



Status of Climate and Water Resources at Casa Grande Ruins National Monument

Water Year 2018

Natural Resource Report NPS/SODN/NRR—2019/1940



ON THE COVER

Adobe wall and creosotebush, Casa Grande Ruins National Monument.
NPS/Alice Wondrak Biel.

Status of Climate and Water Resources at Casa Grande Ruins National Monument

Water Year 2018

Natural Resource Report NPS/SODN/NRR—2019/1940

Prepared by

Kara Raymond
Southern Arizona Office
3636 N. Central Ave., Suite 410
Phoenix, AZ 85012

Editing and Design

Alice Wondrak Biel
Sonoran Desert Network
National Park Service
12661 E. Broadway Blvd.
Tucson, AZ 85748

June 2019

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 Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with 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 peer 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 Sonoran Desert Network website, as well as at the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Raymond, K. 2019. Status of climate and water resources at Casa Grande Ruins National Monument: Water year 2018. Natural Resource Report NPS/SODN/NRR—2019/1940. National Park Service, Fort Collins, Colorado.

Contents

Figures v

Executive Summary vii

Acknowledgements ix

1 Introduction 1

2 Climate..... 3

 2.1 Background and methods 3

 2.2 Results and discussion 3

3 Groundwater 7

 3.1 Background 7

 3.2 Methods..... 7

 3.3 Results and discussion 8

4 Literature Cited 11

Figures

Figure 2-1. Weather stations at Casa Grande Ruins National Monument 3

Figure 2-3. Departures from 30-year (1981–2010) normal minimum and maximum temperature and precipitation, Casa Grande Ruins National Monument, water year 2018 4

Figure 2-2. Aridity index vs. elevation of selected southwestern national parks, including Casa Grande Ruins National Monument 4

Figure 2-4. Climogram for Casa Grande Ruins National Monument, water year 2018..... 5

Figure 2-5. Reconnaissance Drought Index for Casa Grande Ruins National Monument for water years 1981–2018..... 6

Figure 2-6. Five year moving mean of annual precipitation, Casa Grande Ruins National Monument, 1981–2018 6

Figure 3-1. Wells at Casa Grande Ruins National Ruins National Monument..... 8

Figure 3-2. Water-level elevation and depth to water at and near Casa Grande Ruins National Monument, 1977–2018 9

Figure 3-3. Gila River mean daily discharge at Kelvin, Arizona, and water-level elevation in and around Casa Grande Ruins National Monument, 1977–2018. 9

Figure 3-4. Land subsidence and earth fissures in the Eloy subbasin, March 15, 2017–March 10, 2018 10

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 and groundwater is central to assessing the condition of park biota and key cultural resources. This report combines data collected on climate with an overview of groundwater resources at Casa Grande Ruins National Monument (NM) for water year 2018 (October 2017–September 2018).

Air temperatures at Casa Grande Ruins NM tended to be warmer than normal, especially in the fall and winter months, and there were substantially fewer extremely cold days. Annual precipitation was only 63% of normal (5.81" vs. 9.18") in WY2018 when compared to normalized climate data for 1981–2010. Monsoon rainfall was greater than normal, but the rest of the year was substantially drier. A single, 0.65" storm event in June dropped 1,300% of that month's normal rainfall. The reconnaissance drought index indicated that the regional drought that began in 2000 continued through WY2018.

Groundwater levels near Casa Grande Ruins in WY2018 increased 12.3 feet from WY2017, a deviation from the general downward trend since 1995. Irrigation districts in the Eloy basin near the Central Arizona Project canal began receiving water in 1987. However, the San Carlos Irrigation District, adjacent to the park, is outside the Central Arizona Project service area, and groundwater levels have generally declined. Land subsidence at Casa Grande Ruins NM between March 2017 and March 2018 was 0–1 centimeters in most of the park, and up to 2 centimeters in the park's northwest corner.

Acknowledgements

We thank the Arizona Department of Water Resources for monitoring wells near Casa Grande Ruins National Monument and making that data publicly available. Andy Hubbard and Colleen Filippone contributed to this report.

1 Introduction

Climate is a major driver of ecosystems. It helps shape ecosystem structure and function, particularly in arid and semi-arid ecosystems. Understanding changes in climate is central to assessing the condition of park biota and key cultural resources. This document summarizes climate and groundwater conditions for water year (WY) 2018 (Octo-

ber 2017–September 2018) for Casa Grande Ruins National Monument, a small (191-ha) National Park Service unit in central Arizona. Detailed analyses of trends will follow in subsequent reports as the period of record warrants such assessments. For details on monitoring protocols, park setting and resources, and other management issues, please see <https://www.nps.gov/im/sodn/cagr.htm>.

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 the National Park Service manages and protects.

Casa Grande Ruins National Monument (NM) has one of the longest-operating National Oceanic and Atmospheric Administration (NOAA) Cooperative Observer Program (COOP) weather stations in Arizona (Casa Grande Ruins NM, ID#3288778). This weather station, established in 1906, provides a reliable long-term dataset used for analyses in this report.

The monument also contains two recently established climate stations: a remote automated weather station (RAWS), installed in 2014, and a Regional Climate Reference Network station, installed in 2011 (Figure 2-1). Both are maintained and operated by the National Park Service Sonoran Desert Network. In combination with the excellent, long-term, NOAA COOP dataset, these stations provide a unique opportunity to study climate and weather patterns in the Sonoran Desert.

Data from all stations are accessible through www.climateanalyzer.org. The Sonoran Desert Network Climate Monitoring Protocol (Hubbard et al. in prep) includes details on methods and data handling.

An aridity index (UNEP 1992), based on long-term average annual precipitation relative to average annual potential evapotranspi-



Figure 2-1. Weather stations at Casa Grande Ruins National Monument: A remote automated weather station, shown at left, and a high-precision regional climate reference network station, shown at right. A NOAA Cooperative Observer Program station is located near the Great House (seen in background).

ration, can be a useful tool for contrasting the local climate of national parks (Figure 2-2). 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 (1906–present), the climate of Casa Grande Ruins NM is classified as “arid.”

2.2 Results and discussion

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

Data quality at the COOP station during WY2018 was excellent, with missing values on only four days. Compared to the 1981–2010 normalized climate data, annual precipitation at Casa Grande Ruins NM was only 63% of normal (5.81" vs. 9.18") in WY2018.

2.2.1.1 Cool season (October–March)

Precipitation was substantially below normal (31%, -3.73") for the fall and winter of WY2018. February received near-normal rainfall, while December and January received $\leq 40\%$ of normal. No rain fell in the other three months (Figures 2-3 and 2-4). Mean monthly maximum and minimum temperatures were warmer than normal (+1–9°F) in all months, especially November.

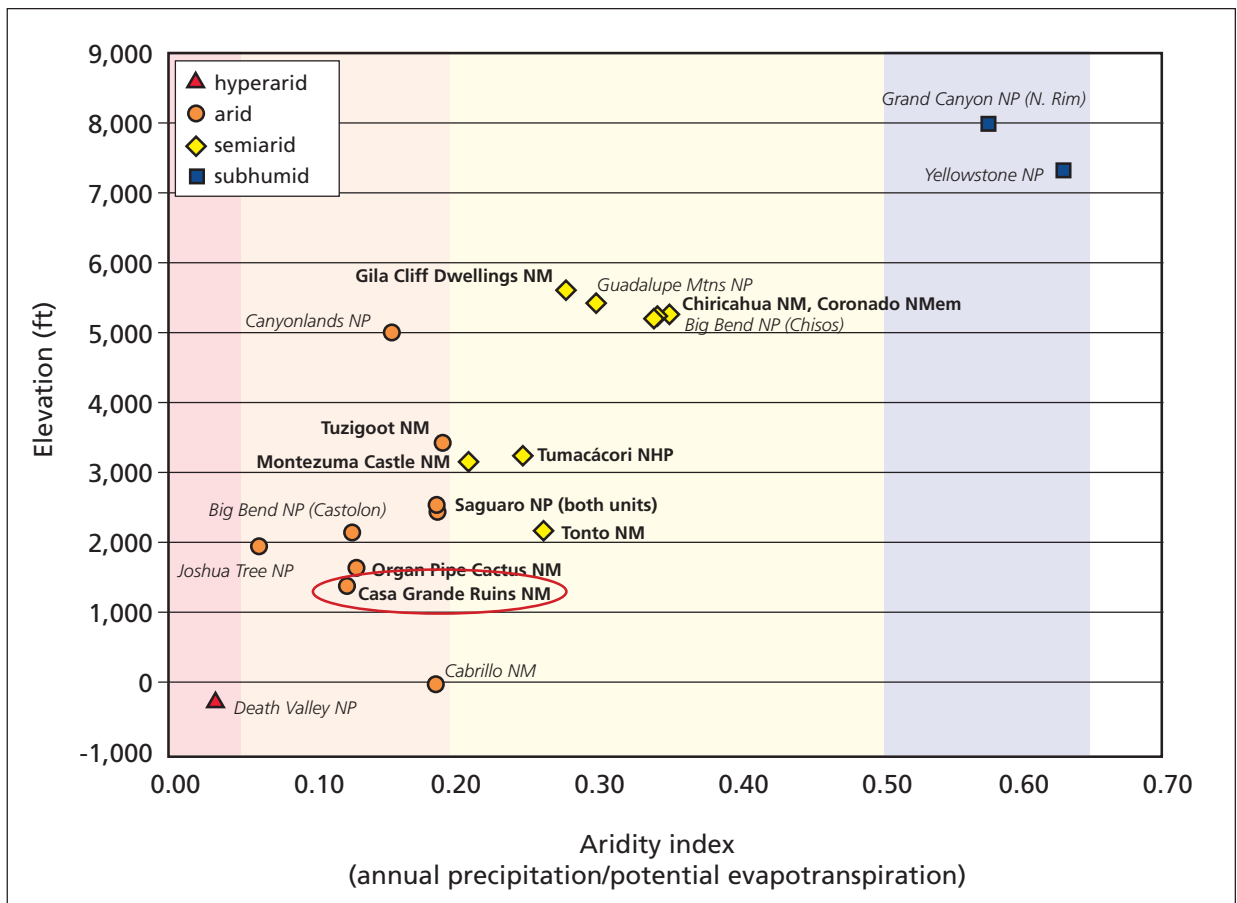
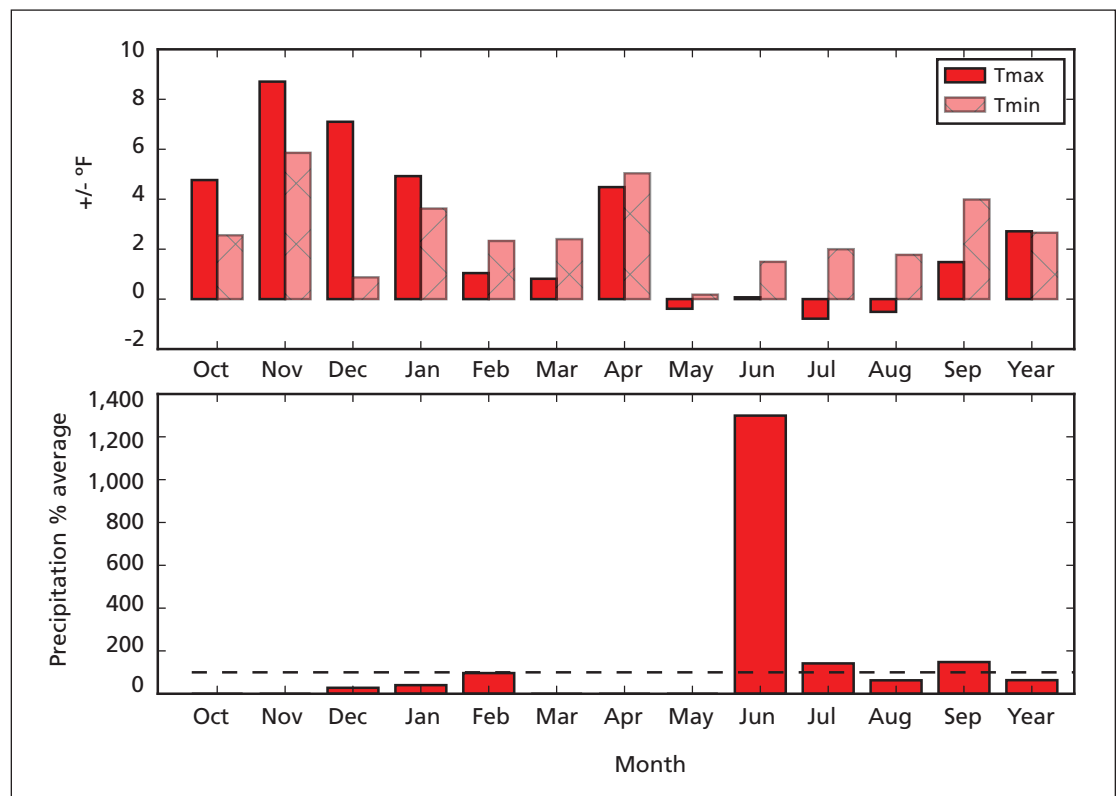


Figure 2-2. Aridity index vs. elevation of selected southwestern national parks, including Casa Grande Ruins National Monument. Figure from Hubbard and others (in prep).

Figure 2-3. Departures from 30-year (1981–2010) normal minimum and maximum temperature and precipitation, Casa Grande Ruins National Monument, water year 2018. Graphics generated by www.climateanalyzer.org.



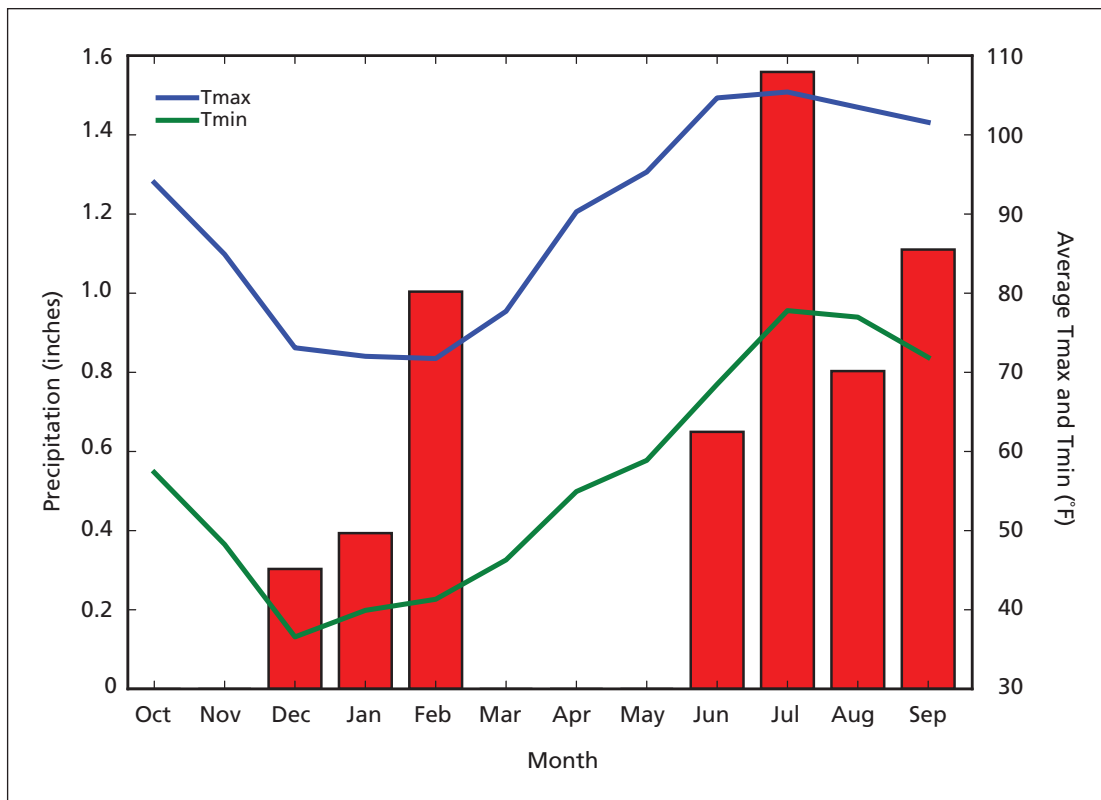


Figure 2-4. Climogram for Casa Grande Ruins National Monument, water year 2018. Graphics generated by www.climateanalyzer.org.

2.2.1.2 Warm season (April–September)

Precipitation in spring and summer was slightly above normal (110%, +0.36") (Figures 2-3 and 2-4). April and May were dry. In June, residual moisture from a Pacific hurricane caused unseasonable precipitation across southern Arizona, leading a single, 0.65" storm event to drop 1,300% of that month's normal rainfall at the park. Monsoon rainfalls were greater than normal in July and September, with a dip in August. Mean maximum temperatures were generally near normal, except in April, which was about 4°F warmer than normal. Mean minimum temperatures were greater than normal (+1–5°F) for all warm-season months (Figures 2-3 and 2-4).

2.2.2 Reconnaissance Drought Index

Reconnaissance drought index (RDI; Tsakiris and Vangelis 2005) is a measure of drought severity and extent relative to long-term climate, based on average precipitation to average potential evapotranspiration over shorter periods of time (seasons to years). RDI for Casa Grande Ruins NM reflects the extended regional drought since 2000 (Figure 2-5). Brief recoveries in WY2005, 2013, and 2015 have been followed by much more

xeric conditions, including WY2018. The five-year moving mean of total annual precipitation from 1981 to 2018 (Figure 2-6) suggests below-average rainfall in WY2016 and 2018 caused a return to drought conditions after a brief water surplus.

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 Sonoran Desert ecosystems. For example, sustained low air temperatures can damage or even kill long-lived keystone plants, such as columnar cacti (e.g., saguaro cactus) and native trees (e.g., velvet mesquite; Turner et al. 2003). Extreme precipitation events can also cause localized flooding and erosion events, spur or inhibit plant productivity and reproduction, and modify animal behavior. Localized erosion and exposure of critical archeological resources by extreme precipitation events is of particular importance at Casa Grande Ruins NM.

Extremely cold days (<30°F, 5th percentile of 1981–2010 data) occurred less frequently (4 days vs. 16.8 ± 0.9 days) in WY2018, and were of a similar duration (2 consecutive days vs. 2.6 ± 0.2 days).

There was one extreme precipitation event (>1") in WY2018, compared to an average of 2.3 ± 0.6 days per year for 1981–2010. The single large event occurred on September 20 (1.05").

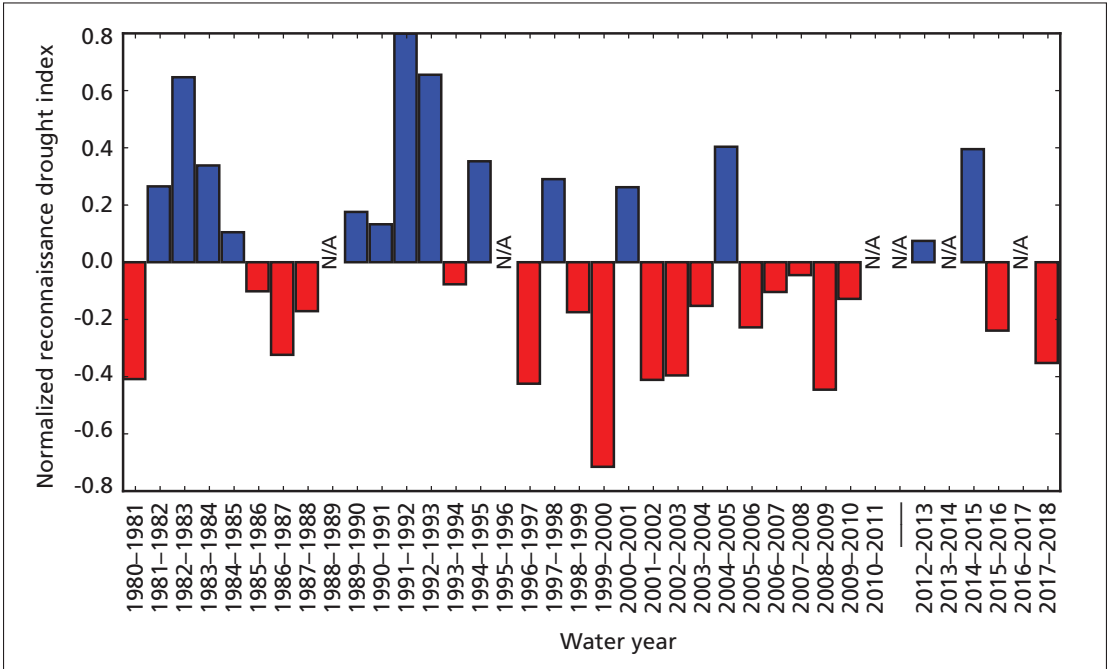


Figure 2-5. Reconnaissance Drought Index for Casa Grande Ruins National Monument for water years 1981–2018. "N/A" = insufficient data to generate reliable RDI estimates. Graphics generated by www.climateanalyzer.org.

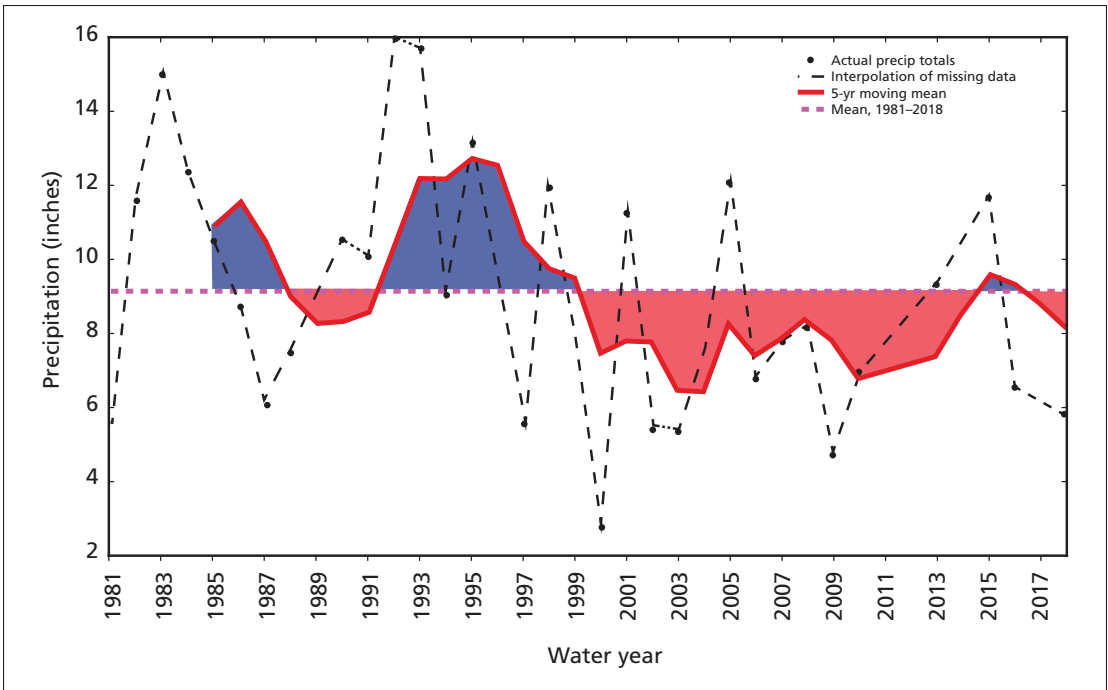


Figure 2-6. Five year moving mean of annual precipitation, Casa Grande Ruins National Monument, 1981–2018. The moving mean (solid red line) is based on a timeseries with 15.8% (6 of 38) missing values, and includes the current year and previous four years. Missing years are linearly interpolated (dashed grey lines). Graphics generated by climateanalyzer.org

3 Groundwater

3.1 Background

Groundwater is one of the most critical natural resources of the American Southwest, providing drinking water, irrigating crops, and sustaining springs, rivers, and streams throughout the region. Groundwater is closely linked to long-term precipitation patterns and surface waters, as ephemeral flows sink below ground to reappear months, years, decades, or even centuries later as perennial and intermittent streams and springs. Groundwater also sustains trees and shrubs that are common throughout the region and is the primary source of water for almost all humans in the southwestern U.S. Groundwater therefore interacts either directly or indirectly with all key ecosystem features of the arid Sonoran Desert ecoregion.

Casa Grande Ruins NM is located in the northeast quadrant of the Pinal Active Management Area (AMA) and in the north-central section of the Eloy groundwater subbasin. The Eloy groundwater subbasin occupies a pair of hydrologically connected structural depressions formed by the relatively impermeable bedrock of the surrounding mountains and pre-Basin and Range sedimentary rocks (Hammett 1992). The bedrock depressions are filled with 800 to more than 1,000 feet of sediments, including sequences of coarse and fine-grained sediments in the area around the monument (Richard et al. 2007). Measurements in the early 20th century indicated that water-level elevations were similar for both shallow and deep wells around the subbasin (Hammett 1992). This indicates horizontal and vertical hydrologic connectivity within the basin. Under those conditions, significant differences in water-level elevations between wells are the result of localized pumping or recharge, which occurs through underflow into the basin, streambed infiltration from the Gila River during flood events, and, to a lesser extent, recharge from the surrounding mountains.

Since about 1900, groundwater conditions in the Eloy subbasin have been increasingly dominated by agricultural use. Between 2001 and 2005, 96% of all water pumped in the

Pinal AMA went to agricultural uses (ADWR 2010). Since the early 20th century, the Eloy subbasin has been in groundwater deficit, with more water pumped from the aquifer than was naturally replenished. This has resulted in substantial changes to the natural flow regime, declining water levels, and land subsidence. The introduction of water from the Central Arizona Project (CAP) in 1987 resulted in reduced groundwater pumping in irrigation districts near the canal (Corkhill 2012). As a result, mean water level across the Eloy subbasin did not change between 1996 and 2016 (ADWR 2017a). However, the San Carlos Irrigation district, adjacent to the park, is outside the CAP service area, and groundwater levels have generally declined (Corkhill 2012).

Long-term declines in groundwater levels throughout Arizona have resulted in areas of land subsidence (gradual collapse, fissuring, or slumping) (ADWR 2017b). Subsidence occurs in areas where deep basins filled with alluvial sediments are dewatered, especially where compressible and plastic, fine-grained materials are present. Land subsidence is not reversible. In response to overdrafting and land subsidence, the Bureau of Land Management is currently studying the Eloy and Maricopa-Stanfield groundwater basins with the goal to better manage groundwater supplies.

3.2 Methods

Casa Grande Ruins NM does not have an accessible well within the park boundary. The State of Arizona Department of Water Resources Water monitors levels at two wells near the park, owned by the San Carlos Irrigation Project. These data are accessible through <http://gisweb.azwater.gov/water-resourcedata>. Well 621935, approximately 1.3 miles northwest of park headquarters, is 820 feet deep and measured annually. Well 621937, immediately west of the park boundary, is 1,110 feet deep and infrequently measured (Figure 3-1).

The former water-supply well for the park (Well 629148) was constructed in 1931. This 180-foot-deep well was used until 1952, when the park connected to the City of Coolidge water supply. The well was acces-



Wells in and near Casa Grande Ruins National Monument

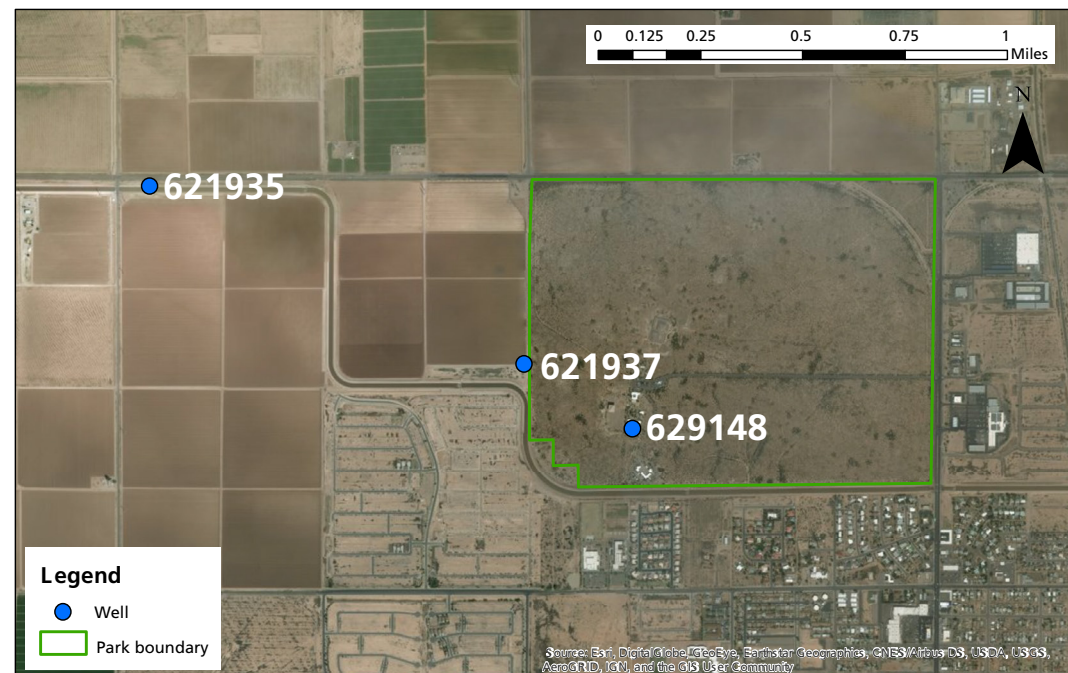


Figure 3-1. Wells at Casa Grande Ruins National Monument.

sible until 1989, when the pump house was remodeled into a library (Clemensen 1992). Monitoring of the park's water-supply well (629148) prior to 1989 indicated that its water level was similar to that of Well 621937. Differences between water levels in these two wells and in well 621935 are attributed to groundwater pumping.

Detailed information on monitoring methods may be found in the SODN groundwater monitoring protocol (Filippone et al. 2014).

3.3 Results and discussion

One water-level measurement was collected from ADWR 621935 in WY2018, on November 7. The recorded level was 124.40 feet below ground surface (bgs), an increase of 12.3 feet from WY2017. This represents a departure from the general downward trend seen since 1995 (Figure 3-2). The cause of the

groundwater increase is unclear, as precipitation at the park has been below normal in recent years. Over the monitoring record, the water level has varied 102.2 feet, with a low of 171.40 feet bgs in June 1986 and a high of 69.20 feet bgs in November 1995.

The historical water-level record documented in Figure 3-3 reflects substantial groundwater-level increases attributed to infiltration from the Gila River following the major regional flood years of 1983 and 1993, and, to a lesser extent, 2007. Groundwater levels in the Eloy subbasin decline between high flow events on the Gila River.

Land subsidence at Casa Grande Ruins NM between March 2017 and March 2018 was 0–1 centimeter in most of the park, and up to 2 centimeters in the park's northwest corner (Figure 3-4).

Figure 3-2. Water-level elevation and depth to water at and near Casa Grande Ruins National Monument, 1977–2018. Wellhead elevation for Well 621935 is 1,409 feet. Wellhead elevation for Well 629148 is 1,419 feet, so 10 feet should be added to the scale shown on the right y-axis to obtain the correct depth. Wellhead elevation for Well 621937 is 1,420 feet, so 11 feet should be added to the scale shown on the right y-axis to obtain the correct depth.

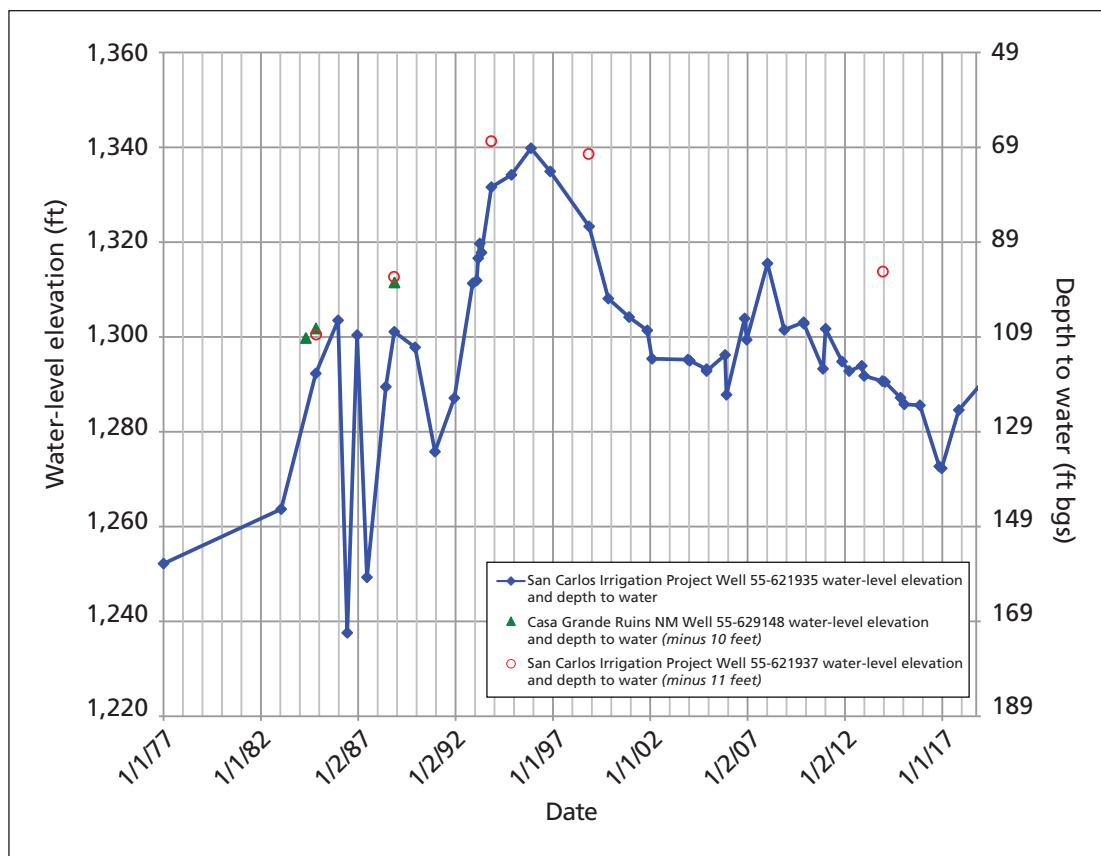
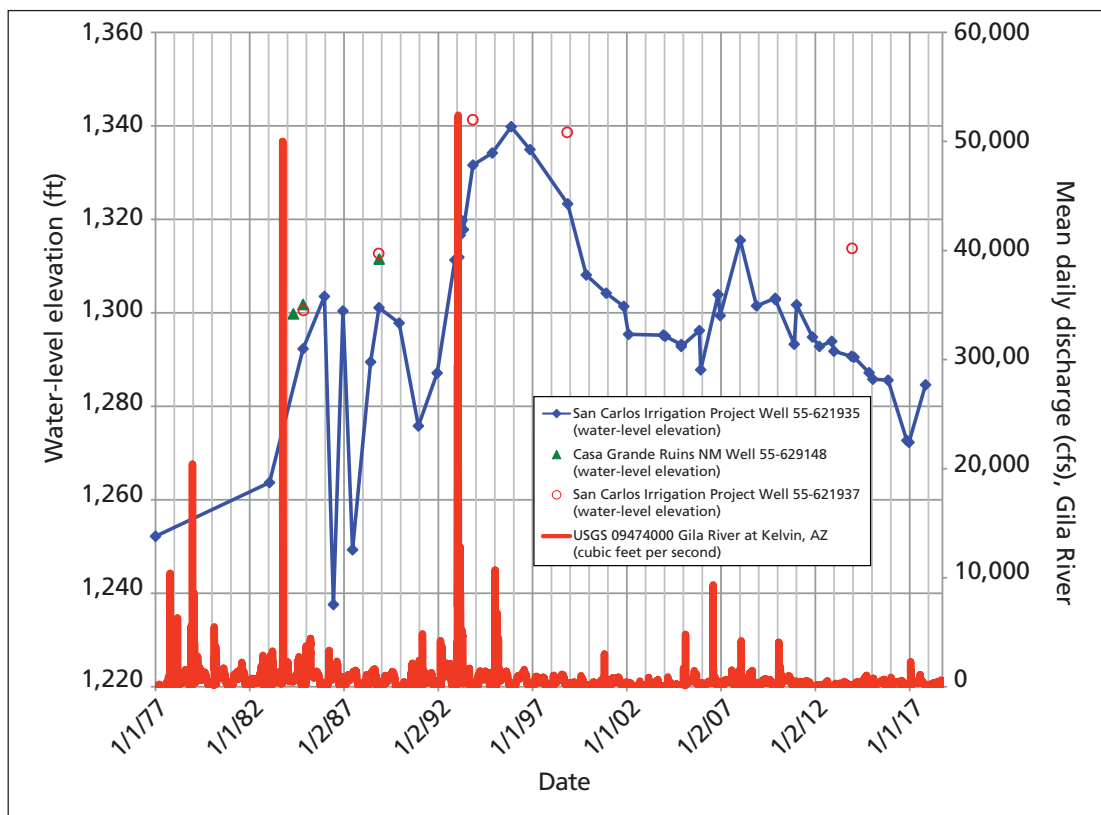


Figure 3-3. Gila River mean daily discharge at Kelvin, Arizona, and water-level elevation in and around Casa Grande Ruins National Monument, 1977–2018.



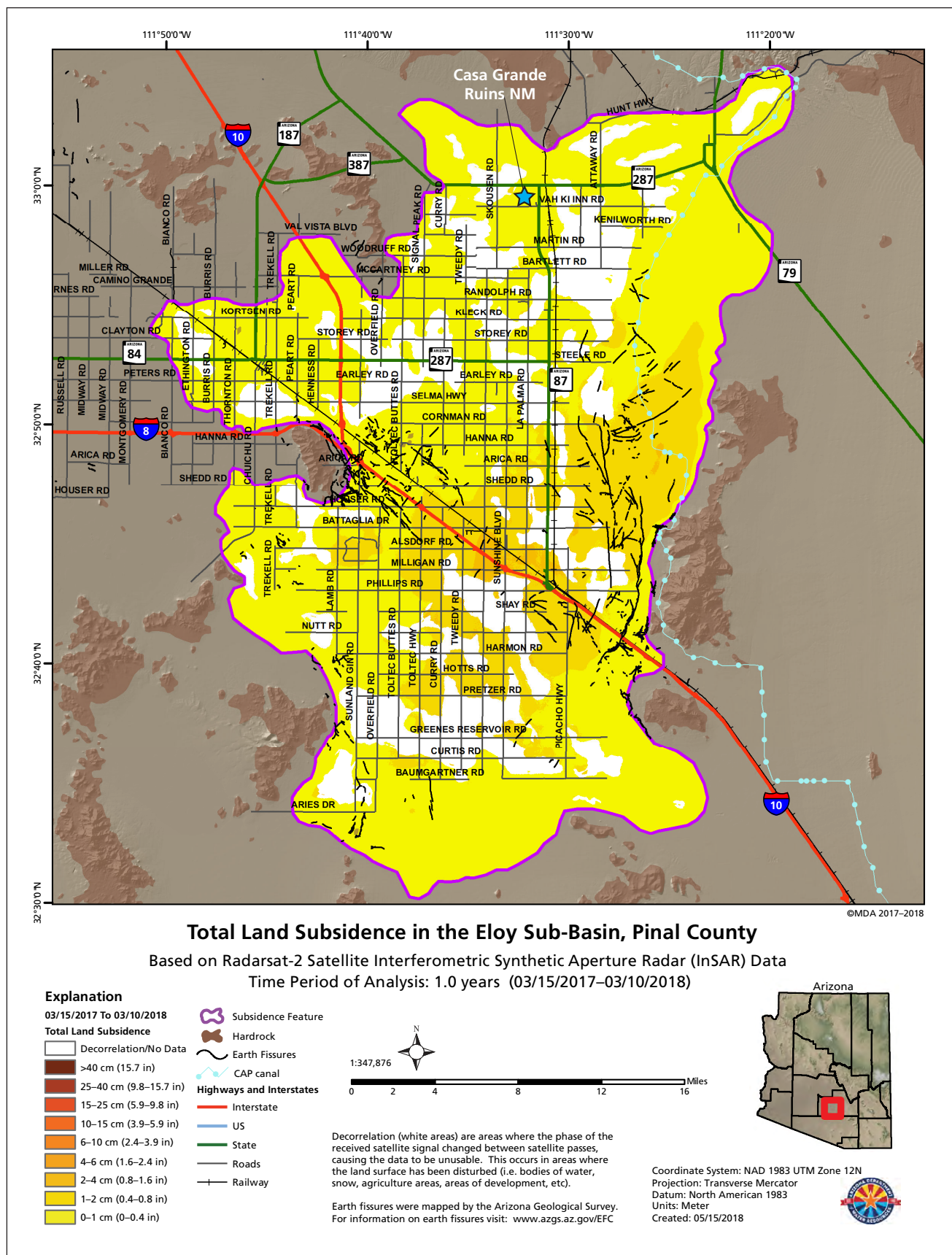


Figure 3-4. Land subsidence and earth fissures in the Eloy subbasin, March 15, 2017–March 10, 2018. Source: https://new.azwater.gov/sites/default/files/PicachoArea03-2017to03-2018_8x11.pdf.

4 Literature Cited

- Arizona Department of Water Resources (ADWR). 2010. Arizona water atlas volume 8: Active Management Area planning area. 454 pp.
- . 2017a. Statewide groundwater level changes in Arizona: Water years 1996–2016, 2006–2016, and 2015–2016. Open File Report No. 14.
- . 2017b. Land subsidence monitoring report no. 3. January. 40 pp.
- Clemensen, A. B. 1992. Casa Grande Ruins National Monument, Arizona: A centennial history of the first prehistoric reserve, 1892–1992. National Park Service.
- Corkhill, F. 2012. Final report: Statewide hydrologic monitoring report (late 1980s early/mid 1990s to mid/late 2000s). Arizona Department of Water Resources, Hydrology Division, Phoenix.
- Filippone, C. L., K. Beaupré, D. Angell, M. H. Reiser, E. Gwilliam, J. A. Hubbard, K. Gallo, M. D. Jacobson, and H. Sosinski. 2014. Groundwater monitoring protocol and standard operating procedures: Sonoran Desert, Chihuahuan Desert, and Southern Plains networks, version 1. Natural Resource Report NPS/SODN/NRR—2014/787. National Park Service, Fort Collins, Colorado.
- Hammett, B. A. 1992. Maps showing groundwater conditions in the Eloy and Maricopa-Stanfield sub-basins of the Pinal Active Management Area, Pinal, Pima, and Maricopa counties, Arizona, 1989. Arizona Department of Water Resources, Hydrologic Map Series no. 23.
- Hubbard, J. A., K. Raymond, E. Gwilliam, and M. Tercek. in prep. Climate monitoring protocol for the Sonoran, Chihuahuan, and Southern Plains national parks.
- Richard, S. M., T. C. Shipman, L. C. Greene, and R. C. Harris. 2007. Estimated depth to bedrock in Arizona. Arizona Geological Survey Digital Geologic Map Series DGM-52, Version 1.0.
- Strahler, A. H. 2013. Introducing physical geography. 6th edition. Hoboken, N.J.: Wiley.
- Tsakiris, G., and H. Vangelis. 2005. Establishing a drought index incorporating evapotranspiration. *European Water* 9/10:3–11.
- Turner, R. M., R. H. Webb, J. E. Bowers, and J. R. Hastings. 2003. *The changing mile revisited*. Tucson: University of Arizona Press.
- United Nations Environment Programme (UNEP). 1992. *World atlas of desertification*. London: Edward Arnold.

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.

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™