



Inventory of Spring Ecosystems at Sevilleta National Wildlife Refuge, New Mexico

Physical and Biological Characteristics

Natural Resource Technical Report NPS/CHDN/NRTR—2013/822



ON THE COVER

Over looking San Lorenzo Spring 2, Sevilleta National Wildlife Refuge
Photograph: NPS

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Executive Summary

This report summarizes information gathered during an inventory of springs in Sevilleta National Wildlife Refuge conducted in 2011. The inventory was conducted as part of a cooperative effort between the Inventory and Monitoring Programs of the U.S. Fish and Wildlife Service and the National Park Service. The purpose of the inventory was to provide a consistent base-level information on springs across refuges and parks and to provide information to develop a strategy for long-term monitoring.

Ten springs were inventoried during this effort. Three springs have historic flow modifications and the remainder has been disturbed very little by human actions. Although three springs were dry during the sampling period and two more had very low flow, typical wetland plants are found at the springs, including cottonwoods, willows, baccharis, cattails, and a variety of grasses and forbs. A number of exotic plants were detected, including Russian olive at Canyon del Ojito spring and Silver Creek A; salt cedar at Canyon del Ojito, Cibola, Los Alamos, and San Lorenzo 1, 2, and 3; Russian thistle at San Lorenzo Spring 1 and 3; and narrowleaf plantain at Four Spring.

Water was sufficient for water quality analysis at 5 of the 10 springs inventoried. Water quality characteristics were mostly within expected values or standards set by the U.S. Environmental Protection Agency or New Mexico Environment Department. Exceptions were with dissolved oxygen concentrations, only one spring, San Lorenzo 2, met levels required to support aquatic life. Sulfate concentrations were also higher than usually found in freshwater in all springs except Four Spring and Silver Creek A. Water quality is largely dependent on the geologic features in the area and the size of the aquifer associated with the spring. Springs often present challenging environments for biota, either because of temperature or chemical extremes found naturally in the water.

Acknowledgments

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Introduction

Other than the Rio Grande, water in the Sevilleta National Wildlife Refuge (NWR), New Mexico comes from seasonal runoff, thundershowers, and aquifers that support springs. Runoff and thundershowers often produce scouring flows that quickly pass through ephemeral streams, and springs often provide the only persistent, reliable water for humans and wildlife. Springs support aquatic and riparian systems where groundwater reaches the land surface through natural processes. They provide much of the aquatic environment in arid lands as well as a substantial portion of regional aquatic and riparian biodiversity. Springs and their related ecosystems are considered to be of high priority for providing goods and services to wildlife.

Spring ecosystems are small, relatively rare “biodiversity hot spots” in arid lands. In the desert southwest, these ecosystems historically supported a substantial proportion of aquatic, riparian, and terrestrial species (Myers and Resh 1999). About 80% of the terrestrial animal species, including two-thirds of non-game bird species, use riparian systems associated with springs (Thomas et al. 1979, Saab et al. 1995, Brussard et al. 1998). Springs in arid lands are sparsely distributed on the landscape and critical to the persistence of native biota and many endemic species. Thus, the ecological importance of springs is disproportionate to their spatial extent (Schmitz et al. 2007). As a consequence of their lengthy isolation and long-term persistence, many arid-land springs support an endemic, obligate-spring-dwelling fauna and flora. Several hundred endemic aquatic and riparian species and subspecies dwell in spring ecosystems in the U.S. (Minckley et al. 1986, Hershler et al. 2002).

When they are persistent, springs are generally more stable than arid-land rivers or streams, because seasonal variability in temperature and discharge is much less in springs. Arid-land springs are distinct from springs in more mesic regions because arid-land springs are typically isolated from other waters and more susceptible

to drought. Aquifers in these arid regions are strongly influenced by high elevations, rugged topography, and diverse geology. Characteristics of each aquifer are influenced most by climate, geology, and topography (Freeze and Cherry 1979). In springs unaffected by human activity, water chemistry, temperature, spring morphology, and persistence are primary factors influencing aquatic communities, and soil moisture, chemistry, and soil structure and particle size are factors that most affect riparian vegetation (Resh 1983, Knopf et al. 1988, Cushing 1996, McCabe 1998, Castelli et al. 2000).

Natural and human stressors similarly influence the structure of aquatic and riparian communities. Springs with high water temperature, high chemical concentrations, or that are disturbed by natural events (drought, fire, flood, avalanche scouring, etc.) and humans (reduced discharge from groundwater pumping or surface diversion, livestock trampling, impoundment, recreation, etc.) are harsh environments compared to persistent springs with cooler water that are unaffected by human or natural stressors. The influence of stressors on aquatic and riparian communities generally varies along a gradient of increasing frequency, duration, and magnitude of stressors. Biological communities of springs respond to stressing factors similar to other aquatic and riparian systems (e.g., Resh et al. 1988, Smith et al. 1991, Stromberg and Patton 1992, Fleischner 1994), however, the effect on arid-land spring biota appears to be more severe due to the naturally harsh arid environment, the isolation of springs from other aquatic systems, and challenges that these factors pose to organism dispersal and colonization. As harshness increases, aquatic communities become less speciose, support fewer environmentally intolerant species (e.g., non-baetid mayflies, caddisflies), and become increasingly dominated by environmentally tolerant and vagile species (e.g., beetles, water boatman, and midges; Sada et al. 2005). Harshness also affects riparian communities by decreasing

diversity and ground cover, and increasing the abundance of upland and non-native species (Fleischman et al. 2006).

Surface-water dynamics and water chemistry have strong effects on aquatic biota; therefore, biological assemblages (e.g. aquatic macroinvertebrates) are often excellent indicators of flow regime, water chemistry, and disturbance history. Alteration of surface-water resources within desert ecosystems has profound ecological and management implications, including loss of species diversity, extinction or extirpation of special-status and endemic species, alteration in the composition and distribution of plant and animal communities, alteration of culturally significant sites, and inability of parks to meet legal and policy mandates.

Discharge rates, aquifer sources, and the presence of rare species (e.g., fishes, aquatic

macroinvertebrates, rare plants, etc.) are known for a number of large springs in arid regions of the western U.S., but basic information describing the physical and biological characteristics of most springs is limited. This paucity of knowledge has stifled spring management strategies and little attention has been given to balancing human use with maintaining ecological integrity (Shepard 1993). As a consequence, most springs have been degraded by human activity and few springs resemble their historic biological and environmental condition (Shepard 1993, Sada 2001, Sada and Vinyard 2002).

The purpose of this inventory is to provide a consistent, base level of information on springs across several U.S. Fish and Wildlife Service (USFWS) refuges and National Park Service (NPS) parks and to provide information to develop a strategy for long-term monitoring.

Methods

Ten springs in Sevilleta NWR (Figure 1, Table 1) were inventoried in September 15-20, 2011 following the procedures described by Sada and Pohlmann (2006; located on enclosed CD). These springs were selected for inclusion in the inventory by USFWS staff led by Steve Cullinan. The inventory was conducted as part of a larger spring inventory effort in national parks in southeastern New Mexico and west Texas and wildlife refuges in New Mexico and Arizona.

The foundation for the protocol developed by Sada and Pohlmann (2006) is a number of hydrological and biological studies of springs in the western U.S. and elsewhere (e.g., Ferrington 1995, Botosaneau 1998, Meffe and Marsh 1983, Williams and Danks 1991, Thomas et al. 1996, Sada et al. 2005, and many others cited herein) that examined spring physicochemical conditions and their influence on spring-fed aquatic and riparian communities. The Sada and Pohlmann (2006) protocol contains two levels of field procedures. The level of the Sada and Pohlmann (2006) protocol conducted at each spring depends on the amount of spring flow. The Level I procedure compiles information that characterizes salient

aspects of each spring's aquatic and riparian environment and the communities that they support. This inventory focused on locating spring sources and recording information to assess their biotic potential, prioritize the importance of individual sites for long-term monitoring, and guide management (see below). The Level II procedure was applied to springs with sufficient flow to support riparian communities. It includes more quantitative estimates of spring habitat and vegetation characteristics (see below).

The Level I inventory consisted of identifying and recording spring orifices (source or water emergence points) using a Trimble Geo XH GPS unit; making site maps and descriptions; evaluating current and historic natural and anthropogenic disturbance; collecting benthic macroinvertebrates; and measuring water quality (water temperature, dissolved oxygen, pH, total dissolved solids [TDS], and conductance collected with a YSI ProPlus meter, and alkalinity, chloride, magnesium, sulfate, and calcium concentration with a YSI field spectrophotometer). Water quality meters were calibrated each morning prior to the sampling event, and post-calibration was conducted at the end of each day to ensure

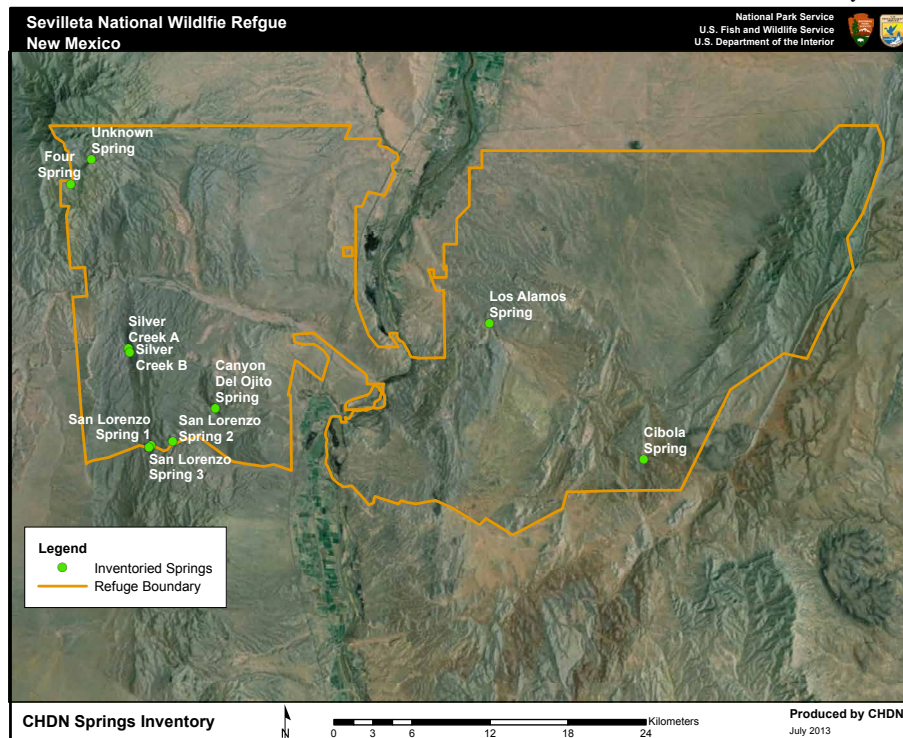


Figure 1. Map of springs surveyed at Sevilleta National Wildlife Refuge.

Table 1. Springs included in the inventory at Sevilleta National Wildlife Refuge including the date, level of sampling, and location.

Spring ID	Spring Name	Date	Level
SENWR004	Canyon del Ojito Spring	9/18/2011	2
SENWR005	Cibola Spring	9/16/2011	2
SENWR037	Four Spring	9/19/2011	2
SENWR036	Los Alamos	9/17/2011	1
SENWR030	San Lorenzo Spring 1	9/15/2011	2
SENWR031	San Lorenzo Spring 2	9/17/2011	2
SENWR032	San Lorenzo Spring 3	9/18/2011	1
SENWR034	Silver Creek A	9/20/2011	1
SENWR039	Silver Creek B	9/20/2011	1
SENWR038	Unknown Spring	9/19/2011	1

the meter remained calibrated throughout the day. Water quality measurements were taken at every orifice with sufficient flow. The crew also measured morphological characteristics such as brook length (if present) or wetted area of pool formations, water depth, discharge, substrate, emergent cover (vegetation), bank cover (vegetation), documented spring type, and took photo points. In addition, the crew documented presence of wildlife and common, rare, or exotic plants. Level I surveys were conducted on five springs at Sevilleta NWR (Table 1). See Appendix A for a full list of attributes collected during Level I surveys.

In addition to data collected during the Level I survey, the Level II survey included quantitative measurements of wetted width, water depth, substrate, detritus, discharge, shade, and vegetation characteristics (including vegetation composition at various distances from the spring). Level II surveys were conducted on five Sevilleta NWR springs: Canyon del Ojito, Cibola, Four, San Lorenzo 1 and 2 (Table 1).

Data collected from each spring were compiled in a Microsoft Access® database developed by U.S. National Park Service database managers. Data used to prepare this report were analyzed by querying this database (located in enclosed CD).

Results and Discussion

Overall, 2011 was a very dry year and New Mexico experienced one of its worst wildfire seasons. The southern half of the state, including Sevilleta NWR was under D4 exceptional drought conditions, which is the most intense category in the U.S. Drought Monitor Index. Prior to monsoon season, Sevilleta NWR received less than 5 mm of rain in 2011. The monsoon season brought 36 mm of rain in July, 22 mm in August, and 19 mm in September.

Three of the ten springs inventoried, Los Alamos, Silver Creek B, and Unknown Spring, were dry at the time of the survey. Water levels at San Lorenzo Spring 3 and Silver Creek A were insufficient for water quality measurements. Therefore, these five springs were surveyed using the Level I procedures. Five of the springs had sufficient flow for the Level II procedures and to maintain well-developed riparian vegetation communities: Canyon del Ojito (discharge=0.1 L/min), Cibola (discharge=8.5 L/min), Four (discharge=1.5 L/min), and San Lorenzo 1 (discharge=13.8 L/min). These conditions are consistent with findings across the region. Of the 502 springs sampled in New Mexico and west Texas during the inventory, 199 (40%) were dry or had insufficient water for water quality measurements. Data and descriptions of the Sevilleta NWR springs are located in Appendix B.

Water Quality

Water quality measurements were taken at each spring with sufficient water (5 out of 10 springs). Water temperatures were fairly warm, ranging from 15.8 to 27.5°C (Table 2). Temperatures were less than 20°C in every spring except Four Spring, which was a warm 27.5°C. Dissolved oxygen (DO) concentrations ranged from 1.14 to 7.4 mg/L. The level necessary to protect fish and other aquatic life, according to the U.S. Environmental Protection Agency (EPA) standard for DO, is 4 mg/L. The DO standard for the New Mexico Environment Department (NMED) for warm waters is 5.0 mg/L. Only San Lorenzo Spring 2, which has a DO concentration of 7.4 mg/L, meet

these standards. DO data are only available for the four of the seven springs sampled, as the meter failed to pass post-calibration. pH levels varied from 7.2 to 9.0, meeting NMED standards of 6.6-9.0. Total dissolved solids (TDS) ranged from 119.6 to 1547 mg/L. The EPA doesn't have a standard for TDS and NMED has set them only for specific river basins; however, TDS values in most springs are fairly low and would likely meet any standard, but TDS in Cibola is relatively high. Only 33 springs of the more than 500 springs sampled across the Southwest had TDS values higher than Cibola. Electrical conductance ranged from 194-2,116 $\mu\text{S}/\text{cm}$. Standards have not been set for conductivity.

Samples were collected for analysis of water quality using a field spectrophotometer. Alkalinity (the water's capacity to neutralize acids) was measured as concentration (in mg/L) of calcium carbonate (CaCO_3), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}). Alkalinity in water results from any dissolved compounds (though usually weak acid ions such as carbonic acid) that can accept and neutralize protons. Because carbon dioxide (CO_2) is soluble and relatively abundant in water, and carbonates are common minerals over much of the Earth, the property of alkalinity of freshwater is determined by the presence of bicarbonates and carbonates. The $\text{CO}_2\text{—HCO}_3^-\text{—CO}_3^{2-}$ equilibrium system is the major buffering system in fresh water. At Sevilleta NWR, calcium carbonate levels ranged from 220 to 370 mg/L, bicarbonate levels ranged from 270 to 450 mg/L, and carbonate values ranged from 135 to 220 mg/L. These levels are typical for fresh water, given the range of pH values around neutral (7; Table 3).

In addition to measuring alkalinity, concentration of common ions was also measured, including calcium (Ca^{2+}), chloride (Cl^-), magnesium (Mg^{2+}), and sulfate (SO_4^{2-}), all of which, when combined with bicarbonate and carbonate, constitute total salinity. Salinity of surface water depends on ionic influences of the surrounding land (geology), atmospheric deposition (e.g. wind-blown dust), and evaporation rates relative to precipitation (Wetzel 2001).

Table 2. Water quality values including temperature (°C), dissolved oxygen (DO; mg/L), pH, total dissolved solids (TDS; mg/L), and electrical conductance (EC; μ S/cm). Also shown is whether the measurement was taken in sun or shade, whether the spring was dry, and notes about quality assurance and quality control (if any). Dashes indicate no data.

Title	Date	Orifice	Temp	DO	pH	TDS	EC	Shade	Dry	QAQC_Notes
Canyon del Ojito	9/18/2011	1	17.3	--	9.03	975	1280	Shade	No	DO failed post-cal
Cibola	9/16/2011	1	19.2	2.35	7.31	1547	2116	Partial	No	none
Four	9/19/2011	1	27.5	1.36	7.17	119.6	194	Sun	No	none
Los Alamos	9/17/2011		--	--	--	--	--	--	Yes	none
San Lorenzo 1	9/15/2011	Pouroff	19	--	8.17	403	550	Shade	No	DO failed post-cal
San Lorenzo 1	9/15/2011	1	18.2	--	7.7	448.5	570	Shade	No	DO failed post-cal
San Lorenzo 1	9/15/2011	2	17.8	--	7.74	474.5	625	Shade	No	DO failed post-cal
San Lorenzo 2	9/17/2011	1	19.1	2.52	7.7	313.95	428.1	Shade	No	none
San Lorenzo 2	9/17/2011	Terminus	17.3	7.4	8.36	507	667	Partial	No	none
San Lorenzo 3	9/18/2011		--	--	--	--	--	--	Yes	none
Silver Creek A	9/20/2011	Single	15.8	1.14	7.29	604.5	--	--	No	EC failed post-cal
Silver Creek B	9/20/2011		--	--	--	--	--	--	Yes	none
Unknown Spring	9/19/2011		--	--	--	--	--	--	Yes	none

Table 3. Water quality values (mg/L) for calcium carbonate (CaCO_3), bicarbonate (HCO_3), carbonate (CO_3), chloride (Cl), magnesium (Mg), sulfate (SO_4), and calcium (Ca). Dashes indicate no data.

Title	Orifice	CaCO_3	HCO_3	CO_3	Cl	Mg	SO_4	Ca	Location
Canyon del Ojito	1	255	310	150	50	5	195	0	Collect in pool at OR1
Cibola	Single	240	295	145	11	700	195	200	Sample collected at orifice
Four	Single	220	270	135	10	170	27	56	
Los Alamos		--	--	--	--	--	--	--	No water
San Lorenzo 1	1	275	335	165	20	47	67	10	Sample collected 11 m downstream of orifice
San Lorenzo 2	1	265	320	160	23	170	112	12	
San Lorenzo 3		--	--	--	--	--	--	--	Insufficient water
Silver Creek A	1	370	450	220	7.4	30	1	18	Small pool underneath vegetation canopy
Silver Creek B		--	--	--	--	--	--	--	No water
Unknown Spring		--	--	--	--	--	--	--	No water

Calcium is a required nutrient for growth of freshwater flora and fauna, and had direct influence on population growth. Many diatoms and invertebrates have calcium as a component of their outer covering or exoskeleton. Chloride is influential in osmotic balance and ion exchange. Magnesium is a component of chlorophyll, and is therefore required universally by plants. Sulfur is utilized by all living organisms for protein synthesis; however, our interests are related to pollution from fertilizer and atmospheric deposition.

Calcium levels range from less than 10mg/L to 200 mg/L. Calcium concentration greater than 20 mg Ca/L is associated with hard water (Wetzel 2001). Chloride levels ranged from 7.4 to 700 mg/L. Concentrations between 1 and 100 mg Cl/L are common in freshwater. Magnesium levels ranged from 5 to 700 mg/L. Sulfate concentration ranged from 1 to 195 mg/L. Typical ranges for sulfate concentration in freshwater is about 5-30 mg/L.

Disturbance

Anthropogenic disturbance to springs is fairly low. Overall, twenty-three percent of springs inventoried across New Mexico and west Texas have some kind of flow modification. Three Sevilleta NWR springs (30%) have had some kind of flow modification historically: a pipe diversion at San Lorenzo Spring 1, an open trough/

tank at San Lorenzo Spring 2, and a pipe diversion and an open trough/tank at Four Spring. Ninety percent of Sevilleta NWR springs are undisturbed or are slightly disturbed by roads (Table 4). Similarly, ninety-four percent of springs in the area are undisturbed or slightly disturbed relative to roads (Figure 2). Cibola Spring is moderately impacted by roads, meaning that a road or OHV trail is present, but located on the

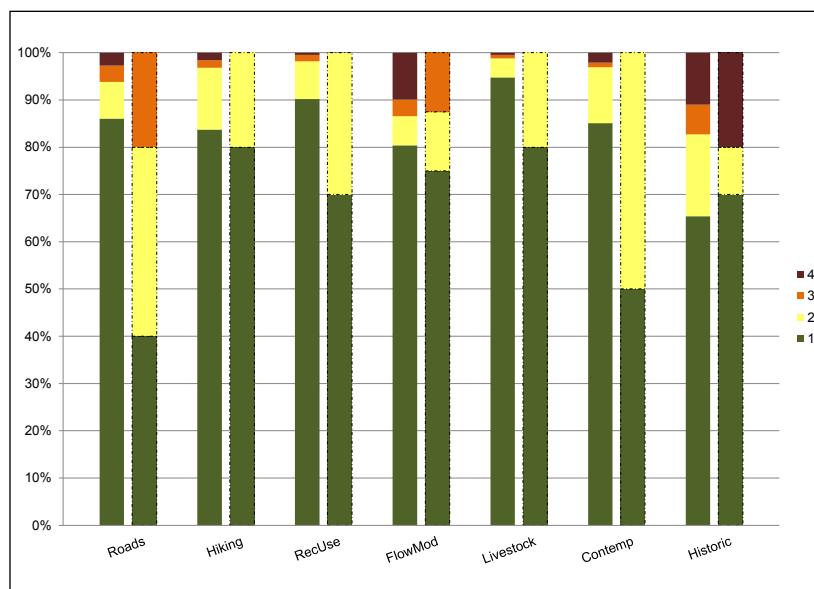


Figure 2. Comparison of levels of anthropogenic disturbance in parks and refuges across New Mexico and west Texas (bars not outlined) and in Sevilleta National Wildlife Refuge (bars with dashed outline). Graph shows the proportion of springs rated in each disturbance category. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed. See Appendix A for additional information.

Table 4. Scores for anthropogenic disturbance in Sevilleta NWR springs. Disturbance types include effect of roads, hiking trails, recreation use, flow modification, livestock presence/grazing, presence of flow modification and type of flow modification. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed. Dashes indicate no data. See Appendix A for additional information.

Title	Roads	Hiking	RecUse	FlowMod	Livestock	Flow Mod	Modification Type
Canyon del Ojito	1	1	1	1	1	No	
Cibola	3	1	1	--	2	No	
Four	2	1	1	--	2	Yes	Pipe Diversion; Trough/Tank
Los Alamos	1	1	1	1	1	No	
San Lorenzo 1	3	2	2	2	1	Yes	Pipe Diversion
San Lorenzo 2	2	2	2	3	1	Yes	Open Trough/Tank
San Lorenzo 3	2	1	2	1	1	No	
Silver Creek A	2	1	1	1	1	No	
Silver Creek B	1	1	1	1	1	No	
Unknown Spring	1	1	1	1	1	No	

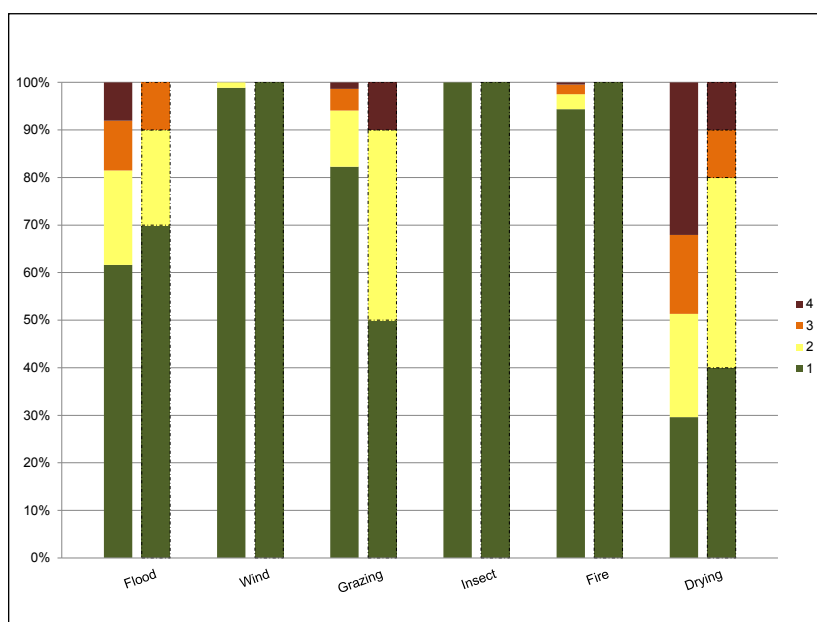


Figure 3. Comparison of levels of natural disturbance in parks and refuges across New Mexico and west Texas (bars not outlined) and in Sevilleta National Wildlife Refuge (bars with dashed outline). Graph shows the proportion of springs rated in each disturbance category. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed. See Appendix A for additional information.

periphery of the spring ecosystem. Less than 50% of the Cibola Spring system is affected by fill, compacted soils, or other road/trail-related disturbance. None of the Sevilleta NWR springs were affected by other forms of anthropogenic disturbance, such as the presence of hiking trails, recreational use, or livestock grazing.

Effects of natural disturbance were also minimal in Sevilleta NWR springs. The majority of springs are in the undisturbed or slightly disturbed categories for all types of disturbance. These results are similar to springs across New Mexico and Texas, except for drying. Twenty percent of springs inventoried in Sevilleta NWR were moderately or highly disturbed by drying or drought, compared to 48% across the other inventoried springs. Estimates of the magnitude of drought disturbance are not based entirely on quantity of water, since many springs are naturally ephemeral. Rather, we consider whether vegetation is dead or dying and whether the vegetation community supports facultative or obligate wetland plants. Moderate or high disturbances in Sevilleta springs include: floods creating a moderate disturbance in Canyon del Ojito spring (more than 50% of vegetation in the area of the spring was affected by flooding); livestock presence or grazing at Four Spring; and drying at Los Alamos and Unknown springs (Figure 3, Table 5). Although Silver Spring B was dry at the time of survey, a number of riparian plant species were present and appeared to be healthy, thus impacts of disturbance were not apparent at the time of survey.

Table 5. Scores for natural disturbance in Sevilleta NWR springs. Disturbance types include effect floods, wind, herbivore grazing (non-livestock), insect damage, fire, and drying or drought. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed. See Appendix A for additional information.

Spring ID	Title	Flood	Wind	Grazing	Insect	Fire	Drying
SENWR004	Canyon del Ojito Spring	3	1	1	1	1	1
SENWR005	Cibola Spring	2	1	1	1	1	1
SENWR037	Four Spring	1	1	4	1	1	1
SENWR036	Los Alamos Spring	1	1	1	1	1	3
SENWR030	San Lorenzo Spring 1	1	1	2	1	1	2
SENWR031	San Lorenzo Spring 2	1	1	1	1	1	1
SENWR032	San Lorenzo Spring 3	1	1	2	1	1	2
SENWR034	Silver Creek A	1	1	1	1	1	2
SENWR039	Silver Creek B	1	1	2	1	1	2
SENWR038	Unknown Spring	2	1	2	1	1	4

Vegetation

Typical wetland plants are found at the springs, including cottonwoods (*Populus* spp.), willows (*Salix* spp.), baccharis (*Baccharis* spp.), cattails (*Typha* spp.), and a variety of grasses and forbs. No emergent vegetation was located in the springs, and bank cover was low (10% at Silver Creek A) to nonexistent (all other springs). Data for all springs are located in Appendix B; a list of the species detected at all springs in the refuge is located in Appendix C. Note, this list reflects dominant or common species and is not intended to be a thorough inventory of plant taxa.

A number of exotic plants were detected, including Russian olive (*Elaeagnus angustifolia*; Canyon del Ojito spring, Silver Creek A), salt cedar (*Tamarix* spp.; Canyon del Ojito, Cibola, Los Alamos, San Lorenzo 1, 2, and 3), Russian thistle (*Salsola tragus*; San Lorenzo Spring 1 and 3), and narrowleaf plantain (*Plantago lanceolata*; Four Spring).

During the Level I surveys at Los Alamos spring, San Lorenzo 3, Silver Creek A and B, and Unknown spring, only dominant and exotic plant species were identified. Dominant species at Los Alamos Spring included eastern cottonwood (*Populus deltoides*), baccharis, and big sacaton (*Sporobolus wrightii*). Dense stands of tamarisk (*Tamarix* spp.) were also present. The dominant species at San Lorenzo 3 Spring were Goodding's willow (*Salix gooddingii*), Fremont cottonwood (*Populus fremontii*), scratchgrass (*Muhlenbergia asperifolia*), rubber rabbitbrush (*Ericameria nauseosa*), and juncus (*Juncus* spp.). The non-natives prickly Russian thistle and tamarisk were also present. New Mexico olive (*Foresteria neomexicana*) was the most abundant species at Silver Creek A, along with scratchgrass, oneseed juniper (*Juniperus monosperma*), willows, and fourwing saltbush (*Atriplex canescens*). Non-native Russian olive was also present at Silver Creek A. At Silver Creek B, dominant species include scratchgrass, Fremont cottonwood, juncus, sacaton, New Mexico olive, goldenbush (*Isocoma* sp.), rubber rabbitbrush, snakeweed (*Gutierrezia* sp.), and common dunebroom (*Parryella filifolia*). No non-native species were present. Fremont

cottonwood was the dominant species at Unknown Spring.

More detailed vegetation information was collected at five springs during the Level II surveys. Dominant riparian vegetation species at Canyon del Ojito Spring included salt cedar and Russian olive in the area within 5 m of the spring. Between 5 and 15 m out from the spring, riparian vegetation species included Russian olive, juncus, and inland salt grass (*Distichlis spicata*). No riparian species were present more than 15 m away from the spring. Within 5 m from the spring, dominant upland species included goldenbush and alkali sacaton on the left bank and mesquite, alkali sacaton, and fourwing saltbush (*Atriplex canescens*) on the right bank. Five to 15 m out from the spring, dominant upland species included prickly pear (*Opuntia* sp.) and goldenbush on the left and mesquite, alkali sacaton, and fourwing saltbush on the right. Fifteen to 30 m out from the spring, dominant upland species included rabbitbrush (*Ericameria* sp.), brickellbush (*Brickellia* sp.), and fourwing saltbush on both sides. Most of the area around the spring was open, with no canopy cover. Russian olive was the only woody species present that was greater than 2 m high.

At Cibola Spring, dominant riparian vegetation species included baccharis, scratchgrass, and Fremont cottonwood in the area within 5 m of the spring. Between 5 and 15 m out from the spring, riparian vegetation species included baccharis, Fremont cottonwood, and tamarisk. Between 15-30 m, baccharis, juncus, and cattails were present. Within 5 m from the spring, dominant upland species included snakeweed and big sacaton on the left bank and big sacaton, apache plume (*Fallugia paradoxa*), and rubber rabbitbrush on the right bank. Five to 15 m out from the spring, dominant upland species included big sacaton and oneseed juniper on the left big sacaton, sideoats grama (*Bouteloua curtipendula*), and threeawn (*Aristida* sp.) on the right. Fifteen to 30 m out from the spring, dominant upland species included oneseed juniper and sideoats grama on the left side and big sacaton and oneseed juniper on the right. The area around the spring was open,



Dry channel at
Canyon del Ojito.

with no canopy cover. No woody species were present that was greater than 2 m high.

Dominant riparian vegetation species at Four Spring included chairmaker's bulrush within 5 m of the spring. Between 5 and 15 m out from the spring, riparian vegetation species included chairmaker's bulrush (*Schoenoplectus americanus*) and common plantain (*Plantago major*). Between 15 and 30 m, juncus was present. Within 5 m from the spring, dominant upland species included honey mesquite (*Prosopis glandulosa*), silverleaf nightshade (*Solanum elaeagnifolium*), and skunkbush sumac (*Rhus trilobata*) on the left bank and honey mesquite, skunkbush sumac, and snakeweed on the right bank. Five to 15 m out from the spring, dominant upland species included prickly pear, honey mesquite, and snakeweed on the left and honey mesquite, snakeweed, and Sonoran scrub oak (*Quercus turbinella*) on the right. Fifteen to 30 m out from the spring, dominant upland species included Sonoran scrub oak, skunkbush sumac, and littleleaf sumac (*Rhus microphylla*) on the left side and skunkbush sumac, fourwing saltbush, and cholla (*Cylindropuntia* sp.) on the right. Chairmaker's bulrush created canopy within 10 m of the spring. Beyond that, the canopy was provided by juncus or barnyard grass (*Echinochloa crus-galli*). Woody species present greater than 2 m

high include Sonoran scrub oak and netleaf hackberry (*Celtis laevigata* var. *reticulata*).

At San Lorenzo 1, the dominant riparian vegetation species included only flatspine burr ragweed (*Ambrosia acanthicarpa*) within 5 m of the spring. No riparian species were present between 5 and 15 m out from the spring. Between 15 to 30 m, juncus was present, as was Goodding's willow and scratchgrass. Within 5 m from the spring, dominant upland species was rubber rabbitbrush on both sides of the spring. Five to 15 m out from the spring, dominant upland species included rubber rabbitbrush and sideoats grama on the left and rubber rabbitbrush and threeawn on the right. Fifteen to 30 m out from the spring, dominant upland species included rubber rabbitbrush on both sides. The canopy was largely open, for the first 25 m away from the spring, after which Goodding's willow created canopy cover.

At San Lorenzo 2, the dominant riparian vegetation species included baccharis, juncus, and cattails within 5 m of the spring. Between 5 and 15 m out from the spring, dominant species were Fremont cottonwood, cattails, and juncus. No riparian plants were found beyond 15 m. Within 5 m from the spring, dominant upland species were oneseed juniper and honey

mesquite on the left side of the spring and rubber rabbitbrush on the right. Five to 15 m out from the spring, dominant upland species included oneseed juniper and honey mesquite on the left and honey mesquite, big sacaton, and fourwing saltbush on the right. The entire 20 m spring brook was shaded by plants. In the first 5 meters, shade was provided by snapdragon vine (*Maurandella antirrhiniflora*), baccharis, and cattails. Juncus created canopy from 6-9 meters, and then cattails provided cover until meter 12. Beyond 12 m, juncus again provided shade. Goodding's willow and Fremont cottonwood also provided overstory canopy.

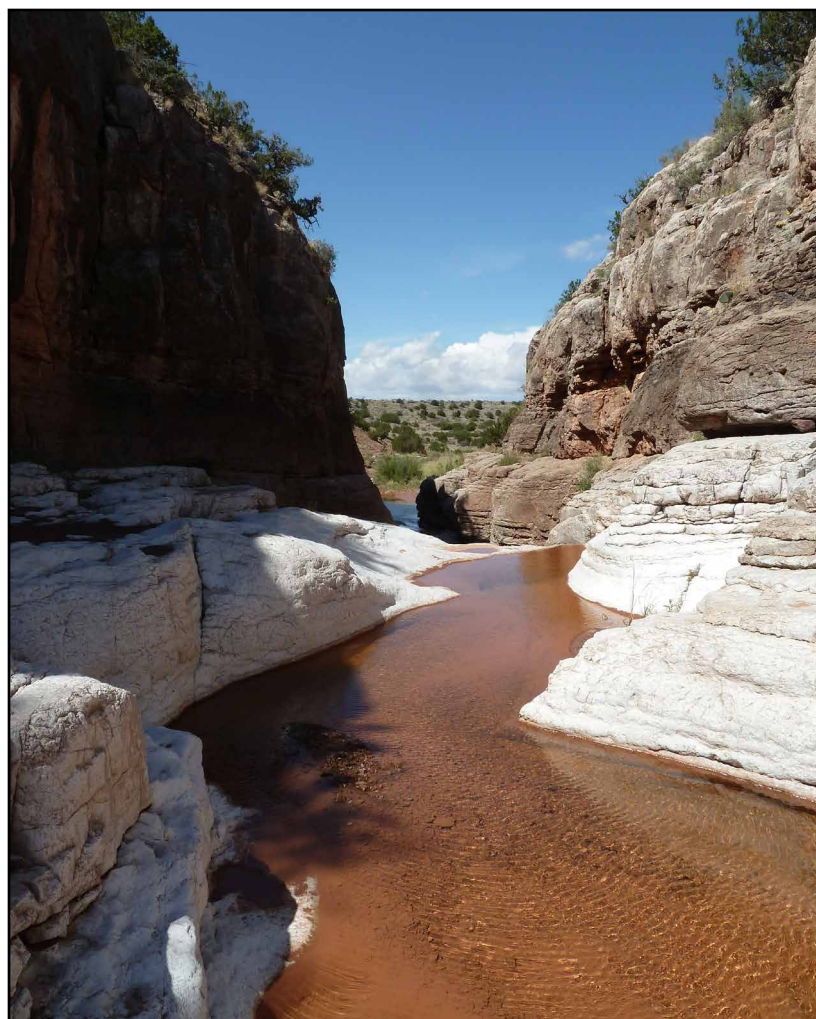
Habitat

Habitat data on the springs were collected at the four springs: Canyon del Ojito, Cibola, Four, and San Lorenzo 1 springs.

The **Canyon del Ojito Spring** brook was 60 m in length. The water was shallow, with depth ranging from less than 1 to 5 cm (mean = 0.5 cm). Wetted width varied from 4-49 cm, and averaged 18 cm wide. There were no overhanging banks. Substrate in the channel was primarily fine substrates with bedrock extending from 19 to 28 m downstream from the orifice. Another patch of bedrock was located at 43 m. A cliff wall shaded the spring brook.

The **Cibola Spring** brook is about 280 m long. The first 100 m was included in the survey. Water went subsurface 6 m downstream from the primary orifice then re-emerged at 16 m, then disappeared again at 36 m, then re-emerged at 46 m and continued flowing. The wetted width of the brook averaged 75 cm (range 0 to 372 cm). Water depth varied from less than 1 to 20 cm (mean = 4 cm). There were no overhanging banks. Substrate consisted of fines and sand with patches of bedrock. Canopy cover was consistently low, less than 5%.

The spring brook at **Four Spring** was 45 m in length. The wetted width of the brook was 45 cm on average (range = 8-124 cm). Water depth ranged from <1 to 41 cm, and averaged 3.7 cm. There were no overhanging banks. Substrates were consistently composed of fine silts and sand covered by detritus, that was typically less than 1 cm deep. Canopy

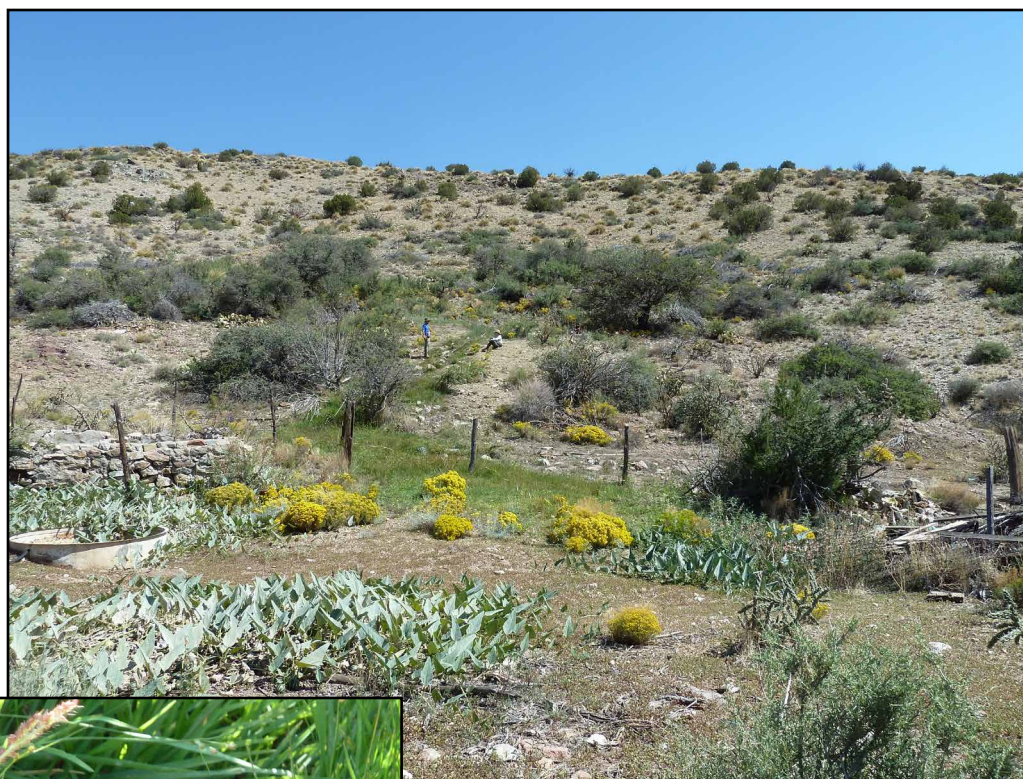


Cibola Spring.

cover was practically non-existent, always less than 1%.

The **San Lorenzo 1 Spring** brook was 69 m long. Average wetted width was 27 cm, (range = 7-96 cm). Width varied from about 10 to 40 cm for its entire length, then the brook widened to a 96 cm pool at the terminus of the brook. Water depth is consistently shallow (average 0.8 cm, range 0.2-1.5 cm). There were no bank overhangs except at the terminus pool, which had a 34 cm overhang on the right bank. Substrate consisted of fine sediment and sand, with a bedrock outcropping at 58 m. Detritus was also present in pockets and the detritus was less than 1 cm deep. Canopy cover was fairly low, never exceeding 12.5 %.

**Four Springs tanks (right)
and Western diamondback
rattlesnake found on site
(below, inset).**



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Appendix A List of Attributes

The following elements were recorded during Level 1 surveys:

- Site Code—identification number for each spring within a national park or refuge. Consists of park or refuge name abbreviation and number
- Date the survey is conducted
- Person (Surveyor) conducting the spring survey
- Park Code—park or refuge name abbreviation
- Access. Record the ease at which the public could visit a spring. Categories 1 through 5. Category 1=inaccessible sites, access only by cross-country hiking; Category 2=sites that can be accessed only by arduous trail hike (e.g., >5 miles); Category 3=sites accessed by easy trail hike (e.g., 1 to 5 miles) and four-wheel drive vehicle; Category 4=sites easily accessed by walking less than 1 mile or a two-wheel drive, high clearance vehicle; and Category 5=sites immediately adjacent to high-quality gravel road or a paved road.
- Description of site access
- Extent of sampling effort with comments
- Sample start and end times
- Total time spent sampling
- Global Positioning System (GPS) location and the datum of the spring source and terminus. Record the UTM zone in the North American Datum of 1983 (NAD83) unless otherwise specified. Document GPS files in a gps log. All geographic information system (GIS) data layers created from GPS files must include FGDC Geospatial and Biological Profile (NBII) compliant metadata. Record PDOP or “+” the number of meters as metrics indicating accuracy of the GPS reading.
- Photos. Photographs should be taken to show the spring and its landscape context. One should overview the spring source and looking downstream, and the second from the spring brook’s end looking upstream. At larger springs, take one photo of the source and a second from a distant area that encompasses as much of the riparian area as possible. Photos should be labeled by site ID number, date, site name, photographer, subject, and GPS coordinates of the point where the photo was taken. Photos should be taken using a digital camera. Maintain a photo log with digital photograph number and description using the Location ID. Note on the site map where photos were taken.
- Site Description—description of overall ecological community and geologic setting in which the spring is situated.
- Site Map—includes locations of orifices, water quality measurements, photo points, and more.
- Important animals and plants. Important species are those that occupy or use the aquatic or riparian environments, and noted during the survey. This list may differ among management areas, and it should be compiled accordingly. It should include (1) rare species, (2) species that are indicative of spring characteristics (e.g., species of woody vegetation, obligatory and facultative wetland vegetation, crenobiontics), (3) species of management interest or concern, and (4) non-native species. Species should be identified, if possible. If a species cannot be identified, the presence of plants and

animals within any of the important groups should be recorded (e.g., native fish and trees, mollusks, aquatic insects, non-native species, etc.). Also note the presence of important terrestrial species, such as bats, if seen. Noting the presence of these types of species provides information that assists with identifying management issues and can be used to determine management priorities. Important species occupy a wide variety of habitats, and they may be very scarce or abundant.

- Aquatic macroinvertebrates can be readily captured from aquatic vegetation, debris, or substrate. Each species prefers a distinct microhabitat, and sampling must include all habitat types that occur in a spring (e.g., sand, gravel, & cobble substrates, all types of emergent and submerged vegetation, all current velocities, mid-channel, backwater, and lateral habitats).
- **Site Condition.** This evaluation qualitatively identifies (1) disturbance factors stressing a spring and (2) the amount of stress of each factor on the spring environment. Influences of flooding are indicated by location of a spring in the bottom of a gully, presence of a naturally incised channel, and usually a paucity of vegetation. The presence of pipes, dikes, or spring box indicates modifications for diversion. Abundance of hoof prints and droppings, and evidence of grazing indicates ungulate use of a spring. The presence of campsites and trash indicates recreation. The most common stressing factors are listed on the field form, and the appropriate factor(s) affecting a spring should be circled. Disturbance may be influenced by multiple factors such as trampling by intensive livestock and diversion into a trough; recreation use along a spring brook that tramples vegetation and the spring brook is channelized away from areas used for picnicking. Each spring is categorized as undisturbed, slightly, moderately, or highly disturbed:
 - **Undisturbed** springs have been unaffected by recent or historical factors or activities. All evidence of trampling, diversion, fire, or drying is absent. Since most springs have been altered by humans, drought, fire, or flood, these types of springs are rare and most undisturbed springs are naturalizing from past disturbances.
 - **Slightly Disturbed** springs exhibit little evidence that vegetation or soil have been disturbed. Vegetation shows slight signs of browsing and foraging, and animal footprints and scat are present but not prominent. Recreation may be evident, but its impact on riparian or aquatic environments is minimal. Evidence of fire or flooding in the distant past may be visible but these events occur infrequently; riparian vegetation is vigorous.
 - **Moderately Disturbed** springs exhibit evidence of recent, comparatively high disturbance. Use by native and non-native ungulates, and recreation has reduced vegetation height and coverage from natural conditions. Vegetation covers, hoof prints, footprints, and scat are common. Where there has been diversion, a spring box may be present but at least 50% of natural discharge remains within the natural spring brook. Neither the spring nor spring brook has been impounded. Where flooding or fire is apparent, >50% of the spring brook banks are covered by vegetation; flood and fire are infrequent and the spring is naturalizing.
 - **Highly Disturbed** springs have little similarity to undisturbed springs. Less than 50% of their banks are covered by vegetation, their spring brooks contain <50% of natural discharge, they are impounded or dredged, or spring boxes collect water. All impounded springs are highly disturbed because flow has been interrupted and functional characteristics of the aquatic system have been highly altered. Hoof prints and scat are abundant where ungulate use is heavy, and campsites are large, trashy, and vehicle use evident. These activities have decreased vegetative cover of spring brook banks to <50%. Springs affected by drought (springs that are dry

when sampled or experience seasonal or annual drying) should also be categorized as highly disturbed. These springs can be identified by the presence of upland riparian species and absence of obligatory wetland plants. Riparian vegetation is sparse at springs recently affected by fire or flooding, there is recent evidence of elevated discharge, and spring brooks are usually incised.

- Dissolved Oxygen Concentration, (D.O., in mg/liter) using a field meter measured as close to the spring source as possible and in flowing water if available.
- Water Temperature in degrees Centigrade
- Conductivity (also called electrical conductance). Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. This ability is dependent on the amount of dissolved ions, and is therefore an indicator of total dissolved solids in the solution. Conductivity provides insight into water sources and it is important to aquatic life because of requirements to maintain osmoregulatory balance. Conductivity is measured using a field meter and recorded in microsiemens.
- pH. pH is the measure of hydrogen activity, which indicates the acid/basic qualities of water.
- Total dissolved solids (TDS) in mg/L. Measure of all organic and inorganic substances dissolved in the water.
- The following are measured field spectrophotometer using water samples collected in the field:
 - Alkalinity—the water's capacity to neutralize acids—measured as concentration (in mg/L) of calcium carbonate (CaCO_3), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}).
 - Chloride concentration in mg/L
 - Magnesium concentration in mg/L
 - Sulfate concentration in mg/L
 - Calcium concentration in mg/L
- Spring Brook Length, measured in meters. Use a tape to measure distance from the spring source (upstream limit of surface water) to the downstream limit of surface water.
- Estimated discharge by recording the length of time required to fill a container with a known volume. Unfortunately, it is usually not possible to use this method because most arid land springs are very small and it is difficult to capture water in a container (their small size also prevents using a water current velocity meter to measure discharge). While these factors limit the precision of most discharge estimates, the amount of water issuing from spring sources should be estimated in liters/minute. These estimates combined with water width, depth, and spring brook length provide sufficient information to characterize spring discharge rates.
- Average Water Depth. This is a qualitative estimate of the vertical distance from substrate to water surface (in centimeters) that is found throughout the aquatic habitat.
- Average Water Width. This is a qualitative estimate of the distance covered by water (and perpendicular to its flow) that lies between banks of the spring brook, less islands, emergent rocks, etc., in centimeters. (This is formally described as the length of wetted contact between flowing or standing water and the spring brook bank in a vertical plane at right angles to the direction of flow.)

- **Emergent Cover.** Estimate to the nearest 10 percent the vegetative, debris, or other material that arises within the water width and covers the water surface.
- **Vegetative Bank Cover.** Estimate to the nearest 10 percent the proportion of spring brook banks that is covered by live vegetation.
- **Substrate Composition.** Qualitatively estimate using a Wentworth particle scale analysis, which describes the substrate by the proportional composition of materials, where materials are classified as: fines (<1 mm), sand (1-5 mm), gravel (>5-80 mm), cobble (>80-300 mm), boulder (>300 mm), or bedrock. Size is defined as the minimum particle size of substrate as measured on a two-dimensional axis, as would pass through a substrate sieve.
- **Spring Type,** as: **Rheocrene** (a spring that discharges into a defined channel), **Limnocrene** (a spring that discharges into a ponded or pooled habitat before flowing into a defined channel), **Helocrene** (similar to a Limnocrene, but marshy and comparatively shallow, not an open pond or pool), or unknown. In some areas, springs have been altered by native peoples or settlers by excavating the source to create a **Qanat**, which is a type of hand-dug well. Where these occur, water is regionally scarce and where surface water is scarce. Also record if a site is a mechanically dug **Well** (usually with rock, metal, or plastic casing). Record **Other** when the source is something else, such as a cliff face, boil, etc. Record spring type as **Unknown** at highly disturbed sites where no semblance of natural characteristics of a spring remains, or where the spring is dry. Examples of disturbances that prevent identifying spring type include impoundment by dikes, sources in a spring box, or dredging and filling to capture water in a pipe leading to a trough. Spring alterations and spring condition are assessed, and recorded, in the Site Condition section below. If further description is necessary, it can be summarized in the Notes Section.
- **Notes,** to include additional pertinent information. This may include observations further describing site condition, use of the spring by other animals (e.g., bats, wild horses, etc.), clarification of difficulties in accessing the spring, etc.

Appendix B Spring Data

The following are data collected at each Sevilleta National Wildlife Refuge spring.

SENWR004—Canyon del Ojito Spring

Sample Date: 9/18/2011

Site description.

Canyon del Ojito Spring is located on east mesa of the refuge in Canyon del Ojito. Orifices at this spring are concentrated in three general areas. The primary/uppermost orifice is 15 m upstream from the 6 m drop, just as the slot begins to form. It is located along an obvious contact, with discharge at base on west edge of wash. At least four discharge points came through soil and two or more are from rock and are less productive. A small pool is formed below the primary orifice, from which water flows downstream for 1 m before going underground. Water reemerges where *Juncus* sp. are abundant and minimal discharge is added from various fracture seeps at the secondary orifice (on northwest edge). The spring brook then enters the narrowest portion of slot canyon and drops 6 m. At about 3.5 meters up fall are additional fracture seeps that compose the tertiary orifice. Most discharge from this orifice fracture dries before joining the spring brook. The tertiary orifice fractures extend for about 7 m downstream along slot canyon walls. The brook continues through the slot canyon until the surface substrate changes from primarily bedrock to sand and gravel. Approximately 30 m downstream near the tamarisk (downstream from the terminus), water reemerges for 20 m before submerging again. The slot canyon is composed of fractured volcanics (basalt?) and is 10-15 m deep. The wash varies between bedrock and sand with gravel. Aside from juncus patch near top of falls, almost no vegetation is found in the wash for the extent of the brook.

Physical characteristics.

Parameter	Value
Spring Type	Rheocrene
Brook Length (m)	60
Slope	10
Slope Variability	Medium
Aspect	70
Multiple Orifices (<200 m)	No
Other Springs Nearby (>200 m)	No
Geology	Volcanic
Weather	5=rain in last 24 h
Type & Setting Notes	Water seeps from volcanic rock. Unconsolidated layers throughout canyon. Spring Aspect = 70° northeast.
Emergence Environment	Sub-aerial
Sub-aerial Classification	Canyon wall
Emergence Substrate	Silt
Orifice Geomorphology	Seepage or filtration
Flow Forcing Type	Gravity
Notes	1° orifice is at base of canyon wall while 2° and 3° are a little above wash. 1° emerges near base of fault but through soil. 2° and 3° emerge from fractured bedrock - no soil.

Habitat.

Parameter	Minimum	Maximum	Mean
Wetted Width (cm)	0	49	17.6
Water Depth (cm)	0.1	5	0.5
Detritus Depth	0	0	0
Left Bank Overhang	0	0	0
Right Bank Overhang	0	0	0
Fines (%)			61
Sand (%)			10
Gravel (%)			2
Cobble (%)			0
Bedrock (%)			27

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	1
Historic	1
Flood	3
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Modification	FALSE
Modification Type	

Vegetation observations. For Wetland Indicator, FACW=facultative wetland.

Tree canopy—diameter at breast height (dbh) and height of every tree greater than 2 m tall.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator Status	dbh (cm)	Height (m)
ELAN	<i>Elaeagnus angustifolia</i>	Russian olive	Non-Native	FACW	11	5
ELAN	<i>Elaeagnus angustifolia</i>	Russian olive	Non-Native	FAXW	16	5

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	Single
Shade	Shade
Temp	17.3
DO (mg/L)	
DO (%)	
pH	9.03
TDS	975
EC (μ S)	1280
Notes	Primary. 1° = Pool near delta where majority of seep spots empty. No other discharge points had enough discharge to sample WQ.
Alka_ CaCO_3	255
Alka_ HCO_3^-	310
Alka_ CO_3^{2-}	150
Chloride	50
Magnesium	5
Sulphate (SO_4^{2-})	195
Sulphur (S)	65
Calcium (Ca)	0
Location	Collect in pool at OR1.
Notes	Contact with soil. Calcium - too low - violet color - No CA atoms to react with reagent.

Spring brook habitat characteristics.

Shrub and herb canopy cover measured on the right or left side of the stream brook bank, the distance downstream from the orifice, near to the brook (0.5 m from wetted edge) or far from the brook (1.5 m from wetted edge), and percent cover.

Bank	Distance	Location	Species	Cover
Left	3	Near	No plants	
Left	6	Far	DISSRI	15-25
Left	6	Far	<i>Juncus</i> sp.	15-25
Left	6	Far	<i>Isocoma</i> sp.	<1
Right	9	Near	<i>Juncus</i> sp.	15-25
Right	9	Near	DISSPI	<1
Right	12	Far	No plants	
Left	18	Near	No plants	
Left	21	Far	No plants	
Right	24	Near	No plants	
Right	27	Far	No plants	

All canopy layers along the first 30 m of the spring brook. Shown is the distance downstream from the orifice (in meters), the substrate in the brook, and the species present from the lowest canopy (Species 1) to the highest canopy (Species n), if present.

Distance	Substrate	Species 1
0	Open Water	No plants
1	Open Water	No plants
2	Bare Ground	No plants
3	Bare Ground	No plants
4	Bare Ground	No plants
5	Bare Ground	No plants
6	Bare Ground	No plants
7	Bare Ground	No plants
8	Bare Ground	No plants
9	Bare Ground	<i>Juncus</i> sp.
10	Bare Ground	No plants
11	Bare Ground	DISSPI
12	Litter	<i>Juncus</i> sp.
13	Bare Ground	No plants
14	Rock	No plants
15	Open Water	No plants
16	Rock	No plants
17	Open Water	No plants
18	Open Water	No plants
19	Open Water	No plants
20	Open Water	No plants
21	Open Water	No plants
22	Open Water	No plants
23	Open Water	No plants
24	Open Water	No plants
25	Open Water	No plants
26	Rock	No plants
27	Open Water	No plants
28	Open Water	No plants
29	Open Water	No plants
30	Open Water	No plants

SENWR005—Cibola Spring

Sample Date: 9/16/2011

Site Description.

Cibola Spring is located within a Juniper Savannah matrix in the southeast corner of the refuge. The spring emerges in the gravel bottom of a wash, and after 20 m enters a limestone canyon, with walls 8-12 m high. Initially, the spring brook runs over gravel/sand/mud bottom of wash, but after about 100 m, the substrate changes to limestone bedrock. From this point, the brook consists of a series of pools, ranging in size from 0.5 m² to large, 8-m diameter pools near the western end of canyon. A 3-m tall waterfall is approximately 160 m downstream of the orifice. The canyon ends about 240 m from orifice, and the brook continues in the wash approximately 40 m before terminating. The brook runs east to west for its entirety, with a width (excluding pools) of 25-100 cm. Vegetation along the bank is limited due to a dearth of soil in the canyon. A few pockets of juncus and baccharis are in the canyon bottom, and a scattering of juniper trees. In spring's first 20 m and last 40 m (outside of canyon), bank vegetation consists mainly of baccharis, a few cottonwood trees, big sacaton, narrowleaf willow, salt cedar, and rubber rabbitbrush. Significant rain in past 48 hours may have altered stream volume/extent.

Physical characteristics.

Parameter	Value
Spring Type	Rheocrene
Brook Length (m)	280
Discharge (L/min)	8.48
Slope	1
Slope Variability	Low
Aspect	270
Multiple Orifices (<200 m)	No
Other Springs Nearby (>200 m)	No
Geology	Limestone
Weather	5=rain in last 24 h
Type & Setting Notes	Substantial amounts of rain have fallen in recent past, so much of the channel contains water.
Emergence Environment	Sub-aerial
Sub-aerial Classification	Channel
Emergence Substrate	Rock
Orifice Geomorphology	Seepage or filtration
Flow Forcing Type	Gravity
Notes	Given rain in last 24 hrs., it was a little difficult to separate orifice from rain water/run-off. Based on description of area by SENWR staff located orifice near wildlife cameras where water "usually starts."

Habitat.

Parameter	Minimum	Maximum	Mean
Wetted Width (cm)	0	372	75
Water Depth (cm)	0.2	20	4.0
Detritus Depth			
Left Bank Overhang	0	7	0.8
Right Bank Overhang	0	0	0
Fines (%)			26
Sand (%)			19
Gravel (%)			21
Cobble (%)			10
Bedrock (%)			24

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	3
Hiking	1
RecUse	1
FlowMod	
Livestock	2
Contemp	1
Historic	1
Flood	2
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Modification	No
Modification Type	

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	Single
Shade	Partial
Temp	19.2
DO (mg/L)	2.35
DO (%)	26
pH	7.31
TDS	1547
EC (μ S)	2116
Notes	At primary orifice; water is likely partially composed of rain water (received substantial rain in last 48 hrs.).
Alka_ CaCO_3	240
Alka_ HCO_3^-	295
Alka_ CO_3^{2-}	145
Chloride	10.5
Magnesium	700
Sulphate (SO_4^{2-})	195
Sulphur (S)	65
Calcium (Ca)	200
Location	
Notes	

Spring brook habitat characteristics.

Shrub and herb canopy cover measured on the right or left side of the stream brook bank, the distance downstream from the orifice, near to the brook (0.5 m from wetted edge) or far from the brook (1.5 m from wetted edge), and percent cover.

Bank	Distance	Location	Species	Cover (%)
Left	3	Near	TAMCHI	1-5
Left	3	Near	<i>Sporobolus</i> sp.	25-50
Left	3	Near	MELOFF	50-75
Left	6	Far	No Plants	
Right	9	Near	TAMCHI	5-15
Right	9	Near	<i>Baccharis</i> sp.	<1
Right	12	Far	<i>Typha</i> sp.	1-5
Right	12	Far	MELOFF	<1
Right	12	Far	<i>Juncus</i> sp.	1-5
Left	18	Near	<i>Baccharis</i> sp.	50-75
Left	18	Near	MUHASP	50-75
Left	18	Near	<i>Typha</i> sp.	<1
Left	21	Far	JUNMON	1-5
Left	21	Far	BOUCUR	1-5
Right	24	Near	No Plants	
Right	27	Far	<i>Baccharis</i> sp.	<1
Left	63	Near	<i>Baccharis</i> sp.	1-5
Left	63	Near	<i>Eriogonum</i> sp.	<1
Left	66	Far	<i>Eriogonum</i> sp.	<1
Left	66	Far	BOUCUR	<1
Right	69	Near	<i>Juncus</i> sp.	5-15
Right	69	Near	MUHASP	1-5
Right	69	Near	MELOFF	<1
Right	72	Far	Unknown grass	<1
Left	78	Near	<i>Baccharis</i> sp.	1-5
Left	78	Near	Unknown grass	<1
Left	81	Far	TAMCHI	1-5
Left	81	Far	BOUCUR	<1
Right	84	Near	No Plants	
Right	87	Far	<i>Baccharis</i> sp.	5-15
Right	87	Far	JUNMAH	50-75
Right	87	Far	MUHASP	<1

All canopy layers along the first 30 m of the spring brook. Shown is the distance downstream from the orifice (in meters), the substrate in the brook, and the species present from the lowest canopy (Species 1) to the highest canopy (Species n), if present.

Distance	Substrate	Species1
0	Open Water	No Plants
1	Open Water	No Plants
2	Open Water	No Plants
3	Open Water	No Plants
4	Bare Ground	No Plants
5	Bare Ground	No Plants
6	Bare Ground	No Plants
7	Bare Ground	No Plants
8	Rock	No Plants
9	Rock	No Plants
10	Rock	No Plants
11	Rock	No Plants
12	Bare Ground	No Plants
13	Open Water	No Plants
14	Rock	No Plants
15	Open Water	No Plants
16	Open Water	No Plants
17	Open Water	No Plants
18	Open Water	No Plants
19	Open Water	No Plants
20	Open Water	No Plants
21	Open Water	No Plants
22	Open Water	No Plants
23	Open Water	No Plants
24	Open Water	No Plants
25	Open Water	No Plants
26	Open Water	No Plants
27	Open Water	No Plants
28	Open Water	No Plants
29	Open Water	No Plants
30	Open Water	No Plants

SENWR0037—Four Spring

Sample Date: 9/19/2011

Site description.

Four Spring emerges from north slope of a hill at about 6,000 ft. elevation. Orifice is about 50 m up from a dry wash below. Spring emerges in a shallow muddy pit amid wetland plants.

Physical characteristics.

Parameter	Value
Spring Type	Rheocrene
Brook Length (m)	45
Discharge (L/min)	1.5
Slope	22
Slope Variability	Medium
Aspect	215
Multiple Orifices (<200 m)	No
Other Springs Nearby (>200 m)	No
Geology	Unconsolidated
Weather	no rain
Type & Setting Notes	
Emergence Environment	Sub-aerial
Sub-aerial Classification	Canyon wall
Emergence Substrate	Silt
Orifice Geomorphology	Seepage or filtration
Flow Forcing Type	Gravity
Notes	

Habitat.

Parameter	Minimum	Maximum	Mean
Wetted Width (cm)	8	124	46
Water Depth (cm)	0	41	4
Detritus Depth	0	8	1
Left Bank Overhang	0	0	0
Right Bank Overhang	0	0	0
Fines (%)			82
Sand (%)			8
Gravel (%)			8
Cobble (%)			3
Bedrock (%)			0

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	2
Hiking	1
RecUse	1
FlowMod	
Livestock	2
Contemp	1
Historic	4
Flood	1
Wind	1
Graze	4
Insect	1
Fire	1
Drying	1
Flow Modification	TRUE
Modification Type	Pipe Diversion; Open Trough/Tank

Vegetation observations. For Wetland Indicator, FACW=facultative wetland.

Tree canopy—diameter at breast height (dbh) and height of every tree greater than 2 m tall.

USDA Code	Scientific Name	Common Name	Nativity	dbh (cm)	Height (m)
QUTU2	<i>Quercus turbinella</i>	Sonoran scrub oak	Native	29	5
CELA	<i>Celtis laevigata</i>	sugarberry	Native	17	6
QUTU2	<i>Quercus turbinella</i>	Sonoran scrub oak	Native	16	6

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	Single
Shade	Sun
Temp	27.5
DO (mg/L)	1.36
DO (%)	17.1
pH	7.17
TDS	119.6
EC (μ S)	194
Notes	Muddy orifice. Top of spring - orifice.
Alka_ CaCO_3	220
Alka_ HCO_3^-	270
Alka_ CO_3^{2-}	135
Chloride	10
Magnesium	170
Sulphate (SO_4^{2-})	27
Sulphur (S)	9
Calcium (Ca)	56
Location	
Notes	

Spring brook habitat characteristics.

Shrub and herb canopy cover measured on the right or left side of the stream brook bank, the distance downstream from the orifice, near to the brook (0.5 m from wetted edge) or far from the brook (1.5 m from wetted edge), and percent cover.

Bank	Distance	Location	Species	Cover
Left	3	Near	SCHAME	15-25
Left	3	Near	PLAMAJ	1-5
Left	3	Near	UNK Grass 1	5-15
Left	3	Near	<i>Echinocereus</i> sp.	5-15
Left	3	Near	MELOFF	<1
Left	3	Near	PLALAN	15-25
Left	6	Far	PANOBT	5-15
Right	9	Near	SCHAME	5-15
Right	9	Near	UNK Grass 1	5-15
Right	9	Near	<i>Juncus</i> sp.	1-5
Right	9	Near	JUNMON	<1
Right	9	Near	<i>Echinocereus</i> sp.	<1
Right	12	Far	PROGLA	<1
Right	12	Far	ATRCAN	5-15
Right	12	Far	<i>Chamaesyce</i> sp.	<1
Right	12	Far	<i>Amaranthus</i> sp.	<1
Left	18	Near	PLALAN	15-25
Left	18	Near	<i>Echinocereus</i> sp.	<1
Left	18	Near	<i>Juncus</i> sp.	15-25
Left	18	Near	JUNMON	<1
Left	18	Near	MELOFF	<1
Left	18	Near	UNK Grass 6	5-15
Left	18	Near	PANOBT	<1
Left	21	Far	RHUTRI	50-75
Left	21	Far	MELOFF	<1
Right	24	Near	<i>Gutierrezia</i> sp.	25-50
Right	24	Near	<i>Echinocereus</i> sp.	1-5
Right	24	Near	PANOBT	1-5
Right	27	Far	SOLELA	5-15

All canopy layers along the first 30 m of the spring brook. Shown is the distance downstream from the orifice (in meters), the substrate in the brook, and the species present from the lowest canopy (Species 1) to the highest canopy (Species n), if present.

Distance	Substrate	Species1
0	Bare ground	No Plants
1	Bare ground	Algae
2	Open water	No Plants
3	Open water	SCHAME
4	Open water	No Plants
5	Open water	No Plants
6	Open water	No Plants
7	Open water	No Plants
8	Open water	SCHAME
9	Bare ground	SCHAME
10	Open water	SCHAME
11	Open water	No Plants
12	Litter	No Plants
13	Bare ground	No Plants
14	Open water	<i>Juncus</i> sp.
15	Open water	No Plants
16	Open water	No Plants
17	Open water	No Plants
18	Bare ground	No Plants
19	Bare ground	<i>Juncus</i> sp.
20	Rock	<i>Juncus</i> sp.
21	Litter	No Plants
22	Open water	No Plants
23	Litter	No Plants
24	Bare ground	<i>Juncus</i> sp.
25	Bare ground	PLALAN
26	Open water	No Plants
27	Bare ground	No Plants
28	Bare ground	<i>Echinocereus</i> sp.
29	Open water	<i>Echinocereus</i> sp.
30	Open water	No Plants

SENWR0036—Los Alamos Spring

Sample Date: 9/17/2011

Site description.

Historic point for spring fell in steep-sided (2 m) arroyo near cottonwood trees. Other than runoff/rain from recent storms, there is no sign of water in or around arroyo. A shallow pool lined with clay is located 250 m upstream of the historic point. Otherwise damp soil is only “sign” of rains. Arroyo is sandy with gravel and cobble. Vegetation in wash bottom is sparse and is composed of tamarisk and baccharis. Banks are lined with tamarisk, few cottonwoods, and big sacaton. Another group of cottonwoods is located about 100 m downstream. Two rattlesnakes were observed.

Physical characteristics, habitat.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0
Mean Water Depth (cm)	0
Mean Water Width (cm)	0
Emergent Cover (%)	
Vegetated Bank Cover (%)	
Fines (%)	30
Gravel (%)	30
Cobble (%)	25
Boulder (%)	15
Sand (%)	0
Comments	Dry. Wet bank areas.

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	1
Historic	1
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	3
Flow Modification	FALSE
Modification Type	

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
BACCH	<i>Baccharis</i> sp.	baccharis species	N/A	YES	CHDN
PODE3	<i>Populus deltoides</i>	eastern cottonwood	Native	YES	CHDN
SPWR2	<i>Sporobolus wrightii</i>	big sacaton	Native		
TAMAR2	<i>Tamarix</i> sp.	tamarisk	N/A	YES	CHDN

Water quality characteristics. Insufficient water for measurement.

SENWR0030—San Lorenzo Spring 1

Sample Date: 9/15/2011

Site description.

The orifice of San Lorenzo Spring 1 emerges from a sandy wash as a trickle of water downstream from a large willow. Another, smaller wash joins stream at point of first orifice. The channel is about 10 m wide at this point. The stream flows and enlarges as it approaches a large willow, a sheer cliff, and then a bedrock pour-off 60 m downstream (the pour-off is 1.4 m tall). Here the flow is constricted into a small waterfall. Water disappears about 10 m below the pour-off and reemerges among boulders another 40 m downstream. Channel is mostly bare sand with basalt-like bedrock cliffs. A handful of large willows are growing throughout wash, as well as rabbitbrush and juncus in wet areas. A few shallow pools can be found among boulders downstream, along with aquatic insects. Uplands vegetation is typical of juniper grassland.

Physical characteristics.

Parameter	Value
Spring Type	Rheocrene
Brook Length (m)	69
Discharge (L/min)	13.8
Slope	4
Slope Variability	Low
Aspect	100
Multiple Orifices (<200 m)	Yes
Other Springs Nearby (>200 m)	Yes
Geology	Volcanic
Weather	Rain in last 24 h
Type & Setting Notes	Curvy channel
Emergence Environment	Sub-aerial
Sub-aerial Classification	Channel
Emergence Substrate	Sand
Orifice Geomorphology	Seepage or filtration
Flow Forcing Type	Gravity
Notes	It is hard to identify true orifice, especially given rains in previous 24 hrs. Orifice "migrated" downstream as day went on, likely due to arroyo drying. Previous surveys placed orifice in pool below 1.5 m pouroff but flow does not seem to increase downs

Habitat.

Parameter	Minimum	Maximum	Mean
Wetted Width (cm)	7	96	27
Water Depth (cm)	0.1	2	0.8
Detritus Depth	0.2	0.2	0.2
Left Bank Overhang	0	0	0
Right Bank Overhang	0	37	2
Fines (%)			64
Sand (%)			28
Gravel (%)			3
Cobble (%)			0
Bedrock (%)			5

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
SpringID	SENWR030
Title	San Lorenzo Spring 1
Date	9/15/2011
ParkCode	SENW
Roads	3
Hiking	2
RecUse	2
FlowMod	2
Livestock	1
Contemp	2
Historic	2
Flood	1
Wind	1
Graze	2
Insect	1
Fire	1
Drying	2
Flow Modification	TRUE
Modification Type	Pipe Diversion

Vegetation observations. For Wetland Indicator, FACW=facultative wetland.

Tree canopy—diameter at breast height (dbh) and height of every tree greater than 2 m tall.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator Status	dbh (cm)	Height (m)
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	32	9
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	42	9
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	37	8

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter		Value	
Orifice	1	Pouroff	2
Shade	Shade	Shade	Shade
Temp	18.2	19	17.8
DO (mg/L)			
DO (%)			
pH	7.7	8.17	7.74
TDS	448.5	403	474.5
EC (μS)	570	550	625
Notes	San Lorenzo 1 = primary. Sandy channel, shade. Additional readings taken at pour-off and secondary orifice.	San Lorenzo 2 = pouroff - rock and sand. Basin, shade.	Secondary orifice
Alka_CaCO ₃	275		
Alka_HCO ₃ ⁻	335		
Alka_CO ₃ ²⁻	165		
Chloride	20		
Magnesium	47		
Sulphate (SO ₄ ²⁻)	67		
Sulphur (S)	22		
Calcium (Ca)	10		
Location			
Notes			

Spring brook habitat characteristics.

Shrub and herb canopy cover measured on the right or left side of the stream brook bank, the distance downstream from the orifice, near to the brook (0.5 m from wetted edge) or far from the brook (1.5 m from wetted edge), and percent cover.

Bank	Distance	Location	Species	Cover
Left	3	N	No Plants	
Left	6	F	No Plants	
Right	9	N	No Plants	
Right	12	F	No Plants	
Left	18	N	No Plants	
Left	21	F	CHRNAU	<1
Left	21	F	AMBACA	<1
Left	21	F	JUNMON	<1
Left	21	F	CONCAN	<1
Left	21	F	<i>Epilobium</i> sp.	<1
Right	24	N	No Plants	
Right	27	F	No Plants	

All canopy layers along the first 30 m of the spring brook. Shown is the distance downstream from the orifice (in meters), the substrate in the brook, and the species present from the lowest canopy (Species 1) to the highest canopy (Species n), if present.

Distance	Substrate	Species1
0	Open Water	No Plants
1	Bare Ground	No Plants
2	Bare Ground	No Plants
3	Open Water	No Plants
4	Rock	No Plants
5	Bare Ground	No Plants
6	Open Water	No Plants
7	Open Water	No Plants
8	Bare Ground	No Plants
9	Bare Ground	No Plants
10	Bare Ground	No Plants
11	Bare Ground	No Plants
12	Open Water	No Plants
13	Open Water	No Plants
14	Bare Ground	No Plants
15	Open Water	No Plants
16	Open Water	No Plants
17	Bare Ground	No Plants
18	Open Water	No Plants
19	Open Water	No Plants
20	Open Water	No Plants
21	Open Water	No Plants
22	Open Water	No Plants
23	Open Water	No Plants
24	Bare Ground	SALGOO
25	Open Water	SALGOO
26	Open Water	No Plants
27	Open Water	SALGOO
28	Bare Ground	No Plants
29	Open Water	No Plants
30	Open Water	No Plants

SENWR0031—San Lorenzo Spring 2

Sample Date: 9/17/2011

Site description.

San Lorenzo Spring 2 is located in a side draw to the north of San Lorenzo Canyon, and emerges under a small rock overhang into a shallow, small (0.5 m diameter) pool on the northeast edge of the channel. Moss and algae line the pool edge. Downstream from the orifice, the soil is saturated with occasional puddles. As water exits the confines of the canyon, it spreads and appears to be contained by an earthen dam. A trough/drinker marks the terminus and is 1x0.5 m, with a depth of 0.6 m. Trough contains watermilfoil, as well as mosquito larva and tiny water boatmen. Water stains are present upstream of the orifice, but no sign of surface water or riparian vegetation was detected. Bedrock appears to be crumbly basalt. Riparian vegetation is dominated by cattails, juncus, baccharis, cottonwoods, and Goodding's willow.

Physical characteristics.

Parameter	Value
Spring Type	Rheocrene
Brook Length (m)	20
Slope	-4
Slope Variability	Low
Aspect	126
Multiple Orifices (<200 m)	No
Other Springs Nearby (>200 m)	No
Geology	Volcanic
Weather	rain in last 24 h
Type & Setting Notes	
Emergence Environment	Sub-aerial
Sub-aerial Classification	Canyon wall
Emergence Substrate	Rock
Orifice Geomorphology	Fracture
Flow Forcing Type	Gravity
Notes	Water is dripping from rock above pool. It is hard to tell if water is also coming from ground.

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	2
Hiking	2
RecUse	2
FlowMod	3
Livestock	1
Contemp	2
Historic	4
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Modification	TRUE
Modification Type	Open Trough/Tank

Vegetation observations. For Wetland Indicator, FACW=facultative wetland.

Tree canopy—diameter at breast height (dbh) and height of every tree greater than 2 m tall.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator Status	dbh (cm)	Height (m)
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	36	13
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	41	13
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	34	13
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	11	5
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	24	3
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	18	4
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	13	2
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	13	4
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	27	5
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	21	7
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	38	11
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	13	5
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	14	13
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	11	4

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value	
Orifice	1	Terminus
Shade	Shade	Partial
Temp	19.1	17.3
DO (mg/L)	2.52	7.4
DO (%)	27.2	
pH	7.7	8.36
TDS	313.95	507
EC (µS)	428.1	667
Notes	San Lorenzo 2 OR = orifice beneath dripping rock. Probe may have contacted substrate.	San Lorenzo 2 - Trough. Terminus = metal drinking basin. No contact with soil.
Alka_CaCO ₃	265	
Alka_HCO ₃ ⁻	320	
Alka_CO ₃ ²⁻	160	
Chloride	22.5	
Magnesium	170	
Sulphate (SO ₄ ²⁻)	112	
Sulphur (S)	38	
Calcium (Ca)	12	
Location		
Notes		

Spring brook habitat characteristics.

Shrub and herb canopy cover measured on the right or left side of the stream brook bank, the distance downstream from the orifice, near to the brook (0.5 m from wetted edge) or far from the brook (1.5 m from wetted edge), and percent cover.

Bank	Distance	Location	Species	Cover
Left	3	Near	<i>Baccharis</i> sp.	>75
Left	3	Near	<i>Juncus</i> sp.	1-5
Left	6	Far	<i>Juncus</i> sp.	1-5
Left	6	Far	MUHASP	5-15
Right	9	Near	<i>Juncus</i> sp.	>75
Right	9	Near	<i>Typha</i> sp.	15-25
Right	12	Far	<i>Juncus</i> sp.	50-75

All canopy layers along the first 30 m of the spring brook. Shown is the distance downstream from the orifice (in meters), the substrate in the brook, and the species present from the lowest canopy (Species 1) to the highest canopy (Species n), if present.

Distance	Substrate	Species 1	Species 2	Species 3
0	Open Water	Snapdragon vine	MAUANT	
1	Bare Ground	<i>Baccharis</i> sp.	MUHASP	
2	Litter	<i>Typha</i> sp.		
3	Litter	<i>Typha</i> sp.	<i>Baccharis</i> sp.	
4	Litter	<i>Baccharis</i> sp.	<i>Juncus</i> sp.	<i>Typha</i> sp.
5	Litter	<i>Baccharis</i> sp.	<i>Juncus</i> sp.	
6	Litter	<i>Juncus</i> sp.		
7	Litter	<i>Juncus</i> sp.	<i>Typha</i> sp.	
8	Litter	<i>Juncus</i> sp.	POPFRE	
9	Litter	<i>Juncus</i> sp.	<i>Typha</i> sp.	POPFRE
10	Litter	<i>Typha</i> sp.	<i>Juncus</i> sp.	POPFRE
11	Litter	<i>Typha</i> sp.	<i>Juncus</i> sp.	POPFRE
12	Litter	<i>Typha</i> sp.	<i>Juncus</i> sp.	POPFRE
13	Litter	<i>Juncus</i> sp.	POPFRE	
14	Litter	<i>Juncus</i> sp.		
15	Litter	<i>Juncus</i> sp.		
16	Litter	<i>Juncus</i> sp.		
17	Litter	<i>Juncus</i> sp.		
18	Litter	<i>Juncus</i> sp.	SALGOO	
19	Litter	<i>Juncus</i> sp.	MUHASP	
20	Bare Ground	<i>Juncus</i> sp.	MUHASP	

SENWR0032—San Lorezno Spring 3

Sample Date: 9/18/2011

Site description.

Orifice 1 of San Lorenzo Spring 3 is a 20x4 m patch of juncus and *Muhlenbergia* sp. on wet ground. Orifice 2 is 20 m downstream and is a similar-sized patch of wetland vegetation. Spring is located in a gravelly wash near the refuge boundary. Volcanic foothills of juniper savannah surround the spring. Cottonwoods, true willows, and a few dead and dying hackberries can be found along channel in vicinity of spring. Rubber rabbitbrush and many grasses and forb species grow in wash. A small tamarisk grows in second orifice. Spring is approximately 150 m upstream from San Lorenzo 1.

Physical characteristics, habitat.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0.00
Mean Water Depth (cm)	0.00
Mean Water Width (cm)	0.00
Emergent Cover (%)	
Vegetated Bank Cover (%)	
Fines (%)	
Gravel (%)	
Cobble (%)	
Boulder (%)	
Sand (%)	
Comments	Area with riparian spp.: OR1 = 20 m x 5 m., OR2 = 15 m x 5 m.

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	2
Hiking	1
RecUse	2
FlowMod	1
Livestock	1
Contemp	2
Historic	1
Flood	1
Wind	1
Graze	2
Insect	1
Fire	1
Drying	2
Flow Modification	FALSE
Modification Type	

Vegetation observations. For Wetland Indicator, FACW=facultative wetland.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ERNA10	<i>Ericameria nauseosa</i>	rubber rabbitbrush	Native		
JUNCU	<i>Juncus</i> sp.	rush	N/A	YES	CHDN
MUAS	<i>Muhlenbergia asperifolia</i>	scratchgrass	Native	FACW	USDA
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	CHDN
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	USDA
SATR12	<i>Salsola tragus</i>	prickly Russian thistle	Non-Native		
TACH2	<i>Tamarix chinensis</i>	fivestamen tamarisk	Non-Native	YES	CHDN

Water quality characteristics. Insufficient water for measurement.

SENWR0034—Silver Creek A

Sample Date: 9/20/2011

Site description.

Silver Creek A is on the east side of a canyon along Silver Creek. Side drainage is narrow and zigzags down to the main creek. At least two orifices are present. The primary/upper orifice is about 110 m up drainage in a dense patch of New Mexico olive, and is marked by a small pool (1 m diameter) with algae layer on bottom, and discharge from just above the pool with channels marked by a dark film. The rate of discharge is very low, despite recent rains (~72 hrs.). Secondary orifice is about 50 m upstream of main arroyo at major zig to south southeast. Drainage walls are primarily sandstone conglomerate bedrock. Drainage bottom is mix of bedrock and small boulders with few patches of sandy soil. Vegetation along drainage bottom is mix of riparian and upland species.

Physical characteristics, habitat.

Parameter	Value
Brook Length (m)	100
Discharge (L/min)	0
Mean Water Depth (cm)	17
Mean Water Width (cm)	1
Emergent Cover (%)	0
Vegetated Bank Cover (%)	10
Fines (%)	10
Gravel (%)	15
Cobble (%)	15
Boulder (%)	15
Sand (%)	15
Comments	

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	2
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	2
Historic	1
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	2
Flow Modification	FALSE
Modification Type	

Vegetation observations. For Wetland Indicator, FACW=facultative wetland.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ATCA2	<i>Atriplex canescens</i>	fourwing saltbush	Native		
ELAN	<i>Elaeagnus angustifolia</i>	Russian olive	Non-Native		
FOPU2	<i>Forestiera pubescens</i>	stretchberry	Native		
JUMO	<i>Juniperus monosperma</i>	oneseed juniper	Native		
MUAS	<i>Muhlenbergia asperifolia</i>	scratchgrass	Native	FACW	USDA
SALIX	<i>Salix</i> sp.	willow	N/A	YES	CHDN

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	
Shade	
Temp	15.8
DO (mg/L)	1.14
DO (%)	11.4
pH	7.29
TDS	604.5
EC (μ S)	
Notes	
Alka_CaCO ₃	370
Alka_HCO ₃ ⁻	450
Alka_CO ₃ ²⁻	220
Chloride	7.4
Magnesium	30
Sulphate (SO ₄ ²⁻)	1
Sulphur (S)	0
Calcium (Ca)	
Location	
Notes	

SENWR0039—Silver Creek B

Sample Date: 9/20/2011

Site description.

The uppermost orifice of Silver Creek B Spring emerges under a single cottonwood, about 150 m from the Silver Creek wash (on eastern slope). No standing water or flowing water could be found, only wet soil and patches of obligate wetland vegetation. Water seeps from multiple spots along the drainage, which is composed mostly of a highly erodible conglomerate bedrock. Junipers grow throughout wash, while *Muhlenbergia* grass, juncus, and forbs grow in patches throughout drainage where water seeps through ground. Near the terminus, the channel widens and thick green vegetation grows. Some wet spots may be from rains that have occurred in the past week.

Physical characteristics, habitat.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0
Mean Water Depth (cm)	0
Mean Water Width (cm)	0
Emergent Cover (%)	0
Vegetated Bank Cover (%)	0
Fines (%)	80
Gravel (%)	10
Cobble (%)	5
Boulder (%)	5
Sand (%)	0
Comments	

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	2
Historic	1
Flood	1
Wind	1
Graze	2
Insect	1
Fire	1
Drying	2
Flow Modification	FALSE
Modification Type	

Vegetation observations. For Wetland Indicator, FACW=facultative wetland.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ERNA10	<i>Ericameria nauseosa</i>	rubber rabbitbrush	Native		
FOPU2	<i>Forestiera pubescens</i>	stretchberry	Native		
GUTIE	<i>Gutierrezia</i> sp.	snakeweed	N/A		
	<i>Isocomoa</i> sp.	goldenbush	Native		
JUNCU	<i>Juncus</i> sp.	rush	N/A	YES	CHDN
JUMO	<i>Juniperus monosperma</i>	oneseed juniper	Native		
MUAS	<i>Muhlenbergia asperifolia</i>	scratchgrass	Native	FACW	USDA
PAFI4	<i>Parryella filifolia</i>	common dunebroom	Native		
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	CHDN
SPORO	<i>Sporobolus</i> sp.	dropseed	N/A		

Water quality characteristics. Insufficient water for measurement.

SENWR0038—Unknown Spring

Sample Date: 9/19/2011

Site description.

Unknown Spring is located in La Cueva Canyon. Water stains are present on rock for ~15 m. Cottonwoods and willows are present at the site. No surface water is present in the area. Site not found on topographic maps or in the Sevilleta NWR database. Wash substrate consisted of bedrock with stains, cobble, and sand. Approximately 250 m downstream is a similar, but more densely vegetated, dry spring. Vegetation in the wash includes large cottonwoods and sandbar willow and banks have large junipers.

Physical characteristics, habitat.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0
Mean Water Depth (cm)	0
Mean Water Width (cm)	0
Emergent Cover (%)	
Vegetated Bank Cover (%)	
Fines (%)	
Gravel (%)	
Cobble (%)	
Boulder (%)	
Sand (%)	
Comments	Dry

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	1
Historic	1
Flood	2
Wind	1
Graze	2
Insect	1
Fire	1
Drying	4
Flow Modification	FALSE
Modification Type	

Water quality characteristics. Insufficient water for measurement.

Appendix C List of Plants Detected

Table C1. List of plants detected at Seville National Wildlife Refuge.

USDA Code	Scientific Name	Common Name	Nativity
AMARA	<i>Amaranthus</i> sp.	pigweed	
AMAC2	<i>Ambrosia acanthicarpa</i>	flatspine burr ragweed	Native
ARIST	<i>Aristida</i> sp.	threeawn	
ATCA2	<i>Atriplex canescens</i>	fourwing saltbush	Native
ATCO	<i>Atriplex confertifolia</i>	shadscale saltbush	Native
BACCH	<i>Baccharis</i> sp.	baccharis	
BOCU	<i>Bouteloua curtipendula</i>	sideoats grama	Native
BRICK	<i>Brickellia</i> sp.	brickellbush	
CELAR	<i>Celtis laevigata</i> var. <i>reticulata</i>	netleaf hackberry	Native
CHAMA15	<i>Chamaesyce</i> sp.	sandmat	
COCA5	<i>Conyza canadensis</i>	Canadian horseweed	Native
CYLIN2	<i>Cylindropuntia</i> sp.	cholla	
DISP	<i>Distichlis spicata</i>	inland saltgrass	Native
ECCR	<i>Echinochloa crus-galli</i>	barnyard grass	Native
ELAN	<i>Elaeagnus angustifolia</i>	Russian olive	Non-native
ERNA10	<i>Ericameria nauseosa</i>	rubber rabbitbrush	Native
ERICA2	<i>Ericameria</i> sp.	rabbitbrush	
ERIOG	<i>Eriogonum</i> sp.	buckwheat	
FAPA	<i>Fallugia paradoxa</i>	Apache plume	Native
FOPU2	<i>Forestiera pubescens</i>	stretchberry	Native
GUTIE	<i>Gutierrezia</i> sp.	snakeweed	
ISOCO	<i>Isocoma</i> sp.	goldenbush	Native
JUNCU	<i>Juncus</i> sp.	rush	
JUMO	<i>Juniperus monosperma</i>	oneseed juniper	Native
MAAN9	<i>Maurandella antirrhiniflora</i>	snapdragon vine	Native
MEOF	<i>Melilotus officinalis</i>	yellow sweetclover	Non-native
MUAS	<i>Muhlenbergia asperifolia</i>	scratchgrass	Native
MYRIO	<i>Myriophyllum</i> sp.	water milfoil	
OPUNT	<i>Opuntia</i> sp.	pricklypear	
PAOB	<i>Panicum obtusum</i>	vine mesquite	Native
PAFI4	<i>Parryella filifolia</i>	common dunebroom	Native
PLLA	<i>Plantago lanceolata</i>	narrowleaf plantain	Non-native
PLMA2	<i>Plantago major</i>	common plantain	Native
PODE3	<i>Populus deltoides</i>	eastern cottonwood	Native
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native
PRGL2	<i>Prosopis glandulosa</i>	honey mesquite	Native
QUTU2	<i>Quercus turbinella</i>	Sonoran scrub oak	Native
RHMI3	<i>Rhus microphylla</i>	littleleaf sumac	Native
RHTR	<i>Rhus trilobata</i>	skunkbush sumac	Native
SAEX	<i>Salix exigua</i>	narrowleaf willow	Native

Table C1. List of plants detected at Sevilleta National Wildlife Refuge (continued).

USDA Code	Scientific Name	Common Name	Nativity
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native
SALIX	<i>Salix</i> sp.	willow	
SATR12	<i>Salsola tragus</i>	prickly Russian thistle	Non-native
SCAM6	<i>Schoenoplectus americanus</i>	chairmaker's bulrush	Native
SOEL	<i>Solanum elaeagnifolium</i>	silverleaf nightshade	Native
SPAI	<i>Sporobolus airoides</i>	alkali sacaton	Native
SPORO	<i>Sporobolus</i> sp.	dropseed	
SPWR2	<i>Sporobolus wrightii</i>	big sacaton	Native
TACH2	<i>Tamarix chinensis</i>	fivestamen tamarisk	Non-native
TYPHA	<i>Typha</i> sp.	cattail	

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