation	2,481		4,865		7,346		442 million	10
Private Non-program	15,702		0		~10,000		736 million	~10
Total	**40,445**	**16,166**	**22,094**	**8,871**	**56,837**	**25,038**	**4.4 billion**	**100**

Table 4. Current and projected targets for wetland ponding frequency and occurrence of early-succession plant communities in the Rainwater Basin region of Nebraska.

Wetland Category	**% of Wetland Acres that Pond Water**		**% of Vegetation in Early-succession**	
	Current	**2030 Goal**	**Current**	**2030 Goal**
Public	17.7	45.0	63.8	80.0
Private	21.5	25.0	30.0	30.0
Long-term Conservation	24.0	45.0	80.0	75.0
Short-term Conservation	7.0	33.0	42.0	60.0

Breeding Waterfowl

The Sandhills have the primary nesting habitat for waterfowl in the RWBJV Administrative Area. However, sufficient data do not currently exist to establish population-based habitat objectives. Conceptually, the RWBJV would like to maintain the Sandhills' capacity to support the 275,000 nesting ducks that are thought to use this region under ideal conditions (Vrtiska and Powell 2011). To identify key landscapes within the Sandhills, a moving window analysis was run in a GIS environment. This analysis identified landscapes with a high density of wetlands. At a local scale, landscapes with a high density of wetlands have been shown to attract higher densities of nesting ducks (Naugle et al. 2001).

A second analysis was done to identify areas containing a diversity of wetland water regimes: temporary, seasonal, semi-permanent, and permanent (Figure 2). Landscapes with a diversity of wetlands provide waterfowl with essential habitats for foraging, brood rearing, and molting. The values assigned to these areas can be used by conservation partners to help identify focus areas and prioritize conservation projects.

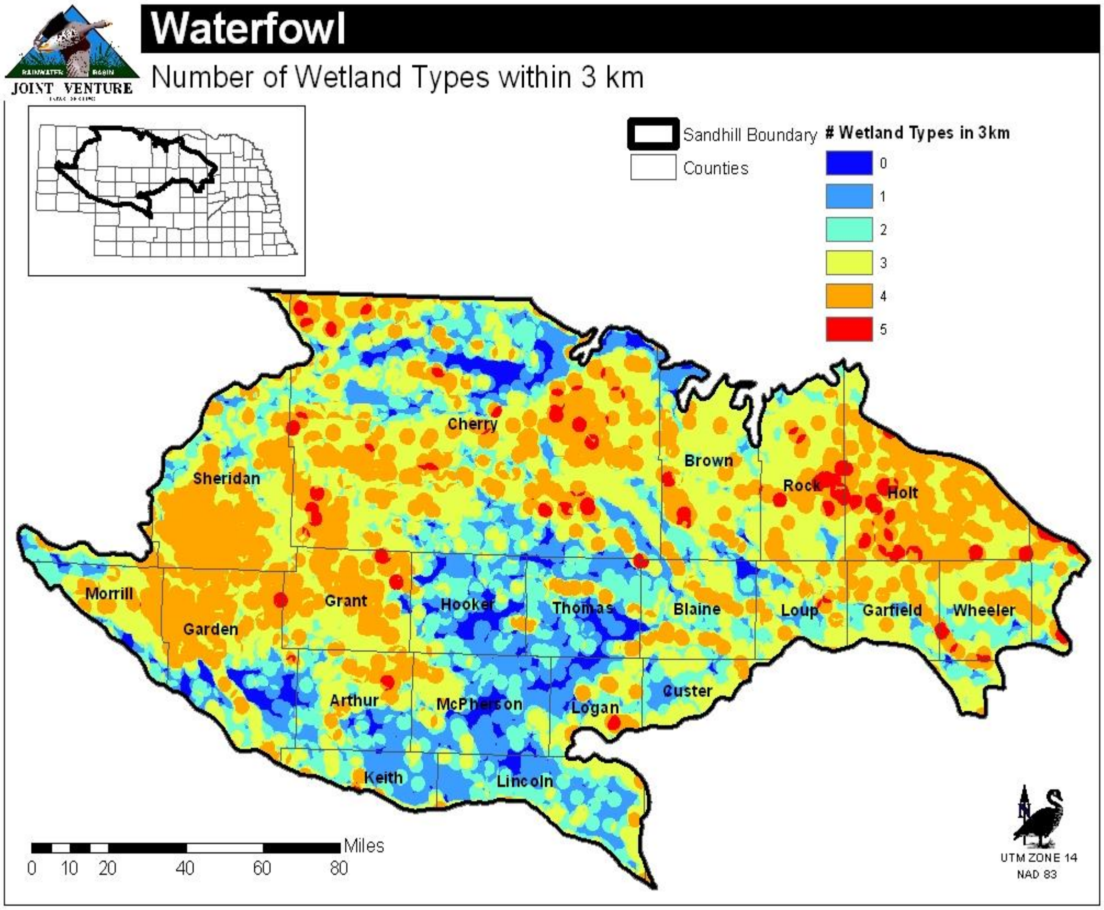

Figure 2. Wetland diversity in the Nebraska Sandhills, based on a moving window analysis at 3km (1.86 mi) radius.

GIS analysis of Trumpeter Swan observations (breeding and non-breeding birds) collected from 2000 to 2010 was completed to better define the local and landscape wetland characteristics for which Trumpeter Swans appear to select. Larger lacustrine and semi-permanent wetlands located in landscapes with a high density of wetlands were preferred (Figure 3).

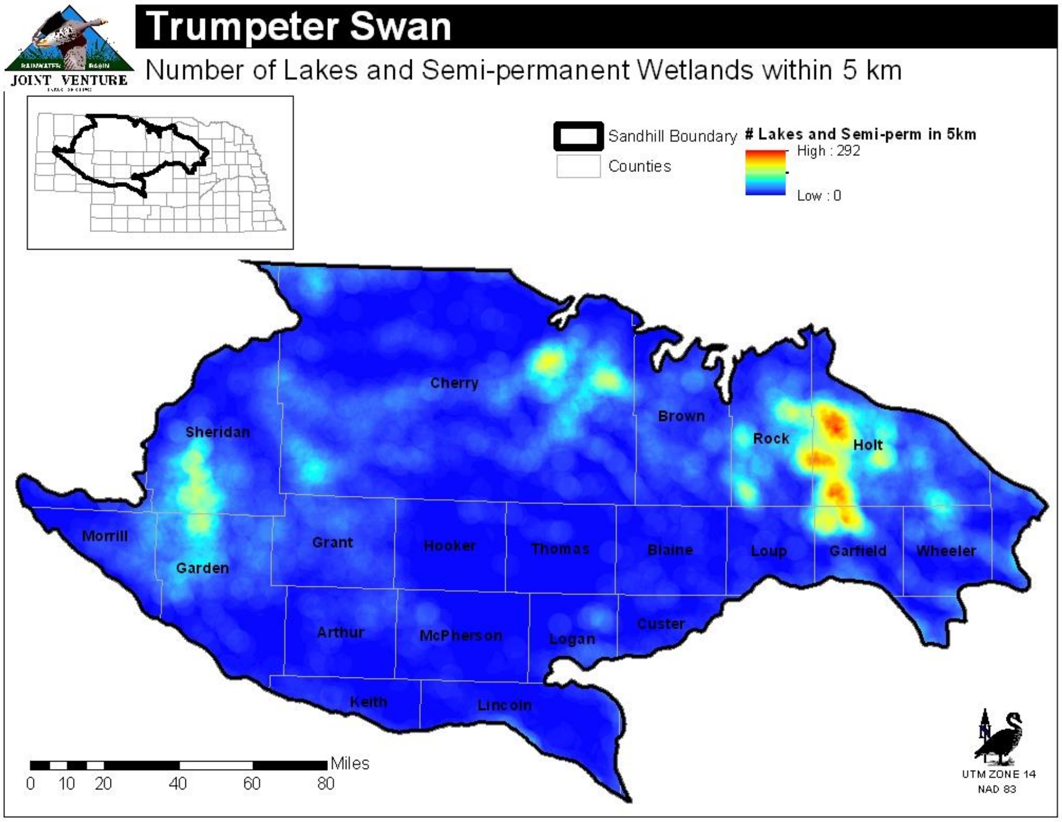

Figure 3. Density of semi-permanent emergent wetlands and Sandhills lakes for a habitat selection model identifying possible Trumpeter Swan nesting areas.

Sandhills Conservation Targets and Strategies

Target 1. Work with partners to identify conservation opportunities that can be developed to promote nesting waterfowl habitat on private lands managed for beef production.

Strategy A: Provide technical resources necessary to complete landscape-level surveys that can be used to define species-habitat relationships and identify priority landscapes for waterfowl conservation.

Strategy B: Develop conservation programs and strategies that will promote waterfowl nesting habitat and complement cattle operations in the Sandhills.

Conservation Delivery

Similar conservation approaches will be taken for breeding and non-breeding waterfowl, relying on partners' expertise, staff, existing conservation programs, and new conservation programs when needed to achieve targets. Conservation programs are grouped into two basic categories: short-term or long-term.

Short-term programs are typically carried out under ten-year agreements. The agreements are designed to complement existing environmental and socio-economic conditions and can be tailored to the specific wishes of the landowner. They often provide financial as well as technical assistance for such practices as wetland restoration, removing concentration pits, and vegetation management. Some of these agreements augment USDA Farm Bill programs.

Acquisition and long-term programs (30 years or more) generally involve the fee-title purchase of lands or the purchase of conservation easements. Easement acquisitions are accomplished by various partners within the RWBJV, with individual partners taking the lead in their respective acquisitions. The RWBJV helps the purchaser identify potential properties, assists with funding, and helps facilitate long-term management. All acquisitions are strictly on a voluntary-seller basis.

It is believed that publicly owned wetlands can provide their share of natural wetland forage through appropriate land and water management. Appropriate management keeps wetlands in early succession, producing a high density of native, seed-producing plants. When management is insufficient or absent, plant communities can lose a majority of their seed production capability (Fredrickson and Taylor 1982, Reid et al. 1989). Management practices can include planned implementation of intense grazing, disking, herbicide application, pumping, and other measures.

Data obtained from Light Detection and Ranging (LiDAR) technology (Tang et al. 2012) is one tool that will be used to assist the RWBJV in the development and implementation of conservation practices to increase ponding frequency and duration. The topographic detail provided by LiDAR is critical to determine water flow that results from rain events and snow melt. The RWBJV has used these data to identify which concentration pits most negatively impact wetlands. Over 1,000 high-priority concentration pits are currently identified.

Research and Monitoring

Non-breeding Populations

Research and monitoring efforts will continue to focus on environmental factors that have the greatest influence on surface water and natural wetland forage in the RWB. It is assumed that as information and technology are obtained, these will be applicable to other areas of the RWBJV Administrative Area as well. Research and monitoring also will focus on variables that best measure waterfowl response to management, including species abundance, residency time, forage abundance, and carrying capacity. Effort is already underway to develop methodology to more accurately assess waterfowl numbers and habitat use during spring migration. An effective and reliable survey is expected to require a combination of ground counts, remote sensing platforms, and statistical extrapolations.

Data are currently being collected via a Structured Decision Making process to more accurately measure the energetic value of various wetland plant communities and to identify management actions which achieve those desired plant communities. Continued monitoring of the acreages of different plant communities and their energetic production will measure progress toward reaching the 4.4 billion kcal target, and will help determine the restoration and management actions that most effectively maintain desirable plant communities and re-establish natural hydroperiods.

In other wetland complexes located in the RWBJV Administrative Area, the RWBJV lacks good estimates of habitat needs or carrying capacity. The RWBJV will need to establish a matrix to evaluate habitat needs of waterfowl that depend on these wetland complexes during migration to better guide conservation goals and objectives. This matrix will allow the partners to evaluate current carrying capacity and, if necessary, to establish habitat goals to support the desired levels of waterfowl that depend on these regions.

Breeding Populations

The distribution and abundance of breeding waterfowl across the RWBJV Administrative Area, especially in the Sandhills, are not well understood. To obtain information identifying landscapes with high use by breeding waterfowl, the RWBJV will help initiate surveys similar to the four-square-mile surveys conducted in the Prairie Pothole Region (Cowardin et al. 1995). Access to wetlands will be difficult, due to the limited number of roads and the fact that over 99% of wetlands are in private ownership. Multiple-year sampling also will be needed, to account for temporal variability.

Research and monitoring are needed to provide insights into the local and landscape habitat features and management actions necessary to increase duck nesting success and recruitment in the Sandhills. Although duck nesting densities are not as high as those found in the Prairie Pothole Region, the amount of grassland currently present in the Sandhills would appear to be conducive to high nesting success (Stephens et al. 2005). However, nesting success appears to be low (Glup 1987, Walker et al. 2008); increased nest success would likely increase duck recruitment from the Sandhills region.

Because livestock grazing is the primary land use in the Sandhills, an improved understanding is needed of how different grazing systems may affect duck recruitment as well as beef production. This knowledge could lead to conservation programs that encourage grazing systems that benefit both the waterfowl and the ranching community.

The carrying capacity and possible limiting factors for Trumpeter Swans in the Sandhills are unknown. The initial population target of 500 individuals needs to be re-evaluated, since the population has exceeded that level and continues to increase at a rate of 4.2% each year (Comeau and Vrtiska 2010).

Summary

The RWBJV Administrative Area has an abundance of wetland resources that provide both non-breeding and breeding waterfowl habitats, supporting a significant proportion of the continent's waterfowl during a portion of their annual life cycle. Conservation by the RWBJV for non-breeding waterfowl habitat will be primarily focused in the RWB. Strategies will include a combination of acquisition and long- and short-term conservation programs. Vegetation management and hydrologic restoration activities will be pursued to increase the ponding frequency and habitat value of project lands.

Conservation delivery to benefit breeding waterfowl will be focused in the Sandhills, where projects will be focused towards those landscapes with a high density of wetlands that have a variety of water regimes. These projects will need to complement cattle production, the predominant agriculture land use. All conservation programs will be developed on a voluntary basis with willing participants.

The RWBJV will support research and monitoring activities to address key uncertainties and validate current planning assumptions. Future priority research and monitoring projects include validation of estimated waterfowl use in the RWB during spring migration, determining seed production from wetlands under different management and ownership, and monitoring management to better understand vegetation response to different management actions. In the Sandhills, research and monitoring will focus on habitat selection and the limiting factors to recruitment by breeding waterfowl.

Appendix A

Energetic Requirements of Migratory Waterfowl Using the Rainwater Basin Region

Migratory waterfowl rely on the Rainwater Basin (RWB) wetland complex for rest and food. Waterfowl that maintain or increase their lipid reserves during migration appear to have higher recruitment (Dubovsky and Kaminski 1994, Dzus and Clark 1998, Devries et al. 2008, Anteau and Afton 2009). Gaining adequate lipid reserves allows females to arrive on the breeding grounds in better physical condition and to secure better nesting habitat (Devries et al. 2008). Also, females in better physical condition tend to produce larger clutches and are more likely to re-nest if the initial nest is lost (Krapu 1981, Dubovsky and Kaminski 1994). Waste grain is abundant within the RWB, but waste grain is deficient in many of the nutrients found in natural foods (Loesch and Kaminski 1989, Krapu et al. 2004, Baldassarre and Bolen 2006). Loesch and Kaminski (1989) and Reid et al. (1989) found that naturally occurring wetland plant seeds were a necessary component of duck diets to offset protein and mineral deficiencies associated with agriculture-based food sources.

Estimating how much natural food is needed by spring-migrating waterfowl depends on several factors: the number of birds of each species that use the area during spring migration, the average number of days waterfowl spend in the area during migration, daily energetic requirements of each species, and the portion of the daily energetic requirement that should come from natural wetland plants. These factors, in turn, are based on assumptions regarding population estimates, wetland seed production, and the impact of vegetation management.

Establishment of population objectives for the RWB requires accurate estimates of waterfowl use and turnover rates. The vast waterfowl numbers, their mobility, and their distribution across the area make it very difficult to obtain accurate estimates. Current population objectives for the RWB come from the best data available, but lack the precision needed to make accurate energetic estimates. The RWBJV has made it a priority to develop a survey protocol to acquire

Table A-1. Continental population goals identified in the North American Waterfowl Management Plan (NAWMP) for primary or priority species within the Rainwater Basin during spring migration (NAWMP 2004).

Ducks	**NAWMP Goal**
Mallard	8,200,000
Northern Pintail	5,600,000
Blue-winged Teal	4,700,000
American Wigeon	3,000,000
Northern Shoveler	2,000,000
Green-winged Teal	1,900,000
Gadwall	1,500,000
Geese	
Lesser Snow and Ross's Geese	1,500,000
Greater White-fronted Goose	600,000
Canada Goose	
(Great Plains & Western Prairie populations)	285,000
(Tall Grass Prairie population)	250,000

accurate and comprehensive data on waterfowl use and turnover.

Current estimates of wetland forage (energetic) production are based on preliminary research within the RWB and on research conducted in other regions. Additional data are needed to validate or refine current production estimates. Management (e.g., disking, spraying) is conducted annually on some portion of publicly owned wetlands, with the assumption that the applied practice is the most effective. However, it is not certain if the effectiveness of a particular practice is due to current conditions, or if past years' treatments set the stage for the current management to be successful.

Because livestock grazing is used on a number of wetlands, it is important to better understand livestock grazing applications. Effective grazing depends greatly on its timing, intensity, and duration. In turn, each of these variables needs to be adjusted according to changes in climate and water conditions. Improved understanding of grazing effects is a priority for future research and monitoring.

Population Objectives for the Rainwater Basin during Spring Migration

Numbers of waterfowl in the RWB, and their duration of stay, vary with climatic conditions (Gersib et al. 1989, Vrtiska and Sullivan 2009). Above-normal water conditions in the RWB and extensive snow cover to the north generally cause a higher build-up of bird numbers. In contrast, mild, dry conditions may reduce the number of migrating birds and their length of stay. However, even in drier years, the area's wetlands provide critical staging habitat that directly influences body condition (Gersib et al. 1989).

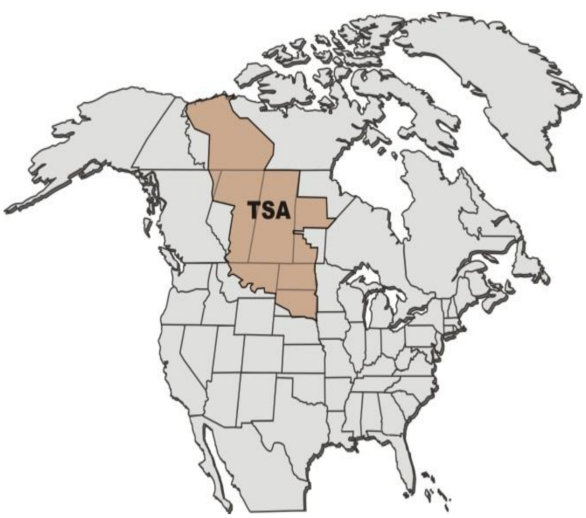

Figure A-1. Traditional Survey Area (TSA) surveyed annually to estimate waterfowl breeding populations (U.S. Fish and Wildlife Service 2012).

Information obtained from survey data and published literature was used to refine NAWMP population objectives (NAWMP 2004) to describe the numbers of waterfowl that would use the RWB if continental population objectives were reached (Table A-1). Spring survey data were used whenever possible, and for those duck species for which limited survey information was available, information on geographic distribution of birds during spring migration was used to extrapolate and estimate bird use in the RWB.

Bellrose (1980) quantitatively mapped waterfowl migration corridors, using the data collected from the Traditional Survey Area (TSA). The TSA covers 1.3 million square miles (Figure A-1) of the Dakotas, northeast to Ontario, and west to British Columbia, an area that produces the majority of the mid-continent population of dabbling ducks (U.S. Fish and Wildlife Service 2012). The TSA includes strata 1-18, 20-50, and 75-77 from the annual May Breeding and Habitat Survey (U.S. Fish and Wildlife Service 2012). Average species-specific fall flight estimates were derived from Bellrose (1980) by summarizing the maximum population estimate described for each of the migration corridors. These species-specific average fall flight estimates were defined as the “Bellrose TSA Estimates”.

The following method was used to estimate the number of waterfowl using the RWB, based on Bellrose’s migration maps. Values described by Bellrose (1980) for each migration corridor intersecting the RWB were identified (Table A-2). When more than one corridor intersected the RWB, the maximum population estimate for the dominant corridor was added to the minimum population estimate for the peripheral corridor(s). The migration corridor values were then divided by the total Bellrose fall TSA estimate for each species (Table A-2) to estimate the proportion of the estimated total population that migrates through the RWB. Although Bellrose (1980) developed these estimates for fall migration, we applied them to spring migration, unless more accurate survey data were available.

Table A-2. Estimates and percent of duck populations that migrate through the Rainwater Basin region of Nebraska, based on estimates derived from the Traditional Survey Area (TSA) and from Bellrose (1980) migration maps.

Species	Bellrose’s Fall TSA Estimate	Estimated Number of Birds using the RWB	Percent of the Fall Migration
Mallard	12,975,000	1,501,000	11.6%
Northern Pintail	5,975,000	1,000,000	16.7%
Blue-winged Teal	4,165,000	750,000	18.0%
Northern Shoveler	1,295,000	216,100	16.7%
Gadwall	1,460,000	201,000	13.8%
Green-winged Teal	2,480,000	300,000	12.1%
American Wigeon	4,500,000	226,000	5.0%
Total		**4,194,100**	

Bellrose (1980) does not provide migration corridor information or estimates of the various goose species/subpopulations. Thus, the RWBJV developed RWB use estimates, or the percent of the population that migrates through the RWB, based on population range maps (Figure A-2; U.S. Fish and Wildlife Service 2012). For this analysis, the RWBJV assumed an even distribution of individuals across the species’ range during migration. GIS software was used to calculate the area (hectares) of each species’ or relevant sub-population’s range that occurred between the same latitudes as the RWB (north latitude $41^{0}20'$ and south latitude $40^{0}10'$). To develop RWB-use estimates by species and sub-population, the area of the RWB was divided by the total area of the population range determined to be at the same latitude (Table A-3).

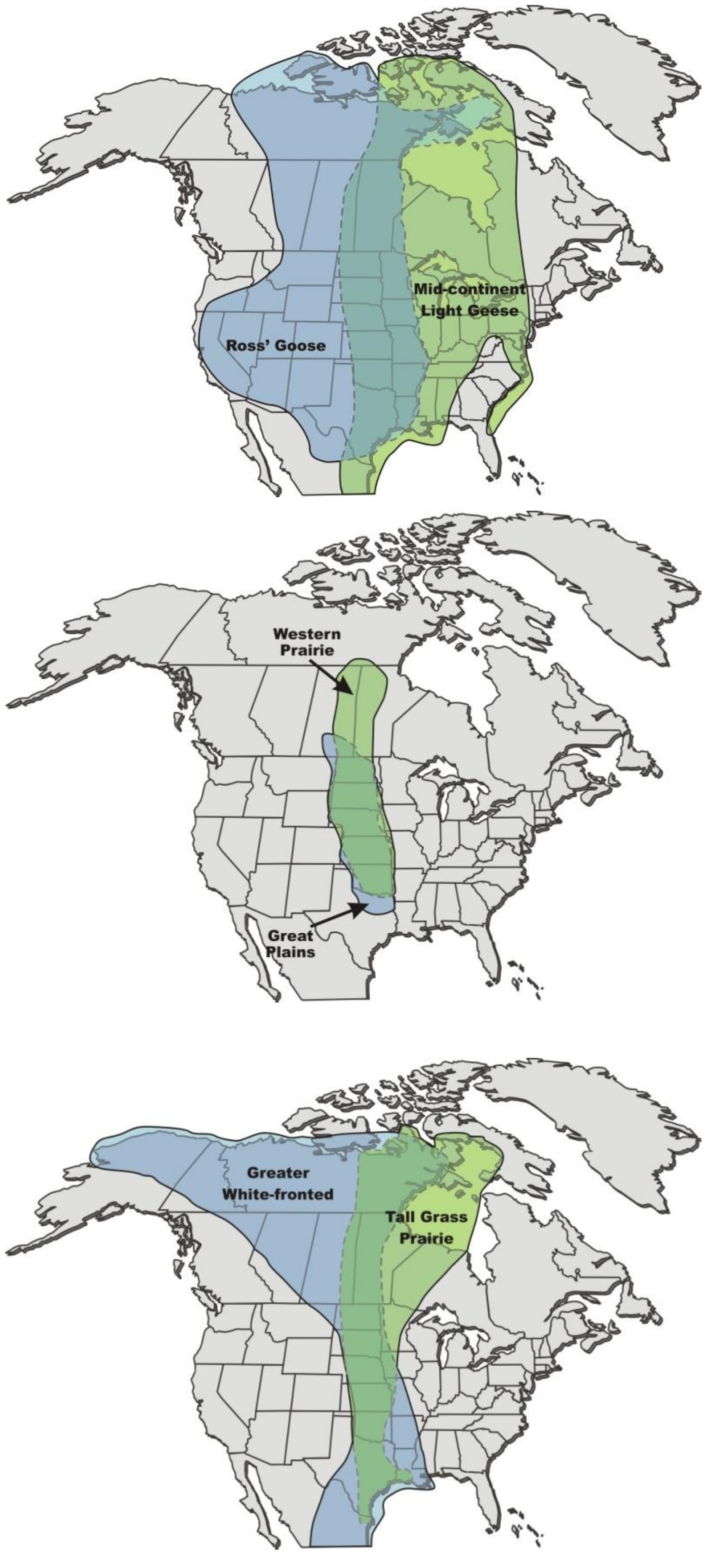

Figure A-2. Approximate range of North America goose populations migrating through the Rainwater Basin region of Nebraska (U.S. Fish and Wildlife Service 2012).

Table A-3. Estimated percentage of continental goose species and sub-populations that migrate through the Rainwater Basin area of Nebraska.

Species	Latitude Range Area (ha) [1]	RWB Latitude Area (ha)[1]	RWB Use Estimate (Percent)
Lesser Snow and Ross's geese	29,620,449	3,470,116	12
Greater White-fronted Goose	7,786,549	3,470,116	45
Canada Goose (GPP/WPP[2] populations)	8,384,481	3,470,116	41
Canada Goose (TGPP[3] population)	7,606,007	3,470,116	46

[1]Area determined in GIS using population range maps from Waterfowl Status Report (USFWS 2012).
[2]Great Plains Population/Western Prairie Population.
[3]Tall Grass Prairie Population.

The RWBJV Waterfowl Plan population objectives are based on the NAWMP population objectives (NAWMP 2004; Table A-1). The RWBJV slightly modified the NAWMP population objectives for duck species, so that the RWBJV Waterfowl Plan would reflect the number of ducks associated with the TSA that potentially migrate through the RWB. This was done by subtracting the Alaska portion of the TSA (strata 1-12), from the total TSA estimate, since these birds traditionally use the Pacific Flyway (Table A-4). The RWBJV analyzed the 1970 – 1979 population estimates from the May Annual Surveys., corresponding to the time period used to set the original NAWMP population objectives.

Table A-4. The 1970–1979 average population estimates from the annual May Breeding Waterfowl and Habitat Survey and proportion of ducks from the Traditional Survey Area that potentially use the Rainwater Basin area of Nebraska.

Species	Population Estimates from All Traditional Survey Strata (Strata 1-18, 20-50, 75-77)	Population Estimates: Traditional Survey Area Excluding Alaska (Strata 13-18, 20-50, 75-77)	% of Population that Potentially Use the RWB
Mallard	8,199,309	7,937,818	96.8
Northern Pintail	5,595,897	4,661,417	83.3
Blue-winged Teal	4,652,673	4,650,836	100.0
Northern Shoveler	1,990,107	1,884,392	94.7
Gadwall	1,517,811	1,516,768	99.9
Green-winged Teal	1,857,780	1,614,912	86.9
American Wigeon	2,974,035	2,574,634	86.6
Total	**26,787,611**	**24,840,777**	**92.7**

To calculate the adjusted NAWMP population objectives, the original NAWMP population objectives (NAWMP 2004; Table A-1) were multiplied by the percentage of the population that potentially uses the RWB (Table A-4). To establish the RWB population objectives, the adjusted NAWMP objective (Table A-4) was multiplied by the estimated proportion of duck and goose populations that migrate through the RWB (Tables A-2 and A-3).

Where published survey data were available, these percentages were used to derive the population objectives for waterfowl using the RWB. For example, Gersib et al. (1989) reported that 50% of the mid-continent population of Mallards and 30% of the continental population of Northern Pintails migrate through the RWB in spring. Vrtiska and Sullivan (2009) estimated that in certain years, upwards of 50% of the mid-continent Lesser Snow Goose population use the RWB. Benning (1987) documented that 90% of the mid-continent Greater White-fronted Goose population used the RWB region during spring migration.

Residency Time

Just as regional use varies during migration, the residency time of waterfowl using the RWB may differ between fall and spring migration. As described earlier, spring migration is climate-driven, and waterfowl follow the freeze line (an east-west oriented zone that shifts northward as wetlands thaw in the spring). The shallow nature of RWB wetlands causes them to thaw before wetland complexes at more northern latitudes. Gersib et al. (1989) noted that RWB wetlands were open seven to ten days before the lacustrine wetlands in the Sandhills. This results in large concentrations of waterfowl staging in the RWB before continuing north.

Fredrickson and Reid (1988) suggested that it would take at least three days for waterfowl to replenish nutrient resources after an eight-hour migration, and up to five days if habitat was limited and weather less than optimal. Pearse et al. (2011*b*) estimated that average residency time for Northern Pintails using the RWB was six days. Thus, for spring migration, a residency time of six days was used for all duck species. Estimates of three days for goose species were based on literature and professional opinion.

Table A-5. Estimated waterfowl population objectives for the Rainwater Basin region of Nebraska during spring migration.

Species	Adjusted NAWMP Population Objectives	% Using Rainwater Basin	RWB Population Objective (Estimated)
Mallard	7,940,000[1]	50[3]	3,970,000
Northern Pintail	4,665,000[1]	30[3]	1,399,000
Blue-winged Teal	4,698,000[1]	18[4]	846,000
Northern Shoveler	1,894,000[1]	17[4]	322,000
Gadwall	1,499,000[1]	14[4]	210,000
Green-winged Teal	1,652,000[1]	12[4]	198,000
American Wigeon	2,597,000[1]	5[4]	130,000
Estimated Spring Duck Population Objective			**7,075,000**
Lesser Snow and Ross's geese	1,500,000[2]	50[5]	750,000
Greater White-fronted Goose	600,000[2]	90[6]	540,000
Canada Goose (GPP/WPP)[8]	285,000[2]	41[7]	117,000
Canada Goose (TGPP)[9]	250,000[2]	46[7]	115,000
Estimated Spring Goose Population Objective			**1,522,000**
Estimated Spring Waterfowl Population Objective			**8,597,000**

[1]Adjusted NAWMP population objective, reflecting ducks from the Traditional Survey Area that potentially use the RWB.
[2]NAWMP population estimates for goose species and sub-populations.
[3]Gersib et al. (1989).
[4]Migration percent estimates derived from Bellrose (1980).
[5]Vrtiska and Sullivan (2009).
[6]Benning (1987).
[7]Based on estimates of population migrating through Rainwater Basin from GIS analysis of population range maps.
[8]Great Plains Population/Western Prairie Population.
[9]Tall Grass Prairie Population.

Daily Energetic Requirements by Species

To assess the daily energetic demand of waterfowl, the RWBJV developed estimates of species-specific Daily Energy Expenditure (DEE). DEE is defined as the energy (kilocalories) expended by wild birds engaged in routine daily activities (e.g., swimming, feeding) and not engaged in reproduction, molt, migration, or other activities (Baldassarre and Bolen 2006). DEE has been calculated to be three times a species' Basal Metabolic Rate (BMR) (King 1974). BMR is the energy required for normal cellular function and the replacement of worn tissue, and is strongly related to body size (Baldassarre and Bolen 2006).

A weighted average incorporating both age and sex ratios (Reinecke and Uihlein 2006) was used to develop a representative species-specific average body mass (Table A-6). Age ratios for ducks were taken from Bellrose (1961), and goose age and sex ratios were derived from Bellrose (1980). The exception was that Greater White-fronted Goose ratios were obtained from Pearse et al. (2011*a*). The Schmidt-Nielsen (1984) BMR equation was then used to estimate species-specific average body mass for each duck and goose species (Table A-6).

The Schmidt-Nielsen (1984) BMR equation is:

$$\text{BMR} = \alpha \text{ Mass}^{b}$$

where:

Mass = the species-specific, weighted mean body weight in Kg;
b = slope of the "all waterfowl" regression line; and
α = the mass proportionality coefficient (y-intercept at Mass equal to 1 Kg), with the values for *b* and α as those described by Miller and Eadie (2006; 422 and 0.74, respectively).

Table A-6. Average body mass values used to estimate daily energy expenditure of the primary waterfowl species migrating through the Rainwater Basin region of Nebraska.

	Adult Male		**Adult Female**		**Immature Male**		**Immature Female**		
Species	Ave. Mass (kg)	% Population	Ave. Mass (kg)	% Population	Ave. Mass (kg)	% Population	Ave. Mass (kg)	% Population	Weighted mean (kg)
Mallard	1.25	33	1.11	23	1.19	22	1.05	22	1.16
Northern Pintail	1.03	33	0.87	23	0.95	22	0.80	22	0.92
Blue-winged Teal	0.46	33	0.38	23	0.46	22	0.39	22	0.43
Northern Shoveler	0.68	33	0.64	23	0.64	22	0.59	22	0.64
Gadwall	0.97	33	0.83	23	0.86	22	0.78	22	0.87
Green-winged Teal	0.32	33	0.31	23	0.33	22	0.29	22	0.31
American Wigeon	0.82	33	0.77	23	0.79	22	0.71	22	0.78
Lesser Snow and Ross's geese	2.75	37	2.49	34	2.18	16	2.01	14	2.50
Greater White-fronted Goose	2.85	31	2.51	30	2.55	20	2.34	19	2.59
Canada Goose (GPP/WPP)	4.17	37	3.49	34	3.54	16	3.08	14	3.73
Canada Goose (TGPP)	2.77	24	2.45	23	2.49	27	2.18	26	2.47

[1]Great Plains Population/Western Prairie Population.
[2]Tall Grass Prairie Population.

DEE was increased by 3% to represent the additional energy required to sequester fat reserves and for body maintenance associated with spring migration (Table A-7). Estimated energy needs of each species were calculated by multiplying the species spring population number by the average residency time, by DEE + 3%. (Table A-8). For example, it is estimated that nearly 4 million Mallards use the RWB each spring, with an average residency time of 6 days, equalling approximately 24 million Mallard-use days. A Mallard's energetic requirement is approximately 348 kcals per day, totalling 8.3 billion kcals.

Total Estimated Energetic Requirements from Wetland Habitats

There is an abundance of waste grain in the RWB available to waterfowl during spring migration (Bishop and Vrtiska 2008); however, waste grains have been shown to be deficient in many of the nutrients found in natural foods (Sherfy 1999, Krapu et al. 2004). Reid (1989) found that naturally occurring wetland plant seeds were a necessary component of duck diets to offset protein and mineral deficiencies associated with agriculture-based food sources. Heitmeyer et al.

(1989) and others have highlighted the changes in foraging strategies and food selection during different periods of the annual life cycle. Baldassarre and Bolen (2006) described foraging strategies and diet selection by different species during wintering and breeding phases of the annual life cycle, but also highlighted the lack of data available during the non-breeding migratory phase. To address this lack of data, the RWBJV compiled forage selection estimates presented in scientific literature in order to estimate the proportion of waterfowl diets that should be derived from wetland habitats. When peer-reviewed literature results were not available, the RWBJV developed estimates based on the best information available (Table A-9). These values were used to estimate the amount of energy from wetland foraging resources that should be available to waterfowl in wetland habitats during spring migration (Table A-9).

Table A-7. Estimated average daily caloric needs of primary waterfowl species using the Rainwater Basin region of Nebraska during spring migration.

Species	Weighted Mean (kg)	BMR (kg/day)	DEE (kcal/day)	DEE + 3% (kcal/day)
Mallard	1.16	112.5	337.5	347.6
Northern Pintail	0.92	94.8	284.3	292.8
Blue-winged Teal	0.43	54	161.9	166.8
Northern Shoveler	0.64	72.4	217.3	223.9
Gadwall	0.87	90.9	272.8	281.0
Green-winged Teal	0.31	42.4	127.1	130.9
American Wigeon	0.78	83.9	251.6	259.1
Lesser Snow and Ross's geese	2.50	198.6	595.7	613.6
Greater White-fronted Goose	2.59	203.8	611.5	629.8
Canada Goose (GPP/WPP)[1]	3.73	267	801	825.0
Canada Goose (TGPP)[2]	2.47	196.8	590.4	608.1

[1]Great Plains Population/Western Prairie Population.
[2]Tall Grass Prairie Population.

In Iowa, spring-migrating Mallards derived over half of their diet from wetland forage resources, of which 30% were derived from wetland seeds (LaGrange 1985). Tidwell (2010) validated LaGrange's findings for Mallard forage selection in the RWB, and described Blue-winged Teal forage selection (80% wetland seeds). McKnight and Hepp (1998) documented that 99% of Gadwall diets were composed of natural wetland plant material, with seeds providing 0.02% of the total diet. However, the availability of foraging resources may have impacted selection. In Oklahoma, Miller et al. (2000) found that approximately 15% of Gadwalls' diets were derived from natural wetland foods, including pondweed, smartweed, duckweed, coontail, barnyard grass, buttonbrush, rushes, curly dock, and sedges. Invertebrates made up 25% of the diet, and the remainder (60%) came from agricultural plant material. Knapton and Pauls (1994) reported that 92% of the American Wigeon diet during fall migration was obtained from natural aquatic vegetation and 8% of the diet came from wetland seeds. Miller et al. (2000) found that approximately 10% of American Wigeon diets were derived from natural wetland foods; invertebrates provided 35% of the diet, and 55% came from agricultural plant material. Ankney and Afton (1988) reported that, on the wintering grounds, seeds provided 6-11% of the diet of Northern Shovelers, while invertebrates and wetland vegetation provided the remaining elements. Recognizing that spring staging is energetically expensive, and that seeds provide significantly higher energy content compared to plant material, the RWBJV set a goal of providing 35% of the diets of Northern Shovelers, Gadwalls, and American Wigeon. Values for the other species were derived from Pearse et al. (2010), Pearse et al. (2011*a*), Pearse et al. (2011*b*), and input from the RWBJV partners when no current literature was available.

The number of kcals that need to come from wetland-derived seed resources for each species was calculated by multiplying the total energy needed by the respective percentage of the diet that should come from natural wetland forage (Tables A-8, A-9). For example, 8.3 billion kcals are needed by Mallards. Estimating that 30% of a Mallard's diet during migration is natural wetland forage, then RWB wetlands must provide 2.5 billion kcals to support Mallards at population objectives (Table A-9).

Table A-8. Estimated energy needs of the primary waterfowl species using the Rainwater Basin region of Nebraska during spring migration.

Species	RWB Spring Population Objectives	Residency (Days)	DEE + 3% (kcal/day)	Total Energy (1000s kcals)
Mallard	3,970,000	6	347.6	8,279,982
Northern Pintail	1,399,000	6	292.8	2,457,880
Blue-winged Teal	846,000	6	166.8	846,598
Northern Shoveler	322,000	6	223.9	432,483
Gadwall	210,000	6	281.0	354,000
Green-winged Teal	198,000	6	130.9	155,530
American Wigeon	130,000	6	259.1	202,131
Duck Total	**7,075,000**			**12,728,603**
Lesser Snow and Ross's geese	750,000	3	613.6	1,380,533
Greater White-Fronted Goose	540,000	3	629.8	1,020,342
Canada Goose (GPP/WPP)[1]	117,000	3	825.0	289,575
Canada Goose (TGPP)[2]	115,000	3	608.1	209,799
Goose Total	**1,522,000**			**2,900,248**
Spring Total	**8,597,000**			**15,628,851**

[1]Great Plains Population/Western Prairie Population.
[2]Tall Grass Prairie Population.

Table A-9. Estimated energy requirements needed from wetland-derived seed resources for waterfowl using the Rainwater Basin region of Nebraska during spring migration.

Species	Total Energy (1000s kcals)	% Wetland Plant Seeds in Diet	Total Wetland kcals (1000s)
Mallard	8,279,982	30[1,2]	2,483,995
Northern Pintail	2,457,880	30[3]	737,364
Blue-winged Teal	846,598	80[2]	677,278
Northern Shoveler	432,483	35[4]	151,369
Gadwall	354,000	35[5]	123,900
Green-winged Teal	155,530	70[6]	108,871
American Wigeon	202,131	35[7]	70,746
Duck Subtotals	**12,728,603**		**4,353,522**
Lesser Snow and Ross's geese	1,380,533	1.0[8]	13,806
Greater White-fronted Goose	1,020,342	2.0[9]	20,406
Canada goose (GPP/WPP) [10]	289,575	2.0[6]	5,784
Canada goose (TGPP) [11]	209,799	2.0[6]	4,196
Goose Subtotals	**2,900,248**		**44,200**
Spring Total	**15,628,851**		**4,397,722**

[1]LaGrange (1985).
[2]Tidwell (2010).
[3]Pearse et al. (2011*a*).
[4]Professional opinion of RWBJV Implementation Plan Team based on Ankney and Afton (1988).
[5]Professional opinion of RWBJV Implementation Plan Team based on McKnight and Hepp (1988) and Miller et al.(2000).
[6]Professional opinion of RWBJV Implementation Plan Team.
[7]Professional opinion of RWBJV Implementation Plan Team based on Miller et al. (2000).
[8] Pearse et al. (2010).
[9] Pearse et al. (2011*b*).
[10]Great Plains Population/Western Prairie Population.
[11]Tall Grass Prairie Population.

Table A-10. Summary of wetland-derived energy requirements for spring-migrating waterfowl in the Rainwater Basin region of Nebraska.

Species	Spring Population Objectives	Ave. Residency (Days)	DEE+3% (kcal/day)	Total Energy (1000s kcals)	% Wetland Plant Seed	Wetland Seed Energy (1000s kcals)
Mallard	3,970,000	6	347.6	8,279,982	30%	2,483,995
Northern Pintail	1,399,000	6	292.8	2,457,880	30%	737,364
Blue-winged Teal	846,000	6	166.8	846,598	80%	677,278
Northern Shoveler	322,000	6	223.9	432,483	35%	151,369
Gadwall	210,000	6	281.0	354,000	35%	123,900
Green-winged Teal	198,000	6	130.9	155,530	70%	108,871
American Wigeon	130,000	6	259.1	202,131	35%	70,746
Duck Subtotals	**7,075,000**			**12,728,603**		**4,353,522**
Lesser Snow and Ross's geese	750,000	3	613.6	1,380,533	1%	13,805
Greater White-fronted Goose	540,000	3	629.8	1,020,342	2%	20,407
Canada Goose (GPP/WPP)[1]	117,000	3	825.0	289,575	2%	5,791
Canada Goose (TGPP)[2]	115,000	3	608.1	209,799	2%	4,196
Goose Subtotals	**1,522,000**			**2,900,248**		**44,200**
Totals	**8,597,000**			**15,628,851**		**4,397,722**

[1] Great Plains/Western Prairie Population.
[2] Tall Grass Prairie Population.

Appendix B

Developing Conservation Strategies for Wetlands within the Rainwater Basin

Wetlands in the Rainwater Basin (RWB) are shallow playa wetlands, known to fill from runoff following an intense thunderstorm or snow melt (LaGrange 2005). The watersheds of the wetlands are relatively small, resulting in quick changes in the wetlands' water level within hours of a weather event. The shallow water disappears after a few weeks or months of warm weather and winds. The quick change from wet to dry and back to wet conditions causes the wetlands to be better defined by the vegetation in the basin than by the presence of water.

Moist, bare wetland soils quickly become covered with early-succession plant species, such as barnyard grass and smartweed. Both species are preferred waterfowl food plants, because their seeds are abundant and high in nutritional value (Reinecke et al. 1989, Checkett et al. 2002). Waterfowl managers recognized the value of these species and began experimenting and refining techniques to promote early successional moist-soil vegetation communities (Fredrickson and Laubhan 1994). The art and science of propagating these wetland vegetation communities is described as "moist soil management". Moist soil management integrates active management actions to promote exposed saturated soil by irrigation and/or drawdown to promote germination, growth, and seed production of desired plants on mudflats to support foraging needs of waterfowl (Haukos and Smith 1993).

Haukos and Smith (1993) evaluated the potential for using moist soil management techniques to maximize seed production in playa wetlands in order to provide migratory habitat. They described a positive response of playa wetland vegetation communities to moist soil management. Actively managed playas provided 539,770 kcals/acre on average, while unmanaged playas only provided foraging resources of 27,110 kcals/acre. Reinecke et al. (1989) suggested that managed moist soil wetlands in the Mississippi Alluvial Valley could provide approximately 400,000 kcals/acre. Rabbe et al. (2004) computed the average energetic resources from seeds produced by early-successional vegetation communities found in RWB wetlands to be approximately 210,000 kcals/acre. This appears logical, since the RWB landscape generally has greater precipitation and better growing conditions than playas found in the Southern High Plains, but it also reflects the limited active moist soil management actions implemented to maximize seed production by early-successional wetland vegetation communities. For planning purposes, the RWBJV set a value of 250,000 kcals/acre as the energetic resources estimated to be available in early-succession moist soil wetland communities.

Wetlands in which the early-succession plant community is left undisturbed will slowly become dominated by late-succession plants, such as river bulrush, cattail, and reed canary grass. Late-successional plants rely less on seed production to propagate, and more on rhizomes and tubers. This group of plants has low nutritional value for waterfowl. Rabbe et al. (2004) estimated food production by late-succession plant communities to be about one-tenth that of early-successional vegetation, with cattail producing about 13,600 kcals/acre; reed canary grass, 12,000 kcals/acre; and river bulrush, 2,700 kcals/acre.

The dramatic difference in natural food production between early- and late-succession vegetation makes management a critical part of achieving adequate migration habitat for waterfowl. Wetland management is highly dependent on the objectives or values of the land manager.

Wetlands in public ownership through conservation agencies are managed more intensely to reduce late-succession plant communities and promote early-succession communities, in the interest of yielding higher food production. Conversely, privately owned wetlands are normally farmed if they are small and dry enough to be tilled. Private wetlands that are too wet for tilling are normally farmed around, leaving the wetland undisturbed and therefore dominated by late-succession plants.

Because land ownership and vegetation management are key factors in determining the quantity of habitat available, the RWBJV classified wetlands based on ownership and management. Four main wetland groups were identified:

- Public wetlands (owned and managed by conservation agencies for the benefit of waterfowl and wildlife),
- Privately owned, long-term conservation wetlands (protected by 30-year to perpetual easements),
- Privately owned, short-term conservation wetlands (protected by 10- to 29-year conservation agreements, and
- Privately owned wetlands not involved in any type of conservation program.

Within each of the four wetland groups, the wetlands were then grouped by vegetative conditions. The five vegetative conditions are:

- Early-succession vegetation (annual, high seed-producing plants).
- Late-succession vegetation (perennial, low seed-producing plants).
- Cropped wetlands (farmed during previous growing season).
- Tree dominated (dense woody vegetation).
- Upland plants (wetland soil, altered or dry enough to support upland plants).

Nutritional food production values are highest for early succession conditions and lowest for tree-dominated and upland conditions (Table B-1). This information was used to estimate what each wetland group will contribute to waterfowl forage production.

Table B-1. Nutritional food production values (kcals/acre) of vegetative conditions found in Rainwater Basin wetlands.

Vegetative Conditions	Kcals/Acre
Early-succession	250,000
Late-succession	25,000
Cropped Wetlands	100,000
Tree-dominated	0
Upland	0

Annual spring habitat surveys conducted in 2004-2012 provided the RWBJV with a measure of how much habitat, on average, is available during spring migration. The most critical factor in determining the number of acres appears to be the weather conditions preceding spring migration. Preliminary analysis of historic weather records showed that 2004 appears to be the most representative of average spring weather and water conditions. The acres of ponded water and vegetative conditions which occurred in 2004 were used to project what could be expected during average spring conditions.

Based on the estimate that 4.4 billion kcals of wetland-derived seed resources are needed to meet the nutritional needs of migrating waterfowl (Appendix A), and using 2004 water and vegetation conditions, the RWBJV determined a suite of strategies that can achieve the 4.4 billion kcal goal.

Public Wetlands

Publicly owned lands are the core of wetland habitat within the RWB. State and federal acquisition beginning in the early 1960's targeted the larger, more prominent wetlands. These wetlands were capable of providing water and habitat during spring migration. Currently, 96 wetland properties totaling 18,814 acres are in public ownership either as Waterfowl Production Areas managed by the U.S. Fish and Wildlife Service (USFWS) or as Wildlife Management Areas managed by Nebraska Game and Parks Commission (NGPC). Public wetlands represent 9% of the area's historic 204,436 wetland acres. Both agencies manage these lands for the benefit of migratory waterfowl, resulting in the public wetlands having the highest probability of providing resting habitat and natural foods.

Wetland acquisition has been a long-term process, depending on willing sellers, and these types of acquisitions often result in only a portion of the wetland becoming public property. The long-term goal is to acquire the remaining portions of wetlands (i.e., roundouts) adjoining public areas. GIS analysis has determined that there are 11,620 acres of hydric soils in private ownership that adjoin or are in close proximity to public wetlands. Split ownership between a public agency and a private landowner has caused about 10% of public wetlands to remain in a non-functioning state (Bishop and Vrtiska 2008).

Determining the Role of Public Wetlands

The RWBJV recognizes that management of these public lands will provide the majority of the 4.4 billion kcals necessary to meet waterfowl needs. The 2004 vegetation survey found that wetland vegetation communities on public acres were approximately 64% in early-succession and 36% in late-succession condition (Bishop et al., 2004; Table B-2). If public wetlands under these vegetative conditions were 100% ponded during spring migration, they would be capable of producing 3.1 billion of the 4.4 billion kcals needed (Table B-2), with 96% of the kcals coming from early-succession wetland acres. This underlines the importance of wetland management toward early-succession vegetation.

Table B-2. Estimated natural food production (kcals) on public wetlands in the Rainwater Basin region of Nebraska, based on 2004 vegetation mapping (Bishop et al. 2004).

Vegetative Condition	Acres	% of Hydric acres	Ponding Frequency	kcal/Ac	Kcals Produced (1000s)
Hydric soils					
Early-succession	12,003	63.8	0.177	250,000	531,133
Late-succession	4,835	25.7	0.177	25,000	21,395
Unsuitable habitat (developed)	396	2.1	0.177	0	0
Upland plants	1,580	8.4	0.177	0	0
Subtotal	18,814	100.0			552,528
Non-hydric soils					
Upland plants	13,268			0	0
Total	**32,082**				**552,528**

Even with optimum management, only about 80% of the wetland acres will be early-succession communities, providing for optimum food production. Direct management of the public land should be sufficient to achieve this nutritional goal; however, another key variable is ponding frequency and ponded-water area. The ability of the wetlands to pond runoff depends on the amount of cumulative degradation that has occurred within each wetland's watershed. It is anticipated that under average climate conditions, wetlands could reach a ponding frequency of 45%. Given current information available, spring 2004 appears to most closely represent average climate conditions. However, even 2004 fell short of the 45% level. During the 2004 "average" weather conditions, water ponded on only 3,300 public acres (17.7%) during spring migration and provided an estimated 552,527,625 kcals. However, if the conservation actions outlined in this plan were implemented on public lands, these properties could support just over 50% of the foraging needs (2.2 billion kcals) of spring migrating waterfowl (Table B-3).

Public Wetland Strategies (Target 1)

The RWBJV identified a public land target: "*By 2030, publicly owned wetlands will provide 55% of the total natural forage needed by waterfowl within the Rainwater Basin*". Listed with this goal, three management strategies will collectively allow public wetlands to provide 2.47 billion kcals by addressing wetland acquisition, vegetation management, and ponding frequency of public wetlands.

Strategy A: Increase public wetland acres from 18,814 to 26,800. Priority will be given to "roundouts" to existing public wetlands. Additional roundout acres will increase the forage production for waterfowl on many publicly managed wetlands.

This strategy was intended to place wetlands under a single, public ownership. Acquisition of roundout acres is expected to result in more resilient wetland systems that may require less vegetation management and should experience increased frequency and duration of ponding. Potential priority roundout acquisitions were identified based on the following: 1) the size of the roundout had to be a minimum of 5 acres; 2) the public portion of the wetland had to be a minimum of 5 acres in size; and 3) the public portion contained more than 10% of the hydric footprint. In some situations, these criteria may not apply. For example, a wetland restoration that requires the removal of a surface drain or subsurface tiles will require the purchase of the entire hydric footprint to make the project viable.

Using GIS, 10,655 acres were deemed to meet these three criteria. The RWBJV accepted 75%, or 7,990 acres, as a realistic goal to achieve over the next 30 years. GIS also will be used to prioritize roundouts that provide the greatest opportunities to fill concentration pits, plug surface drains, and pump water as necessary without negatively affecting adjoining private lands. Ideally, such acquisition and subsequent restoration would improve wetland functionality, especially to those public acres that currently exhibit no wetland function (1,975 acres).

Strategy B: Through management, maintain 80% of public wetland acres in an early successional state to optimize moist-soil seed production.

To reach the goal of 2.47 billion kcals on public wetlands, this strategy is critical. Plant communities are not static, and although newly managed areas are dominated with early-succession vegetation, unmanaged areas are moving toward late-succession vegetation. A target of 80% early-succession is an aggressive, but achievable, target.

Preliminary analysis of public land management indicates that wetlands that are fully restored and have an intact watershed require less management to maintain desirable vegetation. The change from late-succession to early-succession will result in a five-fold increase in natural food production.

<u>Strategy C:</u> Increase ponding frequency under average moisture conditions from 18% to 45%.

In addition to increasing the number of public wetland acres, the frequency with which these wetlands hold water during spring migration needs to be increased. The RWBJV has targeted a ponding frequency of 45% compared to the current 17.7% that occurs in average years.

The presence of water concentration pits associated with gravity-flow irrigation is a significant cause of low ponding frequencies. Within watersheds containing public wetlands are 874 pits which have an aggregate capacity of 3,263 acre-feet, approximately 19% of the total capacity of the historic wetlands (Bishop and Grosse 2012). In addition, alterations within the wetlands (e.g., pits, culturally accelerated sediment, roads, road ditches and drains) need to be evaluated prior to implementing restoration. This strategy seeks to increase the ponding frequency of public wetlands by affecting the natural watershed hydrology. The filling of 656 pits (75% of the existing pits) is expected to increase ponding from 17.7% to 45%.

All RWB wetlands were in private ownership at one time, and numerous attempts were made by their owners to increase their cropping potential (McMurtrey et al. 1972). Both the USFWS and NGPC have made significant progress in restoring these wetlands to the most feasible extent, and in promoting the natural hydrologic characteristics of each wetland. Efforts have included filling concentration pits, removing surface drains, re-contouring waterways, excavating fill material, and removing culturally accelerated sediment.

Many of the public wetlands have a past cropping history and contain high-capacity irrigation wells. Both the USFWS and NGPC use these high-volume wells to provide supplemental water during fall and spring migration. The RWBJV partners continue to upgrade these wells and drill new wells when necessary. Priority is given to properties where a significant portion of the wetland is under public ownership and the wetland can be pumped without negatively impacting adjacent landowners.

<u>Strategy D:</u> Increase the number of upland buffer acres from 13,268 to 17,793 through fee-title acquisition or long-term easements.

Acquisition of upland buffers commonly occurs in conjunction with the acquisition of wetland acres. Squaring off a property boundary is commonly done for ease of farming and recording real estate transactions. In cases where a proposed boundary does not provide adequate grassland buffer for sediment control, efforts will be made to obtain an adequate buffer (e.g., through long-term easements).

Table B-3. Estimated food production (kcals) on public wetlands in the Rainwater Basin region of Nebraska if goals for acres and ponding frequency are met.

Vegetative Condition	Acres	% of Hydric Acres	Ponding Frequency	Kcal/Ac	Kcals Produced (1000s)
Early-succession	21,443	80	0.45	250,000	2,412,360
Late-succession	5,361	20	0.45	25,000	60,309
Totals	26,804	100			2,472,669

Private Long-term Conservation Lands

Long-term conservation wetlands are treated as a distinct group of privately owned wetlands because they provide assurance that, for the duration of the agreement, they will not be destroyed or altered. Wetlands grouped in this classification are protected for 30 years or more and include wetlands protected by the U.S. Department of Agriculture's Wetlands Reserve Program (WRP), Ducks Unlimited Inc.'s Working Lands easements, USFWS grassland/wetland easements, and wetland/grassland easements held by local natural resources districts.

Long-term conservation of privately owned wetlands is relatively new in the RWB. WRP is administered by the Natural Resources Conservation Service, which purchased its first easement in 2001. To date, Ducks Unlimited, USFWS, Tri-Basin Natural Resources District, Little Blue Natural Resources District, and Upper Big Blue Natural Resources District are holding long-term (at least 30 years) conservation easements.

Easements purchased by Ducks Unlimited are usually associated with their Working Lands program. The program acquires flood-prone cropped wetlands and adjacent uplands and restores the wetland to its highest functionality. Uplands are re-seeded to grassland. The property is then sold to a private buyer, with a perpetual conservation easement placed on it. The easement allows livestock grazing and haying, but prohibits development and/or conversion of the wetland and upland to crop production. The program helps provide producers with an economic incentive to transition frequently ponded cropland from row crops to livestock production. It also helps reduce groundwater consumption and increase groundwater recharge.

Easements purchased by the USFWS also promote livestock grazing and prohibit development, and are also perpetual. They differ, however, in the acquisition process. USFWS easements generally are acquired after the wetlands and uplands have been restored. This criterion requires the RWBJV to work with the landowners who have existing wetlands and grasslands, or to restore the land prior to selling the easement.

The diversity of easements and agencies allows sellers to select an option that best suits their situation. Currently, there are 77 properties (6,346 acres) enrolled in long-term conservation agreements, protecting 3,448 acres of wetlands.

Determining the Role of Long-term Conservation Wetlands

Wetland vegetation mapping data from 2004 showed that private wetlands with this protected status had 80% of their wetland acres in early-succession and 20% in late-succession vegetation

(Bishop et al. 2004) (Table B-4). The high percentage of early-succession communities was attributed to the recent restoration work of newly enrolled wetlands and the encouragement of intensive grazing to control plant succession. Total natural forage produced in 2004 was estimated at 168 million kcals, which represent about 17.8% of the 1.1 billion kcals that the RWBJV estimates are needed from long-term conservation wetlands (Table B-4).

Ponding frequency in 2004 was 24% (Table B-4). As with public wetlands, ponding frequency is affected by alterations within the wetlands and by water concentration pits in the surrounding watersheds, which intercept runoff before it reaches the wetlands. Insufficient data exist to assess the integrity of these wetlands' watersheds, or the extent to which they are affected by pits. However, if the density of pits is similar to the density in public watersheds, inferences can be made. For public wetlands, there is an average of 5 pits per watershed, each holding an average of 3.7 acre-feet of water. The 77 existing long-term conservation wetlands may have an estimated 385 pits, storing approximately 1,425 acre-feet of water.

Table B-4. Estimated natural wetland food production on long-term conservation wetlands in the Rainwater Basin region of Nebraska in 2004.

Vegetative Condition	Acres	% of Acres	Ponding Frequency	Kcal/Ac	Kcals Produced (1000s)
Early-succession	2,734	79.3	0.24	250,000	164,040
Late-succession	683	19.8	0.24	25,000	4,098
Tree dominated	3	0.1	0.24	0	0
Upland plants	28	0.8	0.24	0	0
Totals	**3,448**	**100.0**			**168,138**

Privately Owned, Long-term Conservation Wetlands (Target 2)

The RWBJV established a target for long-term conservation wetlands which states: *"By 2030, long-term conservation wetlands will meet 25% of the total natural forage needed by waterfowl in the Rainwater Basin"*. Four management strategies were identified which will collectively help long-term conservation wetlands provide 1.1 billion kcals (Table B-5).

Table B-5. Predicted natural wetland food production of long-term conservation wetlands, if goals for acres and ponding frequency are met.

Vegetative Condition	Target Acres	% of Target Acres	Ponding Frequency	Kcal/Ac	Kcals Produced (1000s)
Early-succession	9,515	75	0.45	250,000	1,070,439
Late-succession	3,172	25	0.45	25,000	35,685
Totals	**12,687**	**100.0**			**1,106,123**

<u>Strategy A:</u> Increase the number of wetland acres from 3,448 to 12,687 through conservation easements or other long-term conservation programs.

Purchase of easements alone will not be adequate to meet the goal of providing 1.1 billion kcals. Hydrologic restoration and vegetation management must also be an integral part of this strategy.

<u>Strategy B:</u> Through management, maintain 75% of these wetland acres in early-succession plant communities.

Livestock grazing is expected to reduce seed production within the wetland. On the other hand, annual grazing may reduce late-succession vegetation and also reduce stand height, creating openings in dense stands of vegetation. These outcomes would potentially offset the reduced seed production. Incentives would provide cost-share assistance for necessary infrastructure, such as perimeter fence, cross fences, and livestock watering facilities.

<u>Strategy C:</u> Increase ponding frequency under average moisture conditions to 45%.

Removing at least 75% of the water concentration pits within watersheds of long-term conservation wetlands would provide an estimated 1,068 acre-feet of additional runoff. Hydrologic modeling predicts the additional water would add approximately 3,687 acres of ponded habitat (under average climate conditions). The additional ponded acres would allow the RWBJV to reach the targeted 45% ponding frequency. Alterations within the wetlands (e.g., pits, drains, and culturally accelerated sediment) also need to be addressed through restoration.

<u>Strategy D:</u> Increase the number of upland buffer acres from 2,899 to 7,245 through conservation easements or other conservation programs.

A ≥50-meter buffer around a wetland may provide an appropriate barrier to reduce sedimentation and pollution from agricultural runoff. The acreage target was determined using GIS to evaluate wetlands currently under long-term protection. Delineating a 50-meter buffer around those wetlands resulted in one acre of upland buffer for every 2.1 acres of wetland. Using this ratio, the addition of 9,239 wetland acres would call for an additional 4,346 acres of upland. This number represents the minimum acres of upland buffer. Properties currently enrolled in long-term conservation generally have a higher upland-to-wetland ratio (1:1.2). The higher ratio has often been a result of land ownership patterns and the transition of full tracts with flood-prone acres back wetland and grassland, with the goal of developing viable grazing lands on these sites. If this trend continues, the acquisition of 9,239 wetland acres would enroll 7,700 acres of upland.

Private Short-term Conservation Lands

Short-term conservation agreements are the foundation of wetland conservation in the RWB. The intensely farmed landscape reflects a culture that promotes crop production from as many acres as possible. Conservation practices, such as restoring wetland habitat, are often seen as counter-culture and are viewed with skepticism by many local landowners and producers. Breaking this paradigm takes both time and successful examples of how wetlands can bring value to the owner and the community. Short-term conservation agreements have proven to be an effective strategy, with 127 signed agreements to date, affecting 2,481 wetland acres.

The agreements are voluntary, generally 10 years, but always less than 30 years in length, and promote a rapport between conservation agencies and private landowners. The fluctuating agricultural economy makes landowners apprehensive about committing their land for a long period of time. Short-term agreements allow landowners to improve wetland habitat without long-term commitments. The agreements bring landowners and conservationists together to design conservation projects that address wildlife needs and landowner concerns. The result also contributes to a greater level of trust toward conservation agencies.

The RWBJV used the 2004 survey data to measure vegetative conditions of wetlands involved in short-term agreements (Table B-6). Vegetation composition was 42% early-succession wetland community, 29% crop residue, and 29% late-succession wetland community (Bishop et al. 2004). The survey also reported 7%, or 175 wetland acres, of ponded water. This low rate of ponding greatly limited the ability of this group of wetlands to provide natural wetland food for migratory birds. With only 7% ponding, these wetlands provided about 24.5 million kcals (Table B-6). If those same wetlands were 100% ponded, that value would have reached 350.5 million kcals.

Table B-6. Natural wetland food production on short-term conservation wetlands in the Rainwater Basin in 2004.

Vegetative Condition	Acres	% of Acres	Ponding Frequency	Kcal/Ac	Kcals Produced (1000s)
Early-succession	1,042	42	0.07	250,000	18,235
Late-succession	720	29	0.07	25,000	1,260
Crop residue	719	29	0.07	100,000	5,033
Totals	**2,481**	**100**			**24,528**

Privately Owned, Short-term Conservation Wetlands (Target 3)

The RWBJV established a target for short-term conservation wetlands which states: *"By 2030, wetlands placed in conservation agreements of less than 30 years will provide 10% of the natural forage needed by waterfowl in the Rainwater Basin"*.

Achieving this goal depends greatly on landowner participation, which requires conservation agreements that have flexibility. Each agreement must be adapted to meet the specific needs of the landowner and the wetland resources. Numerous programs are currently available through the RWBJV. The programs demonstrate the RWBJV's commitment to developing wetland conservation that complements agricultural production.

Three management strategies were identified which will collectively help short-term conservation wetlands provide 44 million kcals (Table B-7).

Strategy A: Increase the number of wetland acres enrolled in conservation programs from 2,481 to 7,346 acres.

The wetland acres were derived based on projecting realistic vegetative conditions and ponding frequency that could be expected in the next 30 years. Increasing the amount of private wetland acres in short-term conservation programs will engage more landowners in wetland conservation.

Strategy B: Restore and maintain wetland plant communities at 60% early-succession, 30% farmed, and 10% late succession.

The 2004 survey data reported 29% of the vegetative condition to be late-succession, producing only one-tenth of the wetlands' potential food value for migrating waterfowl. Short-term conservation agreements will help shift much of the late-succession vegetation toward early succession. Cost-share incentives are available for such practices as restoration, intense grazing, disking, and herbicide application.

Strategy C: Restore watershed function so that ponding frequency reaches 33% under average moisture conditions.

Wetlands enrolled in short-term conservation are generally small and shallow, and in 2004, ponding frequency was only 7%. Removal or modification of even one water concentration pit within the associated watershed of such a wetland would increase the ponding frequency and duration. Other practices, such as removal of culturally accelerated sediment, seasonal water control structures, and control of late-succession vegetation, can contribute greatly toward reaching a 33% ponding frequency.

Table B-7. Predicted natural wetland food production of short-term conservation wetlands if goals for acres and ponding frequency are met.

Vegetative Condition	Target Acres	% of Target Acres	Ponding Frequency	Kcal/Ac	Kcals Produced (1000s)
Early-succession	4,408	60	0.33	250,000	363,627
Late-succession	735	10	0.33	25,000	6,060
Crop residue	2,204	30	0.33	100,000	72,725
Totals	**7,346**	**100**			**442,412**

Privately Owned, Non-program Wetlands

Private, non-program wetlands not involved in any type of conservation program represent the fourth group of wetlands in the RWB. Hydric soils that had no level of functionality were not included in this assessment, but it does include human-made stock ponds. The 2004 wetland survey mapped 12,362 wetland acres and 23,858 acres of stock ponds in this group. Only 25% of the wetland acres had ponded water. Vegetative condition was 30% in early-succession, 50% in crop residue, and 20% in late-succession. Only about 15% of the stock pond acres are $\leq$12 inches in depth (3,340 acres). Depths greater than 12 inches make most of the natural wetland foods unavailable to foraging waterfowl.

The contribution from private, non-program wetlands toward providing natural wetland foods is low, due to low ponding frequency and limited vegetation management. The RWBJV does recognize that these wetlands still provide ecological benefits, such as flood control, sediment and pollution control, and groundwater recharge. In years of isolated high-water conditions, these wetlands help offset limited-water conditions in other portions of the RWB.

Direct application of conservation practices on these wetlands is expected to remain low. Changes within their watersheds, such as pit fills, will allow some increase in ponding frequency. Likewise, contract-free incentives to manage wetland vegetation may increase the occurrence of early-succession vegetation. Total kcals produced in 2004 were about 736 million, or about 17% of the 4.4 billion kcals needed (Table B-8).

It is worth noting that the kcals reported are from private, non-program wetlands that showed some level of functionality in 2004. Historic wetlands that were altered to the extent that they show no functionality were not addressed. There are approximately 160,000 acres of historic wetlands in private ownership, and the number of wet acres in 2004 represents only 2% of the historic number. The future of these non-functional wetlands remains uncertain and it is hoped that some will be restored to some level of functionality.

Private, Non-program Wetland Strategies (Target 4)

The RWBJV established a target for privately owned wetlands not enrolled in a conservation program which states: *"By 2030, wetlands in private ownership that are not in any conservation program will provide 9% of the total natural forage needed by waterfowl in the Rainwater Basin"*.

The 9% natural forage goal is actually less than what was produced in 2004 (17%). It is expected that as more of these wetlands are enrolled in one of the conservation wetland groups, this group's share of total production will decline. Two strategies were identified which will help promote the contribution of these wetlands to natural wetland food production. The strategies will primarily be to maintain the status quo for vegetative condition and ponding frequency.

Table B-8. 2004 vegetative composition and projected nutrient production of wetlands identified as privately owned and not enrolled in any type of wetland conservation program in the Rainwater Basin region of Nebraska.

Vegetative Condition	Acres	% of Acres	Ponding Frequency	Kcal/Ac	Kcals Produced (1000s)
Natural Wetlands					
Early-succession	3,709	30	0.25	250,000	231,813
Late-succession	2,472	20	0.25	25,000	15,450
Crop residue	6,181	50	0.25	100,000	154,525
Subtotals	12,362				401,788
Lacustrine Wetlands					
Mixed (stock ponds)	3,340	100	1.00	100,000	334,000
Totals	**15,702**				**735,786**

<u>Strategy A:</u> Through incentives and education, maintain wetland vegetation communities that are 30% early succession, 50% farmed, and 20% late succession.

<u>Strategy B:</u> Restore watershed function to these wetlands, so that they reach a 25%

ponding frequency under average moisture conditions.

<u>Strategy C:</u> Encourage the development of short-term conservation programs that encourage the establishment of grassland buffers for these wetlands.

The future of these privately owned, non-program lands has a level of uncertainty. Some of the acres represent lands that have been as effectively drained as possible, but leaving a remnant of the original wetland. It is the RWBJV's hope that changes in future farm programs, conservation initiatives, and culture will cause a portion of these to be moved into a more long-term conservation program.

The acreage figures identified in the above strategies represent just one possible scenario by which the RWBJV may achieve its habitat goals (Table B-9). For example, the "privately owned, non-program wetlands" portion of the table does not reflect a goal for acres, because no acreage goals were established for this group. However, if the RWBJV is successful in the other three groups, the acres in the privately owned, non-program group could actually decline, as some of these wetlands will move to other groups. It is also conceivable that some non-functioning wetlands could be restored, adding new wetlands to any one of the four groups.

Table B-9. One possible scenario of wetland acres and their conservation status that would allow the Rainwater Basin Joint Venture to reach its goal of 4.4 billion kcals of natural wetland forage for migrating waterfowl.

Vegetative Condition	Acres	% of Hydric acres	Ponding Frequency	kcal/Ac	Kcals Produced (1000s)
Public Wetlands					
Early-succession	21,443	80	0.45	250,000	2,412,360
Late-succession	5,361	20	0.45	25,000	60,309
Subtotals	**26,804**	**100**			**2,472,669**
Privately-owned, Long-term Conservation Wetlands					
Early-succession	9,515	75	0.45	250,000	1,070,438
Late-succession	3,172	25	0.45	25,000	35,685
Subtotals	**12,687**	**100**			**1,106,123**
Privately-owned, Short-Term Conservation Wetlands					
Early-succession	4,408	60	0.33	250,000	363,627
Late-succession	735	10	0.33	25,000	6,060
Crop residue	2,204	30	0.33	100,000	72,725
Subtotals	**7,346**	**100**			**442,412**
Privately-owned, Non-program Wetlands					
Early-succession	3,709	30	0.25	250,000	231,813
Late-succession	2,472	20	0.25	25,000	15,450
Crop residue	6,181	50	0.25	100,000	154,525
Mixed (stock ponds)	3,340	100	1.00	100,000	334,000
Subtotals	**15,702**				**735,788**
Totals	**62,539**				**4,757,083**

Appendix C

Restoring Hydrologic Functions by Filling Water Concentration Pits

A total of 10,217 water concentration pits are scattered across the Rainwater Basin. They are one of the main contributors to the decline in the hydrologic function of wetlands. Their origin began when they were recognized as a way to convert shallow wetlands into cropland. A deep hole or pit was dug in one area, with the spoil spread out over the remaining portion of the wetland. The result was a few acres of deep water surrounded by cropland.

As the use of gravity-flow irrigation expanded, more concentration pits were developed. Fields were reshaped to allow irrigation water applied at the upper end of the field to gently flow to the lower end. Unused water which collected at the lower end is recycled back to the upper end. At the end of the growing season, the pits are commonly pumped dry, and thus readily collect the next spring's runoff. Advancements in irrigation technology in the 1970's began to shift irrigation away from gravity flow to center-pivot irrigation. Farmers who converted to center-pivot systems allowed their pits to remain, because of the cost of filling them and the lack of fill material.

In recent years, landowners have willingly worked with RWBJV partners to fill abandoned pits. With adequate funding, it is believed that pit filling in select watersheds will have a significant impact on wetland functionality. With the expanding conversion from gravity-flow to center-pivot irrigation, it is a realistic goal to remove 75% of the pits within watersheds, especially those containing public and long-term conservation wetlands.

Currently, there are 874 pits in watersheds containing public wetlands and 385 in watersheds containing long-term conservation wetlands. Filling 75% of the pits in watersheds of public wetlands will deliver an estimated 4,222 acre-feet of runoff. Based on the size and flatness of the wetlands, the added runoff would add about 6 inches of water depth on 8,443 acres. For watersheds of long-term conservation wetlands, the gain would be an estimated 1,844 acre-feet, or 3,687 acres with a depth of 6 inches. An additional 6 inches would dramatically increase the ponding frequency and the occurrence of early-succession vegetation.

Methodology Used

Runoff projections were derived by using Geographic Information Systems (GIS), and information from a hydrologic geomorphic model (Stutheit et al 2004), Natural Resources Conservation Service's Soil Survey Geographic Databases (SSURGO), and Rainwater Basin conservation-tracking databases.

Pit Selection and Measurement

Watersheds of individual wetlands were delineated using Light Detection and Ranging (LiDAR) data. LiDAR uses reflected light wavelengths (typically laser) to map the landscape at a very high resolution. In the Rainwater Basin, the accuracy was to 6-inch elevation differences. LiDAR data were validated by field observations.

Watershed boundaries, location of pits, and soil survey maps were incorporated into GIS to begin to identify those pits having the greatest effect on specific wetlands. The hydrologic geomorphic model (HGM) characterizes the ponding depths of individual wetlands based on soil types.

Calculating Pit Volumes

Pit volumes were calculated using GIS technology, based on the surface area. It was assumed that pits' side slopes and depth were in accord with construction recommendations defined in the Natural Resources Conservation Service's Field Office Technical Guide. For typical rectangular pits, the long sides have an average slope of 2:1. The shorter ends have a 4:1 slope. To simplify calculations, a slope of 2.5:1 was assumed for all sides. An average pit depth of 8 feet was assumed, although pits in the western portion of the Rainwater Basin are typically deeper. The intent was to avoid an inflated estimate.

Playa wetlands have soil signatures defined by different soil morphology and are associated with different water depths. The HGM defines these characteristics. For example, temporary wetlands capable of holding water for a few days have Fillmore soils and generally fill to an average depth of 4 inches. Seasonal wetlands have Scott soils and an average depth of 6 inches. Semi-permanent wetlands have Massie soils and an average depth of 8 inches.

GIS analysis calculated the average size and total surface acres of each wetland type. Also calculated were the average and total water volume of each wetland type. Surface area-to-water-volume ratios were computed (Table C-1). The ratio identifies how many surface acres of wetland can be filled with one acre-foot of water. For example, the ratio for a temporary wetland is 3:1—meaning that the water contained in a 10 acre-foot pit is able to fill a 30-acre temporary wetland.

Estimating Annual Impact

Water-capture by a pit is not a single annual event. During the course of a year, the pit loses water through evaporation and seepage, allowing it to collect additional water from subsequent moisture events. Therefore, the estimated annual impact of a pit on wetland acres is greater than the static holding capacity of the pit. Using information implied by the HGM, wetland literature, and field observations, the Joint Venture estimates the annual impact is about 1.5 times the pit's storage volume.

Calculating Concentration Pits' Impact on Public Wetlands

There are 167 wetland footprints fully or partially owned and managed by public entities within the RWB. The water-holding capacity of these wetlands was estimated to be 16,782 acre-feet. Within the watersheds of these wetland footprints are 874 water concentration pits. Their water-holding capacity is 3,263 acre-feet, 19% of the wetland footprints' estimated storage capacity. Filling 75% of the watersheds' pits would reduce pit storage by 2,447 acre-feet. Multiplying that

Table C-1. Wetland types and their associated water-holding characteristics.

Wetland Type	Soil Type	Ave. Water Depth	Area:Volume Ratio*
Temporary	Fillmore	4	3:1
Seasonal	Scott	6	2.3:1
Semi-permanent	Massie	8	1.7:1

*Acres of wetland filled with one acre-foot of water storage volume by the annual impact factor of 1.5, the added runoff to the 167 wetland sites would be 3,671 acre-feet—enough to fill 8,443 acres of seasonal wetlands.

Equation:

$$0.75 \times PV \times AI \times (Area{:}\,Volume\ Ratio) = Impacted\ Wetland\ Acres$$

0.75 = Portion of total pits targeted for removal
PV = Total pit volume within the watershed
AI = Annual impact index

Example:

$$0.75 \times 3{,}263 \text{ ac-ft} \times 1.5 \times \left(\frac{2.3 \text{ ac}}{\text{ac}-ft}\right) = 8{,}443 \text{ acres of seasonal wetlands}$$

In 2004, public wetlands ponded water on 4,033 acres. The ponding frequency on public wetlands that same year was 18%. Adding 8,443 acres would bring the total to 12,476. If the 75% pit-fill target is reached, ponding frequency is expected to be close to 45%. This level of ponded water corresponds to the 50% indicated by the National Wetland Inventory, HGM, and Soil Survey Geographic Database regarding the expected level of annual function for seasonal wetlands.

Calculating Concentration Pits' Impact on Long-term Conservation Wetlands

The same process used for watersheds containing public wetlands was used for watersheds containing long-term conservation wetlands. The actual number of pits involved has not been determined at this time, but the relationship between pit density and wetlands should be similar to that of public wetlands. For public wetlands, there averaged 5 pits per wetland, with an average volume of 3.7 acre-feet.

There are currently 77 long-term conservation wetlands, and thus an estimated 385 pits within their watersheds. The cumulative volume of these pits would be approximately 1,425 acre-feet. Removing 75 percent of the pit volume would result in approximately 3,687 surface acres of seasonal wetlands (0.75 x 1425 acre-feet x 1.5 x 2.3 acres per acre-foot). The increase in water reaching wetlands is expected to increase the ponding frequency closer to 45%.

Calculating Cumulative Impact of All Concentration Pits

GIS analysis shows that outside of watersheds containing public and long-term conservation wetlands, there exist 8,958 pits. These pits are of lower priority to the Joint Venture than those associated with protected wetlands. However, if the pit characteristics used above are used for this group, removing 75% of their storage capacity would equal approximately 85,762 surface acres in seasonal wetlands. The storage capacity would equal 24,858 acre-feet (0.75 x 8,958 pits x 3.7 acre-feet per pit). 24,858 acre-feet x 1.5 x 2.3 acres per acre-foot = 85,762 surface acres of seasonal wetlands.

Appendix D

Protecting Wetland Function with Vegetative Buffer Zones

A vegetated buffer zone is an integral component of a healthy wetland. Buffers significantly reduce the level of nitrates and other pollutants that may enter a water body (Muscutt et al. 1993, Osborne and Kovacic 1993). Functionally, upland vegetative buffers increase hydraulic roughness and decrease surface flow velocities, thereby reducing sediment-carrying capacity (USDA 1991). Peterjohn and Correll (1984) found that concentrations of nitrogen and phosphorus were significantly reduced from surface runoff from agricultural fields that flowed across a 20-meter riparian buffer. In addition, upland buffers produce suitable cover for many types of wildlife (Poiani and Johnson 1993). Terrestrial habitats surrounding wetlands are essential for many semi-aquatic species that depend on mesic ecotones to complete their life cycle (Semlitsch and Bodie 2003).For example, many species of waterfowl and waterbirds use upland habitats surrounding wetlands for feeding, overwintering, and nesting.

This appendix describes the process used by the RWBV to quantify upland acres needed to buffer RWB wetlands. Information from the RWBJV project tracking database, Hydrologic Geomorphic Model (HGM; Stutheit et al. 2004), Soil Survey Geographic Database (SSURGO), and field observations were used in this assessment. The assessment was completed on public lands and lands enrolled in long-term conservation programs to determine a wetland-to-upland ratio based on the acres necessary to establish 50-meter upland buffers. These ratios were then used to estimate upland acres needed to provide an adequate buffer for the wetland acreage targets outlined in the RWBJV Waterfowl Plan.

Calculating Upland Buffer Acreages

Peer-reviewed literature and results from field studies conducted in the RWB suggest a 50-meter buffer is sufficient to reduce the amount of culturally accelerated sedimentation and agriculture chemicals reaching a wetland. To estimate the acres of buffer needed to protect the wetland acres proposed in the RWBJV Waterfowl Plan, GIS software and data were analyzed. This analysis allowed the RWBJV to produce a wetland-to-upland ratio to calculate the number of upland acres needed to buffer the hydric soil footprints that are fully or partially owned by public entities and the private wetlands enrolled in long-term conservation programs. Results are summarized according to ownership.

For public wetlands, 50-meter buffers were created around the entire hydric soil footprint. As described in the RWBJV Waterfowl Plan, a majority of the public lands contain only a portion of the entire hydric soil footprint. For planning purposes, however, the buffers were generated around the entire footprint, including the private portion of the footprint. Once the buffers were generated, the acres were summarized and compared to the total acres of the hydric soil footprints. The ratio was 1.8 wetland acres to 1 upland acre.

The same process was completed to determine the wetland-to-upland buffer ratio needed to create 50-meter buffers on all of the hydric soil footprints currently enrolled in long-term conservation programs. To complete this assessment, a 50-meter buffer was again created around the historic wetland footprint of those wetlands currently enrolled in the long-term conservation programs. Once the buffers were generated, the acres were summarized and compared to the total acres of the hydric soil footprints. The ratio was 2.1 wetland acres to 1 upland acre. The ratio was used to estimate the associated upland acres necessary to buffer future long-term conservation programs.

Public Land Buffer Acres

Currently, 18,814 wetland acres are publicly owned and managed by NGPC and USFWS. In addition to the wetland acres, these entities manage 13,268 adjacent upland acres. However, most publicly owned wetlands only encompass a portion of the entire hydric soil footprint. Currently, of all the hydric soil footprints in the RWB that contain public lands, 60% of the total wetland footprint acreage (11,620 acres) is privately owned.

For planning purposes the RWBJV developed three criteria to prioritize roundouts. They are: 1) the tract contains at least five acres of the footprint are already publicly owned, 2) at least 10% of the footprint is publicly owned, and 3) at least five acres of the entire footprint are not publicly owned. In some situations these criteria may not apply. For example, in the case of restorations that require removal of surface drains or subsurface tiles, the entire hydric soil footprint must be acquired.

When the roundout criteria are applied, 92 of the 167 wetland footprints partially owned and managed by public entities contain potential priority roundouts. These wetland footprints total 25,941 acres; 15,286 acres are publicly owned and 10,655 acres are privately owned. The RWBJV partnership recognizes the social issues associated with land acquisition, and therefore set a goal of 75% acquisition of the private acres, or 7,990 acres.

Many of the privately owned “roundout” wetland acres are not protected by any buffer. Based on the 1.8:1.0 wetland-to-upland ratio, an additional 4,525 upland acres would be necessary to buffer the 7,990 wetland acres that represent the acquisition goal.

Required Buffer With Public Wetland Acquisitions	
Buffer Size	**50 meters**
Priority Roundout Acres	**10,655**
Priority Footprint Acres Analyzed	**25,941**
Buffer Acres Analyzed	**14,691**
Wetland-to-Upland Ratio	**1.8**
75% Roundout Acquisition Acres	**7,990**
75% Buffer Acquisition Acres	**4,525**

Long-Term Conservation Buffer Acres

Currently there are 3,448 wetland acres and 2,899 upland acres enrolled in long-term conservation programs. The RWBJV goal is to acquire at least a 50-meter buffer for wetland acres enrolled in these programs.

The long-term conservation strategy outlined in the RWBJV Waterfowl Plan is enrollment of 12,687 wetland acres in long-term conservation programs. This would require an additional 9,239 wetland acres to be enrolled. Based on the 2.1:1 wetland-to-upland ratio, 4,346 upland acres would be needed to establish a 50-meter buffer around wetland acres at goal.

To date, lands enrolled in long-term conservation programs have included more upland acres than necessary to achieve a 50-meter buffer. Many of these sites are being developed with cattle production as the intended long-term agriculture use. Current enrollments reflect a 1.2:1 wetland-to-upland ratio (compared to the 2.1:1 wetland-to-upland ratio needed for a 50-meter buffer). If future enrollments continue this pattern, 7,700 adjacent upland acres would be enrolled in long-term conservation programs in concert with the 9,239 wetland acre target.

The upland acreage goal is based on the 2.1:1 ratio. Long-term conservation programs are all designed for private lands, and enrollment is totally voluntary, so additional upland acres may be enrolled into these programs above the acreage necessary to provide the desired 50-meter buffer. At times, however, it will not be possible to achieve a 50-meter buffer; therefore in these situations, projects will be engineered to provide the best protection possible, but the lack of a 50-meter buffer will not necessarily preclude a project from being implemented. Upland acres, including those in excess of a 50-meter buffer, will provide habitat for a variety of resident wildlife species.

Required Buffer With LTC Wetland Enrollments

Buffer Size	**50 meters**
Wetland Acres at Target	**12,687**
Footprint Acres Analyzed	**7,360**
Buffer Acres Analyzed	**3,462**
Wetland-to-Upland Ratio	**2.1**
Additional Wetland Acres to Enroll	**9,239**
Additional Buffer Acres to Enroll	**4,346**

Appendix E

Common and Scientific Nomenclature for Species Described in the RWBJV Waterfowl Plan

Birds	
Common Name	**Scientific Name**
American Wigeon	*Anas americana*
Blue-winged Teal	*Anas discors*
Canada Goose	*Branta canadensis*
Canvasback	*Aythya valisineria*
Common Goldeneye	*Bucephala clangula*
Gadwall	*Anas strepera*
Greater White-fronted Goose	*Anser albifrons*
Green-winged Teal	*Anas crecca*
Hooded Merganser	*Lophodytes cucullatus*
Interior Least Tern	*Sterna antillarum athalassos*
Lesser Snow Goose	*Chen c. caerulescens*
Mallard	*Anas platyrhynchos*
Northern Pintail	*Anas acuta*
Northern Shoveler	*Anas clypeata*
Piping Plover	*Charadrius melodus*
Redhead	*Aythya americana*
Ring-necked Duck	*Aythya collaris*
Ross's Goose	*Chen rossii*
Sandhill Crane	*Grus canadensis*
Trumpeter Swan	*Cygnus buccinator*
Wood Duck	*Aix sponsa*
Whooping Crane	*Grus americana*

Plants	
Common Name	**Scientific Name**
Alfalfa	*Medicago sativa*
Barnyard grass	*Echinochloa muricata*
Buttonbrush	*Cephalantus occidentalis*
Canada thistle	*Cirsium arvense*
Cattail species	*Typhaspp.*
Common reed grass/*Phragmites*	*Phragmites australis*
Coontail	*Ceratophyllum demersum*
Corn	*Zea mays*
Curly dock	*Rumex crispus*
Duckweed	*Lemna spp.*
Eastern red cedar	*Juniperus virginiana*
Hickory species	*Carya spp.*
Hybrid broadleaf cattail	*Typha latifolia*
Hybrid narrowleaf cattail	*Typha angustifolia*
Kentucky bluegrass	*Poa pratensis*
Leafy spurge	*Euphorbia esula*
Milo	*Sorghum bicolor*
Pondweed	*Potamogeton spp.*
Purple loosestrife	*Lythrum salicaria*
Reed canary grass	*Phalaris arundinacea*
River bulrush	*Schoenoplectus fluviatilis*
Rush species	*Scirpus spp.*
Russian olive	*Elaeagnus angustifolia*
Sedge species	*Cyperus spp.*
Smartweed species	*Polygonum spp.*
Smooth brome grass	*Bromus inermis*
Soybean	*Glycine max*
Wheat	*Triticum aestivum*

Literature Cited

Alisauskas, R. T. 2002. Arctic climate, spring nutrition, and recruitment in mid-continent lesser snow geese. Journal of Wildlife Management 66:181–193.

Ankney, C. D., and A. D. Afton. 1988. Bioenergetics of breeding Northern Shovelers: diet, nutrient reserves, clutch size, and incubation. Condor 90:459-479.

Anteau, M. J., and A. D. Afton. 2009. Lipid reserves of lesser scaup (*Aythya affinis*) migrating across a large landscape are consistent with the "spring condition" hypothesis. Auk 126:873–883.

Austin, J. E., and A. L. Richert. 2001. A comprehensive review of the observational and site evaluation data of migrant Whooping Cranes in the United States, 1943-99. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota, and State Museum, University of Nebraska-Lincoln, Lincoln, Nebraska, USA.

Baldassarre G. A., and E. G. Bolen. 2006. Waterfowl ecology and management, 2nd edition. Krieger Publishing Company, Malabar, Florida, USA.

Banko, W. E. 1960. The Trumpeter Swan. Its history, habits, and population in the United States. North American Fauna No 63. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Bellrose, F. C. 1980. Ducks, geese, and swans of North America. Stackpole, Harrisburg, Pennsylvania, USA.

Bellrose, F. C., T. G. Scott, A. S. Hawkins, and J. B. Low. 1961. Sex ratios and age ratios in North American ducks. Natural History Survey Bulletin 26:391–474.

Benning, D. S. 1987. Coordinated mid-continent white-fronted goose survey. U.S. Fish and Wildlife Service Annual Report, Washington, D.C., USA.

Bentall, R. 1990. Streams. Pages 93–114 *in* A. Bleed and C. Flowerday, eds. Atlas of the Sand Hills. Resource Atlas No. 5a. Conservation and Survey Division, University Nebraska-Lincoln, Lincoln, Nebraska, USA.

Bishop, A. A. 2008. Rainwater Basin wetland complex waterfowl habitat use model, Version 2. U.S. Fish and Wildlife Service, Grand Island, Nebraska, USA.

Bishop, A. A., and M. Vrtiska. 2008. Effects of the Wetlands Reserve Program on waterfowl carrying capacity in the Rainwater Basin region of south-central Nebraska. U.S. Fish and Wildlife Service, Grand Island, Nebraska, USA.

Bishop, A. A., and R. Grosse. 2012. Scoring criteria and ranking for Wildlife Habitat Incentive Program, Rainwater Basin public wetland watershed special initiative. http://rwbjv.org/rainwater2012/wp-content/uploads/2012/02/RWB-Pit-Fill-Model-for-2012-WHIP-SI.pdf. Rainwater Basin Joint Venture, Grand Island, Nebraska, USA.

Bishop, A. A., R. Walters, and D. Drahota. 2004. Rainwater Basin wetland complex south central Nebraska; 2003-2004 vegetation mapping and monitoring project. U.S. Fish and Wildlife Service, Grand Island, Nebraska, USA.

Bishop, A.A., A. Barenberg, N. Volpe, and R. Grosse. 2011. Nebraska land cover development, Rainwater Basin Joint Venture report. Grand Island, Nebraska, USA.

Bishop, A.A., J. Liske-Clark, and R. Grosse. 2009. Nebraska landcover development. Great Plains GIS Partnership, Grand Island, Nebraska, USA.

Blanchong, J. A., M. D. Samuel, D. R. Goldberg, D. J. Shadduck, and L. H. Creekmore. 2006. Wetland environmental conditions associated with the risk of avian cholera outbreaks and the abundance of *Pasteurella multocida*. Journal of Wildlife Management 70:54-60.

Brennan, E. K. 2006. Local and landscape level variables influencing migratory bird abundance, diversity, behavior, and community structure in Rainwater Basin wetlands. Dissertation, Texas Technological University, Lubbock, Texas, USA.

Central Flyway Council. 1982. LaCreek Trumpeter Swan Plan. Central Flyway Council. Denver, Colorado, USA.

Checkett, J. M., R. D. Drobney, M. J. Petrie, and D. A. Graber. 2002. True metabolizable energy of moist-soil seeds. Wildlife Society Bulletin 30:1113-1119.

Comeau, S., and M. Vrtiska. 2010. Fall Trumpeter Swan survey of the High Plains Flock. Unpublished report. U.S. Fish and Wildlife Service, LaCreek National Wildlife Refuge, Martin, South Dakota, USA.

Comeau-Kingfisher, S., and T. Koerner. 2005. Management plan for the High Plains Trumpeter Swan flock. U.S. Fish and Wildlife Service, LaCreek National Wildlife Refuge, Martin, South Dakota, USA.

Condra, G. E. 1939. An outline of the principal natural resources of Nebraska and their conservation. University of Nebraska Conservation and Survey Division Bulletin No. 20.

Cowardin, L. M., T. L. Shaffer, and P. M. Arnold. 1995. Evaluation of duck habitat and estimation of duck population sizes with a remote-sensing based system. National Biological Service, Biological Science Report 2, Washington, D.C., USA.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, FWS/OBS/-79/31, Washington, D.C., USA.

Cunningham, Z. C. 2011. Breeding fidelity and landscape effects on distribution of Mallards and duck broods in the Nebraska Sandhills. M.S. Thesis, University of Nebraska-Lincoln, Lincoln, Nebraska, USA.

Devries, J. H., R. W. Brook, D. W. Howerter, and M. G. Anderson. 2008. Effects of spring body condition and age on reproduction in Mallards (*Anas platyrhynchos*). Auk 125:618–628.

Dubovsky, J. A., and R. M. Kaminski. 1994. Potential reproductive consequences of winter-diet restriction in Mallards. Journal of Wildlife Management 58:780–786.

Dzus, E. H., and R. G. Clark. 1998. Brood survival and recruitment of Mallards in relation to wetland density and hatching date. Auk 115:311–318.

Evans, R. D., and C. W. Wolfe, Jr. 1967. Waterfowl production in the Rainwater Basin area of Nebraska. Journal of Wildlife Management 31:788-794.

Fairbairn, S. E., and J. J. Dinsmore. 2001. Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA. Wetlands 21:41–47.

Fredrickson, L. H., and F. A. Reid. 1988. Waterfowl use of wetland complexes. U.S. Fish and Wildlife Service Leaflet 13.2.1. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Fredrickson, L. H., and M. K. Laubhan. 1994. Managing wetlands for wildlife. Pages 623-647 *in* T. A. Bookout, ed. Research and management techniques for wildlife and habitat, 5th edition. The Wildlife Society, Bethesda, Maryland, USA.

Fredrickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildlife Service Resource Publication 148. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Gersib, R. A., B. Elder, K. F. Dinan, and T. H. Hupf. 1989. Waterfowl values by wetland type within Rainwater Basin wetlands with special emphasis on activity time budget and census data. Nebraska Game and Parks Commission, Lincoln, and U.S. Fish and Wildlife Service, Grand Island, Nebraska, USA.

Gersib, R.A. 1991. Nebraska wetlands priority plan. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

Glup, S. S. 1987. Effect of land use and predation on waterfowl production on Valentine National Wildlife Refuge, Nebraska. M.S. Thesis, University of Nebraska-Lincoln, Lincoln, Nebraska, USA.

Grace, J. B., and J. S. Harrison. 1986. The biology of Canadian weeds: *Typha latifolia* L., *T. angustifolia* L. and *T.* x *glauca* Gord. Canadian Journal of Plant Science 66:361-379.

Grosse, R. C., N. D. Niemuth, T. L. Shaffer, and A. A. Bishop. 2012. Landscape-level habitat use by Trumpeter Swans in the Sandhills of Nebraska and South Dakota. Twenty second Trumpeter Swan Society Conference. Polson, Montana, USA.

Haukos, D. A., and L. M. Smith. 1993. Moist-soil management of playa lakes for migrating and wintering ducks. Wildlife Society Bulletin 21:288-298.

Heitmeyer, M. E., D. P. Connelly, and R. L. Pederson. 1989. The Central, Imperial, and Coachella valleys of California. Pages 475–505 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, eds. Habitat management for migrating and wintering waterfowl in North America. Texas Technological University Press, Lubbock, Texas, USA.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Johnson, D. H., and J. W. Grier. 1988. Determinants of breeding distribution of ducks. Wildlife Monographs. Number 100.

Kaul, R. B., D. Sutherland, and S. Rolfsmeier. 2006. The flora of Nebraska. School of Natural Resources, University of Nebraska-Lincoln, Lincoln, Nebraska, USA.

Keech, C., and R. Bentall. 1971. Dunes on the plains: The Sandhills region of Nebraska. Resource Report No. 4. Conservation and Survey Div. University of Nebraska-Lincoln, Lincoln, Nebraska, USA.

King, J. R. 1974. Seasonal allocation of time and energy resources in birds. Pages 4-10 *in* R. A. Paynter, Jr., ed. Avian energetics. Nuttall Ornithological Club, Cambridge, Massachusetts, USA.

Klaassen M., K. F. Abraham, R. L. Jefferies, and M. Vrtiska. 2006. Factors affecting the site of investment, and the reliance on savings for arctic breeders: the capital–income dichotomy revisited. Ardea 94:371–384.

Knapton, R., and K. Pauls. 1994. Fall food habits of American Wigeon at Long Point, Lake Erie, Ontario. Journal of Great Lakes Research 20: 271-276.

Krapu, G. L. 1981. The role of nutrient reserves in Mallard reproduction. Auk 98:29–38.

Krapu, G. L., D. A. Brandt, and R. R. Cox, Jr. 2004. Less waste corn, more land in soybeans, and the switch to genetically modified crops: trends with important implications for wildlife management. Wildlife Society Bulletin 32:127–136.

Krapu, G. L., D. A. Brandt, K. L. Jones, and D. H. Johnson. 2011. Geographic distribution of the mid-continent population of Sandhill Cranes and related management applications. Wildlife Monographs, 175:1-38.

LaGrange, T. G. 1985. Habitat use and nutrient reserves dynamics of spring migratory Mallards in central Iowa. M.S. Thesis, Iowa State University, Ames, Iowa, USA.

LaGrange, T. G. 2005. A guide to Nebraska's wetlands and their conservation needs. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

LaGrange, T. G., and J. J. Dinsmore. 1988. Nutrient reserve dynamics of female Mallards during spring migration through central Iowa. Pages 287–297 *in* M. W. Weller, ed. Waterfowl in Winter. University of Minnesota Press, Minneapolis, Minnesota, USA.

LaGrange, T. G., R. Stutheit, M. Gilbert, D. Shurtliff, and P. M. Whited. 2011. Sedimentation of Nebraska's playa wetlands: A review of current knowledge and issues. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

Loesch, C. R., and R. M. Kaminski. 1989. Winter body-weight patterns of female Mallards fed agricultural seeds. Journal of Wildlife Management 53:1080-1087.

McKnight, S. K., and G. R. Hepp. 1998. Diet selectivity of Gadwalls wintering in Alabama. Journal of Wildlife Management 62:1533 -1543.

McMurtrey, M. D., R. Craig, and G. Schildman. 1972. Nebraska wetland survey. Habitat Work Plan K-71. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

Miller, M. R., and J. M. Eadie. 2006. The allometric relationship between resting metabolic rate and body mass in wild waterfowl (Anatidae) and an application to estimation of winter habitat requirements. Condor 108:166–177.

Miller, O. D., J. A. Wilson, S. S. Ditchkoff, and R. L. Lochmiller. 2000. Consumption of agricultural and natural foods by waterfowl migrating through central Oklahoma. Procedings of the Oklahoma Academy of Sciences 80:25-31.

Monnie, J. B. 1966. Reintroduction of the Trumpeter Swan to its former prairie breeding range. Journal of Wildlife Management 30:691–696.

Murphy, P. J., T. J. Randle, L. M. Fotherby, and J. A. Daraio. 2004. The Platte River channel: history and restoration. Bureau of Reclamation Technical Service Center, Denver, Colorado, USA.

Muscutt A.D., G.L. Harris, S.W. Bailey, D.B. Davies. 1993. Buffer zones to improve water quality: a review of their potential use in UK agriculture. Agricultural Ecosystem Environment 45:59-77.

National Ecological Assessment Team. 2006. Strategic Habitat Conservation. U.S. Geological Survey, Washington, D.C., USA.

National Research Council of the National Academies. 2005. Endangered and threatened species on the Platte River. The National Academies Press, Washington, D.C., USA.

Naugle, D. E., R. R. Johnson, M. E. Estey, and K. F. Higgens. 2001. A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota. Wetlands 21:1–17.

North American Bird Conservation Initiative. 1999. Bird Conservation Regions. http://www.nabci-us.org/bcrs.htm.

North American Waterfowl Management Plan Committee. 2012. North American waterfowl management plan 2012: people conserving waterfowl and wetlands. < http://static. nawmprevision.org/sites/default/files/NAWMP-Plan-EN-may23.pdf>. Accessed 29 August 2012.

North American Waterfowl Management Plan, Plan Committee. 2004. North American Waterfowl Management Plan 2004. Strategic Guidance: Strengthening the Biological Foundation. Canadian Wildlife Service, U.S. Fish and Wildlife Service, and Secretaria de Medio Ambiente y Recursos Naturales.

Osborne, L.L., and D.A. Kovacic. 1993. Riparian vegetated buffer strips in water quality restoration and stream management. Freshwater Biology 29:243-258.

Pearse, A. T., G. L. Krapu, D. A. Brandt, and P. J. Kinzel. 2010. Changes in agriculture and abundance of snow geese affect carrying capacity of Sandhill Cranes in Nebraska. Journal of Wildlife Management 74:479–488.

Pearse, A. T., R. T. Alisauskas, G. L. Krapu, and R.R. Cox. 2011*a*. Changes in nutrient dynamics of midcontinent greater white-fronted geese during spring migration. Journal of Wildlife Management 75:1716–1723.

Pearse, A. T., G. L. Krapu, R. R. Cox, and B. E. Davis. 2011*b*. Spring-migration ecology of Northern Pintails in south-central Nebraska. Waterbirds 34:10–18.

Peterjohn, W.T., and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. Ecology 65:1466-1475.

Poiani, K.A., and W.C. Johnson. 1993. A spatial simulation model of hydrology and vegetation dynamics in semi-permanent prairie wetlands. Journal of Ecological Applications 3(2):279-293.

Rabbe, M., J. Drahota, and A.A. Bishop. 2004. Estimating duck use-days in the Rainwater Basin wetlands—a baseline model for management implications. Unpublished report. Rainwater Basin Wetland Management District, Funk, Nebraska, USA.

Rainwater Basin Joint Venture. 2013*a*. Rainwater Basin Joint Venture Landbird Plan. Grand Island, Nebraska, USA.

Rainwater Basin Joint Venture. 2013*b*. Rainwater Basin Joint Venture Shorebird Plan. Grand Island, Nebraska, USA.

Rainwater Basin Joint Venture. 2013*c*. Rainwater Basin Joint Venture Waterbird Plan. Grand Island, Nebraska, USA.

Reid, F. R., J. R. Kelley, Jr., T. S. Taylor, and L. H. Fredrickson. 1989. Upper Mississippi Valley wetlands: refuges and moist-soil impoundments. Pages 181–202 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, eds. Habitat management for migrating and wintering waterfowl in North America. Texas Technological University Press, Lubbock, Texas, USA.

Reinecke, K. J., and W. L. Uihlein. 2006. Implications of using a representative mix of species rather than Mallard to calculate the daily energy requirements of ducks wintering in the Mississippi Alluvial Valley. Final Report, Patuxent Wildlife Research Center, Vicksburg, Mississippi, USA.

Reinecke, K. J., R. M. Kaminski, D. J. Moorhead, J. D. Hodges, and J. R. Nassar. 1989. Mississippi Alluvial Valley. Pages 203–247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, eds. Habitat management for migrating and wintering waterfowl in North America. Texas Technological University Press, Lubbock, Texas, USA.

Rolfsmeier, S. B., and G. Steinauer. 2010. Terrestrial ecological systems and natural communities of Nebraska. Nebraska Natural Heritage Program, Nebraska Game and Parks Commission, Lincoln, Nebraska. USA.

Schildman, G., and J. Hurt. 1984. Update of Rainwater Basin wetland survey, survey of habitat work plan K-83., W-15-R-40. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

Schmidt-Nielsen, K. 1984. Scaling: why is animal size so important? Cambridge University Press. New York, New York, USA.

Schneider, R., K. Stoner, G. Steinauer, M. Panella, and M. Humpert. 2011. The Nebraska Natural Legacy Project: State Wildlife Action Plan, 2nd edition. Nebraska Game and Parks Commission, Lincoln, Nebraska, USA.

Semlitsch R.D., and J.R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 17(5),:1219-1228.

Sherfy, M. G. 1999. Nutritional value and management of waterfowl and shorebird foods in Atlantic Coastal moist-soil impoundments. Dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA.

Sidle, J. G., E. D. Miller, and P. J. Currier. 1989. Changing habitats in the Platte River valley of Nebraska. Prairie Naturalist 21:91–104.

Stephens, S. E., J. J. Rotella, M. S. Lindberg, M. L. Taper, and J. K. Ringelman. 2005. Duck nest survival in the Missouri Coteau of North Dakota: landscape effects at multiple spatial scales. Ecological Applications 15:2137–2149.

Stutheit, R. G., M. C. Gilbert, P. M. Whited, and K. L. Lawrence, editors. 2004. A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of Rainwater Basin depressional wetlands in Nebraska. ERDC/EL TR-04-4. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi, USA.

Tang, Z., X. Li, Zhao, N., Li, R., Harvey, F.E., 2012, Developing A Restorable Wetland Index for the Rainwater Basin Wetlands in South-Central Nebraska: A Multi-Criteria Spatial Analysis, Wetlands, *32*:975–984.

Tidwell, P. R. 2010. Nutrient reserves, food preferences and mass change of waterfowl migrating through the Rainwater Basin of Nebraska. M.S. Thesis, Arkansas Tech University, Russellville, Arkansas, USA.

Turner, J. K., and D. C. Rundquist. 1980. Wetlands inventory of the Omaha district. U.S. Army Corps of Engineers, Omaha, Nebraska, USA.

U.S. Department of Agriculture. 2009. The USDA/NASS 2009 Cropland Data Layer: Nebraska State Coverage. http://www.nass.usda.gov/research/Cropland/Release/

U.S. Fish and Wildlife Service and Canadian Wildlife Service. 1986. North American Waterfowl Management Plan. U.S. Fish and Wildlife Service, Washington, D.C. USA.

U.S. Fish and Wildlife Service. 1960. Drainage Report Nebraska 1954-1958. Minneapolis, Minnesota, USA.

U.S. Fish and Wildlife Service. 1980. Missouri River stabilization and navigation project, Sioux City, Iowa to mouth. Fish and Wildlife Coordination Act Report. U.S. Fish and Wildlife Service, North Kansas City, Missouri, USA.

U.S. Fish and Wildlife Service. 1981. The Platte River Ecology Study. United States Fish and Wildlife Service Special Research Report, Jamestown, North Dakota, USA.

U.S. Fish and Wildlife Service. 2012. Waterfowl Population Status, 2012. U.S. Fish and Wildlife Service, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 1978. Determination of critical habitat for the Whooping Crane. Federal Register. 43:20938-20942.

U.S. Fish and Wildlife Service. 1986. Sandhills wetlands a special investigation. Unpublished report. Nebraska Game and Parks Commission Lincoln, Nebraska, USA .

United States Department of Agriculture. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA Forest Service, Forest Resources Management, Radnor, Pennsylvania, USA.

Vrtiska, M. P., and L. A. Powell. 2011. Estimates of duck breeding populations in the Nebraska Sandhills using double observer methodology. Waterbirds 34:96–101.

Vrtiska, M. P., and S. Sullivan. 2009. Abundance and distribution of lesser snow and Ross's geese in the Rainwater Basin and Central Platte River Valley of Nebraska. Great Plains Research 19:147–55.

Walker, J. A., Z. J. Cunningham, M. P. Vrtiska, S. E. Stephens, and L. A. Powell. 2008. Low reproductive success of Mallards in a grassland-dominated landscape in the Sandhills of Nebraska. Prairie Naturalist 40:1–13.

Webb, E. K., L. M. Smith, M. P. Vrtiska, and T. G. LaGrange. 2010*a*. Effects of local and landscape variables on wetland bird habitat use during migration through the Rainwater Basin. Journal of Wildlife Management 74:109–119.

Webb, E. K., L. M. Smith, M. P. Vrtiska, and T. G. LaGrange. 2010*b*. Community structure of wetland birds during migration through the Rainwater Basin. Journal of Wildlife Management 74:765–777.