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

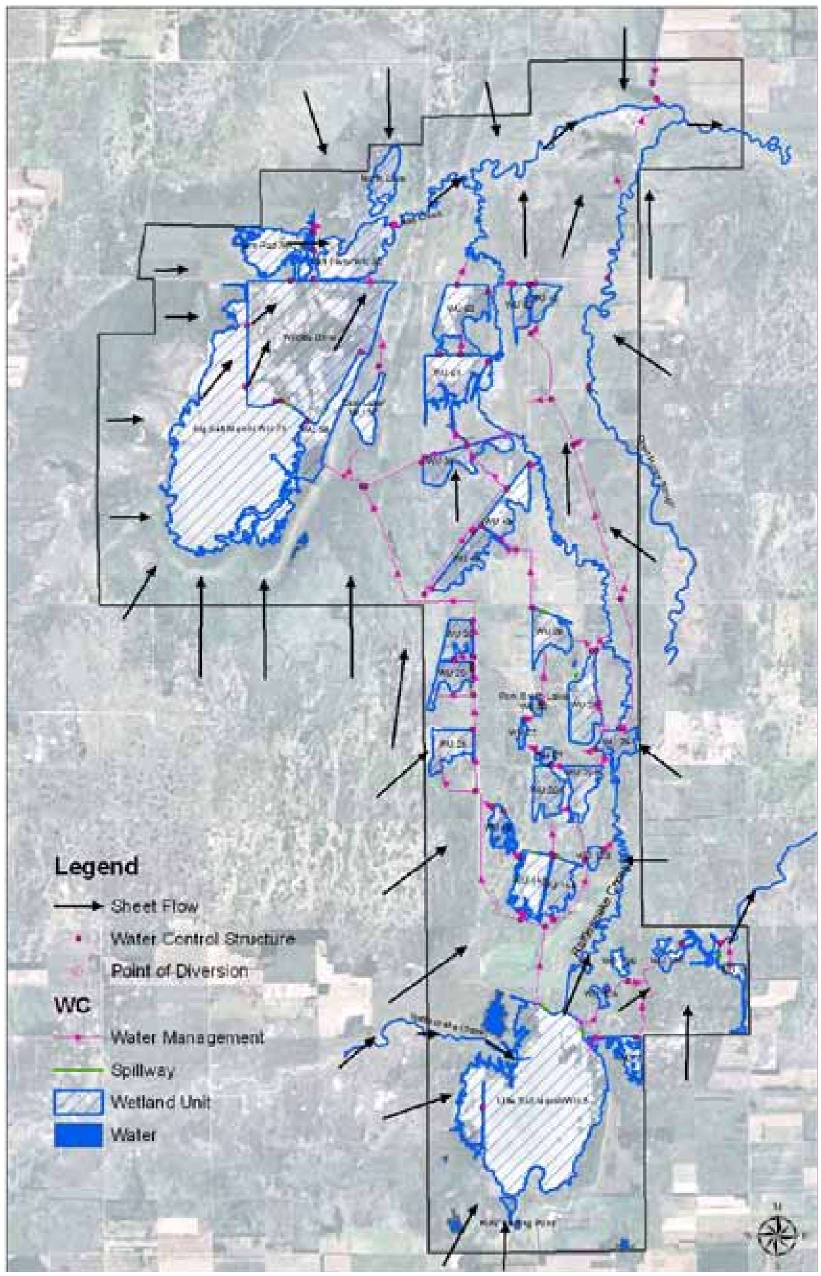

Figure 22. Wetland management units and directions of water flow, including water-control structures on Quivira NWR.

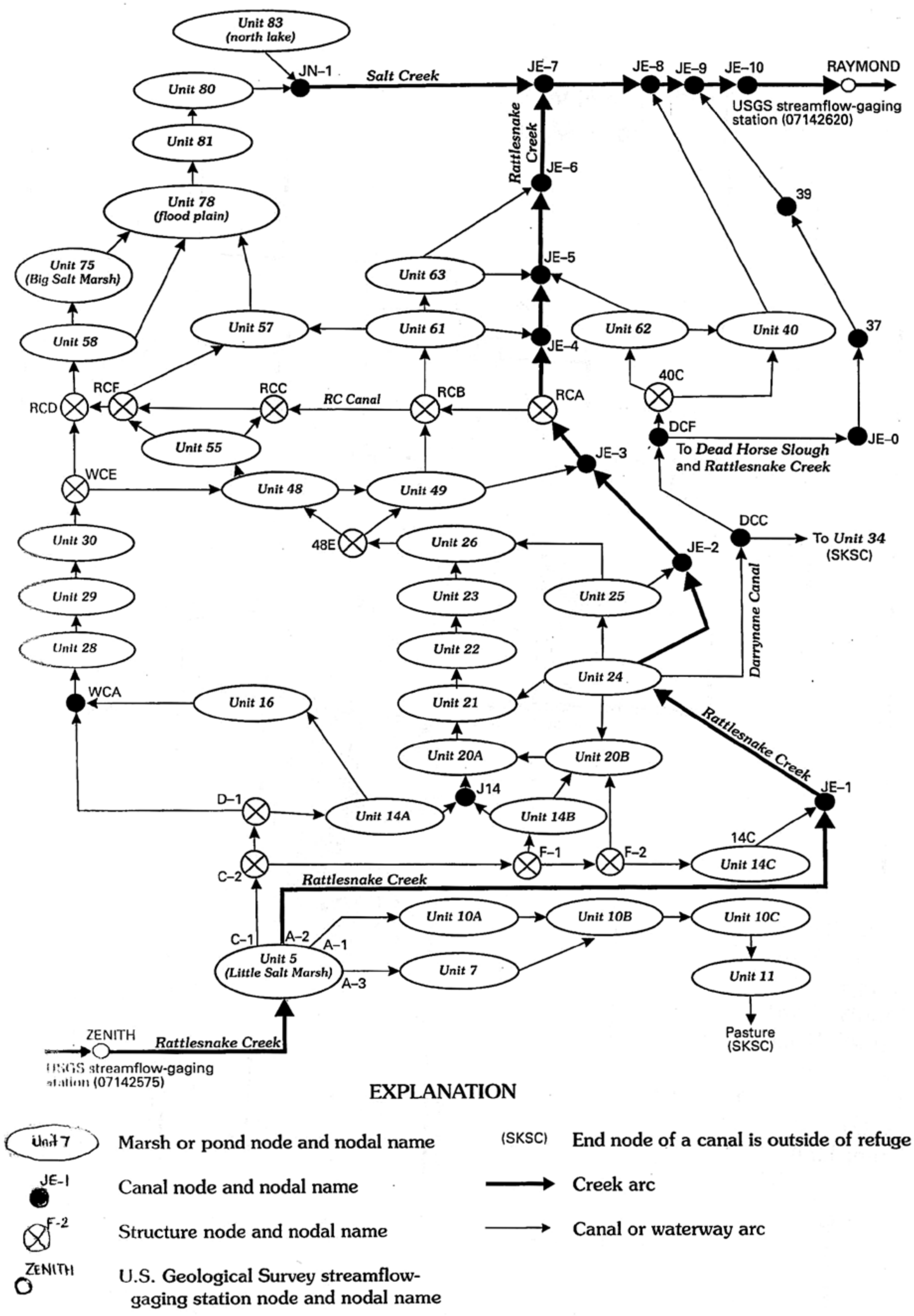

Figure 23. Model of water movement on Quivira NWR (from Jian 1998).

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	big & little bluestem, switchgrass, indiangrass, and less of other prairie grasses and forbs (sometimes lesser amounts of meadow species present)
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	unmapped areas; polygons with >50% Tivin fine sand with 10-30% slopes (SSURGO data)
Saltgrass	1954	Saltgrass (G3 symbol on original map includes Sandhills and Saltgrass cover types)
	2011	Saltgrass
Salt Flat/Bare Ground	1954	bare soil, mostly with alkaline salts (white) on surface (Af symbol on original map)
	2011	bare ground areas, some with alkali and sparse cover of saltgrass
Meadow	1954	little bluestem, indiangrass, three-square, sedges, rushes (H symbol on original map; "wild hay")
	2011	medium-short emergent plants, primarily prairie cordgrass, three-square, sedges, rushes (not tall bulrushes; sometimes lowland prairie grasses mixed in this cover type)
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	cattail, Phragmites, tall bulrushes (mostly softstem bulrush)
Water	1954	surface water (W symbol on original map)
	2011	surface water
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	black locust, tamarisk, cottonwood, Russian olive, Siberian elm, and some tall shrubs that were not plum
Plum	1954	not included in map description
	2011	sand plum with very little coverage (<5%) of American plum and other shrubs
Agriculture	1954	farmed areas and few very small sites that were primarily forbs (weeds)
	2011	farmed areas
Prairie Dog Towns	1954	not included in map description
	2011	active prairie dog towns

[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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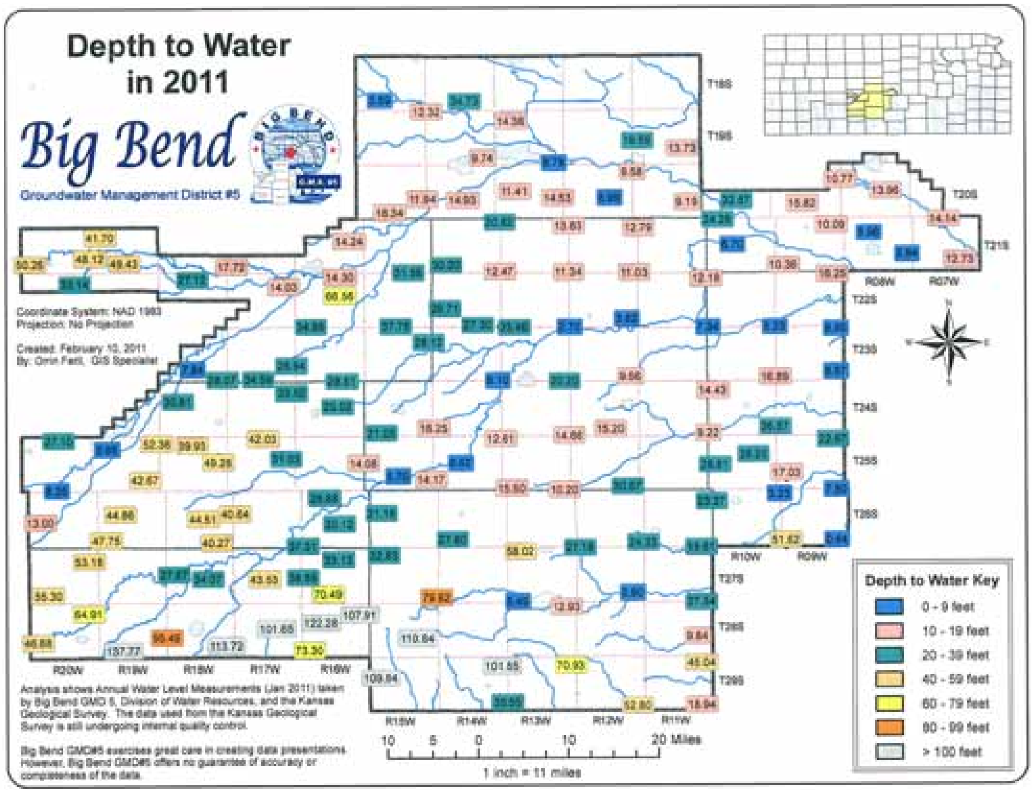

Figure 24. Depth to groundwater in the Big Bend Groundwater Management District No. 5 in 2010 (from Balleau Groundwater Inc. 2010).

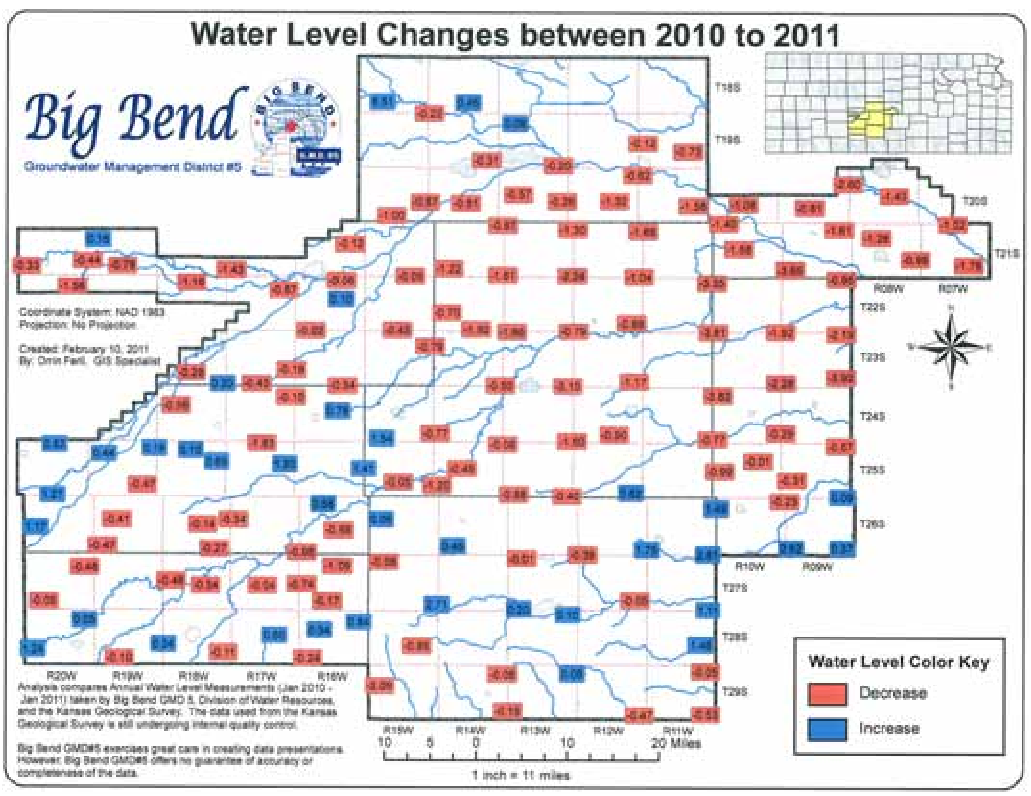

Figure 25. Groundwater depth changes in the Big Bend Groundwater Management District No. 5 between 2009 and 2010 (from Balleau Groundwater Inc. 2010).

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