

**STATION DESCRIPTION**  
**230 S17 E50 36DC1 DEVILS HOLE - 362532116172701**  
**DEATH VALLEY NATIONAL PARK, CA.**

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Date: **05/10/2017**

LOCATION

Devils Hole is a 40 acre detached unit of Death Valley National Park (DEVA) located in southern Nevada within the boundaries of the Ash Meadows National Wildlife Refuge. The gaging station (station) at Devils Hole is located at N 36°25'32" and W 116°17'27", in the SW1/4 SE1/4, Sec. 36, T. 17S., R. 50 E., Hydrologic Unit 18090202, in Nye County, Nevada.

ACCESS

Devils Hole is located along the east side of the Ash Meadows National Wildlife Refuge, approximately 65 miles northwest of Las Vegas, in the Amargosa Valley of southern Nye County, Nevada. From Las Vegas, NV take State Route SR-160 north to Pahrump, NV for 57 miles (traveling northwest). Turn left (west), onto East Bell Vista Avenue and travel 5.6 miles. East Bell Vista Avenue becomes West Bell Vista Road. Continue for 6.4 miles onto Ash Meadows Road and then travel another 6.6 miles. Turn right to stay on Ash Meadows Road and continue for 0.7 miles. Turn right again to continue on Ash Meadows Road for another 4 miles. Turn right on Devils Hole Road and travel 0.5 miles. Devils Hole is on the left (**Figure 1**). The Ash Meadows Road through the refuge is mostly unpaved. Two-wheel drive, low clearance vehicles are suitable to reach this station.

A locked gate blocks access to the service road and at the entrance to the ladder of Devils Hole.

NOTIFICATION

Prior to visiting the station check in with the DEVA hydrologist.

STATION ESTABLISHMENT

The United States Geological Survey (USGS) established the station on January 22, 1953 by installing a copper washer and nail on the rock headwall above Devils Hole to use as the datum. The USGS operated the station until 1989. On August 30, 1989 the National Park Service (NPS) consisting of personnel from DEVA and the Water Rights Branch (WRB) assumed responsibility and has operated the station since then.

Three markers have been used as the datum at Devils Hole (**Table 1**). The copper washer was in place from 1953 to 1979. In 1979, it was learned that the copper washer was missing and vandalism was suspected. On January 17, 1980, a brass screw was installed to replace the copper washer in the hole that remained from the copper washer. The brass screw was used as the datum from 1980 to 1992. In May of 1992, the NPS drilled a new hole next to the original hole left by the copper washer and installed a steel bolt to establish a more secure datum (**Figure 2**). The steel bolt has been used as the datum since 1992.

## REFERENCE MARKS AND BENCHMARKS

A number of reference marks have been used to survey the elevation of the water surface and the datum (**Figures 3 - 7**). The first documented survey was conducted under contract to the USGS by Reynolds Electrical and Engineering Company (REECO) in 1962. The 1962 survey established a concrete monument inside a gate near the entrance to the pool with a 3 inch brass cap (REECO Brass Cap) as a reference mark (also known as Monument C). The elevation of the REECO brass cap was surveyed at 2392.77 ft above mean sea level (amsl).

During a 1976 USGS survey, a second monument was established with a 3-inch bronze tablet (Bronze Tablet) in the spillway near the pool (RM-1). The current elevation of the Bronze Tablet is 2359.72 ft amsl. Since then, six additional reference marks, including two steel bolts, three reference marks and one new brass disc, have been established as survey reference marks near the pool and are used to survey water elevation (**Table 2**).

In 1994, a number of benchmarks were established by the USGS in the vicinity of Devils Hole to support the water level monitoring program and to evaluate crustal deformation and relative land movement over time (**Table 3, Figure 8**). The USGS 1994 survey determined the elevations of these benchmarks. These benchmarks may be used to verify water level measurements and to compare future survey reference mark elevations.

## STAFF GAGES

There is no record of the use of a staff gage to measure water levels at Devils Hole prior to 1962. After 1962, the USGS began recording water level measurements using a staff gage as a reference. Different staff gages have been in use during various time periods to calibrate monitoring equipment and to accommodate changes in the framework that supports the monitoring equipment. The staff gages that have been in use by USGS and NPS are identified chronologically in station folders as Staff gages A, B, C, D, E and F.

Staff gage A was in use from May 22, 1962 to September 30, 1964. Staff gage B was in use from September 30, 1964 to September 9, 1970. Staff gage C has been in use since September 10, 1970. Staff gage D has been in use since July 20, 1976. Staff gage E has been in use since August 30, 1989. Staff gage D was used as the primary reference from August 30, 1989 until May 11, 2010 when staff gages C and D and the framework supporting them were removed (**Figure 9**). A new staff gage F was installed May 13, 2010 (**Figure 10**). All water levels are reported in feet below the datum.

## ELEVATION

The elevation of the copper washer was first determined in 1962 by REECO. The copper washer was difficult to survey directly due to the overhanging rock headwall so the elevation was back calculated. REECO surveyed the water surface elevation of the pool from the REECO Brass Cap and then back-calculated the distance from the water surface elevation to the copper washer using a chart recorder reading. The elevation of the datum was determined to be 2360.05 amsl.

The brass screw, which replaced the copper washer in 1980, was installed in the same hole vacated by the copper washer on the rock headwall above Devils Hole pool. A survey of the brass screw at the time it was installed determined that the elevation of the brass screw was within 0.002 feet of the original copper washer.

The steel bolt installed by the NPS has been used as the datum for Devils Hole since 1992 (**Figure 2**). The elevation of the steel bolt, based on nine surveys conducted by NPS between 1992 and 2015, is 2359.99 feet amsl. The standard deviation for the seventeen surveys is 0.019 feet. The difference of 0.07 feet between the 1962 REECO elevation and NPS surveyed elevations is attributed to imprecision in the method used to back-calculate the elevation of the copper washer from the surveyed water elevation and chart recorder reading.

#### DRAINAGE AREA

The springs in Ash Meadows discharge from a regional carbonate aquifer system that covers an area of several thousand square miles. The rocks that form the hills along the northeast boundary of Ash Meadows, and in which Devils Hole has formed, are part of the carbonate aquifer system.

#### HYDROLOGIC CONDITIONS

Ash Meadows is located within the Death Valley regional groundwater flow system in the Basin and Range physiographic province. The primary aquifer types within the regional flow system are Paleozoic carbonate rock, Tertiary volcanic rock and Cenozoic basin fill aquifers. The carbonate aquifer is the principal aquifer within the Death Valley groundwater flow system. Groundwater moves generally from recharge areas at higher elevations in the north to lower elevation valleys in the south, and ultimately to Death Valley. Because of the immense size and complexity of the flow system, it is often divided into subregions, and the subregions are further divided into groundwater basins and sections.

The Ash Meadows basin is the largest basin within the Central Death Valley subregion. Recharge occurs on the Spring Mountains and Sheep, Pahranaagat and Belted Ranges. Discharge occurs from about 30 springs in the Ash Meadows area. The springs occur along a 16 kilometer spring line that generally coincides with the trace of a buried fault system. The northwest-southeast trending fault system juxtaposes low permeability basin fill sediments and the more permeable carbonate rock aquifer forcing water upwards to discharge from the aquifer system.

The climate at Devils Hole is arid and may be characterized as a rain-shadow desert climate. The summers are hot and dry and the winters are mild. Average summer temperatures are about 85°F and average winter temperatures are about 46°F. Winter storms in the Death Valley region are usually low intensity and account for approximately 65 to 75 percent of the annual precipitation (Fenelon and Moreo, 2002). In the summer, convective rainstorms are typical, as exemplified by the flood of August 2004. Devils Hole receives an average of only 4 inches of precipitation per year.

Large amounts of groundwater have been pumped from the regional flow system. Groundwater pumping to support irrigation and agriculture began as early as 1913. Between 1913 and 1998, about 90 percent of the ground water pumped was for irrigation (Moreo and others, 2003). Nearby pumping in the Ash Meadows area began in the 1960's and resulted in water level declines at Devils Hole beginning around 1969. Nearby groundwater pumping was curtailed in 1973, following a preliminary court injunction that was made final in 1974. Most of the more recent groundwater pumping in the Central Death Valley subregion has occurred about 10 - 12 miles west of Devils Hole from wells completed in the basin fill aquifer.

## EQUIPMENT

NPS has operated the station since 1989. A Stevens float pulley device and Stevens A/F data logger with encoder and a Type A Model 71 strip chart recorder were in use from 1989 - 2000. On August 9, 2000 the Stevens data logger was replaced with a newer GS-98 Stevens data logger. The Stevens GS-98 data logger was in use until May 11, 2010. On April 06, 2010, the Stevens float pulley system was removed to minimize the equipment that was in use in the pool.

A second water level monitoring system that included two pressure sensors connected to a data logger was installed in 1992 to prevent periods of missing data. The pressure sensors were considered the primary system and the chart recorder was considered the backup system. The first two pressure sensors, manufactured by Enmos, were installed in 1992 and were in use until 1994. Between 1994 and 1999 both Druck and Keller pressure sensors were in use. Between 1999 and 2008 both pressure sensors were manufactured by Druck. In 2008, one of the Druck sensors was replaced with an Instrumentation Northwest (INW) 9100 Series sensor. The second Druck sensor was replaced in 2010. The data logger installed with the Enmos sensors was an Omni 800 Series data logger. The Omni data logger was in use until 2000 at which time it was replaced with a Campbell CR10 data logger. The INW sensors were replaced by INW PS9805 sensors in 2014 and 2015.

Currently, the two INW sensors are operated independently with two Campbell data loggers (CR10 and CR510). The data loggers record water levels (gage height) in 15 minute intervals. If a difference in value of 0.02 feet occurs between two consecutive measurements, then the loggers increase the recording frequency to every 15 seconds to capture water level changes due to floods and earthquakes.

A dedicated Lufkin steel tape is used to perform tape downs from the top of the steel bolt (datum at 0.00 foot) to the water surface. The depths are measured as depth below measuring point. The tape is checked against a NIST calibrated steel tape.

## WATER LEVELS

Water levels in Devils Hole have been measured since 1953. Prior to 1989, USGS monitored water level at Devils Hole under a cooperative agreement with NPS. Early water levels were determined by tape-down measurements from the datum to the water surface. The USGS began using continuous water level recorders to collect water level data around 1956. Continuous water level data on the USGS National Water Information System (NWIS) do not begin until 1962. NPS assumed responsibility for monitoring water levels in 1989.

Water levels in Devils Hole are affected by changes in storage in the aquifer and by transitory or temporary stresses on the aquifer. Changes in storage in the aquifer are caused by changes in recharge rate and by groundwater withdrawals from the aquifer. Transitory changes are caused by loading effects on the aquifer due to barometric pressure and earth tides. The effects of barometric pressure and earth tides cause recurring or cyclical changes in water level at Devils Hole that range from 0.1 to 0.3 feet (Cutillo and Ge, 2006). Earthquakes also cause fluctuations in water levels at Devils Hole.

Water levels have been affected by nearby groundwater pumping. Water levels began to decline in 1969 following large scale groundwater development for irrigation in nearby Ash Meadows. Maximum pumpage occurred from 1970 to 1972 with large amounts of pumping continuing until 1977. From 1978 until 1982 pumping was greatly reduced, and in 1982, all nearby pumping had ceased.

The highest water level measurement reported for Devils Hole was 0.95 feet below the datum on August 2, 1962 by USGS. In general, water level measurements ranged from 0.95 feet below the datum to 1.36 feet below the datum prior to large-scale development in 1969. In 1970, water levels had declined to 2.2 feet below the datum, and by 1972, water levels had declined to 3.6 feet below the datum. Water level recovery began in late 1972 and continued until about 1988. However, water levels have never fully recovered to pre-pumping levels.

#### HISTORY

Devils Hole was added to Death Valley National Monument (later Death Valley National Park) by Presidential Proclamation on January 17, 1952. The station has remained at its original location since its establishment by the USGS in 1953.

- 1/22/1953      Copper washer set in headwall (USGS).
- 5/22/1962      Staff gage A installed (USGS).
- 9/21/1962      Concrete monument near gate/pool entrance with brass cap established (REECO).
- 9/30/1964      Staff gage B installed (USGS).
- 1965            BM-0 (BM-2377/RBR-47) established (USGS) 1500 feet south of Devils Hole.
- 9/10/1970      Staff gage C installed (USGS).
- 7/15/1976      Bronze tablet near pool entrance and pool installed (USGS).
- 7/20/1976      Staff gage D installed (USGS).
- 1979            Copper washer missing and vandalism suspected.
- 1/17/1980      Brass screw set in cement in existing hole to replace copper washer (USGS).
- 1985            Bronze tablet missing. No other information available.
- 8/30/1989      Staff gage E installed (NPS).
- 8/30/1989      Stevens float pulley device with electronic data logger and strip chart recorder installed (NPS).
- 11/29/1989     USGS removed their monitoring equipment.
- 5/20/1992      Steel bolt installed to replace brass screw (NPS).
- 6/28/1992      Landers earthquake occurred and noted in water level record.
- 6/29/1992      Little Skull Mountain earthquake occurred near Yucca Mountain.

7/2/1992 Enmos pressure sensor and Omnidata electronic data logger installed in addition to existing instrumentation (NPS).

9/10/1992 Second Enmos (Enmos2) pressure sensor installed (NPS).

5/3/1993 Stevens A-71 chart recorder replaced with new Stevens A-71 chart recorder.

9/2/1993 Established network of benchmarks at land surface near Devils Hole for relative-movement surveys (USGS).

4/19/1994 Enmos pressure sensors replaced with Keller pressure sensors (Keller1 and Keller2) (NPS).

6/21/1994 Druck pressure sensor (Druck) replaced Keller2 sensor (NPS).

12/12/1995 Keller2 sensor reinstalled and Druck sensor removed (NPS).

2/7/1996 RM-2 and RM-3 installed and surveyed (USGS).

2/13/1996 Staff Plate D replaced (NPS). Park staff and a Stevens representative installed a datalogger and telemetry system as an agreement with the manufacturer (Inmarsat) for promotional purposes. Equipment was wired in with the existing Stevens system. WRB did not participate.

10/16/1996 A second Druck sensor (Druck2) was installed to replace Keller1 sensor (NPS).

4/27/1998 Druck sensor (Druck3) installed to replace Druck2 sensor (NPS).

10/19/1998 Druck sensor (Druck4) installed to replace Keller2 sensor (NPS).

4/11/1999 Keller sensor (Keller3) installed to replace Druck3 sensor (NPS).

10/16/1999 Hector Mine earthquake noted in water level record.

12/7/1999 Druck sensor (Druck5) installed to replace Keller3 sensor (NPS).

8/9/2000 Stevens A/F datalogger replaced with a GS-98 datalogger (NPS).

12/4/2000 Druck sensor (Druck6) installed to replace Druck4 sensor (NPS). Campbell CR10 data logger installed to replace Omnidata data logger.

5/16/2002 Druck sensor (Druck7) installed to replace Druck5 sensor (NPS).

9/11/2004 Rainfall event produced flooding in the Devils Hole drainage and deposited debris on shelf.

10/12/2004 Druck sensor (Druck8) installed to replace Druck7 sensor (NPS).

- 12/26/2004 Massive undersea earthquake known as Sumatra Andaman earthquake generated tsunamis along the Indian Ocean coasts and was noted in water level record.
- 6/15/2005 Earthquake off northern coast of California noted in water level record.
- 11/28/2006 The Stevens GS-98 data logger and Stevens A-71 were relocated from the wooden platform at the southeast side of the shelf over onto to the stilling well.
- 11/28/2006 Staff Gage E was removed. It had not been in use at the time.
- 11/29/2006 A Setra (Campbell CS100) Barometer was installed with the Campbell CR10 data logger and began recording in millibars at 15 minute intervals.
- 11/29/2006 Campbell CR10 data logger was reprogrammed to record more frequently during events that exceed 0.02 feet from one 15 minute interval to the next.
- 09/12/2007 A major rain event was documented by Park staff.
- 06/03/2008 Ninth Druck sensor (Druck9) briefly installed to replace Druck6 (NPS).
- 09/09/2008 Instrumentation Northwest sensor installed to replace Druck8 sensor (NPS) and Druck10 sensor installed to replace Druck9 sensor (NPS).
- 12/31/2008 Site type code changed in USGS Automated Data Processing System (ADAPS) from well (GW) to subsurface-cave (SB-CV).
- 04/06/2010 The Stevens float pulley device and Stevens A/F data logger with encoder and a Type A Model 71 strip chart recorder were removed.
- 05/11/2010 The staff gages C and D were removed along with the stilling well (NPS).
- 05/13-14/2010 Staff gage F was installed and RM8 and RM9 were established.
- 05/14/2010 Campbell CR510 data logger installed to replace the Stevens data logger and chart recorder. The Druck10 sensor was replaced with a second Instrumentation Northwest sensor. This sensor was run in conjunction with the CR510 data logger (NPS).
- 08/09/2010 New monitoring platform installed at Devils Hole (NPS).
- 09/14/2010 New access ladder installed at Devils Hole (NPS).
- 03/20/2012 Park staff captured a video of an earthquake (Oaxaca, Mexico).
- 09/18-19/2012 Campbell CR510 datalogger and Instrumentation Northwest PS9805 pressure sensor was installed to support a Seismic Study to collect data at a frequency of 1 hertz (second).
- 06/25/2013 Seismic Study equipment turned off.

- 11/19/2013 Seismic Study equipment removed.
  - 11/07/2014 Instrumentation Northwest PS9105 EP (INW2) replaced with an Instrumentation Northwest PS9085 (INW3).
  - 03/02/2015 Instrumentation Northwest PS9105 EP (INW1) replaced with an Instrumentation Northwest PS9085 (INW4).
  - 06/19/2015 Staff plate F exchanged due to enamel deterioration.
  - 06/30/2016 Flood event occurred and was recorded by an onsite camera.
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ACCURACY

The datum is installed in the rock headwall above the pool and level surveys indicate it has remained stable. USGS state that their records indicate "there has never been a significant discrepancy between the reference staff gage 0.00 foot mark and the elevation of the copper washer or the brass screw" (See letter to Owen Williams, NPS, from Stephen Hammond, USGS, dated July 18, 1994). During each site visit, NPS staff take tape-down measurements from the datum and take a separate depth to water reading using a staff gage. The reported data record is based on the staff gage reading.

COOPERATION

Devils Hole station is maintained by Death Valley National Park staff and the WRB. DEVA staff visit the station bimonthly to inspect instrumentation and the chart recorder. Data are downloaded monthly. The WRB process and analyze the data using USGS protocols and the USGS data processing software ADAPS, collect periodic survey data, and provide QA/QC for all data collection and analyses.

The USGS has been a cooperator in the monitoring of Devils Hole. USGS staff collected water level measurements up until 1989. In 1989, NPS assumed responsibility for the monitoring program. USGS continued taking periodic manual measurements as part of the USGS-DOE Yucca Mountain Environmental Monitoring Program. In 1999, USGS ceased collecting manual measurements due to NPS access concerns. Since 1999, NPS staff has provided USGS with monthly measurements. In 2006, NPS began sending USGS quarterly measurements, although bimonthly visits still occur. In 2009, the USGS-DOE Yucca Mountain Environmental Monitoring Program network ceased operating, and NPS no longer sends data to USGS.

LOCAL PARK PARTNER

Park Staff Contacts:

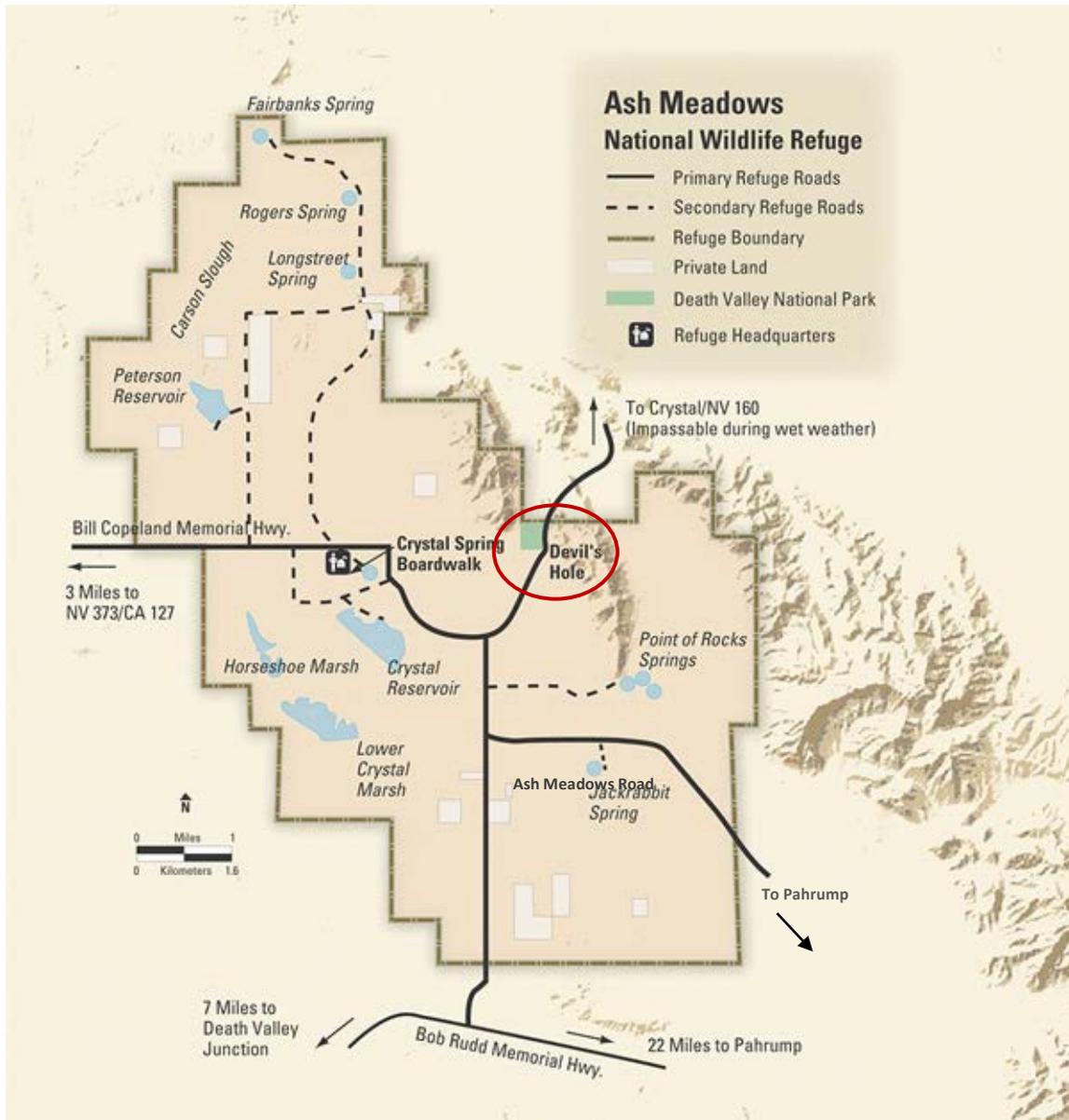
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## REFERENCES

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**Figure 1. Location of Devils Hole station**

**Table 1. Description of Devils Hole Water Level Datum Locations (See Figure 2).**

<b>Datums</b>	<b>Description</b>	<b>Period</b>
Copper Washer	Driven in the rock headwall above the southeast side of the Devils Hole pool.	1953-1979
Brass Screw	Set in the rock headwall to replace the copper washer.	1980-1992
Steel Bolt	New hole drilled in the rock headwall to replace the brass screw.	1992 - present

**Table 2. Description of Devils Hole Reference Marks (See Figures 3-7 for locations).**

<b>Reference Marks</b>	<b>Description</b>	<b>Year Established</b>
REECO Brass Cap	Concrete monument with a 3" brass cap inside a lower gate near the entrance to Devils Hole (aka Monument C or Benchmark C)	1962
RM-1	Bronze Tablet (brass cap monument marker) set near pool (reset 1994). Sometimes described as Brass Cap near pool.	1976
RM-2	Steel bolt set in concrete near west edge of pool, behind large boulder, near recorder.	1996
RM-3	Steel bolt set in concrete in rock wall on north side of pool.	1996
RM-4	Nail at 1.5 ft mark on northwest facing Staff Gage C on stilling well (aka north facing gage).	1970
RM-5	Lag screw at 0.00 mark on southwest facing Staff Gage D on Stilling Well.	1976
RM-6	Lag Screw at 0.5 ft mark on south (aka southwest) facing Staff Gage E on frame.	1976
RM-7	Brass tablet on northwest rock slope above Devils Hole pool.	2002
RM-8	Lag Screw at 0.50 ft mark on northwest facing Staff Gage F on headwall.	2010
RM-9	0.00 ft on northwest facing Staff Gage F on headwall.	2010

**Table 3. Description of Benchmarks in the Vicinity of Devils Hole (See Figure 8 for locations).**

<b>Benchmarks</b>	<b>Description</b>	<b>Year Established</b>
BM-0	Benchmark south of Devils Hole, and 1,517 feet south of BM-5. Stamped BM-2377/RBR-47.	1965
BM-1	Section benchmark southwest of Devils Hole.	1993
BM-2	Brass monument 90 feet south of the lower gate, and 248 feet southwest of BM-5.	1993
BM-3	Brass monument 129 feet northwest of BM-2 and 295 feet west of BM-5.	1993
BM-4	Brass monument above Devils Hole inside locked enclosure and 169 feet west of BM-5.	1993
BM-5	Brass monument east of Devils Hole locked enclosure.	1993
BM-6	Brass monument 149 feet north of BM-5.	1993
BM-7	Brass cap, BLM section marker, and NPS SE corner marker near Devils Hole well, 828 feet southeast of BM-5.	Unknown
BM-8	Brass monument at Point of Rocks on hillside, located 1,953 feet east of BM-5.	1993
BM-9	Brass monument and NPS NE corner marker, located 1,221 feet northeast of BM-5.	1993
BM-10	U.S. Coast and Geodetic Survey Benchmark (USCGS BM) about 0.8 miles northeast of Devils Hole. Stamped BM-2486.7.	Unknown



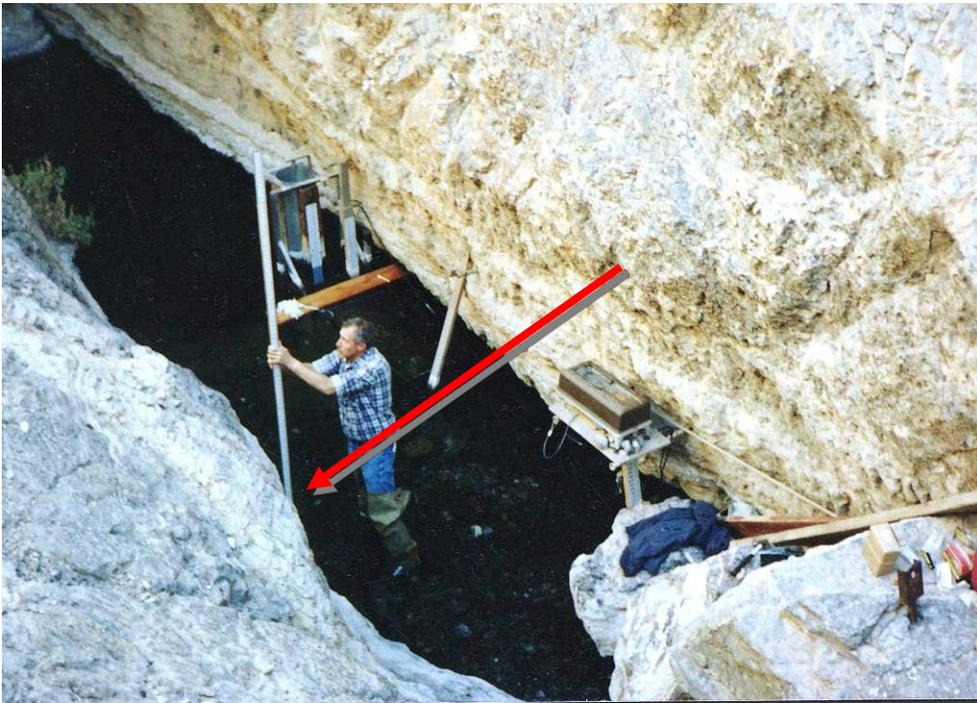
**Figure 2. Steel Bolt (Datum). Court mandated measuring point to water surface.(Photo credits: Jeff Albright and Mel Essington (inset)).**



**Figure 3. Rod placed on survey reference mark 1 (RM-1). Bronze tablet set in rock at spillway to pool.**



**Figure 4. Rod placed on survey reference mark 2 (RM-2). Steel concrete bolt set in side of boulder at the south end of the pool.**



**Figure 5. Rod placed on survey reference mark 3 (RM-3). Steel bolt set in concrete on the northwest headwall.**



**Figure 6. Rod placed on nail at 1.5 feet mark on staff gage C on west side of stilling well (RM-4). [Note: RM-5 and RM-6 shown on Figure 9. (Removed, 5-11-2010).**



**Figure 7. Survey reference mark 7 (RM-7). Brass tablet on northwest rock slope near pool.**

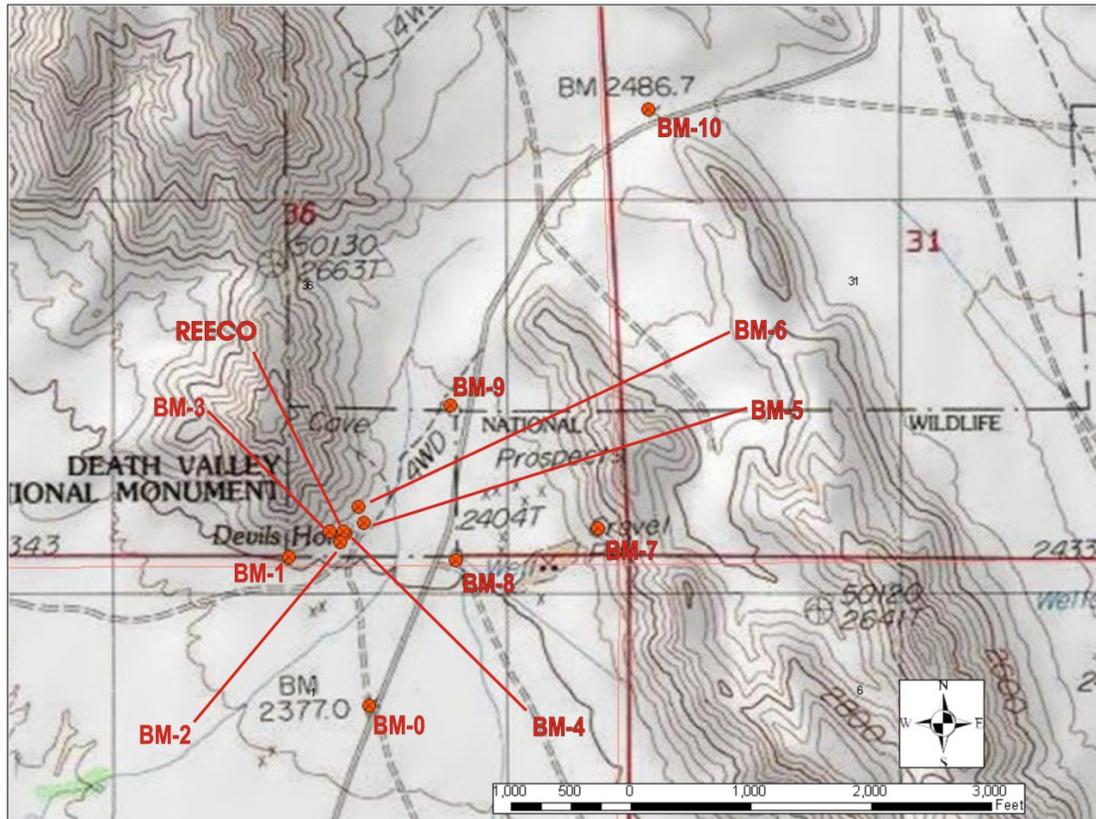


Figure 8. Location of Benchmarks in the vicinity of Devils Hole.

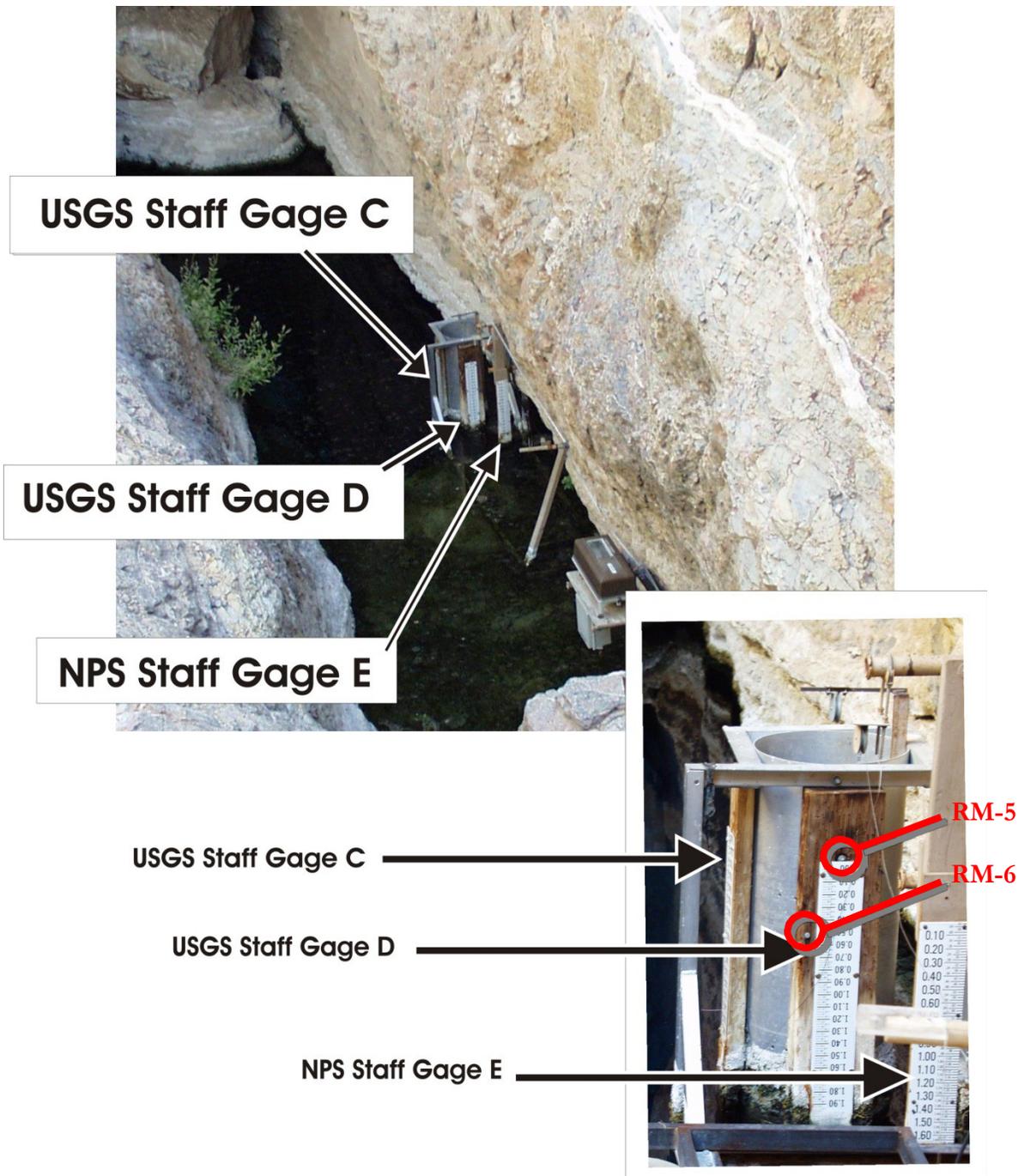
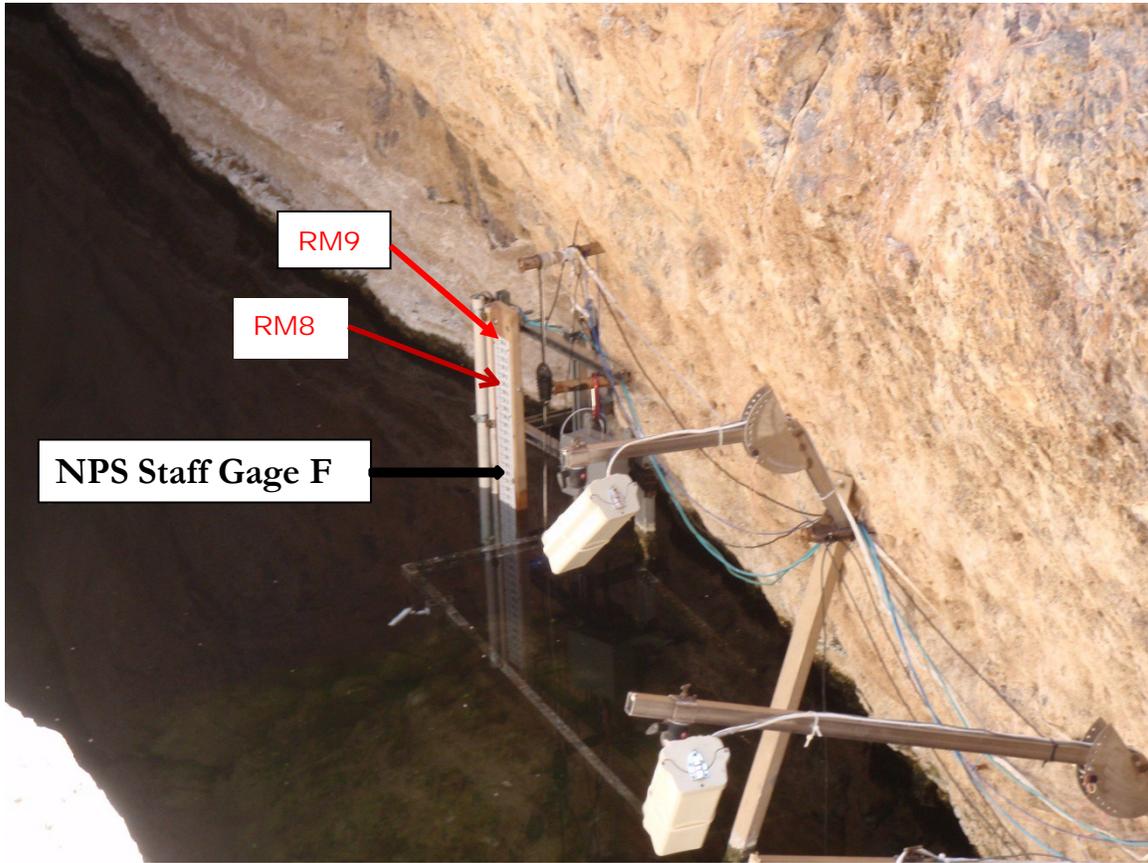


Figure 9. Locations of Staff Gages C, D, and E. Screw at 0.00 foot mark (RM-5) and lag bolt at 0.5 foot mark (RM-6) on southwest facing staff gage D of stilling well (Removed, 5-11-2010).



**Figure 10. Locations of NPS Staff Gage F, Lag bolt at 0.50 foot mark (RM-8) on northwest facing staff gage and RM9 a lag bolt set at 0.00 foot.**