APPENDIX D
WATER RESOURCES

D. Water Resources

D.1 Overview

The Bitter Lake NWR is at the juncture of the Roswell Artesian Basin of southeastern New Mexico and the Pecos River. The Roswell Artesian Basin is a natural hydrologic basin six to eighteen miles west of the Pecos River and twenty miles north of Roswell, in Chaves County, to twenty miles south of Artesia, in Eddy County, a distance of approximately eighty miles. The Pecos River runs through the eastern side of the basin from north to south through the refuge. Several large tributaries drain from the west to the east. These two systems and their interactions account for the diversity of water resources within the refuge, including sinkholes, springs, wetlands, oxbow lakes, and riverine habitat.

D.2 Surface Water Hydrology

The refuge has about 1,200 surface acres of water in the form of natural lakes, impoundments, sinkholes, and streams. The portion of the Pecos River being considered for the proposed river restoration is from the southern boundary of the refuge (Project River Mile 0) to the northern boundary (Project River Mile 16). The affected river reaches are described in detail in Section 2.1. These figures show the five reaches and cross sections referenced in this EA. For much of its length, the river is bordered by refuge-impounded wetlands on the west side and a 300-foot-high bluff running along the east side of the river valley. The proposed project is entirely within the boundaries of the Bitter Lake NWR. The confluence with the Rio Hondo, a major tributary, is approximately two miles south of the Highway 380 Bridge, near the southern refuge boundary. The Rio Hondo originates in the foothills of the Sacramento Mountains, at the junction of Rio Ruidoso and Rio Bonita. From this point, it flows eastward for approximately 85 miles.

D.2.1 Pecos River Hydrology

The hydrology of the Pecos River through the Bitter Lake NWR is controlled by reservoir releases from Sumner Reservoir and inflows from tributaries and agricultural return flows south of Sumner Reservoir and north of Roswell. Before Sumner Dam was built in 1938, floods were much more intense and base flows were higher than under post-dam conditions. Table D-1 shows the pre-dam and post-dam floods, and Table D-2 shows the pre-dam and post-dam flow duration. There are data for twenty-seven of the thirty-two years before 1938 and for fifty-seven years after 1938. Data from the USGS

Table D-1
Flood Frequency Statistics Associated with the USGS Artesia Gage

Flood Frequency: Artesia Gage		
Return Period (year)	**Pre-Sumner Dam (27 years)**	**Post-Sumner Dam (57 years)**
2	10,100 cfs	2,700 cfs
5	21,000 cfs	6,000 cfs
10	31,500 cfs	9,700 cfs
50	66,900 cfs	25,900 cfs
100	88,400 cfs	38,200 cfs

(cfs = cubic feet per second)
Source: FLO Engineering 1999

Table D-2
Flow Duration Statistics Associated with the USGS Artesia Gage

Flow Duration: Artesia Gage		
% of time flows exceed	**Pre-Sumner Dam (27 years)**	**Post-Sumner Dam (57 years)**
1	2800 cfs	1900 cfs
2	1800 cfs	1400 cfs
5	1070 cfs	870 cfs
10	670 cfs	672 cfs
20	391 cfs	233 cfs
30	296 cfs	132 cfs
40	246 cfs	97 cfs
50	200 cfs	76 cfs
60	167 cfs	57 cfs
70	134 cfs	44 cfs
80	103 cfs	31 cfs
90	72 cfs	16 cfs
95	44 cfs	6 cfs
98	32 cfs	<5 cfs
99	24 cfs	<5 cfs

Source: FLO Engineering 1999

Gage, Pecos River Near Artesia, New Mexico (08396500, the Artesia Gage), located south of the Bitter Lake NWR, is used to compare the pre-dam to post-dam hydrology because the record goes back to 1906. The USGS Gage, Pecos River Near Acme (08386000, the Acme Gage) is in the reach proposed for restoration but does not have as long a record (FLO Engineering 1999).

Table D-1 shows how Sumner Dam has substantially decreased the intensity of floods for all return periods. There is a decrease in quantity and height of the spikes. Table D-2

compares the pre- and post-dam flow duration values. The post-dam flows are consistently lower, especially at the lower flows due to the policy of moving water in larger block releases.

Since 1937 the quantity of water released from Sumner Reservoir has been determined by the irrigation needs of the Carlsbad Irrigation District (CID) and state line water delivery requirements. Brantley Reservoir is the delivery point for Carlsbad Project water. Water is transported most efficiently to Brantley Reservoir using larger block releases. The maximum release through the gates at the reservoir at typical reservoir levels is 1,400 cubic feet per second (cfs), which typically results in a flow of approximately 1,200 cfs at the Acme Gage. The frequency of these block releases depends on downstream irrigation needs, water availability, and river conditions. Releases usually begin in March, and there can be several each year, lasting up to two weeks. Storms during a block release, or at other times, can cause peak flows above 1,200 cfs at the Acme Gage (FLO Engineering 1999).

As a result of a jeopardy determination in 1992 for the Pecos bluntnose shiner (shiner) on water operations on the Pecos River, the Bureau of Reclamation (Reclamation) is working to maintain a minimum discharge to support fish populations in the river and to avoid block releases at periods in the shiner's life cycle where the release could be harmful. Current Pecos River operations are governed by the 2006 – 2016 Biological Opinion, which sets a year-round target flow of 35 cfs as measured at the Taiban Gage (Pecos River Below Taiban Creek Ft. Sumner, NM, USGS gage number 08385522) and to keep the river continuous.

Actual flows through the Bitter Lake NWR are variable. A base flow of 35 cfs at Acme Gage has been used for planning restoration actions, although the target is not expected to be met consistently during the irrigation season (Service 2003). The portion of the Pecos River being considered for the proposed river restoration is a gaining reach due to groundwater inflows and is not subject to the same concerns about intermittency as the reach above the Acme Gage.

D.2.2 Pecos River Channel Morphology

The construction of Sumner Dam and the excavation of the channels in the Bitter Lake NWR in the 1940s have altered the channel morphology of the Pecos River. The original meanders had greater sinuosity or curving and meander length, meander amplitude, and mean radius of curvature. Current Reaches 2 and 4 are now straight excavated channels, so their morphology cannot be compared to the original meanders. Reaches 1, 3, and 5 have developed a new morphology, which is characterized by lower sinuosity, as a result of the present hydrology. Table D-3 presents the morphology characteristics of the current reaches. Information on the characteristics of Reach 5 is based on information from 1975, before the current Highway 380 Bridge was built. The rest of the reaches are based on 1991 aerial photos (FLO Engineering 1999).

Table D-3
Characteristics of Current Channel Reaches

Reach	Length (feet) River	Length (feet) Valley	Sinuosity	Slope (feet/mile)	Average Channel Width	Mean Radius of Curve (feet)	Meander length (feet)	Meander Amplitude (feet)
1	23,800	18,200	1.31	4.4	144	560	3,380	1,555
2	15,000	14,000	1.07	3.5	111	0	0	0
3	20,900	10,400	2.01	4.9	129	460	2,184	2,141
4	8,200	8,000	1.03	2.8	86	0	0	0
5*	16,200	14,000	1.16	3.4	120	360	2,440	1,500

*Before the Highway 380 Bridge
Source: FLO Engineering 1999

Table D-4 presents the morphology characteristics of the original meanders in 1940. The reach through Oxbow 1 was not a meandering river, so the mean radius of curvature, meander length, and meander amplitude are not applicable. The information for these tables was derived from USGS quadrangle maps and aerial photos (FLO Engineering 1999).

Table D-4
Characteristics of Original Oxbows

Oxbows	Length (feet) Meander	Length (feet) Valley	Sinuosity	Slope (feet/mile)	Average Channel Width	Mean Radius of Curve (feet)	Meander length (feet)	Meander Amplitude (feet)
1	22,200	14,000	1.63	2.2	154	NA	NA	NA
2	9,800	3,400	2.88	2.4	108	611	4,420	3,780
3	7,400	3,000	2.47	2.8	No Info	671	4,130	2,790
4	8,000	3,000	2.67	0.5	169	706	4,430	3,600
5	8,000	3,800	2.11	1.1	379	866	4,930	2,740

Source: FLO Engineering 1999

Each reach of the river has adapted to the lower flows associated with post-dam hydrology and to the straightening of the meanders. Reach 1 did not have any diversions and has remained dynamic, particularly around the bends, where new floodplain continues to be created. The channel that was excavated at the north end of Reach 2 was bypassed by a small meander by 1975. The channel was excavated again and has remained a straight section. The rest of Reach 2 has also remained straight. Reach 3 became a straight run of river following the excavation of the southern channel, which is downstream in Reach 4. The river in Reach 3 immediately began to reform, progressively increasing the meander length and amplitude and decreasing the radius of curvature of the meanders. Reach 3 is a good example of the morphology created by the post-dam hydrology (FLO Engineering 1999). Reach 4 has remained straight and unchanged.

Reach 5 is difficult to interpret due to the confinement of the river in this reach, caused by the construction of the Highway 380 Bridge.

The section of the Pecos River in Reach 3 has a meandering pattern that can be used as a template for the restored areas. This section has been developing within the context of the post-dam hydrology since the southern channel was dug in the 1940s. The sinuosity in this section is 2.01, the mean radius of curvature is 460 feet, the meander length is 2,184 feet, and the meander amplitude is 2,141 feet.

The river also was examined for ten miles upstream and twenty miles downstream of the restoration area for sections where a new morphology had developed with the post-dam hydrology. Two sections, one upstream and one downstream, were observed to have changed substantially since 1940. Table D-5 lists the slope, sinuosity, mean radius of curvature, meander length, and meander amplitude of these two sections. A comparison of these characteristics to Reach 3 in the Bitter Lake NWR shows a lower sinuosity, greater radius of curvature, and greater meander length in the upstream and downstream sections. However, the meander amplitudes of the three sections are similar.

Table D-5
Pecos River Characteristics Upstream and Downstream of the Bitter Lake NWR

	Slope (feet/mile)	Sinuosity	Mean Radius of Curve (feet)	Meander length (feet)	Meander Amplitude (feet)
Upstream	4.6	1.45	1,438	6,578	2,485
Downstream	2.4	1.34	817	3,599	1,553

FLO Engineering 1999

D.2.3 Other Surface Water Features

The Bitter Lake NWR includes a large variety of surface water types, including arroyos, spring-fed streams, isolated oxbow lakes, large and small playa lakes, developed impoundments, artesian springs, and sixty sinkholes throughout the refuge. These surface water features depend highly on local groundwater flows, which in turn depend on precipitation and water use to the north and west.

In the North Tract, major features include the Arroyo del Macho and Salt Creek. Arroyo del Macho is an ephemeral stream that drains in to Salt Creek. Salt Creek is also fed from groundwater sources and drains into the Pecos River from the west. The North Tract also includes at least 21 gypsum sinkholes, which were formed by the dissolving of underlying strata and subsequent collapse of the surface dome. These sinks vary in surface diameter from 60 to 200 feet and in depth from 20 to over 100 feet. Most of the shallow sinks are now dry due to the general lowering of the water table, but some of the deeper sinks are connected with the artesian system and hold water year-round. The Inkpot is a vertical-walled sinkhole 150 feet in diameter and 90 feet deep. In 1937 this sinkhole overflowed, feeding another sink and 60-acre playa lake.

Major surface water features of the Middle Tract include Bitter Lake playa, Bitter Creek, Lost River, Dragonfly Spring, Sago Spring, Lake St. Francis, Hunter Marsh, and numerous sinkholes, streams, and springs. The Middle Tract also includes the oxbow lakes created naturally or by river channelization and a series of water impoundments west of the Pecos River that are filled and drained seasonally for the benefit of bird populations. The surface water features of the Middle Tract provide habitat for several unique species, including some that are threatened or endangered. The Bitter Lake playa basin is thought to be the result of subsidence caused by an underground stream. The depth of the playa ranges from 0 to 4 feet. Bitter Creek and the Lost River are intermittent streams that drain into Bitter Lake. Lake St. Francis is the largest sinkhole in the refuge, measuring 200 feet across and 60 feet deep. Hunter Marsh is a natural wetland at the south end of the Middle Tract. The South Tract includes some human-made water impoundments.

D.3 Groundwater Hydrology

The Bitter Lake NWR is in the discharge zone for the Roswell Groundwater Basin. The basin encompasses 10,779 square miles and includes most of Chaves County and portions of Torrance, Guadalupe, and Roosevelt Counties. Groundwater supplies are derived from several geological formations, including the Yeso and San Andres Formations, the Artesia Group, the Glorieta Sandstone, and alluvium and terrace deposits. The two major aquifers that provide the largest supplies of water are the Permian artesian aquifer and the shallow-water aquifer, located in the alluvium deposits and terraces. These two aquifers provide water for the cities of Roswell, Artesia, Dexter, Lake Arthur, and Hagerman. Irrigation wells have been developed throughout the basin, with the largest concentration located in the Pecos River Valley between Roswell and Seven Rivers.

Groundwater from the artesian zone flows from west to east into the sinkholes, springs, and seeps of the refuge and maintains the wetlands and surface water impoundments. Groundwater also preserves perennial flows in the Pecos River through the proposed project area. Artesian flows historically maintained groundwater levels that were 80 feet above the mean topographic surface (mts, 3,500 feet) of the refuge. This level dropped to 20 feet above mts in the 1970s and since then has been on the rise toward the current level of 40 feet above mts. Trends suggest that spring flows will continue to increase, and sinkhole levels will continue to rise.

D.4 Water Rights

The Bitter Lake NWR has a water right associated with the North Tract for 4,393.2 acre-feet per year, with a priority date of 1916. As part of the adjudication of its federally reserved water rights by the State of New Mexico, the Service agreed not to use this

water right because it wished to enhance natural hydrologic conditions within this wilderness unit. The stipulation states that the refuge shall not use this water right unless the State Engineer would allow for the change in purpose of use from agriculture to instream flow.

The refuge has received recognition from the State of New Mexico for their federally reserved water right. This right allows for the refuge to manage wetlands on the Middle Tract of the Refuge and protects spring resources from impairment. Since the mid-1990s the Service has changed how the impounded wetlands of the Middle Tract are managed. Formerly, water levels in these wetlands were kept high year-round. Now lake levels are left low during the summer when evaporation is highest and are allowed to rise during the colder months. While the primary reason for this change was to mimic natural conditions and improve wetland habitat, this change may also have reduced losses due to evaporation.. These actions protect groundwater levels of the Roswell Basin in the refuge vicinity and preserve Pecos River flows.

D.5 Water Quality

Potential contaminant sources in the area include natural salinity, irrigated agriculture, grazing, feedlots, oil and gas production wells and pipelines, septic tanks, and historic municipal wastewater discharges to Hunter Marsh.

Upstream of the refuge, the Pecos River enters a basin dominated by evaporitic sedimentary rock. Natural salinity in the Pecos River and refuge water bodies greatly increases below this point due to geologic-based salt-loading and high evaporation rates. Water quality in the river is also affected by return flows from upstream agricultural diversion. Return flows are usually more saline than native river waters because salts are concentrated when water is removed through transpiration. The river also carries runoff from fertilizer application and other upstream contaminants. For many years during the last century, salts, selenium, and other contaminants were further concentrated in the water of refuge sinkholes due to dramatic declines in water levels. Reduced groundwater withdrawal in recent years has led to higher water levels in the sinkholes and probable decreases in salt concentrations. Change in the management of the impounded lakes may have reduced the salinity of these waters, and the removal of saltcedar may have helped remove surface salt and mineral encrustations.

There are three active oil wells and three active natural gas wells on the refuge that were included in lands acquired from the BLM in the late 1960s. The BLM continues to permit extensive natural gas development in the Pecos River floodplain just north of the boundary of the refuge Middle Tract, and leasing activity has accelerated throughout the region, including on the mesa immediately to the east of refuge. The refuge does not control subsurface mineral rights, and additional development could occur. Oil spills have occurred in the past within the holding berm of the oil tanks, and there is an area that has crusted oil in spots and is void of vegetation. In 1997, a gathering system was

installed to transport produced water and oil from leases on the refuge onto private property to the south. Fluids are now pumped to a central battery located off-refuge, which greatly reduces the chance of any future spills and associated habitat damage. An old abandoned delivery line and three produced water storage tanks were also removed.

The BLM administers a habitat protection zone (HPZ) within the 500-year source water capture zone for the refuge. All oil and gas activities within the primary area of the HPZ must incorporate groundwater protection features, including steel tanks instead of earthen pits and a stringent casing protocol (US BLM 2002).

Other water contaminant pathways include the following:

- Arroyo del Macho—Irrigated agriculture, grazing, oil, and natural gas wastes drain to Salt Creek;
- Salt Creek—Natural gas pipeline, power line, and gas well;
- Bitter Creek—Lowered water tables and subsequent increases in salinity, selenium, and arsenic;
- Lost River—Lowered water tables and subsequent increases in salinity, selenium, and arsenic, plus nutrient inputs from septic tanks and feedlots;
- Rio Hondo—Wastewater treatment point-source inputs, and agricultural, grazing, and oil and gas;
- Feedlot/dairy farms—Adjacent to South Tract of the refuge; and
- Industrial/commercial—Point sources in Roswell.

Since 1996, temperature, salinity, and conductivity have been measured monthly at 14 refuge wetland locations. Data from monitoring at the refuge showed that aluminum, cadmium, lead, selenium, and mercury concentrations were elevated in water samples when compared to regional averages. Aluminum, boron, mercury, selenium, and zinc were the only elements in plants, invertebrates, fish, or eggs that exceeded literature-based thresholds for adverse health effects. Lake St. Francis contained biota that had greater concentrations of copper, selenium, and zinc than at other sites, although sediment metal concentrations were low. Hunter Marsh, which historically received municipal wastewater, contained sediment and biota with elevated concentrations of lead and mercury.

No organic chemicals were detected in water, but several organics were found in sediments from the mouth of Lost River at Bitter Creek and in Hunter Marsh and in fish collected at Hunter Marsh. The remaining areas of the refuge were relatively contaminant free. Although polychlorinated biphenyls (PCBs) and organochlorine insecticides were not measured in Lost River sediments, fish contained only trace concentrations of these compounds. Several polycyclic aromatic hydrocarbons were measured in sediments in Hunter Marsh at concentrations as high as 20 milligrams per kilogram (mg/kg) dry weight parts per million (ppm), which could adversely affect invertebrate communities and wildlife that forage there regularly. Fish from Hunter Marsh also contained total PCBs at concentrations up to 5 ppm dry weight. A diet that contains greater than 0.1 ppm

total PCBs can have adverse effects on wildlife. Hunter Marsh contains contaminated sediments, invertebrates, and fish that, when consumed regularly by local wildlife, could result in adverse health effects (Service 2000, 2001).

Sediment and water samples were collected from Oxbow 4 in March of 2008. The samples were analyzed for PCBs, pesticides, and metals in order to assess any potential water quality impact of the reconnection of Oxbow 4 to the Pecos River mainstem channel. All samples were clear of PCBs and pesticides. The water sample had trace amounts of arsenic (0.090 micrograms per liter [µg/l] of water) and barium (0.021 µg/L). The sediment samples had concentrations of arsenic (~10 mg/kg), barium (~100 mg/kg), and chromium (~9 mg/kg). These concentrations are at or below average New Mexico background concentrations for these elements (AALI 2008, Tashjian 2008).