HYDROGEOMORPHIC EVALUATION
OF
ECOSYSTEM RESTORATION
AND MANAGEMENT OPTIONS FOR
QUIVIRA NATIONAL WILDLIFE REFUGE

Prepared For:

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Region 6
Denver, Colorado

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Greenbrier Wetland Services
Report 12-04

March 2012

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Publication No. 12-04

Suggested citation:

Heitmeyer, M. E., R. A. Laubhan, and M. J. Artmann. 2012. Hydrogeomorphic evaluation of ecosystem restoration and management options for Quivira National Wildlife Refuge. Prepared for U. S. Fish and Wildlife Service, Region 6, Denver, CO. Greenbrier Wetland Services Report 12-04, Blue Heron Conservation Design and Printing LLC, Bloomfield, MO.

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EXECUTIVE SUMMARY

This report provides an evaluation of ecosystem restoration and management options for Quivira National Wildlife Refuge (NWR) located in south-central Kansas. Hydrogeomorphic information (HGM) about geology and geomorphology, soils, topography, hydrology, plant and animal communities, and physical anthropogenic features was obtained for the Quivira NWR region. Objectives of the HGM evaluation were to: 1) Describe the pre-European settlement ecosystem condition and ecological processes; 2) Determine the changes from the Presettlement period with specific reference to alterations in hydrology, landform, and vegetation communities; and 3) Identify restoration and management options and ecological attributes needed to restore specific habitats and conditions that have been altered.

Quivira NWR was originally established in 1955 as the "Great Salt Marsh NWR" in recognition of two historic salt marshes, the "Little" and "Big" Salt Marshes on the site. In 1958, the name of the refuge was changed to "Quivira NWR." The refuge contains 22,135 acres and includes a mixed-grass sand prairie ecosystem with diverse grassland and wetland associations of variable salinity that surround the historic Little and Big Salt Marshes. Rattlesnake Creek flows through Quivira NWR to its confluence with the Arkansas River about 15 miles northeast of the refuge.

Quivira NWR is within the Great Bend Sand Prairie physiographic province of south-central Kansas and the surficial geology of the region is dominated by unconsolidated Quaternary deposits of eolian and alluvial origin. Most of the NWR is Quaternary-age alluvial deposits along the Rattlesnake Creek floodplain. Smaller areas on the edges of the alluvial plain are eolian sand dunes and hills. The relatively flat depression areas of the Little and Big Salt Marsh areas are underlain by < 15 feet of clay, silt, sand, and gravel derived from nearby sand dunes and Meade and Kiowa shale. A ridge of beach sand derived from a large Wisconsin-age lake occurs along the east and southeast sides of the Big Salt Marsh. Soils at Quivira NWR include many loamy sand types with varying salinity. Certain soils have high water tables and are considered "subirrigated."

At the time of this evaluation, topographic information was obtained from the Natitonal Elevation Dataset at 10 meter resolution, and as visually depicted using the USGS 7.5 minute quadrangle topographic map. Generally elevations on the refuge slope from about 1,815 feet above mean sea level (amsl) in the south to about 1,716 feet amsl in the northeast parts of the refuge. Local topography reflects historical migration of Rattlesnake Creek, the salt marsh depressions, and windblown sand hills and dunes.

The climate of Quivira NWR is dry subhumid. Average annual precipitation is about 24 inches, with about 75% occurring as rain between April and September. Evapotranspiration rates average about 64 inches, which causes quick drying of water in hot summer months and concentration and accumulation of salts in wetlands. Long-term precipitation records indicate relatively regular alternating high (> 30 inches) vs. low (< 20 inches) amounts of annual precipitation with occasional spikes of very high and low precipitation. Drought periods of 3-4 years have been common.

Rattlesnake Creek is a primary source of surface water at Quivira NWR. Average annual runoff of Rattlesnake Creek at Zenith, just upstream from the refuge, is about 34,000 acre-feet/year and average streamflow is about 47 cubic-feet/second but varies significantly among seasons and years in relationship to regional precipitation and groundwater recharge. Rattlesnake Creek and its tributaries act as both sources and sinks of groundwater for the underlying Great Bend Prairie Aquifer system. Quivira NWR lies in a discharge zone for groundwater exiting this aquifer and the lower bedrock. This groundwater subsequently becomes surface flow in Rattlesnake Creek and also contributes direct groundwater seepage into alluvial depressions, especially the Big Salt Marsh. Groundwater discharge into Quivira NWR, and depth to groundwater, varies among years depending on precipitation in the basin and aquifer-source areas.

Historically, most wetlands at Quivira NWR were seasonally flooded by surface water runoff and local precipitation, overbank flows from Rattlesnake Creek, and groundwater seepage/discharge from the Great Bend Prairie Aquifer. The Little Salt Marsh seems to have been recharged primarily by overbank flow from Rattlesnake Creek. In contrast, the Big Salt Marsh received water mostly from groundwater discharge. Recent monitoring of groundwater discharge into the Big Salt Marsh suggests about 5,000 acre-feet/year while the Little Salt Marsh loses about 545 acre-feet/year of surface to the underlying aquifer.

Quivira NWR historically was dominated by mixed-grass prairie, the Rattlesnake Creek corridor, scattered small wetland depressions, and the unique Big and Little Salt Marshes. The Rattlesnake Creek channel has migrated frequently across its floodplain and the size of the historical Little Salt Marsh was much smaller than the currently developed marsh area, which was altered by directly connecting it with Rattlesnake Creek in the late 1920s or early 1930s. Ecologically distinct vegetation communities, largely defined by soil type and hydrology included: 1) sand dunes and hills, 2) choppy sand beach-ridge grassland, 3) salt marsh, 4) saltgrass "flats", 5) creek channels with narrow riparian corridors, 6) seasonal herbaceous wetland, 7) subirrigated saline grassland, 8) subirrigated nonsaline grassland, 9) upland sandy grassland, and 10) upland loess-loam grassland. Trees and woody vegetation historically were present in only very limited sites such as scattered small patches of sand plum and occasional willow along the Rattlesnake Creek channel. The primary ecological processes and disturbances for these communities were annually- and seasonally-variable inputs of surface and ground water of varying salinity, fire, herbivory, wind, and other weather events. A HGM matrix of relationships of the communities to geomorphic surface, soil, general topographic position, and hydrology was developed to map the potential distribution of historical communities, and to compare with current conditions, on Quivira NWR. The heterogeneity of grassland communities coupled with the unique salt marshes and diverse wetland habitats provided important resources used by a diversity of animal species at Quivira, especially migrant waterbirds.

Few alterations to the Quivira NWR area occurred until the late 1800s. Early land uses included salt extraction and manufacturing, hay and cattle production, and eventually small grain agriculture. The salt marshes were used as commercial and recreational hunting areas and hunting clubs began to ditch, dike, and divert surface waters along Rattlesnake Creek and other small wetland sites in the early 1900s. By the 1930s, many upland prairie areas had been converted to cropland and pasture and by 1954; about 4,266 acres of Quivira NWR lands were in agricultural production.

The original development plans for Quivira NWR were designed to hold water in the salt marshes using local drainage if possible and also to divert “surplus” Rattlesnake Creek water into the marshes and developed wetland units. Ultimately, 34 constructed wetland management units were developed and water was diverted to the units through a complex series of ditches, dikes, and water-control structures. In 1957, the U.S. Fish and Wildlife Service (USFWS) filed for a “senior” right to divert 22,200 acre-feet of water from Rattlesnake Creek to refuge wetlands. In 1996, the Kansas Division of Water Resources certified a permit to the USFWS for only 14,632 acre-feet of water diversion from Rattlesnake Creek that reflected historical actual diversion due to frequent insufficient flows of water in the creek and the fill capacity of refuge wetlands.

Since the early 1970s, development of groundwater irrigation for agricultural production in the Rattlesnake Creek Basin has increased greatly, and groundwater withdrawals have caused precipitous declines in the baseflow of Rattlesnake Creek and also decreased discharge from natural groundwater seeps and springs, especially during summer when irrigation is occurring. Changes in amount and timing of surface water and ground discharge has reduced flow from Rattlesnake Creek into Quivira NWR and altered water quality. Attempts have been made to increase groundwater levels in the Rattlesnake Creek Basin and to support long-term sustainability of streamflow in Rattlesnake Creek using a variety of approaches developed in part as a “Rattlesnake Creek Subbasin Management Plan.” Certain planned activities have proven unsuccessful. Despite efforts of the Rattlesnake Creek Partnership Group to encourage voluntary water conservation measures, the average change in groundwater levels since 2001 has been a decline of 1.43 feet. Groundwater levels declined over three feet along Rattlesnake Creek in Quivira NWR between 2010 and 2011.

In summary, the major contemporary ecosystem changes in the Quivira NWR region have been: 1) alterations to the distribution, chronology, quality, and abundance of surface and groundwater; 2) extensive construction of water-control infrastructure to manage the distribution and retention of water in constructed wetland impoundments and the Little Salt Marsh; 3) conversion of native grassland to agriculture and the increased presence of woody vegetation; and 4) the increased presence of invasive species. A critical overriding issue for future management of Quivira NWR is the increased extraction of groundwater for irrigation in the Rattlesnake Creek Basin and the serious consequences of continued over-drafting of the underlying Great Bend Prairie Aquifer. Further, a major challenge for future management of Quivira NWR will be to determine how a potentially more limited availability of water will affect efforts to restore and provide critical habitats and communities.

This HGM evaluation contributes to previous studies and suggests the following general ecosystem restoration and management goals for Quivira NWR:

1. Maintain and restore functional mixed-grass sand prairie communities within the Rattlesnake Creek alluvial floodplain and adjacent sand hills and dunes.
2. Promote efforts to protect and restore critical groundwater aquifers, and natural seasonal groundwater discharge, in the Rattlesnake Creek Basin, specifically within Rattlesnake Creek and seeps originating on the west side of the Big Salt Marsh. Also, management should seek to emulate natural surface water regimes in the Big and Little Salt Marshes and the small wetland depressions on the refuge.
3. Restore the natural topography, water regimes, and physical integrity of surface water flow patterns in and across the Rattlesnake Creek floodplain corridor, salt marshes, and adjacent sand dune/hills uplands where appropriate and feasible.

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

Specific management recommendations to help meet the above goals include:

Goal #1

- Delineate specific grassland types and design management prescriptions to the respective community types.
- Continue to use fire to sustain grasslands and remove and discourage woody vegetation.
- Control invasive species.
- Restore natural hydrological regimes to grasslands.
- Protect sand hills and dunes by appropriately adjusting management prescriptions to the associated HGM communities.

Goal #2

- Consider recommendations from the recent Water Resources Inventory Assessment to protect and restore ground and surface water in the Rattlesnake Creek Basin.
- Manage historic wet meadow and seasonal herbaceous wetland depressions for annually variable, seasonal water regimes.
- Restore at least some regular drawdown and seasonal surface water dynamics in the Little Salt Marsh.
- Restore natural surface water sheetflow into small temporary wetland depressions in grasslands.
- Reduce or eliminate diversion of Rattlesnake Creek water to unnaturally high elevation dune surfaces.

Goal #3

- Evaluate restoring some water flow into former channels of Rattlesnake Creek.

- Evaluate all roads, ditches, levees/dikes, and water-control infrastructure to determine the need for, and effectiveness of the structures.
- Remove water diversion infrastructure into higher elevation Quaternary dune surfaces and upland grasslands where artificial wetlands formerly were created.

Goal #4

- Restore basic ecological disturbance practices in naturally occurring patterns and times.
- Carefully target grassland and wetland restoration to appropriate HGM sites, especially related to soils and hydrology.

Future management of Quivira NWR should incorporate active monitoring and evaluation to determine how factors related to ecosystem structure and function are changing, regardless of whether the restoration and management options identified in this report are undertaken. Critical information needs include:

- Ground and surface water quality and quantity
- Method and effects of attempts to restore natural topography, water flow patterns, and natural water regimes
- Long-term changes in vegetation and animal communities

Rachel Laubhan, USFWS

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INTRODUCTION

Quivira National Wildlife Refuge (NWR) contains 22,135 acres in Stafford, Rice, and Reno counties in south-central Kansas (Fig. 1). In May 1955, the Migratory Bird Conservation Commission approved establishment, and processing of purchase agreements, of the "Great Salt Marsh NWR" in recognition of two unique historical salt marshes on the area – the Little and Big Salt Marshes (Fig. 2). In 1958, the name of the refuge was changed to Quivira NWR after the Spanish word "Quivira" for the native American name "Kirikuru, which local people called themselves when the Spanish explorer Don Francisco Vasquez de Coronado visited the region in 1541 in search of the fabled Seven Cities of Cibola. The authorizing purpose of the refuge was "…for use as an inviolate sanctuary, or for any other management purpose, for migratory birds (16 USC 715d Migratory Bird Conservation Act)" … for the development, advancement, management, conservation, and protection of fish and wildlife resources (16 USC 742f(a)4" … for the benefit of the U.S. Fish and Wildlife Service (USFWS), in performing its activities and services: subject to the terms of any restrictive or affirmative covenant, or condition of servitude …" (16 USC 742f(b)1 Fish and Wildlife Act of 1956).

Quivira NWR is located in the Great Bend Sand Prairie Ecoregion (Chapman 2001) and contains a mixed-grass sand prairie ecosystem imbedded with the original namesake salt marshes and bisected by Rattlesnake Creek, a tributary of the Arkansas River. Habitats currently on the refuge include diverse grassland and wetland communities (Faber-Langedoen 2001) with a range of salinities along with stream corridors, salt flats, sand dunes and hills, and agricultural

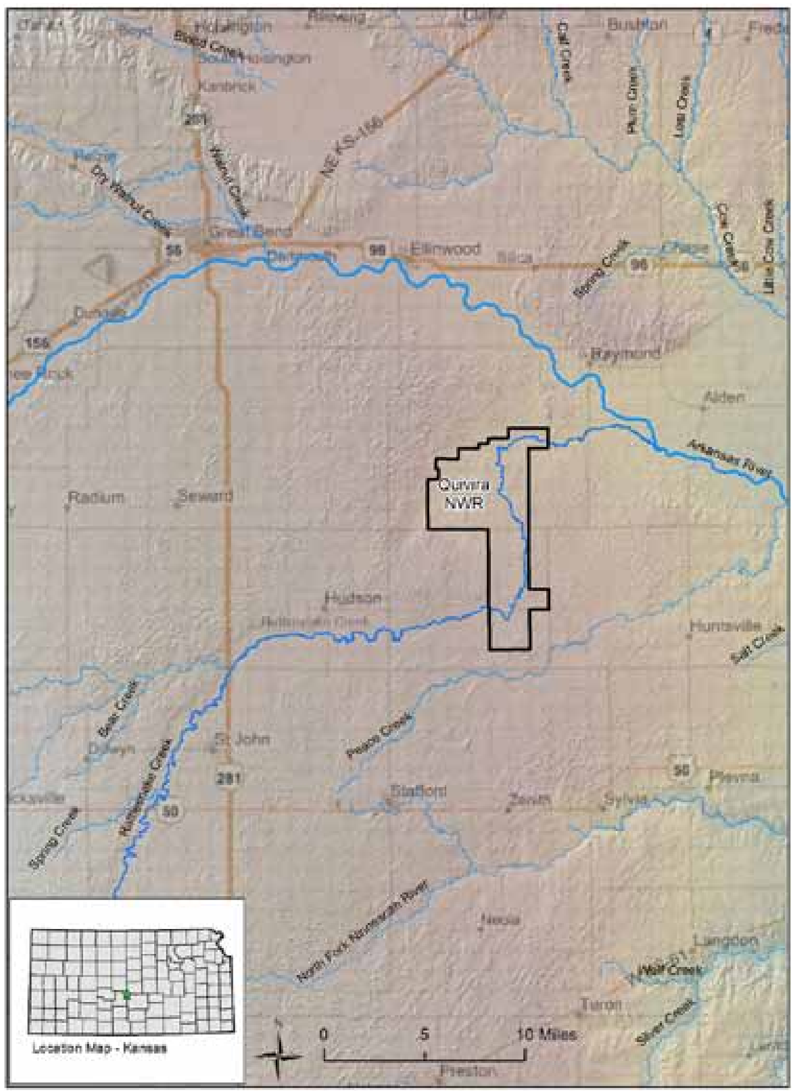

Figure 1. General location of Quivira NWR.

Figure 2. 2010 NAIP aerial photograph showing locations of the Big and Little Salt marshes.

lands. Rattlesnake Creek flows through Quivira NWR enroute to its confluence with the Arkansas River about 15 miles northeast of the refuge. The creek drains the 1,047 square mile Rattlesnake Creek Basin, and the creek section at Quivira NWR generally is a gaining stream that receives most of its surface water from groundwater discharge (Sophocleous 1992). This groundwater discharge originates from the Great Bend Prairie Aquifer, which contacts Permian bedrock formations that contain evaporates such as halite and anhydrite and causes the aquifer, and its discharge, to be saline (Buchanan 1984). Historically, surface water flows in Rattlesnake Creek seasonally recharged many wetlands in the Quivira NWR region, including the Little Salt Marsh. The Big Salt Marsh on Quivira NWR was not historically connected to Rattlesnake Creek and was recharged primarily from groundwater seepage that originated from the underlying aquifer along the west side of the refuge.

Intentional and unintentional use and modification of groundwater and Rattlesnake Creek streamflow have been occurring in the Rattlesnake Creek Basin and in the Quivira NWR region since the early 1900s (e.g., Latta 1950). Many regions of western and central Kansas have experienced significant declines in these waters, especially in the last three decades, primarily from extensive groundwater appropriations in the Great Bend Prairie Aquifer. While the refuge had an original senior right to divert about 22,200 acre-feet of water from Rattlesnake Creek to refuge wetlands annually, actual diversion has typically been < 14,000 acre-feet partly because of low flows in the creek during the growing season (Estep 2000). In 1996, the Kansas Division of Water Resources certified a water right permit for 14,632 acre-feet for the refuge based on recorded usage. Water from Rattlesnake Creek has been diverted to the Little Salt Marsh since the late 1920s or early 1930s, and since 1959, Quivira NWR has diverted Rattlesnake Creek water through a complex series of ditches, dikes, water-control structures, and three main points of creek water diversion into 34 constructed wetland impoundments and into the Big Salt Marsh. The reduced and altered surface and groundwater availability and controlled distribution of surface water on the refuge are serious challenges for future management of the refuge and for attempts to restore and sustain historical habitats and resources to endemic plants and animals.

In 2010, the USFWS initiated a Comprehensive Conservation Plan (CCP) for Quivira NWR. The CCP process seeks to articulate the management direction for the refuge for the next 15 years and develops goals, objectives, and strategies to define the role of the refuge and its contribution to the regional landscape and the overall mission of the NWR system. At Quivira NWR, the CCP is being facilitated by an evaluation of ecosystem restoration and management options using Hydrogeomorphic Methodology (HGM). The HGM process obtains and collates historic and current information about: 1) geology and geomorphology, 2) soils, 3) topography and elevation, 4) hydrologic condition and flood frequency, 5) aerial photographs and cartography maps, 6) land cover and vegetation communities, 7) key plant and animal species, and 8) physical anthropogenic features of the Quivira ecosystem. Recently, hydrogeomorphic information has been used to evaluate ecosystem restoration and management options on many NWR's (e.g., Heitmeyer and Fredrickson 2005, Heitmeyer and Westphall 2007, Heitmeyer et al. 2009, Heitmeyer et al. 2010, Heitmeyer et al. 2012) and provides a context to understand the physical and biological formation, features, and ecological processes of lands within the NWR and surrounding region. This historical assessment provides a foundation, or baseline condition, to determine what changes have occurred in the abiotic and biotic attributes of the ecosystem and how these changes have affected ecosystem structure and function. Ultimately, this information helps define the capability of the area to provide key ecosystem functions and values and identifies options that can help to restore and sustain fundamental ecological processes and resources.

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

- Describe the pre-European settlement (hereafter Presettlement) ecosystem condition and ecological processes in the Quivira NWR region.
- Document changes in the Quivira NWR ecosystem from the Presettlement period with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.
- Identify restoration and management options and ecological attributes needed to restore specific habitats and conditions within the Quivira NWR region.

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THE HISTORICAL QUIVIRA ECOSYSTEM

GEOLOGY AND GEOMORPHOLOGY

Quivira NWR is within the Great Bend Sand Prairie physiographic province, and Rattlesnake Creek Basin, of south-central Kansas. Structurally, the region lies on the southwestern flank of the Central Kansas uplift (Barton arch) and the northern one-half of the Pratt anticline (Merriam 1963). Basement rocks are Permian and early Cretaceous in age. Permian rocks, consisting of the Ninnescah Shale, Stone Corral Formation, Harper Sandstone, Salt Plain Formation, Cedar Hills Sandstone, and undifferentiated strata in the Great Bend region are often referred to as "red beds" because they contain red to brown shale, siltstone, and sandstone with minor beds of limestone, dolomite, and anhydrite (Arbogast 1998). Overlying the Permian and Cretaceous bedrock are varying thicknesses of unconsolidated Tertiary and Quaternary deposits of silt and fine sand with interbedded caliche that were derived from the Rocky Mountains (Fader and Stullken 1978). Permian bedrock subcrops along an approximately north-south trend near U.S. Highway 281.

The surficial geology of the Quivira region is dominated by unconsolidated Quaternary deposits of eolian and alluvial origin (Arbogast 1998). Quaternary sediments of the region have a maximum thickness of about 360 feet. The kinds of material (e.g., quartz, feldspar, granite) found in these deposits suggests a Rocky Mountain origin with the ancestral Arkansas River serving as the primary source. The bend of the Arkansas River has apparently migrated laterally from the south to its current position via successive captures by its northern tributaries, leaving a thick deposit of sand, silt, and clay behind (Fent 1950). Most of the surficial geology of Quivira NWR is Post-Kansas Quaternary (Qal3) alluvial deposits from the more recent Rattlesnake Creek floodplain with smaller areas on the edge of the alluvial plain being comprised of Quaternary Dune eolian sand dunes hills (Qds on Fig. 3). The Great Bend Sand Prairie province is covered with a veneer of loess deposits and sand dunes that overlie the Pleistocene alluvium. The stratigraphy of the Quaternary alluvium at Quivira NWR in descending order is: 1) sand dunes, 2) relatively continuous near-surface silt-clay bed from a loess deposit, 3) alternating sequences of sandy silt-clay and sand and gravel lenses, 4) basal sand and gravel beds of fluvial origin, and 5) bedrock (Figs. 4,5 and http://www.ksda.gov/subbasin/content/201).

Pleistocene alluvium at Quivira NWR was deposited by the ancestral Arkansas River and a small number of local streams and is composed of undifferentiated early Pleistocene sediments (the Meade Formation, which consists of interbedded lenses of unconsolidated gravel, sand, and silt; caliche is common throughout the formation) and other late Pleistocene period sediments (the Sanborn Formation, which consists of silt, sandy silt, and fine sand that locally contains lenses of coarse sand and gravel) (Arbogast 1998). The alluvium in the Rattlesnake Creek Valley is relatively thin, probably < 20 feet deep everywhere. It is composed mainly of poorly sorted sand and gravel derived from the Meade Formation. The relatively flat depression areas of the Big and Little Salt Marshes are underlain by unconsolidated materials consisting of clay, silt, sand, and fine to medium gravel derived mostly from nearby sand dune sands with minor contribution from the Meade Formation and Kiowa Shale (Fig. 5). The thickness of these salt marsh depression deposits is < 15 deep; the upper 1-2 feet consist of fossiliferous sand, silt and clay. A ridge of beach sand derived from a large Wisconsin-age lake is up to 15 feet deep and occurs along the east and southeast sides of the intermittent lake in the center of the current Big Salt Marsh area

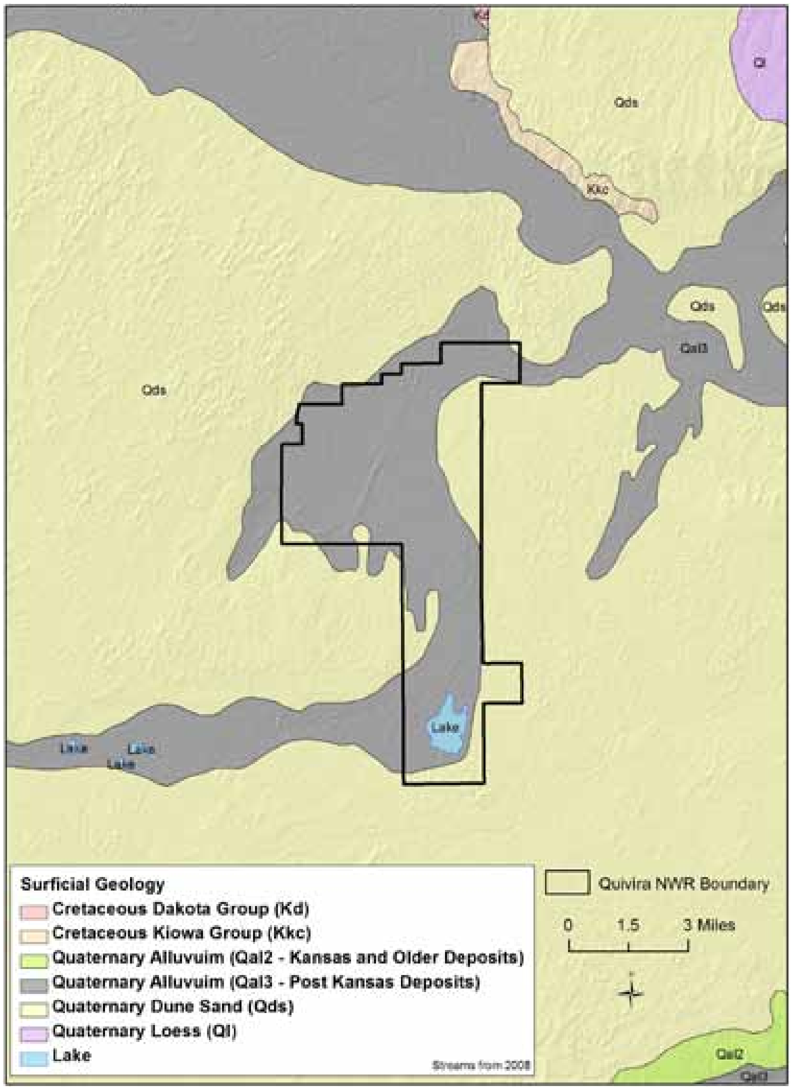


Figure 3. Surficial geology/geomorphology at Quivira NWR.

on Dillwyn-Tivin complex and Pratt-Tivoli fine sandy soils up to 20% slope (Fig. 6). The form, position, and soil characteristics of the beach ridge reflect the strong northwesterly winds that prevailed in this earlier late Wisconsin time. Choppy sand Dillwyn-Tivin complex beach-ridge sands also are present on the east and south sides of the Little Salt Marsh (Fig. 6). The beach sands are fine to medium sand and are lithologically similar to the dune sand.

Overlying silty sands in the Quivira region are eolian sands of varying thickness. Radiocarbon ages from the upper sands are late Wisconsin period, suggesting that overlying eolian sands accumulated during the Woodfordian time. In most areas, however, the upper silty sand dates from about 7,000 BP to 800 BP, indicating that overlying sand dunes are largely Holocene deposits. Landforms on uplands range from nearly flat sand sheets to parabolic dunes (Arbogast 1988). Dune sands are well sorted with a mean particle size of very fine to fine sand and imply a warmer climate during the Holocene period compared to the Woodfordian time. The orientation of parabolic dunes indicates a prevailing southwesterly wind. Dunes usually contain one to two weakly developed buried soils representing brief periods of landscape stability. Some dune soils are poorly developed, suggesting that they can be easily mobilized if increased aridity occurs in the region.

SOILS

Soils in the Great Bend Prairie include Mollisols, Alfisols, Entisols, and Inceptisols. Soil classification is based on landscape position and parent-material associations. The best developed soils in the Quivira NWR area are Typic Argiaquolls (Carwile Series), Udic Argiustolls (Naron Series), Pachic Argiustolls (Blanket and Farnum Series), and Vertic Argiustolls (Tabler Series). These soils are loamy, generally considered to have formed in old alluvium, and occur on the broad landscapes of relatively low relief between large dune fields (Figs. 6,7). Soils in the Tabler Series have the finest texture, generally occupy depression positions in upland areas, and are the least well drained. Carwile soils occur in similar topographic positions as Tabler soils but are more coarse textured and slighter better drained. Naron and Farnum soils contain the highest proportions of sand, occupy slightly higher landscape positions, and are better drained. Abbyville loam occur along the transition zone from sand hills to alluvium in the north-central part of the refuge

Soils that evolved in the complex, wind-modified dune topography consist of Psammentic Haplustalfs (Pratt Series), Typic Ustipsamments (Tivoli Series), and Aquic Ustipsamments (Dillwyn Series). Each has formed in sediments classified as loamy fine sand. Dillwyn soils are deep, somewhat poorly drained and subirrigated soils in interdunes where seasonal water tables are relatively high. Pratt soils are well drained and occupy the lowest, least erodible slopes on dunes. Tivoli and Tivin soils also are well drained, but are found on dune crests where eolian erosion is mostly likely to occur. These soils have the poorest development of any series in the region.

Soils that have formed in younger, fluvial landscapes are classified as Fluvaquentic Haplustolls (Plevna Series) and Leptic and Typic Natrustolls (Natrustolls). Natrustolls developed in loamy, calcareous alluvium that contains layers of sand or clay in places. They are somewhat poorly drained and often contain high concentrations of salt. Seasonal water tables are high in these sites. Plevna soils are often heavily gleyed and typically have developed in slight depressions on floodplains and on chaotic, channeled floodplains. Parent material is usually fine, sandy loam at the surface that is underlain by sandy and clayey alluvium (Dodge et al. 1978). Soils under the current flooded areas of Little Salt Marsh and Big Salt Marsh are mapped as water, marsh, or Aquolls (Fig. 6).

TOPOGRAPHY

USGS 7.5-minute quadrangle (Fig. 8) and 3-foot contour interval maps (Fig. 9) identify the gross-scale topographic heterogeneity of the refuge. Generally elevations slope from about 1,815 feet above mean sea level (amsl) in the south to 1,716 feet amsl in the northeast parts of the refuge. Also elevations slope from sandhills to the Rattlesnake Creek drainage and toward the salt marsh depressions. The bottom elevation of the Little Salt Marsh located at the south end of the refuge is 1,780 feet amsl and the bottom elevation of Big Salt Marsh located at the north end of the refuge is 1,736 feet amsl (Jian 1998).

CLIMATE AND HYDROLOGY

Climate data for Quivira NWR is available from the U.S. Historical Climatology Network (Menne et al. 2010) and are summarized in Striffler (2011). The climate of the Quivira NWR region is dry subhumid. The region lies along the transition boundary between the rain shadow of the Rocky Mountains and the warm moist air currents of the Gulf of Mexico. Average annual rainfall is about 24 inches, with about 75% of precipitation falling as rain between April and September. Snowfall averages less than 20 inches annually. Evaporation rates (ET) are high during summer and summer precipitation seldom exceeds ET rates. Average annual free-surface ET is

System	Epoch	Unit	Thickness feet
Quaternary	Holocene	Alluvium and Marsh	0-20
		Dune Sands	0-50+
	Pleistocene	Loess	0-40
		Mead Formation	50-200
Cretaceous		Dakota Formation	0-30
		Kiowa Shale	0-100
		Cheyenne Sandstone	0-80
Permian		Undifferentiated Redbeds	≤350
		Cedar Hills Sandstone	≤200
		Salt Plain Formation	≤300

Figure 4. Generalized stratigraphy of geological surfaces under Quivira NWR (from Fader and Stulken 1978).

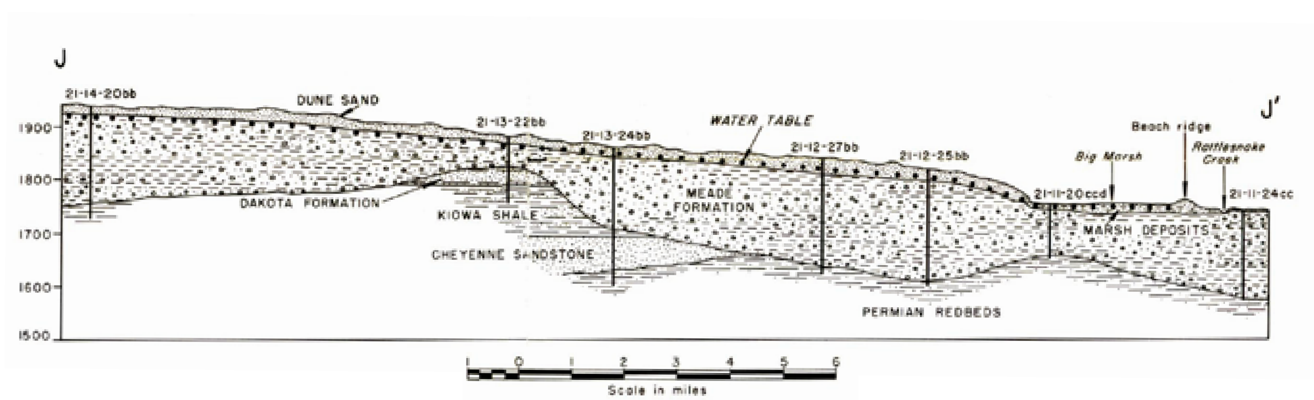
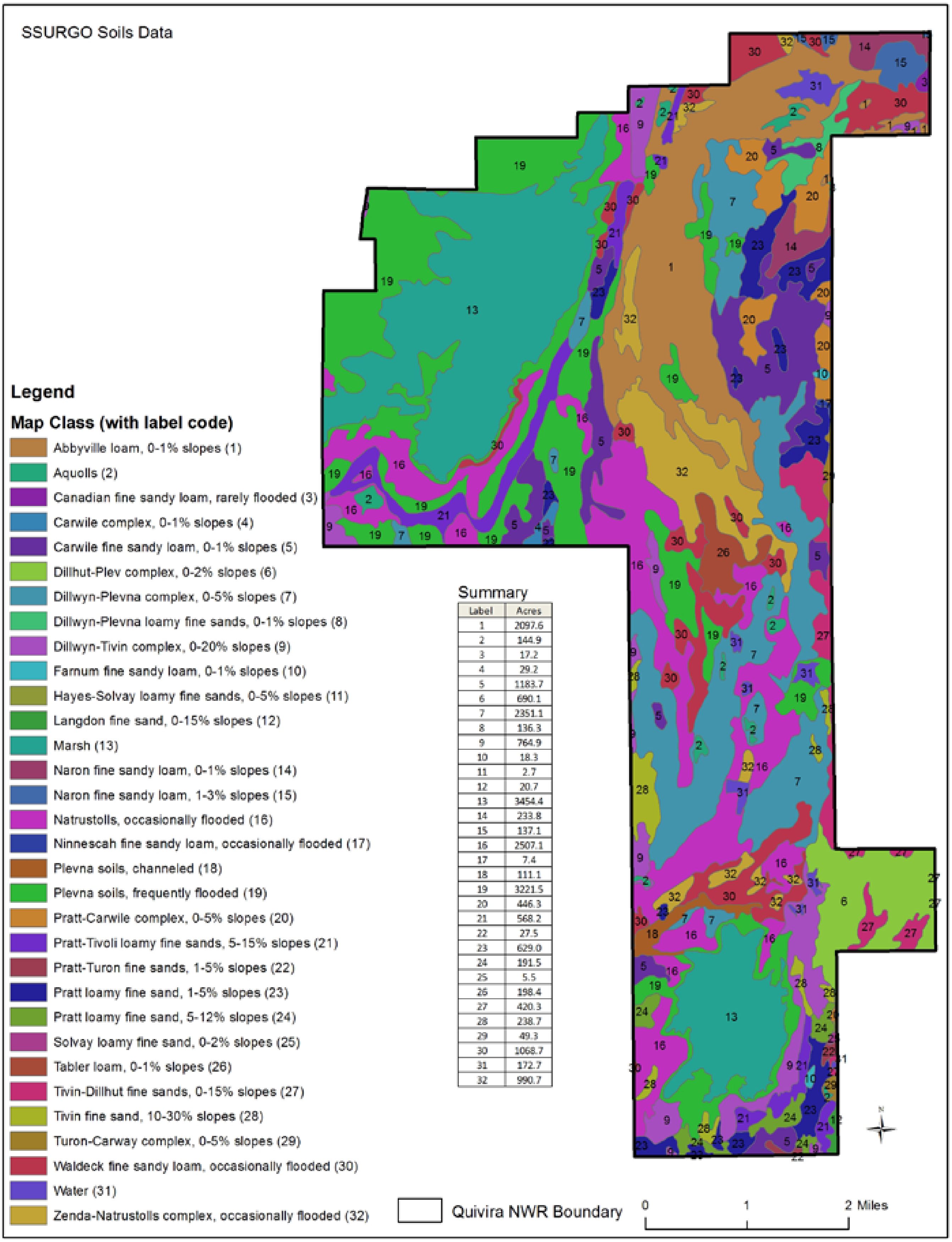


Figure 5. Geologic cross sections of Tertiary deposits in northeastern Stafford County, along line J-J' (from Latta 1950, http://www.kgs.ku.edu/General/Geology/Barton/index.html).



Label	Acres
1	2097.6
2	144.9
3	17.2
4	29.2
5	1183.7
6	690.1
7	2351.1
8	136.3
9	764.9
10	18.3
11	2.7
12	20.7
13	3454.4
14	233.8
15	137.1
16	2507.1
17	7.4
18	111.1
19	3221.5
20	446.3
21	568.2
22	27.5
23	629.0
24	191.5
25	5.5
26	198.4
27	420.3
28	238.7
29	49.3
30	1068.7
31	172.7
32	990.7

Figure 6. SSURGO soil types on Quivira NWR.

about 64 inches. With the exception of very wet years, rain and snow water does not pass through the soil into the zone of saturation. Long term precipitation records indicate relatively regular alternating high (> 30 inches) vs. low (< 20 inches) amounts of annual precipitation with occasional spikes of very high (1973) and very low (1939) precipitation (Fig. 10). Drought conditions have occurred in the Rattlesnake Creek Basin for extensive periods of time; perhaps the most extensive and notable period was the "Dirty Thirties" when very low annual rainfall and high winds created large dust storms. Drought periods of 3-4 years have been common, such as the extreme droughts in the late 1930s, mid 1950s, 1964-67, 1987-1990, and 1999-2002 (Fig. 10, Sophocleous and McAllister 1990). Mean annual temperature in the region is about 55° F and the growing season averages about 185 days. Prevailing wind direction is southerly, except during winter, and winds are strongest during March with average velocities of about 14 mph.

Rattlesnake Creek is a primary source of surface water at Quivira NWR. The creek meanders from the High Plains of Kansas northeast through the Great Bend Sand Prairie Ecoregion and Quivira NWR where it joins the Arkansas River. Average annual runoff of Rattlesnake Creek at Zenith, just upstream from the refuge, is about 34,000 acre-feet/year and average streamflow is about 47 cfs but varies significantly among seasons and years in relationship to regional precipitation (Fig. 11, Table 1). When Quivira NWR was established flow of Rattlesnake Creek into the refuge was estimated at about 100 cfs with greatest discharge occurring in April and May and a rarer high discharge in early fall; minimum summer flows were estimated at about 10 cfs (USFWS 1954). Local people living in the area in the mid-1900s, reported that this small meandering prairie stream could shallowly flood nearly a mile wide after large storm and precipitation events (USFWS 1962). Since 1938, the primary channel of Rattlesnake Creek has shifted locations several times in response to natural lateral creek migration and man-made diversions (Fig. 12).

The Rattlesnake Creek Basin contains about 1,047 mi², but the underlying groundwater basin is not a closed system; nearly half of the drainage area is considered noncontributing (Putnam et al. 2001). Regional groundwater flow is to the northeast and is impacted by groundwater levels outside the limits of the surface watershed. Rattlesnake Creek and its tributaries act as both sources and sinks of groundwater for the underlying Great Bend Prairie Aquifer system. Quivira NWR lies in a discharge zone for groundwater exiting the aquifer and the bedrock. This groundwater discharge subsequently becomes surface flow in Rattlesnake Creek and also contributes direct groundwater seepage into alluvial depressions, especially the Big Salt Marsh. Water enters the groundwater-driven system as underflow from outside the refuge area, as inflows from the bedrock, through infiltration of precipitation, and percolation of surface runoff through

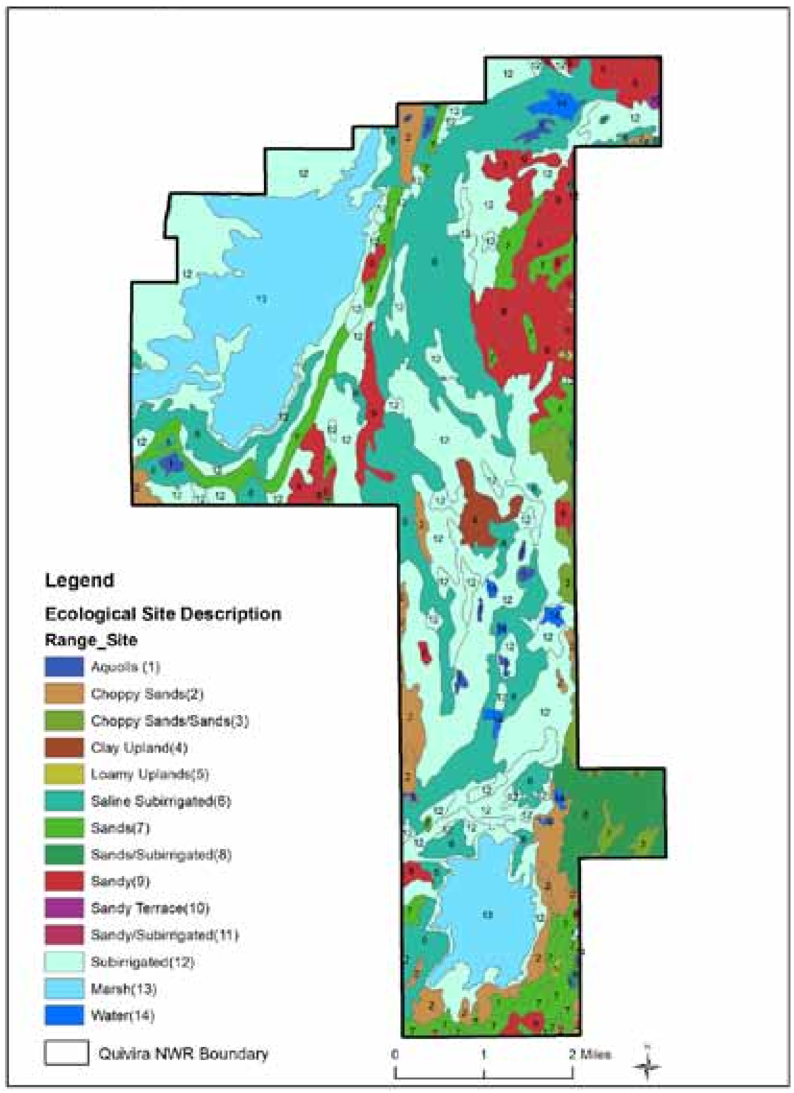


Figure 7. Soil grouping by taxon category and ecological site type on Quivira NWR (from NRCS 2010).

Rattlesnake Creek and its tributaries. Groundwater exits the study area as evaporation, underflow from the area, baseflow of streams and marshes, and now through groundwater well pumping. Discharge into the Quivira region, and depth to groundwater varies among years depending on precipitation in the basin and aquifer-source areas. Depth to water may be as little as one foot in wet seasons and up to 5 feet in dry seasons (Sophocleous and Perkins 1993).

The Great Bend Prairie Aquifer that underlies the Quivira region is part of the broader High Plains aquifer system and is a shallow (usually less than 300 feet thick from the land surface to bedrock) alluvial aquifer of Quaternary age. The hydraulic conductivity of the Great Bend Prairie Aquifer in the Quivira NWR region ranges from 11 to 230 feet/day with storage coefficients of 0.0007 to 0.18. In areas where the aquifer is thickest, wells can yield 1-2,000 gallons/minute. In the Quivira region the aquifer is overlain by a silt-clay bed that acts as a confining unit and causes artesian conditions in some areas, such as Boiling Springs, which discharges fresh water. Two artesian springs (wells) are located on the south side of the Big Salt Marsh and another artesian well is on the northwest side of the Little Salt Marsh (Fig. 13). These artesian springs are uniquely fresh, unlike many other surface water resources on the refuge that range from slightly brackish to saline.

Historically, most wetlands at Quivira were seasonally flooded by surface water runoff from local precipitation, overbank flow of Rattlesnake Creek, and discharge/seepage and springs originating from the Great Bend Prairie Aquifer. Historically, the Little Salt Marsh seems to have been recharged primarily by overbank flow from Rattlesnake Creek (e.g., unpublished Quivira NWR annual narratives), as the creek channel did not run through the marsh, but rather immediately to its north (Figs. 12, 14). In contrast, the Big Salt Marsh has historically received water mostly from groundwater seepage and discharge from springs (Sophocoleous 1992, Sophocleous and Perkins 1993). Based on a geologic cross-section passing through the Big Salt Marsh, a bedrock ridge trending roughly north-south beneath the marsh and the resulting thinning of the permeable water-bearing material was a major factor causing the discharge of saline groundwater at that location (Fig. 5). Models of groundwater leakage upward from the Great Bend Prairie Aquifer into the Big Salt Marsh area are about 98 acre-feet/day and seepage from the adjacent sand hills that flows overland to the marsh are only about one acre-foot/day (Sophocleous 1997, Jian 1998). Recent monitoring of groundwater discharge into the Big Salt Marsh indicates about 5,000 acre-feet of discharge /year (Jian 1998). In contrast, the Little Salt Marsh loses, or recharges, about 545 acre-feet/year to the underlying aquifer.

Permian bedrock outcrops in the Quivira NWR region are saline and salt water intrudes into the Great Bend Prairie Aquifer where the shallow alluvial aquifer is in contact with the

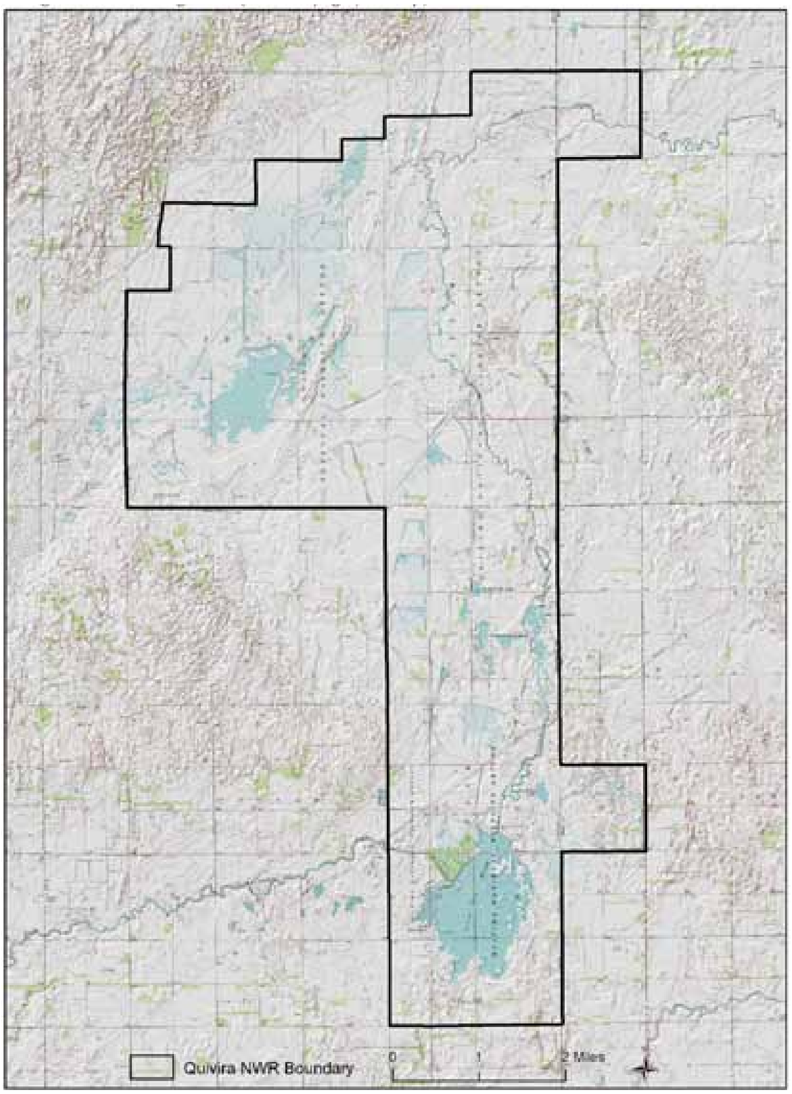


Figure 8. USGS 7.5-minute topographic quadrangle of Quivira NWR and surrounding lands.

bedrock formations. Permian "red bed" subcrops increase the salinity of the water in the unconsolidated aquifer in the lower reaches of Rattlesnake Creek. The average chloride load of flow in Rattlesnake Creek at its mouth is about 130 ton/d. Water near the salt marshes, especially Big Salt Marsh reflects the occurrence of artesian saltwater encountered deeper to the west. The salt water flows from the edges of the bedrock formation into the overlying sediments and then rises to the surface in low areas primarily along Rattlesnake Creek. The upper reaches of Rattlesnake Creek have low chloride levels but abrupt increases in conductivity occur in the 3 mile reach about one mile east of where Rattlesnake Creek crosses US Highway 281 with values of about 3-4,000 uS/cm. Where the creek exits Quivira NWR, another rise in conductivity occurs up to > 20,000 uS/cm, but by the time it discharges into the Arkansas River the creek's conductivity drops to about 3,100 uS/cm (Fig. 15).

Rattlesnake Creek historically flowed through the prairie grasslands of the Great Bend Sand Prairie Province from southwest to northeast on what is now Quivira NWR and did not directly flow into, or through, either the Big or Little Salt Marsh (see Fig. 2). Likely, the Little Salt Marsh received annually variable inputs of surface water from local runoff, modest seepage from the underlying aquifer, and seasonal overbank flooding from Rattlesnake Creek. The size of the historical Little Salt Marsh basin was much smaller than the current developed marsh area (Figs. 2, 14) and likely had annually variable amounts of open water surrounded by moderately brackish concentric bands of persistent emergent and seasonal herbaceous marsh plant species. The historical Little Salt Marsh apparently did not have a natural drainage outlet, and consequently, saline conditions occurred because of evaporation of surface

PLANT AND ANIMAL COMMUNITIES

The Quivira NWR region historically was dominated by mixed-grass prairie, the Rattlesnake Creek stream corridor, scattered small wetland depressions, and the unique Big and Little Salt Marsh basins. GLO surveys and maps from 1871 (Fig. 14), Santé Fe Railroad Field Notes in the mid 1870s (Fig. 16), and the Stafford County Township Map from 1886 (Fig. 17) provide descriptions of topography, geography, hydrological features, and plant communities prior to major alteration by European settlers. Other sources of information about vegetation and communities in the region are accounts of early explorers (e.g., Nathan Boone's journal from 1843, Fessler 1929), county history documents (e.g., Cutler 1883), early soil surveys, physiography (e.g., Adams 1903) and botanical investigations (e.g., Ungar 1961 and references cited). Aerial photographs of the refuge area from 1938 (Fig. 18) also provide evidence of general landscape features and communities prior to major alterations of land and water.

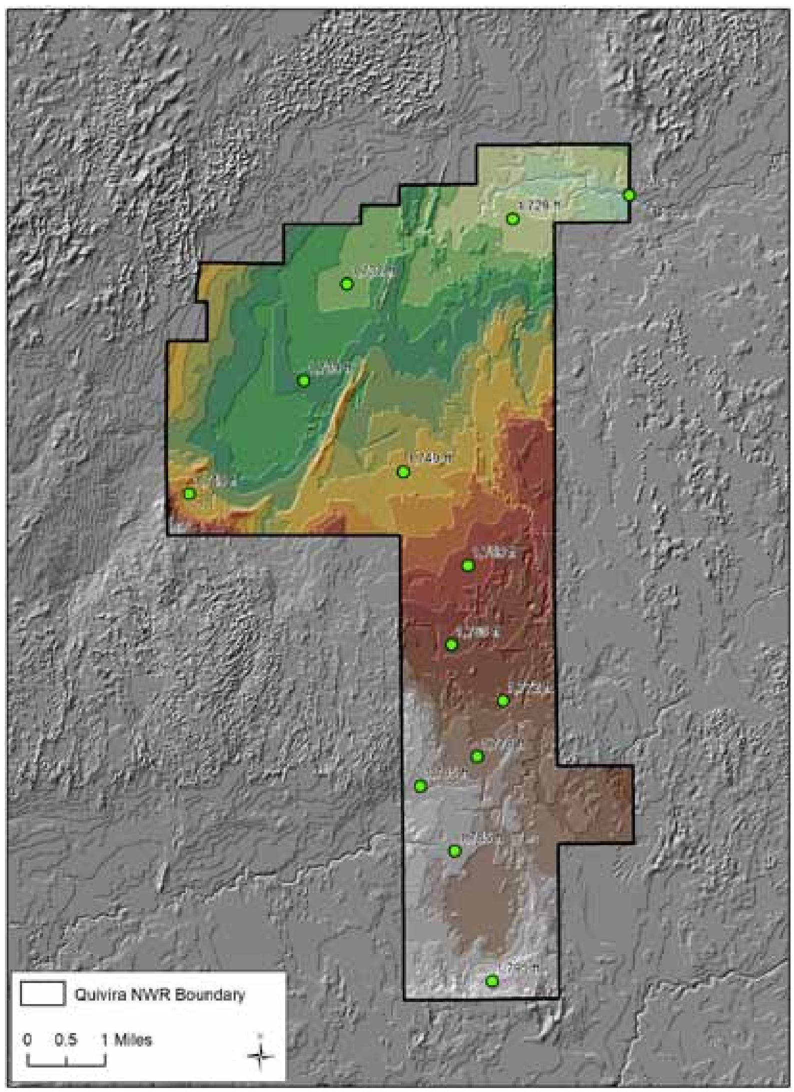


Figure 9. Elevation map (3 foot contours) of Quivira NWR.

water. In contrast, the Big Salt Marsh basin received more regular, albeit typically low pulsed amounts, of highly saline surface water from groundwater seepage and springs on the southwest side of the marsh. The highly saline groundwater and overland flow of this water across the Big Salt Marsh created wide areas of some open water surrounded by alkaline flats, salt grass assemblages, and alkaline herbaceous marsh vegetation. Surface water exited the Big Salt Marsh via Salt Creek, a tributary flowing into Rattlesnake Creek and eventually to the Arkansas River (Figs. 14, 17).

The historical Rattlesnake Creek corridor, including its relict, now abandoned, meandering channels (Fig. 12) and small natural levees contained mostly grass, wetland, and narrow riparian vegetation depending on topography, source and quality of water, and soil types. Early accounts of the Rattlesnake Creek channel do not mention trees bordering the creek channel, and only occasionally refer to scattered willows (*Salix* spp.) in riparian areas (e.g., Fessler 1929). The majority of upland non-wetland areas on the refuge were mixed-grass prairie, with type and diversity of grass communities determined by the type and extent of seasonal flooding or soil saturation, salinity, and soil type. Sand dunes occurred on the upland edges of the Rattlesnake Creek valley and supported more xeric vegetation communities with some scattered Chickasaw plum (*Prunus angustifolia*).

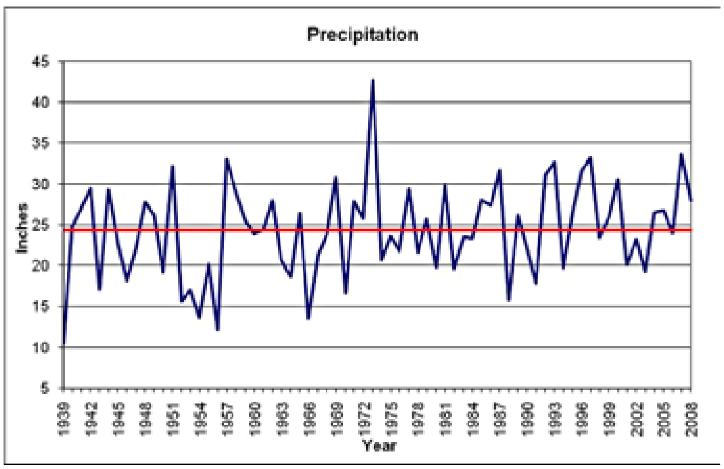


Figure 10. Mean annual precipitation at Zenith, KS 1939-2008.

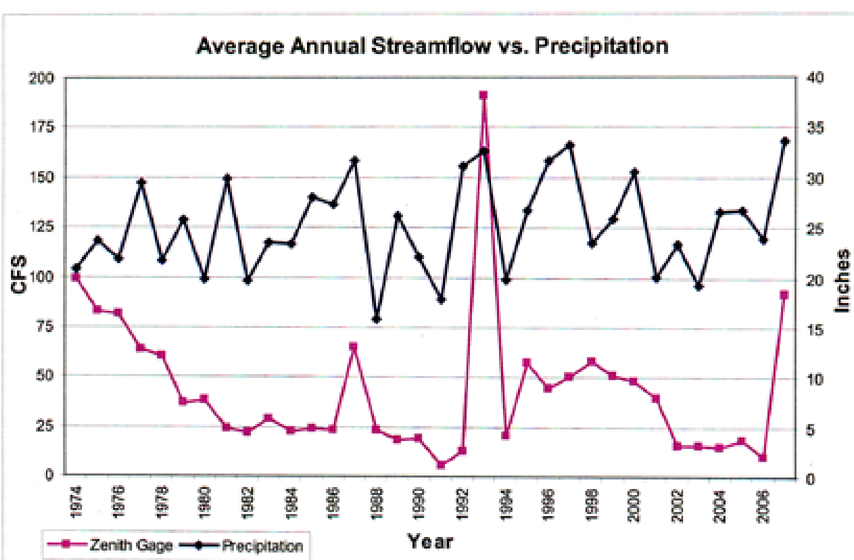


Figure 11. Average annual streamflow in Rattlesnake Creek compared to annual precipitation at Zenith, KS.

The primary ecological "drivers" that sustained natural vegetation communities at Quivira NWR were annually- and seasonally-variable inputs of surface and ground water of varying salinity and periodic physical disturbance events of fire, herbivory, wind, and other climate factors such as hail and dust storms. Occasional fire removed thatch residue and recycled and released nutrients and stimulated new growth in grasslands. Grazing by large ungulates and herbivory by small mammals, invertebrates, and some waterfowl species such as geese and wigeon (*Anas americana*) also helped sustain the long-term productivity and sustainability of grass and salt flat communities. The distribution and extent of historical plant communities on Quivira NWR were influenced by geomorphic position, soils, topography, and associated surface and groundwater hydrology. Specific, ecologically distinct, communities included: 1) sand hills, 2) choppy sand beach-ridge grassland, 3) salt marsh, 4) saltgrass flats, 5) creek channels with narrow riparian corridors, 6) seasonal herbaceous wetland, 7) subirrigated saline grassland, 8) subirrigated nonsaline grassland, 9) upland sandy grassland, and 10) upland loess-loam grassland (Ungar 1961, NRCS 2010). Information on these communities, including relationships with ecosystem attributes (e.g., soil texture and salinity, hydroperiods, disturbance events, etc.) is provided in the following

Table 1. USGS surface water monthly statistics for Rattlesnake Creek near Zenith, KS, 1973-2010.

YEAR	00060, Discharge, cubic feet per second, Monthly mean in cfs (Calculation Period: 1973-10-01 -> 2010-09-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973										690.6	184.8	269.8
1974	191.6	140.6	173.5	160.6	105.2	79.8	38.9	45.5	51.6	53.4	66.5	82.4
1975	80.7	86.3	82.1	83	65.2	177.1	131.5	79.5	60.8	32.9	54	57.6
1976	52.4	65.3	55.8	271.9	189.4	69.7	79.1	22.9	33.1	33.2	43.9	61.9
1977	38.1	47.8	52.6	59.7	160.2	146.2	46.2	32.7	43.7	39.2	44.5	49
1978	50.8	57.9	92.2	52.1	120.6	222.7	30.5	11	9.07	11.9	28.2	33.1
1979	27.8	46.1	75.1	57.6	48.7	33.1	24.6	32.6	6.87	6.51	44.3	35.9
1980	40	59.7	93.2	99.1	59.5	49.7	15.2	7.92	2.78	2.37	9.08	23.5
1981	22	21.5	26.7	21.2	46.9	46.2	20.4	8.42	5.48	7.2	34.9	25.2
1982	25.1	47.7	38	26.1	36.2	35.8	21.9	6.5	4.28	5.46	8.53	11.3
1983	14.7	29.1	29	75.5	68.5	88.7	16.7	2.99	2.29	3.04	9.04	8.46
1984	17.3	21.1	61.3	72.5	47.9	20	6.24	1.51	0.855	3.42	3.27	15.7
1985	8.58	23.6	25.9	31.3	46.1	23.9	8.39	9.94	6.01	59.4	22.4	25.9
1986	27.7	28.5	24.6	23.4	16.4	16.4	45.5	14.2	17.9	21.6	20.1	23.4
1987	22.6	29.9	207.4	132.1	61.5	40.3	108	53.5	28.7	23.6	32.4	40.7
1988	46.8	41.2	44.2	60.4	34.4	21.8	9.46	2.65	1.47	2.65	6.61	7.86
1989	11.4	9.3	15.5	11.3	40.4	39.9	27.8	13.8	24.7	8.32	9.07	8.79
1990	16.2	19.9	28.7	34.5	56.1	44	6.35	3.8	2.16	4.17	7.4	6.78
1991	8.28	9.5	11.3	11.2	8.12	10.2	1.54	0.875	0.091	0.046	3.64	5.56
1992	6.48	6.64	7.78	6.47	5.24	37.3	22.2	18.1	4.53	5.44	10.2	21.5
1993	31.8	57.4	86.4	48.2	177.8	595.9	1,099	49.6	30.6	30.5	39	43
1994	41.4	41.7	37.5	40.8	35.3	11.7	7.24	3.65	1.35	5.83	7.16	12.1
1995	14.4	15	18.1	21.5	370.9	100.2	84.7	19.6	6.42	8.05	13	18.6
1996	22.1	22.9	26.9	31	55.1	57.7	10.2	29.8	93.3	70.4	60.4	50.3
1997	45	59.5	54.2	60.4	42.2	49.5	40.3	63.9	35	41.9	49.7	63.3
1998	71	81.5	135.5	131.1	66.2	36.6	28	18.2	4.9	22.9	62.7	37.8
1999	45	71.4	70.1	93.9	64	50.6	110.5	17.2	13.9	17.6	23.1	30.5
2000	37.5	45.6	159.5	80.3	64.5	33.1	56.4	21	4.32	14.4	36.9	25.2
2001	34.3	68.2	65.5	45.5	70	129.4	14.3	6.9	7.45	7.13	11.8	14.7
2002	17.8	23.8	22.9	22.3	18.6	21	6.07	6.32	3.76	14.7	12	13.1
2003	14.7	17.2	48.1	29.5	31.4	14.1	4.51	3	3.26	7.29	6.48	8.71
2004	9.13	8.8	24.5	13.2	15.8	8.85	20.7	21	6.75	11.6	16.5	17.6
2005	15.3	27.9	19.2	20.4	19.6	30	22.4	26.8	9.97	5.81	9.02	12
2006	13.4	16.9	17.6	14.4	9.81	7.7	4.25	8.13	3.04	5.39	6.64	10.4
2007	14.9	13.5	23.8	152.6	399.9	133.1	218.7	30	19	18.1	23.5	53.4
2008	47.8	45.6	40.7	75.3	131.9	46.1	20	18.4	13.9	82.4	40.2	35.5
2009	34.6	37	38.7	187.8	179.9	191.9	38.7	25.7	21.2	26.8	33.2	30
2010	40.7	55.9	55.9	43.9	38	68.6	76.2	61	21.9			
Mean of monthly Discharge	34	41	56	65	81	75	68	22	16	38	30	35

** No Incomplete data have been used for statistical calculation

paragraphs and in NRCS (2010) ecological site descriptions. The NRCS site descriptions also include detailed lists of plant species in each community type.

Sandhills and choppy sand beach-ridge grassland at Quivira NWR occurs on Quaternary dune sand surfaces (Fig. 3) with deep sandy soils that absorbed inputs of surface water from local precipitation and runoff rapidly (see NRCS 2010). Dune surfaces with up to 30% slopes typically have Tivin fine sand soils and sparse grassland vegetation; these dune areas support "sandhill" habitats. Sandy dune areas with up to 15-20% slopes historically had denser, more complete, land cover of grasses and were on Dillwyn-Tivin complex, Langdon fine sand, and Tivin-Dillhunt fine sand soils. Sand beach-ridge habitats are dominated by warm-season grasses including sand bluestem (*Andropogon hallii*), switchgrass (*Panicum virgatum*), Indiangrass (*Sorghastrum nutans*), and

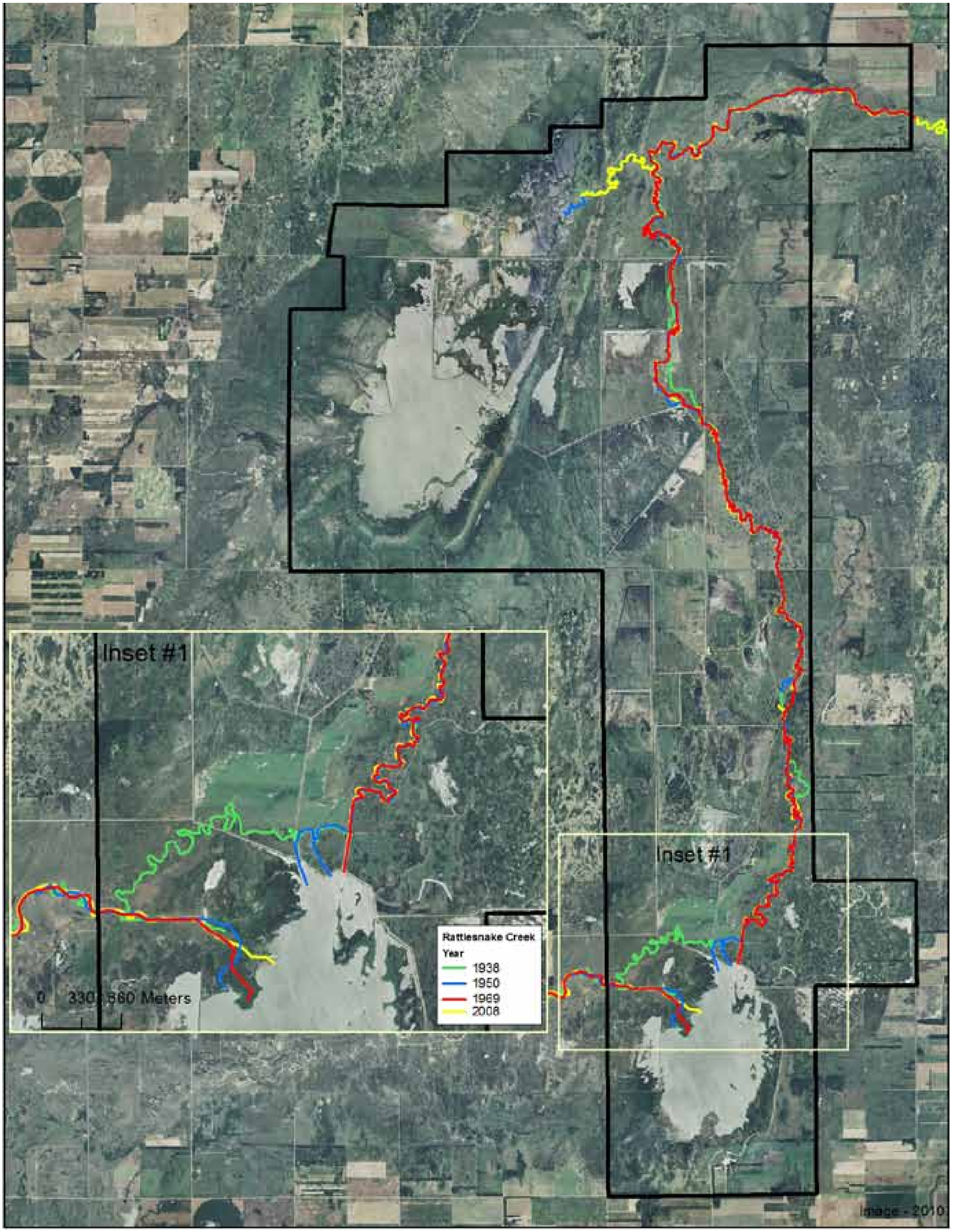


Figure 12. Movement of Rattlesnake Creek from 1938 through 2008 on Quivira NWR as mapped from sequential aerial photographs.

giant sandreed (*Calamovilfa gigantean*) (NRCS 2010). Little bluestem (*Schizachyrium scoparium*) historically was common in sand hills and beach-ridge areas as was Canada wildrye (*Elymus canadensis*), sand lovegrass (*Eragrostis trichodes*), composite dropseed (*Sporobolus composites*), and purple sandgrass (*Triplasis purpurea*). Scattered minor amounts of blue grama (*Bouteloua gracilis*), hairy grama (*Bouteloua hirsute*), thin paspalum (*Paspalum seteceum*), and sand dropseed (*Sporobolus cryptandrus*) also occur in these sand habitats along with a few legume species. A few small clumps of Chickasaw plum and skunkbrush sumac (*Rhus trilobata*) often are present on steeper dune and beach-ridge slopes. Soils in dune areas are susceptible to wind erosion and grasses that evolved in this community have deep root systems capable of utilizing moisture throughout the loose soil profile where almost no surface water runoff occurs. Fire was an important ecological process that sustained dune and beach-ridge communities; most fires occurred in spring and early summer when thunderstorms and lightning were most prevalent. All of the dominant grasses in dune and beach-ridge areas are rhizomatous, which helps them to survive intense wildfires. Trees and shrubs in dune and beach-ridge were suppressed by fires. This community also evolved under periodic grazing by large herds of bison that while intense at times, was usually of short duration. Dune areas cannot sustain prolonged heavy grazing because of sparse vegetation and highly erodible soils.

Salt marsh and saltgrass communities historically were present in areas within and immediately surrounding the Little Salt Marsh and Big Salt Marsh depressions (see descriptions in Ungar 1961). The deeper parts of the historic salt marshes had more prolonged flooding regimes with variable salinity and duration based on water source, topography, and inter-annual flooding dynamics related to regional precipitation and subsequent seepage of groundwater from the Rattlesnake Creek Basin. Occasional drought alternating with periodic high precipitation years and events created a dynamic balance of amount and extent of surface water and its relative salinity. This dynamic caused marsh and alkaline flat communities to contract or expand among years, mainly in the Big and Little Salt Marsh areas, depending on water inputs. Occasional drought was important to rejuvenate marsh and flat areas by releasing and recycling nutrients, consolidating sediments, volatilizing salts and minerals, and providing substrates for germination of some species. The Big Salt Marsh received relatively regular small amounts of groundwater discharge, of high saline content, throughout the year. This groundwater seepage, supplemented by rainfall and local groundwater runoff flowed into and across the marsh area and created a mosaic of salt marsh and salt flat habitats dominated by salt tolerant wetland plants such as alkali sacaton (*Sporobolus airoides*), saltgrass (*Distichlis spicata*), Pursch seepweed (*Suaeda depressa*), and alkali bulrush (*Scirpus paludosus*). Deeper, more permanently flooded parts of the Big Salt Marsh contain submergent aquatic plants such as wigeongrass (*Ruppia*

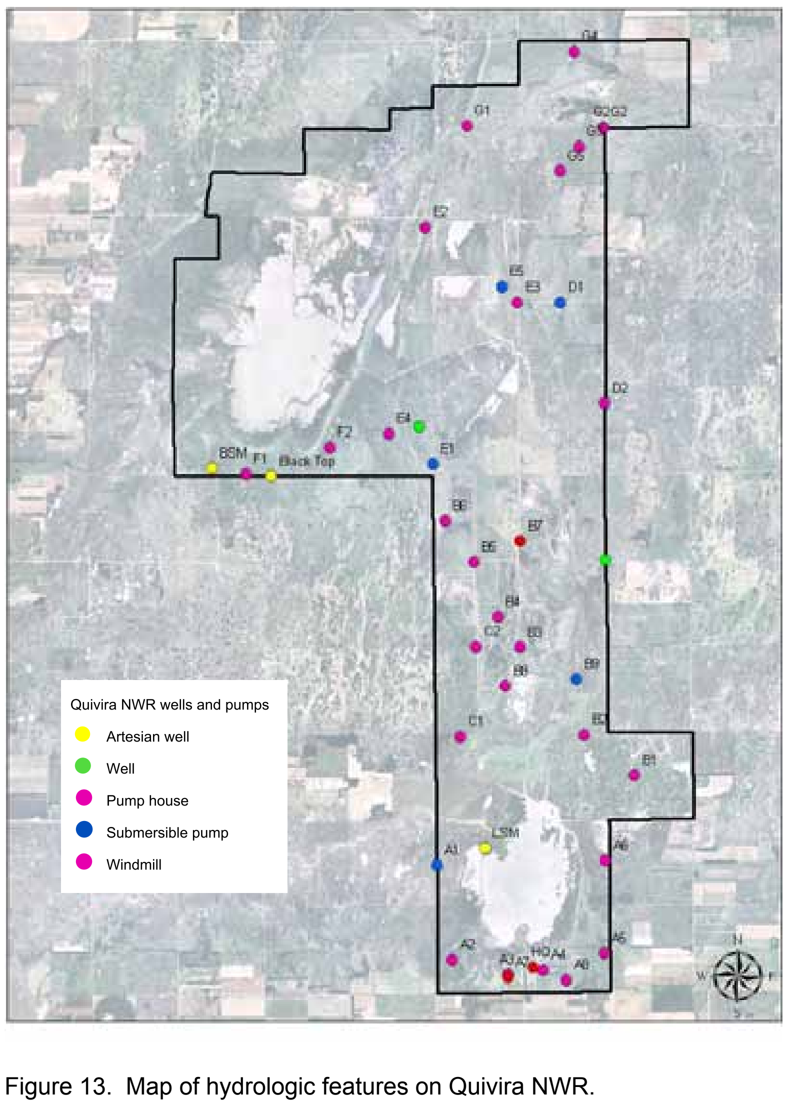


Figure 13. Map of hydrologic features on Quivira NWR.

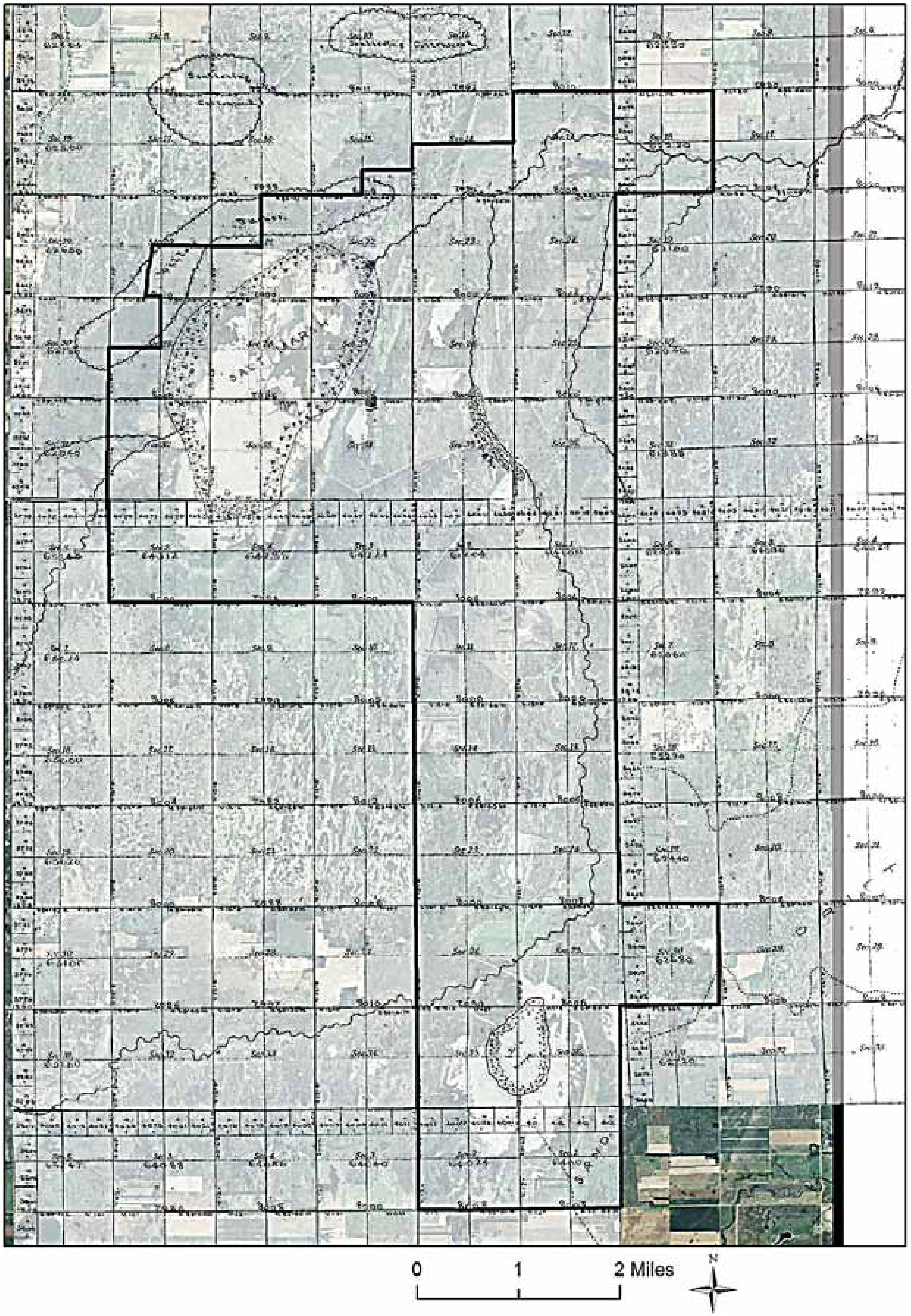


Figure 14. General Land Office map from 1871 overlain on 2010 NAIP photography.

maritime), muskgrass (*Chara* spp.), and pondweeds (*Potamogeton* spp.) while semipermanently flooded areas contain alkali bulrush, spikerush (*Eleocharis* spp.), and scattered American bulrush (*Scirpus americanus*). Areas along the edges of the Big Salt Marsh that seldom have surface flooding, but are subirrigated by high groundwater tables, support often wide saltgrass flats with some prairie cordgrass (*Spartina pectinata*) (Ungar 1961). These upper elevation edges of salt marsh typically have Plevna soils (Fig. 6).

Less is known about the historic vegetation composition of the Little Salt Marsh, however, the extent of the marsh and its naturally flooded area was much smaller than the present larger flooded area created by diversion and storage of Rattlesnake Creek water into the Little Salt Marsh basin (e.g., Fig. 14). It appears that most annual flooding of the Little Salt Marsh area historically was from periodic overbank flows from Rattlesnake Creek during high discharge events and seasons, direct rainfall, and local surface runoff with relatively small amounts of groundwater discharge/seepage (see above hydrology section). These sources of water were less regular and less saline than the groundwater seepage that flowed into and across the Big Salt Marsh. In wet years, more of the historic Little Salt Marsh was flooded for longer periods than in dry years, and likely water was fresher and open water areas in the center of the basin was surrounded by bands of persistent emergent and sedge/rush communities. Open water areas likely supported extensive submergent communities in wet years. During drier years, water area in the Little Salt Marsh likely was reduced and high evapotranspiration rates probably caused the wetland to be more saline. Bands of saltgrass occur on the edges of the Little Salt Marsh (usually on Plevna soils) and historically were less extensive and narrower than in the Big Salt Marsh.

Rattlesnake Creek flows through Quivira NWR and historically contained open water habitats in the creek channel and persistent emergent and seasonal herbaceous wetland vegetation along the channel edges. Only limited evidence suggests that scattered willows were present along the creek; apparently other trees were not present (Fessler 1929). Recently abandoned channels of Rattlesnake Creek (e.g., Fig. 12) probably had relatively regular connectivity with the active channel and may have had semipermanent water regimes. Older Rattlesnake Creek channel depressions (and other small drainages) likely had less, if any, regular connectivity with high flows of Rattlesnake Creek, and appear to have been sustained by combined surface runoff from seasonal rainfall and local runoff and groundwater discharge including the current wetland units 22 and 23 and Unit 57 (McCandless Lake or East Lake). Wetland vegetation in these smaller wetland sumps appears to have been diverse mixtures of seasonal herbaceous plants dominated by alkali sacaton, sedges and rushes, and some more water tolerant grasses, such as prairie cordgrass. A few larger, and deeper, depressions may have been flooded for longer periods at least in wet years. Wetland depressions in grasslands on Quivira NWR typically occur on Aquoll and Waldeck sandy loam soils (Fig. 6).

Grasslands dominated the Quivira NWR landscape where surface water does not seasonally or permanently flood areas. Areas that are subirrigated by high groundwater levels and that also have short duration sheetflow of surface water runoff from uplands are dominated by warm season grasses. Subirrigated grasslands occur on both saline and nonsaline soils and species composition depends on, and can be ecologically separated, by soil salinity. In both soil types, grassland vegetation evolved on broad, nearly level alluvium with high water tables, under a diverse and fluctuating climate, grazing by herds of large herbivores, and periodic intense wildfires. The major influence for plant adaptation and growth is the presence of a relatively high permanent water

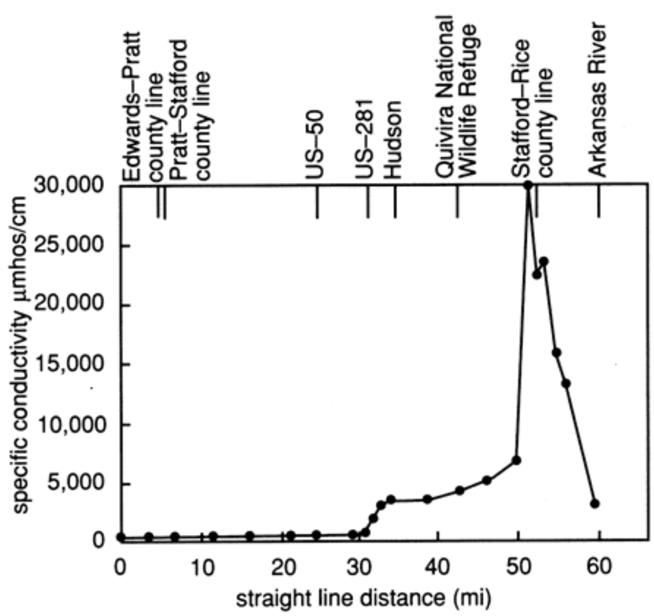


Figure 15. Relative salinity of Rattlesnake Creek at various locations including Quivira NWR (from Sophocleous and McAllister 1990, http://www.kgs.ku.edu/Publications/Bulletins/GW11).

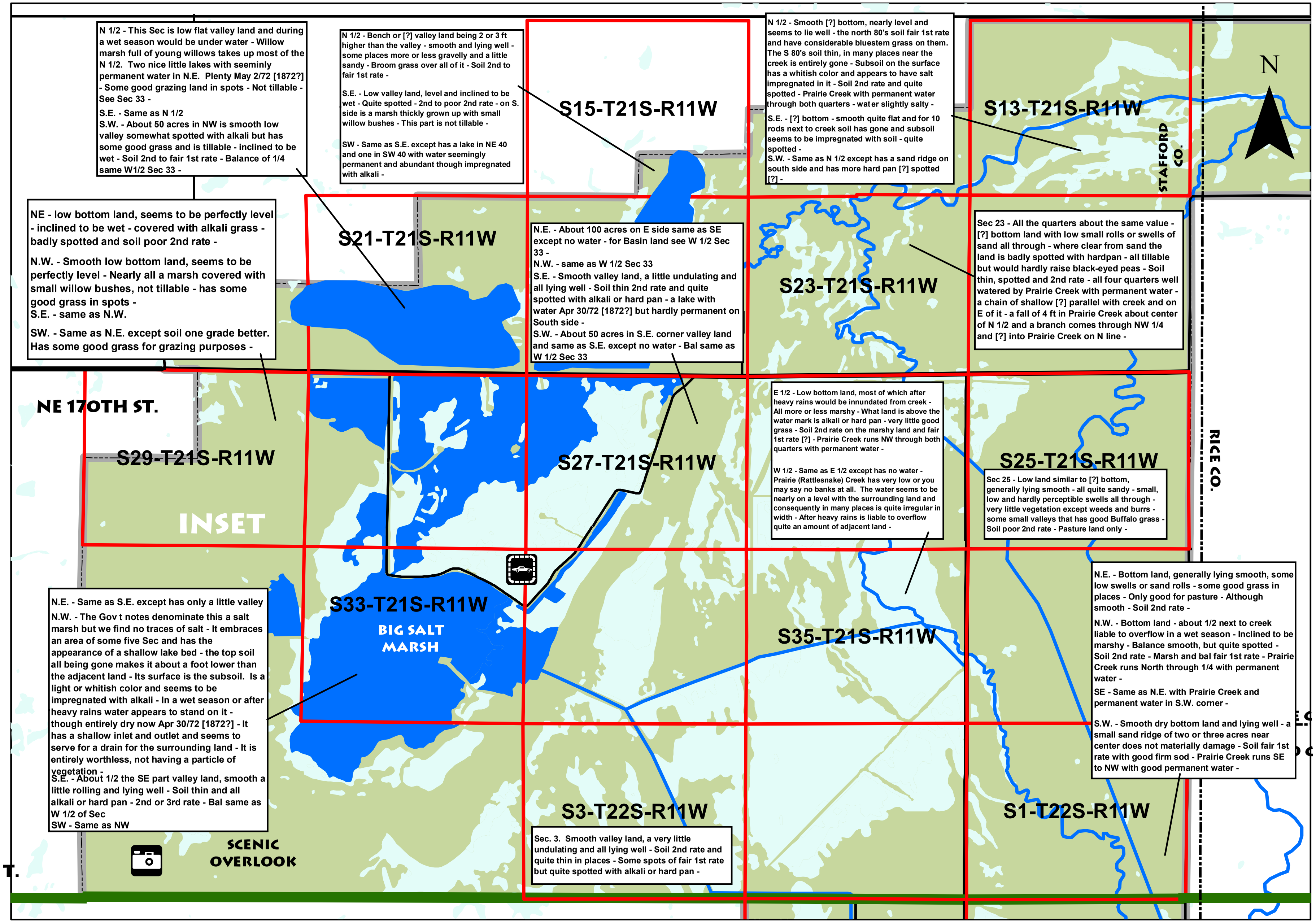


Figure 16a. Map of Quivira NWR with field notes from the Santa Fe Railroad surveys in the 1870s(north section).

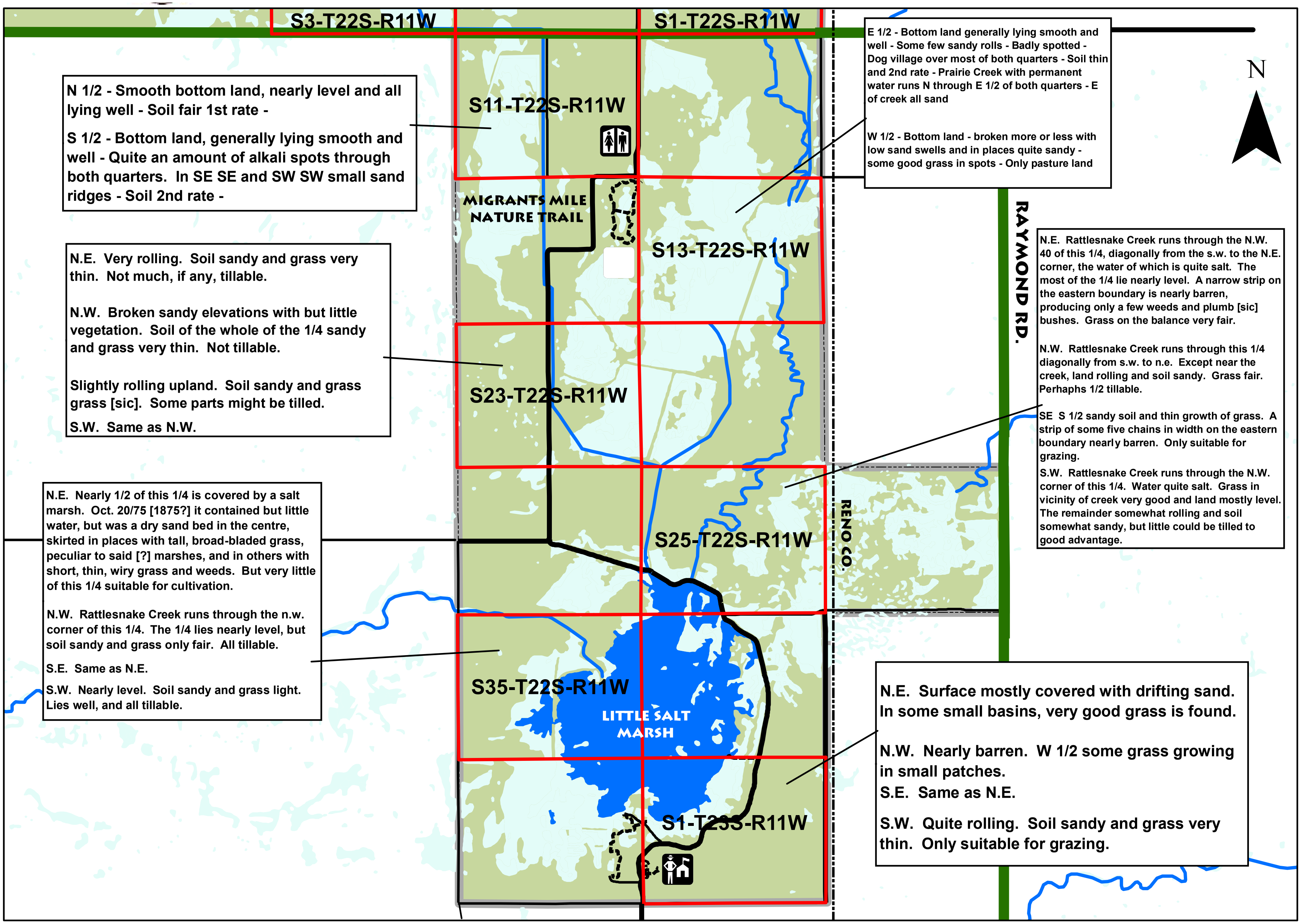


Figure 16b. Map of Quivira NWR with field notes from the Santa Fe Railroad surveys in the 1870s(south section).

table that generally varies from a few inches from the surface to a depth of two to four feet. The rhizomatous grasses and subirrigated saturated soils allow grasses to survive intense, regular wildfires. Trees and shrubs historically were suppressed in subirrigated grasslands by occasional fires and the few trees and shrubs that did occur in these areas probably survived only on wet protected sites such as along stream banks. Grazing history has a major impact on the dynamics of grasslands (NRCS 2010) and native herbivores included large ungulates, rabbits, insects, and numerous burrowing rodents. Nonsaline subirrigated sites at Quivira NWR occur on Dillhunt-Pleva complex, Dillwyn Plevna complex, Hayes-Solvay, Ninnescah, Solvay, Turon-Caraway complex, and Zenda-Natrustolls complex soils (Fig. 6). These habitats typically are dominated by big bluestem, Indiangrass, eastern gammagrass (*Tripsacum dactyloides*), and prairie cordgrass (NRCS 2010). Other prevalent grasses include Canada wildrye, little bluestem, sideoats grama (*Bouteloua curtipendula*), buffalograss (*Bouteloua dactyloides*), and marsh bristlegrass (*Setaria parviflora*). Common forbs interspersed with grasses in nonsaline subirrigated habitats include Maximillian sunflower (*Helianthus maximiliani*), golden tickseed (*Coreopsis tinctoria*), prairie acacia (*Acacia angustissima*), and many others. Desert false indigo (*Amorpha fruticosa*), buttonbush (*Cephalanthus occidentalis*), and roughleaf dogwood (*Cornus drummondii*) occasionally are present in nonsaline subirrigated sites. The fresher subirrigated grasslands at Quivira NWR were often sites of native "hay" production and cutting, and are sometimes referred to as "prairie hay" habitats in older literature and historical accounts of the region (e.g., Fig. 16).

Saline subirrigated grassland communities have similar physical attributes as fresher subirrigated grassland habitats, but occur on moderately tight alkaline or saline soils that are poorly drained. These saline subirrigated sites usually are located on low terraces bordering floodplains. Major soil types in alluvial subirrigated saline grassland include Abbyville and Natrustolls types. Subirrigated saline grassland soil-plant moisture relationships are dictated by the relative salt or sodium concentrations, and are typically have high annual biomass production. Dominant grass species are similar to alluvial subirrigated nonsaline grassland, but more alkali sacaton and composite

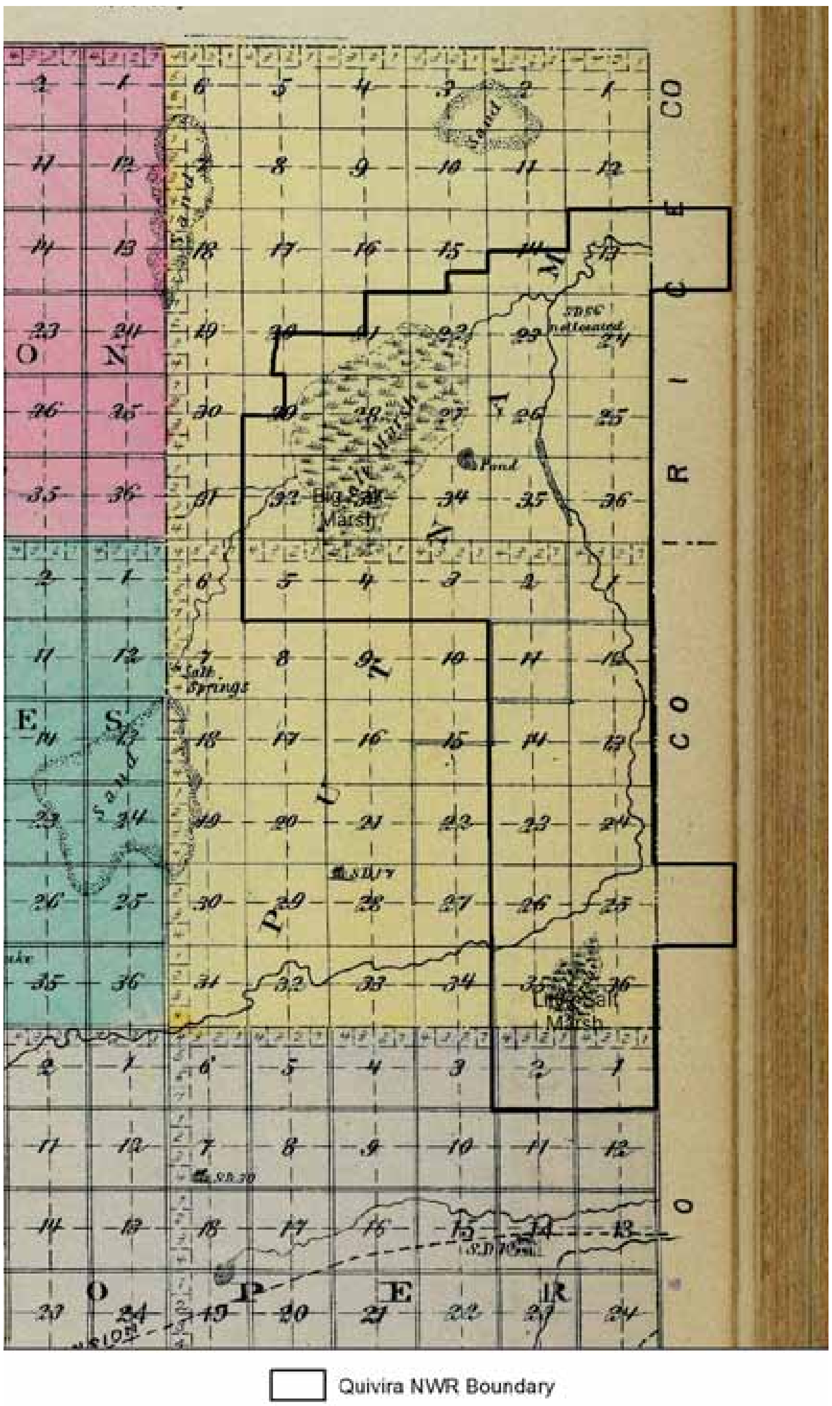


Figure 17. Stafford County, KS township map from 1886.

dropseed are present (NRCS 2010). Eastern gamma-grass, big bluestem, and little bluestem occur on more neutral pH soil inclusions.

Higher elevation non-floodplain, and non-subirrigated, upland grasslands historically were extensive on Quivira NWR and contained sandy and clay/loam mixed grass assemblages (NRCS 2010). Sandy upland-type grassland at Quivira NWR is present on deep sandy Canadian, Carwile, Naron, and Pratt soils (Fig. 6) that have moderate water retention capability. Occasional fire was an integral ecological driver of upland grasslands and fires occurred mostly during spring and summer lightning events and perhaps some intentional burning by native people. Grazing by native ungulates, rodents, and insects also was an important influence on plant composition and structure in upland grasslands. Upland sandy grasslands were essentially free of trees and large shrubs and were dominated by warm season grasses such as sand bluestem, switchgrass, and Indiangrass. Other common species in these sandy uplands include Canada wildrye, sideoats grama, sand lovegrass, purple lovegrass (*Eragrostis spectabilis*), and sand dropseed. Short grasses including blue grama, hairy grama, thin paspalum (*Paspalum setaceum*), and sideoats grama are scattered in sandy grassland sites. Many legumes are present in sandy grasslands including Nuttall's sensitive-briar (*Mimosa nuttallii*), roundhead lespedeza (*Lespedeza capitata*), sessileleaf tick trefoil (*Desmodium sessilifolium*), golden prairie clover (*Dalea aurea*), silky sophora (*Sophora nuttalliana*), and prairie bundleflower. Common forbs include scaly blazing star (*Liatris squarrosa*), downy ragged goldenrod (*Solidago* petiolaris), and pitcher sage (*Salvia azurea*). Small seasonal and temporary wetland depressions are common in some sandy grassland areas, e.g., the Unit 10 and 11 areas (Fig. 19). These small depressions receive annually variable inputs of surface water from onsite precipitation and runoff and support unique vegetation including many wet meadow species such as spikerush, sedges (*Carex* spp.), herbaceous species, and wetland grasses.

Loamy–clay uplands at Quivira NWR contain extensive mixed warm season grass species and endemic grasses have root systems capable of using often low amounts of water that slowly percolates through soil profiles (NRCS 2010). Loamy-clay soils in these assemblages usually are Farnum and Tabler types (Fig. 6). Dominant grass species in upland loamy-clay areas include big bluestem, switchgrass, and Indiangrass; the major mid-height grass species is little bluestem. Scattered short stature grasses

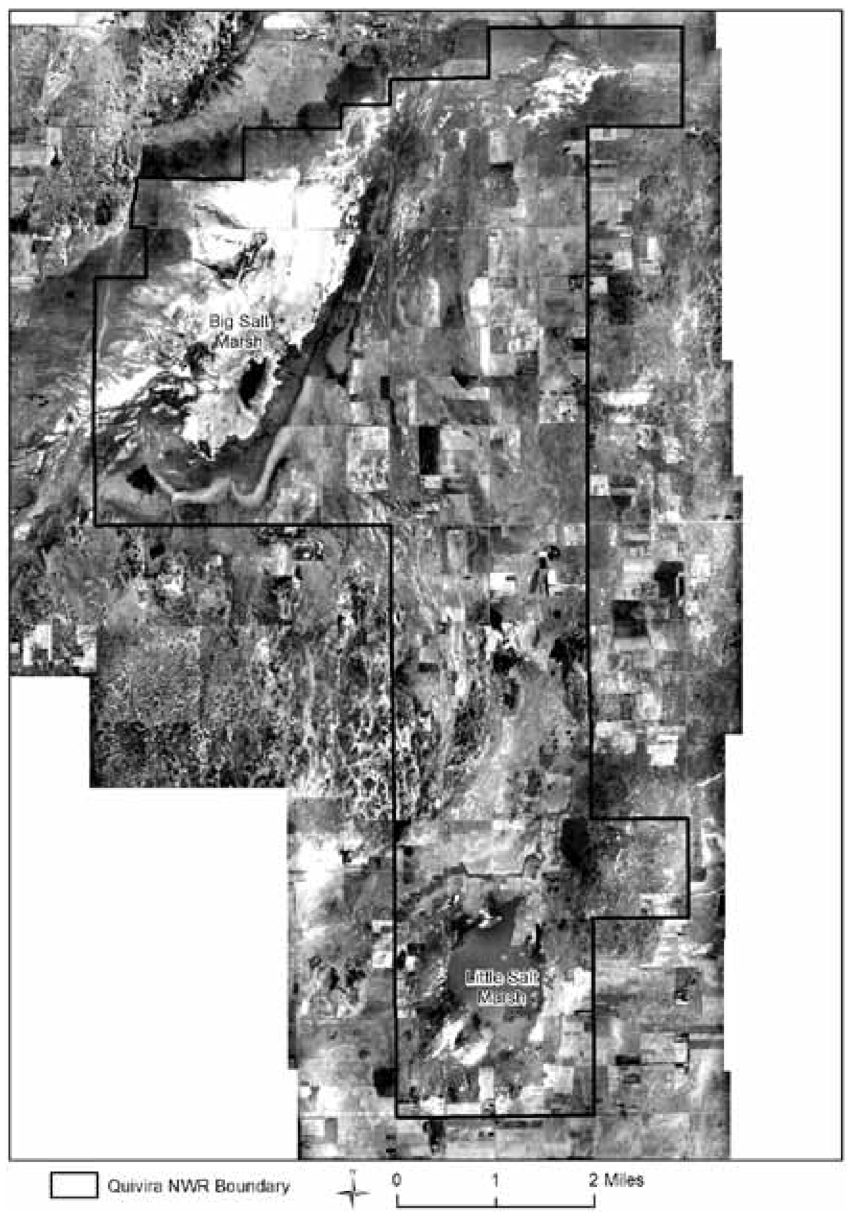


Figure 18. 1938 aerial photograph of the Quivira NWR region.

Figure 19. Photograph of small ephemeral wetland depressions in upland grasslands on Quivira NWR.

include blue grama and buffalograss. These upland sites support a wide variety of native legumes interspersed throughout the grass sward. Common legume species include groundplum milkvetch (*Astragalus crassicarpus*), purple prairie clover, slimflower scrufpea (*Psoralea tenuiflora*), and prairie bundleflower. Leadplant (*Amorpha canescens*) and Jersey tea (*Ceanothus herbaceous*) are common low-growing shrubs that are tolerant to fire, and clumps of smooth (*Rhus* glabra) and fragrant sumac (*Rhus aromatic*) occur in areas that partially escape fires. Because these shrub areas often occur on ridgetops and other high elevations, they are often used by grazing animals during the hot days of late summer to gain relief from heat and insects.

A HGM matrix of relationships of the above major plant communities to geomorphic surface, soil, general topographic position, and hydrology was developed (Table 2) to map potential distribution of historic communities on Quivira NWR (Fig. 20). The hydrogeomorphic matrix of understanding, and prediction of, potential historic vegetation communities was developed from plant associations described in published literature, vegetation community reference sites, and state-of-the-art understanding of plant species relationships (i.e., botanical correlation) to geomorphology, soil, topography and elevation, hydrological regimes, and ecosystem disturbances (e.g., Ungar 1961, Nelson 2005, NRCS 2010). These plant-abiotic correlations are in effect the basis of plant biogeography and physiography whereby information is sought on where plant species, and community assemblages, occur throughout the world relative to geology and geomorphic setting, soils, topographic and aspect position, and hydrology (e.g., Barbour and Billings 1991). The hydrogeomorphic matrix provides a way to map the potential historic vegetation communities at Quivira NWR in an objective manner based on the botanical correlations that identify community type and distribution, juxtaposition, and "driving" ecological processes that are most influential in community formation and sustainability. Obviously, the predictions of type and historic distribution of communities are only as accurate as the understanding and documentation of plant-abiotic relationships and the geospatial data for the abiotic variables for a location and period of interest, such as Presettlement period. For example, the precise delineation of salt marsh vegetation zones and shallow small wetland depressions in upland grassland areas, is limited by the gross-scale topographic information available when this report was prepared. When recently completed LIDAR topography survey data are available and processed for Quivira NWR, then analyses of topographical/hydrological relationships of these specific wetland vegetation zones can be conducted.

At Quivira NWR, the major vegetation communities that were present during the Presettlement period are known (e.g., discussion in NRCS 2010) and the botanical relationships of these communities with at least some abiotic factors are documented (e.g., Ungar 1961). The interrelationships among abiotic factors at Quivira NWR generally are understood and documented. For example, the type and spatial position of soils generally are closely related to geomorphic surface and formation. As a specific example, Plevna sub-order soils are present in frequently flooded, depressions in alluvial floodplains and abandoned channel areas. These soils are formed in loamy alluvium and are underlain

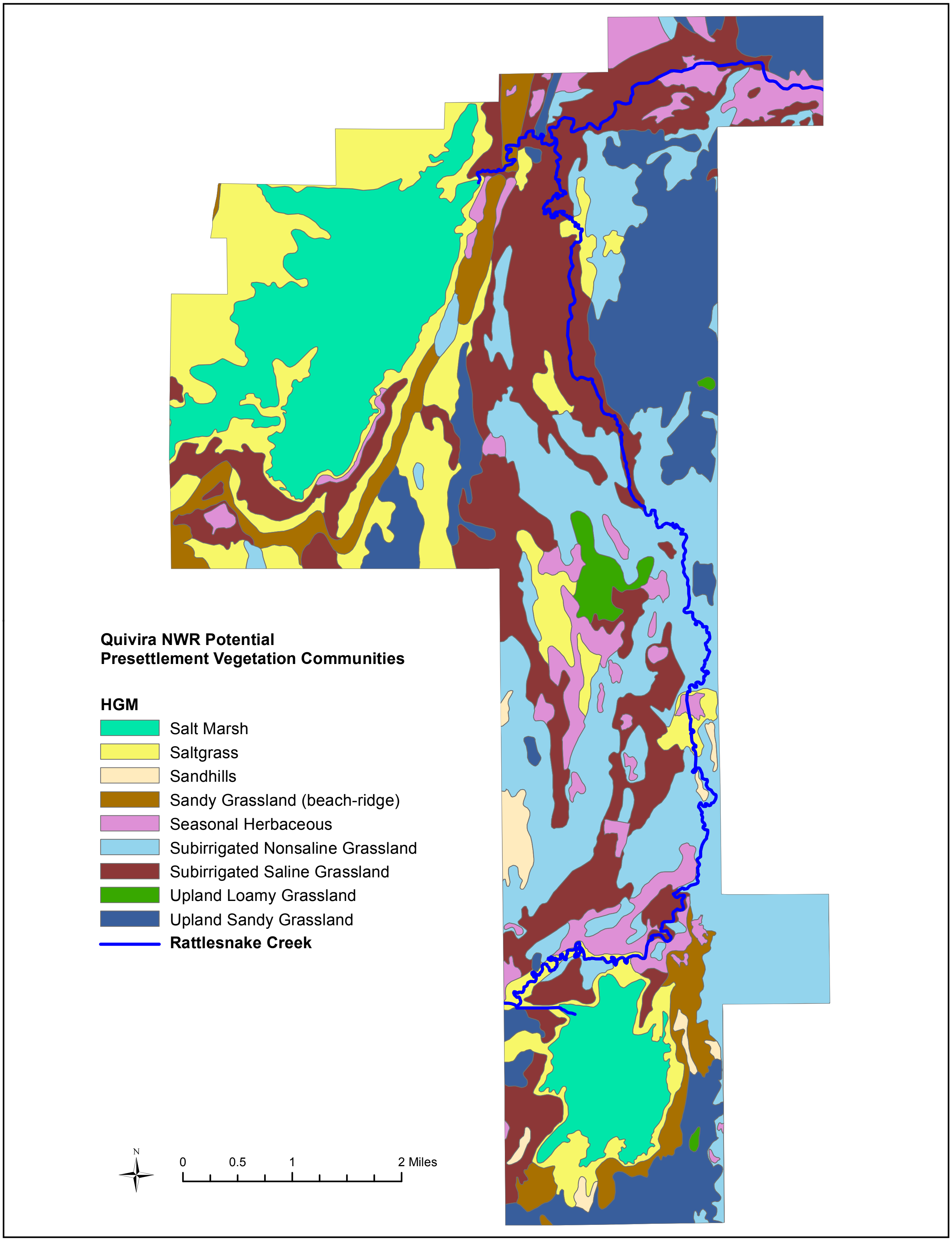


Figure 20. A model of potential Presettlement vegetation communities on Quivira NWR.

Table 2. Hydrogeomorphic (HGM) matrix of historical distribution of major vegetation communities/habitat types in the Quivira NWR region in relationship to geomorphic surface, soils, and hydrological regime. Relationships were determined from land cover maps prepared for the Government Land Office survey notes taken in the late 1800s, historic maps and photographs (e.g., Fig. 16), current and historic USDA soil maps (Dodge et al. 1978, NRCS 2010), geomorphology maps (Fig. 3), region-specific hydrology data (e.g., Fader et al. 1978, Sophocleous 1997, Jian 1998, Estep 2000, Striffler 2011), and various botanical accounts and literature (e.g., NRCS 2010, Ungar 1961).

Habitat type	Geomorphic surface	Major soil types	Flood frequency[a]
Sand hills	Dune sands	Tivin	OP
Sandy grassland (Beach ridge)	Beach ridge	Pratt-Tivoli	OP
Salt marsh	Alluvial/lacustrine depressions	SSURGO marsh	SGD, ROB
Saltgrass	Depression fringes	Plevna	SGD, ROB
Seasonal Herbaceous	Alluvium depressions	Aquoll, Waldeck	Seasonal surface
Riparian Creek Corridors	Rattlesnake Creek corridor	Varied, sand	Continual creek flow
Subirrigated saline grassland	Alluvium	Abbyville, Natrisols	SGD, OP
Subirrigated nonsaline grassland	Alluvium	Dillhut-Plevna, Hayes-Solweg, Dillwyn, Zenda	GD, OP
Upland sandy grassland	Dune sands	Canadian, Carwille, Naron, Pratt, Tivin-Dillhut	OP
Upland clay/loam Grassland	Dune loess, loam	Farnum, Tabler	OP

[a] OP - predominantly onsite precipitation; SGD- saline groundwater discharge; GD – groundwater discharge, with low salinity; ROB – Rattlesnake Creek overbank and backwater surface flows; Seasonal surface - predominantly seasonal surface water runoff and minor creek overbank flooding, relatively fresh or slightly brackish water; Continual creek flow – sustained flows in Rattlesnake Creek.

by clay material (Striffler 2011). Detailed maps of the geomorphology (Fig. 3), soils (Figs. 6,7), and hydrology (see reviews in Striffler 2011) at Quivira NWR are available.

The major factors influencing the type and distribution of historical vegetation communities at Quivira NWR are:

1. The geomorphic surface of either Quaternary alluvium or Quaternary upland dune sands (Fig. 3).
2. Soil type and salinity (Fig. 6).
3. The historic basin boundaries of the Big and Little Salt Marsh depressions (Fig. 14).
4. On-site hydrology that is affected by type and input of at least seasonal surface water (such as in topographic depressions in both alluvium and sand dune surfaces) and whether the site is subirrigated by high ground water tables (Fig. 7).

These ecosystem attributes were used to make the HGM matrix (Table 2) and subsequent map of potential historical vegetation community distribution (Fig. 20). The first step in this process was to determine the distribution of major vegetation/community types from GLO surveys (Fig. 14), early explorer/naturalist accounts (Fig. 16 and various journal and literature accounts), and Stafford County Township plat maps (Fig. 17). This information defines the locations of "water" areas in the Big and Little Salt Marshes at the time of the map or account, larger alluvial floodplain wetland depressions, the historic channel of Rattlesnake Creek, sand hills and dunes, and the extensive grasslands in the area. The presence of these major landscape and vegetation features was overlaid on contemporary geomorphology, soil, and topography maps to determine correspondence. While older maps and accounts have limitations and may not be completely georeferenced, they do provide the opportunity to specifically define some areas, such as the general water and marsh areas of the Big and Little Salt Marsh, the location of possible narrow riparian areas along the historical channel of Rattlesnake Creek, sand hills on Tivin-associated soils, and larger alluvial wetland depressions in Aquoll and Waldeck soils. Further, the narrow linear relict "beach ridge" along the east side of the Big Salt Marsh is tightly aligned with Pratt-Tivoli, Pratt, and Carwile fine sandy loam soils. These soil types also are present on the southeast side of the Little Salt Marsh, and while it is unknown if some type of beach ridge existed there, the similarity of soils adjacent to a salt marsh suggests similar communities.

The historically extensive grasslands at Quivira NWR contained diverse assemblages of grass and forb species in relationship to soil salinity, textural material (i.e., sand, loam, loess), and soil-surface saturation (NRCS 2010). Recent vegetation mapping (Fig. 21) and description of ecological land types (NRCS 2010) provides a means to separate grassland types based on whether soils were alluvium or upland loess/dune derived, saline or nonsaline, and subirrigated or nonsubirrigated (Fig. 7). This classification is helpful because it by default integrates geomorphology, soil type and salinity, and hydrology, which can define grassland assemblages. Consequently, grasslands at Quivira NWR were separated into four categories (subirrigated nonsaline, subirrigated saline, upland loamy, and upland sandy) in addition to the previously mentioned "beach-ridge" sandy grassland association. Soil types associated with these four categories are provided in Table 2.

The final distinction of major historical vegetation communities at Quivira NWR was to separate the unique saltgrass community from the historical salt marsh complex of diverse herbaceous and aquatic wetland species along with more barren salt "flats" and hummocks. The best information on historical vegetation communities associated with and near Quivira NWR salt marshes is the 1954 vegetation maps (Fig. 21) and botanical descriptions provided in Ungar (1961) for the Big Salt Marsh. This botanical information separates the saltgrass assemblage, where saltgrass is the most dominant species, from other salt marsh and grassland categories, and generally correlates saltgrass with Plevna frequently flooded soil types (Fig. 6). It is important to note that saltgrass occurs in other vegetation communities, such as subirrigated saline grassland, but it is not the dominant species present. For lack of any other defining information, we mapped Plevna soils as the location of the historical saltgrass-dominated community. Further, a generic salt marsh community was mapped as the boundary of the current "marsh" soil type. This generic salt marsh boundary reflects not only the historical maps showing the smaller water area of the Big and Little Salt marshes (e.g., Fig 14), but also the associated marsh basin areas that had annually and seasonally variable flooding, but not permanent water, depending on water inputs within and among years. Consequently, this mapping attempts to delineate the possible extent of the salt marsh during the wettest years, while understanding that during dry periods the actual flooded areas of the Big and Little Salt Marsh would be much smaller. We acknowledge that the mapping of saltgrass and salt marsh communities is generic and hopefully can be refined when more detailed topographic information becomes available and can be correlated with seasonal and annual hydroperiods. For example, one-foot elevation differences in the Big Salt Marsh flats can cause specific sites to be either moderately covered with saltgrass or Suaeda vs. nearly barren salt flats.

As with all attempts to model the distribution of historical vegetation for a site, the potential vegetation map is only as good as the information available to prepare it. As such, Fig. 20 should be seen as a "hypothesis" of community distribution that hopefully will be refined when more detailed information, such as topography, becomes available.

Collectively, the Quivira NWR ecosystem historically was dominated by sandy, mixed warm season grasslands, essentially no trees or large shrubs, and the unique large Big Salt Marsh basin and the smaller, fresher, Little Salt Marsh basin.

Rattlesnake Creek was the primary source of slightly saline water moving through the Quivira ecosystem and provided periodic flooding of the Little Salt Marsh and subirrigation of alluvial grasslands and herbaceous wetland depressions. Saline groundwater discharge was the primary ecological driver causing regular sustained low flow surface water inputs into and through the Big Salt Marsh wetland complex and exiting via Salt Creek that merged with Rattlesnake Creek and ultimately flowed to the Arkansas River. Upland grasslands were dependent on local rainfall and surface water percolation into soils. These grasslands also historically had relatively regular fire and herbivory occurrences.

The heterogeneity of grassland communities coupled with unique salt marsh and diverse wetland habitats provided important resources used by varied and abundant animal species at Quivira NWR under past and present conditions. Among the more obvious differences between past (prior to refuge establishment) and present wildlife communities on the refuge are increasing populations of white-tailed deer (*Odocoileus virginanus*) and eastern wild turkey (*Meleagris gallopavo*) and the introduction of

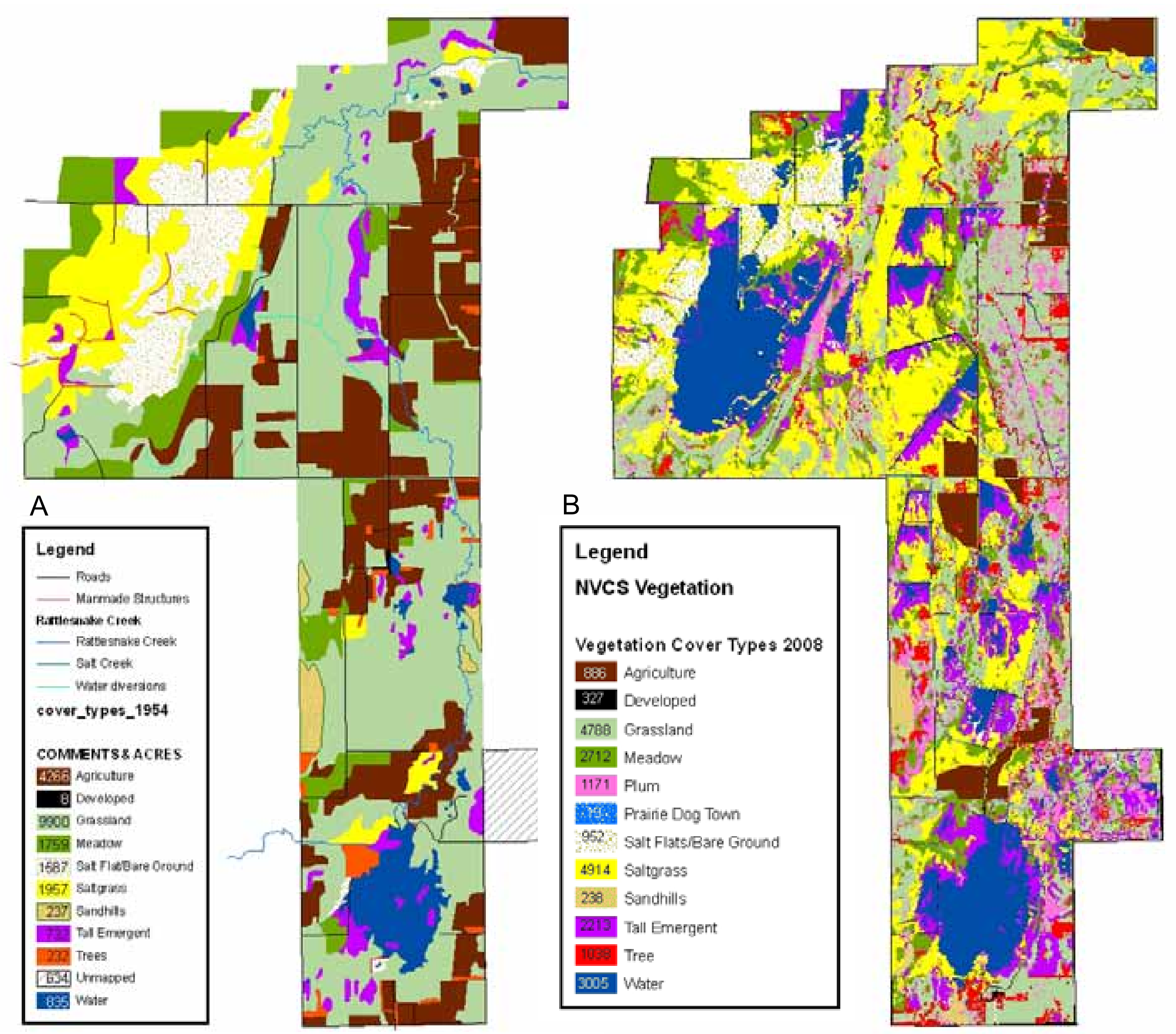


Figure 21. Vegetation land cover on Quivira a) in 1954 adapted from aerial photographs and b) field mapping and interpretation conducted 2008-2011.

common carp (*Cyprinus carpio*) into a largely flow-through surface water system. Major changes in wildlife abundance and habitat use on Quivira NWR are related to alterations in habitat types and conditions at various spatial and temporal scales. General habitat associations and life history characteristics of animal species currently present at Quivira NWR are provided in Appendices A-C).

The critical inputs of ground and surface water to the Quivira NWR ecosystem occurred mainly in spring and summer each year and caused pulses of resource availability that was used by both migrant and resident animals. In spring, increases in discharge of Rattlesnake Creek and some seepage of groundwater recharged wetlands and greatly increased wetland resources used by migrant waterbirds. This water subsequently dried through summer, but more regular inputs of groundwater and high flows in some years created variable amounts of wetland area used by breeding waterbirds, especially those species adapted to using salt flats and saline marshes such as snowy plover (*Charadrius alexandrines*) and least tern (*Sterna antillarum*). The larger salt marsh habitats provided important stopover habitats for spring and fall migrant waterbirds in an otherwise relatively dry prairie landscape in the Great Bend Sand Prairie Region. Grassland habitats supported many mammal and bird species (Appendices A,B).

Rachel Laubhan, USFWS

Cary Aloia

Bob Gress

CHANGES TO THE QUIVIRA NWR ECOSYSTEM

SETTLEMENT AND EARLY LAND USE CHANGES

Available archaeological studies and associated dating methodologies suggest that native people apparently first occupied the south-central Kansas region 10,000 to 12,000 years before the present (BP) (Buller 1976). These people had a highly mobile lifestyle that depended largely on big game hunting. About 9,000 BP, patterns of human use of the region began to change due to regional climate fluctuations and increasing populations of people. Archaeological evidence suggests more localized, less mobile, population centers and a greater diversity of tools. By about 3,000 BP, larger repeatedly-occupied campsites apparently occurred along floodplains of the Arkansas River and presumably Rattlesnake Creek. Inhabitants of the area collected wild plants, hunted large and small animals, and created chipped and ground tools. By about 2,000 BP, human populations in south-central Kansas continued to increase and small villages were established; evidence of early agriculture is found along some waterways. When Coronado reached the region in 1541 several Native American groups were present in central Kansas including the Pawnee, Wichita, Plains Apache, Kansa, Kiowa, and Osage (Grajeda 1976, Wedel 1942). Throughout recorded early history, native people were attracted to the Quivira region because of the presence of salt, camp sites on higher elevation sand hills and uplands, and abundant wildlife. Although many tribes moved in and out of the region, by the mid 1800s the influx of European settlers was prevalent and by the late 1870s most tribes had been relocated to Oklahoma.

The first European apparently known to visit the Great Bend Region after Coronado was the French explorer Etienne de Bourgmont in 1724 (http://en.wikipedia.org/wiki/Quivira). Thereafter, only a few trappers and explorers visited the area until the mid 1800s (Dolin 2010). Western explorers and fur trapping expeditions traveled through the Great Bend region of Kansas in the mid and late 1800s, and the Sante Fe Trail was within 12 miles of the current refuge boundary (Cutler 1883, Blackmar 2002). The first apparent European settlement in Stafford County occurred in 1876 when a few people located in the vicinity of the Big Salt Marsh on Quivira NWR (Cutler 1883, Ogle and Company 1904, Steele 1953). A company was organized for the purpose of manufacturing salt, which was soon determined to be unprofitable and the homesteaders began using the marshes and adjacent grasslands for pasture, hay land, and cattle production (Sheridan 1956). The artesian seeps and springs near the Big Salt Marsh were relished by people in the area and this spring water was believed to have health benefits. Early settler accounts from the region commonly speak of the abundance and desirability of "wild hay" lands adjacent to the Big Salt Marsh basin (Hutchinson News 1886, Hay 1890). By the early 1900s, some upland areas at Quivira NWR had been converted to small grain agriculture and some native prairies were modified with introductions of non-native species.

In addition to agriculture expansion in the Quivira NWR area, the salt marshes were used for commercial and recreational waterfowl hunting after the turn of the century. Private hunting clubs including the Hutchinson Gun and Hunting Club, Stafford Gun Club, Ellinwood Club, Park Smith Club and the McGuire Club either owned or leased much of the marsh lands and in the late 1920s or early 1930s they dug a permanent ditch to connect and divert water from Rattlesnake Creek to the Little Salt Marsh. Other wetland areas along Rattlesnake Creek also were partly impounded by hunting clubs with small dikes and ditches, such as the 16-acre Darrynane Lake (Unit 24) impoundment. By the 1930s, many upland areas on and adjacent to Quivira had been converted to cropland and pasture (Fig. 18). By 1954, about 4,266 acres of what is now Quivira NWR were in agricultural production (Fig. 21).

HYDROLOGICAL AND VEGETATION COMMUNITY CHANGES AFTER ESTABLISHMENT OF QUIVIRA NWR

The major contemporary ecosystem changes in the Quivira NWR region have been: 1) alterations to distribution, chronology, quality, and abundance of surface and groundwater; 2) enlargement and permanent water management in the Little Salt Marsh; 3) conversion of native vegetation assemblages to agriculture and invasive plant species; 4) increased presence of woody species; and 5) altered topography including many levees, roads, ditches, borrow areas, and water-control structures.

After Quivira NWR was established, acquisitions were made to bring the refuge area to 21,820 acres by 1969 (Quivira NWR, unpublished annual narratives). Subsequent acquisitions enlarged the refuge to 22,135 acres. In 1957 the USFWS filed for a "senior" right to divert 22,200 acre-feet of water from Rattlesnake Creek to refuge wetlands (see water history in Estep 2000, Striffler 2011). In 1982, the USFWS filed a Notice of Proof of completion of work for water right permit #7571. In 1996, the Kansas Division of Water Resources certified a permit for only 14,632 acre-feet of water diversion from Rattlesnake Creek because the USFWS could not demonstrate that it had diverted 22,200 acre-feet during the period of proof. The current Kansas Water Right for the refuge is for 14,632 acre-feet/year at 134,640 gallons/minute from Rattlesnake Creek (Striffler 2011). The actual quantity of water normally diverted from Rattlesnake Creek for refuge management is less than this water right, often because sufficient quantities are not available at the same time that water is desired to achieve refuge habitat goals and objectives. In years with below average precipitation and heavy agricultural irrigation demands, insufficient water quantities are delivered to the refuge to exercise all habitat management options. Water leaving the refuge is not metered largely because of the absence of water rights downstream before entering the Arkansas River.

The original development for Quivira NWR was envisioned to hold water in the salt marshes and adjoining salt "flats" using local drainage if possible and also to divert "surplus" Rattlesnake Creek water into the marshes and wetland units in the east half of the refuge (USFWS 1953). In the eastern half of the refuge, water from Rattlesnake Creek was to be diverted into low "sump" areas and some existing diked areas such as Darrynane Lake. The original refuge development plans stated that "… no great expanses of water impoundment are planned, but rather to produce as much "edge" as possible and such water areas as are necessary to distribute birds throughout the project" (USFWS 1953). Beginning in 1959, the refuge began constructing water-control and delivery infrastructure and by 1962, more elaborate water-control infrastructure was developed to divert Rattlesnake Creek water to various refuge wetland units because local precipitation and runoff proved unreliable and was insufficient to flood desired wetland areas. Ultimately, 34 water management units were developed or enhanced and water was diverted to these units through a complex series of ditches, dikes, and water-control structures and with several main points of diversion of water from Rattlesnake Creek (Figs. 22,23). A detailed summary of current water-control structures, canals, and dikes/levees is provided in Striffler (2011). Maintenance of the water-control system at Quivira NWR is ongoing and routinely involves filling in eroded areas, replacing and repairing structures and culverts, replacing staff gauges, and removing detritus and sediment. Excess vegetation is removed and sediment dredging keeps canals operable. In addition to the appropriated surface water used by the refuge, 31 cattle watering facilities are maintained and three artesian wells and three domestic wells are present (Fig. 13). At least one artesian well currently owned by the refuge supplements a natural spring that provides habitat for a breeding population of the state threatened Arkansas darter (*Etheostoma cragini*).

The original proposed impoundments for Quivira NWR would have required, at full operation, about 30,536 acre-feet of water annually, accommodating seepage and evapotranspiration (USFWS 1962). Canals transporting water were capable of distributing from 100-300 cfs at peak inflow periods to the storage area of the Big Salt Marsh. Descriptions quoted or paraphrased from the original master plan for development and management of wetland units on Quivira NWR are provided below (condensed from USFWS 1962:30-45). While this information provides historical context and information from different time periods, other management activities and philosophies and external influences have since contributed to current environmental conditions, changes in refuge infrastructure, and management decisions.

"Units 5 (Little Salt Marsh) and 72 (Big Salt Marsh) are to be designed for maximum water storage capacity. Other units are designed to cover a maximum area with shallow depth of water, creating the best habitat for the dabbling ducks common to the refuge."

"Plan to raise the Little Salt Marsh dike to increase the maximum depth from about 4 feet to 6.5-7 feet and to increase surface area from about 640 acres (current maximum area at a 4 foot depth) to about 960 acres."

"Unit 7 was formerly a 15 acre sump that received water from overflow from the Little Salt Marsh. Drainage from Unit 11 is northeast through a natural channel. Units 14a and 14b lie along an old creek channel and are dominated by alkali sacaton and saltgrass. Unit 16 is a natural sump with alkali sacaton and saltgrass flats. Unit 21 was a natural depression in an old creek channel. Units 22 and 23 were natural ponds/depressions that depended on local runoff and precipitation for flooding; they both historically had good waterfowl use when wet."

"Unit 24 (Darrynane Lake) was an existing 16-acre impoundment on Rattlesnake Creek dammed by a former hunting club and had a washed-out concrete spillway that has been replaced with a barrel culvert. Unit 25 was a natural low saltgrass-alkali sacaton area located between sand knolls. Unit 26 contained about 90 acres of good cropland and it was anticipated to be one of the most productive units on the refuge because of its versatility and high fertility. Unit 28 was surrounded by tall grasses to the south and west."

"Units 47 and 55 were expansive saltgrass flats that usually flooded shallowly in spring; over 50,000 ducks were observed in Unit 47 in spring when 3-4 inches of water inundated the flats. It was anticipated that both units would be grazed and irrigated to create marsh meadow habitats that could be used by waterfowl for 2+ weeks after flooding in spring (Note: saltgrass was considered meadow at that time by refuge staff). After shallow flooding, water would be removed from these units to avoid changing the saltgrass/meadow composition of the area."

"Unit 48 contained about 75 acres and Unit 49 contained about 100 acres. Unit 50 was an old hunting club property. Unit 34 was a natural low

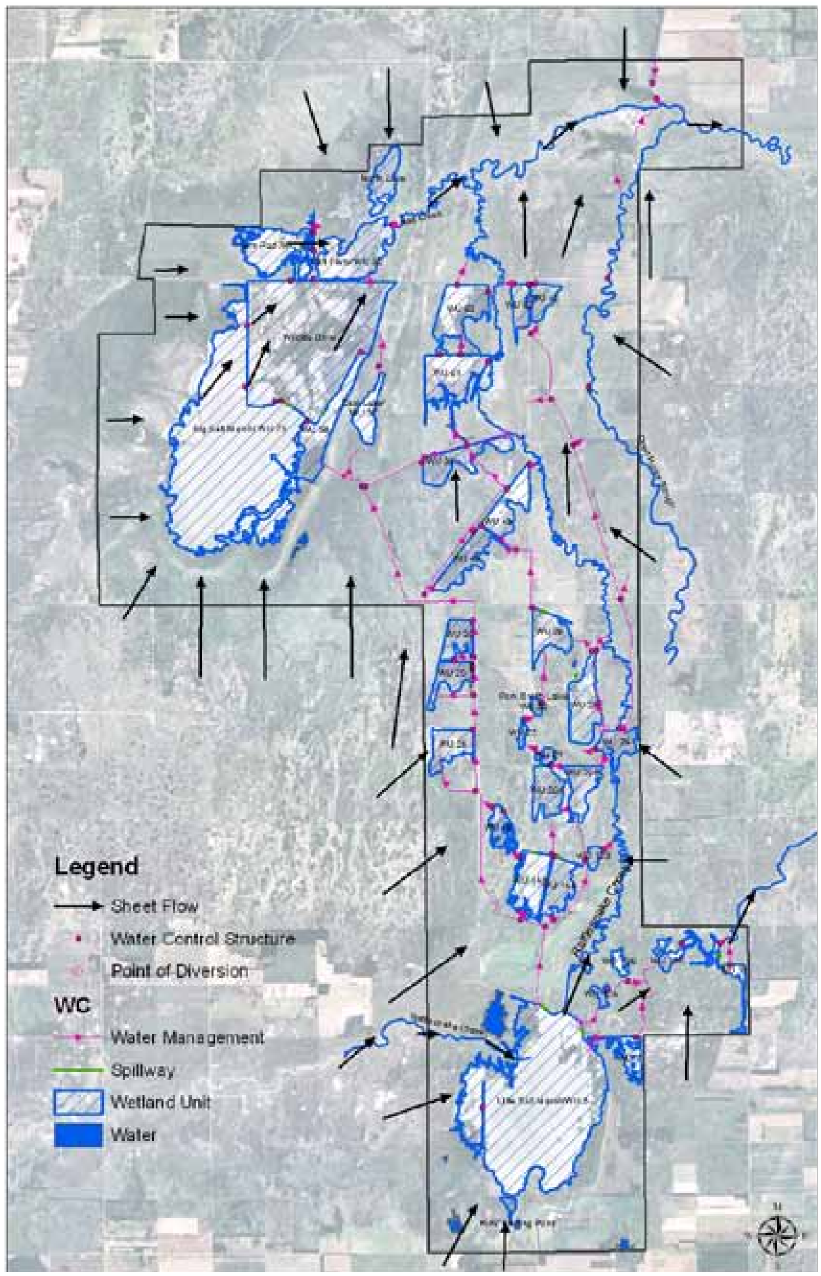


Figure 22. Wetland management units and directions of water flow, including water-control structures on Quivira NWR.

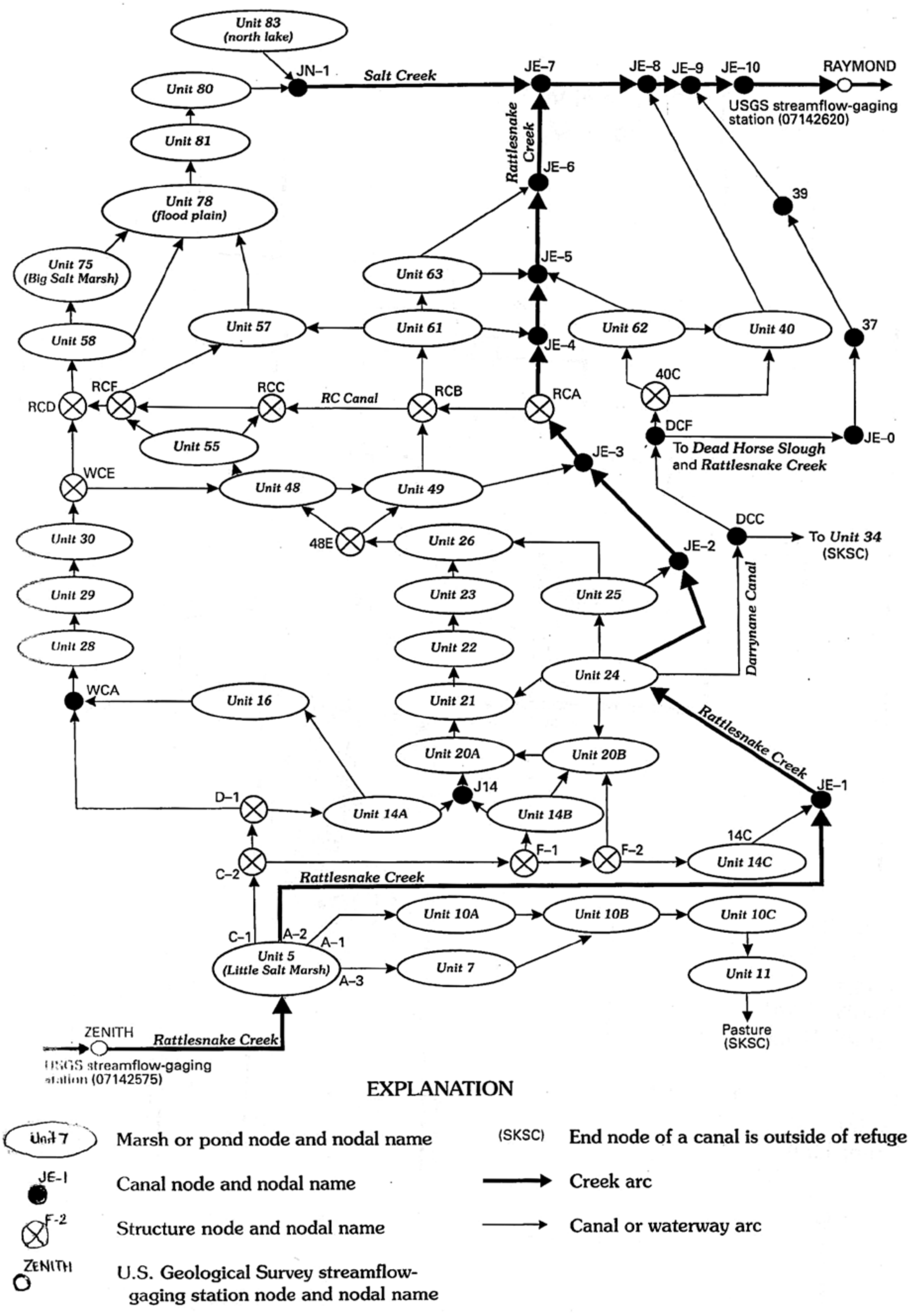


Figure 23. Model of water movement on Quivira NWR (from Jian 1998).

depression within a tall grass pasture. Unit 60 had a history of heavy duck use in late winter and Unit 62 was covered by a dense stand of prairie cordgrass."

"Development of Unit 44 was intended to have cultivated land in the NW and SE portions of the unit with some timber in the middle. Unit 44 was to drain into scattered sump areas on the flats to the north. Unit 57 (McCandless Lake or East Lake) was a natural lake and Dead Horse Slough was an existing natural slough. Unit 72, the Big Salt Marsh, was planned to be major water storage area for flooding the wetland habitats in the northwest part of the refuge, mainly the Big Salt Marsh Basin, and to attract diving ducks such as redhead, scaup, and canvasback.

A general assumption of early management plans for Quivira NWR was that water management (as designed above) would not be well suited for growing submergent aquatic plants and would encourage emergent plants such as cattail and American bulrush that would need to be discouraged. Wetland units scheduled for production (i.e., flooding) in a given year were to be flooded in spring; drawn down in summer to encourage germination of smartweed, wild millet, and alkali bulrush; and then reflooded in fall to make food available to migrant waterfowl (i.e., dabbling ducks). Summer drainage of some units was to be done occasionally to discourage undesirable plants and rough fish. It was felt that if left alone, the marsh "meadows" would produce three-square bulrush, prairie cordgrass, and "other types of vegetation" that were of "no use" in that condition because of the "dense" vegetation coverage, with the possible exception of sora rail. It was further believed that these dense meadows should be grazed or hayed for wildlife to use them.

At some level, water management on the refuge since early development has attempted to obtain and store as much water as possible each year, often as early as February (to create habitat for spring migrant waterfowl and shorebirds). Current surface water area and capacity of management units are 6,138 acres and 11,701 acre-feet, respectively and have a maximum potential 6,553 surface acres and 14,179 acre-feet of water (Jian 1998, Estep 2000). In many years, water has been diverted into management units (primarily from Rattlesnake Creek) and held as full as possible to offset the possibility that water will not be available to refill the units later in summer and early fall. The primary water storage occurs in the Little Salt Marsh, which is often flooded throughout the year to provide water as needed to manage other units. The west edge of the Little Salt Marsh is maintained as shallow wet meadow habitat that is heavily used by shorebirds, white-faced ibis (*Plegadis chihi*), sandhill cranes (*Grus canadensis*), and occasional whooping cranes (*Grus americana*). During March through May some wetland units are drawn down to provide habitat for migrating shorebirds. The areas north of the Big Salt Marsh and North Lake have been managed as salt flats for nesting snowy plover and interior least tern. From May to September, smaller wetland units (but not the Little Salt Marsh) are managed so that they dry out gradually to promote moist soil vegetation production. Water levels in the Big Salt Marsh area decline in summer as groundwater flow from seeps and springs diminishes and high temperatures and winds increase evapotranspiration. To some degree, water levels in the Little Salt Marsh also decrease in summer depending on the wetness of the year and flows in Rattlesnake Creek. In recent years summer flow in Rattlesnake Creek has been greatly reduced as irrigation use of groundwater in the Rattlesnake Creek Basin has increased and reduced aquifer levels and subsequent discharge into the creek. If possible, many units are reflooded in fall after irrigation season and groundwater flow into Rattlesnake Creek and seepage into the Big Salt Marsh has recovered.

Over time, the extent and composition of vegetation communities on Quivira has changed. The vegetation maps for potential historical (Fig. 20), 1954 (Fig. 21), and 2008 (Fig. 21) periods demonstrate these changes (Table 3). First, development of the aforementioned water-control infrastructure and subsequent water management on the refuge has caused:

- enlargement and more permanent flooding of the Little Salt Marsh
- enlargement, expansion, and annually regular flooding regimes in over 30 wetland impoundment units
- diversion of Rattlesnake Creek and groundwater through artificial flow corridors
- expansion of cattail, phragmites, and tall bulrush in more permanently flooded areas (Table 3)
- expansion of open water areas

The combination of changed fire recurrence, grazing, and agriculture on refuge and adjacent regional lands that started well before refuge establishment eventually caused:

- reduced native plant diversity and occurrence in grasslands with shifts to more invasive (native and nonnative) and short grass plant species and reduced numbers of native forbs (e.g., NRCS 2010).
- increased presence and expansion of trees from shelterbelt strips, groves near buildings and cultivated fields, and invasion of nonnative and aggressive species including tamarisk, black locust, Russian olive, and Siberian elm.
- expansion of sandhill plum thickets, with some expanded coverage of American plum.

In 1997, a simulation model of canal and control-pond operation was developed for Quivira NWR (Jian 1998). The model used actual streamflow data and evaporation rates from 1991 (a very dry year) and 1996 (a very wet year) and was calibrated to the extent possible with actual outflow data measured at the Raymond gauge on Salt Creek. Results from the model suggested that in an average water year (measured by discharge in Rattlesnake Creek) the refuge would hold spring flows and store as much as possible in the Little Salt Marsh and Units 14a, 14b, 20a, 20b, 29, 48, and 61. Stored water in these units could be released to adjacent units if insufficient streamflow was available in late summer and fall. If insufficient water was available, efforts would be made to primarily maintain water in the Little Salt Marsh, and Units 10a, 10b, 11, 14a, and 14b totaling about 954 acres and 2,900 acre-feet of water. An implementation plan for initiating a "Drought Contingency Plan" contained the following actions:

1. If the mean daily January flow in Rattlesnake Creek at the Zenith gauge is < 25 cfs, the refuge would anticipate a drought year.
2. A review will be made in July using the Palmer Drought Severity Index to determine if drought conditions exist and if the index is -3.0 or lower for Region 8 of Kansas, most diversions to the north of Units 14a and 14b will cease and water primarily will be concentrated in Units 5,7, 10a, 10b, 11, 14a, and 14b.
3. Diversions of water from the Little Salt Marsh will continue until it is determined that habitat in the Little Salt Marsh is being detrimentally affected to the point that it offsets benefits of moving water to another unit, at such time all subsequent diversions from the Little Salt Marsh will cease.
4. Water primarily will be maintained in Units 5, 7, 10a, 10b, 11, 14a, and 14b unless sufficient precipitation occurs to raise the Palmer Drought Severity Index to > -1.0, or streamflow recovers to the level where it is possible to fill units to the north of the above units.

Since the early 1970s, development of groundwater irrigation in the Rattlesnake Creek Basin has increased greatly and groundwater withdrawals have caused precipitous declines in the baseflow of Rattlesnake Creek and also decreased discharge from natural seeps and springs in the region, especially during summer when irrigation is occurring. Changes in amount and timing of surface and groundwater have reduced flow from Rattlesnake Creek into Quivira NWR and altered water quality including pH, temperature, turbidity, conductivity, and dissolved oxygen (Christensen 2002). It has been estimated that about 44,400 acre-feet of water from Rattlesnake Creek flowed into Quivira NWR prior to the 1970s when major groundwater extractions began compared to only about 10,500 acre-feet per year that flows into Quivira currently (Burns and McDonnell 1999). This change in water inflow from Rattlesnake Creek suggests that the average amount of annually flooded wetland habitat on the refuge was about double and the 80th percentile habitat area was nearly three times as much prior to water/irrigation developments.

Attempts have been made to stabilize groundwater levels over the long-term to improve streamflow in Rattlesnake Creek, and into and through Quivira NWR, using a variety of approaches including retiring water rights, water banking, flex accounts, conservation practices and irrigation management, and altering vegetation and agricultural management. Many of these measures impact current and future management on Quivira NWR. Beginning in 1993, the USFWS participated in the Rattlesnake Creek/Quivira Partnership to develop a Rattlesnake Creek Subbasin Management Plan. This management plan attempted to provide incentive-based programs for reducing irrigation water use in the subbasin over a 12 year period. The Kansas Division of Water Resources, the Groundwater Management District No. 5, Water Protection Association of Central Kansas, and the USFWS formed the partnership and the Quivira Project Coalition was the fund-seeking arm of the project, which included Water PACK, Kansas Farm Bureau, Kansas Livestock Association, the cities of

Table 3. Comparison of vegetation cover types on Quivira NWR between 1954 and 2008.

COVER TYPE	MAP	DESCRIPTIONS (DOMINANT PLANT SPECIES)
Grassland	1954	big & little bluestem, switchgrass, indiangrass, sand lovegrass, buffalo grass, blue grama, sideoats grama, three-awn, sand dropseed, wild barley, wild rye, bluestem wheatgass, panic grass, saltgrass (G1, G2 symbols on original map)
	2011	orbs
Sandhills	1954	Sandhills with carrying capacity of >5 acres/cow and calf for 6 months due to low vegetation density. Based on the SSURGO soil map, this is most of the Tivin fine sand with 10-30% slope sites on QNWR. (G3 symbol on original map includes Sandhills and Saltgrass cover types)
	2011	ata)
Saltgrass	1954	Saltgrass (G3 symbol on original map includes Sandhills and Saltgrass cover types)
	2011	
Salt Flat/Bare Ground	1954	bare soil, mostly with alkaline salts (white) on surface (Af symbol on original map)
	2011	
Meadow	1954	little bluestem, indiangrass, three-square, sedges, rushes (H symbol on original map; "wild hay")
	2011	shes
Tall Emergent	1954	three square bulrush, hardstem bulrush, nutgrass [*Scirpus paludosus*], sedges, rushes (M symbol on original map; for Marsh, fresh; in swales and depressions and adjacent to wetland areas)
	2011	
Water	1954	surface water (W symbol on original map)
	2011	
Trees	1954	mostly shelterbelt strips or groves near buildings & cultivated fields. One site with saltcedar on the delta where Rattlesnake Creek enters the Little Salt Marsh. Several groves of open, mixed oaks scattered in the "grazing type" (B, T symbols on original map)
	2011	that
Plum	1954	not included in map description
	2011	
Agriculture	1954	farmed areas and few very small sites that were primarily forbs (weeds)
	2011	
Prairie Dog Towns	1954	not included in map description
	2011	

[a]The 1954 map was adapted to improve visual clarity. The current map used 2008 aerial photos that were ground-truthed in 2010-2011 (finalized in 2011). Of note, descriptions of certain cover types are similar but not exactly the same for the 1954 and current maps. For instance, current "tall emergent" plant types are taller than what occurred in the past.

Wichita, Hutchinson, and Great Bend; and the Kansas Audubon Society.

The major parts of the Rattlesnake Creek Subbasin Management Plan were:

1. Delineate target areas in the basin to assign priority for funding of various management actions. These areas, in order of priority, were the stream corridor, "high decline" areas where groundwater declines exceeded 15 feet based on the 1996 period, and the remainder of the basin. In addition, a target streamflow of 25 cfs in January was set for the Zenith gauge.

2. Water rights buy-back to obtain 8,333 acre-feet in the high decline areas and 2,083 acre-feet in the stream corridor area.

3. Water banking to enable a water user to "bank" a portion of a water right and sell to another user subject to a 10% conservation component.
4. Water transfers to enable a water user to move water from one point of diversion to another, with the goal to move water rights out of the high decline areas and the stream corridor.
5. Conservation practices to reduce water use in the basin by 9,269 acre-feet.
6. Voluntary removal of "end guns", which would result in reduction of water use of 3,044 acre-feet in high decline areas and 996 acre-feet in the stream corridor.
7. 5-year rolling water right that would enable water users to have a five-year water use amount. If users use less than 1/5 of that amount in one year they could transfer the residual to a subsequent year and vice versa if use exceeded 1/5 of the total use.
8. Increased compliance and enforcement.

The goal of total reductions in water used from the above 8 actions would have been 27,346 acre-feet. By 2007, only the water banking and end-gun removal programs were initiated (Basin Management Team 2009). The water rights buy-back program was largely unsuccessful because of a lack of funding, sellers asked high prices, and the Kansas State Engineer was unwilling to permanently retire those rights. The State Engineer has indicated that administrative remedies, such as an Intensive Groundwater Control Area, might be instituted if significant progress was not achieved in subsequent years.

Water resource investigations conducted in the late 1990s on the refuge evaluated several structural and nonstructural options for implementing more efficient and effective use of available water resources at Quivira NWR (GEI Consultants and Burns and McDonnell 1998). Few of the options including possible upstream reservoir sites on Rattlesnake Creek, using the Great Bend Prairie Aquifer as a storage reservoir, and providing operational flexibility for the refuge water diversion and conveyance systems proved feasible. Supplemental water from ground water wells could help increase water availability for the refuge, but extracting more groundwater is not consistent with attempts by the Rattlesnake Creek Partnership Group to decrease groundwater use. The USFWS has, however, removed over 60,000 trees that were consuming water, rehabilitated numerous water-control structures to better manage available water, filled water-holding borrow areas, and cleaned canals and removed invasive cattails to improve water delivery with less seepage and ET loss. Despite efforts of the Rattlesnake Creek Partnership group to encourage voluntary water conservation measures, the average change in groundwater levels since 2001 has been a decline of 1.43 feet. Groundwater levels declined over three feet along the Rattlesnake Creek Corridor in Quivira NWR between 2010 and 2011 (Figs. 24,25) and in some areas the depth to groundwater in January 2011 was 10-13 feet. In 2010 a quantitative hydrogeological model of the surface and groundwater system in the Big Bend Groundwater Management District No. 5 was completed to clarify the relationship between alternative water management actions and the resulting hydrologic conditions of the aquifer and the streams in the district (Balleau Groundwater, Inc. 2010), which includes the Rattlesnake Creek Basin, to evaluate potential future water management ooptis or scenarios consistent with the ongoing Kansas State Water Plan.

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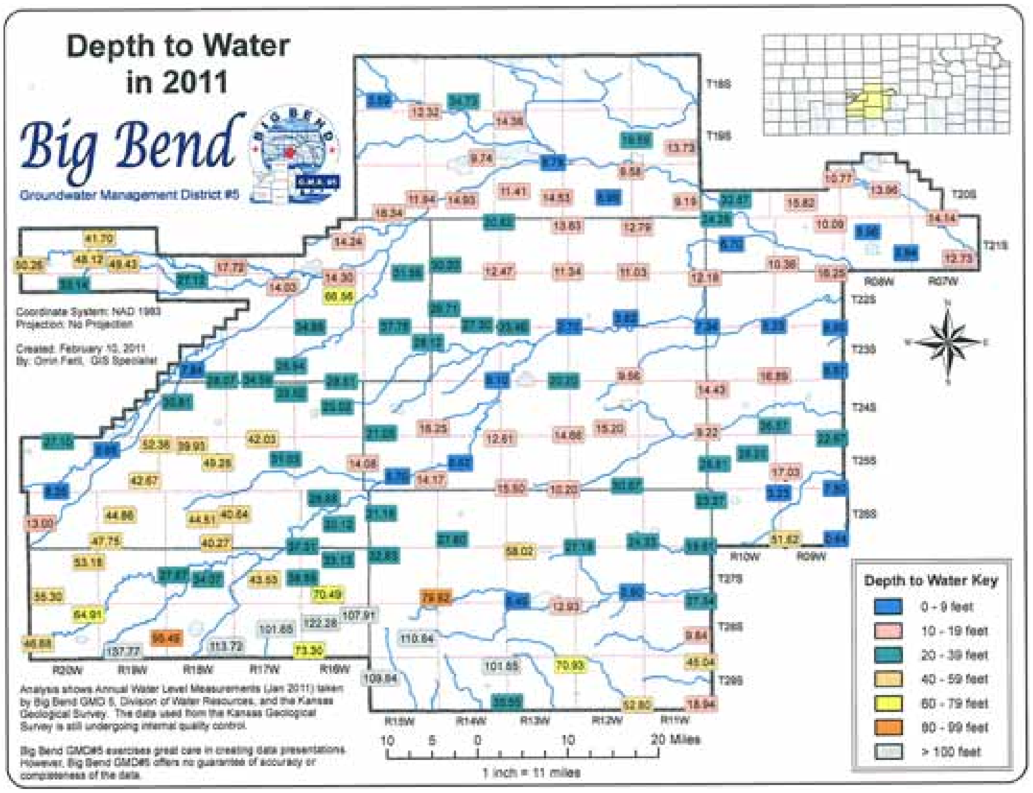

Figure 24. Depth to groundwater in the Big Bend Groundwater Management District No. 5 in 2010 (from Balleau Groundwater Inc. 2010).

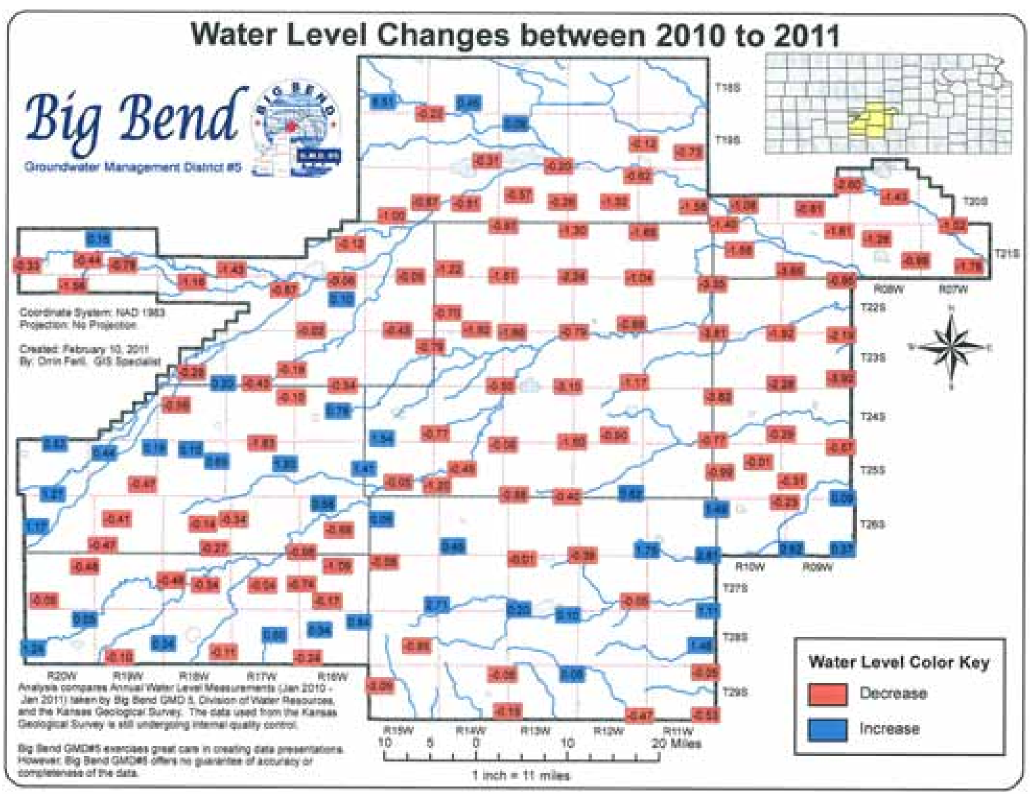

Figure 25. Groundwater depth changes in the Big Bend Groundwater Management District No. 5 between 2009 and 2010 (from Balleau Groundwater Inc. 2010).

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OPTIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

SUMMARY OF HGM INFORMATION

Information obtained in this study helps identify and evaluate the historical and current ecological attributes of the Quivira NWR ecosystem. Quivira NWR historically contained predominantly sand, mixed-grass, prairie that was dissected by Rattlesnake Creek and that had two relatively large salt marshes fed by annual spring overbank flows from Rattlesnake Creek (Little Salt Marsh) and saline groundwater discharge from the underlying Great Bend Prairie Aquifer. Annual surface water inputs to the ecosystem were dynamic and likely caused significant annual variation in amount and distribution of flooded salt marsh wetland area including their heterogeneous open water, salt flat, salt grass, and emergent vegetation communities. The driving ecological process of alternating flooding and drying from seasonal and inter-annual inputs of slightly saline Rattlesnake Creek and hypersaline groundwater seepage created and maintained the important salt marsh ecosystem. A wide range of salinities, and other water quality measures, occur on Quivira NWR and change within and among years. The mixed-species grassland in the region historically contained diverse assemblages related to topography, geomorphology, soil type, and presence of high ground water levels that caused subirrigation of alluvial surfaces. Regular fire and occasional intense herbivory sustained grassland communities and prohibited encroachment of woody vegetation.

The primary changes to the Quivira ecosystem have been: 1) alterations to the amount, timing, duration, and quality of surface water flowing into, and through, naturally occurring salt marshes and floodplain depressions; 2) extensive construction water-control infrastructure to manage the distribution and retention of water in constructed and altered wetland impoundments and natural basins; 3) conversion of native grassland to agriculture and increased presence of woody vegetation; and 4) increased presence of invasive species. A critical overriding issue for future management of Quivira NWR is the increased extraction of groundwater for irrigation in the Rattlesnake Creek Basin and the serious consequences of continued over drafting of the underlying Great Bend Prairie Aquifer. A major challenge for future management of Quivira NWR will be to determine how potentially more limited surface water availability will affect efforts to restore and provide critical habitats and communities. Past attempts to plan management of the refuge were largely designed to continue prior water management strategies to store water in the Little Salt Marsh and subsequently divert this stored water to seasonally flood wetland impoundments and divert some water to the Big Salt Marsh. Future management plans that affect timing, distribution, and movement of water on the NWR must consider how, and if, they are contributing to desired objectives of restoring native communities and inherent ecological processes on the refuge.

GENERAL RECOMMENDATIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

This study is an attempt to evaluate restoration and management options that will protect, restore, and sustain natural ecosystem processes, functions, and values at Quivira NWR. Quivira NWR provides key resources to meet annual cycle requirements of many plant and animal species in the Great Bend Sand Prairie Region of the central U.S., and the signature salt marshes of Quivira NWR are especially critical habitats for migrant waterbirds. Likewise the extensive sand mixed-grass prairie habitats that formerly extended throughout the High Plains region, are key components of the holistic Quivira NWR ecosystem. This study does not address where, or if, the many sometimes competing uses of the refuge can be accommodated, but rather this report provides information in context of evaluating potential future management alternatives and The National Wildlife Refuge System Improvement Act of 1997, which seeks to ensure that the biological integrity, diversity, and environmental health of the (eco)system (in which a refuge sets) are maintained (USFWS 1999, Meretsky et al. 2006). Administrative policy that guides NWR goals includes mandates for: 1) comprehensive documentation of ecosystem attributes associated with biodiversity conservation, 2) assessment of each refuge's importance across landscape scales, and 3) recognition that restoration of historical processes is critical to achieve goals (Mertetsky et al. 2006). Most of the CCP's completed for NWR's to date have highlighted ecological restoration as a primary goal, and choose historical conditions (those prior to substantial human related changes to the landscape) as the benchmark condition to evaluate system changes (Meretsky et al. 2006). General USFWS policy, under the Improvement Act of 1997, directs managers to assess not only historic conditions, but also "opportunities and limitations to maintaining and restoring" such conditions. Furthermore, USFWS guidance documents for NWR management "favor management that restores or mimics natural ecosystem processes or functions to achieve refuge purpose(s) (USFWS 2001).

Given the above USFWS policies and mandates for ecosystem restoration and subsequent management of NWR's, this HGM study has attempted to objectively understand: 1) the fundamental physical and biological processes that historically formed and sustained the structure and functions of the system and its communities and 2) what changes have occurred that caused degradations and that might be reversed and restored to historic and functional conditions within a "new desired" environment. This HGM approach helps identify the historic "role" of ecosystem types and resources at Quivira NWR in meeting larger conservation goals and needs at different geographical scales. In many cases, restoration of functional ecosystems on NWR lands, such as at Quivira NWR, can help the refuge lands serve as a "core" of critical, sometimes limiting, resources than can complement and encourage restoration and management on adjacent and regional private and public lands.

The HGM evaluation process, and discussion of restoration and management options, used in this report is not species-based, but rather seeks to identify options to restore and maintain system-based processes, communities, and resources that ultimately will help support local and regional populations of endemic species, both plant and animal, along with other important ecosystem functions, values, and services. Consequently, recommendations from the HGM evaluation in this study are system-based first, with the goal of restoring and sustaining native communities and their inherent resources, with the assumption that if the integrity of the system is maintained and/or restored, that key resources for species of concern can/will be accommodated. This approach is consistent with recent recommendations to manage the NWR system to improve the ecological integrity and biodiversity of landscapes in which they set (Fischman and Adamcik 2011). Obviously, some systems are so highly disrupted that all natural processes and communities/resources cannot be restored, and key resources needed by some species may need to be replaced or provided by another, similar habitat or resource. However, where appropriate, a primary consideration of refuges should be to attempt to restore the basic features of former functional landscapes.

Based on the context of information obtained and analyzed in this study, we believe that future restoration and management of Quivira NWR should consider the following goals:

1. Maintain and restore sustainable sand (mixed-grass) prairie communities within the Rattlesnake Creek alluvial floodplain and adjacent sand dune/hills uplands.

2. Promote efforts to protect and restore critical groundwater aquifers, and natural seasonal groundwater discharge, in the Rattlesnake Creek Basin, specifically within Rattlesnake Creek and seeps originating on the west side of the Big Salt Marsh.

3. Restore the natural topography, water regimes, and physical integrity of surface water flow patterns in and across the Rattlesnake Creek floodplain corridor, salt marshes, and adjacent sand dune/hills uplands, where feasible and appropriate.

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

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

1. Maintain and restore functional sand (mixed-grass) prairie communities within the Rattlesnake Creek alluvial floodplain and adjacent sand dune/hills uplands.

Quivira NWR is located within the large Great Bend Sand Prairie Province that supported extensive contiguous mixed-grass prairie. The extensive historic grasslands at Quivira contained both alluvial and upland-type species assemblages differentiated by: 1) whether the area was in relict alluvial floodplains or loess sand hills, 2) whether alluvial areas were subirrigated by high groundwater tables and 3) the salinity of soils. Additionally, the region contained unique grassland assemblages associated with choppy sands deposited by relict Wisconsin-age lake beach ridges and on sand dunes/hills. The potential historical HGM vegetation map (Fig. 20) identifies the relative distribution and juxtaposition of these grasslands and sand dunes/hills, which created high diversity and interspersion of grass-dominated species and provided critical resources to many animal species.

Over time, the integrity of grasslands at Quivira has been degraded because of changed land use and management philosophies at some level, conversion to other land covers, and altered ecological drivers such as recurrence intervals of fire and grazing intensity. These system alterations have reduced the overall diversity and occurrence of native grass and forb species and increased the presence of woody vegetation and expansion of invasive plant species. Restoring the general nature of the once expansive grasslands at Quivira NWR will require reconnection of grassland areas, restoration of native plant communities, control of woody and invasive species, and reestablishment of the basic drivers of the grassland system including use of fire and herbivory in more natural patterns and recurrence. Further, the relatively sensitive sand dunes/hills are subject to significant alteration if they are exposed to high or unnatural disturbances such as high grazing rates, road construction, and other physical developments. The more delicate ecological nature of these sand dunes/hills will require careful protection and use.

2. Promote efforts to protect and restore critical groundwater aquifers, and natural seasonal groundwater discharge, in the Rattlesnake Creek Basin, specifically within Rattlesnake Creek and seeps originating on the west side of the Big Salt Marsh.

The critical importance of the regional groundwater system in the Rattlesnake Creek Basin to sustaining the ecological integrity of the Quivira NWR ecosystem cannot be overstated. The increased unsustainable uses of groundwater in the region, particularly the Big Bend Groundwater Management District No. 5, has reduced the groundwater levels in the Rattlesnake Creek Basin, and ultimately caused reduced surface water flows into and through Quivira NWR. Also, changed groundwater use and seasonal extraction threatens the unique groundwater seepage system that historically maintained the Big Salt Marsh ecosystem. Ultimately, development of regional water conservation plans that have effective and enforceable groundwater use reductions are needed to achieve sustainability (Striffler 2011). Unfortunately, voluntary incentive programs to reduce groundwater use have not been effective to date and Kansas State administrative action will be needed to achieve water use and distribution changes. Land management in the Great Bend region will need to change to protect and recharge surface and groundwater quantity and quality. Certain changes to water use may be possible on Quivira NWR proper, but the most significant gains will require efforts to enhance regional aquifer recharge, restrict groundwater pumping, and protect riparian corridors and historic stream channels-water flow pathways (see below).

3. Restore the natural topography, water regimes, and physical integrity of surface water flow patterns in and across the Rattlesnake Creek floodplain corridor, salt marshes, and adjacent sand dune/hills uplands.

The highly heterogeneous and productive Quivira ecosystem was created and sustained by its unique physiographic landscape position where the relict Arkansas River course dissected the Holocene eolian-derived sand hills and dunes. Quivira NWR lies in a discharge zone for groundwater exiting the Great Bend Prairie aquifer and basement rock layers. Contact of the shallower Great Bend alluvial aquifer with the Permian saline basement rocks causes' groundwater (and its subsequent surface discharges) to be saline, thus creating the "salt" nature of the Quivira ecosystem and the namesake salt marshes. The variable source and flow of ground and surface waters across and through Quivira NWR created the variable soil salinities, subirrigation from high water tables, and seasonal hydroperiods in the heterogeneous communities. Historic water flow pathways at Quivira had: 1) the signature contemporary and relict channels of Rattlesnake Creek, 2) intricate labyrinth channels where ground water discharge contributed annual flows into and through the Big Salt Marsh system, and 3) sheetflow of surface water from upland drainage and periodic overbank flooding of Rattlesnake Creek. Unfortunately, all of these three flow systems have been altered from varied activities including altered topography, altered Rattlesnake Creek channels, and diversions of surface water via the extensive water-control infrastructure on the refuge. Restoring at least some portions of the former water flow system at Quivira seems desirable to restore basic hydrologic processes, communities, and resources.

Past water management on Quivira has promoted water storage in the Little Salt Marsh and then diverted this water to over 30 wetland impoundments and the Big Salt Marsh. It is understandable that water storage, especially in dry years and over time as seasonal discharges in Rattlesnake Creek has decreased, was desired. The long-term annually consistent pattern of water storage and diversion, however, has altered the natural water flow pattern and inundation regimes in the area. With uncertain, but probably reduced, surface and ground water availability to the refuge, future water management plans and diversions/storage on Quivira should be reevaluated in the context of restoring more natural water regimes in the various wetlands. This HGM evaluation identifies the general distribution of historic wet meadow/seasonal herbaceous marsh habitats, but unfortunately did not have detailed topographic information to delineate the small grassland depressions or elevation contours of the larger depressions and the salt marshes. Nonetheless, general natural water regimes for these sites are understood and can form a basis for future water management plans.

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

As previously stated and evaluated in the HGM approach, the heterogeneous complex of ecological communities at Quivira NWR was created by the unique mix of geomorphology, soils, topography, and hydrology. Future restoration and management of Quivira should promote sustainability of this geographic, hydrologic, and resource pattern by clearly targeting community restoration and management to appropriate HGM-determined sites. The mix of grassland assemblages discussed under #1 above provides an example of this targeting. Here, the grassland assemblages are determined by: 1) which geomorphic surface the site is in (i.e., relict alluvial or sand hills/dunes), 2) the subirrigation capacity of the site (i.e., high seasonal water tables or nonsubirrigated levels), and 3) the salinity of the soils (i.e., saline or nonsaline). The distribution of vegetation assemblage "zones" in and around the salt marshes also is determined by the source and amount of water, soils, topography, and water flow pathways. Much of this information for the salt marshes is available, but future detailed understanding of salt marsh vegetation zones will require more refined topographic information.

In addition to understanding of the relative position and proximity of various communities at Quivira, a key management/restoration criterion is determining how and to what degree basic ecological processes or "drivers" have been altered. At Quivira, these basic "drivers" are source, timing, and duration of flooding (hydrology); recurrence intervals of fire; and timing, type, and severity of herbivory, mostly from large ungulates. Future management of all communities at Quivira NWR must match the process with the HGM-location of the community. As an example, the sedge-rush dominated wet meadows/seasonal herbaceous marshes were located in alluvial depressions along Rattlesnake Creek and in small depressions within some grassland sites. In general these wetlands historically had seasonal water regimes, usually caused by overflow of Rattlesnake Creek or sheetwater flow of water draining from uplands. The sites received variable water among years, and in dry years many of the depressions may not have been inundated at all. The sites therefore had both seasonal (winter-spring flooding) and long-term dynamic water regimes. Attempts to more regularly flood these depressions, extend hydroperiods, or sustain flooding in unnatural ways with few drying, fire, or herbivory disturbances usually causes these wetlands to become choked with persistent emergent vegetation, have nutrients bound in vegetation and detritus, and ultimately lose productivity.

SPECIFIC RECOMMENDATIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT OPTIONS

1. Maintain sand mixed-grass prairie and sand hills/dunes

Protecting, restoring, and maintaining the diverse grasslands on Quivira NWR are priority management actions to improve the integrity and productivity of not only the refuge lands, but also the larger regional Great Bend Sand Prairie Ecoregion. Management actions specific to the refuge should include:

- Delineate the various grassland types relative to the HGM categories and design management prescriptions specific to the community type.
- Introduce fire at more natural recurrence intervals to sustain specific assemblages and production, at least once an area is beyond the restoration phase and in more of a maintenance phase of management.
- Remove and discourage woody vegetation in grassland areas.
- Control invasive species.
- Restore appropriate grassland communities in some retired agricultural fields.
- Restore natural hydrological regimes to specific grassland types, where appropriate. For example, upland Quaternary dune geomorphic surface grasslands are supported by seasonal unimpeded sheetflow of surface water from local precipitation and runoff. In contrast, alluvial floodplain subirrigated grassland is supported by high groundwater tables and occasional short duration overbank flooding from Rattlesnake Creek.
- Use recently completed LIDAR topographic survey to delineate the many small wetland depressions in the grasslands and protect these depressions from future physical and hydrological disturbance and degradation.
- Protect sand dune areas from harmful disturbances of cattle, vehicles, and other activities.
- Develop careful deferred grazing plans for specific grassland units.

2. Protect and Restore Ground and Surface Water Resources and Manage for Natural Hydroperiods

The Water Resources Inventory and Assessment (WRIA) completed for Quivira NWR (Striffler 2011) and additional information provided in this report identify the primary hydrological issues for the refuge. The WRIA provides recommendations about protecting and restoring ground and surface water in the Rattlesnake Creek Basin and GMD No. 5 that are consistent with the HGM information. We concur with these recommendations and suggest:

- Implement the recommendations provided in the WRIA to revise the refuge water management plan and address threats associated with regional water depletion. These recommendations specifically address the critical need for the USFWS to continue efforts, with the Rattlesnake Creek Subbasin Partnership Group, to protect refuge water rights and restore groundwater resources through voluntary and enforceable water use reductions and changed land use and land use policy.
- Manage historic wet meadow and seasonal herbaceous marsh depressions (now mostly in managed impoundments) for annually variable, seasonal water regimes. Past management over four decades has shifted many wetland impoundments to more seimpermanent and annually consistent water regimes. These water management regimes can be reversed back to more naturally occurring seasonal regimes with spring inputs, summer drawdowns, and some modest reflooding in fall. Water management in the units should periodically include prolonged year-long drawdown to emulate the natural interannual patterns of periodic drying in this system.
- Restore at least some regular drawdown and seasonal surface water dynamics in the Little Salt Marsh to restore and recycle productivity, vegetation diversity, and resource availability to wetland associated species.
- Restore and maintain the sustained groundwater flow system into and through the Big Salt Marsh to create seasonal inundation related to natural topography, soils, and subirrigation.
- Restore natural sheetflow into small temporary and ephemeral wetland depressions in grasslands.
- Reduce or eliminate diversion of scarce Rattlesnake Creek water flow to higher elevation Quaternary dune geomorphic surface areas.

3. *Restore natural topography and water flow patterns*

The Quivira landscape historically contained heterogeneous land forms and topography that enabled complex and sometimes intricate patterns of water flow into, through, and within the region. Hopefully subsurface groundwater pathways can remain intact, albeit perhaps with reduced or changed temporal aspects of groundwater movement. In contrast, alterations in topography and development of water-control infrastructure at Quivira NWR have changed surface water movement patterns. Generally, restoring at least some aspects of natural water flow patterns is desirable to restore hydrological regimes associated with, and required by, the different communities on the refuge. Specific management recommendations to restore topography and water flow include:

- Evaluate restoring high water, or some seasonal flow, into former main and abandoned swale channels of Rattlesnake Creek. This would include some limited managed bypass of water within the old Rattlesnake Creek channel around the Little Salt Marsh.
- Evaluate all roads, ditches, levees/dikes, and water-control infrastructure to determine structures that are not critical to, or that are impeding, water conservation and management and remove or modify unnecessary ones. The many new and old structures in the historic Big Salt Marsh area should be carefully considered for removal or modification to allow natural patterns of water movement into, across, and within the salt marsh basin including the salt flats and pans on the edges of the marsh.
- Improve water flow through road levees and corridors where the road is retained. This can be achieved with low water crossings, permeable fill, multiple culverts or bridges, etc.
- Remove water diversion infrastructure into higher elevation Quaternary dune upland grasslands where artificial wetlands were formerly created. Restore previous modified upland topography, especially the integrity of former small wetland depressions and their small watersheds.
- Do not further compartmentalize wetland units or natural floodplain areas with levees and water-control structures unless the new structure is consistent with restoration objectives.

4. *Restore appropriate vegetation communities related to HGM attributes.*

In most locations on Quivira NWR, the current types and distribution of major vegetation communities are relatively similar to historic conditions, but some changes have occurred in species composition and hydrology (see above). The primary changes are within the various grassland assemblages (addressed under #1 above), alluvial wetlands, the Little Salt Marsh, and northeastern parts of the Big Salt Marsh. The native mixture of communities at Quivira provided critical resources to many animal populations throughout the mid-continent U.S. Maintaining and restoring, where possible, the distribution and types of historic habitats is important to the long term capability of the Quivira, Great Bend, and mid-continent U.S. Certain future management actions to restore native communities are addressed above, but additional specific considerations include to the extent possible:

- Control invasive species in all plant communities.
- Restore natural water regimes and sources within communities. Much of this is discussed above, but restoring the appropriate surface water sheetflow and runoff to loess sand hill and dune grasslands and depressions, subsurface subirrigation of alluvial grasslands, periodic overbank flow of Rattlesnake Creek into alluvial wetland depressions, and the intricate groundwater discharge into and through the Big Salt Marsh is critical.
- Restore basic ecological disturbance practices in naturally occurring patterns and times including drought, flooding, fire, grazing, and soil disturbance (e.g., that would emulate ground and vegetation disturbance from large numbers of native ungulates).
- Carefully target grassland and wetland restorations to appropriate HGM sites, especially related to soils and hydrology.

MONITORING AND EVALUATION

The current understanding of the Quivira NWR ecosystem has been greatly enhanced by past monitoring and evaluation studies of vegetation and animal communities, water quality and quantity, and specific management actions. When detailed topographic maps are available, additional analyses of vegetation distribution and relationships with hydrogeomorphic attributes of the system should be possible. Future management of the system should continue key monitoring studies and also conduct select directed studies as needed. Monitoring is determined primarily by refuge objectives, but some measures should be collected that indicate how factors related to ecosystem structure and function are changing, regardless of whether the restoration and management options identified in this report are undertaken. Ultimately, the success in restoring and sustaining communities and ecosystem functions and values at Quivira NWR will depend on how well the physical integrity and hydrological processes and events, especially the sustained groundwater discharges into and within the refuge can be restored, maintained, and emulated by management actions. Uncertainty exists about the future of some important water issues and the ability of the USFWS to make some system changes because they are not completely under the control of the USFWS. Also, specific techniques for certain management actions, such as controlling and reducing introduced plant species, are not entirely known.

Whatever future management actions occur on Quivira NWR, activities should be done in an adaptive management framework where: 1) predictions about community response and water issues are made (e.g., increased diversity and vigor of native grass and meadow species) relative to specific management actions (e.g., restoration of sheetwater flow and regular fire recurrence) in specific locations or communities (e.g., loess sand hill grassland) and then 2) follow-up monitoring is conducted to evaluate ecosystem responses to the action. Information and monitoring needs for Quivira NWR related to the hydrogeomorphic information evaluated in this report are identified below:

GROUND AND SURFACE WATER QUALITY AND QUANTITY

The recently completed WRIA for Quivira NWR identified several important future monitoring and information needs related to water. These and other needs include:

- Revised and updated information on all water-control and conveyance structures and determining annual water budgets for all wetland management units and the refuge as a whole.
- Annual monitoring of water management and storage/flooding especially as related to future changes in water use and management identified in this report.
- Completion of bathymetry and detailed topographic information for all wetland units and the Big and Little Salt Marsh areas.
- Routine monitoring of water quality and contaminant issues in relation to water source and routing. Regular monitoring of surface, ground, and soil salinity if key reference locations related to HGM-determined communities should be established.
- Water flow metering at key points in the refuge.

- Documentation of how existing water rights are being met, used, and maintained.

RESTORING NATURAL TOPOGRAPHY, WATER FLOW PATTERNS, AND WATER REGIMES

This report identifies several physical and management changes that could help restore some more natural topography, water flow, and flooding/drying dynamics in managed wetlands. These changes include restoring at least some more natural water flow through natural drainages and across sandhill and higher alluvial terraces in a sheetflow manner and managing impoundments (that are retained) for more natural spring-flooded seasonal flooding regimes. Further, restoring interannual dynamics of flooding and at least partial drying of the Little Salt Marsh and managed impoundments is desired. The following monitoring will be important to understanding effects of these changes if implemented:

- Annual monitoring of water use and distribution including water source, delivery route and mechanism, extent and duration of flooding and drying, and relationships with non-refuge water and land uses in the GMD No. 5.
- Documentation of how water moves across sand hill and alluvial areas.
- Evaluation of surface and ground water interactions and flow.

LONG TERM CHANGES IN VEGETATION AND ANIMAL COMMUNITIES

The availability of historic vegetation information coupled with regularly documenting changes in general and specific vegetation communities is extremely important to understand the long term changes and management effects on Quivira NWR. Also, regular monitoring of at least some select animal species or groups helps define the capability of the Quivira NWR ecosystem to supply key resources to, and meet annual cycle requirement of, animals that use the refuge and regional area. Important survey/monitoring needs include:

- Detailed inventory and mapping of plant species composition, distribution, productivity, and coverage in all habitats, especially grasslands.
- Coverage, including expansion and contraction rates of invasive and woody species.
- Abundance, chronology of use, survival, and reproduction of key waterbird and neotropical migrant songbirds including dabbling ducks, geese, sandhill cranes, least tern, piping and snowy plover, other shorebirds, and grassland nesting passerines.
- Rates and occurrence of fire, grazing, and mechanical disturbances in wetlands and grasslands.
- Occurrence, distribution, and abundance of amphibians and reptiles.

Rachel Laubhan, USFWS

ACKNOWLEDGEMENTS

This project was supported by Contract No. F10PD77626 from the USFWS to Blue Heron Conservation Design and Printing, LLC. Dan Severson and staff of Quivira NWR sponsored the project and assisted with all field visits, planning meetings, gathering of information for the refuge, and review of report drafts. Kimberly Farr, Melanie Olds, and Barry Jones helped prepare certain figures and tables. Wayne King, USFWS Regional Biologist, helped initiate the project and provided administrative support and review of the report. Meg Estep and Pete Striffler provided assistance with obtaining and analyzing the hydrological data for the study including providing the WRIA information for Quivira NWR. Toni Griffin and Meg VanNess provided information and assistance with information pertaining to the ongoing CCP for the refuge. Karen Kyle of Blue Heron Conservation Design and Printing LLC administered the contract for the project and provided assistance with analyses of data and geographical information, preparation of report drafts, and publication of the final report.

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Cary Aloia

APPENDIX A. List of bird species by community type on Quivira NWR.

Species[a]	Occur[a]	Nest	Saltflat/ bare-ground[b]	Water (open)[c] Shal-low	Water (open)[c] Deep	Stream	Salt-grass (dry/ wet)	Mea-dow (dry/ wet)	Tall emerg-ent	Trees: Riparian/ Near Water	Trees: Isolated-scat-tered; grove	Trees: Large upland/ shelterbelt	Sand Plum (Shrub): Short <1.5m	Sand Plum (Shrub): Tall ≥1.5m	Grassland & Sandhills: Short-Mid prairie	Grassland & Sandhills: Mid-Tall prairie	Agri-cul-ture[d]
Greater White-fronted Goose	craa			X	X												X
Snow/Blue Goose	cxaa			X	X												X
Ross' Goose	oxuu			X	X												X
Cackling Goose	cxcu			X	X												X
Canada Goose	acaa	•		X	X			X									X
Trumpeter Swan	rxrr				X												
Tundra Swan	oxor				X												
Wood Duck	cuuo	•		X	X	X		X									
Gadwall	aucc	•		X	X		X	X									
American Wigeon	aucc		X	X	X	X	X	X									X
Mallard	acaa	•		X	X	X	X	X									X
Blue-winged Teal	acax	•	X	X		X	X	X									
Cinnamon Teal	uooo	•	X	X			X	X									
Northern Shoveler	auac	•		X		X	X	X									
Northern Pintail	auca	•	X	X		X	X	X									X
Green-winged Teal	aoac	•	X	X		X	X	X									
Canvasback	cocc	•		X	X												
Redhead	auca	•		X	X												
Ring-necked Duck	crcu			X	X												
Lesser Scaup	cocc	•			X			X									
Bufflehead	cxcc				X	X											
Common Goldeneye	crcc				X	X											
Hooded Merganser	uouo	•			X	X											
Common Mergaser	uxuc				X	X											
Ruddy Duck	auau	•			X			X									
Ring-necked Pheasant	cccc	•						X	X			X	X	X	X	X	X
Greater Prairie-Chicken	rrrr	•													X	X	
Wild Turkey	cccc	•								X	X	X					
Northern Bobwhite	uuuu	•											X	X	X	X	
Pied-billed Grebe	cuco	•			X				X								
Horned Grebe	uxuo			X	X												
Eared Grebe	cocr			X	X												
American White Pelican	auao				X												
Double-crested Cormorant	auau	•			X	X											

Cont'd. next page

Appendix A., cont'd.

Species[a]	Occur[a]	Nest	Saltflat/ bare-ground[b]	Water (open)[c] Shal-low	Water (open)[c] Deep	Stream	Salt-grass (dry/ wet)	Mea-dow (dry/ wet)	Tall emerg-ent	Trees: Riparian/ Near Water	Trees: Isolated-scat-tered; grove	Trees: Large upland/ shelterbelt	Sand Plum (Shrub): Short <1.5m	Sand Plum (Shrub): Tall ≥1.5m	Grassland & Sandhills: Short-Mid prairie	Grassland & Sandhills: Mid-Tall prairie	Agri-cul-ture[d]
American Bittern	uuuo	•		X					X								
Least Bittern	ouox	•		X					X								
Great Blue Heron	cccu	•		X		X		X		X							
Great Egret	cccx	•		X		X		X		X							
Snowy Egret	cccx	•		X		X		X		X							
Little Blue Heron	ccux	•		X				X									
Cattle Egret	cccx	•						X							X		X
Green Heron	uuox	•	X	X		X		X	X	X							
Black-crowned Night-Heron	cccx	•	X	X		X		X	X	X		X					
Yellow-crowned Night-Heron	uuux	•	X	X		X				X		X					
White-faced Ibis	cccx	•	X	X			X	X	X								X
Turkey Vulture	cuux	•								X	X	X					X
Mississippi Kite	uuox	•								X	X	X		X	X		X
Bald Eagle	uxuu	1		X	X	X				X	X	X					
Northern Harrier	cocc	•		X			X	X	X						X	X	
Sharp-shinned Hawk	uxou									X	X	X					X
Cooper's Hawk	uouu	•								X	X	X					
Swainson's Hawk	cuux	•									X	X			X	X	X
Red-tailed Hawk	cccc	•								X	X	X			X	X	X
Ferruginous Hawk	oxoo														X	X	X
Rough-legged Hawk	uxxu						X	X	X	X	X	X			X	X	X
Golden Eagle	oxoo			X	X			X							X	X	
American Kestrel	uuuu	•					X	X		X	X	X	X	X	X	X	X
Merlin	uxuo		X				X	X		X	X	X			X	X	
Peregrine Falcon	uouo		X	X	X		X	X	X						X	X	
Prairie Falcon	uxuu						X								X	X	X
Black Rail	uurx	•						X									
King Rail	uuox	•	X	X				X	X								
Virginia Rail	ccux	•	X	X					X								
Sora	cuux	•	X	X					X								
Common Moorhen	ourx	•			X				X								
American Coot	acau	•			X	X			X								
Sandhill Crane	axau		X	X			X	X									X
Whooping Cranes[E]	oxor		X	X			X										X
Black-bellied Plover	uuur		X	X			X										
American Golden-Plover	uoox		X	X			X										
Snowy Plover[T]	cccx	•	X	X			X										

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Appendix A., cont'd.

Species[a]	Occur[a]	Nest	Saltflat/ bare-ground[b]	Water (open)[c] Shallow	Water (open)[c] Deep	Stream	Salt-grass (dry/ wet)	Mea-dow (dry/ wet)	Tall emerg-ent	Trees: Riparian/ Near Water	Trees: Isolated-scattered; grove	Trees: Large upland/ shelterbelt	Sand Plum (Shrub): Short <1.5m	Sand Plum (Shrub): Tall ≥1.5m	Grassland & Sandhills: Short-Mid prairie	Grassland & Sandhills: Mid-Tall prairie	Agri-culture[d]
Semipalmated Plover	cuux		X	X													
Piping Plover[E]	uoux		X	X													
Killdeer	ccco	•	X				X								X		X
Mountain Plover[E]	rxrx		X				X										
Black-necked Stilt	ccux		X	X			X										
American Avocet	cccx		X	X			X										
Spotted Sandpiper	cucx		X	X		X											
Solitary Sandpiper	uuux		X	X		X	X										
Greater Yellowlegs	ccco		X	X		X	X	X									
Willet	uuux		X	X			X	X									
Lesser Yellowlegs	acar		X	X		X	X	X									
Upland Sandpiper	cuux	•					X								X		X
Whimbrel	ooox		X	X			X	X									
Long-billed Curlew	ooox		X				X	X									
Hudsonian Godwit	urxx		X	X			X	X									
Marbled Godwit	uuux		X	X			X	X									
Ruddy Turnstone	ooox		X	X			X										
Red Knot	orox		X	X			X										
Sanderling	cocx		X	X			X										
Semipalmated Sandpiper	acax		X	X													
Western Sandpiper	cccx		X	X													
Least Sandpiper	acax		X	X													
White-rumped Sandpiper	aarx		X	X													
Baird's Sandpiper	acax		X	X													
Pectoral Sandpiper	cccx		X	X			X										
Dunlin	uour		X	X			X										
Stilt Sandpiper	acax		X	X			X										
Buff-breasted Sandpiper	orox		X	X			X	X									
Short-billed Dowitcher	uuox		X	X			X										
Long-billed Dowitcher	cccx		X	X			X										
Wilson's Snipe	uoux		X	X		X	X	X									
Wilson's Phalarope	acax	•		X	X		X	X									
Franklin's Gull	auax		X	X	X			X									X
Ring-billed Gull	cucu		X	X	X			X									X
Herring Gull	oxuu		X	X	X			X									X
Least Tern (Interior)[E]	uuox	•	X	X	X												
Black Tern	cccx	•	X	X	X												
Forster's Tern	ccux	•	X	X	X												
Mourning Dove	aaao	•								X	X	X	X	X			X

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Appendix A., cont'd.

				Water (open)[c]						Trees			Sand Plum (Shrub)		Grassland & Sandhills		
Species[a]	Occur[a]	Nest	Saltflat/ bare-ground[b]	Shal-low	Deep	Stream	Salt-grass (dry/ wet)	Mea-dow (dry/ wet)	Tall emerg-ent	Riparian/ Near Water	Isolated-scat-tered; grove	Large upland/ shelterbelt	Short <1.5m	Tall ≥1.5m	Short-Mid prairie	Mid-Tall prairie	Agri-cul-ture[d]
Black-billed Cuckoo	rrxx									X	X	X	X	X			
Yellow-billed Cuckoo	ourx									X	X	X	X	X			
Eastern Screech-Owl	uuuu	•								X	X	X					
Great Horned Owl	uuuu	•								X	X	X					X
Burrowing Owl	ooox	•													X		
Short-eared Owl	rxrr	•	X					X							X	X	
Common Nighthawk	ucux	•	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Common Poorwill	ooxx												X	X	X	X	
Chuck-will's-widow	ooox	•								X		X					X
Chimney Swift	uuux	•		X	X	X				X		X					X
Ruby-throated Hummingbird	rrxx					X				X	X	X	X	X	X	X	
Belted Kingfisher	uuuo					X				X							
Red-headed Woodpecker	cccr	•								X	X	X			X	X	X
Red-bellied Woodpecker	uuuu	•								X	X	X					
Downy Woodpecker	uuuu	•								X	X	X					
Hairy Woodpecker	uuuu	•									X	X					
Northern Flicker	cccc	•								X	X	X	X	X	X	X	
Olive-sided Flycatcher	oxox									X	X	X					
Eastern Wood-Pewee	uuxx	•									X	X					
Willow Flycatcher	oxox									X	X						
Least Flycatcher	uxux									X	X	X					
Eastern Phoebe	uuux	•								X	X	X					
Say's Phoebe	oxox									X	X	X	X	X	X		X
Great-crested Flycatcher	uuox	•								X	X	X					
Western Kingbird	ccux	•								X	X	X	X	X	X	X	X
Eastern Kingbird	ccux	•								X	X	X	X	X	X	X	X
Scissor-tailed Flycatcher	uuux	•									X	X	X	X	X	X	X
Loggerhead Shrike	uuuo	•					X	X		X	X	X	X	X	X	X	X
Northern Shrike	rxoo						X	X		X	X	X	X	X	X	X	X
Bell's Vireo	uuux	•								X			X	X			
Warbling Vireo	uuux	•								X	X	X					
Red-eyed Vireo	uorx	•										X					
Blue Jay	cucu	•								X	X	X					
Black-billed Magpie	oooo							X			X	X			X	X	X
American Crow	cucu	•								X	X	X			X		X
Horned Lark	cuua	•													X		X
Purple Martin	ooxx	•								X		X					X

Cont'd. next page

Appendix A., cont'd.

Species[a]	Occur[a]	Nest	Saltflat/ bare-ground[b]	Water (open)[c]		Stream	Salt-grass (dry/ wet)	Mea-dow (dry/ wet)	Tall emerg-ent	Trees			Sand Plum (Shrub)		Grassland & Sandhills		Agri-cul-ture[d]
				Shal-low	Deep					Riparian/ Near Water	Isolated-scat-tered; grove	Large upland/ shelterbelt	Short <1.5m	Tall ≥1.5m	Short-Mid prairie	Mid-Tall prairie	
Tree Swallow	uocx	•	X	X	X	X	X	X	X	X	X		X	X	X	X	
N. Rough-winged Swallow	cccx	•		X	X	X	X	X		X							
Bank Swallow	ccox	•				X	X	X		X							
Cliff Swallow	aacx	•	X			X	X	X		X					X		
Barn Swallow	aaax	•	X					X		X					X		X
Black-capped Chickadee	uuuu	•										X					
Tufted Titmouse	xxoo											X					
White-breasted Nuthatch	uuuu	•										X					
Brown Creeper	xxoo									X							
Carolina Wren	oooo									X							
Bewick's Wren	ooxx	•								X						X	
House Wren	ccux	•								X		X					X
Sedge Wren	oxox						X	X	X						X	X	
Marsh Wren	uxuu							X	X								
Golden-crowned Kinglet	oxoo									X	X	X					
Ruby-crowned Kinglet	uxuo									X	X	X					
Blue-Gray Gnatcatcher	uurx	•								X	X	X					
Eastern Bluebird	uuuo	•								X	X	X	X	X	X	X	X
Mountain Bluebird	xxoo									X	X	X	X	X	X	X	
Townsend's Solitaire	rxro										X	X					
Swainson's Thrush	oxox									X	X	X					
American Robin	ccca	•								X	X	X					
Gray Catbird	ccox	•									X	X	X	X			
Northern Mockingbird	uuuo	•										X			X		X
Brown Thrasher	ccor	•								X	X	X	X	X			
American Pipit	uxux		X			X											X
Cedar Waxwing	uouu									X	X	X	X	X			
Tennessee Warbler	rxxx									X	X	X	X	X			
Orange-crowned Warbler	uxux									X	X	X	X	X			
Nashville Warbler	oxox									X	X	X	X	X			
Yellow Warbler	urux	•								X	X	X	X	X			
Yellow-rumped Warbler	uxuo									X	X	X	X	X	X	X	X
Palm Warbler	oxxx									X	X	X	X	X	X	X	X
Black-poll Warbler	oxxx									X	X	X	X	X			
Black-and-White Warbler	rxxx									X	X	X	X	X			
American Redstart	oxox									X	X	X	X	X			
Northern Waterthrush	oxxx									X							
Common Yellowthroat	ccuo	•					X	X	X	X					X	X	

Cont'd. next page

Appendix A., cont'd.

Species[a]	Occur[a]	Nest	Saltflat/ bare-ground[b]	Water (open)[c]		Stream	Salt-grass (dry/ wet)	Mea-dow (dry/ wet)	Tall emerg-ent	Trees			Sand Plum (Shrub)		Grassland & Sandhills		Agri-cul-ture[d]
				Shal-low	Deep					Riparian/ Near Water	Isolated-scat-tered; grove	Large upland/ shelterbelt	Short <1.5m	Tall ≥1.5m	Short-Mid prairie	Mid-Tall prairie	
Wilson's Warbler	oxox									X	X	X	X	X			
Yellow-breasted Chat	orrx	•								X	X	X	X	X			
Spotted Towhee (Rufous-sided)	uxcu									X	X	X	X	X			
Am Tree Sparrow	uxca									X	X	X	X	X	X	X	
Chipping Sparrow	crcx										X	X					X
Clay-colored Sparrow	cxcx										X	X	X	X		X	
Field Sparrow	uuuu	•									X		X	X	X	X	
Vesper Sparrow	uxor												X	X	X	X	X
Lark Sparrow	cuux	•									X	X	X	X	X		X
Lark Bunting	orxx														X		X
Savannah Sparrow	uxuo							X					X	X	X	X	X
Grasshopper Sparrow	uuox	•													X	X	
Le Conte's Sparrow	oxor							X								X	
Nelson's Sharp-tailed Sparrow	oxox							X							X	X	
Fox Sparrow	oxor									X	X	X	X	X			
Song Sparrow	cxcc						X	X	X	X	X	X	X	X	X	X	
Lincoln's Sparrow	oxuo									X	X	X	X	X	X	X	
Swamp Sparrow	uxuu						X	X	X	X							
White-throated Sparrow	uxuu									X	X	X	X	X			
Harris' Sparrow	cxcc									X	X	X		X	X	X	X
White-crowned Sparrow	uxuu									X	X	X	X	X	X	X	X
Dark-eyed Junco	cxca									X	X	X	X	X			
Lapland Longspur	rxou														X		X
Chestnut-collared Longspur	rxxr														X		X
Northern Cardinal	cuuc	•								X	X	X	X	X			
Rose-breasted Grosbeak	orxx									X	X	X					
Black-headed Grosbeak	orxx	•								X	X	X					
Blue Grosbeak	ooxx	•								X	X	X	X	X	X		
Indigo Bunting	uorx	•								X	X	X	X	X			
Dickcissel	ccrx	•													X	X	X
Bobolink	uuxx	•					X	X							X	X	
Red-winged Blackbird	aaaa	•					X	X	X								X
Eastern Meadowlark	cccc	•						X							X	X	X
Western Meadowlark	cccc	•						X							X	X	X
Yellow-headed Blackbird	aacr	•					X	X	X								X
Rusty Blackbird	xxrr		X					X									X

Cont'd. next page

Appendix A., cont'd.

				Water (open)[c]						Trees			Sand Plum (Shrub)		Grassland & Sandhills		
Species[a]	Occur[a]	Nest	Saltflat/ bare-ground[b]	Shal-low	Deep	Stream	Salt-grass (dry/ wet)	Mea-dow (dry/ wet)	Tall emerg-ent	Riparian/ Near Water	Isolated-scat-tered; grove	Large upland/ shelterbelt	Short <1.5m	Tall ≥1.5m	Short-Mid prairie	Mid-Tall prairie	Agri-cul-ture[d]
Brewer's Blackbird	oxuu							X							X		X
Common Grackle	cccu	•								X	X	X					X
Great-tailed Grackle	cccc	•					X	X	X		X						X
Brown-headed Cowbird	ccca	•								X	X	X	X	X			X
Orchard Oriole	uuox	•								X	X	X					
Baltimore (Northern) Oriole	ccrx	•								X	X	X					
Purple Finch	xxrr	•								X	X	X					
House Finch	oooo	•								X	X	X					X
Pine Siskin	orou									X	X	X					
American Goldfinch	cocc	•								X	X	X	X	X	X	X	X
House Sparrow	cuuu	•								X	X	X					X

[a] Species & Occurance based on December 2010 refuge bird list, but omitted accidental species. Does not include nesting habitat for waterfowl because primary importance on Quivira NWR is food and cover habitat for waterfowl during migrations. Occurance codes written in order of spring, summer, fall, and winter as on refuge bird list. Codes: c=common; u=uncommon; o=occasional; r=rare; x= no occurance. For example, cccc means species is common in all seasons. Superscript E or T means the species is federally endangered or threatened.

[b] Bare includes areas with no or sparse vegetation that area generally <0.5 acres and ~0-2" water.

[c] The quality and use of 'Water' is influenced by conditions of submergent/floating aquatic vegetation and/or if it is ice-free in winter. Deep is generally >15-30cm.

[d] Association with 'Agriculture' habitat may be negative and/or positive, depending on various factors. E.g., Often Bobwhite attracted to grains for food, but agriculture has also

References: Birds of North America accounts March 15, 2011; QNWR observations; Kansas GAP

Appendix B. List of mammal species by community type on Quivira NWR.

Species[a]	Water	Saltgrass (dry/wet)	Meadow (dry/wet)	Tall emer-gent	Trees: Riparian / Near water	Trees: Isolated-scattered; grove	Trees: Large upland/ shelterbelt	Sand Plum (Shrub): Short <1.5m	Sand Plum (Shrub): Tall ≥1.5m	Grassland & Sandhills: Short-Mid prairie	Grassland & Sandhills: Mid-Tall prairie	Agricul-ture	COMMENTS
Armadillo, Nine-banded					X	X	X						Alluvial, sandy soils; wooded areas grading into savannah and scrub
Bat, Brazilian Free-tailed					X								Bridges, culverts, buildings, caves
Bat, Eastern Red					X		X		X				Breeding range; Edge species; use tree and plum, esp. prefer riparian areas
Badger, American									X	X	X	X	Only use plum when open areas to dig burrows
Beaver, American	X				X								Cottonwood, willow preferred
Bobcat					X		X		X				Association with prey (cottontail)
Cottontail, Eastern					X	X	X	X	X		X		Prefer dense thickets
Coyote		X								X	X		Open country
Deer, White-tailed				X	X				X			X	
Gopher, Plains Pocket						X				X	X	X	Characteristic of Sand Prairie
Jackrabbit, Black-tailed										X		X	Prefers heavily grazed grassland
Mole, Eastern						X	X		X	X	X		Burrows in moist, loose loamy or sandy soils
Mouse, Deer						X				X	X	X	Sparse ground vegetation assoc, esp tallgrass
Mouse, N. Grasshopper										X		X	Sandy soils; open; grazed; sandsage scrub optimal
Mouse, Plains Harvest										X			
Mouse, Plains Pocket										X	X		Dry, sandy soils
Mouse, Western Harvest					X			X	X	X	X	X	Dense cover, litter (ungrazed)

Cont'd. next page

Appendix B., cont'd.

Species[a]	Water	Saltgrass (dry/wet)	Meadow (dry/wet)	Tall emer-gent	Trees: Riparian / Near water	Trees: Isolated-scattered; grove	Trees: Large upland/ shelterbelt	Sand Plum (Shrub): Short <1.5m	Sand Plum (Shrub): Tall ≥1.5m	Grassland & Sandhills: Short-Mid prairie	Grassland & Sandhills: Mid-Tall prairie	Agricul-ture	COMMENTS
Mouse, White-footed					X	X	X		X				
Muskrat	X			X									
Opossum					X		X						
Prairie Dog, Black-tailed										X			
Raccoon					X		X						Usually within 1/4-mi of water
Rat, Hispid Cotton											X		
Rat, Ord's Kangaroo										X			Sand dunes optimal; prefer sandy soils & with bare areas within grassland
Shrew, Least			X							X	X		Low or wet prairie optimal/suboptimal; mesic mixed or tallgrass
Shrew, Short-tailed											X		Litter impt; lowland prairie a preferred habitat
Skunk, Striped					X		X						
Squirrel, Eastern Fox					X		X						
Vole, Prairie						X				X	X		Prefer upland prairie; litter; ungrazed
Weasel, Long-tailed					X			X	X	X	X		Burrows of prey (mammals); not abundant anywhere KS
Woodrat, Eastern									X	X	X		

[a]Kansas GAP, Stafford Co. and observations largely used to develop species list. March 31, 2011; http://www.k-state.edu/kansasgap/KS-GAPPhase1/finalreport/in

GAP did not include extirpated or migratory species on their list.

Beaver and muskrat not listed in Stafford Co., but common on QNWR.

Swift fox listed and red fox not listed for Stafford Co. and no records for swift fox near QNWR; obs. of red fox near QNWR.

Mink & Mule deer not listed for Stafford, but rarely seen on QNWR.

Spotted skunk mentioned in old narrative(s), but no known observations in area in many years.

Weasel not listed for Stafford, but listed for Rice Co. and in refuge narratives.

Appendix C. List of amphibian and reptile species and life history notes by community type on Quivira NWR.

SPECIES		HABITAT, HABITS, NOTES	CHRONOLOGY	BREEDING CHORUSES	EST. MAX. LIFESPAN
FROGS & TOADS (ANURA)					
Great Plains Toad	*Anaxyrus cognatus*	resident in upland mixed- and short-grass prairie (rarely woodlands) but occurs in floodplains, mostly w & c KS; digs burrows in bare, sandy areas; underground during summer days, emerging for food at night; underground during winter; 2 clutchs/season	active early Mar-early Nov (peak early May to mid-Jul); late Mar thru Aug, congregate at temporary pools	late Mar thru Aug (peak early May to mid-Jun); most robust 10P-2A	>10yrs
Woodhouse's Toad	*Anaxyrus woodhousii*	prefers lowlands, sandy areas near rivers & streams KS, and uncommon in wooded uplands; uses small mammal burrows as retreats during day and forages aboveground at night; breeds opportunistically in ditches, ponds, river floodplains	active mid-Feb & mid-Oct (peak late May to early Aug); breeding sites Mar to Aug	late Mar to late Aug (peak May & June); 10P-2A	>13yrs
Blanchard's Cricket Frog	*Acris blanchardi*	most active during day, but both day and night when temperature warm; prefer muddy, beachlike edges of small shallow streams & ponds; avoids deep water; breeds in ditches, marshes, ponds, streams; eggs hatch after 3-4 days; tadpoles 5-10 wks; feeds underwater and on surface	active Feb - Nov (peak late Apr to mid-Aug); breeding sites mid-Mar to late Jul (peak May to late Jun); females found with eggs from mid-Apr to mid-Jul	breeding sites mid-Mar to late Jul (peak May to late Jun); chorus heard at other times too; 1P-3A when temps are warm	>4yrs
Boreal Chorus Frog	*Pseudacris maculata*	damp meadows and pastures, streams, ditches, temp or permanent ponds/lakes, floodplains, moist woods; uses other animal burrows during extreme weather; eggs attached to plant stems in water & take 2 wks to hatch; tadpoles metamorphose within 2 mos	active early Feb to mid-Nov (peak early Apr to late Jun); emerges earlier in spring than other anurans	choruses from late Feb thru Aug (peak early Apr to early Jun); 7P-3A	
Plains Leopard Frog	*Lithobates blairi*	common in permanent & temp aquatic habitat; travels far from water; no known home range or territory; digs into mud and leaves of lake and stream bottoms during winter; diet incl crickets, grasshoppers, worms, snails, nonaquatic insects; predators incl raccoons, opossums, and skunks	active all year, only in winter when temperatures are favorable (peak late Apr to early Aug)	recorded early Mar to late Aug (peak mid-Apr to mid-Jun); 12P-2A	
Bullfrog	*Lithobates catesbeianus*	restricted to permanent waters where deep habitat available; burrow in mud under water during winter; opportunistic feeder (e.g., insects, small vertebrates); eggs hatch 4-5 days; tadpoles 3-14 mos in water	active mid-Feb to early Dec (peak late Apr to late Jul); breeds early Mar to mid-Aug (peak mid-May to late Jun, later than other anura)	breeds early Mar to mid-Aug (peak mid-May to late Jun); 12P-3A	>7yrs

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Appendix C., cont'd.

SPECIES		HABITAT, HABITS, NOTES	CHRONOLOGY	BREEDING CHORUSES	EST. MAX. LIFESPAN
SALAMANDERS (CAUDATA)					
Barred Tiger Salamander	*Ambystoma mavorortium*	much of summer & winter in underground caves or burrows of other animals, emerging at night or after rain; courtship in water, eggs on sticks or weeds at water's edge (few wks to hatch); often use shallow, non-flowing water in floodplain; ephemeral & permanent waters used; loose soils impt	active annually in KS from early Feb to mid-Dec, peak mid-Apr to ealry Jul; breeds after rains from Dec to Mar		>12yrs
TURTLES (CHELONIA)					
Common Snapping Turtle	*Chelydra serpentina*	varied semi-aquatic habitat, but prefers water bodies with soft mud bottom, aq edge vegetation, and sunken wood; mostly nocturnal and buried in mud about as deep as neck to allow breathing with little effort; breed in water; nest 4-7" in sandy or loamy soil, sometimes far from water; eggs hatch 55-125 days; omnivorous; many predators of eggs and young--lg birds, fishes, snakes, bullfrogs, and sm mammals; winter in mud; unable to retain moisture like some other turtles	active early Mar to late Dec (peak early May to late Jul); mating between Apr & Nov; egg depositing July-Aug and hatch Aug-Oct (55-125 days)		>38yrs
Northern (Western) Painted Turtle	*Chrysemys picta (bellii)*	slow-moving to still, shallow waters with soft mud bottom, aq veg, & 1/2-submerged wood; burrows in mud up to 1-1/2 ft deep in winter; hatchlings can survive winters through natural freezing (up to 54% of body fluids); sleep at night in water on logs or bottom and bask and feed during day; omnivorous; many predators of young; nests dug in soft soil up to 4" deep, and eggs hatch in 2 to 2-12 mos; young may not emerge until late fall or following spring	active mid-Feb to late Dec (peak late Apr to late Jul); mating usu Mar to Jun; egg-laying May to Jul		>20yrs
Ornate Box Turtle	*Terrapene ornata*	most abundant on W open prairie, but also like pasture & open woodland and fields; terrestrial; digs underground up to 18" in grassland and as shallow as 6" in woodland or uses dens or burrows of other animals for winter; diurnal; home range of about 5 ac, but not territorial; lay 1-2 clutches; eggs hatch little past 2 mos; young sexually mature at 7-8 yrs; primarily carnivorous; mammals as coyotes and skunks are predators; daily	active late Feb to mid-Dec (peak mid-May to mid-Aug); mating most common in spring and fall, and nesting most common in June		>26yrs

Cont'd. next page

Appendix C., cont'd.

SPECIES		HABITAT, HABITS, NOTES	CHRONOLOGY	BREEDING CHORUSES	EST. MAX. LIFESPAN
Slider (Red-eared)	*Trachemys scripta (elegans)*	semiaquatic; quiet, permanent water with soft mud bottom, aq veg, & basking sites; winter in bottom mud or shoreline earth; active in day, sleep in water at night either floating or on bottom; nest 1-4" deep in loose, damp soil near water's edge; eggs hatch 2 to 2-1/2 mos; young emerge after or wait until spring; omnivorous	active Mar to Oct; usu breed Mar to Jun and in fall (>2x/yr)		>25yrs
Yellow Mud Turtle	*Kinosternon flavescens*	prefers quiet water with mud or sandy bottom and presence of aq veg; active afternoon; active afternoon to dusk & from midnight to sunrise; may forage on land btwn waters; bask on brush or logs; winters in mud above or below water or in muskrat dens, stumps; omnivorous; predators of young incl snakes, fish, and other turtles	active early Mar to mid-Oct (peak mid-May to mid-Jul); breeding likely before Jun (not well documented); nesting in Jun & hatch wi 3 mos;		>10yrs
Spiny Softshell (Western)	*Apalone spinifera (hartwegi)*	semiaquatic; use variety of water types; prefers areas with sandbars or mudflats and soft bottoms; winters several inches in mud under water; active mostly in day; nests are on land, a cavity in sand or soft soil 4-10" deep; young may not emerge until next spring; carnivorous; predators of eggs and young are mostly mammals	active early Mar to mid-Oct (peak mid-May to mid-Jul); mating Apr - May; nesting Jun, some Jul; hatch late summer-fall		>25yrs
LIZARDS (LACERTILIA)					
Lesser Earless Lizard	*Holbrookia maculata*	"Species in need of information" (see website). Flat, sandy, cultivated, clay, or gravel sites with loose soil & little to no vegetation; around prairie dog towns and sandy areas around impoundments and streams or rivers; underground in cold months; active in day; home range where one male usually dominant; most diet grasshoppers & true bugs	active late May to late Oct (peak mid-May to mid-Jul); egg-laying May or Jun, hatch in 1-2 mos		
Prairie Lizard (Northern)	*Sceloporus consobrinus (garmani)*	prefers dry, open forests in e KS, but in sc-w KS inhabits low, sandy regions; burrows in ground in winter; active during day; home range 1/10 ac; uses logs & rocks for basking and foraging; female lays 1-10 eggs & likely have 2-3 clutches of 2-7 eggs (underground)/season; underground nests in loose soil; eats insects and spiders	active early Mar to early Nov (peak late Apr to early Jul); breeds May to Aug & eggs hatch in 1-2 mos		>1yr

Cont'd. next page

Appendix C., cont'd.

SPECIES		HABITAT, HABITS, NOTES	CHRONOLOGY	BREEDING CHORUSES	EST. MAX. LIFESPAN
Six-lined Racerunner	*Aspidoscelis sexlineata*	dry, open, sandy areas with little leafy veg; also open, rocky, grazed, & cultivated areas; in 2 counties, found most abund in natural sand prairie and sandy basins; prefers higher temps than most other KS lizards; underground during colder mos; active during day (8A-3P ne KS; home range <1/4 ac; 1-8 (av 3) eggs/clutch buried few inches beneath sandy soil; may have >1 clutch/season; eats spiders, snails, insects	active early Mar to mid-Oct (peak early May to late Jul); mating in May, Jun; nest Jun or Jul; hatch in 2 mos		
SNAKES (SERPENTES)					
Eastern (Kansas) Glossy Snake* **	*Arizona elegans (elegans)*	"Kansas species in need of conservation" (see website) and characteristic (peak abundance) in sand prairie. Prefers dry, open, sandy areas; primarily nocturnal; under rocks or in burrows during day; average 8 eggs/clutch & maybe 1 clutch/season; diet of small rodents and lizards	late Apr to early Oct (peak late May to early Jul); mates May-Jul; hatch 2-3 mos		
Eastern (Yellowbelly) Racer	*Coluber constrictor (flaviventris)*	open grassland, pasture, prairie areas in summer & rocky wooded hillsides in spring and fall; common in sand prairie in Harvey Co publ; dirurnal; av home range 25 ac, but not seem territorial; uses rock crevices on wooded hillsides in winter & known to co-habit with other snakes; eggs laid in tunnels or in burrows of sm mammals (e.g., moles); eats any small animal that moves	active early Jan to mid-Nov (peak late Apr to early Aug); breeds May; eggs laid mid-Jun to early Aug		
Prairie Kingsnake	*Lampropeltis calligaster*	open woods, grassland, sand prairie; secretive; beneath rocks or in burrows of other animals in winter; nocturnal in hot summers; does not breed every year; constrictor--sm mammals, snakes, and lizards	active late Jan to late Nov (peak late Apr to mid-Jul); breed in spring; 5-17 (av 9-11) eggs laid Jun or Jul and hatch in 1-3 mos (late Aug or Sep)		>23yrs
Gopher Snake (Bullsnake)	*Pituophis catenifer*	open grasslands, open woods, edge, cultivated fields; generally diurnal; uses deep crevices on rocky hillsides and burrows of sm mammals during winter; lays eggs in soft earth beneath rocks & logs; favors rodents for food	active late Mar to mid-Nov (peak mid-May to mid-Aug); mating Apr and May; eggs laid May-Jul hatching Aug, Sep		>33yrs
(Western) Massasauga	*Sistrurus catenatus (tergeminus)*	variety of habitats from sagebrush and rocky prairie hillsides to open wetlands; peak abund in grassy wetlands; in cold, use rock crevices or rodent burrows; diurnal in spring and fall and nocturnal in hot summer; mostly eats frogs, lizards, other snakes and rodents	active late Mar to early Dec (peak early May to late Jul); mates spring and fall; 3-13 (av6) young born in Jul and Aug		>20yrs

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Appendix C., cont'd.

SPECIES		HABITAT, HABITS, NOTES	CHRONOLOGY	BREEDING CHORUSES	EST. MAX. LIFESPAN
Plainbelly Water Snake	*Nerodia erythrogaster*	swamps, marshes, slow-moving streams; but may wander great distances from water during summer; basks on driftwood, low-hanging branches, stumps, brush; foraging at night; in winter, use brush & rock piles or underground burrows; primary food is leopard frogs and bullfrogs, but young prefer fishes	active early Mar to early Nov (peak late Apr to early Jul); mating Apr & May; young in Jul, Aug, & Sep (4-30 young/brood)		>14yrs
Diamondback Water Snake	*Nerodia rhombifer*	perm lakes, marshes, swamps, backwaters; basks on brush, logs, grassy banks; uses muskrat dens or other burrows around water during cold; primary foods are slow-moving or dead fishes	active early Mar to late Oct (peak late Arp to mid-Jun); mate in spring; young (13-62/litter) born from Aug to early Oct		>4yrs
Northern Water Snake	*Nerodia sipedon*	various aquatic habitats, from fast to still waters; basks on overhanging or near-water branches and logs; winters in deep crevices on rocky hillsides to below water level crayfish burrows; some females reproduce every other year; eats mostly fish, some frogs and toads	active late Jan thru Oct (peak early May to late Jul); mating in spring; young (6-66/litter, av 20-25) Aug to Oct		>9yrs
Graham's Crayfish Snake	*Regina grahamii*	ponds, sluggish prairie streams, river valleys, wet meadows; active in day in spring and fall and during night in summer; females don't breed until 3rd season, but males mature after 1 year; rests and winters in crayfish burrows; feeds primarily on crayfish	active early Feb to late Oct (peak late Apr to early Jun); breeds Apr-May; young (4-39/litter, av 16) late Jul, Aug, or Sep		
Brown Snake	*Storeria dekayi*	moist areas in woodlands and edge; active in day during spring and fall and at night during summer; underground in winter, as deep as 2 ft; preferred food is earthworms	generally active early Jan to late Nov (peak mid-Apr to mid-Jul); mating in spring and fall; young in late Jul to Sep		>7yrs
Western Ribbon Snake	*Thamnophis proximus*	edges of swamps, marshes, lakes, streams, rivers; diurnal and nocturnal, depending on temps; baks on matted reeds and grasses; feeds on waters edge in veg; uses water to escape; winters beneath ground in burrows; feeds on sm frogs, toads, salamanders, and fishes	active early Mar to mid-Nov (peak early May to early Aug); mates Apr and May; young (4-28/litter, av 12-13) late Jun to Sep		>3yrs
(Western) Plains Garter Snake	*Thamnophis radix (haydenii)*	open, grassy, prarie, esp. near water; underground when cold; active usu in day; basks on gravel rds often; abund in sand prairie; eats earthworms, herps, fishes, sm rodents	active early Mar to late Dec (peak mid-May to mid-Aug); mates Apr and May and sometimes fall; young (5-60/litter, av 20) late Jul, Aug, or Sep		>8yrs

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SPECIES		HABITAT, HABITS, NOTES	CHRONOLOGY	BREEDING CHORUSES	EST. MAX. LIFESPAN
Common Garter Snake	*Thamnophis sirtalis*	variety of habitats, esp. with moist veg--marshes, wet meadows, water edge, woodland, woodland edge, cultivated fields; home range 22-35 ac; active in day; primary foods are frogs and earthworms	active (early Feb to mid-Nov (peak early May to late Aug); mates early spring and sometimes fall; young (av 20/litter) late summer or fall		>14yrs
Lined Snake	*Tropidoclonion lineatum*	hillsides of open prairies and woodland edge; human activity seems to effect pop very little; nocturnal; hide beneath rocks and debris during day; underground during cold; eats exclusively earthworms	active late Feb to mid-Nov (peak late Apr to mid-Aug); mate spring and fall; young (2-12/litter, av 6-7) in Aug		
Western (Plains) Hognose Snake***	*Heterodon nasicus (nasicus)*	"Kansas species in need of conservation" (see website). Grassland or sand prairie; diurnal; burrows under sandy loose soil when inactive; not territorial and home range size varies depend on resources; eggs laid in nests few inches below soil surface; incubation 50-65 days; usu eats toads, reptile eggs, small lizards & snakes; plays dead for up to 5 minutes	active Apr to Oct (peak Jun & Jul); mates in May, few in fall; eggs (4-23 & av 9/clutch) laid in Jul		>19yrs
Eastern Hognose Snake***	*Heterodon platirhinos*	"Kansas species in need of conservation" (see website). Prefers sandy areas, most common in c Low Plains in river valleys, esp e KS border; burrows deep into loose soil or sand to avoid cold temps; nests burrowed out several inches below soil surface; eats mosty frogs and toads	active Apr to Oct (peak May & mid-Jul); mating Apr, May; eggs (4-61, av22/clutch) in late Jun, Jul		>7yrs
1 Distribution confirmation: http://www.k-state.edu/kansasgap/KS-GAPPhase1/finalreport/index.htm (April 1, 2011)					
2 2002 Fort Hays State Univ. QNWR inventory - QNWR study (QNWR Files)					
3 Notes & distribution adapted from Collins et al. 2010					
4 Personal observations, mainly QNWR staff					
Note: Western Chorus Frog is not included in Collins et al. 2010; but listed in KS-GAP.					
SPECIES WITH REPORTED OCCURRENCE IN STAFFORD, RENO, AND/OR RICE COUNTIES, BUT NOT DOCUMENTED ON QUIVIRA NWR:					
FROGS & TOADS (ANURA)					
Spotted Chorus Frog	*Pseudacris clarkii*	open prairie grassland and woodland edge; breeds in open, shallow pools, but some mate in permanent water; eggs deposited on grasses or stem just below water surface; eggs hatch 2-10 days; tadpoles metamorphose in late summer; likely underground in dry weather	late Mar to late Sep (peak mid-Apr to early Jun); breeds late Mar to late Aug, depending on rainfall & temps		

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SPECIES		HABITAT, HABITS, NOTES	CHRONOLOGY	BREEDING CHORUSES	EST. MAX. LIFESPAN
Great Plains Narrowmouth Toad	*Gastrophryne carolinensis*	common under rocks on dry, open upland (grassy slopes, woodland edge or open woods); tolerant of various habitat; where no rocks, use rodent burrows; secretive--mostly underground; use temp wtlds for breeding--opportunistic, >1x btwn May-Aug; tadpoles metamorphose within 20-30 days; diet nearly all ants; predators incl bullfrogs, Leopard frogs, and shrews.	active mid-Mar to early Nov (peak early May to early Jul); breeds early Apr & late Jul with peak in Jun	breeds early Apr & late Jul with peak in Jun; choruses 9P-midnight	>6yrs
Plains Spadefoot	*Spea bombifrons*	prairies & open floodplains, preferring loose soil or sand, generally w & c KS; uses other animal burrows for retreats & attaches eggs to partly submerged vegetation or other; emerges at night to forage, esp after rain	active mid-Jan to mid-Oct (peak early May thru mid-Jul); breeds from late Mar to mid-Aug (peak early May to late Jun)	most robust chorus 10P to 3A &min of 3.5" of rain & at least 52 degrees F required to stimulate mating	
TURTLES (CHELONIA)					
Smooth Softshell (Midland)	*Apalone mutica (mutica)*	semiaquatic; prefers sand or mud bottoms with mod-fast moving water, rarely away from water except to bask or nest; avoids open water; sensitive to disturbance; usu inactive when water levels low; in ground under water at night; burrowed in stream/river bottoms in winter; mating in water; nests in sandbars; 3-25 (av 11) eggs/clutch that hatch in 2-21/2 mos; females matgure at 6-9 yrs and males 4 yrs; carnivorous (mostly insects); various predators of eggs and young	active late Feb to mid-Nov (peak late May to mid-Aug); mating Apr, May & in fall; nest peak late May & Jun;		ukn
LIZARDS (LACERTILIA)					
Western Slender Glass Lizard	*Ophisaurus attenuatus*	mostly e KS; inhabits open and edge habitats (e.g., tallgrass and sand prairie; open woodlands) often near streams or ponds, esp where abund abandoned rodent burrows; mostly diurnal; max home range of about 1 ac, but not territorial; underground in rodent burrows below frost line in winter; 5-17 eggs laid in nest; female mature at 3-4 yrs; eats insects, spiders, snails, frogs, snakes, newborn sm mammals; freq loses tail as a defense mechanism, but will grow back	active early Mar-early Dec (peak early May to late Jul); breeds May; eggs from late Jun to mid-Jul; incubate about 7 wks		>9yrs (min natural)

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SPECIES		HABITAT, HABITS, NOTES	CHRONOLOGY	BREEDING CHORUSES	EST. MAX. LIFESPAN
Great Plains Skink	*Plestiodon obsoletus*	open, rocky hillsides with low veg; avoids sandy areas; burrows beneath soil or in crevices during winter; active in day, below sun-warmed rocks; av home range 50 ft in diameter, but will wander to find new terr if conditions unfavorable; females build deep burrows under rocks to lay eggs, 5-32 (av 12)/clutch with 1-2 mos incubation period; eats insects, spiders, and snails	active all year (peak late Apr to late Jul); breed in May		>6yrs
SNAKES (SERPENTES)					
Great Plains Rat Snake	*Pantherophis emoryi*	rocky hillsides & canyons, caves, open woods edge; avoids heavily forested regions; mostly nocturnal; during day, under rocks or in crevices; eats mostly sm mammals and birds (constrictor); egg clutches probably 15-30 (av 13)	active late Feb to early Nov (peak late Apr to mid-July); mating likely in spring; egg-laying in Jul		>21yrs
(Central Plains) Milk Snake	*Lampropeltis triangulum (gentilis)*	In w KS, rocky ledges of prairie canyons & stream edges; active in day, but nocturnal in hot summer; 3-24 (av 5-7) eggs/clutch and incubation 40-65 days; hidden under sun-warmed rocks; uses mammal burrows or dens on rocky wooded hillsides during winter; eats sm lizards, snakes, newborn mice	active late Mar to late Nov (peak late Apr to early Jul); mating in spring; egg-laying Jun or Jul; hatch Aug/Sept		>21yrs
Western (Black) Rat Snake	*Scotophis obsoleta (obsoleta)*	mostly resides e 1/2 KS; prefers rocky hillsides of open woodlands; in w part of range, in wooded areas of streams or rivers; active mostly day in spring & summer, and more nocturnal in summer when hot; home ranges 25-30 ac; winters in burrows in hillsides; 6-44 eggs laid in moist soil or in logs/rocks; freq climbs trees in seach of food; constrictor--eats small mammals, birds, eggs, snakes, frogs, lizards	active early Mar to early Dec (peak late Apr to mid-Jul); egg-laying Jun or Jul; hatch 1-2 mos		>22yrs
Ringneck Snake (Prairie)	*Diadophis punctatus (arnyi)*	rocky hillsides of open woodland, mostly e KS; lay beneath sun-warmed rocks on moist soil in day and active at night; belowground in winter; nests likely located underground (probably deep); egg clutches 1-10 (av 4); females mature at 3 seasons; eats mostly worms and some frogs	active early Mar to early Nov (peak mid-Apr to mid-Jul), but rarely seen Jul-Aug; egg-laying late Jun or early Jul; hatch late Aug or early Sep		>15yrs