



Hydrologic Monitoring for the Historic Pool in El Morro National Monument

2010–2011 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2012/356



ON THE COVER

Historic Pool in El Morro National Monument
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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. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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1 Introduction and background

The National Park Service Inventory and Monitoring Program was designed to determine the current status and monitor long-term trends in the condition of park natural resources, providing park managers with a scientific foundation for making decisions and working with other agencies and the public to protect park ecosystems. Hydrologic vital signs are the fundamental components defining overall riparian and aquatic ecosystem integrity. The Southern Colorado Plateau Network (SCPN) has identified 7 vital signs pertaining to riparian and spring ecosystems, the first two of which we focus on in this report: 1) spring, seep and tinaja ecosystems, 2) stream flow and depth to groundwater, 3) stream water quality, 4) spring water quality, 5) channel morphology, 6) riparian vegetation, composition, and structure, and 7) aquatic macroinvertebrates. These vital signs are closely related and are all included in the *Vital Signs Monitoring Plan for the Southern Colorado Plateau Network* (Thomas et al. 2006). The context and ecological significance of these vital signs are further explained in Scott et al. (2005).

El Morro National Monument (ELMO) is located in west-central New Mexico and is the second-oldest monument in the national park system. The monument was established in 1906 to preserve unique and significant cultural as well as natural resources. Inscription Rock, a 200-foot sandstone bluff, is the main geographic feature at the monument. Nearly 2,000 prehistoric and historic inscriptions are found along the base of the bluff and in nearby areas. The inscriptions record human activity spanning from the prehistoric Ancestral Pueblo and Native American culture, through the early Spanish explorations of conquest, and continuing through the era of historic 19th-century American explorers, cavalry troops, and railroad survey crews.

Through pre-historic and historic times a pool (known as the Historic Pool) at the base of Inscription Rock was a reliable water source for inhabitants and travelers in the semi-arid region. During the 1900s the size of the pool was enhanced through several dam construction efforts (Greene 1978). In recent years the inscriptions have gradually eroded, possibly due to water flowing on and over the rock or to capillary action (Pranger 2002). The source of water in the pool is uncertain, with some maintaining the pool is fed by only surface runoff and others believing a groundwater source exists (van Dam and Hendrickx 2007).

In 2010, the SCPN implemented hydrologic monitoring at ELMO with the objective of documenting changes in the water level of the Historic Pool. We monitored the Historic Pool and 3 poly-vinyl chloride (PVC) observation wells surrounding it; the wells had been installed during an earlier study by New Mexico Institute of Mining and Technology. We monitored the following sites (fig. 1), and list their locations, codes and common names in Appendix A:

- *Historic Pool* (ELMOHPL01) is identified in this report as HPL01.
- *North observation well* (ELMOOBW01) is identified in this report as OBW01.
- *Center observation well* (ELMOOBW02) is identified in this report as OBW02.
- *South observation well* (ELMOOBW03) is identified in this report as OBW03.

The purpose of this report is to (a) document SCPN hydrologic monitoring activities that occurred at the Historic Pool in ELMO in 2010–2011, (b) summarize the data collected, and (c) where appropriate, place the data in the context of current environmental conditions.

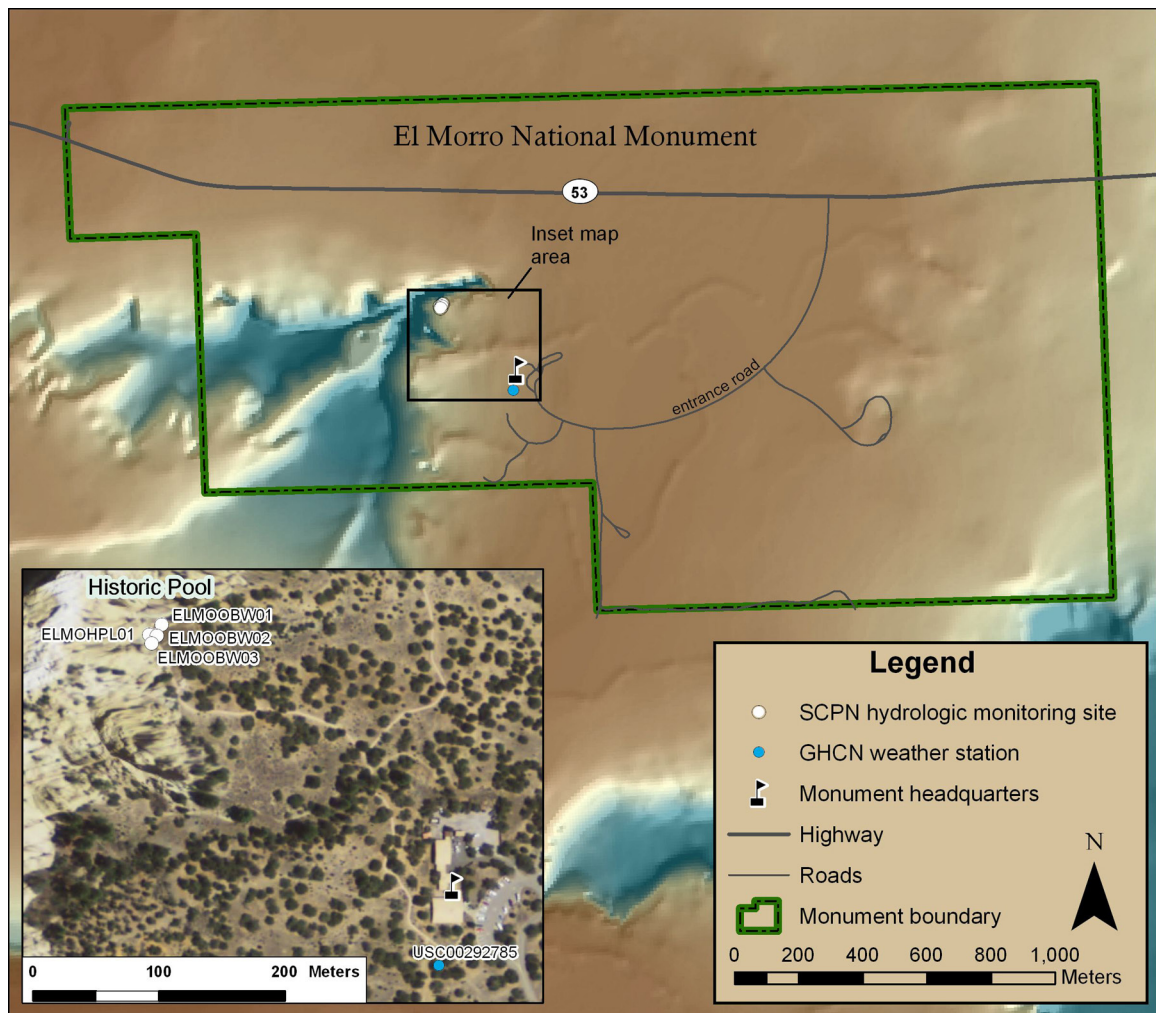


Figure 1. Location of sites associated with SCPN hydrologic monitoring in El Morro N.M., New Mexico, 2010–2011

2 Methods

Following is a brief outline of hydrologic monitoring data collection and processing methods used by SCPN staff at ELMO during 2010–2011. This report covers the period from monitoring implementation through the end of water year 2011 (October 27, 2010–September 30, 2011). SCPN water resources staff visits ELMO on a quarterly basis, downloading all instrumentation and obtaining manual measurements of water levels at the Historic Pool and observation wells. The hydrologic monitoring methods used here will be available in the SCPN draft spring ecosystems monitoring protocol (Monroe, Snyder, et al. in preparation) and are also included in the SCPN draft integrated riparian monitoring protocol (Monroe, Norris, et al. in preparation).

2.1 Field methods

2.1.1 *Site reconnaissance*

On September 1, 2010, the SCPN water resources crew initiated hydrologic monitoring in ELMO with a reconnaissance of the Historic Pool using a small boat. We examined an existing staff plate for monitoring pool water levels. Apparently the plate and a 2-inch diameter PVC pipe housing a recording transducer had been installed in 1996 or 1997 during a study of local hydrology by the New Mexico Institute of Mining and Technology (NMT) (Sayre 1997). The staff plate was poorly attached to the bottom of the pool and was no longer entirely functional. However, it did provide a temporary location for installing a recording water pressure transducer (Solinst Levelogger Junior) for monitoring pool water levels and temperatures. The transducer was suspended beneath the water surface from a nut attached to the back of the staff plate. A recording barometric pressure sensor (Solinst Barologger Gold) was also installed, positioned in a small stand of juniper trees just east of the sidewalk from the Visitor's Center to the Historic Pool, about 40 meters from the pool. In addition to recording pressure, both instruments record temperature. The recording interval for both instruments was set to one hour. We documented the staff plate reading and measured the depth of the pool at several locations.

2.1.2 *Hydrologic monitoring equipment installation*

The SCPN water resources crew returned to ELMO on October 26–27, 2010, to improve the pressure transducer installation in HPL01. To facilitate the installation we temporarily removed the existing 2-inch diameter PVC pipe from the pool. The pipe extended about 3 meters into the north end of the pool between the spillway and the bedrock wall, and a Global Water Corporation recording transducer found in the pipe was removed. The transducer had been abandoned in 2007 at the end of NMT's study and was no longer functional. We also removed the existing staff plate after recording the current water level and a high water mark observed higher on the plate. We shortened the PVC pipe to better conceal it in the poolside vegetation, and reinstalled it in its previous location. An SCPN-owned pressure transducer was suspended in the pipe and the pipe was secured and sealed with a locking well plug. A 1-inch diameter steel pipe was installed near the water edge on the pool side of the wood fence, at the north end of the prominent boulder next to the fence. Direct measurements are made manually from the top of this pipe, a known elevation, to the water surface. Approximately 15 cm of the pipe was exposed above the ground surface. The transducer, 1-inch steel pipe, and Barologger collectively comprise HPL01.

2.1.3 *Survey*

After completing the hydrologic monitoring equipment installation, we surveyed the installations and key features of HPL01. A survey instrument (Topcon GTS-229W total station) was set up on the large boulder near the wood fence at the pool's edge. All survey point coordinates are reported relative to the arbitrary survey origin and datum of the control point established on the rock surface beneath the total station; the datum was set as 1000.00 m. We located, mapped, and photographed a number of existing features to provide permanent survey control points, for future repeatability of comparative surveys. These included a brass cap found at the Historic Pool interpretive site, bedrock outcrops around the pool, and a corner of a steel grate in the spillway channel downstream of the pool. The lower end of the 2-inch PVC pipe, top of the 1-inch metal pipe, and the lip of each of the existing PVC wells (with cap removed) were surveyed. The top and bottom of the dam feature and the spillway were also mapped. A small inflatable boat enabled the rod personnel to map a series of points on the bottom of the pool and the water surface at the bedrock walls. Where bedrock outcrops precluded lines of sight between the total station and the south bedrock wall, offset shots were used to obtain water surface elevations and locations at the wall.

2.1.4 Hydrologic data collection

SCPN water resources staff visited ELMO at quarterly intervals during 2011. These visits were on February 7, May 10, August 28, and November 23. During each site visit, manual measurements were made from the top of the 1-inch pipe to the pool water surface to provide quality control for data collected by the transducer. Depth to water in each of the 3 existing PVC wells near HPL01 was measured, data were downloaded from both of the electronic data loggers deployed at the site, and photographs were taken of the site.

Local precipitation data were downloaded from the National Climatic Data Center (National Climatic Data Center, Climate Data Online n.d.); these data were collected at Global Historical Climatology Network (GHCN) station USC00292785, located near the ELMO Visitor Center.

2.2 Data analysis

2.2.1 Hydrologic data processing

Hydrologic data collected by SCPN consist of (a) water and barometric pressure data collected by the Solinst transducer and Barologger, respectively, in metric units; (b) water and air temperatures collected by the same 2 instruments (in °C); and (c) manual measurements of the depth to water made within each observation well, and from the top of the one-inch metal pipe to the pool water surface at HPL01. The Barologger data are used to correct (compensate) for barometric pressure effects on the raw transducer water level data.

We used the points surveyed at the bottom of the 2-inch PVC pipe (the transducer's location), on top of the 1-inch metal pipe, and on top of each well to transform water levels recorded by the pool transducer (compensated for barometric pressure) into elevation format. Water levels obtained by manual measurements are converted to elevation format by the same method. The transformed water levels data were graphed in SigmaPlot (v. 8.0, 2007) and all data are archived in the SCPN groundwater database. The transformed data document changing pool water levels relative to the spillway elevation and relative to measured water levels in the observation wells. These water level data can be evaluated relative to measurements of daily precipitation collected at the GHCN station.

2.2.2 Survey data processing

The survey data consist of coordinates (x, y) and elevations (z) for each point mapped during the total station survey, reported in metric units relative to the arbitrary survey origin and datum. Terramodel terrain modeling software (v. 10.4, 2005) was used to construct a contour diagram of approximate ground elevations within and around HPL01, from the points mapped on the bottom, dam, and spillway of the pool. Points surveyed at the water surface of HPL01 were joined to show the pool's surface area on the day of the survey.

3 Results

Results from the data collected from September 2010 through September 2011 are summarized below.

3.1 Hydrologic conditions

Two different types of hydrologic data were collected: water levels, and air and water temperatures.

3.1.1 Water levels

Figure 2 shows pool water levels recorded by the transducer for the period, relative to the minimum spillway elevation and deepest point mapped on the bottom of the pool. Manual measurements of the pool water surface level, and of water levels inside each well, are also shown. Table 1 presents details from the total station survey and measurements made on October 26–27, 2010.

Figure 3 shows the pool water elevation data from September 2010 through September 2011, relative to daily precipitation recorded at the GHCN weather station near the ELMO Visitor Center over the same period. The greatest one-day rainfall, just under 27 mm, was recorded on September 23, 2010. The pool spillway was overtopped the same day. Zero rainfall was recorded on 316 days during the period (80%). The pool dropped to its lowest level of the period in mid-July 2011, and then rose during a series of rain events continuing into early September. The data show that the spillway was overtopped a number of times shortly before a site visit on August 28, and evidence of overtopping (flattened vegetation and light flood debris in the spillway channel) was found during the visit. The pool water level remained at or near the top of the spillway through September. More than 24 mm of rainfall was recorded on October 5, and the pool also overtopped the spillway that day.

Water level measurements at the 3 shallow observation wells were made during quarterly site visits by SCPN water resources staff. OBW01 and OBW02 frequently contained no water. Measurable water levels in the 3 wells rose after the spillway was overtopped in August 2011. The pool water level was generally stable from late August through September 2011. OBW01 is positioned at the lowest elevation of the 3 wells, in the spillway channel,

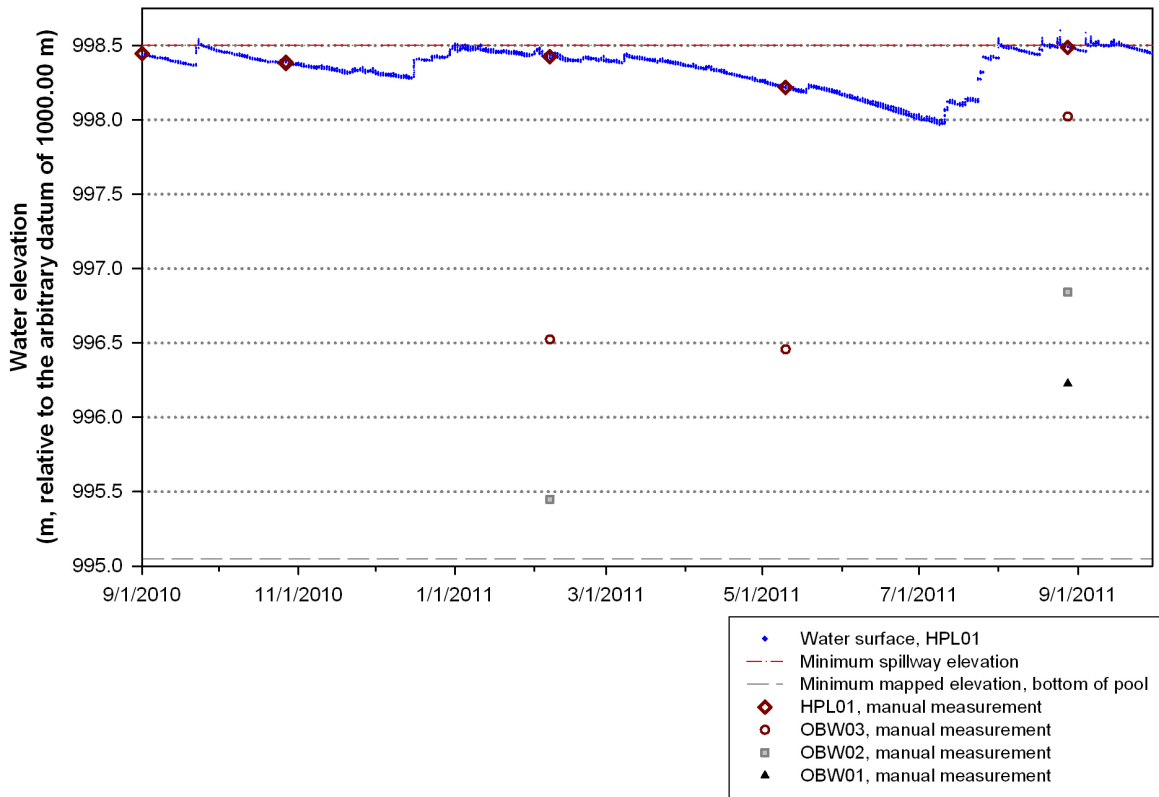


Figure 2. Manual and recorded water levels at HPL01 in El Morro N.M., relative to water levels for other relevant pool features, September 1, 2010–September 30, 2011. Spillway and pool bottom elevations reflect conditions on October 27, 2010. The wells were not measured on September 1, 2010; otherwise, where no water level is shown for a well on a date when the pool water level was measured, the well contained no water.

Table 1. Depths and elevations for HPL01 and 3 observation wells (OBW01, OBW02, OBW03) at El Morro N.M. on October 26–27, 2010

Measurement	Depth (m) ^a	Elevation (m) ^b
HPL01		
Maximum depth	3.35	
Depth at transducer	2.90	
Water surface elevation ^c		998.40
Bottom, deepest		995.05
Spillway		
Minimum elevation		998.50
Maximum elevation		998.69
Dam		
Maximum elevation		998.72
OBW01		
Total depth	1.05	
Lip		996.93
Ground surface		996.79
OBW02		
Total depth	2.47	
Lip		997.82
Ground surface		997.60
OBW03		
Total depth	3.29	
Lip		999.59
Ground surface		999.43

^aPool depths are measured from the bottom of pool to water surface. Well depths are total depths; all wells were dry when measured on 10/27/2010.

^bElevation is relative to the arbitrary survey datum at 1000.00 m.

^cAt the upstream face of dam.

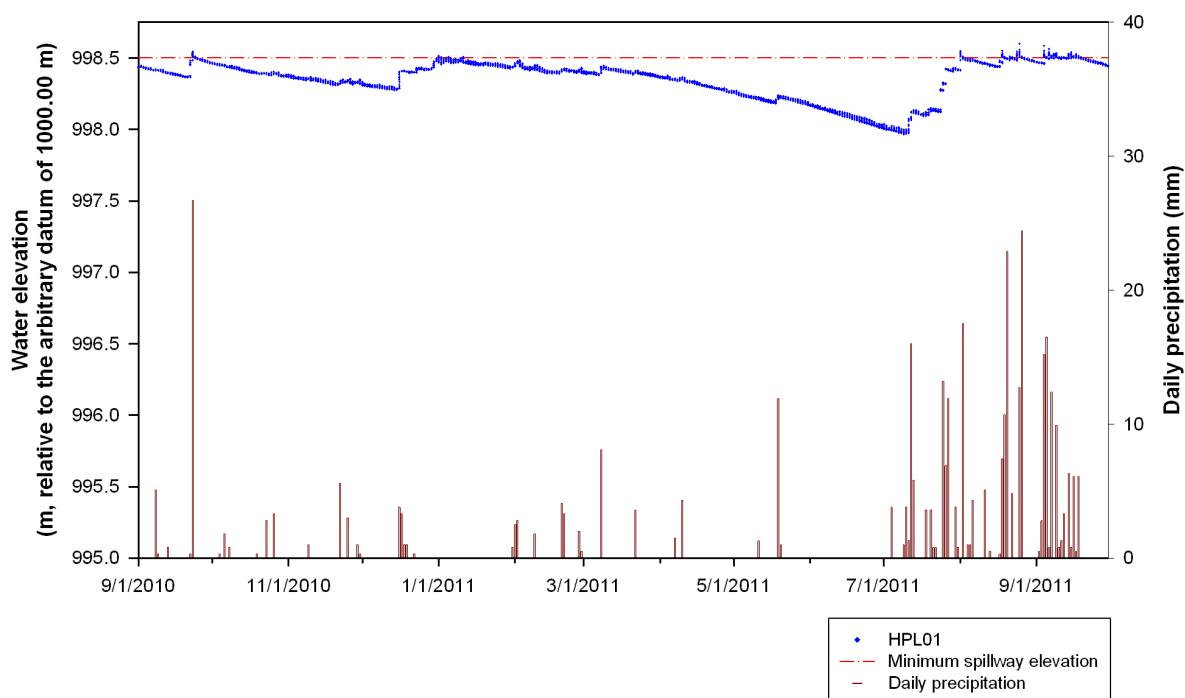


Figure 3. Recorded water levels at HPL01 in El Morro N.M., September 1, 2010–September 30, 2011. Daily precipitation at the GHCN weather station (USC00292785) near the ELMO Visitor Center is plotted relative to the right axis. The pool spillway was overtopped at least 6 times during the period.

approximately 20 m downstream of the pool. It contained water during only one measurement—in August 2011. However, the well is only about 1 m deep, so groundwater below that depth will not appear in the well. Measured water elevations to date are highest in OBW03, located at the highest elevation of the 3 wells. Measurable water levels in the wells during the period ranged from about 0.5 m to about 2.7 m below the pool water level.

3.1.2 Air and water temperature

Comparisons of water and air temperature data collected during the monitoring period from the pool transducer and Barologger, respectively, are shown in Figure 4. Both sets of temperature data follow the same general seasonal pattern. Daily fluctuations in water temperature are subdued compared to air temperatures; diurnal air temperature variation was frequently 20°C–30°C while water temperatures usually remained within a 5°C range each day. The largest daily variances in water temperatures occurred during the summer months. For the monitoring period to date (September 1, 2010 through September 30, 2011), water temperatures were moderated compared to air temperatures, although the overall range of water temperatures was large. Minimum pool water temperature for all days in the months of April through September was 8.7°C, while minimum air temperature was -6.3°C. For all days in the months of October through March, the minimum water temperature was 3.1°C, and minimum air temperature was -27°C. Maximum water temperatures ranged from 16.7°C to 29.7°C; maximum air temperatures from 27.7°C to 33.2°C. However, the median pool water temperature for all days during the months of April through September actually was warmer than median air temperature for the period to date (18.1°C versus 16.5°C).

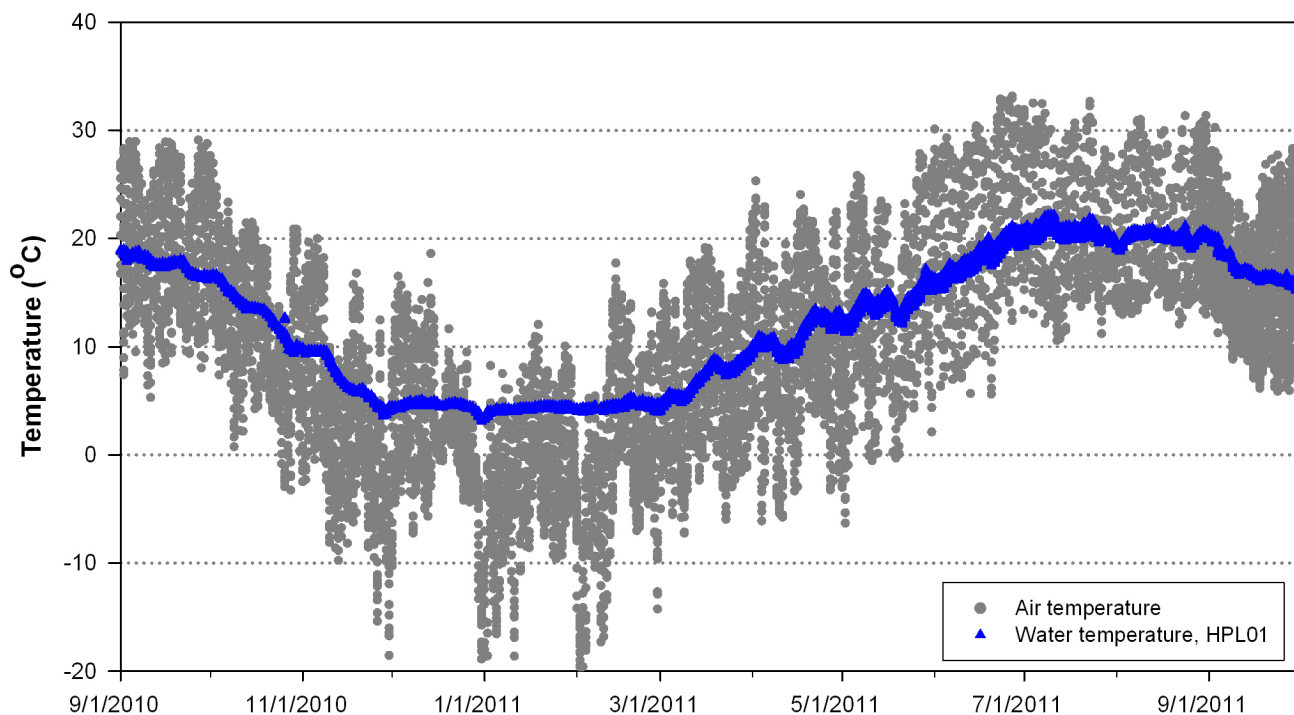


Figure 4. Air temperature recorded by the HPL01 Barologger, and water temperature recorded by the HPL01 transducer, for the period from September 1, 2010 through September 30, 2011, in El Morro N.M.

3.2 Bathymetric mapping

Figure 5 is a contour diagram of the Historic Pool (HPL01), and includes a site layout of the dam, spillway, observation wells and instrumentation locations, constructed from the bathymetric survey data. We did not intensively survey the bottom and sides of the pool below the water surface. The resulting bathymetry is generalized rather than highly detailed, but provides a good description of pool depths and surface area, at the time of the survey. The internal survey precision was ± 0.01 m, both horizontally and vertically. Survey accuracy, particularly of points surveyed on the vertical bedrock walls surrounding the pool, was reduced to ± 0.02 m, due to the boat's instability. The minimum spillway crest elevation was 998.50 m and the lowest mapped pool bottom elevation was 995.05 m. Maximum water depth at the time of the survey was 3.35 m, corresponding to an elevation of 998.40 m. All elevations are relative to the arbitrary local datum. The pool's surface area on the day of the survey was approximately 353 m².

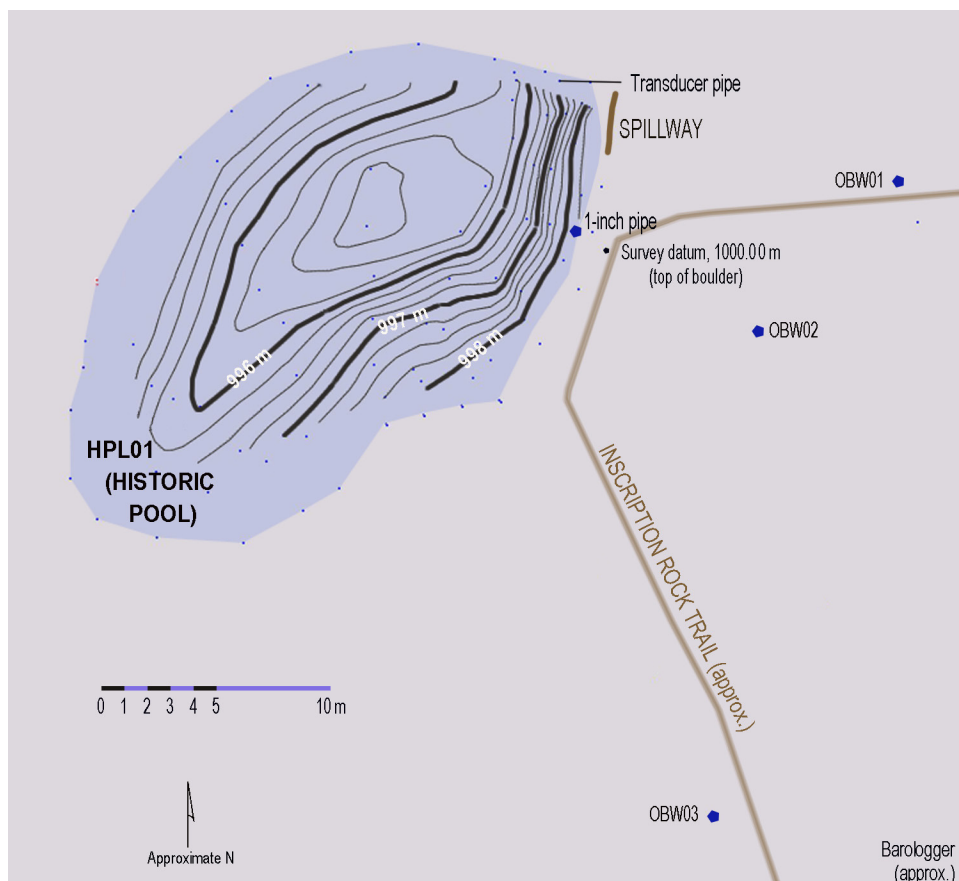


Figure 5. Contour diagram of the Historic Pool and surrounding site layout created from the total station survey data collected October 27, 2010, in El Morro N.M. Contour intervals shown in the pool are at 0.25 m intervals; 1 m contours are labeled in white. The arbitrary survey datum, set to 1000.00 m and from which all elevations are derived, was a point on the top of the large boulder on the east side of the pool fence. Blue dots are surveyed points; blue shading shows the extent of the pool water surface on the survey date.

4 Summary

This report presents the results of data collected during the first 13 months of SCPN hydrologic monitoring at El Morro National Monument. The data are summarized here and are available on request. Evaluations of hydrologic trends at any site in this region depend on long-term monitoring because of the region's high climatic variability. SCPN water resources staff will continue quarterly site visits to download the instrumentation placed at the site and to collect manual measurements.

4.1 Historic Pool water levels and temperatures

During the period for which data have been collected, water levels in HPL01 varied by slightly more than 0.6 m, from about 0.5 m below to 0.1 m above the spillway. The highest recorded water levels occurred from late July to early October, and aligned with periods of substantial rainfall. The lowest water levels in the pool were recorded during late spring and early summer months.

Water temperatures at the transducer in HPL01 varied over a wide range through the measurement period, although diurnal fluctuations were moderate compared to daily variations in recorded air temperatures. The highest temperatures recorded in HPL01 occurred when water levels in the pool were lowest, reaching a maximum of almost 30°C. Water temperatures during the winter months dropped to low levels, about 3°C.

4.2 Notes on the total station survey

The bathymetric survey by which the Historic Pool's deepest points and general elevation contours were determined was not an intensive mapping effort. Rather, the goals were to develop good estimates of the areas of greatest depth, to determine the approximate configuration of the pool, to obtain an estimate of pool surface area, and to ensure that the planned location for the recording transducer was suitable; i.e., not in a shallow location. The survey produced highly accurate elevation data from which the relative elevations of points such as those on the pool spillway and water surface were determined. However, producing a detailed map of the bedrock walls surrounding the pool, both above and below the water surface, was beyond the scope of the mapping effort.

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Appendix A: Monitoring site locations, metrics, collection methods and time-frames for hydrologic data collected at El Morro National Monument, September 2010–September 2011

Site code	Site common name	Coordinates UTM NAD 83 (m)	Elevation (m)	Data type(s)	Data period	Collection method, interval
ELMOHPL01	Historic Pool	741596 E, 3880733 N	2216 (est.)	water levels, baro- metric pressure	9/1/2010– 9/30/2011	recording, hourly
				water levels	9/1/2010– 9/30/2011	manual, quarterly
				bathymetric	10/26/2010– 10/27/2010	total station, once
ELMOOBW01	North well	741606 E, 3880741 N	2214 (est.)	water levels	9/1/2010– 9/30/2011	manual, quarterly
ELMOOBW02	Center well	741602 E, 3880732 N	2215 (est.)	water levels	9/1/2010– 9/30/2011	manual, quarterly
ELMOOBW03	South well	741598 E, 3880726 N	2217 (est.)	water levels	9/1/2010– 9/30/2011	manual, quarterly
USC00292785	ELMO GHCN climate station	741825.9 E, 3880470.4 N	2201.6	precipitation	9/1/2010– 9/30/2011	unknown, daily