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Natural Resource Stewardship and Science

Status of Climate and Water Resources at Gila Cliff Dwellings National Monument

Water Year 2017

Natural Resource Report NPS/SODN/NRR—2019/1890



ON THE COVER

West Fork of the Gila River, Gila Cliff Dwellings National Monument. NPS photo.

Status of Climate and Water Resources at Gila Cliff Dwellings National Monument

Water Year 2017

Natural Resource Report NPS/SODN/NRR—2019/1890

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Glossary

anthropogenic: caused by human activities

aquifer: an underground layer of rock, sand, etc., containing water

defile: A steep sided gully or drainage

dissolved oxygen: the amount of oxygen in a solution, typically measured as a concentration of milligrams of DO per liter

facultative wetland species: plants usually occurring in wetlands

macroinvertebrate: insects, snails, clams and other animals without backbones that can be seen without magnification

non-native: a plant or animal that occurs outside of its native or natural range

obligate wetland species: plants almost always occurring in wetlands

orifice: aboveground emergence of a spring

perennial: persisting for many growing seasons (plant); flowing throughout the year (spring)

pH: a measure of hydrogen ion concentration; a measure of the acidity or alkalinity of a solution

rheocrene: spring type that emerges as a flowing stream

riparian: associated with the edges of a spring, stream, lake, or river, such as a riparian species, landowner, etc.

specific conductivity: a measure of how well water can conduct an electrical current

spring: a place where water naturally flows from the ground or rock upon the land to form a stream or into a body of water

spring box: a box structure engineered to capture, filter and/or transport spring water

temperature: the degree or intensity of heat present in water

total dissolved solids: a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized, or micro-granular suspended form

Executive Summary

Climate and hydrology are major drivers of ecosystems. They dramatically shape ecosystem structure and function, particularly in arid and semi-arid ecosystems. Understanding changes in climate, groundwater, streamflow, and water quality is central to assessing the condition of park biota and key cultural resources. This report combines data collected on climate, springs, and surface water to provide an integrated look at climate and water conditions at Gila Cliff Dwellings National Monument (NM) during water year 2017 (October 2016–September 2017).

Overall annual precipitation was 126% of normal in WY2017. A wet winter and strong monsoon season made up for below-normal rainfall in the early fall and early spring. Temperatures tended to be warmer than normal and there were substantially fewer extremely cold days. The reconnaissance drought index indicates that WY2017 continued the recovery from a regional drought that began in 2000.

Two springs are monitored at the monument. Both had surface water present and flowing when visited in WY2017. Both were wetted and showed little sign of change or disturbance.

This was the first water year of data for USGS stream gauge 09430010. The U.S. Geological Survey maintains the equipment for this gauge, and also collects and manages its data. The hydrograph for WY2017 was typical of the Upper Gila Basin, with peak streamflow occurring during late February to early April. The largest flow event occurred in late December. Snowmelt and late winter storms made crucial contributions to the hydrologic season. The median value for the winter season (53.2 cfs) was nearly 50% greater than the spring median value (17.0 cfs) and more than eight times the summer value (6.43 cfs).

There were 240 discrete analyses of water samples collected from the West Fork Gila River index site in WY2017. Of these samples, 87 were associated with New Mexico surface-water criteria. Of those 87 samples, there was one exceedance of state standards, meaning that 98.9% of samples were compliant with state standards. The single exceedance was for total cyanide. It is suspected that the volcanic geology of the watershed is the source of this cyanide.

Macroinvertebrates were collected to provide data for compliance with the New Mexico biological standards. In WY2017, the index reach scored 54.99 on the New Mexico integrated biological index, putting it in the “fair” category.

Acknowledgements

We thank former superintendent Hugh Hawthorne and the staff and volunteers of Gila Cliff Dwellings National Monument for their on-site support of the monitoring effort. Colombe LeFort assisted with data collection and processing. Kristen Bonebrake led the management and posting of all data products. Macroinvertebrate identifications were completed by the Utah State University BugLab, and TestAmerica (Arizona) processed the water chemistry samples. Andy Hubbard contributed to this report.

1 Introduction

Climate and hydrology are major drivers of ecosystems. They dramatically shape ecosystem structure and function, particularly in arid and semi-arid ecosystems. Understanding changes in climate, groundwater, streamflow, and water quality is central to assessing the condition of park biota and key cultural resources. This document summarizes climate and water resource conditions for water year (WY) 2017 (October 2016–September 2017) at Gila Cliff Dwellings National Monument (NM), a small (216-ha) National Park Service unit in southwestern New Mexico. Detailed analyses of trends will follow in subsequent reports as the period of record warrants such assessments. For details on the monitoring protocols, park setting and resources, and information on other resources of management focus, please see http://www.nps.gov/im/sodn/.

2 Climate

2.1 Background and methods

Climate is the suite of characteristic meteorological conditions of the near-surface atmosphere at a given place (Strahler 2013), and is the primary driver of ecological processes on earth. A broader temporal scale (seasons to years) is what distinguishes climate from the instantaneous conditions reflected by the term, "weather."

Climate mediates the fundamental properties of ecological systems, such as soil–water relationships, plant–soil interactions, net primary productivity, the cycling of nutrients and water, and the occurrence, extent, and intensity of disturbances—in short, the underpinnings of the natural resources that the National Park Service manages and protects.

Gila Cliff Dwellings NM has had a nearby National Oceanic and Atmospheric Administration (NOAA) Cooperative Observer Program (COOP) weather station since 1957 (GILA HOT SPRINGS #0293530). This station provides a reliable long-term climate dataset. We used this excellent data source for all subsequent analyses. The monument has also hosted a Remote Automated Weather Station (RAWS) since 1998. Both stations are accessible through www.climateanalyzer.org. See the SODN climate monitoring protocol (Hubbard et al. in prep) for details on methods and data handling.

An Aridity Index (UNEP 1992), based on the long-term average annual precipitation relative to the average annual potential evapotranspiration, can be a useful tool for contrasting the local climate of national parks (Figure 2-1). Used globally to classify climate zones, aridity index seeks to answer the question "How dry is dry?" (Tsakiris and Vangelis 2005). Using the period of record (1957–present), the climate of Gila Cliff Dwellings NM is classified as semi-arid.

2.2 Results and discussion

2.2.1 Departures from 30-year normals (1981–2010)

Data quality during WY2017 was excellent, with missing values on only one day. Overall annual precipitation was 126% of normal for Gila Cliff Dwellings NM (20.41" vs 16.26").

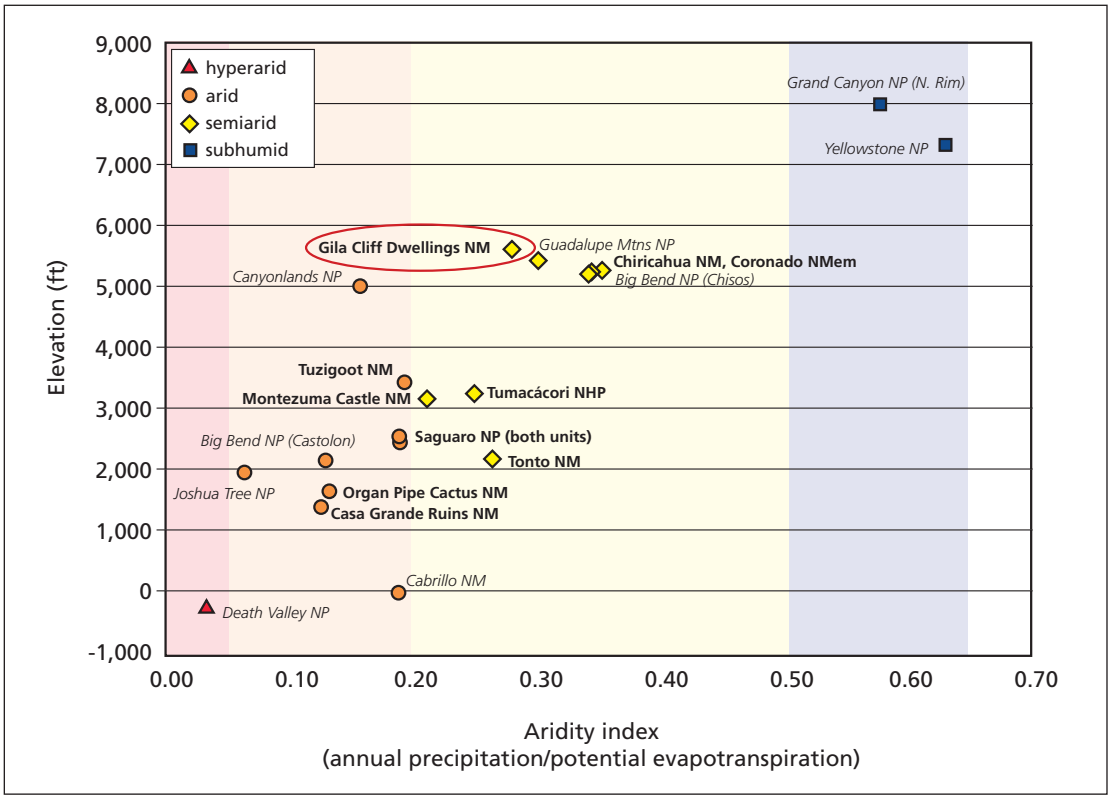


Figure 2-1. Aridity index vs. elevation of selected southwestern national parks, including Gila Cliff Dwellings National Monument. Figure from Hubbard and others (in prep).

2.2.1.1 Cool season (October–March)

Overall precipitation was substantially greater than normal (142% or +2.27") for the fall and winter of WY2017. There was little rain in October and March. November through February were wetter than normal, with 157–262% of the 1981–2010 normal precipitation levels (Figure 2-2). Fall and early winter air temperatures were generally warmer than normal—except in January, when the mean monthly maximum was 2°F below normal. The mean monthly maximum temperature was unusually high in October and March (+6.4°F and +8.7°F, respectively). As is typical, mean monthly low temperatures were below freezing in November–March. The mean daily diurnal temperature range in fall and winter was 38°F, and up to 54°F in a single day.

2.2.1.2 Warm season (April–September)

Overall precipitation was above normal (114%, 1.38") for the spring and summer months of WY2017. A strong and early monsoon season made up for a drier-than-normal April, May, and September (Figure 2-3). Mean monthly maximum air temperatures were warmer than normal during the warm season, while mean monthly minimum temperatures were generally lower than normal. The mean daily diurnal temperature range in spring and summer was 40°F, and up to 60°F in a single day.

2.2.2 Reconnaissance drought index

Reconnaissance drought index (Tsakiris and Vangelis 2005) provides a measure of drought severity and extent relative to the long-term climate based on the ratio of average precipitation to average potential evapotranspiration over shorter periods of time (seasons to years). The reconnaissance drought index for Gila Cliff Dwellings NM reflects the extended regional drought since 2000 (Figure 2-4). From the perspective of both precipitation and evaporative demand, however, conditions at the park began a recovery in WY2015 that continued through WY2017. The five-year moving mean of total annual precipitation from years 1981–2017 (Figure 2-5) suggests that that the last three "wet" years have started to remedy the multi-year precipitation deficit.

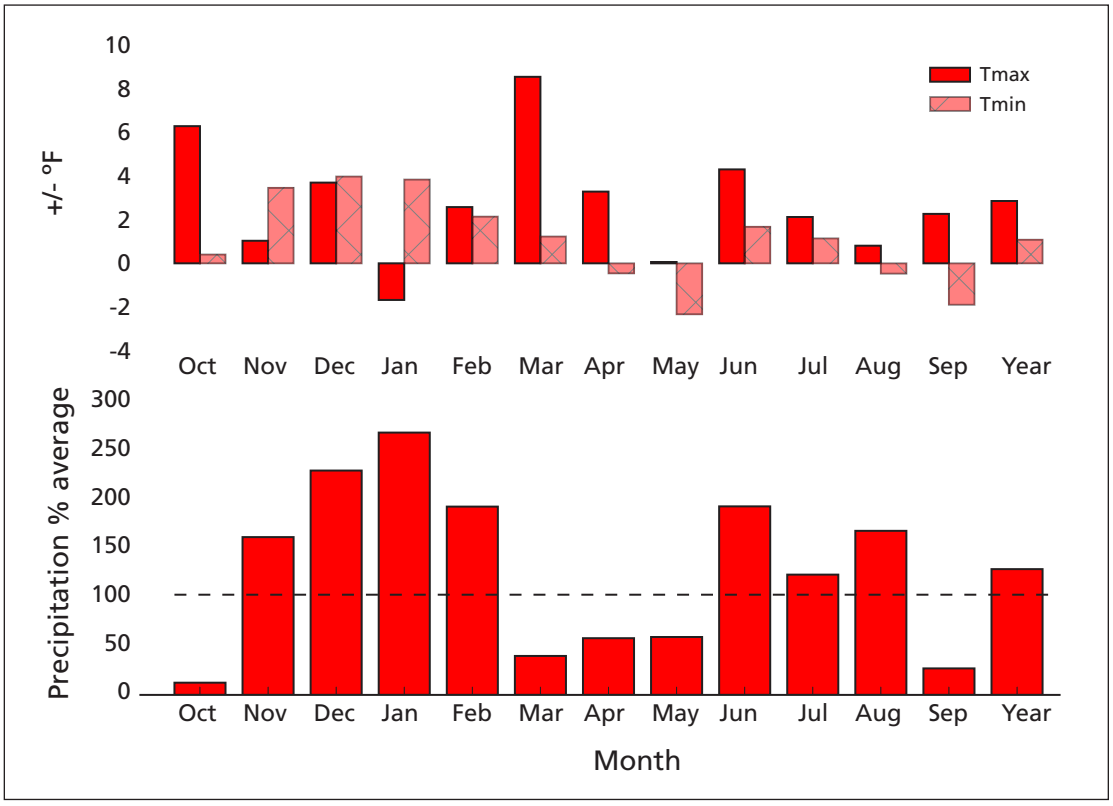


Figure 2-2. Departures from 30-year (1981–2010) normal minimum and maximum air temperature and precipitation, Gila Cliff Dwellings National Monument. Graphics generated by climateanalyzer. org.

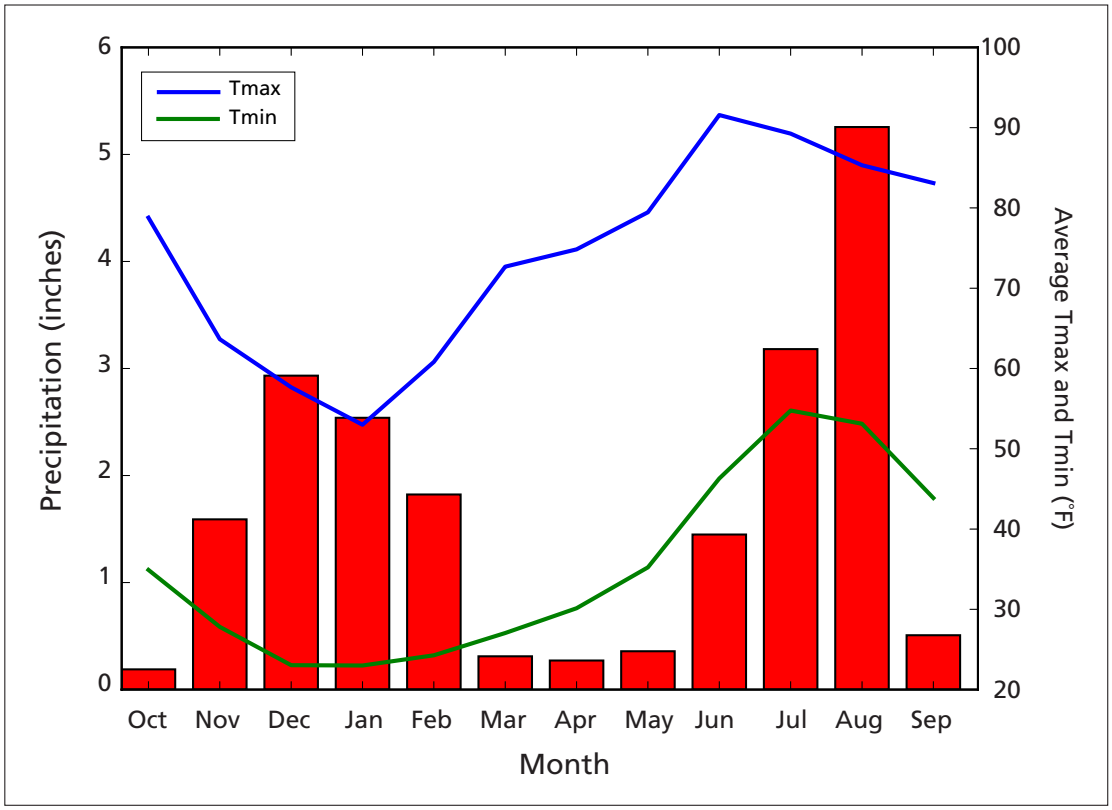


Figure 2-3. Climogram for water year 2017, Gila Cliff Dwellings National Monument. Graphics generated by climateanalyzer.org.

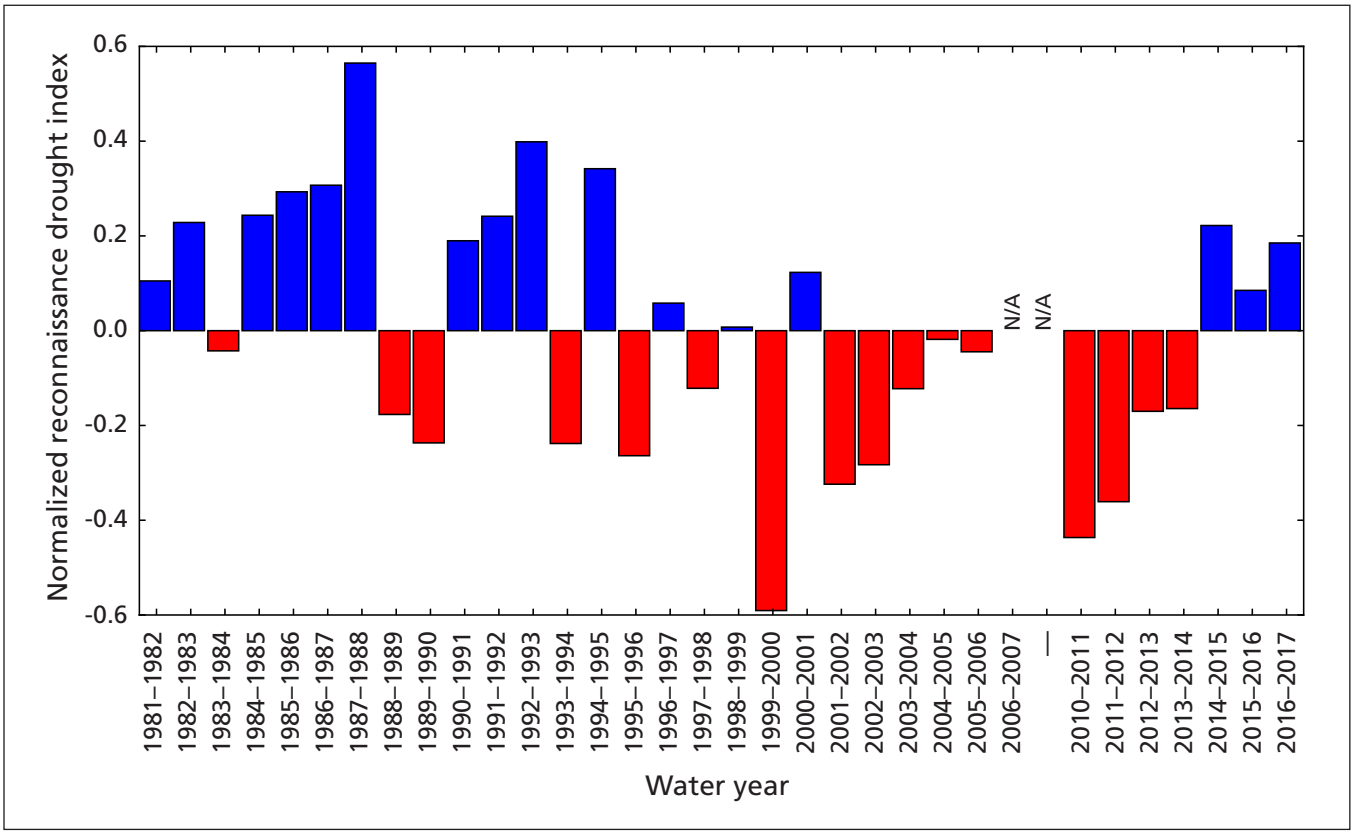


Figure 2-4. Reconnaissance drought index, Gila Cliff Dwellings National Monument, water years 1981– 2017. "n/a" = insufficient data to generate reliable RDI estimates. The station was abandoned from 2007 to 2009. Graphics generated by climateanalyzer.org.

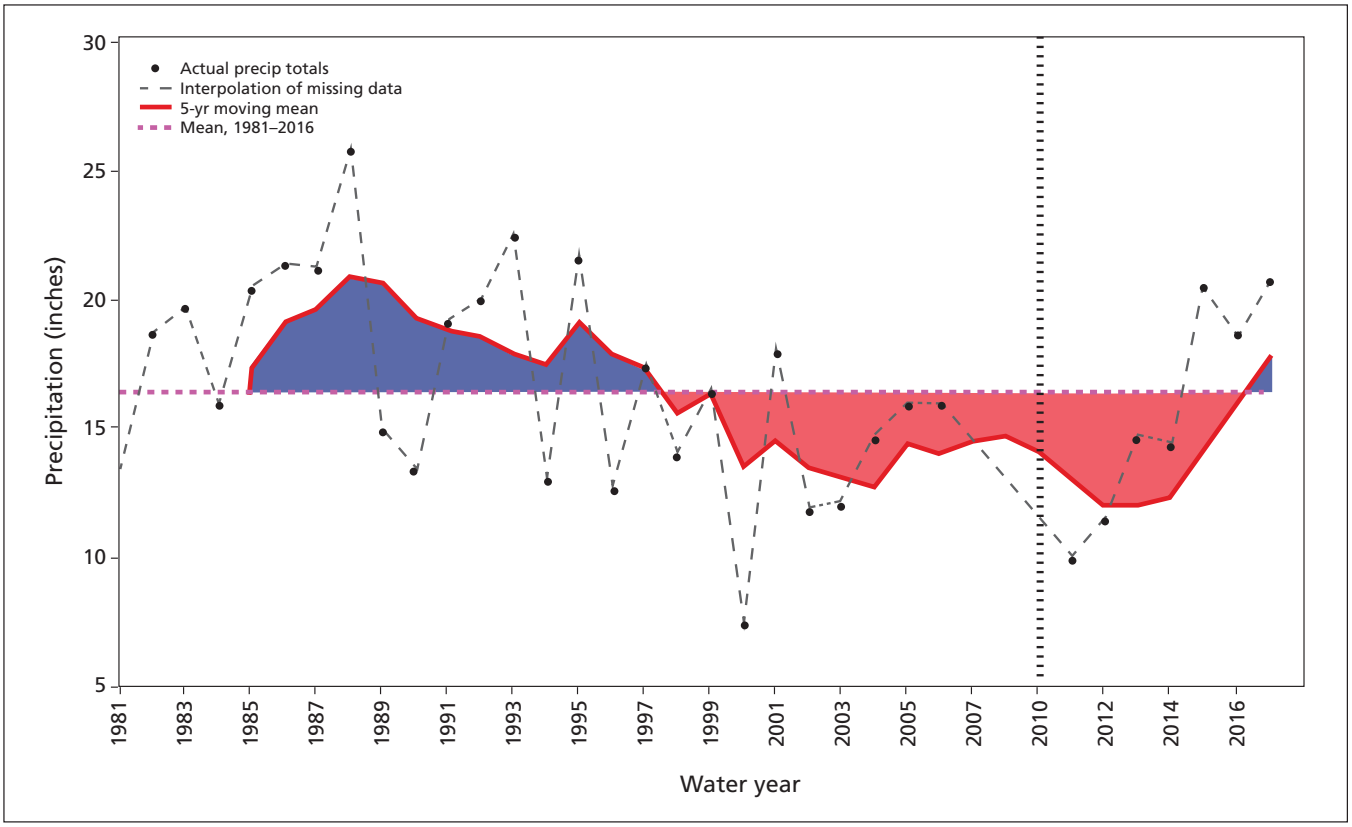


Figure 2-5. Five-year moving mean of annual precipitation, Gila Cliff Dwellings National Monument, 1981–2017. The moving mean (solid red line) is based on a timeseries with 10.8% (4 of 37) missing values, and includes the current year and previous four years. Blue and red fields represent water surplus and deficit. Missing years are linearly interpolated (dashed grey lines). The station was abandoned from WY2007–2010. Graphics generated by climateanalyzer.org.

2.2.3 Extreme weather events

Stochastic events, such as air-temperature extremes and unusually intense precipitation events, may be as important to understanding ecological patterns as long-term climate averages are. Although high air temperatures are a defining feature of warm deserts, extreme frost events also have important consequences for Arizona–New Mexico Mountains ecosystems. In particular, sustained low air temperatures can damage or even kill long-lived keystone plants (including the large deciduous trees that dominate the riparian woodlands of the park) (Turner et al. 2003) and aquatic organisms. Extreme precipitation events can also cause localized flooding and erosion events, spur or inhibit plant productivity and reproduction, and modify animal behavior.

Extremely cold days (<13°F, 5th percentile of 1981–2010 data) occurred about 80% less often than normal in WY2017 (4 vs. 19.7 ± 1.9 days), and were of a shorter duration (1.3 consecutive days vs. 2.1 ± 0.1 days). No days remained below 32°F all day.

The number of extreme precipitation events (>1") in WY2017 occurred at twice the normal frequency (4 vs 2.3 days for 1981–2010). Large events occurred on November 4 (1.04"), December 22 (1.35"), January 15 (1.28"), and August (1.87").

3 Springs

3.1 Background

Surface water is rare in the desert southwest. While a few perennial rivers and lakes exist, they are rare and widely distributed across the region. Because most water from thundershowers produces scouring flows that quickly pass through ephemeral streams and arroyos, springs often provide the most persistent, reliable water for humans and wildlife (Sada and Pohlmann 2007). 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 and a substantial portion of regional aquatic and riparian biodiversity (Hubbs 1995). Springs and their related ecosystems are considered to be of high priority for providing goods and services to humans and wildlife (Stevens and Meretsky 2008). 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.

Gila Cliff Dwellings National Monument and much of the surrounding watershed was burned in 2011 by the Miller Fire and in 2012 by the Whitewater–Baldy Fire. These fires likely impacted springs in the monument, as indicated in the results below. Both of the monument's springs are located in drainages: one in Cliff Dweller Canyon, the other in an unnamed drainage upstream of the cliff dwelling (Figure 3-1).

3.2 Methods

The overarching goal of the Sonoran Desert Network's arid-land springs monitoring program is to detect broad-scale changes in aquatic and riparian ecological condition by observing selected drivers, stressors, and processes (McIntyre et al. 2018). To meet this goal, network staff monitors a suite of vital signs and measures organized into four modules: water quantity (including persistence), water quality, site condition, and site characterization (Table 3-1). A brief description of the data collection and processing methodologies followed by SODN staff at Gila Cliff Dwellings NM during WY2017 is presented below. Detailed descriptions of these procedures will be available in the published protocol.

3.2.1 Site location

Variation in local geology and hydrology make it difficult to specify meaningful target populations for springs, even on local scales (Predick 2016; Weissinger et al. 2017). Instead, we focus our monitoring effort on "sentinel springs" selected using a decision tree that incorporates the following considerations:

1. Management priority, access, and stable sampling locations (*sensu* Weissinger et al. 2017);
2. Presence of wetland species, aquatic habitat (surface water) persistence, scouring (repeatable measurement location), and human disturbance used to prioritize springs to monitor for climate change impacts (Sada 2013a, 2013b); and
3. Surface water presence and persistence, wetland species, and disturbance criteria developed by Thompson and others (2002).

In general, springs were *not* chosen as sentinel sites if they:

- Were inaccessible according to network safety protocols and/or took too long to access (>3-hour hike).
- Were too small for any type of survey (e.g., they had no observable or measurable flow, had no perennial riparian vegetation, or consisted of little more than "wet spots" on the ground or cliff face).
- Had extensive modification or diversion.
- Were intermittent streams (i.e., channel was runoff-dominated and subject to scour).

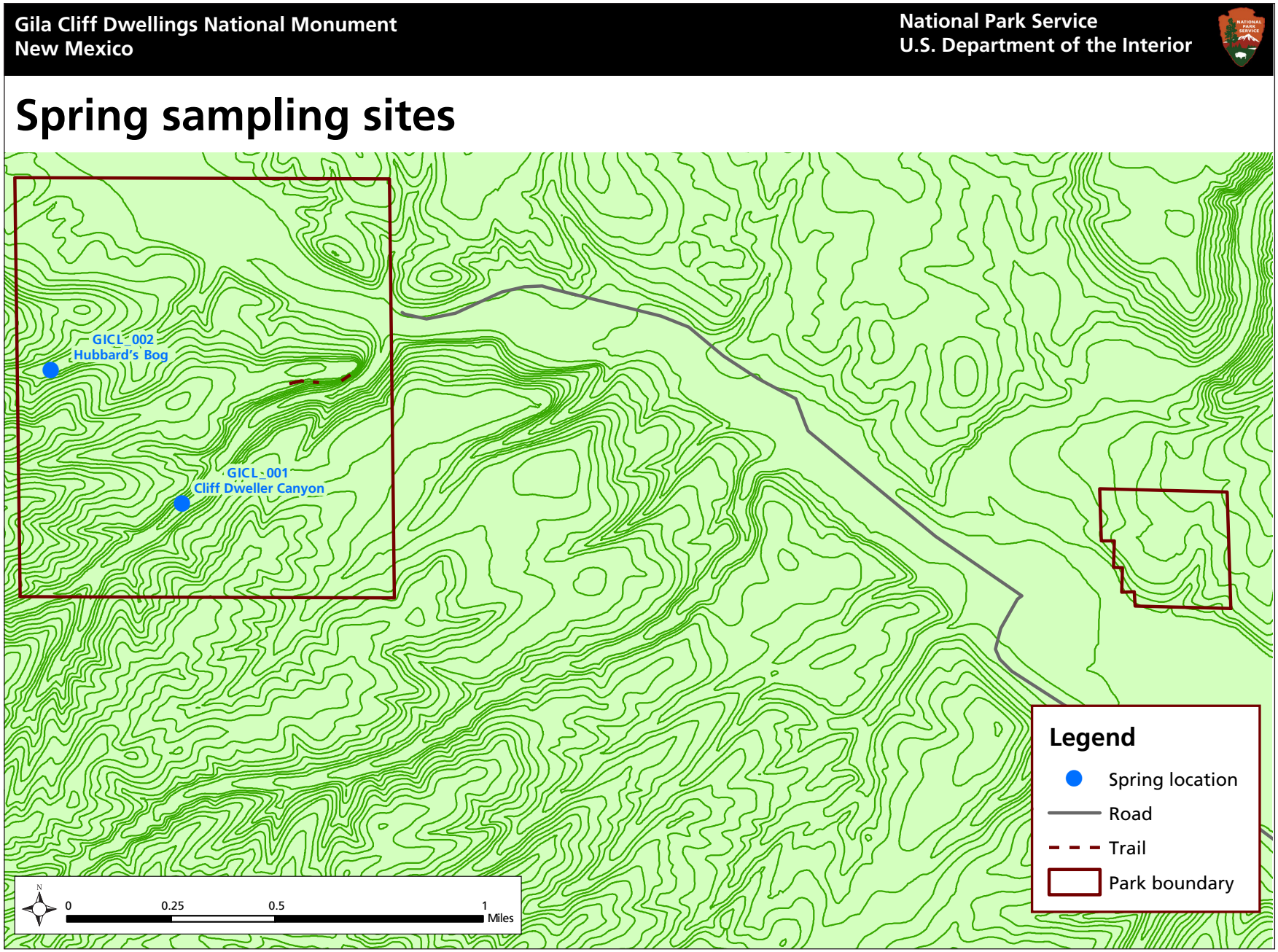


Figure 3-1. Locations of the springs monitored at Gila Cliff Dwellings National Monument in WY2017.

Table 3-1. Objectives and metrics for modules of the springs monitoring protocol.

Module	Vital signs	Monitoring objective(s)	Measured parameters	Measurement frequency
Water Quantity	Persistence of springs	Determine status and long-term trend in the persistence of surface water (number of dry days)	Number of wet and dry days	Every 1 or 2 hours
	Surface water dynamics	Determine status of spring discharge and wetted extent	Spring discharge, wetted extent (length, width, depth)	Annual, in spring
Water Quality	Water quality (core parameters)	Determine status and long-term trend in core water-quality parameters (temperature, pH, conductivity, and dissolved oxygen)	Temperature, pH, specific conductance, dissolved oxygen	Annual, in spring
	Water chemistry, pollutant metals (metal and metalloids)	Determine status in select metals and metalloids, inorganics, and alkalinity	Potassium, magnesium, calcium, sulfate, alkalinity, chloride	Annual, in spring
Site Condition	Invasive/ non-native plants	Determine presence (status) of select obligate/facultative wetland plants and non-native plants	Presence of species, genera, and families	Annual, in spring
		Determine status and long-term trend of anthropogenic and natural disturbances	Categorical rating of disturbance categories	
Site Characterization	None	None. Information from this module is intended to provide on-site contextual information to assist in the interpretation of data collected for the other three modules.	Contextual information	Every 5 years

- Showed signs of frequent scouring (i.e., erosion).
- Were a site park staff requested be excluded from sampling.

It is acknowledged that these parameters limit the statistical inference provided by this design to only the individual spring over time.

3.2.2 Site condition

The disturbance assessment is a qualitative measure of natural and anthropogenic disturbance and the level of stress on vegetation and soils in spring ecosystems. Types of natural disturbance evaluated included flood, drying, fire, wildlife, wind throw, and insects. Types of anthropogenic disturbance included roads and off-highway vehicle trails, hiking trails, and contemporary human use as evidenced by presence of campsites, fire rings, trash, etc. An "other" category was also included. Magnitude of each disturbance on the spring was classified on a scale of 1–4, where:

- **1 = Undisturbed.** No evidence of recent or historical factors or activities. Because 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.
- **2 = Slightly disturbed.** Little evidence that vegetation or soils have been disturbed. Evidence of past disturbance may be present if impact to vegetation and soils appears minimal or is no longer evident. Riparian vegetation community appears vigorous.
- **3 = Moderately disturbed.** Evidence of recent, comparatively high disturbance to vegetation or soils. Height or distribution of riparian vegetation is reduced. The disturbance could be of relatively low magnitude, covering more than half the spring ecosystem area, or of higher magnitude, covering a small portion of the ecosystem. Less than 50% of spring banks are covered by vegetation. Springbrooks contain > 50% of natural discharge because they are impounded or dredged, or contain spring boxes collect water.
- **4 = Highly disturbed.** Evidence of significant impact on vegetation and soils across most of the spring ecosystem. Less than 50% of the banks are covered by riparian vegetation.

3.2.3 Water quantity

Water quantity determines the stability and persistence of a spring system, as influenced by aquifer size, rate of groundwater recharge, and geology (Sada 2013a; 2013b). In arid regions, recharge tends to be sporadic and confined to relatively small areas, but discharge can remain consistent until water tables decline below a certain threshold (Kreamer and Springer 2008).

SODN monitors three measures of surface water quantity at springs: volumetric discharge, hydroperiod, and wetted extent. Volumetric discharge calculates the system's surface outflow through a timed sample of water volume. Hydroperiod calculates the variance between a pair of temperature sensors that collect data from primary water emergence sites and ambient air temperature. Wetted extent is a comprehensive metric assessment of the physical length, width, and depth of present surface water.

3.2.4 Water quality

Core water-quality parameters are a group of ecologically important metrics that provide the most basic level of information about water quality (NPS 1992). Aquatic ecosystems depend on the maintenance of particular water-quality conditions to sustain life-supporting biochemical processes to which particular plant and animal communities are adapted. In this sense, water quality is relative for monitoring purposes; deviations from any particular water-quality metric can change a particular system, even those occurring under harsh conditions.

Water-quality monitoring examines three measures: core water-quality parameters, water chemistry, and turbidity. Core parameters sampled by SODN included water temperature, pH, specific conductivity, dissolved oxygen, and total dissolved solids, collected as discrete samples with a multiparameter me-

ter (YSI Professional Plus) deployed on-site. Water chemistry was assessed by extracting surface-water samples on site, then subjecting samples to photometer (YSI 9500 Photometer) analyses examining alkalinity, metals/metalloids, and inorganic compounds. Samples collected on site were analyzed for turbidity with a turbidometer (Hach 2100Q).

3.3 Results

Both springs were visited in May 2017 (Table 3-2). Both had surface water present and flowing. Both were wetted in 2017 and showed little sign of change or disturbance.

3.3.1 Site location

Table 3-3 provides basic site-location information for the two sentinel springs at Gila Cliff Dwellings NM.

Cliff Dweller Canyon Spring is a rheocrene spring that emerges in a runoff-dominated channel (intermittent channel emergence). The only orifice, Orifice A, emerges at the intersection of the channel and a large bedrock wall on river right. In WY2017, it flowed for beyond 500 meters. The springbrook flowed over gravel, cobble, and bedrock substrate and remained narrow (21–98 cm width). The flow was quick, clear, and cold, with little algae or detritus. The springbrook flowed continuously downstream before terminating into the West Fork Gila River (Figure 3-2).



Figure 3-2. Springbrook at Cliff Dweller Canyon Spring (site GICL_001).

Hubbard's Bog is a rheocrene spring that emerges in a runoff-dominated channel (intermittent channel emergence). The only ori-

Table 3-2. Site location information and metrics for sentinel springs, Gila Cliff Dwellings NM, WY2017.

Site code	Site name	Date visited	Wet/Dry
GICL_001	Cliff Dweller Canyon Spring	7/19/2016	Wet
GICL_002	Hubbard's Bog	7/20/2016	Wet

Table 3-3. Site location information and metrics for sentinel springs, Gila Cliff Dwellings NM, WY2017.

Site code	Site name	Spring type	Multiple orifices (<200 m)	Dominant discharge type	Slope (deg)	Slope variability	Aspect (deg)	Channel present (#)	Channel length (m)
GICL_001	Cliff Dweller Canyon Spring	Rheocrene	No	Mixed	5	Low	90	1	>500
GICL_002	Hubbard's Bog	Rheocrene	Yes	Mixed	10	Low	75	1	74.2



Figure 3-3. Vegetation at Hubbard's Bog (site GICL_002).

fice, Orifice A, emerges below a small earthen defile mid-channel. In WY2017, it flowed for 74.2 meters before disappearing into streambed sediment. The springbrook flowed over silt and gravel substrate and remained narrow (12–146 cm width). The flow was quick, clear, and cold, with little algae or detritus. The springbrook (Figure 3-3) flowed intermittently along the length of the drainage bottom before disappearing ~200 meters above where the drainage meets the West Fork Gila River.

3.3.2 Site condition

3.3.2.1 Anthropogenic disturbance

There was little to no observed anthropogenic disturbance at either spring in WY2017. The median disturbance magnitude for both springs was 1 (Table 3-4), the lowest possible value (see Section 3.2.2). Results from pilot work conducted in WY2016 were the same, with a median value of 1. This indicates the sites are likely not frequently impacted by human activity. The drainage occupied by Hubbard's Bog is relatively remote and unremarkable from the nearest trail, not attracting attention from hikers.

3.3.2.2 Natural disturbance

There was little indication of natural disturbance to either spring in WY2017. The median disturbance magnitude for both springs was 1 (Table 3-5), the lowest possible value (see Section 3.2.2).

Cliff Dweller Canyon Spring is located in an ephemeral stream channel, and thus has an inherent propensity for disturbance (i.e., flooding during intense precipitation events). However, there is little indication of recent flow events in the channel, and little evidence of the fires that occurred in 2011 and 2012.

At Hubbard's Bog and in the channel/along the springbrook, there was evidence of the fire that burned the area in 2012 (e.g., burned stumps). Impacts from this fire may be contributing to the increased amount of water flowing through the system (see Section 3.3.3). The relative lack of vegetation following a fire may result in reduced evapotranspiration and greater output by springs (i.e., when water is not captured and transferred to the atmosphere by plants, it remains travelling through the ground, eventually to emerge at the spring). In the future, this spring may decrease in hydroperiod and flow rates as plants recover and reduce the water available to be discharged at the spring.

3.3.3 Water quantity

3.3.3.1 Discharge (volumetric or visual estimate as appropriate)

Both of the springs visited during WY2017 were flowing. Much more water was flowing through the system in WY2017 than in WY2016 (Table 3-6). The flow from Cliff Dweller Canyon Spring was nine times greater in WY2017 than WY2016. At Hubbard's Bog, there was a measurable discharge of almost two liters per minute, compared to no measurable discharge in WY2016. The increase in discharge at both springs in WY2017 may have been influenced by the lingering impact of the fire in 2012, and the above-average precipitation during WY2017 (see Figure 2-2).

Hydroperiod—. Temperature-sensor data indicated that both springs were wet for the entire sample period in WY2017 (Figure 3-4).

Table 3-4. Anthropogenic disturbance magnitudes[†] for springs, Gila Cliff Dwellings NM, WY2017.

Site code	Site name	Roads/ OHV trails	Hiking trails	Contem-porary human occupancy	Historic human occupancy	Live-stock	Feral animals	Exotic plant treat-ments	Flow modifi-cation	Other
GICL_001	Cliff Dweller Canyon Spring	1	1	1	1	1	1	1	1	1
GICL_002	Hubbard's Bog	1	1	1	1	1	1	1	1	ND[‡]

[†]Magnitude scores: 1 = Undisturbed, 2 = Slightly disturbed, 3 = Moderately disturbed, 4 = Highly disturbed. See Section 3.2.2 for definitions.

[‡]ND=no data were collected for this parameter.

Table 3-5. Natural disturbance magnitudes[†] for springs, Gila Cliff Dwellings NM, WY2017.

Site code	Site name	Recent flooding	Drying	Fire	Non-livestock use	Wind throw	Insect infesta-tion	Beaver activity	Other
GICL_001	Cliff Dweller Canyon Spring	1	1	1	1	1	1	1	1
GICL_002	Hubbard's Bog	1	1	2	1	1	1	1	1

[†]Magnitude scores: 1 = Undisturbed, 2 = Slightly disturbed, 3 = Moderately disturbed, 4 = Highly disturbed. See Section 3.2.2 for definitions.

Table 3-6. Volumetric measurement of spring discharge.

Site code	Site name	Water year	Discharge L/min (SD)[†]	Data-quality estimate[‡]
GICL_001	Cliff Dweller Canyon Spring	2016	2.92 (0.46)	0.95
		2017	26.6 (1.25)	0.7
GICL_002	Hubbard's Bog	2016	no flow	–
		2017	1.94 (0.12)	0.85

[†]SD=standard deviation

[‡]Data-quality estimate is an estimate of the proportion of flow captured during sampling. It can be interpreted as an index with a range of 0–1, with a score of 1 representing complete reliability, and 0 representing complete unreliability of discharge metric.

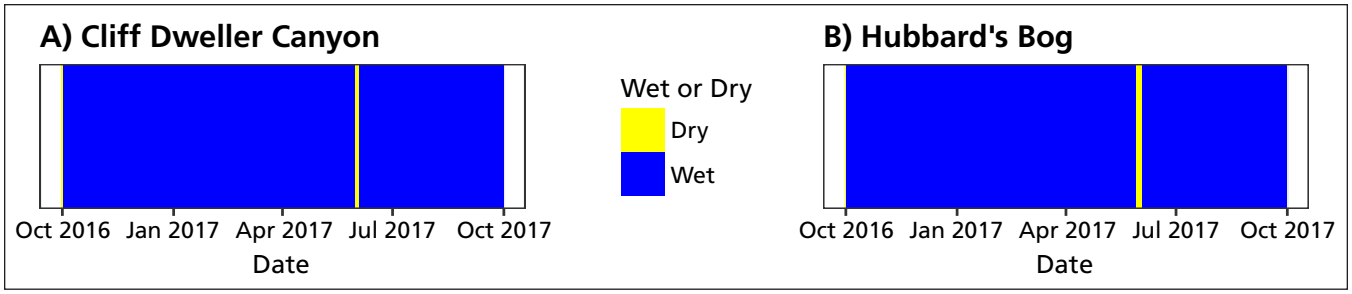


Figure 3-4. Raster of hydroperiod data from (A) Cliff Dweller Canyon Spring (GICL_001) and (B) Hubbard's Bog (GICL_002). The X axis represents the day of the water year (i.e., October 1 is day one). The Y axis represents the water year. Solid blue indicates that the spring was wet for almost of all of the year.

Recent observations of discharge at these two sites (see Table 3-6) support the conclusion that the hydroperiod of these springs was complete for the sample period at the location where the logging temperature sensors are deployed.

Wetted extent and channel morphometrics—. The length and morphometrics of the springbrook convey information about the status and processes occurring at the sample sites. The width and depth of the springbrook (Table 3-7), considered in conjunction with the associated variability (expressed at standard deviation), can provide information about flow and scour events. For example, the relative shallowness of the channels at both springs (width:depth 0.03 at GICL_001 and 0.10 at GICL_002) indicates that flow was limited, along with subsequent scour events in the channels where these springs are located.

3.3.4 Water quality

3.3.4.1 Core parameters

Sampling results for core water-quality parameters were in the range of expected values, except for the unusually low dissolved-oxygen measurement at Hubbard's Bog (Table 3-8). Collecting an accurate dissolved-oxygen measurement can be difficult in shallow spring orifices, potentially leading to artificially low results.

3.3.4.2 Water chemistry

The water chemistry results from both spring samples were within the expected ranges, except for the calcium measurement from Hubbard's Bog (Table 3-9). This measurement (38 mg/L) was much higher than the measurement from Cliff Dweller Canyon Spring (2.8 mg/L). The high measurement may have resulted from the difficulty of collecting samples at this site; even using a syringe, the water's shallow depth made it difficult to collect a sample that did not contain suspended solids.

It is also possible that Cliff Dweller Canyon Spring contains higher concentrations of calcium than the measurement reflects. The recorded concentrations are not a threat to human safety of wildlife.

Table 3-7. Morphometrics (and standard deviation) of springbrooks at Gila Cliff Dwellings NM, WY2017.

Site code	Site name	Mean wetted width (cm)	Mean depth (cm)	Detritus depth (mm)	Mean substrate particle size (mm)
GICL_001	Cliff Dweller Canyon Spring	51.9 (18.7)	1.8 (1.0)	3.7 (8.5)	8.8 (5.6)
GICL_002	Hubbard's Bog	45.2 (34.9)	4.3 (4.5)	0 (0)	5.4 (10.7)

Table 3-8. Sampling results for core water-quality parameters, Gila Cliff Dwellings NM, WY2017.

Site code	Site name	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductivity (µS/cm)	Total dissolved solids (mg/L)	pH	Sunlight
GICL_001	Cliff Dweller Canyon Spring	11.2	5.79	276.6	180.05	7.35	Partial
GICL_002	Hubbard's Bog	13.6	2.26	222.2	ND[†]	7.48	Partial

[†]ND=no data were collected for this parameter.

Table 3-9. Water chemistry data (mg/L), Gila Cliff Dwellings NM, WY2017.

Site code	Site name	Alkalinity ($CaCO_3$)	Chloride	Magnesium	Nitrate[†]	Sulfate	Calcium	Potassium
GICL_001	Cliff Dweller Canyon Spring	115	20	8	ND	5	2.8	0.8
GICL_002	Hubbard's Bog	160	5	7	ND	2	38	0.2

[†]ND=no data were collected for this parameter.

4 Surface Water

4.1 Background

The West Fork Gila River, which crosses the northeastern portion of Gila Cliff Dwellings NM, is a high-quality, mountainous stream. Located in the Gila Wilderness, its watershed is nearly devoid of residential, agricultural, and industrial land use. Visitor impacts are minimal. Consequently, this small (120-mi^2) watershed is more subject to natural stressors than anthropogenic disturbances.

The impacts of natural stressors vary temporally and spatially. The headwaters region of the Gila River has been in a nearly continuous drought since approximately 2000 (see Section 2.2.2). This has resulted in decreased streamflow in the West Fork Gila River, which sometimes runs dry near the park's eastern boundary. This area is also prone to flooding. Inside the park, the narrow floodplain is bounded by canyon walls that act as a bottleneck, increasing the destructive force of high flood waters. This was demonstrated in 2008, when a large rain-on-snow event carved a new stream channel. That event also caused economic damage when camp facilities and a bridge providing access to the monument were washed out, resulting in necessary repairs and reduced visitation.

In July 2012, the Whitewater–Baldy Fire burned in the watershed of the Gila Wilderness. Impacts of this fire have included aquatic habitat degradation, the establishment of invasive exotic plants, and potential future flooding and channel change.

In WY2017, Sonoran Desert Network (SODN) staff made four sampling visits to the West Fork Gila River at Gila Cliff Dwellings NM. Water-quality monitoring occurred at the pedestrian bridge near the park's eastern boundary (Figure 4-1).

4.2 Methods

A brief description of data collection and processing methodologies for stream sampling at Gila Cliff Dwellings NM during WY2017 is presented below. Detailed descriptions of these procedures are available in the network's streams monitoring protocol (Gwilliam et al. 2018).

Sampling is conducted at the West Fork Gila River index site (water quality, quantity, and discharge) and index reach (macroinvertebrates). The index site is located adjacent to the visitor center. The index reach is located downstream of the visitor center (see Figure 4-1).

4.2.1 Water quality core parameters

Core water-quality parameters are a group of ecologically important metrics that provide the most basic level of information about water quality (Irwin 2008). Water temperature, pH, specific conductivity, dissolved oxygen, turbidity, and discharge were sampled. During each visit, we noted hydrologic conditions and sampled core parameters using the following methods:

- On arrival at the site, a multi-parameter meter (YSI Professional Plus) was calibrated and deployed in a well-mixed part of the stream channel, logging temperature, pH, specific conductivity, and dissolved oxygen data at one-minute intervals. The meter was left in the stream for the entire visit.
- Turbidity samples were collected and analyzed within one hour using a portable turbidimeter (HACH 2100P).
- Discharge was measured using a FlowTracker Acoustic Doppler Velocimeter.

In addition to regular sampling, we used a logging multi-parameter instrument (YSI XLM600 V2) to collect data on temperature, pH, specific conductivity, and dissolved oxygen at 15-minute intervals for a minimum of two weeks during quarters 1, 3, and 4. (The sonde was not deployed during quarter 2 in WY2017 due to channel movement and the likelihood of the instrument's being damaged by ice.)

4.2.2 Water quality samples

During each site visit, water samples were collected in a three-liter Nalgene sample-collection bottle, following non-isokinetic sampling methods as described in the Na-

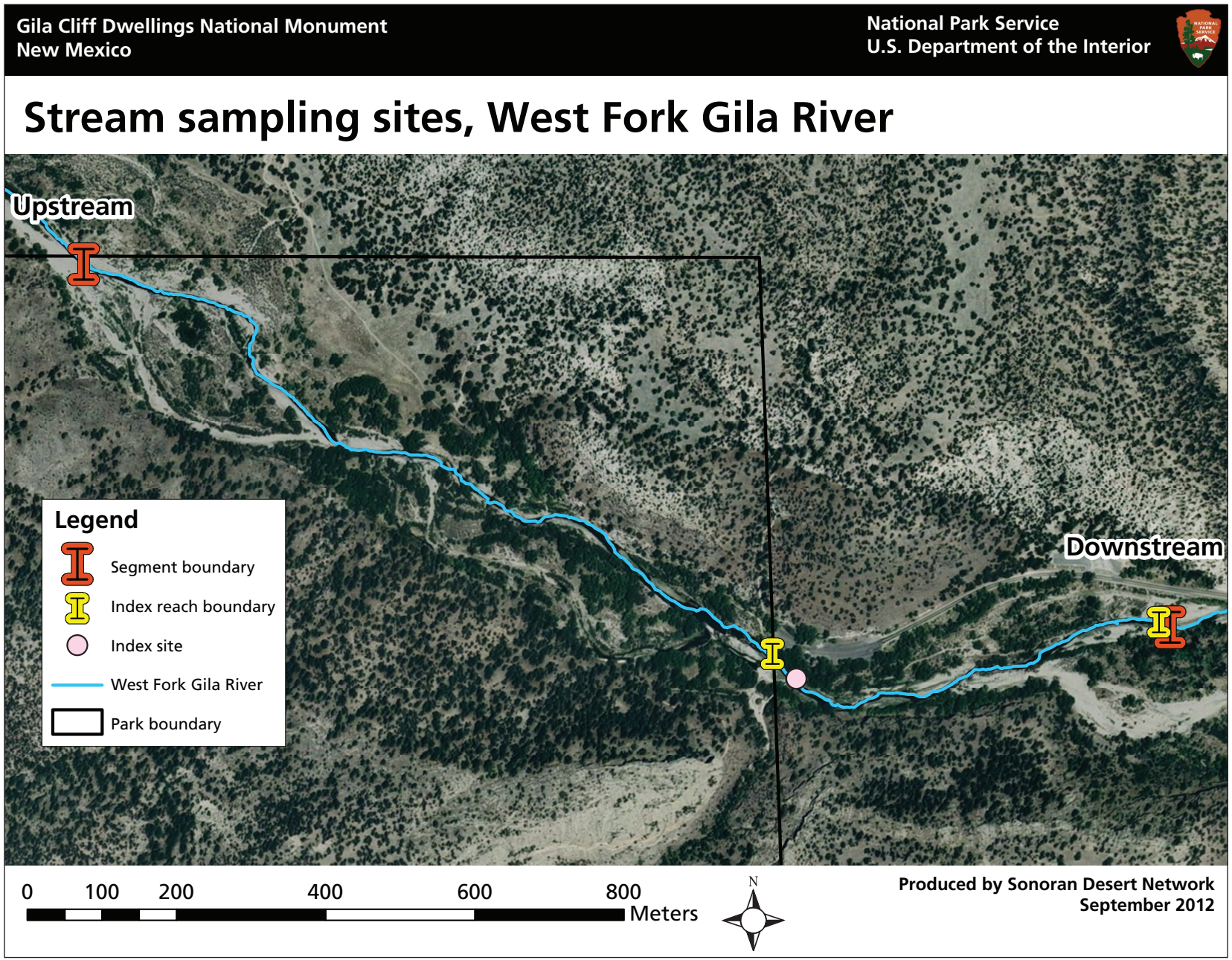


Figure 4-1. Locations of sample units on the West Fork of the Gila River, Gila Cliff Dwellings National Monument. Data on water quality and water quantity are collected at the index site. Macroinvertebrates are collected in the index reach.

tional Field Manual for the Collection of Water Quality Data (USGS 2006). We transferred the sample water to bottles for analysis of bacteria, turbidity, metals, and other constituents. The sample water was filtered and/or treated as required, kept on ice, and dropped off at the contract laboratory. For WY2017, that lab was TestAmerica in Phoenix, Arizona.

4.2.3 Water quantity data

In WY2017, SODN partnered with the U.S. Geological Survey (USGS) to install a stream gauge (USGS 09430010) at the index site (see Figure 4-1). The USGS Las Cruces Field Office operates this gauge following all USGS methods (Sauer and Turnipseed 2010; Turnipseed and Sauer 2010; Kenney 2010). This station uses a water-level radar telemetry system to measure water quantity. A Waterlog radar gauge is mounted to the bottom of the footbridge across the West Fork Gila River (Figure 4-2). Every 15 minutes, the gauge sends a pulse of electromagnetic energy down toward the surface of the river and measures the reflected energy to determine the distance from the radar to the water surface (Sauer and Turnipseed 2010), thereby measuring the elevation of the water. This instrument is attached to a Waterlog data recorder and a Sutron telemetry system using the National Weather Service GOES satellite system. This allows for remote real-time access and logging of water-level data (Sauer and Turnipseed 2010). These real-time data are available at http://www.climateanalyzer.org/sonoran_desert/HADS/wfgn5.

4.2.4 Aquatic macroinvertebrates and habitat

To ensure compatibility of monitoring samples, SODN macroinvertebrate sampling coincides with the index period used by the New Mexico Environment Department. The sampling period for warmwater streams is August 15–November 15 (Jacobi et al. 2006).

The index reach at Gila Cliff Dwellings NM is 570 meters long, starting upstream of the park's western boundary and continuing onto U.S. Forest Service land (see Figure 4-1). The reach contains 11 equally spaced transects. At each transect, we measured wetted width, water depth, velocity, and can-



Figure 4-2. Location of the radar gauge at Gila Cliff Dwellings National Monument. The radar emitter (center of white circle) is not stationed over the center of the stream due to channel movement.

opy cover; estimated substrate size, bank erosion (using the Rosgen Bank Erosion Hazard Index), and diversity of aquatic habitat; and completed a bank erosion hazard index. Two types of samples were collected:

- A quantitative sample was collected from four targeted riffle habitats to provide data on organism abundance. Using a kicknet with a 0.3-meter opening for one minute, a total of 12 replicate samples were collected from a 0.09-m^2 area. At each habitat, we also measured depth, velocity, particle size, and particle embeddedness. This method is comparable to the methods used by the State of New Mexico.
- A reach-wide qualitative sample was collected to develop a comprehensive list of species present in the reach. Using dip- and kicknets, samples were collected from all habitat types within the reach during a one-hour collection period, proportionally allocated by habitat type, and compiled into one composite sample.

Aquatic macroinvertebrate samples were sent to the National Aquatic Monitoring Center (BugLab), a Bureau of Land Management laboratory at Utah State University in Logan, Utah. There, a taxonomist certified by the North American Benthological Society identified all aquatic macroinvertebrates to the lowest taxonomic level possible.

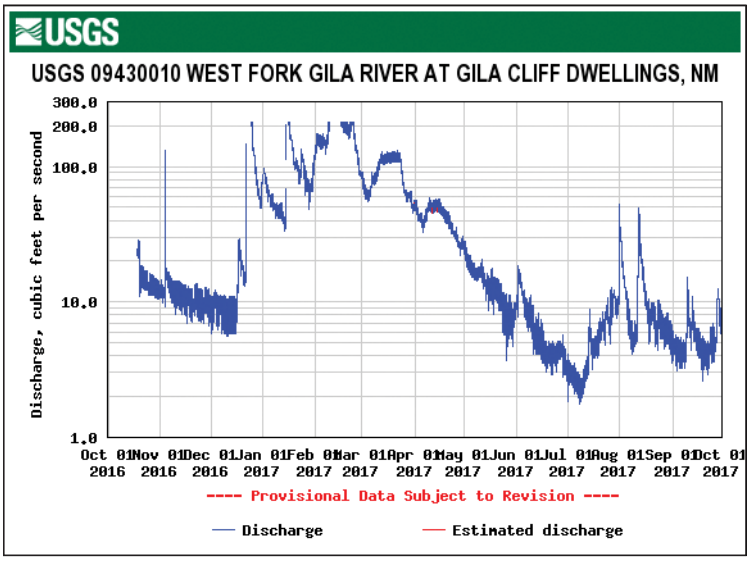


Figure 4-3. West Fork of the Gila River hydrograph (from USGS 09430010).

4.2.5 Data handling and analysis

All water quality and quantity data are stored on the SODN server. This report includes all discrete water quality data collected except for turbidity, coliform, and *E. coli* samples, for which the mean of the triplicate samples are presented. For total coliforms and *E. coli* samples, most probable numbers (MPN/100 mL) are reported (IDEXX 2018). The continuous multi-parameter sonde measurements are presented with the minimum, first quartile, median, third quartile, and maximum to demonstrate variability. When applicable, this report compares SODN water quality data against the State of New Mexico water quality standards (NMAC 2013) and notes any exceedances.

4.3 Results and discussion

4.3.1 Water quantity

This was the first water year of data for USGS stream gauge 09430010. The USGS maintains the equipment for this gauge, and also collects and manages its data. The data record began on 10/18/2016, so it does not represent the entirety of WY2017. However, the majority of the water year was captured by the gauge.

The hydrograph for WY2017 was typical of the Upper Gila Basin (NPS 1998), with peak streamflow occurring during late February to early April, corresponding to snowmelt in the watershed. The WY2017 hydrograph (Figure 4-3) shows truncated peaks on the larger flow events during the year. This truncation is due to a lack of discharge measurements during high-flow events. These measurements are difficult to collect due to dangerous conditions when attempting to wade in streams with elevated flow.

The largest flow event during WY2017 occurred in late December 2016 (Figure 4-3). It was likely a ~1,000–2,000 cubic feet per second (cfs), bankfull-plus event, with the stream topping the banks in places—but not an extensive flood event. This type of flow event is important for the maintenance of stream geomorphology and the movement of organic material through the system (Rosgen 1996).

4.3.1.1 Mean annual discharge and seasonal statistics

The mean annual discharge at the Gila Cliff Dwellings NM index site in WY2017 was 36.38 cfs (SD 46.04), with a median of 12.6 cfs. In WY11 (the last year for which we have flow data meeting quality assurance/quality control requirements for this site), the median discharge was 14.19 cfs (Gwilliam unpublished data). The median values for the hydrologic seasons* (Figure 4-4) illustrate the importance of snowmelt and late winter storms to annual discharge totals. Median discharge for the winter season (53.2 cfs) was nearly 50% greater than the spring median value (17.0 cfs), and more than eight times the summer value (6.43 cfs). In the future, discharge values will be compared to the gauge record, which should provide valuable insight into the physical and biological processes in the West Fork Gila River.

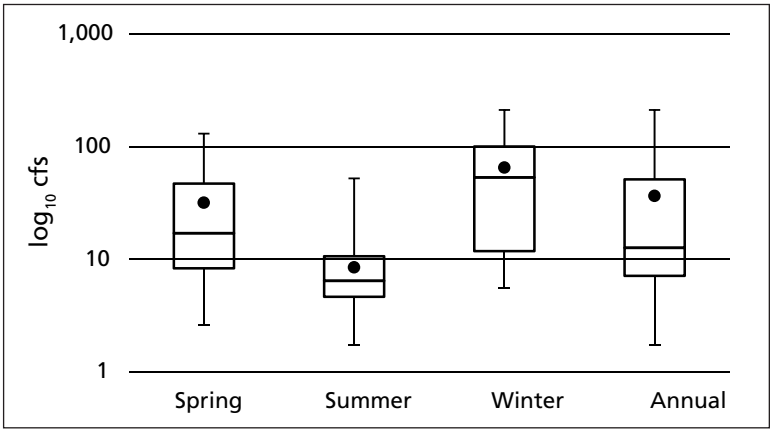


Figure 4-4. Hydrologic-season (as defined in NPS 1998) and annual-discharge statistics for the West Fork Gila River in WY2017. The top whisker is the maximum value for the parameter. The boxes indicate the 25th (bottom of box) to 75th (top of box) percentile of the data, with the line in the middle as the median value. The bottom whisker represents the minimum value. The mean value is indicated by a dot. The variance associated with these mean values is large. For example, as noted in Section 4.3.1.1, the standard deviation (SD) associated with the annual mean value was 46.04 cfs. (The SD was omitted from this graphic for clarity). Please note that the Y axis is measured using a log scale of the discharge (cfs). The statistics were generated from USGS data (USGS 09430010).

4.3.2 Water quality

In WY2017, SODN staff made a total of four sampling visits to the West Fork Gila River index site. Discrete samples were collected in each quarter (Table 4-1). Continuous sampling occurred during deployment periods in quarters 1, 3, and 4. (Continuous sampling did not occur in Q2 due to high-flow conditions that exceeded safety-protocol proscriptions.)

Table 4-1. Sampling dates, West Fork Gila River, WY2017.

Quarter	Sample date
Q1	10/19/2016
Q2	2/8/2017†
Q3	5/2/2017
Q4	8/10/2017

†No continuous data were collected due to unsafe, high-flow, sampling conditions.

A total of 240 discrete analyses were performed on water samples collected in WY2017. Of these, 87 were associated with state standards. There was one exceedance of New Mexico state water quality standards, indicating 98.9% compliance with state standards. The exceedance was for total cyanide (0.038 mg/L; see Table 4-9).

4.3.2.1 Core parameters

Discrete sampling—. The discrete measurements shown in Table 4-2, made in the field, represent conditions at the West Fork Gila River index site during site visits in WY2017. The results were all within the expected range for a mid-elevation stream in New Mexico.

Discharge data were collected during quarterly visits (Table 4-1) at the index site. Measurements fell within the expected range. There were several bankfull events during WY2017. One event in late December 2016 was likely a bankfull-plus event, with water from the river topping the bank sporadically.

***Continuous sampling*—.** A logging multiparameter sonde was deployed for a 2–3 week period during each quarter of WY2017 (excluding Q2) to measure temperature, pH, specific conductivity, and dissolved oxygen at 15-minute intervals (Table 4-3). More than 6,600 measurements were collected. The sonde was not deployed during the second quarter of WY2017 due to high flow condi-

*As defined in NPS (1998), the hydrologic seasons are Summer (July 1–October 31), Winter (November 1–March 14), and Spring (March 15–June 30).

Table 4-2. Discrete data summary for core water-quality parameters, West Fork Gila River, WY2017.

Parameter	Quarter				New Mexico state standard	
	Q1	Q2	Q3	Q4	Measure	Beneficial use
Temperature (°C)	11.4	3.8	11.2	18.3	<23[†]	–
Specific conductivity (µS/cm)	125.0	70.6	103.6	137.0	<400	High-quality coldwater aquatic life
Turbidity (NTU)	1.4	22.3	3.1	1.3	<10 over background[‡]	Park-specific
pH	7.9	8.2	7.7	7.4	6.6–8.8	General
Dissolved oxygen concentration (mg/L)	8.7	10.8	8.4	6.5	>6	High-quality coldwater aquatic life
Discharge	10.4	ND[1]	17.9	6.5	NS	High-quality coldwater aquatic life

[†]Not to be exceeded for four or more consecutive hours on three or more days.

[‡]No more than 10 NTU over background (when background is 50 NTU or less), or 20 percent increase when background is over 50 NTU.

Table 4-3. Sonde deployment date and number of samples collected, West Fork Gila River, WY2017.

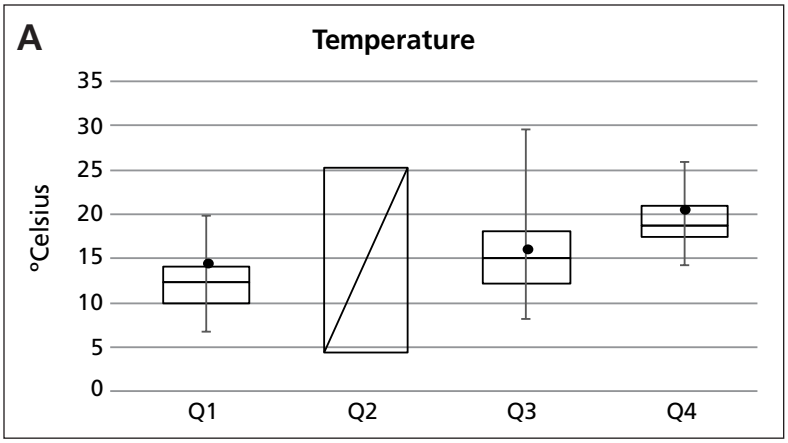
Quarter	Sample period	# samples
Q1	10/18/2016–11/4/2016	1,573
Q2	No probe deployed (winter low temperatures are too cold)	0
Q3	5/1/2017–5/30/2017	2,869
Q4	7/17/2017–8/9/2017	2,194

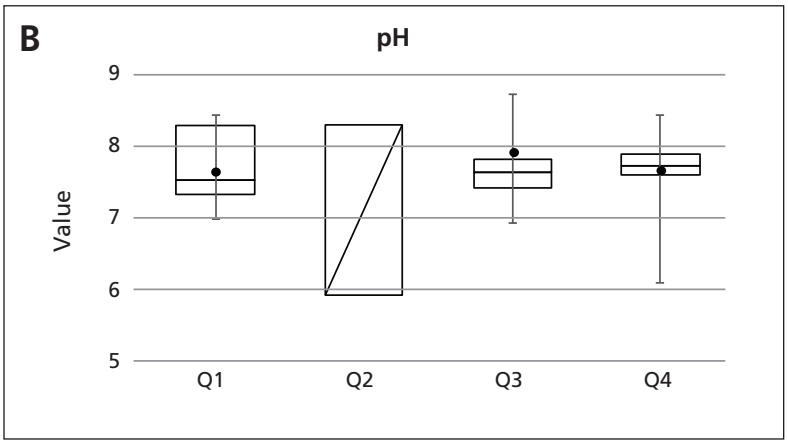
tions during the deployment visit, and concern over possible damage to the sonde by ice.

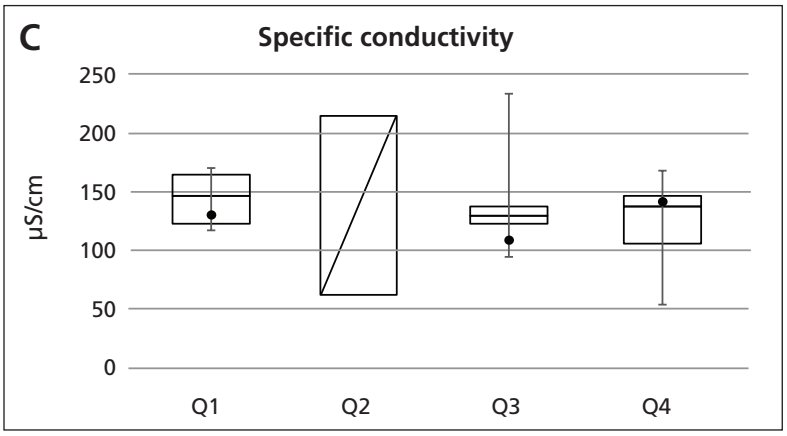
The sonde sampling location is currently at a secondary site approximately 100 meters downstream from the footbridge. The primary site was previously located upstream of the footbridge but was abandoned when the stream channel moved, stranding the site on dry land.

Although the segment of the West Fork Gila River at Gila Cliff Dwellings NM is in the "High Quality Cold Water" beneficial-use category, the park's elevation is at the bottom of the range for this group. This leads to possible exceedances of state water quality standards for core water-quality parameters. For example, in Figure 4-5a, Q4, the 75th-percentile statistic for temperature (20.88°C) approached the state temperature standard of 23°C. This indicates that commonly observed water temperatures at the index site frequently approach state standards due to the positioning of the index site (and the park unit) in the landscape. The main impetus behind the High Quality Cold Water beneficial-use designation is fishery management, and trout fisheries in particular. Trout are encountered within the monument, but historically in low numbers because of lack of habitat and sub-optimal water temperature (NMAC 2013).

The median values for core parameters from WY2017 were generally within the expected range (between percentiles 25 and 75), with the exception of the Q3 pH data (Figure 4-5b) and specific conductivity in Q3 (Figure 4-5c). There is no obvious explanation for these outliers. There may have been an extended, slightly elevated discharge during spring WY2017 (see Figure 4-3), but the measurements from the nearest gauge with an extensive (89–90 year) record are inconclusive. The record from that gauge (USGS 09430500, near Gila, New Mexico, ~40 km downstream) showed that WY2017 discharge was on the higher side of average during spring WY2017 (Figure 4-6). The slightly elevated pH and low median specific conductivity records may be a result of this apparently extended, elevated flow.







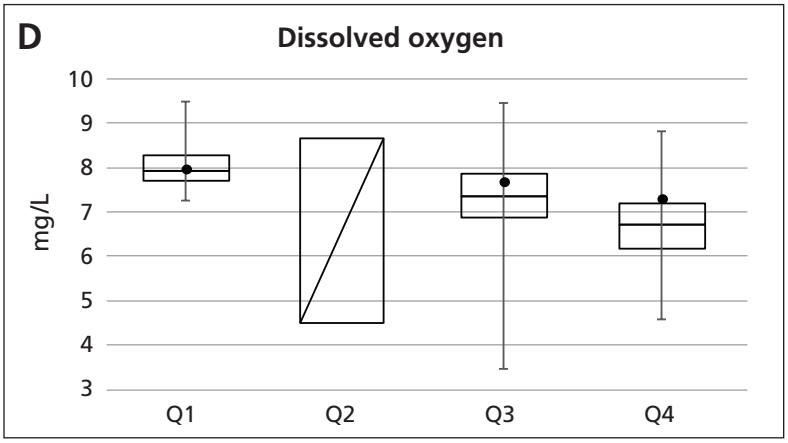


Figure 4-5. Seasonal variability in continuous data for (A) water temperature, (B) pH, (C) specific conductivity, and (D) dissolved oxygen concentration, West Fork Gila River, WY2017.

These box-and-whisker graphs display data from WY2011 to 2016. The top whisker is the maximum value for the parameter. The boxes indicate the 25th (bottom of box) to 75th (top of box) percentile of the data, with the line in the middle as the median value. The bottom whisker represents the minimum value. The solid black dots mark the median value from WY2017 sampling for each parameter. The sonde was not deployed during Q2.

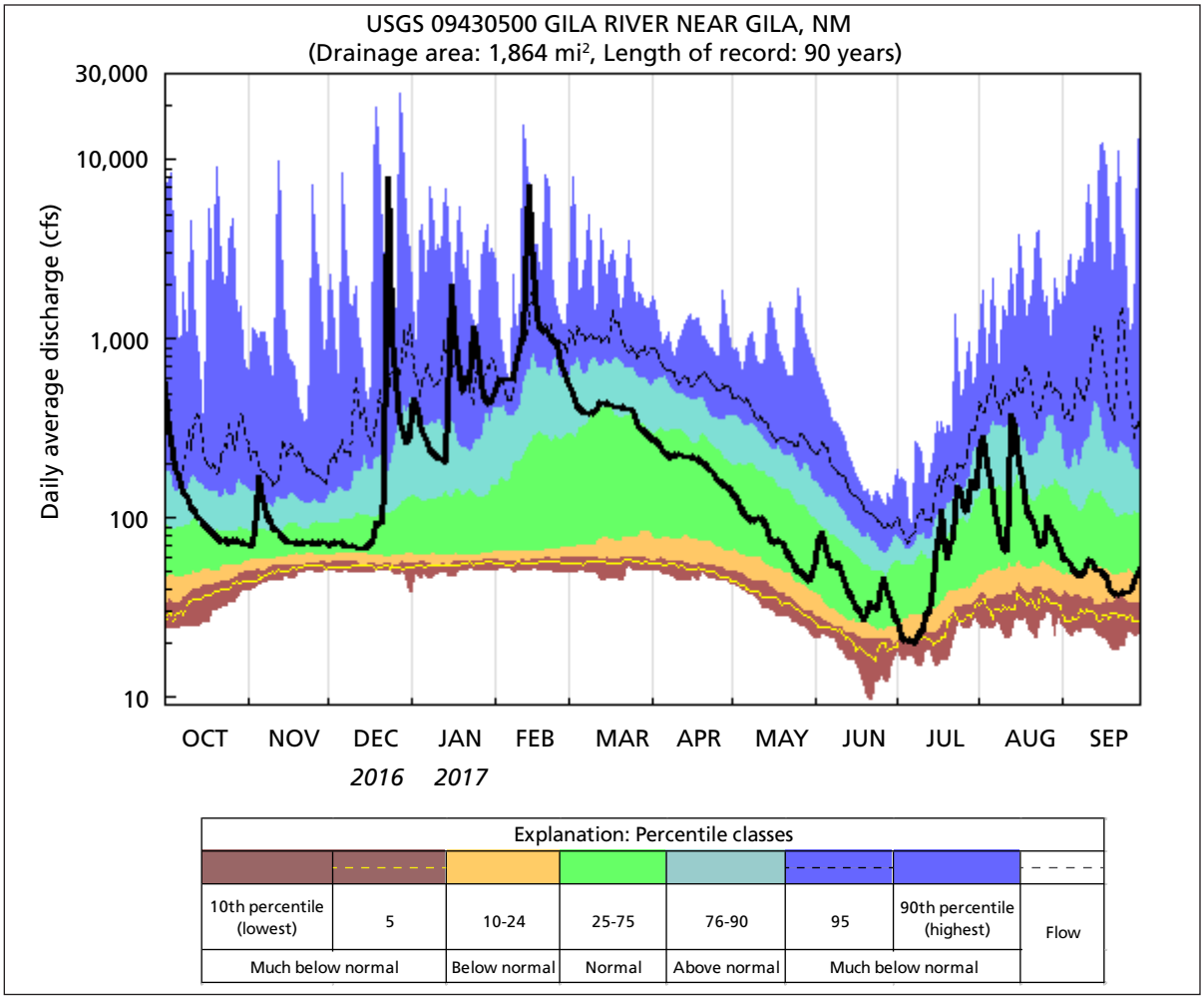


Figure 4-6. Discharge data from gauge USGS 09430500, near Gila, New Mexico. Note the black line in late February and early March is in the "above normal" flow category.

4.3.2.2 Nutrients

The results from nutrient sampling during WY2017 (nitrate, nitrite, total nitrogen, and Kjeldahl nitrogen) were all below the detection limit of the instrumentation used for analysis, with the exception of the Q1 results for nitrate, nitrate as N and total N (Table 4-4). In high concentrations (>1–2 mg/L), nitrate is an indicator of contamination from agriculture/fertilizer (Weiner 2000). The presence of nitrate is not unexpected in natural waters. It is an important nutrient for plants, and the recorded values were well below any ecological or state threshold. Please see Appendix A for the detection limits and methods for nutrient analysis.

4.3.2.3 Biological condition

No exceedances were detected for this parameter group, which includes *E. coli* (Table 4-5). SODN data for total coliforms and *E. coli* are expressed as a most probable number (MPN) per 100 mL of stream water, a statistical estimate of the number of bacteria. Although water-quality criteria are expressed as colony-forming units (cfu) per 100 mL (which, unlike MPN, does not assume estimation), the two units are comparable.

The bacterium, *E. coli*, is a naturally occurring member of the biotic community. It is found in soil, decaying material, and the guts of mammals. It is used as an indicator of contamination of water by human fecal waste. There have been past exceedances of state *E. coli* standards at the West Fork Gila River index site. However, these exceedances have been attributed to natural sources, mainly beavers and beaver pools directly upstream from the sample site. In WY2017, there were no beaver dams within one kilometer upstream of the sample site.

Only parameters with results are reported. Please note that parameters not reported should not assumed to be zero, but rather below the detection limit of the analytical equipment. They may have been present in very low concentrations.

4.3.2.4 Metals and metalloids

There were no exceedances of state water-quality standards for metals and metalloids in WY2017 (Tables 4-6 and 4-7). Other results were within expected ranges. During Q2, there was a sampling error during the field filtering process for the dissolved metals sample. This sample has been flagged, and use in future analysis will be carefully considered.

The Q3 result for dissolved zinc (0.027 mg/L) is an analytical anomaly. The corresponding analysis for total zinc was a non-detect result. These low concentrations approached the limit of the analytical equipment to reliably detect. The dissolved value for an analyte is a fraction of the total value for an analyte; that is, if there is a detection of a dissolved

Table 4-4. Results from nutrient sampling, West Fork Gila River, WY2017.

Analyte (mg/L)	Quarter				Method	New Mexico state standard	
	Q1	Q2	Q3	Q4		Measure	Beneficial use
Nitrate, Nitrate as N	0.13	<0.10	<0.10	<0.10	353.2	132	–
Total Nitrogen	0.13	<0.10	<0.10	<0.10	calculated	–	–

Table 4-5. Results from biological condition sampling, West Fork Gila River, WY2017.

Analyte	Quarter				Method	New Mexico state standard	
	Q1	Q2	Q3	Q4		Measure	Beneficial use
Total organic carbon (mg/L)	NC[1]	NC[1]	NC[1]	1.7	SM 5310B	NS[2]	–
E. coli (MPN)[3]	7.43	2	3.06	17.9	SM 9223B	235 (single sample)	Park-specific

[1]NC = not collected; [2]NS = no standard; [3] MPN = Most probable number/100 mL

Table 4-6. Results from metal and metalloids (dissolved) sampling, West Fork Gila River, WY2017.

Analyte (mg/L)	Quarter				Method[2]	New Mexico state standard	
	Q1	Q2[1]	Q3	Q4		Measure[3]	Beneficial use
Barium	NC[4]	NC[4]	NC[4]	0.006	EPA 200.8	2	Domestic water supply
Calcium	16	7.6	8.4	16	EPA 200.7	NS	–
Iron	<0.10	<0.10	0.44	0.44	EPA 200.7	NS	–
Magnesium	3.1	2.4	1.8	3.2	EPA 200.7	NS	–
Manganese	<0.010	<0.010	<0.010	0.011	EPA 200.7/200.8	1.1–1.3	Aquatic life chronic[5]
Silica	33	22	18	34	EPA 200.7	NS	–
Sodium	8.3	<5.0	6.7	8.3	EPA 200.7	NS	–
Zinc	<0.020	<0.020	0.027	<0.020	EPA 200.7	–	–

[1]Sampling technique affected dissolved metal measurements
[2]Methods are from Eaton and others (2005).
[3]NS = no standard
[4]NC = not collected
[5]Standard calculated using total hardness of sample.

Table 4-7. Results from metal and metalloids (total) sampling, West Fork Gila River, WY2017.

Analyte (mg/L)	Quarter				Method[2]	New Mexico state standard	
	Q1	Q2[1]	Q3	Q4		Measure[3]	Beneficial use
Aluminum	<0.10	<0.10	0.18	<0.10	EPA 200.7/200.7 Rev 4.42	0.34–1.18	Aquatic life chronic[4]
Barium	NC[5]	NC[5]	NC[5]	0.0061	EPA 200.8	NS	–
Calcium	13	6.9	10	15	EPA 200.7/200.7 Rev 4.42	NS	–
Iron	<0.10	0.11	0.11	<0.10	EPA 200.7/200.8	NS	–
Magnesium	2.9	2	2.3	2.8	EPA 200.7/200.7 Rev 4.42	NS	–
Manganese	<0.10	<0.10	<0.10	0.014	EPA 200.7/200.8	NS	–
Silica	30	24	25	31	EPA 200.7/200.7 Rev 4.42	NS	–
Sodium	7.5	<5.0	5.7	8.3	EPA 200.7/200.7 Rev 4.42	NS	–

[1]Sampling technique affected dissolved metal measurements
[2]Methods are from Eaton and others (2005).
[3]NS = no standard
[4]Standard calculated using total hardness of sample.
[5]NC = not collected

fraction of an analyte, then there should be a corresponding detection for the total value of an analyte that is numerically equal to or more than the dissolved fraction. However, when concentrations approach the detection limits of the analytical equipment, the results can be just the dissolved fraction. In the Q3 sample for zinc, there was a barely detectable concentration of zinc, most of which was in a dissolved state (i.e., able to pass through a 45-nm filter).

Only parameters with results are reported. Please note that parameters not reported should not assumed to be zero, but rather below the detection limit of the analytical equipment. They may have been present in very low concentrations.

4.3.2.5 Suspended and total sediment

During WY2017, suspended and total sediment results fell within the expected range (Table 4-8). Only parameters with results are reported. Please note that parameters not reported should not assumed to be zero, but rather below the detection limit of the analytical equipment. They may have been present in very low concentrations.

4.3.2.6 General water quality & inorganics

During WY2017, results for general water quality and inorganics (Table 4-9) were within the range of expected values, with the exception of total cyanide. There was an exceedance of the New Mexico state standard for total cyanide for wildlife habitat in the Q4 sample. There have been detections of cyanide in samples from this stream before; in the Q4 sample in WY12, there was a result of 0.011 mg/L.

It is suspected that the volcanic geology of the watershed is the source of this cyanide (Ratte et al. 2014). A similar situation occurs in Wet Beaver Creek at Montezuma Castle National Monument (Gwilliam et al. 2018; Gwilliam et al. 2014), where the surrounding geology contains rock that leaches arsenic into the stream water. The cyanide is a natural feature, and although it infrequently exceeds the state standard for wildlife habitat, and may increase physiologic stress on the plants and animals that live in and use the water, it is a natural occurrence. SODN will assess the impact of the cyanide as more data

Table 4-8. Results from suspended and total sediment sampling, West Fork Gila River, WY2017.

Analyte (mg/L)	Quarter				Method†	New Mexico state standard	
	Q1	Q2	Q3	Q4		Measure‡	Beneficial use
Total dissolved solids	180	94	81	110	SM 2540C	NS	–
Total suspended solids	<10	13	<10	<10	SM 2540D	NS	–

†SM = standard method (Eaton et al. 2005); ‡NS = no standard.

Table 4-9. Results from general and inorganic sampling, West Fork Gila River, WY2017.

Analyte (mg/L)	Quarter				Method[1]	New Mexico state standard	
	Q1	Q2	Q3	Q4		Measure[2]	Beneficial use
Alkalinity as $CaCO_3$	59	27	43	61	SM 2320B	NS	–
Bicarbonate alkalinity as $CaCO_3$	59	27	43	61	SM 2320B	NS	–
Fluoride	0.71	<0.50	<0.50	0.82	EPA 300.0	NS	–
Sulfate	<5.0	6.4	5.6	<5.0	EPA 300.0	NS	–
Total hardness	44	26	35	50	SM 2340B	NS	–
Anion/Cation balance	7.2	-8	-5	6	SM 1030E	NS	–
Total cyanide	NC	NC	NC	**0.038**[3]	SM 4500 Cn E	0.0052	Wildlife habitat

[1]SM = standard method (Eaton et al. 2005); [2]NS = no standard; [3]Exceedance (also shown in bolded red font).

are collected in the future.

Please note that parameters not reported should not assumed to be zero, but rather below the detection limit of the analytical equipment. They may have been present in very low concentrations.

4.3.3 Macroinvertebrates

Macroinvertebrate samples and associated habitat data were collected on October 18, 2016. The samples were received by the analytical lab on December 6, and the report from the lab was issued on June 20, 2017. A list of taxa collected from the index reach can be found in Appendix B.

The State of New Mexico uses the New Mexico Stream Condition Indices (NMSCI; Jacobi et. al 2006) to meet EPA mandates. In WY2017, the index was measured at 54.99 (Figure 4-7). This placed Gila Cliff Dwellings NM in the "Fair" category, falling in the middle 20% of index sites in the "high-elevation small watershed" category.

This index reach has been sampled with the same methods since WY2012. The NMSCI value has been near the upper 25th percentile each year—even after major fires in the monument watershed (2011–2012). These results show the resilience of the macroinvertebrate community, and the ability of the stream reach to recover after postfire flows of debris and ash.

As noted in Section 4.3.2.1, the park's elevation often places it at the edge of various water-quality categories. In this case, it is at the lower end of the elevation in the "high-elevation small watershed" category." This may influence the score. The median value for the index is 57.22 for the years since the WY2012 fire, and the boundary for the "good" rating is 56.70. The value for WY2017 fell within the expected range of values for the index site.

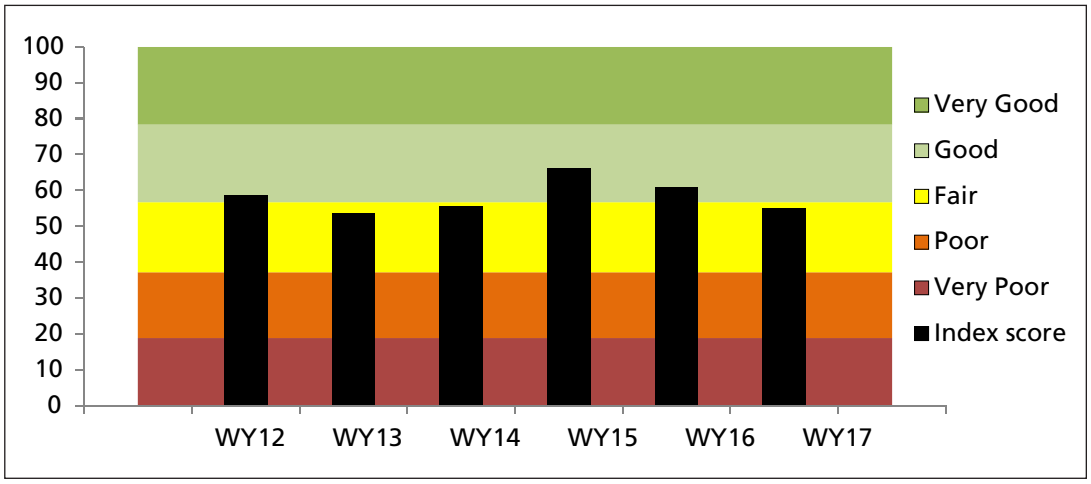


Figure 4-7. New Mexico Stream Condition Index scores, West Fork Gila River, WY2012–2017.

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Appendix A. Detection Limits and Methods for Nutrient Analysis

Table A-1. Detection limits and methods for nutrient analysis, West Fork Gila River, Gila Cliff Dwellings National Monument, WY2017.

Analyte	RL	Units	Method
Acidity	10.00	mg/L	SM 2310B
Alkalinity as CaCO3	5.00	mg/L	SM 2320B
Aluminum	0.10	mg/L	200.7 Rev 4.4
Ammonia	0.10	mg/L	350.1
Anion/Cation Balance	N.A.	%	SM 1030E
Antimony	2.00	ug/L	200.8
Arsenic	5.00	ug/L	200.8
Barium	1.00	ug/L	200.8
Beryllium	1.00	ug/L	200.8
Bicarbonate Alkalinity as CaCO3	5.00	mg/L	SM 2320B
Biochemical Oxygen Demand	2.00	mg/L	SM5210B
Boron	0.10	mg/L	200.7 Rev 4.4
Cadmium	1.00	ug/L	200.8
Calcium	0.20	mg/L	200.7 Rev 4.4
Carbonate Alkalinity as CaCO3	5.00	mg/L	SM 2320B
Chloride	3.00	mg/L	300.0
Chromium	3.00	ug/L	200.8
Copper	2.00	ug/L	200.8
Cyanide, Total	0.01	mg/L	SM 4500 CN E
Dis Aluminum	0.10	mg/L	200.7
Dis Antimony	2.00	ug/L	200.8
Dis Arsenic	5.00	ug/L	200.8
Dis Barium	1.00	ug/L	200.8
Dis Beryllium	1.00	ug/L	200.8
Dis Boron	0.10	mg/L	200.7
Dis Cadmium	1.00	ug/L	200.8
Dis Calcium	0.20	mg/L	200.7
Dis Chromium	3.00	ug/L	200.8
Dis Copper	2.00	ug/L	200.8
Dis Iron	0.10	mg/L	200.7
Dis Lead	1.00	ug/L	200.8
Dis Magnesium	0.20	mg/L	200.7
Dis Manganese	2.00	ug/L	200.8
Dis Mercury	0.00	mg/L	245.1
Dis Molybdenum	2.00	ug/L	200.8
Dis Nickel	2.00	ug/L	200.8
Dis Phosphorus	3.00	mg/L	200.7
Dis Potassium	3.00	mg/L	200.7
Dis Selenium	5.00	ug/L	200.8
Dis Silver	1.00	ug/L	200.8
Dis SiO2, Silica	1.10	mg/L	200.7

Table A-1. Detection limits and methods for nutrient analysis, West Fork Gila River, Gila Cliff Dwellings National Monument, WY2017, cont.

Analyte	RL	Units	Method
Dis Sodium	5.00	mg/L	200.7
Dis Thallium	1.00	ug/L	200.8
Dis Uranium	1.00	ug/L	200.8
Dis Zinc	10.00	ug/L	200.8
Fluoride	0.50	mg/L	300.0
Hardness, as CaCO3	1.30	mg/L	SM 2340B
Iron	0.10	mg/L	200.7 Rev 4.4
Lead	1.00	ug/L	200.8
Magnesium	0.20	mg/L	200.7 Rev 4.4
Manganese	2.00	ug/L	200.8
Mercury	0.00	mg/L	245.1
Molybdenum	2.00	ug/L	200.8
Nickel	2.00	ug/L	200.8
Nitrate Nitrite as N	0.10	mg/L	353.2
Nitrate, Dissolved	0.50	mg/L	300.0
Nitrite, dissolved	0.50	mg/L	300.0
Nitrogen, Kjeldahl	1.00	mg/L	351.2
Nitrogen, Total	0.10	mg/L	Computed
pH	0.10	SU	SM 4500 H+ B
Phosphorus	3.00	mg/L	200.7 Rev 4.4
Potassium	3.00	mg/L	200.7 Rev 4.4
Selenium	5.00	ug/L	200.8
Silver	1.00	ug/L	200.8
SiO2, Silica	1.10	mg/L	200.7 Rev 4.4
Sodium	5.00	mg/L	200.7 Rev 4.4
Specific Conductance	2.00	umhos/cm	SM 2510B
Sulfate	5.00	mg/L	300.0
Thallium	1.00	ug/L	200.8
Total Dissolved Solids	10.00	mg/L	SM 2540C
Total Organic Carbon	1.00	mg/L	SM 5310B
Total Suspended Solids	4.00	mg/L	SM 2540D
Uranium	1.00	ug/L	200.8
Zinc	10.00	ug/L	200.8

Appendix B. Macroinvertebrate Taxa

This appendix combines the results from all macroinvertebrate sampling at the index site, including the targeted riffles, and the reach-wide samples.

Table B-1. Macroinvertebrate taxa collected at the index reach on the West Fork Gila River, Gila Cliff Dwellings National Monument, WY2017.

Phylum	Class	Order	Family	Genus	Species
Arthropoda	Arachnida	Trombidiformes	Hygrobatidae	–	–
Arthropoda	Arachnida	Trombidiformes	Lebertiidae	Lebertia	–
Arthropoda	Arachnida	Trombidiformes	Sperchonidae	Sperchon	–
Arthropoda	Arachnida	Trombidiformes	Sperchonidae	Sperchonopsis	–
Arthropoda	Arachnida	Trombidiformes	Torrenticolidae	Torrenticola	–
Arthropoda	Arachnida	Trombidiformes	–	–	–
Arthropoda	Insecta	Coleoptera	Dryopidae	Helichus	–
Arthropoda	Insecta	Coleoptera	Dryopidae	Postelichus	–
Arthropoda	Insecta	Coleoptera	Elmidae	Microcylloepus	pusillus
Arthropoda	Insecta	Coleoptera	Elmidae	Optioservus	pecosensis
Arthropoda	Insecta	Coleoptera	Elmidae	Optioservus	–
Arthropoda	Insecta	Coleoptera	Elmidae	Zaitzevia	parvulus
Arthropoda	Insecta	Coleoptera	Elmidae	–	–
Arthropoda	Insecta	Coleoptera	Psephenidae	Psephenus	–
Arthropoda	Insecta	Diptera	Ceratopogonidae	Probezzia	–
Arthropoda	Insecta	Diptera	Chironomidae	–	–
Arthropoda	Insecta	Diptera	Empididae	Neoplasta	–
Arthropoda	Insecta	Diptera	Simuliidae	Simulium	–
Arthropoda	Insecta	Diptera	Simuliidae	–	–
Arthropoda	Insecta	Diptera	Tabanidae	Tabanus	–
Arthropoda	Insecta	Diptera	Tipulidae	–	–
Arthropoda	Insecta	Ephemeroptera	Baetidae	Acentrella	–
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	–
Arthropoda	Insecta	Ephemeroptera	Baetidae	Fallceon	–
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Ephemerella	–
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	–	–
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus	–
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Rhithrogena	–
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	–	–
Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	Leptohyphes	–
Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	–
Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	–	–
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	–	–
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Leptophlebia	–
Arthropoda	Insecta	Hemiptera	Corixidae	–	–
Arthropoda	Insecta	Lepidoptera	Crambidae	Petrophila	–

Table B-1. Macroinvertebrate taxa collected at the index reach on the West Fork Gila River, Gila Cliff Dwellings National Monument, WY2017, cont.

Phylum	Class	Order	Family	Genus	Species
Arthropoda	Insecta	Megaloptera	Corydalidae	Corydalus	cornutus
Arthropoda	Insecta	Odonata	Calopterygidae	Hetaerina	_
Arthropoda	Insecta	Odonata	Gomphidae	Erpetogomphus	_
Arthropoda	Insecta	Odonata	Gomphidae	Ophiogomphus	_
Arthropoda	Insecta	Plecoptera	Capniidae	_	_
Arthropoda	Insecta	Plecoptera	Chloroperlidae	_	_
Arthropoda	Insecta	Plecoptera	Perlidae	Claassenia	sabulosa
Arthropoda	Insecta	Plecoptera	Perlodidae	Isogenoides	_
Arthropoda	Insecta	Plecoptera	Perlodidae	Isoperla	_
Arthropoda	Insecta	Plecoptera	Perlodidae	_	_
Arthropoda	Insecta	Plecoptera	Perlodidae	Skwala	americana
Arthropoda	Insecta	Plecoptera	Pteronarcyidae	Pteronarcys	californica
Arthropoda	Insecta	Plecoptera	Taeniopterygidae	_	_
Arthropoda	Insecta	Plecoptera	_	_	_
Arthropoda	Insecta	Plecoptera	Leuctridae	_	_
Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentrus	occidentalis
Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentrus	_
Arthropoda	Insecta	Trichoptera	Glossosomatidae	_	_
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Protoptila	_
Arthropoda	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	_
Arthropoda	Insecta	Trichoptera	Hydrobiosidae	Atopsyche	_
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	_
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche	_
Arthropoda	Insecta	Trichoptera	Hydropsychidae	_	_
Arthropoda	Insecta	Trichoptera	Hydroptilidae	_	_
Arthropoda	Insecta	Trichoptera	Lepidostomatidae	Lepidostoma	_
Arthropoda	Insecta	Trichoptera	Leptoceridae	Nectopsyche	_
Arthropoda	Insecta	Trichoptera	Leptoceridae	Oecetis	_
Arthropoda	Insecta	Trichoptera	Limnephilidae	_	_
Arthropoda	Insecta	Trichoptera	Philopotamidae	Chimarra	_
Arthropoda	Insecta	Trichoptera	Psychomyiidae	Psychomyia	_
Arthropoda	Malacostraca	Amphipoda	Gammaridae	Gammarus	_

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.

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