



Inventory of Spring Ecosystems at San Andres National Wildlife Refuge, New Mexico

Physical and Biological Characteristics

Natural Resource Technical Report NPS/CHDN/NRTR—2013/820



ON THE COVER

San Andres Spring, San Andres National Wildlife Refuge
Photograph: NPS

Inventory of Spring Ecosystems at San Andres National Wildlife Refuge, New Mexico

Physical and Biological Characteristics

Natural Resource Technical Report NPS/CHDN/NRTR—2013/820

Author

Kirsten Gallo
National Park Service
Chihuahuan Desert Network
3655 Research Dr. Building D
Las Cruces, NM 88003

Editor

Nina Chambers
Northern Rockies Conservation Cooperative
P.O. Box 2705
Jackson, WY 83001

November 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations..

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the web sites of the Chihuahuan Desert Network (<http://science.nature.nps.gov/im/units/>) and NPS Natural Resource Publication Management (<http://www.nature.nps.gov/publications/nrpm>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Gallo, K. 2013. Inventory of spring ecosystems at San Andres National Wildlife Refuge, New Mexico: physical and biological characteristics. Natural Resource Technical Report NPS/CHDN/NRTR—2012/820, National Park Service, Fort Collins, Colorado.

Contents

Executive Summary v

Acknowledgments vi

Introduction 1

Methods 3

Results and Discussion 5

 Water Quality..... 5

 Disturbance 6

 Vegetation..... 8

 Habitat..... 9

Literature Cited 11

Appendix A List of Attributes 13

Appendix B Spring Data 17

Appendix C List of Plants Detected..... 41

Figures

Figure 1. Map of springs surveyed at San Andres National Wildlife Refuge.	3
Figure 2. Comparison of levels of anthropogenic disturbance in parks and refuges across New Mexico and west Texas (bars not outlined) and in San Andres 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.	7
Figure 3. Comparison of levels of natural disturbance in parks and refuges across New Mexico and west Texas (bars not outlined) and in San Andres 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.	8

Tables

Table 1. Springs included in the inventory at San Andres National Wildlife Refuge including the date and level of sampling.	4
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.	5
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).	6
Table 4. Scores for anthropogenic disturbance in San Andres 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. See Appendix A for additional information.	6
Table 5. Scores for natural disturbance in San Andres 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. Dashes indicate no data.	7
Table C1. List of plants detected at San Andres National Wildlife Refuge.	41

Executive Summary

This report summarizes information gathered during an inventory of springs in San Andres 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 of information on springs across refuges and parks and to provide information to develop a strategy for long-term monitoring.

Four springs were inventoried during this effort: Upper Ash, Ropes, San Andres, and West Little San Nicholas springs. Water flowed at all springs despite severe drought conditions and flow was sufficient to support riparian plant communities. Common riparian plants included eastern cottonwood, Goodding's willow, and velvet ash in the upper canopies; baccharis in the shrub layer; and a diverse mix of forbs and graminoids, including some sedges, rushes, and cattails. One non-native plant was recorded, beardless rabbitsfoot grass (*Polypogon viridis*) at West Little San Nicholas spring.

All four springs were characterized as being only slightly disturbed or undisturbed by anthropogenic disturbances; roads and flow modifications (pipe diversion or a flume) were recorded at both Ropes and Upper Ash springs. Natural disturbances such as flooding, fire, grazing, insects, wind, and drying were also categorized for each spring. Flooding was reported as affecting half the riparian vegetation at both San Andres spring and Upper Ash spring, while fire damage was notable at West Little San Nicholas spring. Moderate levels of drying were also reported for West Little San Nicholas spring. All other natural disturbance types were ranked as undisturbed or only slightly disturbed at the springs.

Water levels were sufficient for water quality analyses at all springs. 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. Upper Ash spring was the only spring with dissolved oxygen concentrations likely high enough to support aquatic life; however, Upper Ash spring met the Environmental Protection Agency's standard, but not the New Mexico Environment Department's standard for dissolved oxygen. pH levels ranged from 7.2 to 7.5 and were within the standard set by the New Mexico Environmental Department.

Acknowledgments

Field work was conducted by John Benning, Julie Christian, Ben Cooper, Gene Halsey, Jessica Kindred, Stephanie Roussel, and Alex Tye. Thanks to Mara Weisenberger at San Andres National Wildlife Refuge for providing local expertise and logistical support. Jessica Savage and Gina Gesting transcribed and verified all data. Comments from Julie Christian and Cheryl McIntyre improved the quality of this document.

Introduction

Water in the San Andres 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

Four springs in San Andres NWR (Figure 1, Table 1) were inventoried in 2011 following the procedures described by Sada and Pohlmann (2006; located on enclosed CD): Upper Ash Spring, Ropes Spring, San Andres Springs, and West Little San Nicholas Spring. 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,

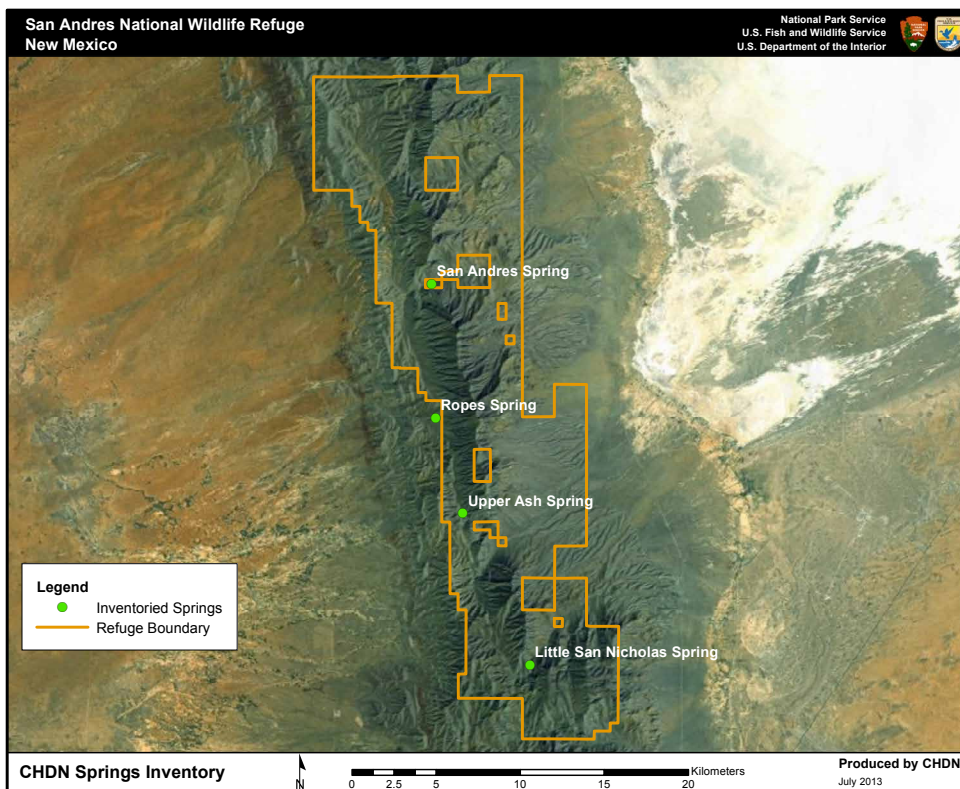


Figure 1. Map of springs surveyed at San Andres National Wildlife Refuge.

Table 1. Springs included in the inventory at San Andres National Wildlife Refuge including the date and level of sampling.

Spring ID	Spring Name	Date	Level
SANWR001	Upper Ash Spring	10/19/2011	2
SANWR009	Ropes Spring	8/19/2011	2
SANWR013	San Andres Spring	8/17/2011	2
SANWR016	West Little San Nicholas	11/15/2011	2

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 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. 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 all San Andres NWR springs surveyed (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 San Andres NWR was under D4 exceptional drought conditions, which is the most intense category in the U.S. Drought Monitor Index.

All springs inventoried were wet at the time of the survey and had sufficient flow for water quality measurements and to maintain well-developed riparian vegetation communities. These conditions are inconsistent 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 for San Andres NWR springs are located in Appendix B.

Water Quality

Water quality measurements were taken at each spring. Water temperatures were fairly warm, ranging from 13.7 to 22.3°C (Table 2). Dissolved oxygen (DO) concentrations were 0.4-4.7 mg/L. The level of dissolved oxygen 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. Upper Ash Spring, which has a DO concentration of 4.7 mg/L, meets the EPA standard; no springs

meet the NMED standard. pH levels varied from 7.2 to 7.5, meeting NMED standards of 6.6-9.0. Total dissolved solids (TDS) ranged from 386.1 to 682.5 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. Electrical conductance values were 466.5-682.5 µS/cm. Standards have not been set for conductivity.

Crews used a field spectrophotometer to analyze water samples for alkalinity and common ions. Alkalinity (the water's capacity to neutralize acids) was measured as concentration (in mg/L) of calcium carbonate (CaCO₃), bicarbonate (HCO₃⁻), and carbonate (CO₃²⁻). Alkalinity in water results from any dissolved species (though usually weak acid ions such as carbonic acid) that can accept and neutralize protons. Because carbon dioxide (CO₂) 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 CO₂—HCO₃⁻—CO₃²⁻ equilibrium system is the major buffering system in freshwater. Calcium carbonate levels ranged from 280 to 380 mg/L, bicarbonate levels ranged from 345-460 mg/L, and carbonate values ranged from 170 to 230 mg/L. These levels are typical for fresh water, given the range of pH values in the 7-7.5 range (Table 3).

Table 2. Water quality values including temperature (°C), dissolved oxygen (DO; mg/L), pH, total dissolved solids (TDS; mg/L), and electrical conductance (EC; µS/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.

Name	Orifice	Temp	DO	pH	TDS	EC	Shade	Dry	QAQC Notes
Upper Ash Spring	1	13.7	2.9	7.15	416	642	Sun	No	
	2	13.8	4.74	7.51	386.1	466.5	Shade	No	Point 2 taken in second large pool with discharge on west side.
Ropes Spring	1	18.5	0.35	7.15	682.5	--	Shade	No	Orifice primary. Taken in shaded channel in a pool 15 cm deep at orifice.
San Andres Spring	1	22.3	--	7.24	448.5	685	Shade	No	Orifice 1 primary. Sample taken approx. 1 m downstream from emergence. Water depth = approx. 6 cm.
West Little San Nicholas Spring	1	14.8	2.91	7.24	591.5	914	Partial	No	Orifice 1 taken at 5 m, primary orifice.

Table 3. Water quality values (mg/L) for calcium carbonate (CaCO₃), bicarbonate (HCO₃), carbonate (CO₃), chloride (Cl), magnesium (Mg), sulfate (SO₄), and calcium (Ca). ND indicates the parameter was not detected.

Name	Orifice	CaCO ₃	HCO ₃	CO ₃	Cl	Mg	SO ₄	Ca	Location
Upper Ash Spring	2	280	345	170	8	130	116	ND	Sample taken at upstream end of second large pool
Ropes Spring	1	380	460	230	19	350	195	130	
San Andres Spring	1	310	380	180	16	400	155	40	
West Little San Nicholas Spring	1	310	380	190	24	375	180	66	Primary orifice

In addition to measuring alkalinity, concentration of common ions was also measured, including calcium (Ca²⁺), chloride (Cl⁻), magnesium (Mg²⁺), and sulfate (SO₄²⁻), 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). 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 ranged from non-detectable (<5 mg/L) to 130 mg/L. Calcium concentration greater than 20 mg Ca/L is

associated with hard water (Wetzel 2001). Chloride levels ranged from 8 to 24 mg/L. Concentrations between 1 and 100 mg Cl/L are common in freshwater. Magnesium levels ranged from 130 to 400 mg/L. Sulfate concentration ranged from 116 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. Twenty three percent of springs inventoried across New Mexico and west Texas have some kind of flow modification. Two of the San Andres NWR springs have had some kind of flow modification historically: pipe diversion and excavation at Ropes Spring and flume at Upper Ash Spring. Fifty percent of San Andres NWR springs are undisturbed or are slightly disturbed for roads (Table 4). Ninety four percent of springs in southern New Mexico and west Texas are undisturbed or slightly disturbed relative to roads (Figure 2). Roads are present close to Ropes and Upper Ash springs; however, both springs have naturalized and the effects of the road on the

Table 4. Scores for anthropogenic disturbance in San Andres 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. See Appendix A for additional information.

Name	Roads	Hiking	Rec Use	Flow Mod	Livestock	Flow Mod	Modification Type
Ropes Spring	2	1	1	2	1	Yes	Pipe Diversion; Excavation
San Andres Spring	1	1	1	1	1	No	
Upper Ash Spring	2	1	1	2	1	Yes	Other (flume)
West Little San Nicholas Spring	1	1	1	1	1	No	

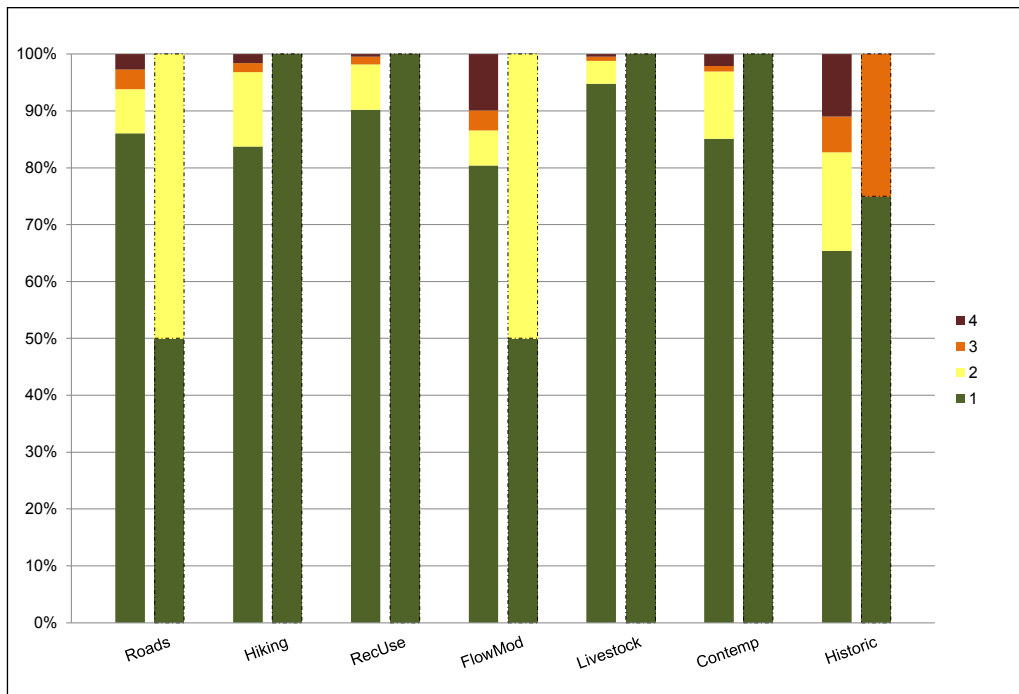


Figure 2. Comparison of levels of anthropogenic disturbance in parks and refuges across New Mexico and west Texas (bars not outlined) and in San Andres National Wildlife Refuge (bars with dashed outline). Graph shows the proportion of springs rated in each disturbance category. Categories are 1=undisturbed,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

spring system are minimal. None of the San Andres NWR springs were affected by other forms of anthropogenic disturbance, such as the presence of hiking trails, recreational use, or livestock grazing.

Evidence of flood disturbance affecting more than half of the riparian vegetation community was evident at San Andres Spring and Upper Ash Spring. Effects of other types of natural disturbance were minimal in San Andres NWR springs.

Evidence of fire was notable at West Little San Nicholas Spring. The majority of springs are in the undisturbed or slightly disturbed categories for all types of natural disturbance (wind, insects, ungulate grazing, fire, drying; Table 5 and Figure 3). These results are similar to springs across New Mexico and Texas, except for drying. Only one spring (25%) inventoried in San Andres NWR was moderately or highly disturbed by drying or drought, compared to 48% across the other inventoried springs.

Table 5. Scores for natural disturbance in San Andres 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. Dashes indicate no data.

Name	Flood	Wind	Grazing	Insect	Fire	Drying
Upper Ash Spring	3	1	1	1	1	1
Ropes Spring	1	1	1	1	1	1
San Andres Spring	4	1	1	1	1	1
West Little San Nicholas Spring	1	- -	2	1	3	3

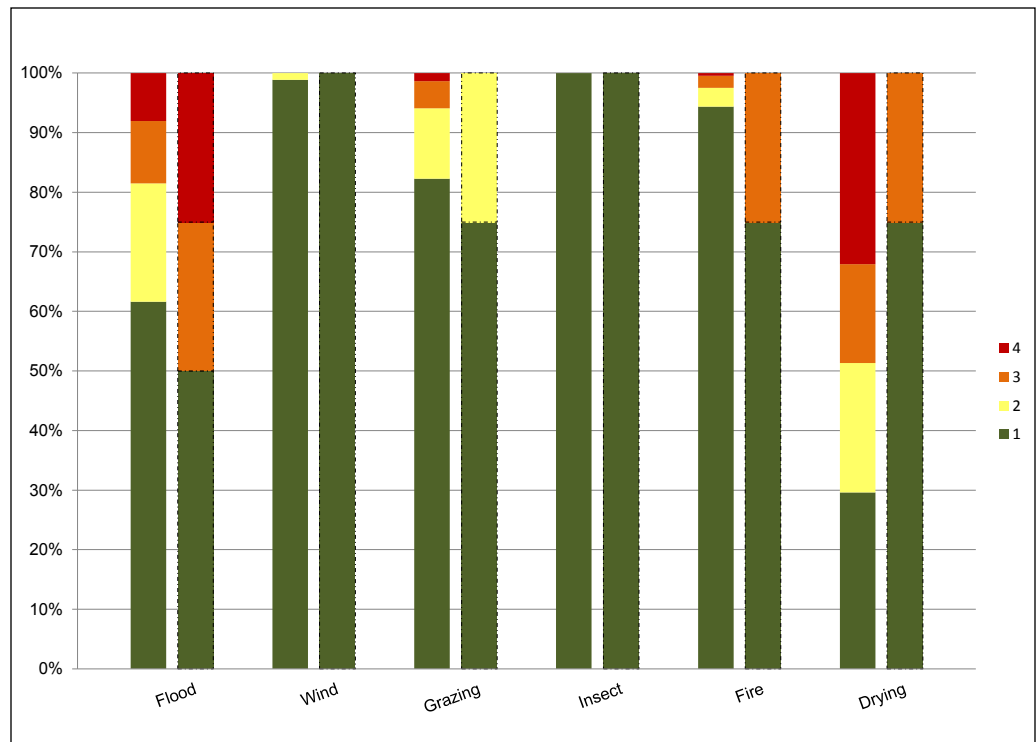


Figure 3. Comparison of levels of natural disturbance in parks and refuges across New Mexico and west Texas (bars not outlined) and in San Andres National Wildlife Refuge (bars with dashed outline). Graph shows the proportion of springs rated in each disturbance category. Categories are 1=undisturbed,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

Vegetation

Typical wetland plants were found at the springs, including cottonwoods (*Populus* spp.), willows (*Salix* spp.), baccharis (*Baccharis* spp.), cattails (*Typha* spp.), and a variety of grasses and forbs. 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. Only one non-native plant was found, beardless rabbitsfoot grass (*Polypogon viridis*) at West Little San Nicholas Spring. Data for all springs are located in Appendix B.

Dominant riparian vegetation species at **Upper Ash Spring** included maidenhair fern (*Adiantum capillus-veneris*), equisetum, and goldenrod (*Solidago* sp.) in the area within 5 m of the spring. Between 5 and 15 m out from the spring, riparian vegetation species included maidenhair fern, equisetum, and velvet ash (*Fraxinus velutina*). Beyond 15 m away from the spring, maidenhair fern,

equisetum, and Goodding's willow (*Salix gooddingii*). Within 5 m from the spring, dominant upland species included prairie sumac (*Rhus lanceolata*), alderleaf mountain mahogany (*Cercocarpus montanus*), and Wright's silktassel (*Garrya wrightii*) on the left bank and alderleaf mountain mahogany on the right bank. Five to 15 m out from the spring, dominant upland species included Wright's silktassel and honeysuckle (*Lonicera* sp.) on the left and Wright's silktassel, alderleaf mountain mahogany, and honeysuckle on the right. Fifteen to 30 m out from the spring, dominant species included Wright's silktassel on the left side and alderleaf mountain mahogany, prairie sumac, and oaks (*Quercus* spp.) on the right side. Most of the area around the spring was closed canopy. The tree canopy consisted primarily of velvet ash and Goodding's willow.

Dominant riparian vegetation species at **Ropes Spring** included velvet ash, and Wright's silktassel in the area within 15 m

of the spring. Between 15-30 m, eastern cottonwood trees (*Populus deltoides*) were present. No upland species were detected within 30 m of the right side of the spring. Nor were upland species detected on the left side within the first 5 meters. On the left side within 5-15 m from the spring, dominant upland species included honey mesquite (*Prosopis glandulosa*) and littleleaf sumac (*Rhus microphylla*). Fifteen to 30 m out from the spring, dominant upland species included littleleaf sumac and whitethorn acacia (*Acacia constricta*). Trees, primarily velvet ash, but also eastern cottonwood, netleaf hackberry (*Celtis reticulata*), and California buckthorn (*Frangula californica*), created a closed canopy above the spring.

Dominant riparian vegetation species at **San Andres Spring** included Goodding's willow and eastern cottonwood within 5 m of the spring. Between 5-30 m, baccharis was also present. No upland species were detected on the left side of the spring or within the first 5 m of the right side. Five to 15 m out from the spring, dominant upland species included Wright's silktassel and hackberry (*Celtis* sp.). Fifteen to 30 m out from the spring, dominant upland species included clematis, honey mesquite, and sumac (*Rhus* sp.). The canopy above the spring was closed, primarily by presence of Goodding's willow. Other tree species present include eastern and Fremont cottonwoods.

At **West Little San Nicholas Spring**, the dominant riparian vegetation species included baccharis, California loosestrife (*Lythrum californicum*), and the non-native beardless rabbitsfoot grass within 5 m of the spring. Between 5 and 15 m, the same species were present, with the addition of *Juncus* sp. Between 15-30 m, baccharis was present, as was California loosestrife and western umbrella sedge (*Fuierena simplex*). Within 5 m from the spring, dominant upland species was skeleton goldeneye (*Viguiera stenoloba*), sideoats grama (*Bouteloua curtipendula*), and barberry (*Berberis* sp.) on the left side of the spring and sideoats grama on the right. Five to 15 m out from the spring, dominant upland species included acacia, skeleton goldeneye, and sideoats grama on the left and skeleton goldeneye and alderleaf mountain mahogany on the right. Fifteen to



Upper Ash Spring with maidenhair fern growing along the adjacent bank.

30 m out from the spring, dominant upland species included acacia and apache plume (*Fallugia paradoxa*) on the left side and beargrass (*Nolina* sp.) and Wright's beebrush (*Aloysia wrightii*) on the right. The canopy was more than half closed. Oneseed juniper (*Juniperus monosperma*) was the only tree species present.

Habitat

The **Upper Ash Spring** brook is 400 m in length; the first 100 m was included in the survey. Water was shallow, with depth ranging from less than 1 to 73 cm (average 11 cm). Wetted width varied from 13-308 cm, and averaged 123 cm wide. Bank overhangs were present on both sides of the spring brood. A 70-110 cm overhang was present on the left bank from 40-60 m downstream from the orifice. On the right bank, a 65-cm overhang was present about 80 m downstream from the orifice. Substrate in the channel is primarily bedrock covered by fine substrates. Canopy cover was high, with an average of 90%.

The **Ropes Spring** brook is about 76 m long. Discharge was about 2 L/min. The wetted width of the brook averaged 51 cm (range 0-189 cm). Water depth varied from <1-17 cm (mean=4 cm). Substrate consisted of sand and gravel with some fine sediment

**West Little San
Nicholas Spring,
showing dominance
of baccharis.**



and patches of bedrock. Canopy cover was consistently high, averaging 99%.

The spring brook at **San Andres Spring** is more than 1,000 m in length. The first 100 m was included in the survey. Discharge was about 8 L/min. The wetted width of the brook was 85 cm on average (range=17-155 cm). Water depth ranged from <1-28 cm, and averaged 2 cm. Banks hung over channels by 5 cm on the left side and 44 cm on the right about 80 m downstream from the orifice. Substrates were consistently composed of sand with smaller amounts of fine sediment and gravel. Detritus was rare. Canopy cover was consistently high, averaging 85%.

The **West Little San Nicholas Spring** brook was more than 1,000 m in length, with intermittent flows. Average wetted width was 63 cm (range 21-226 cm). Water depth was consistently shallow (average 3 cm, range 0.2-17 cm). There were no bank overhangs on the left bank, and a 20-cm overhang on the right bank near the orifice. Substrate consisted of fine sediment and sand, with some gravel. Detritus was also present in pockets less than 1 cm deep. Canopy cover was high, and averaged 57%.

Literature Cited

- Botosaneanu, L. (ed.). 1998. Studies in Crenobiology. The Biology of Springs and Springbrooks. Backhuys Publishers, Leiden, The Netherlands.
- Brussard, P. F., D. A. Charlet, and D. S. Dobkin. 1998. The Great Basin-Mojave Desert Region. Pages 505-542 in M. J. Mac, P. A. Opler, C. E. Puckett-Haecker, and P. D. Doran, editors. The status and trends of the nation's biological resources. U.S. Geological Survey, Reston, VA.
- Castelli, R. M., J. C. Chambers, and R. J. Tausch. 2000. Soil-plant relations along a soil-water gradient in Great Basin riparian meadows. *Wetlands* 20:251-266.
- Cushing, C. E. 1996. The ecology of cold desert spring-streams. *Archiv für Hydrobiologie* 135:499-522.
- Fleischner, T. L. 1994. Ecological costs of livestock grazing in western North America. *Conservation Biology* 8:629-644.
- Fleishman, E., D. D. Murphy, and D. W. Sada. 2006. Effects of environmental heterogeneity and disturbance on the native and non-native flora of desert springs. *Biological Invasions* 8:1091-1101.
- Freeze, R. A. and J. A. Cherry. 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
- Hershler, R., Madsen, D. B. and Currey, D. (eds). 2002. Great Basin aquatic systems history. Smithsonian Contributions to the Earth Sciences No. 33. Washington, D.C.
- Knopf, F. L., R. R. Robinson, T. Rich, F.B. Samson, and R.C. Sazo. 1988. Conservation of riparian ecosystems in the United States. *Wilson Bulletin* 100:272-284.
- McCabe, D. J. 1998. Biological communities in springbrooks. Pages 221-228. in L. Botosaneanu (ed.). Studies in Crenobiology. The Biology of Springs and Springbrooks. Backhuys Publishers, Leiden, The Netherlands.
- Meffe, G. K. and P. C. Marsh. 1983. Distribution of aquatic macroinvertebrates in the Sonoran Desert springbrooks. *Journal of Arid Environments* 6:363-371.
- Minckley, W. L., D. A. Hendrickson, and C. E. Bond. 1986. Geography of western North American freshwater fishes: Description and relationships to intracontinental tectonism. Pages 519-614. In C. H. Hocutt and E. O. Wiley (eds.). The Zoogeography of North American Freshwater Fishes. John Wiley and Sons Publishing, New York, NY.
- Myers, M. J. and V. H. Resh. 1999. Spring-formed wetlands of the arid west. Islands of aquatic invertebrate biodiversity. Pages 811- 828. In D. P. Batzer, R. B. Radar, and S. A. Wissner (eds.). Invertebrates in Freshwater Wetlands of North America: Ecology and Management. John Wiley and Sons, New York, NY, USA.
- Resh, V. H. 1983. Spatial differences in the distribution of benthic macroinvertebrates along a springbrook. *Aquatic Insects* 5:193-200.
- Resh, V. H., A. V. Brown, A. P. Covich, M. E. Gurtz, H. W. Li, W. Minshall, S. R. Reice, A. L. Sheldon, J. B. Wallace, and R. C. Wissmar. 1988. The role of disturbance in stream ecology. *Journal of the North American Benthological Society* 7:433-455.
- Saab, V. A., C. E. Brock, T. D. Rich, and D. S. Dobkin. 1995. Livestock grazing effects in western North America. Pages 311-353 In T. E. Martin and D. M. Finch (eds.). Ecology and management of Neotropical migratory birds. Oxford University Press, New York.
- Sada, D. W. 2001. Demography and habitat use of the Badwater snail (*Assimineae infima*), with observations on its

- conservation status. *Hydrobiologia* 466:255-265.
- Sada, D. W. and K. F. Pohlmann. 2006. U.S. National Park Service, Mojave Inventory and Monitoring Network, Spring Survey Protocols: Levels I and II. Unpublished report, U.S. National Park Service, Mojave Inventory and Monitoring Network, Boulder City, Nevada.
- Sada, D. W. and G. L. Vinyard. 2002. Anthropogenic changes in historical biogeography of Great Basin aquatic biota. Pages 277-293. In R. Hershler, D. B. Madsen, and D. Currey (eds.). Great Basin Aquatic Systems History. Smithsonian Contributions to the Earth Sciences No. 33.
- Sada, D. W., E. Fleischman, and D. D. Murphy. 2005. Associations among spring-dependent aquatic assemblages and environmental and land use gradients in a Mojave Desert mountain range. *Diversity and Distributions* 11:91-99.
- Schmitz, D., B. McGlynn, and D. Patten. 2007. Development of a spring ecosystem monitoring protocol in Bighorn Canyon National Recreation Area. Final Report Submitted to Greater Yellowstone Network Inventory and Monitoring Program, National Park Service. Land Resources and Environmental Sciences, Montana State University.
- Shepard, W. D. 1993. Desert springs—both rare and endangered. *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:351-359.
- Smith, S. D., A. B. Wellington, J. L. Nachlinger, and C. A. Fox. 1991. Functional responses of riparian vegetation to streamflow diversion in the eastern Sierra Nevada. *Ecological Applications* 1:89-97.
- Stromberg, J. C. and D. T. Patten. 1992. Mortality and age of black cottonwood stands along diverted and undiverted streams in the eastern Sierra Nevada, California. *Madrono* 39:205-223.
- Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Wildlife habitats in managed rangelands: the Great Basin of southeastern Oregon. Riparian Zone. US Bureau of Land Management General Technical Report PNW-80. Washington, D.C.
- Thomas, J. M., A. H. Welch, and M. D. Dettinger. 1996. Geochemistry and isotope hydrology of representative aquifers in the Great Basin region of Nevada, Utah, and adjacent states. U.S. Geological Survey Professional Paper 1409-C.
- Wetzel, R. G. 2001. Limnology: Lake and river ecosystems. 3rd Edition. Academic Press, San Diego, CA. 1006 pp.
- Williams, D. D. and H. V. Danks (eds). 1991. Arthropods of springs, with special reference to Canada. Memoirs of the Entomological Society of Canada, No. 155.

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 San Andres National Wildlife Refuge spring.

SANWR001—Upper Ash Spring

Sample Date: 10/19/2011

Site description.

The spring is in a wash with large limestone boulders. The orifice is located at the roots of a lot of vegetation. Much of the flow goes underground and comes out along the side of a 10 m high wall. Less than 25% of flow moves along side a boulder into a pool, the remainder of flow seeps through cracks in the wall, which is covered in maidenhair fern and cardinal flower (*Lobelia cardinalis*). Water flows into two pools, one on either side of wall. Water from both pools flow into another pool, from which a channel has formed. Cattails are present along perimeter of the pools. The channel forms a step-pool system, influenced by boulders. A large cottonwood is present just up from orifice. Also present are desert willow, alkali sacaton, mesquite, and other shrubs and grasses. Vegetation is thick along the sides of the spring. Evidence (debris piles along channel) exists of a flood, however, vegetation is reestablished. Site length sampled was 74 m. Water went below surface at 74 m and resurfaced at 105 m, and flowed 40-45 m before going back underground.

Physical characteristics.

Parameter	Value
Spring Type	Rheocrene
Brook Length (m)	400
Discharge (L/min)	25
Slope	4
Slope Variability	Medium
Aspect	150
Multiple Orifices (<200 m)	Yes
Other Springs Nearby (>200 m)	Yes
Geology	Limestone
Weather	no rain
Notes	
Emergence Environment	Sub-aerial
Sub-aerial Classification	Channel; Mountain ide
Emergence Substrate	Rock
Orifice Geomorphology	Seepage or filtration
Flow Forcing Type	Gravity
Notes	Spring emerges from various orifices, some of which are ephemeral contacts. Main orifice is where water seeps out of the hill slope onto travertine walls and then drips into clear, deep (0.5-2 m) pools along channel.

Habitat.

Parameter	Minimum	Maximum	Mean
Wetted Width (cm)	13	308	123
Water Depth (cm)	0.5	73	11
Detritus Depth	0.2	4	0.9
Left Bank Overhang	0	110	20
Right Bank Overhang	0	65	5
Fines (%)			29
Sand (%)			4
Gravel (%)			9
Cobble (%)			2
Bedrock (%)			56

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	2
Livestock	1
Contemp	1
Historic	1
Flood	3
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Modification	Yes
Modification Type	Other

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

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator Status	dbh (cm)	Height (m)
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native	FACW	16	5
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native		41	8
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		12	5
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		14	7
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		36	14
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		14	8
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		21	8
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		10	5
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		10	6

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

Parameter	Value	
Orifice	1	2
Shade	Sun	Shade
Temp	13.7	13.8
DO (mg/L)	2.9	4.74
DO (%)	28	45.8
pH	7.15	7.51
TDS	416	386.1
EC (µS)	642	466.5
Notes	Point 2 in second large pool with discharge on west side.	
Alka_CaCO ₃	280	
Alka_HCO ₃ ⁻	345	
Alka_CO ₃ ²⁻	170	
Chloride	8	
Magnesium	130	
Sulphate (SO ₄ ²⁻)	116	
Sulphur (S)	38	
Calcium (Ca)	ND	
Location	Sample taken at upstream end of second large pool.	
Notes		

ND indicates the parameter was not detected

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	6	Far	ADICAP	25-50
Left	6	Far	<i>Solidago</i> sp.	25-50
Right	9	Near	AQUCHR	5-15
Right	12	Far	LONALB	25-50
Right	12	Far	<i>Equisetum</i> sp.	1-5
Right	12	Far	FRAVEL	25-50
Right	18	Near	EQULAE	1-5
Right	18	Near	<i>Equisetum</i> sp.	25-50
Right	18	Near	SALGOO	25-50
Right	21	Far	RHUVIR	1-5
Right	21	Far	CERMON	5-15
Right	21	Far	SALGOO	50-75
Left	24	Near	ADICAP	>75
Left	24	Near	AQUCHR	15-25
Left	24	Near	FRAVEL	25-50
Left	24	Near	SALGOO	15-25
Left	3	Near	<i>Solidago</i> sp.	5-15
Left	3	Near	EQULAE	<1
Left	3	Near	<i>Equisetum</i> sp.	1-5
Left	3	Near	<i>Typha</i> sp.	<1
Left	24	Near	LONALB	5-15
Left	27	Far	ADICAP	25-50
Left	27	Far	AQUCHR	25-50
Left	27	Far	SALGOO	>75
Right	63	Near	AQUCHR	15-25
Right	63	Near	FRAVEL	25-50
Right	66	Far	SYMROT	5-15
Right	66	Far	SNAG	>75
Right	66	Far	EQULAE	<1
Right	66	Far	<i>Equisetum</i> sp.	<1
Right	66	Far	<i>Baccharis</i> sp.	1-5
Left	69	Near	Cyperaceae	1-5
Left	69	Near	<i>Equisetum</i> sp.	25-50
Left	69	Near	<i>Typha</i> sp.	1-5
Left	69	Near	EQULAE	<1
Left	69	Near	FRAVEL	50-75
Left	69	Near	SANWR001C	5-15
Left	72	Far	FRAVEL	>75
Left	72	Far	JUNMON	1-5

Spring brook habitat characteristics (continued).

Bank	Distance	Location	Species	Cover
Right	78	Near	<i>Solidago</i> sp.	25-50
Right	78	Near	GARWRI	25-50
Right	78	Near	FRAVEL	50-75
Right	78	Near	<i>Baccharis</i> sp.	<1
Right	78	Near	EQULAE	1-5
Right	81	Far	<i>Solidago</i> sp.	15-25
Right	81	Far	AQUCHR	1-5
Right	81	Far	<i>Baccharis</i> sp.	25-50
Right	81	Far	FRAVEL	>75
Right	81	Far	GARWRI	1-5
Right	81	Far	Honeysuckle	<1
Left	84	Near	AQUCHR	1-5
Left	84	Near	EQULAE	<1
Left	84	Near	<i>Equisetum</i> sp.	1-5
Left	84	Near	FRAVEL	>75
Left	87	Far	<i>Baccharis</i> sp.	5-15
Left	87	Far	AQUCHR	1-5
Left	87	Far	FRAVEL	>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	Species1	Species2	Species3	Species4
0	Rock	FRAVEL			
1	Open Water	FRAVEL			
2	Bare Ground	<i>Equisetum</i> sp.			
3	Litter	<i>Equisetum</i> sp.			
4	Litter	<i>Equisetum</i> sp.	AQUCHR		
5	Rock	<i>Equisetum</i> sp.	FRAVEL		
6	Litter	<i>Equisetum</i> sp.	FRAVEL		
7	Bare Ground	GARWRI	FRAVEL		
8	Rock	FRAVEL			
9	Rock	FRAVEL			
10	Open Water	FRAVEL			
11	Open Water				
12	Open Water	FRAVEL			
13	Open Water	FRAVEL			
14	Open Water	FRAVEL			
15	Open Water	FRAVEL			
16	Open Water	FRAVEL			
17	Open Water	FRAVEL			
18	Open Water				
19	Open Water				
20	Open Water				
21	Open Water	SNAG			
22	Litter	Cyperaceae			
23	Litter	Cyperaceae	Cyperaceae	<i>Equisetum</i> sp.	FRAVEL
24	Litter	<i>Equisetum</i> sp.	FRAVEL		
25	Open Water	FRAVEL	SALGOO		
26	Open Water	FRAVEL	SALGOO	ADICAP	
27	Open Water	ADICAP	SALGOO		
28	Open Water	ADICAP			
29	Open Water	ADICAP	SALGOO		
30	Open Water	ADICAP	SALGOO		

SANWR009—Ropes Spring

Sample Date: 8/19/2011

Site Description.

The site is situated along a natural drainage in a highly forested area. It is located within 10 meters of several historic buildings and picnic sites built by the Civilian Conservation Corps and used by the public prior to the establishment of White Sands Missile Range. Thick upland vegetation surrounds the drainage. The orifice observed emerges at the base of two ash trees. It forms a small pool around 1 m² with a depth of around 4 cm. This pool trickles downstream and flows for approximately 80 m through a narrow channel with numerous small pools. About 25 m downstream, the hill to the east of the channel is damp and thickly covered with a mat of *Juncus* sp., wildflowers, maidenhair fern, and columbine, suggesting seepage of water. A dense canopy of cottonwoods and ash trees is found throughout the spring area. Smaller shrubs make travel along channel difficult. Birds, insects, and wildflowers are numerous at the site. Box elders and an apple tree persist from historic human use. Many sightings of hummingbirds, grosbeaks (one black), neon skippers, dragonflies, and flame skippers, an unidentified hemiptera occurred. Channel terminated at 26 m downstream but reemerged and continued to flow beyond 100 m.

Physical characteristics.

Parameter	Value
Spring Type	Rheocrene
Brook Length (m)	76
Discharge (L/min)	1.6
Slope	11
Slope Variability	Medium
Aspect	220
Multiple Orifices (<200 m)	Yes
Other Springs Nearby (>200 m)	No
Geology	Unconsolidated
Weather	rain in last 24 hours
Notes	
Emergence Environment	Sub-aerial
Sub-aerial Classification	Channel
Emergence Substrate	Rock
Orifice Geomorphology	Seepage or filtration
Flow Forcing Type	Gravity
Notes	

Habitat.

Parameter	Minimum	Maximum	Mean
Wetted Width (cm)	0	189	51
Water Depth (cm)	0	17	4
Detritus Depth	0	4	0.6
Left Bank Overhang	0	10	1
Right Bank Overhang	0	19	2
Fines (%)			16
Sand (%)			38
Gravel (%)			33
Cobble (%)			2
Bedrock (%)			11

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	2
Livestock	1
Contemp	1
Historic	3
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Modification	Yes
Modification Type	Pipe Diversion; Excavation

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator Status	dbh (cm)	Height (m)
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native	YES	24	9
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		18	7
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		19	2.5
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		20	8
CERE2	<i>Celtis reticulata</i>	netleaf hackberry	Native		13	7
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		11	7
PODE3	<i>Populus deltoides</i>	eastern cottonwood	Native		86	20
FRCA12	<i>Frangula californica</i>	California buckthorn	Native		11	4
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		10	10
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		21	8.5
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		11	5
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		19	7
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		17	8
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		25	8
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		26	8
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		33	12
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		37	11.5
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		20	9
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		27	11
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		15	8
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		24	8
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		25	11
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		16	9
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		11	6
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		46	10
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		17	11
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		11	6
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		13	6
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		19	12
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		29	11
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native		18	9

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

Parameter	Value
Orifice	Single
Shade	Shade
Temp	18.5
DO (mg/L)	0.35
DO (%)	3.8
pH	7.15
TDS	682.5
EC (μS)	
Notes	Orifice primary. Taken in shaded channel in a pool 15 cm deep at orifice.
Alka_CaCO ₃	380
Alka_HCO ₃ ⁻	460
Alka_CO ₃ ²⁻	230
Chloride	19
Magnesium	350
Sulphate (SO ₄ ²⁻)	195
Sulphur (S)	65
Calcium (Ca)	130
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	FRAVEL	>75
Left	6	Far	Honeysuckle	1-5
Left	6	Far	RHATOM	50-75
Left	6	Far	FRAVEL	>75
Left	6	Far	SNAG	5-15
Right	9	Near	FRAVEL	>75
Right	9	Near	ADICAP	15-25
Right	9	Near	AQUCHR	1-5
Right	12	Far	SNAG	>75
Right	12	Far	RHATOM	<1
Right	12	Far	FRAVEL	5-15
Left	18	Near	AQUCHR	50-75
Left	18	Near	RHATOM	5-15
Left	18	Near	FRAVEL	>75
Left	21	Far	SNAG	50-75
Left	21	Far	BERHAE	1-5
Left	21	Far	Honeysuckle	<1
Left	21	Far	RHATOM	50-75
Left	21	Far	POPDEL	>75
Left	21	Far	FRAVEL	5-15
Right	24	Near	ADICAP	>75
Right	24	Near	AQUCHR	5-15
Right	24	Near	FRAVEL	>75
Right	27	Far	<i>Juncus</i> sp.	>75
Right	27	Far	FRAVEL	>75
Right	27	Far	VITARI	5-15
Right	27	Far	LOBCAR	<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	Species2	Species3	Species4
0	Root	FRAVEL	RHATOM		
1	Open Water	RHATOM	FRAVEL		
2	Rock	FRAVEL	RHATOM		
3	Litter	RHATOM	FRAVEL		
4	Litter	FRAVEL	RHATOM		
5	Open Water	FRAVEL	RHATOM		
6	Litter	RHATOM			
7	Open Water	FRAVEL			
8	Litter	FRAVEL	RHATOM		
9	Rock	FRAVEL			
10	Litter	CELRET	FRAVEL		
11	Open Water	FRAVEL			
12	Open Water	FRAVEL			
13	Open Water	FRAVEL			
14	Open Water	FRAVEL			
15	Rock	FRAVEL			
16	Open Water	FRAVEL			
17	Litter	LOBCAR	FRAVEL		
18	Litter	LOBCAR	RHATOM	FRAVEL	
19	Open Water	FRAVEL			
20	Litter	FRAVEL			
21	Litter	FRAVEL			
22	Litter	FRAVEL			
23	Litter	POPDEL	FRAVEL	RHUTRI	
24	Open Water	FRAVEL	POPDEL		
25	Open Water	QUETUR	LONALB	POPDEL	
26	Open Water	FRAVEL	POPDEL	QUETUR	LONALB
27	Open Water	FRAVEL	POPDEL		
28	Open Water	FRAVEL	POPDEL		
29	Litter	FRAVEL			
30	Rock	FRAVEL	POPDEL		

SANWR013—San Andres Spring

Sample Date: 8/17/2011

Site description.

The spring is located in San Andres Canyon, about $\frac{3}{4}$ miles up the channel drainage from the end of Connie Road. The area was recently flooded, as evidenced by debris (branches and litter) piled up behind trees in drainage about 1.5 m high. Vegetation is healthy and diverse. The riparian community dominated by cottonwood trees and Goodding's willow with a canopy height of about 6 m. The channel in which the spring expresses itself is about 25 m wide and is frequently scoured by seasonal floods. This has resulted in a mix of gravel and boulders depositing in this almost flat channel bed. The channel is well shaded by willow and cottonwood.

Physical characteristics.

Parameter	Value
Spring Type	Rheocrene
Brook Length (m)	
Discharge (L/min)	8
Slope	4.5
Slope Variability	Low
Aspect	70
Multiple Orifices (<200 m)	No
Other Springs Nearby (>200 m)	No
Geology	Unconsolidated
Weather	no rain
Notes	
Emergence Environment	Sub-aerial
Sub-aerial Classification	Channel
Emergence Substrate	Rock; Silt
Orifice Geomorphology	Seepage or filtration
Flow Forcing Type	Gravity
Notes	Emerges from side of channel.

Habitat.

Parameter	Minimum	Maximum	Mean
Wetted Width (cm)	17	155	85
Water Depth (cm)	0	28	2
Detritus Depth	0	2	0.0
Left Bank Overhang	0	5	0.3
Right Bank Overhang	0	44	3
Fines (%)			18
Sand (%)			50
Gravel (%)			23
Cobble (%)			8
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	1
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	1
Historic	1
Flood	4
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Modification	No
Modification Type	

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

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator Status	dbh (cm)	Height (m)
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	16	5.5
PODE3	<i>Populus deltoides</i>	eastern cottonwood	Native	YES	34	6.5
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	10	4
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	28	6.5
PODE3	<i>Populus deltoides</i>	eastern cottonwood	Native	YES	14	7
PODE3	<i>Populus deltoides</i>	eastern cottonwood	Native	YES	25	13
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	34	16
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	38	12
PODE3	<i>Populus deltoides</i>	eastern cottonwood	Native	YES	17	9
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	29	11
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	16	11
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	11	4.5
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	12	4
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native	YES	50	18
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	26	6
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	23	6
PODE3	<i>Populus deltoides</i>	eastern cottonwood	Native	YES	54	9
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	37	5
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	22	5
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	19	5
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	13	5
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	37	7
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	27	7
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native	FACW	11	5

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

Parameter	Value
Orifice	Single
Shade	Shade
Temp	22.3
DO (mg/L)	
DO (%)	7
pH	7.24
TDS	448.5
EC (μ S)	685
Notes	Orifice 1 primary. Sample taken approx. 1 m downstream from emergence. Water depth = approx. 6 cm.
Alka_ CaCO_3	310
Alka_ HCO_3^-	380
Alka_ CO_3^{2-}	180
Chloride	16
Magnesium	400
Sulphate (SO_4^{2-})	155
Sulphur (S)	50
Calcium (Ca)	40
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	No plants	
Left	6	Far	POPDEL	5-15
Right	9	Near	No plants	
Right	84	Near	<i>Baccharis</i> sp.	>75
Right	87	Far	MORMIC	>75
Right	12	Far	No plants	
Left	18	Near	No plants	
Left	21	Far	<i>Baccharis</i> sp.	5-15
Right	24	Near	<i>Baccharis</i> sp.	50-75
Right	27	Far	<i>Baccharis</i> sp.	25-50
Left	63	Near	SALGOO	50-75
Left	66	Far	No plants	
Right	69	Near	Unknown grass	<1
Right	72	Far	LARTRI	5-15
Right	72	Far	<i>Celtis</i> sp.	5-15
Left	78	Near	No plants	
Left	81	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	Species1	Species2
0	Open Water	SALGOO	
1	Rock	SALGOO	
2	Rock	SALGOO	
3	Open Water	SALGOO	
4	Litter	SALGOO	
5	Open Water	SALGOO	
6	Open Water	SALGOO	
7	Open Water	SALGOO	
8	Open Water	SALGOO	
9	Open Water	SALGOO	
10	Bare Ground	SALGOO	
11	Open Water	SALGOO	
12	Open Water	SALGOO	
13	Open Water	SALGOO	
14	Open Water	SALGOO	
15	Open Water	SALGOO	
16	Bare Ground	SALGOO	POPDEL
17	Open Water	SALGOO	POPDEL
18	Open Water	SALGOO	
19	Open Water	SALGOO	
20	Root	SALGOO	
21	Rock	NONE	
22	Rock	NONE	
23	Bare Ground	NONE	
24	Bare Ground	NONE	
25	Rock	NONE	
26	Open Water	POPDEL	
27	Open Water	BACSALN	POPDEL
28	Open Water	POPDEL	
29	Open Water	POPDEL	
30	Open Water	POPDEL	

SANWR016—West Little San Nicholas Spring

Sample Date: 11/15/2011

Site description.

Little San Nicholas lies in a wash. The primary orifice emerges from sand and is surrounded by a dense patch of *Baccharis* sp. that extends downstream for 7 m. After this, the brook begins to diffuse, but is constrained by bedrock outcrops on both sides for the first 100+ meters. Dominant riparian vegetation along spring brook are *Baccharis* sp., *Fuirena simplex* (western umbrella sedge), and *Juncus* sp. Approximately 11 m downstream of the primary orifice, a secondary orifice emerges 3 m to the west of the primary spring brook. It primarily emerges from sand substrate and has high evidence of trampling by wildlife. A 1x1 m patch of baccharis grows at this orifice. The channel from the secondary orifice runs for about 3 m and does not converge with the primary spring brook. Dominant riparian vegetation includes *Baccharis* sp. and *Fuirena simplex*, which is dry and trampled. From meters 46 to 80, a baccharis patch follows the spring brook. At 80 m to ~110 m the baccharis thins and *Fuirena simplex* and *Juncus* sp. rejoin the dominants. After meter 100, the slope steepens, bedrock and gravel substrate become more dominant, and the spring brook constricts and widens through a series of cascades and pools/tinajas. Pools range from 1 m to 4 m in width, and 10 cm to 2 m in depth. As bedrock becomes the dominant substrate, baccharis is replaced by *Typha* sp. as the dominant riparian vegetation. There are approximately six pools. After the pools, the channel disappears and reemerges intermittently before flowing through a grove of ash trees 50 m downstream that contains the ruins of a rock house. The channel disappears for 100 m only to reemerge for 10 m in a second grove of ash trees.

Physical characteristics.

Parameter	Value
Spring Type	Rheocrene
Brook Length (m)	1000
Discharge (L/min)	4
Slope	4.5
Slope Variability	Medium
Aspect	320
Multiple Orifices (<200 m)	TRUE
Other Springs Nearby (>200 m)	FALSE
Geology	Limestone
Weather	0=no rain
Notes	
Emergence Environment	Sub-aerial
Sub-aerial Classification	Channel
Emergence Substrate	Sand
Orifice Geomorphology	Seepage or filtration
Flow Forcing Type	Gravity
Notes	

Habitat.

Parameter	Minimum	Maximum	Mean
Wetted Width (cm)	21	226	63
Water Depth (cm)	0.2	17	3
Detritus Depth	0	7	1
Left Bank Overhang	0	0	0
Right Bank Overhang	0	20	2
Fines (%)			30
Sand (%)			43
Gravel (%)			23
Cobble (%)			0
Bedrock (%)			4

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	
Graze	2
Insect	1
Fire	3
Drying	3
Flow Modification	No
Modification Type	

Vegetation observations.

Scientific Name	Common Name	Nativity	Wetland Indicator Status	dbh (cm)	Height (m)
<i>Juniperus monosperma</i>	oneseed juniper	Native		101	4
<i>Juniperus monosperma</i>	oneseed juniper	Native		37	4
<i>Juniperus monosperma</i>	oneseed juniper	Native		32	3

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

Parameter	Value
Orifice	Single
Shade	Partial
Temp	14.8
DO (mg/L)	2.91
DO (%)	28.8
pH	7.24
TDS	591.5
EC (μS)	914
Notes	OR1 taken at 5 m. Primary orifice.
Alka_CaCO ₃	310
Alka_HCO ₃ ⁻	380
Alka_CO ₃ ²⁻	190
Chloride	24
Magnesium	375
Sulphate (SO ₄ ²⁻)	180
Sulphur (S)	60
Calcium (Ca)	66
Location	Primary orifice.
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	6	Far	RHUTRI	50-75
Left	6	Far	Unknown vine	15-25
Left	6	Far	<i>Baccharis</i> sp.	<1
Left	6	Far	Unknown forb	<1
Right	9	Near	<i>Juncus</i> sp.	15-25
Right	9	Near	POLVIR	1-5
Right	9	Near	LYTCAL	1-5
Right	12	Far	Unknown grass	<1
Left	18	Near	<i>Baccharis</i> sp.	1-5
Left	18	Near	POLVIR	1-5
Left	21	Far	<i>Echinocereus</i> sp.	<1
Left	21	Far	ALOWAI	50-75
Right	24	Near	<i>Baccharis</i> sp.	<1
Right	24	Near	BOTLAG	5-15
Right	27	Far	<i>Baccharis</i> sp.	<1
Left	63	Near	No plants	
Left	66	Far	No plants	
Right	69	Near	No plants	
Right	72	Far	<i>Baccharis</i> sp.	50-75
Right	72	Far	Unknown forb	<1
Left	78	Near	<i>Baccharis</i> sp.	>75
Left	81	Far	<i>Baccharis</i> sp.	<1
Right	84	Near	BOTLAG	<1
Right	84	Near	JUNMON	<1
Right	84	Near	CERBRE	<1
Right	84	Near	Snakeweed	15-25
Right	87	Far	CERBRE	<1
Right	87	Far	BOUCUR	1-5
Right	87	Far	POLVIR	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	Species2	Species3
0	Bare ground	LYTCAL	POLVIR	<i>Baccharis</i> sp.
1	Bare ground	POLVIR	<i>Baccharis</i> sp.	
2	Bare ground	JUNMON	<i>Baccharis</i> sp.	POLVIR
3	Litter	<i>Baccharis</i> sp.		
4	Litter	<i>Baccharis</i> sp.		
5	Open Water	<i>Baccharis</i> sp.		
6	Bare ground	<i>Baccharis</i> sp.		
7	Bare ground	<i>Baccharis</i> sp.	POLVIR	
8	Open Water	<i>Baccharis</i> sp.	POLVIR	
9	Rock	POLVIR	<i>Baccharis</i> sp.	
10	Bare ground	FUISIM		
11	Open Water	FUISIM		
12	Open Water	POLVIR		
13	Rock	No plants		
14	Open Water	POLVIR		
15	Open Water	POLVIR		
16	Open Water	POLVIR		
17	Open Water	No plants		
18	Open Water	POLVIR		
19	Open Water	POLVIR		
20	Open Water	POLVIR		
21	Open Water	No plants		
22	Open Water	No plants		
23	Open Water	POLVIR		
24	Open Water	No plants		
25	Open Water	No plants		
26	Open Water	No plants		
27	Open Water	POLVIR		
28	Open Water	No plants		
29	Open Water	LYTCAL		
30	Open Water	<i>Baccharis</i> sp.		

Appendix C List of Plants Detected

Table C1. List of plants detected at San Andres National Wildlife Refuge.

USDA Code	Scientific Name	Common Name	Nativity
ACACI	<i>Acacia</i> sp.	Acacia	N/A
ACCO2	<i>Acacia constricta</i>	whitethorn acacia	Native
ACNE2	<i>Acer negundo</i>	boxelder	Native
ADCA	<i>Adiantum capillus-veneris</i>	common maidenhair	Native
ALWR	<i>Aloysia wrightii</i>	Wright's beebrush	Native
AQCH	<i>Aquilegia chrysantha</i>	golden columbine	Native
BACCH	<i>Baccharis</i> sp.	baccharis species	N/A
BASA4	<i>Baccharis salicifolia</i>	mule's fat	Native
BASA	<i>Baccharis salicina</i>	Emory's baccharis	Native
BERBE	<i>Berberis</i> sp.	barberry	Native
BEHA	<i>Berberis haematocarpa</i>	red barberry	Native
BOLA2	<i>Bothriochloa laguroides</i>	silver beardgrass	Native
BOCU	<i>Bouteloua curtipendula</i>	sideoats grama	Native
CEGR	<i>Ceanothus greggii</i>	desert ceanothus	Native
CERE2	<i>Celtis reticulata</i>	netleaf hackberry	Native
CELT1	<i>Celtis</i> sp.	hackberry	N/A
CEMO2	<i>Cercocarpus montanus</i>	alderleaf mountain mahogany	Native
CLEMA	<i>Clematis</i> sp.	leather flower	N/A
ECHIN3	<i>Echinocereus</i> sp.	hedgehog cactus	N/A
EQUIS	<i>Equisetum</i> sp.	horsetail	N/A
EQLA	<i>Equisetum laevigatum</i>	smooth horsetail	Native
ERICA2	<i>Ericameria</i> sp.	goldenbush	N/A
FAPA	<i>Fallugia paradoxa</i>	Apache plume	Native
FRCA12	<i>Frangula californica</i>	California buckthorn	Native
FRVE2	<i>Fraxinus velutina</i>	velvet ash	Native
FUS1	<i>Fuirena simplex</i>	western umbrella-sedge	Native
GAWR3	<i>Garrya wrightii</i>	Wright's silktassel	Native
GUSA2	<i>Gutierrezia sarothrae</i>	broom snakeweed	Native
JUNCU	<i>Juncus</i> sp.	rush	N/A
JUMO	<i>Juniperus monosperma</i>	oneseed juniper	Native
LATR2	<i>Larrea tridentata</i>	creosote bush	Native
LOCA2	<i>Lobelia cardinalis</i>	cardinalflower	Native
LOAL	<i>Lonicera albiflora</i>	western white honeysuckle	Native
LONIC	<i>Lonicera</i> sp.	honeysuckle	N/A
LYCA4	<i>Lythrum californicum</i>	California loosestrife	Native
MALUS	<i>Malus</i> sp.	apple	N/A
NOLIN	<i>Nolina</i> sp.	beargrass	N/A
POVI9	<i>Polypogon viridis</i>	beardless rabbitsfoot grass	Non-native
PODE3	<i>Populus deltoides</i>	eastern cottonwood	Native

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

USDA Code	Scientific Name	Common Name	Nativity
POFR2	<i>Populus fremontii</i>	Fremont cottonwood	Native
PRGL2	<i>Prosopis glandulosa</i>	honey mesquite	Native
QUERC	<i>Quercus</i> sp.	oak	N/A
QUTU2	<i>Quercus turbinella</i>	Sonoran scrub oak	Native
RHTO6	<i>Rhamnus tomentella</i> Benth. ssp. <i>ursina</i> (Greene) J. O. Sawyer	Buckthorn	Native
RHLA3	<i>Rhus lanceolata</i>	prairie sumac	Native
RHMI3	<i>Rhus microphylla</i>	littleleaf sumac	Native
RHUS	<i>Rhus</i> sp.	sumac	N/A
RHTR	<i>Rhus trilobata</i>	skunkbush sumac	Native
RHVI3	<i>Rhus virens</i>	evergreen sumac	Native
SAGO	<i>Salix gooddingii</i>	Goodding's willow	Native
SALIX	<i>Salix</i> sp.	willow	N/A
SANI	<i>Salix nigra</i>	black willow	Native
SOLID	<i>Solidago</i> sp.	goldenrod	N/A
TAMAR2	<i>Tamarix</i> sp.	tamarisk	N/A
TYPHA	<i>Typha</i> sp.	cattail	N/A
VIST	<i>Viguiera stenoloba</i>	resinbush, skeletonleaf goldeneye	Native
VIAR2	<i>Vitis arizonica</i>	canyon grape	Native

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 960/122840, November 2013

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™