



Streams Monitoring at Tumacácori National Historical Park

2011 Summary Report

Natural Resource Technical Report NPS/SODN/NRDS—2014/743



ON THE COVER

Santa Cruz River, Tumacácori National Historical Park. NPS photo.

Streams Monitoring at Tumacácori National Historical Park

2011 Summary Report

Natural Resource Technical Report NPS/SODN/NRDS—2014/743

Prepared by

Evan Gwilliam
Kara Raymond
Laura Palacios
Sonoran Desert Network
National Park Service
12661 E. Broadway Blvd.
Tucson, Arizona 85748

Editing and Design

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

December 2014

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 Data Series is intended for timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

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, <http://www.nature.nps.gov/im/units/sodn>, as well as at the Natural Resource Publications Management web site, <http://www.nature.nps.gov/publications/nrpm>. To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Gwilliam, E. L., K. L. Raymond, and L. Palacios. 2014. Streams monitoring at Tumacácori National Historical Park: 2011 summary report. Natural Resource Data Series NPS/SODN/NRDS—2014/743. National Park Service, Fort Collins, Colorado.

Contents

Figures iv

Tables iv

Executive Summary v

1 Introduction 1

 1.1 Background 1

 1.2 Goal and objectives.....2

 1.3 Management outcomes.....2

 1.4 Scope of this report 2

 1.5 Streams monitoring at Tumacácori National Historical Park 3

2 Methods.....4

 2.1 Water quality core parameters 4

 2.2 Water quality samples 4

 2.3 Water quantity data 4

 2.4 Aquatic macroinvertebrates and habitat 4

 2.5 Data handling and analysis 5

 2.6 Understanding water quality data and standards.....5

3 Results.....6

 3.1 Water quality sampling 6

 3.2 Water quantity.....11

 3.3 Aquatic macroinvertebrates and habitat 11

 3.4 Quality assurance/quality control 11

4 Literature Cited 15

Figures

Figure 1-1. Map of Sonoran Desert Network parks	1
Figure 1-2. Map of the Santa Cruz River, Tumacácori NHP, with the SODN water quality sampling locations.....	3
Figure 3-1. Seasonal variability data from the Santa Cruz River, Tumacácori National Historical Park, WY2011	8
Figure 3-2. Hydrograph of mean daily discharge (cfs) and acre feet per day, Santa Cruz River at Tubac, Arizona, WY2011.....	12
Figure 3-3. Proportion of seasonal streamflow, Santa Cruz River at Tubac, Arizona, WY2011, and annual mean since 1996.....	12
Figure 3-4. Mean monthly flow, Santa Cruz River at Tubac, Arizona, WY2011, and annual mean since 1996.....	13
Figure 3-5. Annual peak flow, Santa Cruz River at Tubac, Arizona, 1996–2011.....	13
Figure 3-6. Aquatic habitat in the index reach of the Santa Cruz River, Tumacácori National Historical Park, WY2011.....	14
Figure 3-7. Substrate size in the index reach of the Santa Cruz River at Tumacácori National Historical Park, WY2011.....	14

Tables

Table 3-1. Sampling results for core water quality parameters, Tumacácori National Historical Park, WY2011.	7
Table 3-2. Summary of multi-parameter sonde sampling period on the Santa Cruz River, Tumacácori National Historical Park, WY2011.	7
Table 3-3. Sampling results for total coliform and <i>E. coli</i> , Santa Cruz River at Tumacácori National Historical Park, WY2011.....	7
Table 3-4. Sampling results (mg/L) for inorganics, Santa Cruz River at Tumacácori National Historical Park, WY2011.....	9
Table 3-5. Sampling results (mg/L) for nutrient dynamics, Santa Cruz River at Tumacácori National Historical Park, WY2011.....	9
Table 3-6. Sampling results (mg/L) for metals and metalloids, Santa Cruz River at Tumacácori National Historical Park, WY2011.	10

Executive Summary

The Sonoran Desert Network (SODN) performs long-term streams monitoring at four national park units with the goal of detecting broad-scale changes in aquatic and riparian ecological condition. This document reports on data related to water quality, water quantity, and aquatic macroinvertebrates collected on the Santa Cruz River at Tumacácori National Historical Park (NHP) during water year (WY) 2011 (October 1, 2010–September 30, 2011). It evaluates water quality data in the context of state standards and provides descriptive statistics for water quality, water quantity, and aquatic macroinvertebrate data.

All data were collected following the SODN streams monitoring protocol. The data represent a snapshot of conditions at the time of data collection. The initial analyses of data in this report are provisional and no conclusions should be drawn about trends.

The Santa Cruz River at Tumacácori NHP is an effluent-driven system, with most surface water provided by the Nogales International Wastewater Treatment Plant. In WY2011, 235 discrete water quality measurements were made. Of those 235 individual analyses, 87 were associated with Arizona surface water quality criteria. Of those 87 measurements, 85 (97.7%) were compliant with state standards, while two exceeded Arizona state surface water quality standards for *E. coli*. Results from the logging multi-parameter instrument demonstrated seasonal water quality variability.

Water quantity data were taken from the U.S. Geological Survey gage on the Santa Cruz River at Tubac, Arizona. The largest flow events occurred during the monsoon season. However, the period from November through March (late winter/early spring) had consistently higher baseflow discharge than the monsoon. The highest proportion of streamflow occurred during spring (December 8–April 30), followed by the monsoon season (July 5–October 10). The peak flow in WY2011 was 1,700 cubic feet per second.

Macroinvertebrate samples were collected, and a stream habitat survey completed, in May 2011. The macroinvertebrates samples were sent to the National Aquatic Monitoring Center; however, they never arrived. The stream is dominated by glide/run habitat. The majority of stream substrate was sand, followed by gravel. The Bank Erosion Hazard Index indicated that the stream banks had a low to moderate risk of erosion.

1 Introduction

1.1 Background

Perennial streams are among the most critical and impacted natural resources of the Sonoran Desert. The presence and extent of surface water has traditionally provided a focus for human habitation in the region, resulting in prehistoric and historic development coincident with reliable and abundant rivers, streams, wetlands, and springs. Further, more than 90% of all species in the ecoregion utilize aquatic ecosystems for some portion of their lifecycles (Phillips and Comus 2000), yet natural surface waters have decreased by an estimated 99% since the mid-19th century due to human demands for water (Tellman et al. 1997).

Eight of the 11 Sonoran Desert Network (SODN) parks contain regionally important surface waters (Sprouse et al. 2004). Perennial rivers and streams (hereafter, “streams”) are an important subset of surface waters in SODN parks, with portions of three major river systems (or their tributaries) found

in Gila Cliff Dwellings, Montezuma Castle, and Tuzigoot national monuments, and in Tumacácori National Historical Park (Figure 1-1). As human development in the American Southwest accelerates, these critical waters and the abiotic and biotic resources they support will grow in significance, as will the threats to their persistence. Therefore, effective protection of streams and their aquatic ecosystems is of paramount importance to managers of SODN parks (NPS 2005).

To support a comprehensive understanding of stream condition, the Sonoran Desert Network (SODN) employs a holistic approach to monitoring that integrates geomorphological, hydrological, and biological indicators of six vital signs: surface water quality (core water quality parameters, alkalinity, primary nutrients, biological condition, pollutant metals, carcinogens and toxins), surface water quantity, stream channel morphology, riparian vegetation, benthic macroinvertebrates and periphyton, and fish and crayfish. When investigated in combination, these vital signs will provide a useful index of stream condition and function.

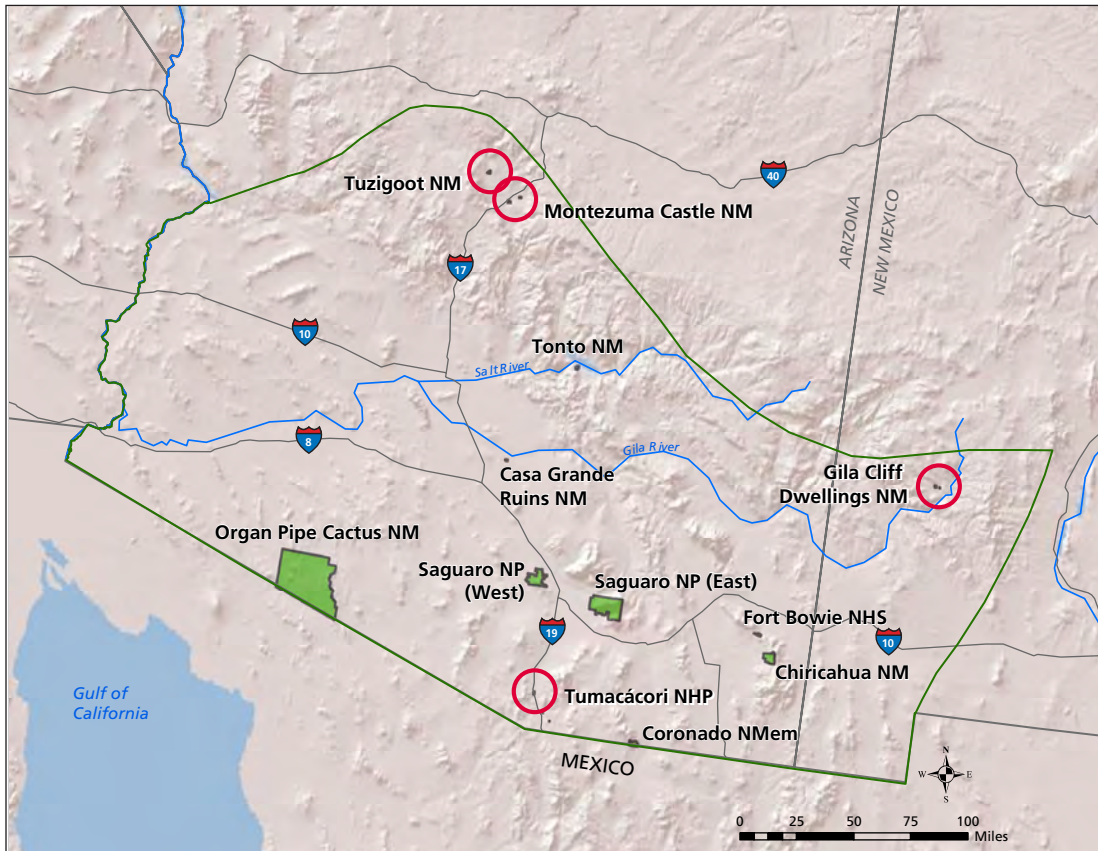


Figure 1-1. Map of Sonoran Desert Network parks. Portions of three major river systems (or their tributaries) are found in the highlighted parks.

1.2 Goal and objectives

The goal of Sonoran Desert Network streams monitoring is to detect broad-scale changes in aquatic and riparian ecological condition by observing selected ecological drivers, stressors, and processes, and to communicate this information to park managers. This integrated approach explores patterns and identifies candidate explanations to support effective management and protection of park natural resources in a cumulative fashion, such that the results of each successive round of monitoring build upon the knowledge gained from previous efforts and related research and monitoring activities.

Objectives of SODN streams monitoring are:

1. **Water quality:** Determine status as well as seasonal and annual trends in core water quality parameters; selected inorganic, nutrient, and metals parameters; and microbiological elements, toxins, and suspended solids.
2. **Water quantity:** Determine status and measure trend in annual, seasonal, and monthly stream discharge means and totals; and flood/low flow magnitude and frequency.
3. **Channel morphology:** Determine the status of stream-channel habitat and measure trends in channel cross-section area, channel slope, sinuosity and streamflow continuity.
4. **Riparian vegetation:** Measure trend in common riparian vegetation abundance (including non-native species), community structure, and recruitment.
5. **Macroinvertebrates:** Determine status of biological indices and trends in macroinvertebrate taxa abundance, richness, and derived metrics.
6. **Fish:** Determine status and measure trends in native and non-native fish abundance and frequency.

1.3 Management outcomes

The knowledge gained by achieving the measurable objectives of this monitoring will be used to evaluate and report on the condition of water bodies in SODN park units. Additionally, it can be used to inform park managers about water resources in order to:

- a) Maintain waters that vary within their natural chemical and biological ranges and meet applicable federal and state water quality criteria.

Justification: Waters that vary within their natural ranges can typically support healthy aquatic ecosystems and most beneficial uses.

- b) Improve water quality of impaired waters.

Justification: The NPS GPRA goal is that 99.3% of streams and rivers managed by the NPS will meet state and federal water quality standards.

- c) Demonstrate and maintain high water quality where it exists.

Justification: The antidegradation provision of the Clean Water Act specifies that high-quality waters will be maintained (USEPA 2006; Section 303).

1.4 Scope of this report

This document reports on data related to water quality, water quantity, and aquatic macroinvertebrates collected on the Santa Cruz River at Tumacácori National Historical Park (NHP) during water year (WY) 2011 (October 1, 2010–September 30, 2011). The focus of this report is on current status of selected parameters. Trend evaluations will be conducted in a synthesis report in 2014. With this report, we seek to:

- Evaluate the WY11 water-quality data in the context of state standards and
- Provide descriptive statistics for water quality, water quantity, and aquatic macroinvertebrate data.

The discrete data in this report should be viewed as a snapshot of water quality conditions existing at the time when the data were collected.

Although care has been taken to ensure accuracy of raw data values, a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change, and no conclusions should be drawn about trends. The information discussed relates only to WY11.

After channel morphology and riparian

vegetation protocols are completed at the park, SODN staff will produce a report that includes status and trend analysis of water quality data.

1.5 Streams monitoring at Tumacácori National Historical Park

Historically, the Santa Cruz River has been an intermittent stream (Norman et al. 2013). Today, however, the Santa Cruz River at Tumacácori NHP is an effluent-driven system, with most surface water provided by the Nogales International Wastewater Treatment Plant (NIWTP). The NIWTP has been discharging treated effluent into the Santa Cruz River since 1951. In 2011, the NIWTP discharged ~13–15 million gallons per day (mgd) of water into the Santa Cruz River. Approximately 9–12 mgd of this water originated in Mexico. This artificial flow alters natural conditions but provides an otherwise unavailable quasi-perennial supply, allowing for the persistence of a diverse riparian habitat for wildlife within Tumacácori NHP (Norman et al. 2013).

There are several concerns regarding the current status of the Santa Cruz River, including water quality and drought. The Arizona Department of Water Quality has designated the 4.8-mile section of the Santa Cruz River from Josephine Canyon to Tubac Bridge, which runs through the park, as impaired for aquatic life and wildlife (due to ammonia), and for partial body contact (due to *E. coli* levels that exceed Arizona water quality criteria) (ADEQ 2012). In the past, nutrient and bacterial contamination sometimes resulted from agricultural land use and upstream sewage-treat-

ment facilities. In 2009, however, the NIWTP upgraded wastewater treatment methods, greatly reducing the nitrogen content of the effluent (Norman et al. 2013).

The U.S. Southwest has been in a drought since approximately 2001 (Blunden and Arndt 2013). Reduced precipitation levels have in turn reduced the amount of surface flow in regional rivers, as well as groundwater levels. Effluent from the NIWTP has reduced the drought's effects on the portion of the river that runs through the park, but the stream channel often runs dry near the park's northern boundary during the springtime. In the future, the amount of discharge from the NIWTP is expected to decrease due to the construction of the Los Alisos wastewater treatment plant in Mexico, which will likely further reduce the flow of the Santa Cruz through Tumacácori NHP. (Norman et al. 2013).

In WY11, SODN staff made a total of four sampling visits to the Santa Cruz River at Tumacácori NHP. Water quality monitoring occurred ~150 m downstream from the southern boundary of the park (Figure 1-2).

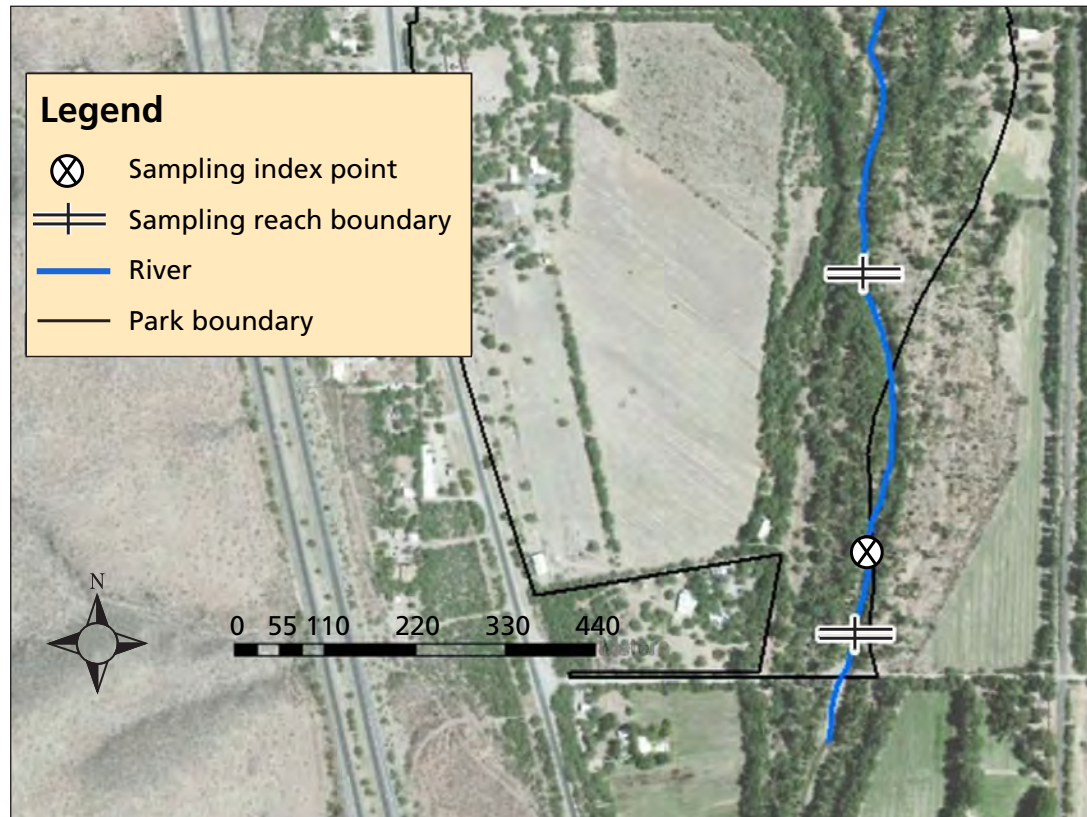


Figure 1-2. Map of the Santa Cruz River, Tumacácori NHP, with the SODN water quality sampling locations.

2 Methods

A brief description of the data collection and processing methodologies followed by SODN staff at Tumacácori NHP during WY11 is presented below. Detailed descriptions of these procedures will be available in SODN's water quality monitoring protocol (Gwilliam et al. in prep [a]).

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). Parameters sampled by SODN included water temperature, pH, specific conductivity, dissolved oxygen, turbidity, and discharge. During each visit, we noted the hydrologic conditions and sampled the 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 collected data on temperature, pH, specific conductivity, and dissolved oxygen at 15-minute intervals for a minimum of two weeks every quarter, using a logging multi-parameter instrument (YSI XLM600-V2).

2.2 Water quality samples

During each site visit, water samples were collected in a 3L Nalgene sample collection bottle, following USGS non-isokinetic sampling methods as described in the National 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 consti-

tuents. The sample water was filtered and/or treated as required, kept on ice, and dropped off at the contract laboratory. For WY11, that lab was Test America in Phoenix, Arizona.

2.3 Water quantity data

Streamflow data for this report were recorded at the U.S. Geological Survey (USGS) gage 09481740 on the Santa Cruz River at Tubac, Arizona. This gage is located 5 km downstream from our index sampling site in Tumacácori NHP. Data on daily mean discharge and annual peak discharge are downloaded from the USGS website to the SODN server and processed.

2.4 Aquatic macroinvertebrates and habitat

Macroinvertebrate sample collection by SODN coincides with the index period used by the Arizona Department of Environmental Quality to ensure compatibility of monitoring samples. The index period for warm-water streams is from April to May (Lawson 2005).

The index reach at Tumacácori NHP is 460 meters long, starting at the park's southern boundary. The reach contains 11 equally spaced transects. At each transect, we measured wetted width, water depth, velocity, and canopy cover, and estimated substrate size, bank erosion (using the Rosgen Bank Erosion Hazard Index), and diversity of aquatic habitat. Two types of samples were collected in the reach:

- A quantitative sample was collected from five targeted riffle habitats to provide data on organism abundance. A total of 12 replicate samples were collected from a 0.09-m² area, using a kicknet with a 0.3-m opening for one minute. At each of the five habitats, we also measured depth, velocity, particle size, and particle embeddedness.
- A qualitative sample was collected to develop a comprehensive list of species present in the reach. Using nets, samples were actively collected from all habitat types within the reach during a one hour collection period and compiled into one composite sample.

Aquatic macroinvertebrate samples were sent to the National Aquatic Monitoring Center's Bug Lab, a Bureau of Land Management laboratory at Utah State University in Logan, Utah, with the goal of having a taxonomist, certified by the North American Benthological Society, identify all aquatic macroinvertebrates to the lowest taxonomic level possible.

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; these were determined using IDEXX MPN Generator software provided by the manufacturer (IDEXX Inc.). 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 Arizona's water quality standards (ADEQ 2009) and notes any exceedances.

2.6 Understanding water quality data and standards

The State of Arizona has developed state-wide water quality standards and criteria for surface waters to meet requirements of the Federal Clean Water Act (ADEQ 2009).^{*} A water quality standard refers to a specific parameter and its associated beneficial-use

designation, in conjunction with a criterion, which is the numeric component against which a result is compared.

The State of Arizona has identified three beneficial uses for the Santa Cruz River at Tumacácori NHP: aquatic and wildlife effluent-dependent water, partial-body contact recreational use, and agricultural livestock watering (ADEQ 2009). Each beneficial use may have different criteria for one parameter.

Numeric criteria for aquatic and wildlife water quality standards address potential effects of both chronic exposure to a parameter over an extended period of time (months) and acute exposure over a short period of time (hours or days). Acute criteria are based on a single sample. Criteria are usually much lower for chronic exposure than for acute exposure and are not necessarily comparable to the results obtained from a one-time grab sample (chronic standards are based on the geometric mean of samples collected over a period of several days) (ADEQ 2009).

When determining attainment of both acute and chronic standards, the representative nature of the data must be considered. From a compliance standpoint, the acute instantaneous criteria afford the only direct comparison for such data because they apply to a single sample. However, from a resource-conservation standpoint, instantaneous grab-sample data, when compared against more stringent chronic criteria, can provide a means of early warning and an indication of a problem that may require more attention. Therefore, we have identified when results are outside the chronic criterion.

^{*}The National Park Service (NPS) does not have regulatory authority over waters in the United States, or even the authority to make assessments for designated use. The NPS cooperates with states in collecting data used in the protection of water bodies under state jurisdiction.

3 Results

3.1 Water quality sampling

Of 235 individual analyses of sample water collected from the Santa Cruz River at Tumacácori NHP during WY11, 87 were associated with Arizona surface water quality criteria. Of those 87 measurements, 85 (97.7%) were compliant with state standards, while two exceeded Arizona state surface water quality standards for *E. coli*.

3.1.1 Core parameters

3.1.1.1 Grab samples

The discrete measurements shown in Table 3-1, made in the field, represent conditions at the Tumacácori NHP index site during site visits in WY11.

3.1.1.2 Continuous sampling

A logging multi-parameter sonde was deployed for two weeks during each quarter to collect temperature, pH, specific conductivity, and dissolved oxygen data at 15-minute intervals. Figure 3-1 (page 8) summarizes the seasonal variability in water temperature, pH, specific conductivity, and dissolved oxygen.

During the summer and fall sampling periods, the results indicated that pH and dissolved oxygen, respectively, did not meet the Arizona water quality criteria. However, observations indicated that the low readings were a factor of debris accumulation on some of the sonde probes, resulting in inaccurate data. In Figure 3-1(b), a subset of data is provided for the summer pH results. In Figure 3-1(d), the fall data for dissolved oxygen are excluded and a subset is provided for the summer results.

The continuous sampling period is summarized in Table 3-2. Change in water depth was taken from logging multi-parameter sonde results. Baseflow and peak discharge information were recorded at the USGS gage on the Santa Cruz River at Tubac, Arizona, downstream from the sampling site in the park. Flow at the sampling site may have been higher than at the gage. During the fall sampling period, flow events occurred on October 15 and 16. The winter and spring sampling periods had stable stream discharges, while several flow events occurred during the summer sampling period.

3.1.2 Total coliforms and *E. coli*

E. coli results exceeded the state partial body contact standard during fall and summer sampling, and exceeded the upper detection limit of the IDEXX Colilert® test, at 2,420 MPN/100 mL (Table 3-3). SODN's 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 criterion for a single sample of *E. coli* is 575 cfu/100 mL.

3.1.3 Water quality laboratory data

Four water samples collected at Tumacácori NHP during WY11 were sent to Test America Phoenix to be analyzed for a suite of analytes. All parameters met state standards. Complete laboratory results are provided in Tables 3-4 through 3-6. Some water quality criteria are based on hardness, which varied between samples; therefore, the numeric criteria are expressed as a range where applicable.

Table 3-1. Sampling results for core water quality parameters, Tumacácori National Historical Park, WY2011.

Core parameter	Fall 10/14/2010	Winter 2/15/2011	Spring 5/18/2011	Summer 8/11/2011	AZ criterion (effluent-dependent)
Temperature (°C)	24.2	15.2	23.5	29.6	No discrete criterion ¹
pH	7.99	8.80	8.60	8.01	6.5–9.0
Specific Conductivity (µS/cm)	571	605	649	655	No criterion
Dissolved Oxygen (mg/L)	6.54	10.8	10.4	5.04	>3 ²
Turbidity (NTU)	11.1	2.18	2.04	169	No criterion
Discharge (cfs)	24.7	11.7	4.39	5.61	No criterion

¹ Maximum allowable increase in ambient water due to a thermal discharge is 3.0°C

² Dissolved oxygen concentration of 3.0 mg/L applies from three hours after sunrise to sunset, 1.0 mg/L applies from sunset to three hours after sunrise.

Table 3-2. Summary of multi-parameter sonde sampling period on the Santa Cruz River, Tumacácori National Historical Park, WY2011.

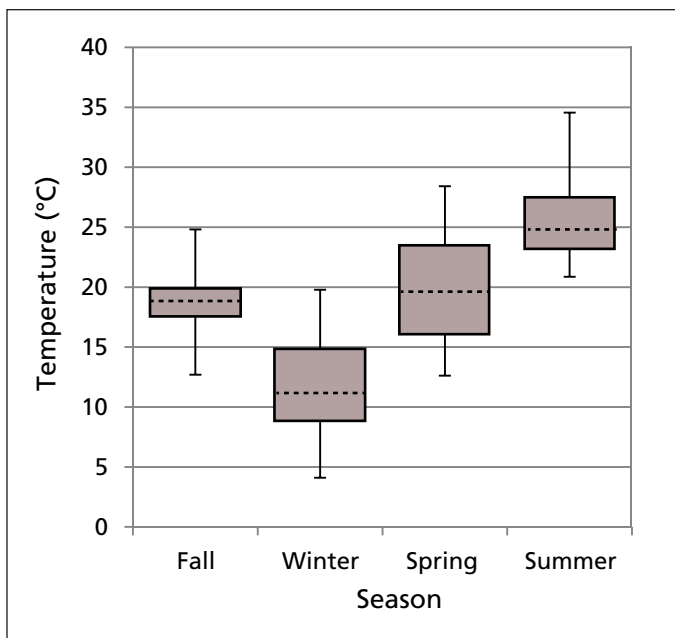
Season	Sampling period	# readings	Change in depth (in)	Baseflow discharge (cfs)	Peak discharge (cfs)
Fall	10/14/2010–11/02/2010	1,815	13.7	4.5–29	107
Winter	02/01/2011–02/15/2011	1,343	7.52	6.3–20	20
Spring	05/04/2011–05/18/2011	1,345	8.03	0.52–7.5	7.5
Summer	07/22/2011–08/11/2011	1,922	55.8	0–5.6	1,120

Table 3-3. Sampling results for total coliform and *E. coli*, Santa Cruz River at Tumacácori National Historical Park, WY2011.

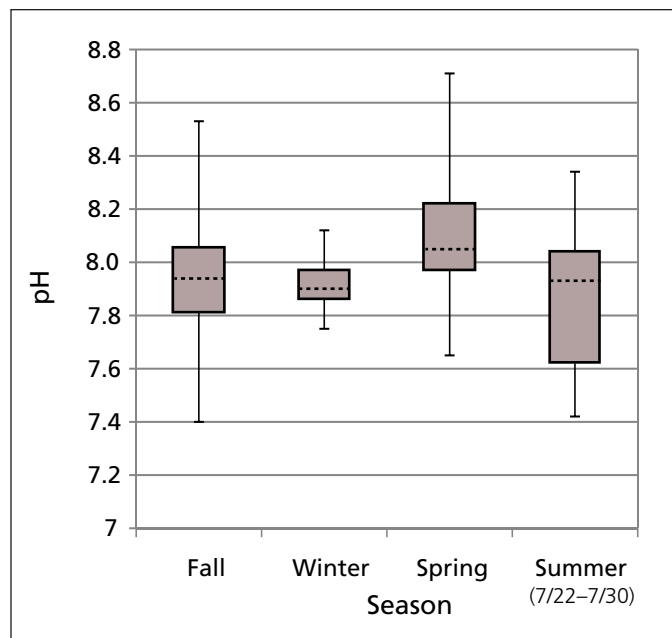
Bacteria	Fall 10/14/2010	Winter 2/15/2011	Spring 5/18/2011	Summer 8/11/2011	AZ criterion (partial body contact)
Total Coliforms (MPN/100 mL)	>2,420	1,270	1,990	>2,420	No standard
<i>E. coli</i> (MPN/100 mL)	>2,420	10.4	36.0	>2,420	575 cfu/100 mL ¹

¹ Standard for a single sample. The geometric mean standard is 126 cfu/100mL. Red, bolded values exceeded the standard.

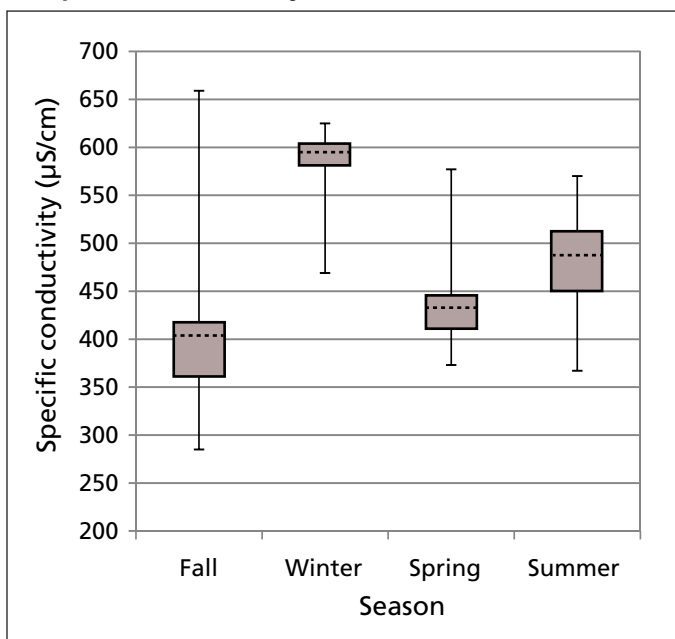
(a) Water temperature



(b) pH



(c) Specific conductivity



(d) Dissolved oxygen

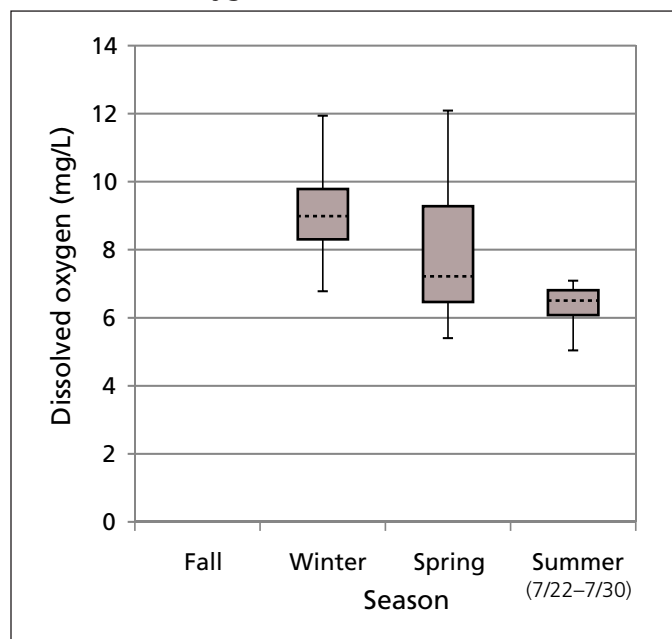


Figure 3-1. Seasonal variability data from the Santa Cruz River, Tumacácori National Historical Park, WY2011. Dotted lines represent median values. Bars show range of values.

Table 3-4. Sampling results (mg/L) for inorganics, Santa Cruz River at Tumacácori National Historical Park, WY2011.

Analyte	Fall 10/14/2010	Winter 2/15/2011	Spring 5/18/2011	Summer 8/11/2011	AZ criterion	Beneficial use
Alkalinity as CaCO ₃	170	190	190	220	No criterion	
Bicarbonate Alkalinity as CaCO ₃	170	190	180	220	No criterion	
Carbonate Alkalinity as CaCO ₃	<2.0	<2.0	8.0	<2.0	No criterion	
Hydroxide Alkalinity as CaCO ₃	<2.0	<2.0	<2.0	<2.0	No criterion	
Chloride	43	41	42	38	No criterion	
Fluoride	0.78	0.56	0.72	0.58	140	Partial body contact
Sulfate	79	83	98	85	No criterion	
Total Cyanide	NC	NC	NC	<0.0050	No criterion	
Total Dissolved Solids	470	530	460	440	No criterion	
Total Suspended Solids	<10	<10	<10	140	No criterion	
Total Hardness	220	200	240	220	No criterion	

NC = not collected

Table 3-5. Sampling results (mg/L) for nutrient dynamics, Santa Cruz River at Tumacácori National Historical Park, WY2011.

Nutrients	Fall 10/14/2010	Winter 2/15/2011	Spring 5/18/2011	Summer 8/11/2011	AZ criterion	Beneficial use
Total Nitrogen	7.8	9.9	2.8	3.6	No criterion	
Nitrate-N	7.8	9.9	2.8	2.2	3,733.333	Partial body contact
Nitrite-N	<0.20	<0.20	<0.20	<0.20	233.333	Partial body contact
Ammonia-N	<0.50	<0.50	<0.50	<0.50	0.51–1.28 (chronic)	Aquatic and wildlife
Total Kjeldahl Nitrogen	<1.3	<1.0	<1.0	1.4	No criterion	
Total Phosphorus	2.5	2.6	<0.04	1.7	No criterion	
Dissolved Phosphorus	2.1	2.4	2.1	1.6	No criterion	
Biological Oxygen Demand	NC	<5.0	<5.0	<5.0	No criterion	
Total Organic Carbon	NC	NC	NC	11	No criterion	

Table 3-6. Sampling results (mg/L) for metals and metalloids, Santa Cruz River at Tumacácori National Historical Park, WY2011.

Total metals	Fall 10/14/2010	Winter 2/15/2011	Spring 5/18/2011	Summer 8/11/2011	AZ criterion	Beneficial use
Aluminum	0.81	0.074	0.051	5.2	No criterion	
Dissolved Aluminum	<0.050	<0.050	<0.050	<0.010	No criterion	
Antimony	NC	NC	NC	<0.0040	0.747	Partial body contact
Dissolved Antimony	NC	NC	NC	<0.0020	0.60	Aquatic and wildlife (chronic)
Arsenic	<0.010	<0.010	0.011	0.010	0.20	Livestock
Dissolved Arsenic	0.011	<0.010	<0.010	0.0078	0.15	Aquatic and wildlife (chronic)
Barium	NC	NC	NC	0.14	98	Partial body contact
Dissolved Barium	NC	NC	NC	0.073	No criterion	
Beryllium	NC	NC	NC	<0.0010	1.867	Partial body contact
Dissolved Beryllium	NC	NC	NC	<0.00050	No criterion	
Boron	0.18	0.16	0.19	0.14	186.667	Partial body contact
Dissolved Boron	0.15	0.15	0.17	0.15	No criterion	
Cadmium	NC	NC	NC	<0.0020	0.050	Livestock
Dissolved Cadmium	NC	NC	NC	<0.0010	0.00091–0.0010	Aquatic and wildlife (chronic)
Calcium	67	64	74	68	No criterion	
Dissolved Calcium	61	61	71	66	No criterion	
Chromium	NC	NC	NC	<0.0040	1.0	Livestock
Dissolved Chromium	NC	NC	NC	<0.0020	No criterion	
Copper	<0.010	<0.010	<0.010	0.012	0.50	Livestock
Dissolved Copper	<0.010	<0.010	<0.010	0.0041	0.016–0.019	Aquatic and wildlife (chronic)
Iron	0.74	0.075	0.047	2.6	No criterion	
Dissolved Iron	<0.040	<0.040	<0.040	<0.040	1.0	Aquatic and wildlife (chronic)
Lead	<0.0050	<0.0050	<0.0050	0.010	0.015	Partial body contact
Dissolved Lead	<0.0050	<0.0050	<0.0050	<0.0010	0.0053–0.0064	Aquatic and wildlife (chronic)
Magnesium	12	11	13	12	No criterion	
Dissolved Magnesium	11	11	11	11	No criterion	
Manganese	0.081	0.043	<0.020	0.37	130.667	Partial body contact
Dissolved Manganese	<0.020	0.034	<0.020	0.053	No criterion	
Mercury	NC	NC	NC	<0.00020	0.010	Livestock
Dissolved Mercury	NC	NC	NC	<0.00020	0.000010	Aquatic and wildlife (chronic)
Molybdenum	<0.020	<0.020	<0.020	0.0058	No criterion	
Dissolved Molybdenum	<0.020	<0.020	<0.020	0.0069	No criterion	
Nickel	NC	NC	NC	0.013	28	Partial body contact
Dissolved Nickel	NC	NC	NC	0.0089	0.093–0.011	Aquatic and wildlife (chronic)
Potassium	9.5	9.3	8.4	13	No criterion	
Dissolved Potassium	8.6	8.9	8.2	12	No criterion	
Selenium	NC	NC	NC	<0.0040	0.002	Aquatic and wildlife (chronic)
Dissolved Selenium	NC	NC	NC	<0.0020	No criterion	
Silica	41	38	38	68	No criterion	
Dissolved Silica	37	39	36	37	No criterion	
Silver	NC	NC	NC	<0.0020	0.004667	Partial body contact
Dissolved Silver	NC	NC	NC	<0.0010	0.011–0.015	Aquatic and wildlife
Sodium	73	73	71	61	No criterion	
Dissolved Sodium	64	70	64	63	No criterion	
Thallium	NC	NC	NC	<0.0020	0.075	Partial body contact

Table 3-6. Sampling results (mg/L) for metals and metalloids, Santa Cruz River at Tumacácori National Historical Park, WY2011, cont.

Total metals	Fall 10/14/2010	Winter 2/15/2011	Spring 5/18/2011	Summer 8/11/2011	AZ criterion	Beneficial use
Dissolved Thallium	NC	NC	NC	<0.0010	0.15	Aquatic and wildlife (chronic)
Uranium	NC	NC	NC	0.0042	2.8	Partial body contact
Dissolved Uranium	NC	NC	NC	0.0034	No criterion	
Zinc	0.025	0.034	0.34	<0.040	25	Livestock
Dissolved Zinc	0.020	<0.020	<0.020	<0.020	0.21 –0. 25	Aquatic and wildlife

3.2 Water quantity

3.2.1 Mean daily discharge

A hydrograph, or a graphical representation of streamflow over time, displays the occurrence, length, and intensity of streamflow over a water year. Figure 3-2 displays the hydrograph on the Santa Cruz River at Tubac for WY11. The largest individual flow events occurred during the monsoon season, but daily discharge was consistently higher in the period from November through March.

3.2.2 Proportion of seasonal flow

At Tumacácori NHP, the seasons for water quantity are defined as winter (October 11–December 7), spring (December 8–April 30), summer (May 1–July 4), and monsoon (July 5–October 10) (NPS 2003). In WY11, the winter and spring seasons contributed a greater proportion of annual streamflow than the annual mean (20% and 43%, respectively, Figure 3-3). The summer and monsoon seasons contributed lesser proportions of annual streamflow in WY11 than in the annual mean (2% and 34%, respectively).

3.2.3 Mean monthly discharge

The WY11 data from the USGS gage on the Santa Cruz River at Tubac showed that flow was stable from October through March (Figure 3-4), likely due to consistent effluent discharge and low evapotranspiration. August and September were strongly influenced by the monsoon season.

3.2.4 Peak flow

The peak flow in WY2011 (Figure 3-5) was 1,700 cfs, occurring on August 13, 2011.

3.3 Aquatic macroinvertebrates and habitat

Macroinvertebrate samples were collected in WY11. The samples were sent to the National Aquatic Monitoring Center; however, the samples did not arrive at their destination. The habitat data collected concurrently with the macroinvertebrate samples are described below.

The stream habitat was relatively homogenous, dominated by glide and run habitats (Figure 3-6). There were no pools and although we tried to collect samples in locations with characteristics similar to riffles (because the Arizona Department of Environmental Quality collects their macroinvertebrate samples in riffles), the riffle designation was generous. Riffles areas are usually composed of cobble and boulder substrate (particles greater than 64 mm), but the riffles in the Santa Cruz River had a median size of 11 mm and an 84th-percentile size of 32 mm. The whole index reach was dominated by sand, followed by gravel (Figure 3-7). Silt tended to be on the edges of the wetted channel and cobble was only observed in one location. Canopy cover of the wetted channel was high, at 47.8%. Results from the Bank Erosion Hazard Index indicated that the banks of the Santa Cruz River have a low to moderate risk of erosion. While the sandy substrate is prone to erosion, the banks have low angles and are heavily vegetated.

3.4 Quality assurance/quality control

To ensure data quality, network staff followed the quality assurance/quality control procedures described in Gwilliam and others (in prep. [a]). Results of these procedures for WY11 can be found in Gwilliam and others (in prep. [b]).

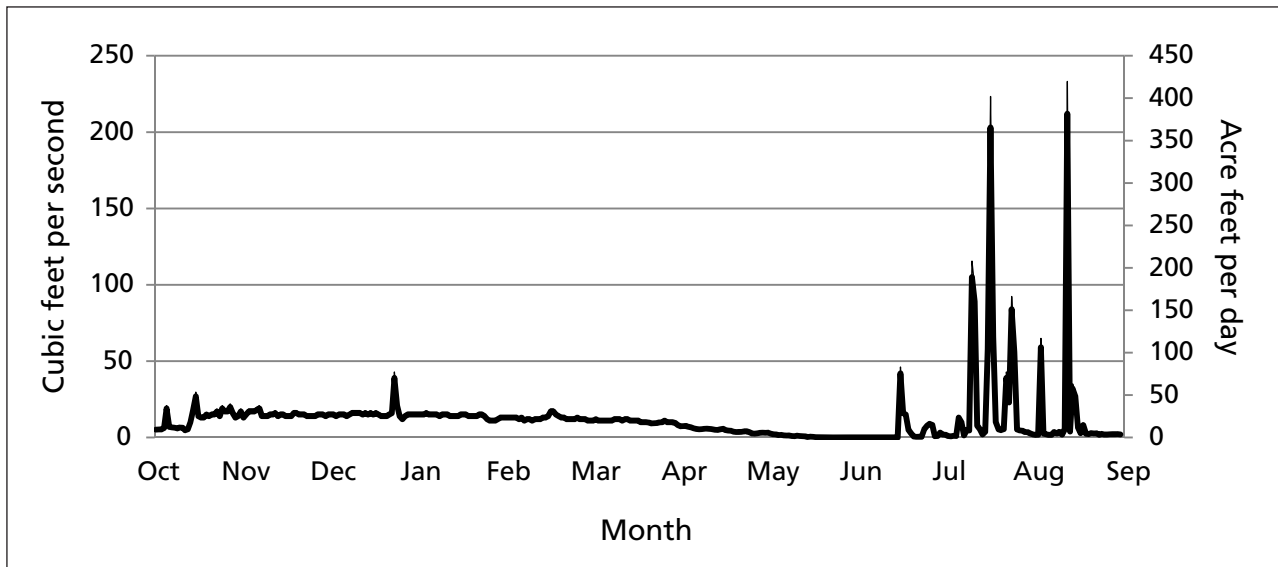


Figure 3-2. Hydrograph of mean daily discharge (cfs) and acre feet per day, Santa Cruz River at Tubac, Arizona, WY2011.

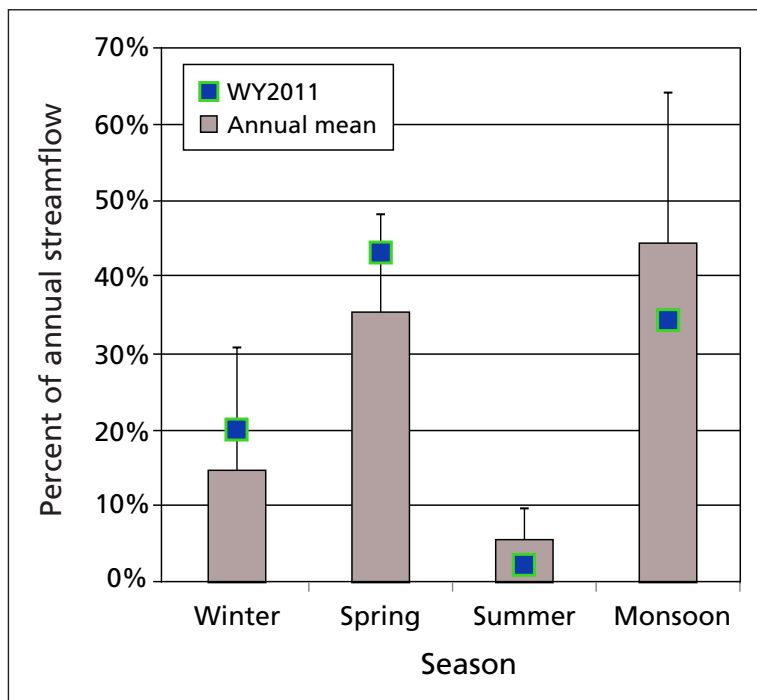


Figure 3-3. Proportion of seasonal streamflow, Santa Cruz River at Tubac, Arizona, WY2011, and annual mean since 1996. Error bars indicate standard deviation.

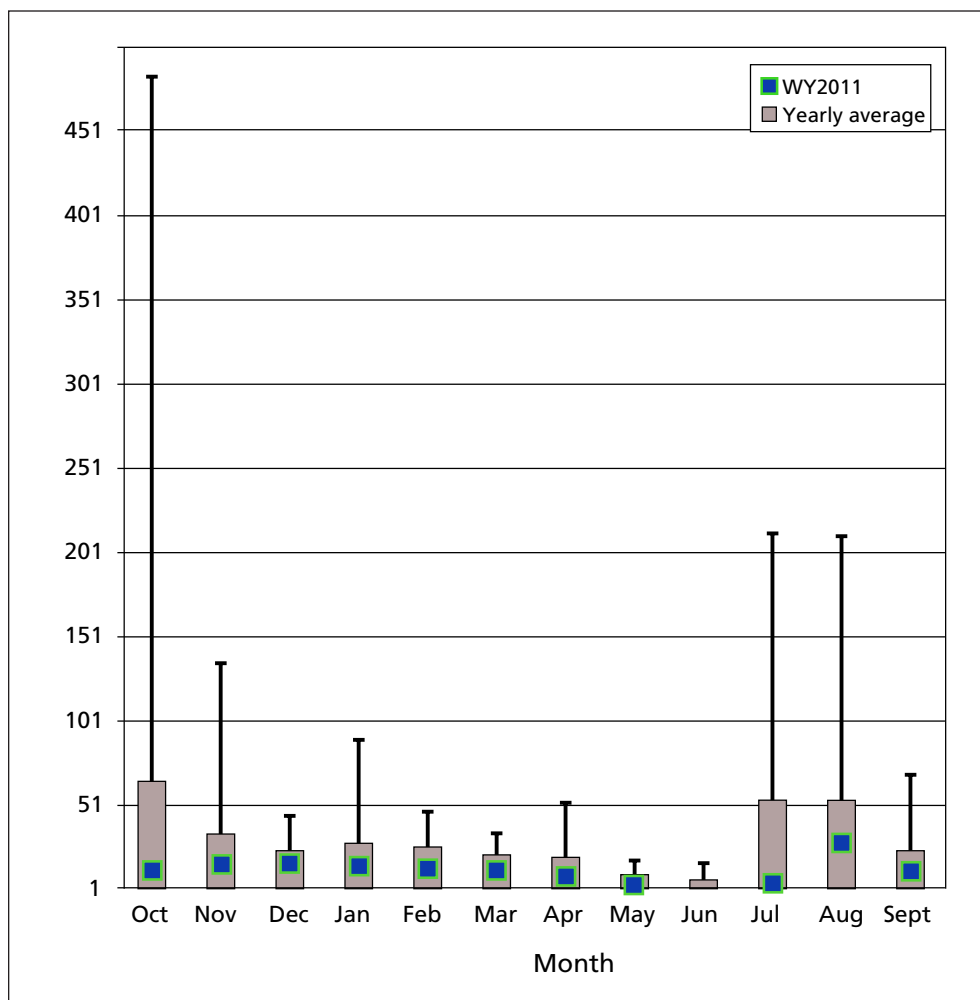


Figure 3-4. Mean monthly flow, Santa Cruz River at Tubac, Arizona, WY2011, and annual mean since 1996. Error bars indicate standard deviation.

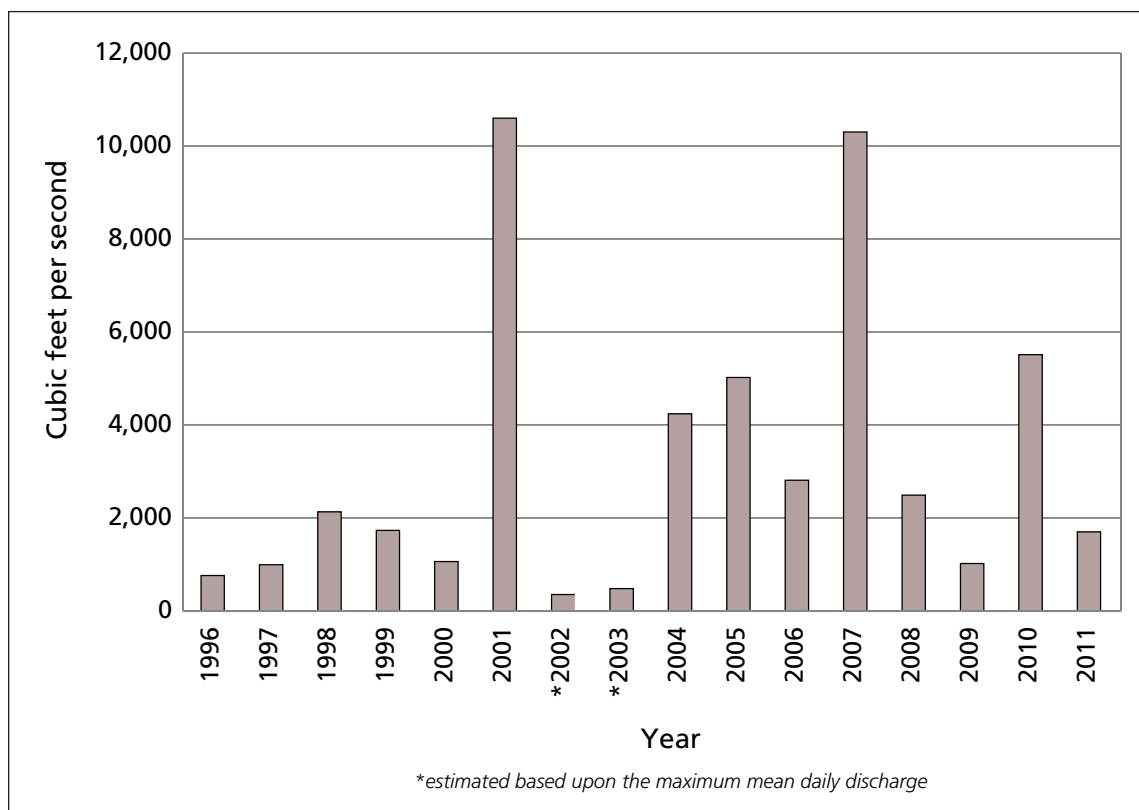


Figure 3-5. Annual peak flow, Santa Cruz River at Tubac, Arizona, 1996–2011.

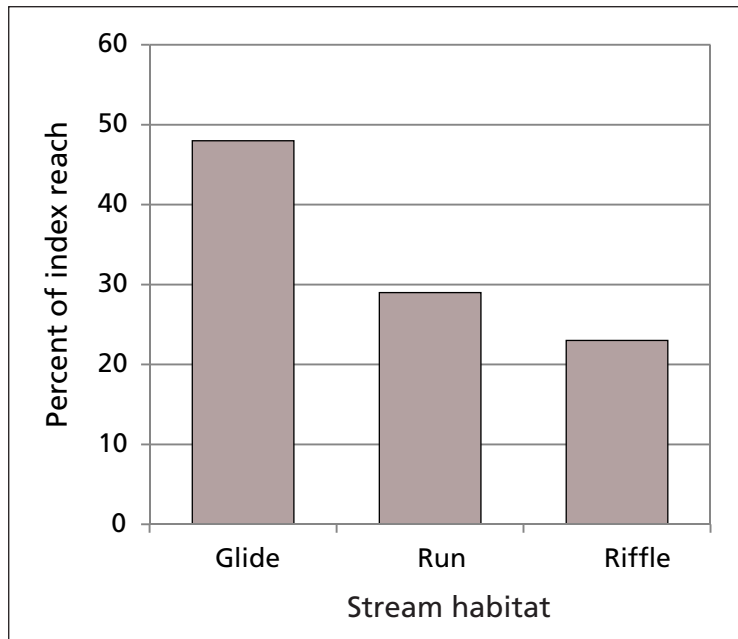


Figure 3-6. Aquatic habitat in the index reach of the Santa Cruz River, Tumacácori National Historical Park, WY2011.

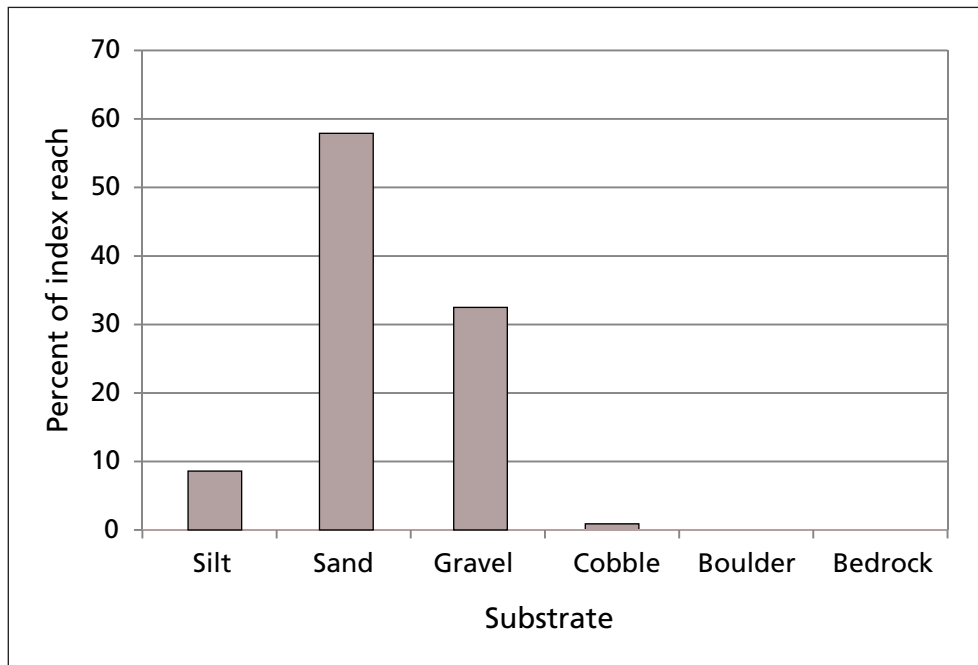


Figure 3-7. Substrate size in the index reach of the Santa Cruz River at Tumacácori National Historical Park, WY2011.

4 Literature Cited

- Arizona Department of Environmental Quality (ADEQ). 2009. Unofficial copy of the 2009 surface water quality standards (18 A.A.C., Chapter 11, Article 1). Available at http://www.azdeq.gov/environ/water/standards/download/SWQ_Standards-1-09-unofficial.pdf. Last accessed December 3, 2013).
- . 2012. 2010 status of water quality: Arizona's integrated 305(b) assessment and 303(d) listing report. Available at <http://www.azdeq.gov/environ/water/assessment/download/ch1-2.pdf>. Last accessed December 3, 2013).
- Blunden, J., and D. S. Arndt, eds., 2013. State of the climate in 2012. Bulletin of the American Meteorological Society, 94(8): S1–S238.
- Gwilliam E. L., K. L. Raymond, S. Buckley, C. L. Fillippone, J. A. Hubbard, C. McIntyre, and S. Studd. In prep (a). Streams monitoring protocol for the Sonoran Desert Network. National Park Service, Fort Collins, Colorado.
- Gwilliam, E. L., and K. L. Raymond. In prep (b). Streams monitoring in the Sonoran Desert and Southern Plains networks. Supplemental QA/QC report, Water Year 2011. National Park Service, Fort Collins, Colorado.
- Irwin, R. J. 2008. Draft part B lite QA/QC review checklist for aquatic vital sign monitoring protocols and SOPs, National Park Service, Water Resources Division. Fort Collins, Colorado.
- Lawson, L. L., ed. 2005. Macroinvertebrate sampling and analysis procedures, section 3, part A, in A manual of procedures for the sampling of surface waters. Report TM05-01, Arizona Department of Environmental Quality, Phoenix.
- National Park Service. 2003. Baseline water quality data, inventory and analysis: Tumacácori National Historical Park. Technical Report NPS/NRWRD/NRTR-2001/284. National Park Service, Water Resource Division, Fort Collins, Colorado.
- . 2005. Sonoran Desert Network vital signs monitoring plan. Technical Report NPS/IMR/SODN-003. National Park Service, Denver, Colorado.
- Norman, L. M., M. L. Villarreal, R. Niraula, T. Meixner, G. Frisvold, and W. Labiosa. 2013. Framing scenarios of binational water policy with a tool to visualize, quantify and value changes in ecosystem services. *Water* 5(3):852–874. Available online at <http://www.mdpi.com/2073-4441/5/3/852>.
- Phillips, S. J. and P. W. Comus (eds.). 2000. A natural history of the Sonoran Desert. Tucson, Ariz.: Arizona-Sonora Desert Museum.
- Sprouse, T., R. Emanuel, and B. Tellman. 2002. Surface water quality monitoring overview and assessment: National Park Service, Sonoran Desert Network. Water Resource Research Center, University of Arizona, Tucson.
- Tellman, B., R. Yarde, and M. Wallace. 1997. Arizona's changing rivers: How people have affected rivers. Water Resources Research Center, University of Arizona, Tucson.
- U.S. Geological Survey (USGS). 2006. National field manual for the collection of water-quality data: U.S. Geological survey techniques of water-resources investigations, book 9, chapters A1–A9. Available online at <http://pubs.water.usgs.gov/twri9A>.

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

NPS 311/127480, December 2014

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™