Desert Research Institute

DOE/NV/0003590-10

Monitoring Potential Transport of Radioactive Contaminants in Shallow Ephemeral Channels: FY2017

Prepared by

Steve A. Mizell, Scott A. Campbell, Greg McCurdy, and Julianne J. Miller

Submitted to

U.S. Department of Energy
Environmental Management Nevada Program
Las Vegas, Nevada

April 2018

Publication No. 45281

Nevada System of Higher Education

Available for sale to the public from:

U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Rd.
Alexandria, VA 22312
Phone: 800.553.6847
Fax: 703.605.6900
Email: orders@ntis.gov
Online ordering: http://www.osti.gov/ordering.htm

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to the U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
Phone: 865.576.8401
Fax: 865.576.5728
Email: reports@adonis.osti.gov

DOE/NV/0003590-10

Monitoring Potential Transport of Radioactive Contaminants in Shallow Ephemeral Channels: FY2017

Prepared by

Steve A. Mizell, Scott A. Campbell, Greg McCurdy, and Julianne J. Miller

Desert Research Institute
Nevada System of Higher Education

Publication No. 45281

Submitted to

U.S. Department of Energy
Environmental Management Nevada Program
Las Vegas, Nevada

April 2018

The work upon which this report is based was supported by the U.S. Department of Energy under Contract #DE-NA0003590 and Contract #DE-NA0000939. Approved for public release; further dissemination unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

The Desert Research Institute (DRI) is conducting a field assessment of the potential for contaminated soil to be transported from the Smoky Site Contamination Area (CA) as a result of storm runoff. This activity supports U.S. Department of Energy (DOE) Environmental Management Nevada Program (EM-NV) efforts to establish post-closure monitoring plans for the Smoky Site Soils Corrective Action Unit (CAU) 550. The work is intended to confirm the likely mechanism of transport and determine the meteorological conditions that might cause the movement of contaminated soils, as well as determine the particle size fraction that is most closely associated with transported radionuclide-contaminated soils. These data will facilitate the design of the appropriate post-closure monitoring program.

In 2011, DRI installed a meteorological monitoring station on the west side of the Smoky Site CA and a hydrologic (runoff) monitoring station within the CA, near the east side. Air temperature, wind speed, wind direction, relative humidity, precipitation, solar radiation, barometric pressure, soil temperature, and soil water content are collected at the meteorological station. The maximum, minimum, and average or total values (as appropriate) for each of these parameters are recorded for each 10-minute interval. The maximum, minimum, and average water depth in the flume installed at the hydrology station are also recorded for every 10-minute interval. This report presents data collected from these stations during fiscal year (FY) 2017.

During the FY2017 reporting period, the warmest months were June, July, and August and the coldest were December and January. Solar radiation showed the same seasonal trend, although the months with the most solar radiation were May and June. Monthly mean wind speeds were highest in the spring (April and May). Winds were generally from the southwest during the summer and from the northwest throughout the remainder of the year. The monthly average relative humidity ranged from the teens to greater than 60 percent. Humidity was lowest in the summer and fall and highest during the winter. During storms, the relative humidity was approximately 100 percent. Monthly total precipitation ranged from 0 in June to approximately 2.23 inches (in) (56.64 millimeters [mm]) in January. Total precipitation for FY2017 was 8.36 in (212.34 mm).

During the reporting period, two major rainfall events occurred: one on July 25, 2017, and the other on August 3, 2017. These storms were relatively high-intensity, short-duration storms, which are typical of the summer thunderstorm season. None of the other rainfall events exceeded 0.06 in (1.52 mm) in a 10-minute observation period. None of the FY2017 rainfall events produced sufficient flow to cause erosion and transport sediment with the runoff. Therefore, no bedload samples were collected for radiological analysis.

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

Am-241	americium-241
CA	Contamination Area
CAS	Corrective Action Site
CAU	Corrective Action Unit
DOE	Department of Energy
DRI	Desert Research Institute
EM-NV	Environmental Management Nevada Program
FY	fiscal year
GOES	Geostationary Operational Environmental Satellite
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
TDR	time domain reflectometry
WRCC	Western Regional Climate Center

THIS PAGE INTENTIONALLY LEFT BLANK

INTRODUCTION

The U.S. Department of Energy (DOE), Environmental Management Nevada Program's (EM-NV) Soils Activity has authorized Desert Research Institute (DRI) to conduct field assessments of the potential transport of radionuclide-contaminated soils from Corrective Action Unit (CAU) 550, Smoky Site Contamination Area (CA) during precipitation runoff events. Corrective Action Unit 550 includes Corrective Action Sites (CASs) 08-23-03, 08-23-04, 08-23-06, and 08-23-07. These CASs are associated with the tests designated Ceres, Smoky, Oberon, and Titania, respectively. Aerial surveys at this location, as well as at other locations on the Nevada National Security Site (NNSS), suggest that radionuclide-contaminated soils may be migrating along ephemeral channels in Areas 3, 8, 11, 18, and 25 (Colton, 1999).

Figure 1 shows the results of a low-elevation aerial survey for americium-241 (Am-241) (Colton, 1999) in Area 8. The numbered markers in Figure 1 identify ground zero for three safety experiments conducted in 1958 (Oberon [number 1], Ceres [number 2], and Titania [number 4]) and a weapon effects test conducted in 1964 (Mudpack [number 3]). The survey identified a northwest-southeast elongated zone of higher contamination that is approximately parallel to ephemeral drainages emanating from the Smoky Hills north of the test locations. An unnamed mapped drainage lies along the west side of the elongated contamination zone and discharges into a drainage that conveys runoff to the southeast toward Circle Road. (The line that curves around Sedan Crater from south to east in Figure 1.) Additionally, lobes in the 1,500-3,200 count per second (dark green) zone and in the 320-700 count per second (maroon) zone in Figure 1 extend toward the south-southeast. This orientation is approximately parallel to the mapped drainage east of the contamination plume and may indicate transport along a drainage channel. Anecdotal information also indicates that runoff in an adjacent channel has deposited sediment on Circle Road, which is on the southeast border of the CAU (J. Traynor, personal communication, 2011). These observations led to the selection of the Smoky Site as the location for an investigation of the potential for radionuclide migration by water-driven sediment transport during storm runoff events.

Contamination is particularly close to the boundary of CAU 550, Smoky Site CA. Therefore, it is important to know if radionuclide-contaminated soils are moving, what meteorological conditions result in the movement of contaminated soils, and what particle size fractions associated with contamination are involved. Closure of CAU 550, the Smoky Site, was approved by the Nevada Division of Environmental Protection on March 2, 2015 (C.D. Andres, personal communication, March 2, 2015). The assessment of potential transport of radionuclide contaminated soil material by storm runoff was undertaken to facilitate the appropriate design of post-closure monitoring plans and procedures.

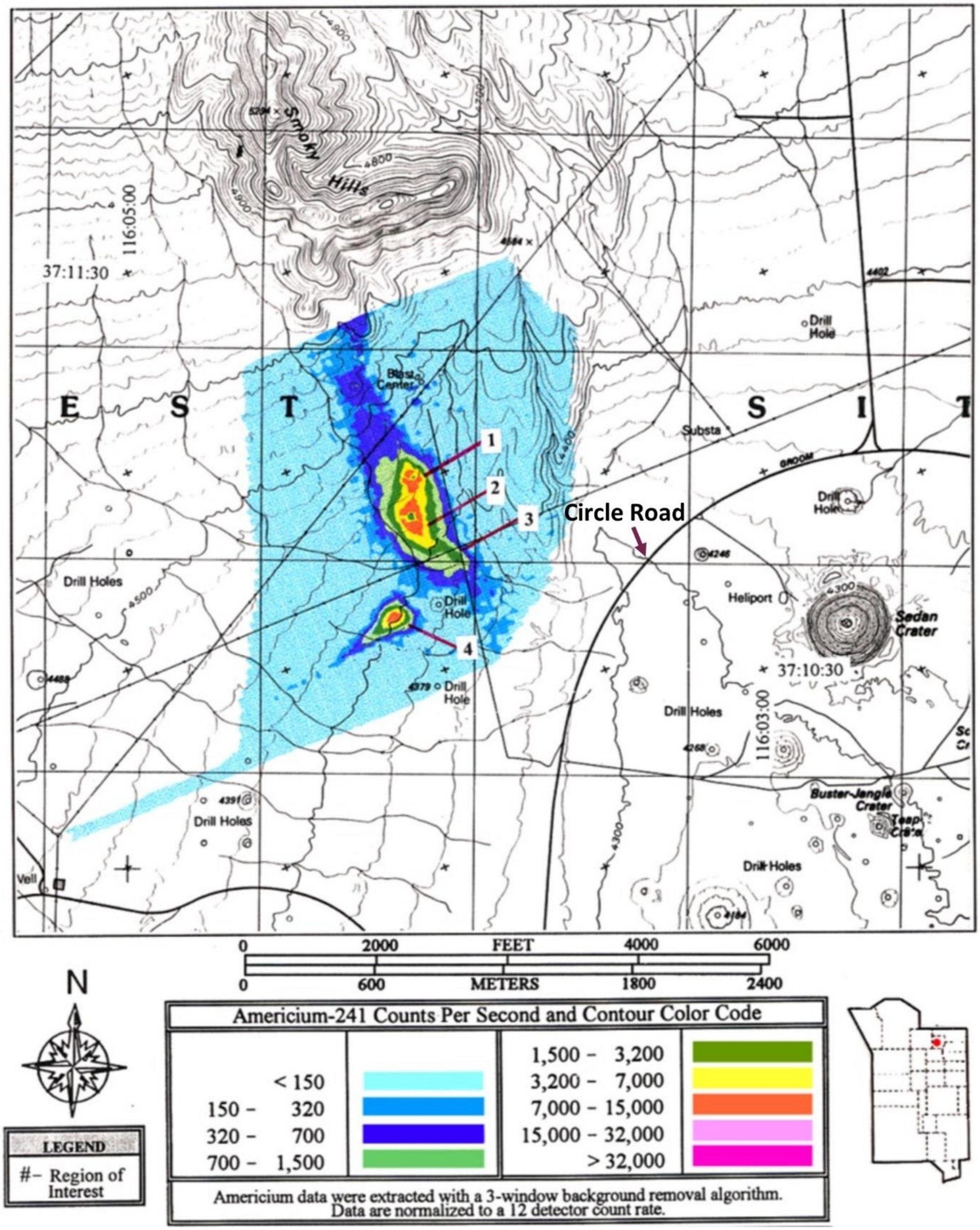

Figure 1. Americium-241 detections at the Smoky Site CA in northwest Yucca Flat, Nevada (Colton, 1999). Numbered markers identify ground zero for the three safety experiments Oberon (number 1), Ceres (number 2), and Titania (number 4) and the weapons test Mudpack (number 3) (from Colton [1999]).

BACKGROUND

The Smoky Site CA is located in Area 8 of the NNSS in the northern part of Yucca Flat, which is in southeastern Nye County, Nevada. In addition to the namesake test, Smoky—which was an aboveground nuclear device test detonated in 1957—four additional tests were conducted in the area. These tests included three safety tests (Oberon, Ceres, and Titania) conducted in 1958 and a weapon effects test (Mudpack) conducted in 1964 (Colton, 1999). As a result of these tests, there is an elongated area of surface contamination trending in a northwest-southeast direction (Colton, 1999). This area of surface contamination encompasses the Smoky, Oberon, Ceres, and Mudpack test locations. Near the southern extent and slightly to the southwest of this CA, there is a triangular area of surface contamination associated with the Titania test. A low-level aerial survey of the area (Figure 1) reported up to 15,000 counts per second of Am-241 at the center of the two contamination areas (Colton, 1999). Additionally, transported contamination has been measured across Circle Road from an adjacent channel (J. Traynor, personal communication, 2011).

The Smoky Site CA is situated on a dissected alluvial fan approximately 0.6 mile (1,000 meters) south of the Smoky Hills. The mapped drainages shown on the topographic map of Oak Spring, Nevada (U.S. Geological Survey 1:24000 scale), trend south-southeast from the Smoky Hills, and then easterly toward the center of Yucca Flat. The larger of the two contaminated areas in the Smoky Site CA is bounded on the east, west, and south by mapped channels. The western corner of the smaller contaminated area surrounding the Titania test site is drained by a mapped channel trending west to east. Elevation contours in the immediate vicinity of these contaminated areas suggest that unmapped channels may convey runoff from the areas of highest contamination into the mapped drainages.

RESEARCH APPROACH

The general distribution of Am-241 indicated in Figure 1 is believed to be the result of conditions that existed at the time of the safety experiments. The presence of radionuclide-contaminated soils in channels that traverse and convey runoff from the Smoky Site CA suggests that radionuclide-contaminated soil has been transported by rainfall-generated runoff. However, there are insufficient data to determine if the observed contamination is the result of an ongoing process or if the transport was limited to a period of higher hydraulic energy resulting from the reduced ground cover that immediately followed the Smoky Site area tests.

Desert Research Institute proposed performing a field-scale assessment of meteorological and hydrologic conditions that could potentially lead to the transport of radionuclide-contaminated soil from the Smoky Site CA. The research plan includes measuring local meteorological parameters, measuring the runoff resulting from local rainfall, and collecting bulk channel bed samples (i.e., bedload) for laboratory analysis after flow events. Meteorological observations outside the western boundary of the Smoky Site CA (Figure 2). Storm runoff measurements are made at a flume installed in the channel that exits the northeast corner of the Smoky Site CA (Figure 2). The precipitation and runoff data

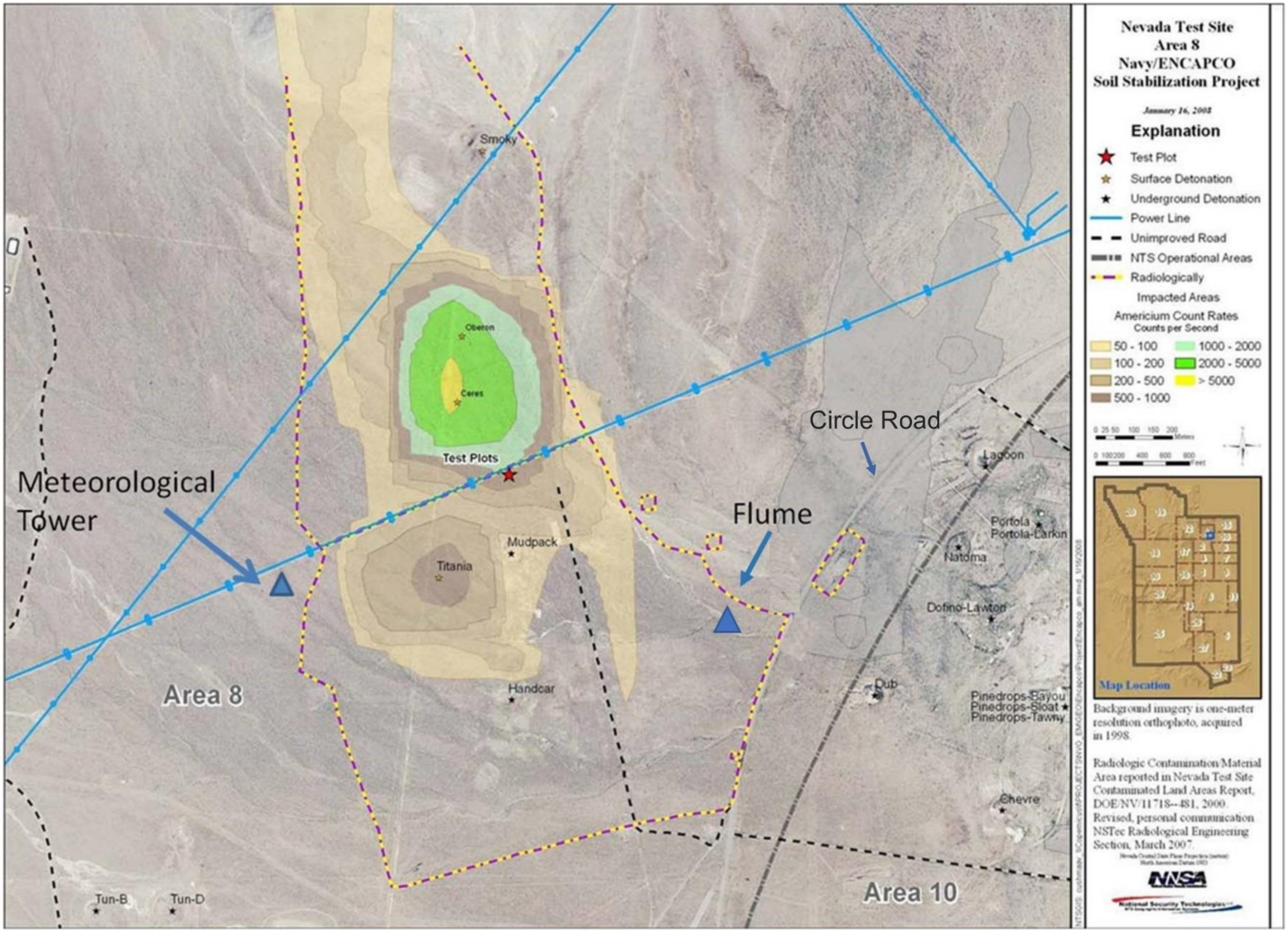

Figure 2. Approximate locations of the meteorological station and flume installations at the Smoky Site CA in Yucca Flat, Nevada National Security Site.

are used to establish threshold conditions that could lead to the transport of soil particles, including radionuclide-contaminated soils. These thresholds will help establish the conditions that would require monitoring the drainage channel transport pathways to develop a post-closure monitoring strategy.

The meteorological station (Figure 3)—which has instrumentation to measure temperature, relative humidity, wind speed, wind direction, soil volumetric water content, soil temperature, solar radiation, barometric pressure, and precipitation—was installed in an uncontaminated area adjacent to the Smoky Site CA on July 14 and 15, 2011. The coordinates of the meteorological station are 37º 10’ 39.48” latitude and -116º 4’ 25.59” longitude. The meteorological station also includes Geostationary Operational Environmental Satellite (GOES) transmission equipment and equipment to receive radio frequency data transmissions from the flume instrumentation station (Figure 2). The accumulated meteorological data are transmitted daily to the Western Regional Climate Center (WRCC) at the DRI offices in Reno, Nevada, via GOES. At the WRCC, the data are uploaded to a restricted-access internet webpage that is available to project personnel.

A Parshall flume with a 6-in (15.24-cm) throat was installed to measure channelized runoff. The original location of the flume was to be between the Smoky Site CA boundary and the adjacent road (Figure 2). However, because (1) there was not sufficient space on the shoulder of Circle Road and (2) a Radiological Control assessment determined that it was not possible to downgrade contamination controls on the study channel, the flume (Figure 4) was placed inside the Smoky Site CA. The coordinates of the flume that was installed on July 19, 2011, are 37º 10’ 37.13” latitude and -116º 3’ 34.85” longitude. The flume installation includes a pressure transducer for measuring the depth of flow through the flume and a radio frequency transmitter/receiver (Figure 5) to allow communication with the meteorological station. Meteorological and flume data transmissions from the Smoky Site CA were received beginning on July 20, 2011. Output from the monitoring equipment has been reported annually since the equipment was installed (Miller *et al.*, 2012a,b; Mizell *et al.*, 2017a,b).

Figure 3. The Smoky Site CA meteorological station was installed to measure precipitation, wind, and other climate parameters.

Figure 4. View looking downstream through the Parshall flume installed to measure runoff from the Smoky Site CA (prior to washout in July 2013).

Figure 5. Runoff conditions in the flume are detected by the pressure transducer (yellow cable), recorded in the datalogger (white box), and relayed by radio (black antenna) to the meteorological station for transmission to the WRCC via the GOES.

FISCAL YEAR 2017 OBSERVATIONS

Data collection from the electronic sensors placed at the meteorological station at the Smoky study site began on July 14, 2011. Data collection at the flume site began on July 20, 2011 (Appendix B). Measurements of air temperature, relative humidity, wind speed and direction, soil volumetric water content, soil temperature, solar radiation, barometric pressure, and precipitation are collected every three seconds. Water depth in the flume is collected every five seconds. Maximum, minimum, and average or total values are recorded on the datalogger for every 10-minute interval and every hour. The hourly values are transmitted daily via GOES to the WRCC, where the data are reviewed to identify collection or transmission irregularities, and then uploaded to the restricted-access project website. The 10-minute data are retained on the datalogger and downloaded during quarterly site visits. When data quality is confirmed, the 10-minute data are uploaded to the website and hourly data for the same time period are deleted. Table 1 lists the significant events in the data collection history at the Smoky Site and the datalogger download exercises accomplished during fiscal year (FY) 2017.

Table 1. History of significant events associated with meteorological and hydrological observations at the Smoky Site for shallow ephemeral channel transport monitoring.

Date	Description
FY2017	
October 21, 2016	Quarterly datalogger download and routine maintenance at meteorological station.
November 21, 2016	Repaired malfunctioning water depth pressure sensor at flume because of animal damage.
January 6, 2017	Quarterly datalogger download and routine maintenance at meteorological station.
January 24, 2017	Repaired malfunctioning instrumentation at Smoky Site inside the CA because of animal damage.
March 24, 2017	Quarterly datalogger download and routine maintenance at meteorological station.
July 7, 2017	Quarterly datalogger download and routine maintenance at meteorological station.
October 6, 2017	Quarterly datalogger download and routine maintenance at meteorological station.

Meteorological Observations

Daily average values of the meteorological parameters for the period October 1, 2016, through September 30, 2017, are shown in time series plots in Appendix A. Table 2 summarizes the 10-minute meteorological data by month and fiscal year. The monthly summary data indicate that:

1) Average daily maximum temperatures were highest in June, July, and August.
2) May and June recorded the highest monthly solar radiation (sunshine). July, August, and April had the next highest solar radiation.
3) The coldest months were December and January. These were also the months with the lowest solar radiation.
4) Monthly mean wind speeds were highest in April, followed by March and May when wind speeds were slightly lower. Winds were from the southwest in October, February, June, July, and August. Winds were from the northwest in January, March, April, May, September, November, and December.
5) Monthly average relative humidity ranged from the mid-teens to greater than 60 percent. Monthly precipitation ranged from 0 to approximately 2.23 in (56.64 mm); the highest monthly rainfall occurred in January 2017. Total rainfall was 8.36 in (212.34 mm) in FY2017.

Table 2. Monthly meteorological observations at the Smoky Site, NNSS, during FY2017.

Date	Total Solar Radiation	Mean Wind Speed	Mean Wind Direction (vector ave.)	Max. Wind Gust	Ave. Air Temp	Ave. Daily Max. Temp	Max. Temp	Ave. Daily Min. Temp	Min. Temp	Ave. Soil Temp @ 4 Inches	Max. Soil Temp. @ 4 inches	Min. Soil Temp. @ 4 inches	Ave. Relative Humidity	Max. Relative Humidity	Min. Relative Humidity	Ave. Barometric Pressure	Total Precip.
(mm-yy)	**(ly.)**	**(mph)**	**(Deg)**	**(mph)**	**(Deg F)**	**(Deg F)**	**(Deg F)**	**(Deg F)**	**(Deg F)**	**(Deg F)**	**(Deg F)**	**(Deg F)**	**(%)**	**(%)**	**(%)**	**(in Hg)**	**(in)**
Oct-16	12496	6.2	250	36.4	60.7	72.9	80.7	47.4	39.0	66.5	87.5	48.6	35.6	97.1	4.0	25.56	0.26
Nov-16	9474	5.3	318	51.3	48.9	62.4	75.5	35.9	20.8	53.0	77.7	29.7	37.9	92.0	8.2	25.63	0.07
Dec-16	7402	5.4	330	45.9	37.9	49.7	60.2	26.7	14.0	40.4	59.1	23.3	49.7	99.4	6.4	25.59	1.28
Jan-17	7653	5.4	284	40.7	36.3	46.2	59.7	26.7	15.8	38.1	56.7	28.0	67.6	100.0	16.4	25.55	2.23
Feb-17	8502	6.5	241	40.3	44.2	53.5	67.6	35.4	22.8	45.7	66	31.5	60.3	100.0	14.0	25.52	1.78
Mar-17	14756	7.2	283	60.7	52.5	66.0	77.2	38.3	22.0	56.1	78.9	32.6	36.0	92.9	8.9	25.59	0.26
Apr-17	18149	8.3	300	45.8	56.1	68.7	77.5	41	29.4	63.8	87.1	42.9	29.6	88.5	6.7	25.50	0.02
May-17	21218	7.0	299	43.7	66.0	78.7	90.6	49.7	36.4	76.5	104.3	51.4	26.2	87.9	5.3	25.47	0.07
Jun-17	22638	6.9	233	49.1	79.5	92.9	104.2	62.3	44.3	90.0	119.3	59.2	15.7	48.4	2.7	25.49	0.00
Jul-17	19962	5.6	212	38.2	84.0	96.7	104.4	68.5	60.9	93.3	118.8	70.5	25.7	90.7	3.7	25.59	0.78
Aug-17	18399	5.1	248	45.8	79.4	92.6	100.8	65.3	60.1	88.3	109.9	69.4	30.2	89.7	6.0	25.58	0.67
Sep-17	15405	6.1	336	35.4	69.4	81.3	97.7	56.3	38.2	76.4	106.9	51.5	34.4	97.8	10.9	25.54	0.94
FY2017	*176054*	*6.2*	*277.8*	*60.7*	*59.6*	*71.8*	*104.4*	*46.1*	*14.0*	*65.7*	*119.3*	*23.3*	*37.4*	*100.0*	*2.7*	*25.55*	*8.36*

Hydrologic Observations

Figures 6a through 6d show, at various scales, the total amount of precipitation and the average water depth reported by the flume pressure sensor for 10-minute observation intervals during FY2017. Precipitation events were recorded at the Smoky Site rain gage each month during the year except during June (Table 2, Figure 6a). Most precipitation events during FY2017 were short duration and low intensity. Two winter storms—January 19 to 24, 2017, and February 17 and 18, 2017—were characterized by periods of low intensity precipitation interspersed with periods of no precipitation (Figure 6a). Neither winter storm produced a single 10-minute interval with more than 0.04 in (1.02 mm) of precipitation.

Two short-duration, high-intensity thunderstorm events occurred on July 25, 2017, and August 3, 2017 (Figure 6d). The July 25, 2017, storm produced 0.03 in (0.76 mm) between 12:30 and 12:50, and 0.59 in (14.59 mm) between 13:30 and 14:50. The most intense 10-minute period produced 0.21 in (5.33 mm) between 13:50 and 14:00 and was followed by two 10-minute periods that produced 0.11 in (2.79 mm) each between 14:00 and 14:20. The August 3, 2017, storm produced 0.38 in (9.65 mm) between 18:10 and 19:00. The most intense 10-minute period produced 0.14 in (3.56 mm) between 18:30 and 18:40. The period of intense precipitation on August 3, 2017, was followed by a 110-minute interval that produced a total of 0.1 in (2.54 mm) at intensities of less than 0.02 in (0.51 mm) per 10-minute period. Both of these precipitation events occurred in the context of precipitation at the NNSS gages surrounding the Smoky Site (J. Wood, personal communication, August 4, 2017; J. Wood, personal communication, September 7, 2017).

Because of damage to the cables that was apparently a result of animal activity, the connection between the pressure sensor and the datalogger was destroyed in August 2016. Repairs were made in November 2016, but the repaired cables were almost immediately destroyed by animals again. No water depth data were collected between August 2016 and January 2017. The new pressure transducer was installed on January 24, 2017, after the precipitation stopped. The pressure transducer cable was installed in flexible metal tubing to ensure no further damage. There was no record of flow through the flume during the January 19 to 24, 2017, storm.

After installation, the pressure transducer was tested in place by pouring water into the stilling well at the flume and observing the reported pressure values as the water flowed away. At the end of the testing, the pressure sensor was partially submerged in a 2.5 in (6.35 cm) column of water in the base of the stilling well below the pipe connecting the flume. Because nighttime temperature dropped below freezing, the water in the stilling well and in the pressure sensor appears to have frozen and caused the extreme pressures (reported as water depths > 150 in) evident during the early morning hours of January 25, 26, and 28, 2017 (Figures 6a and 6b).

By March 15, 2017, the stilling well and the pressure sensor dried out (Figure 6c). After drying out, a reported pressure or water depth of 0.0 indicated no water was present above the pressure sensor, which was approximately 2.5 in (6.35 cm) below the floor of the flume. To indicate water flow through the flume, the pressure sensor must report depth of water greater than 2.5 in (6.35 cm). The actual depth of flow in the flume could then be calculated by subtracting 2.5 from the reported water depth.

Following the period of overnight freezing, temperatures moderated and the standing water in the stilling well evaporated or seeped out of the stilling well (Figure 6c) between January 28, 2017, and March 15, 2017. Multiple small precipitation events between February 17 and 20, 2017, added water to the stilling well and increased the water depth reported by the pressure sensor to approximately 2.0 in (5.08 cm). However, this water depth was not sufficient to indicate flow through the flume.

Short-duration, high-intensity precipitation events in July and August increased the water depth reported by the pressure sensor. However, the reported depth did not rise above the floor of the flume and did not indicate flow through the flume. It is believed that these storms did not produce flow in the flume because the precipitation went to satisfy the deficit in the soil water content. These storms increased the soil water content to 15 percent following the July rainfall and 22 percent following the August rainfall, but the soil water content never exceeded the amount reported following the winter storms of January and February (Figure 7).

There were no water depths exceeding the 2.5-in (6.35-cm) threshold reported after March 15, 2017 (Figure 6d). During FY2017, no water depths at the flume exceeded the threshold necessary to indicate flow through the flume as a result of precipitation runoff. No sediment-transporting flow events were reported in the Smoky Site drainage during FY2017 and no bedload samples were collected.

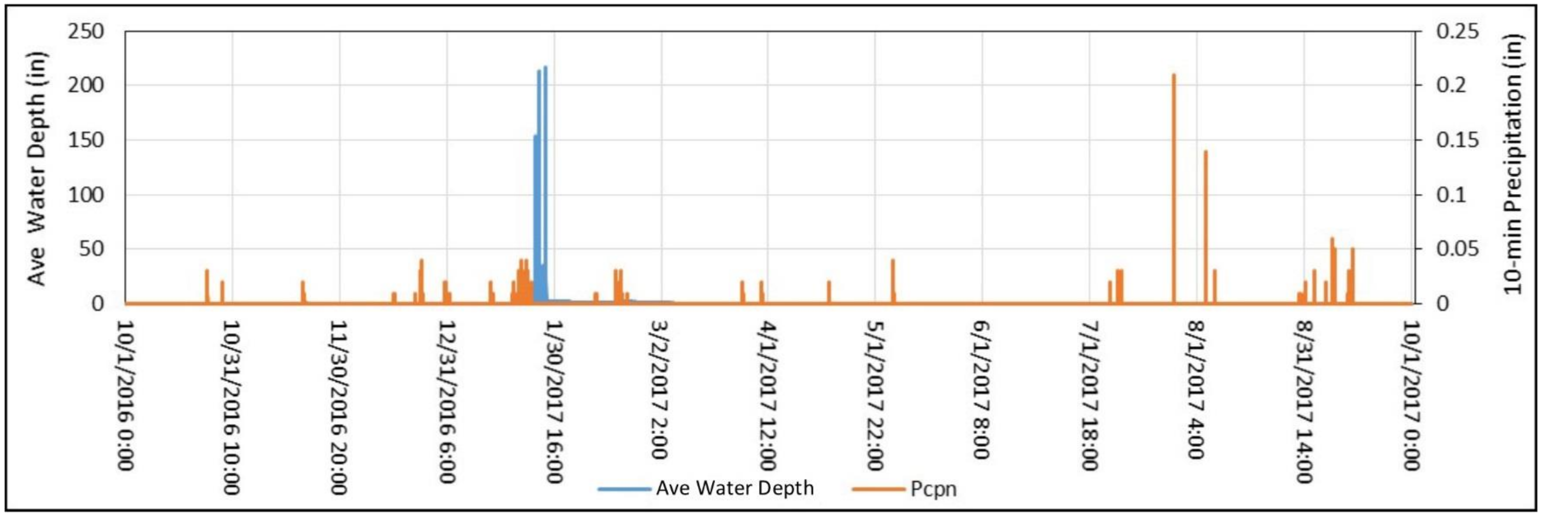

Figure 6a. Average water depth reported by the flume pressure sensor and 10-minute precipitation totals for FY2017.

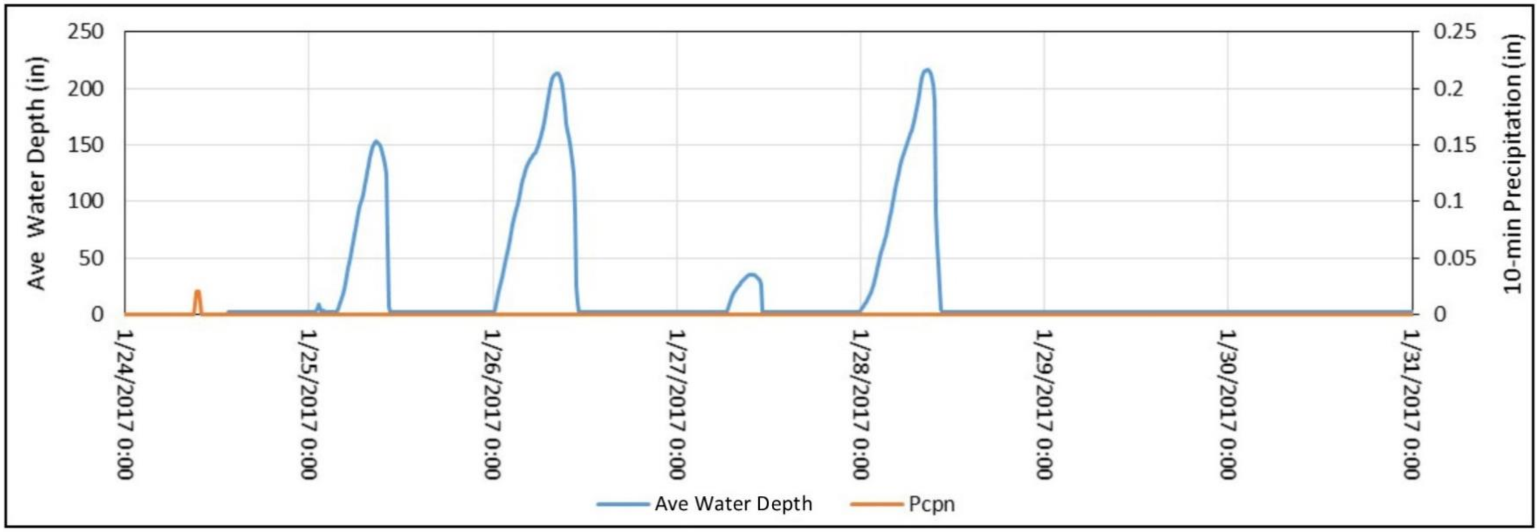

Figure 6b. Average water depth reported by the flume pressure sensor and 10-minute precipitation totals for January 24 through January 30, 2017.

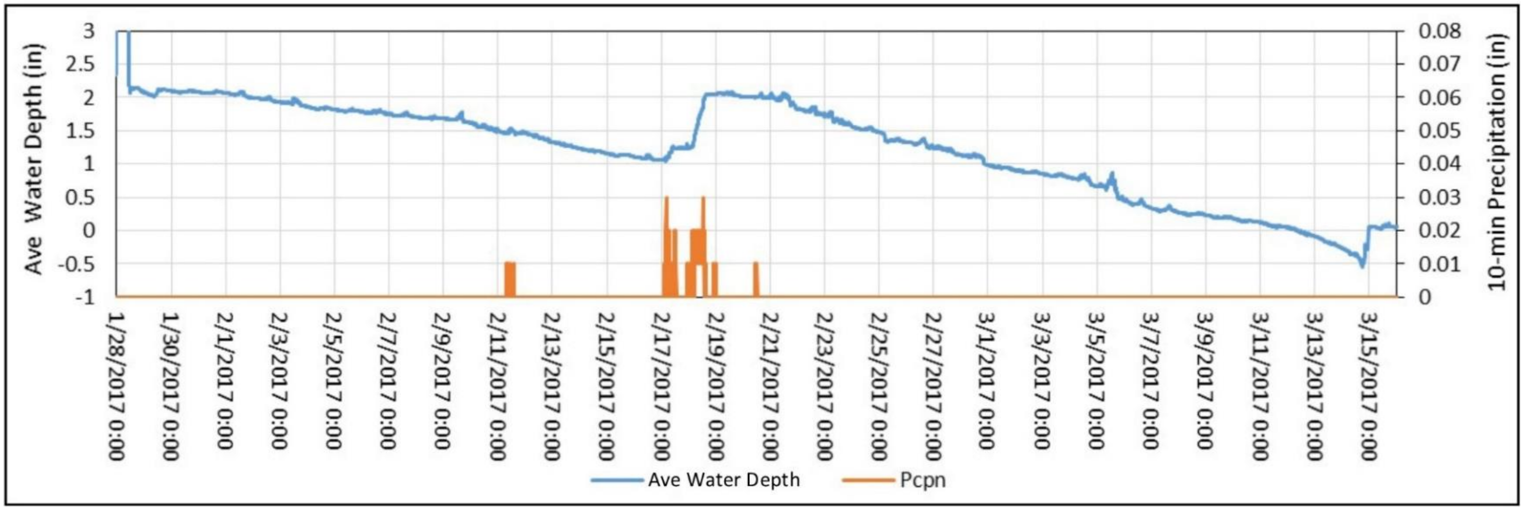

Figure 6c. Average water depth reported by the flume pressure sensor and 10-minute precipitation totals for January 28 through March 15, 2017.

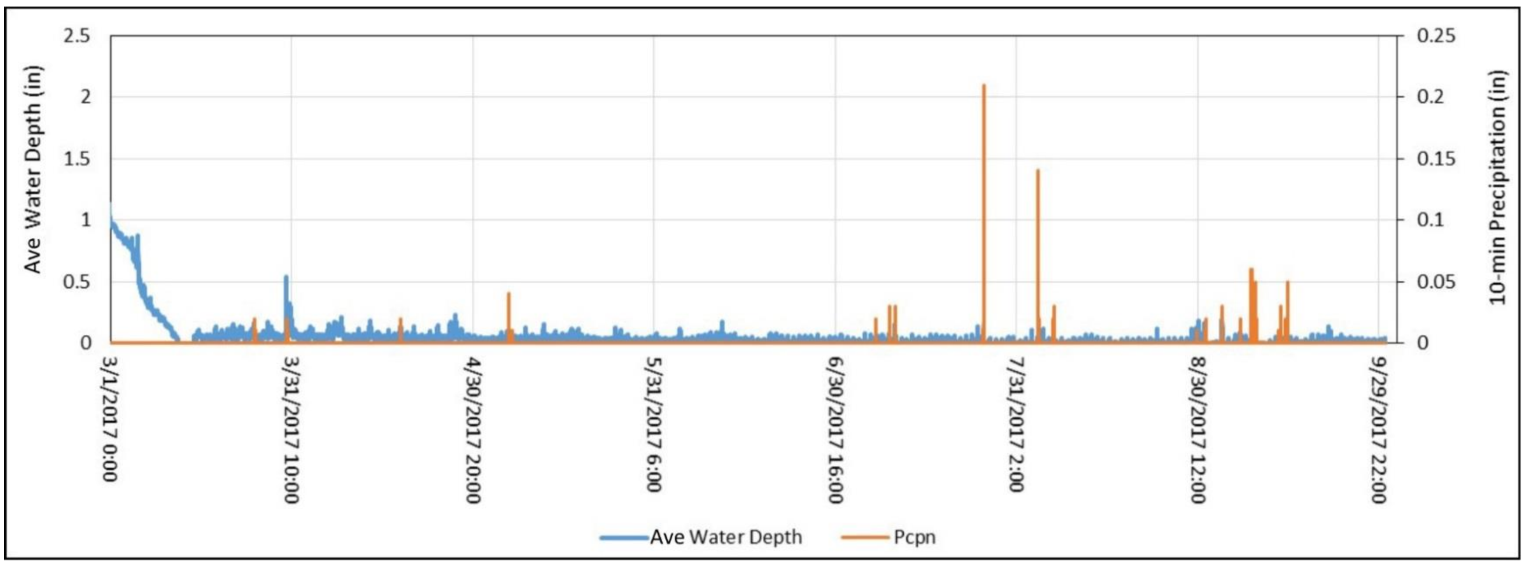

Figure 6d. Average water depth reported by the flume pressure sensor and 10-minute precipitation totals for March 1 through September 30, 2017.

Related Hydrologic Data

Soil moisture is measured over the top 4 in (10.16 cm) of the soil column using factory calibrated time domain reflectometry (TDR) sensors installed adjacent to the meteorological station. The TDR sensor readings have not been compared with laboratory-determined soil moisture content, and therefore may not reflect actual moisture content. However, the TDRs are expected to give accurate indications of changes in soil moisture content that result from meteorological conditions.

The observed volumetric soil moisture content ranged between 0.069 (6.9 percent) and 0.284 (28.4 percent) during FY2017 (Figure 7). The minimum soil water content values occurred in late October of 2016. The fall season low soil moisture conditions occur after the summer thunderstorm season and prior to the winter frontal storm season. The highest reported water content in FY2017 was recorded on February 18, 2017. The magnitude of the soil water content response to individual precipitation events appears to be dependent on the intensity and duration of the precipitation and the antecedent soil water conditions.

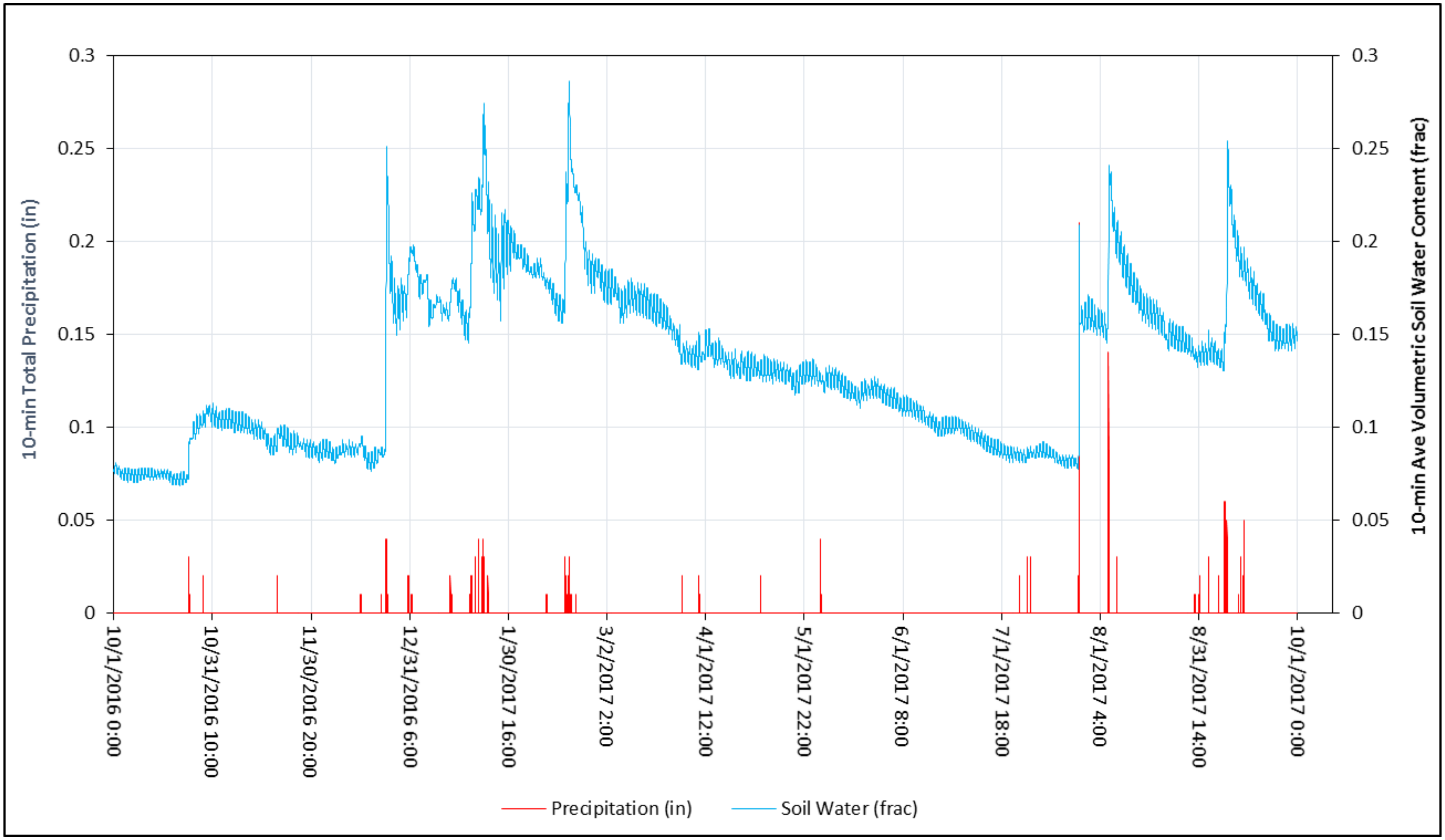

Figure 7. Soil water content over the upper four inches of soil responded to most precipitation events during FY2017.

Soil Particle Size Distribution and Radionuclide Analysis

Because there were no flow events of sufficient magnitude to transport sediments, no bedload samples were collected for radionuclide analysis during FY2017.

CONCLUSIONS

1) No flow events were observed through the flume during FY2017.
2) No bedload samples were collected for radionuclide analysis during FY2017.
3) Short-duration, high-intensity precipitation events that occurred throughout the year were insufficient to produce flow in the flume. However, the soil moisture content typically increased following the precipitation events.

RECOMMENDATIONS

Although not observed in FY2017, storm runoff through the flume has overtopped the flume on several occasions in the past (Mizell *et al.*, 2017a,b). These previous events indicate that the 6-in (15.24-cm) Parshall flume is not large enough to convey the runoff that may be conveyed through the instrumented watershed. It is recommended that the 6-in (15.24-cm) flume be replaced with a larger flume or a weir. Additionally, it is recommended that sediment traps be installed to facilitate the collection of bedload samples following runoff events and ensure that samples are collected from consistent locations in the channel.

FUTURE WORK

Data transmitted from the Smoky Site CA instrumentation will be reviewed monthly by project personnel to identify precipitation events that exceed the specified rainfall threshold (~0.2 in [0.5 cm]) and to assess proper operation of the instrumentation and remote communication equipment. Field inspections will be scheduled to service instrumentation if necessary.

Meteorological data collected leading up to and during a detected runoff event will be analyzed to identify precipitation amounts and intensity, antecedent soil water conditions, and other factors that contributed to the observed runoff. This analysis will help delineate threshold conditions that are likely to result in sediment transport and possible radionuclide migration in conjunction with the sediment. Establishing these thresholds will help identify meteorological conditions that may require monitoring and sampling of channel runoff migration pathways under a post-closure monitoring plan. The requirements for monitoring meteorological conditions and sampling runoff pathways can then be appropriately incorporated into the post-closure monitoring plan for this and similar sites, as well as aid in determining appropriate closure strategies for other Soils CAUs. Any service work on the flume or datalogger and the communication equipment associated with the flume will require the support of a radiological control technician because this equipment is located inside the CA.

REFERENCES

Andres, C.D., 2015. Approval of Final Corrective Action Decision Document/Closure Report (CADD/CR) for Corrective Action Unit (CAU) 550: Smoky Contamination Area, Nevada National Security Site, Nevada. Letter from Nevada Division of Environmental Protection to R.F. Boehlecke, Manager, Environmental Management Operations, U.S. Department of Energy, National Nuclear Security Administration, Nevada Field Office, Las Vegas, Nevada. ERD.150302.0001.

Colton, D., 1999. A series of low-altitude aerial radiological surveys of selected regions within areas 3, 5, 8, 9, 11, 18, and 25 at the Nevada Test Site. DOE/NV/11718-362, prepared for the U.S. Department of Energy, Nevada Operations Office by Bechtel Nevada.

Miller, J.J., S.A. Mizell, G. Nikolich, and S.A. Campbell, 2012a. Monitoring Potential Transport of Radioactive Contaminants in Shallow Ephemeral Channels. Desert Research Institute report number 45242 prepared for the U.S. Department of Energy, Nevada Field Office. Las Vegas, Nevada. DOE/NV/26383-28.

Miller, J.J., S.A. Mizell, G. McCurdy, and S.A. Campbell, 2012b. Monitoring Potential Transport of Radioactive Contaminants in Shallow Ephemeral Channels: FY2012. Desert Research Institute report number 45249 prepared for the U.S. Department of Energy, Nevada Field Office. Las Vegas, Nevada. DOE/NV/0000939-07.

Mizell, S.A., J.J. Miller, G.D. McCurdy, and S.A. Campbell, 2017a. Monitoring Potential Transport of Radioactive Contaminants in Shallow Ephemeral Channels: FY2013 and FY2014 (revised). Desert Research Institute report number 45276 prepared for the U.S. Department of Energy, Nevada Field Office. Las Vegas, Nevada. DOE/NV/0000939-42.

Mizell, S.A., J.J. Miller, G.D. McCurdy, and S.A. Campbell, 2017b. Monitoring Potential Transport of Radioactive Contaminants in Shallow Ephemeral Channels: FY2015 and FY2016. Desert Research Institute report number 45277 prepared for the U.S. Department of Energy, Nevada Field Office. Las Vegas, Nevada. DOE/NV/0003590-02.

Wood, J., 2017a. July 2017 NNSS Precip. Email from Special Operations and Research Division, Air Resources laboratory, National Oceanic and Atmospheric Administration to Julie Miller, Desert Research Institute; August 4, 2017.

Wood, J., 2017b. August 2017 NNSS Precip. Email from Special Operations and Research Division, Air Resources laboratory, National Oceanic and Atmospheric Administration to Julie Miller, Desert Research Institute; September 7, 2017.

APPENDIX A: FY2017 10-MINUTE METEOROLOGICAL OBSERVATIONS FOR THE SMOKY SITE

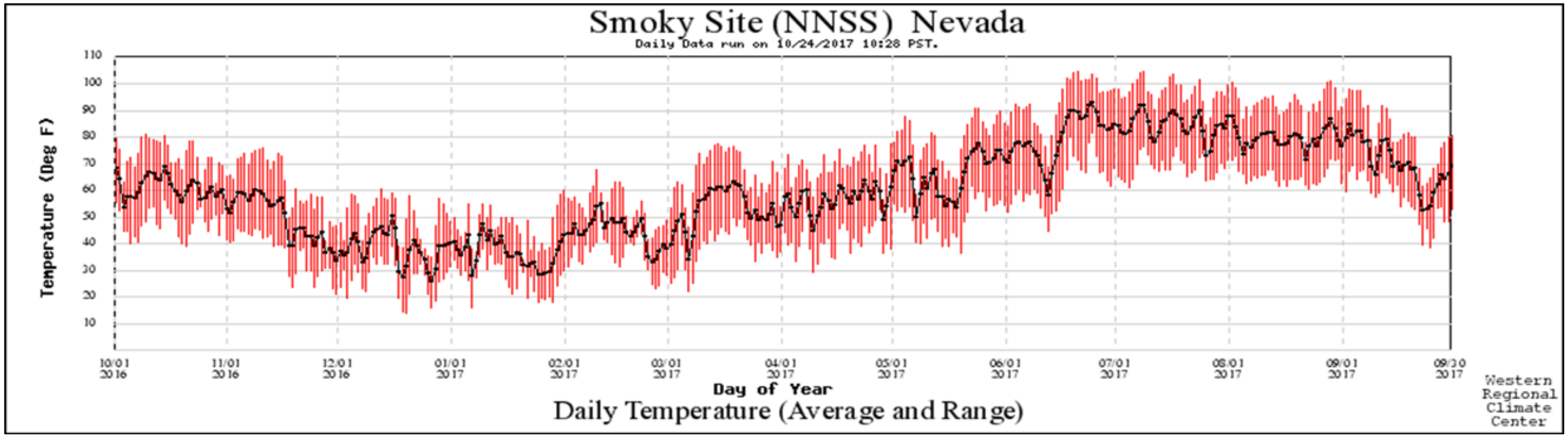

Figure A-1. Daily average (black ticks), maximum, and minimum (end points of verticle red bars) air temperature observed at the Smoky Site meteorological station during FY2017. Data depict short-term variations superimposed on the expected seasonal trend.

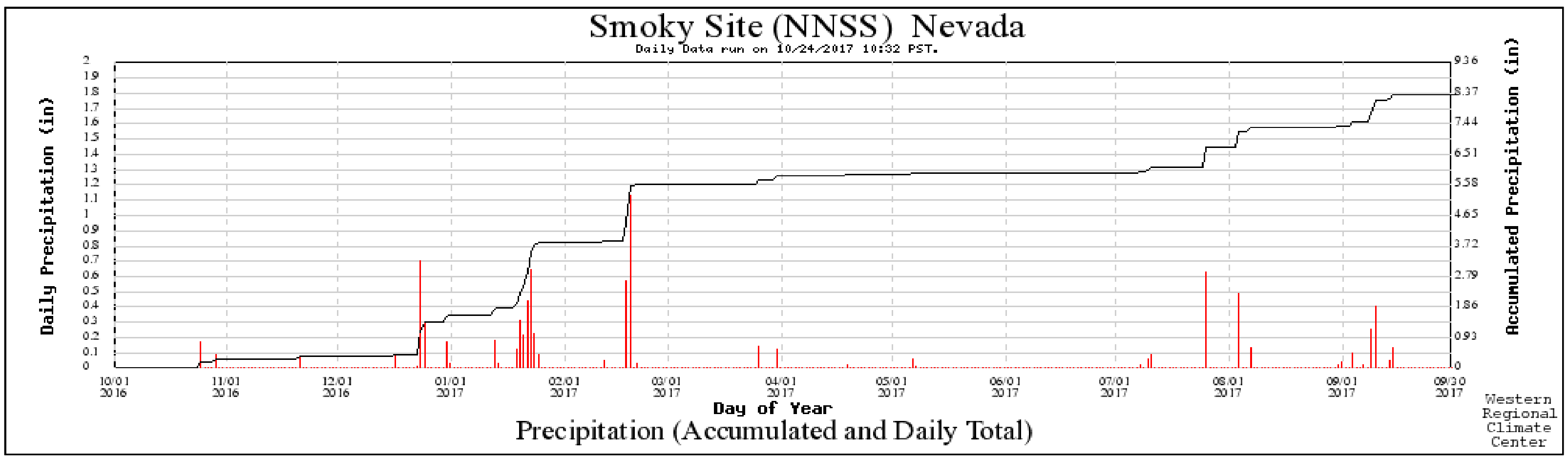

Figure A-2. Daily (red bars) and cumulative (black line) precipitation at the Smoky Site meteorological station during FY2017. Precipitation equaled or exceeded 0.1 in (2.54 mm) on 25 days. Total precipitation in FY2017 was approximately 8.36 in (212.34 mm).

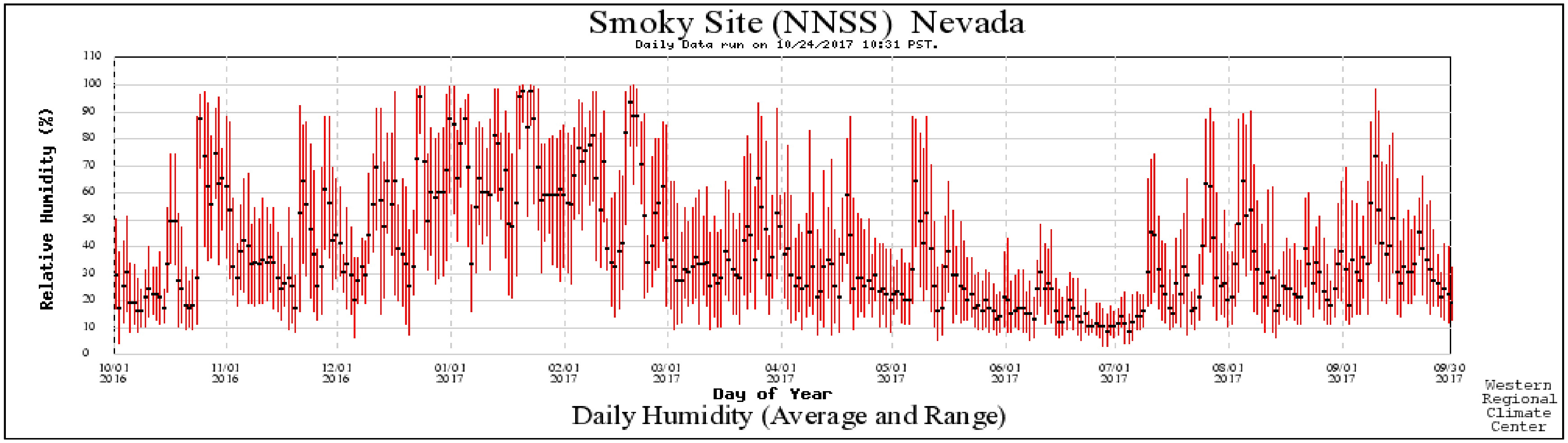

Figure A-3. Daily average (black ticks), maximum, and minimum (ends of verticle red bars) relative humidity at the Smoky Site during FY2017.

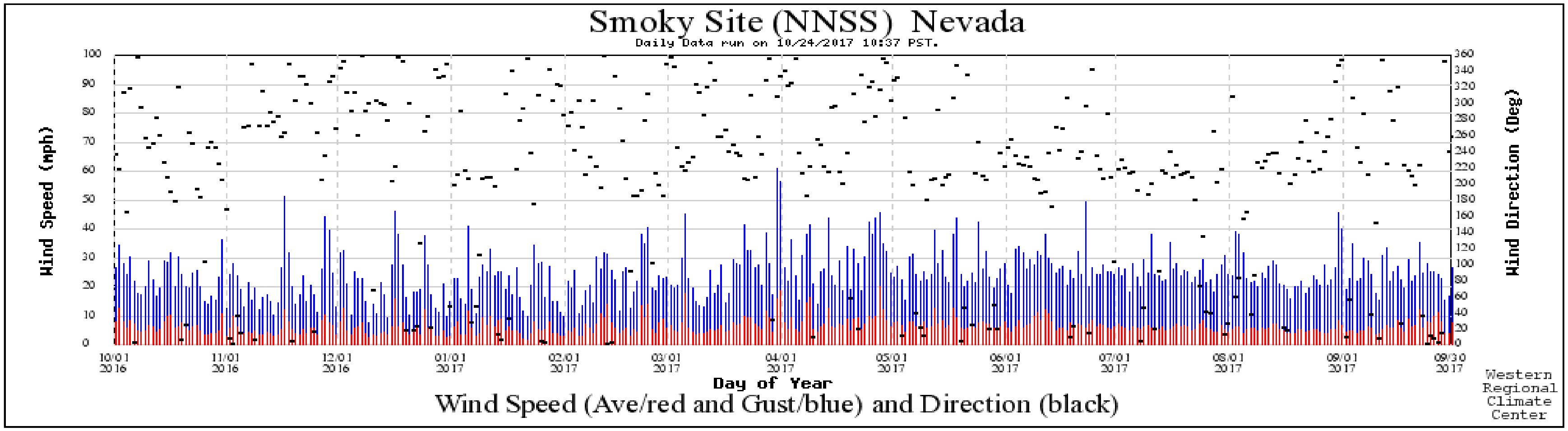

Figure A-4. Daily average (red bars) and peak (blue bars) wind speeds and daily average (black ticks) wind direction at the Smoky Site during FY2017. Peak wind speed exceeded 50 mph (80.47 km/hr) on one day in November 2016, on two days in March 2017, and on one day in June 2017. Generally, the wind direction tends to be from the southwest between late May and September and from the northwest between October and early May.

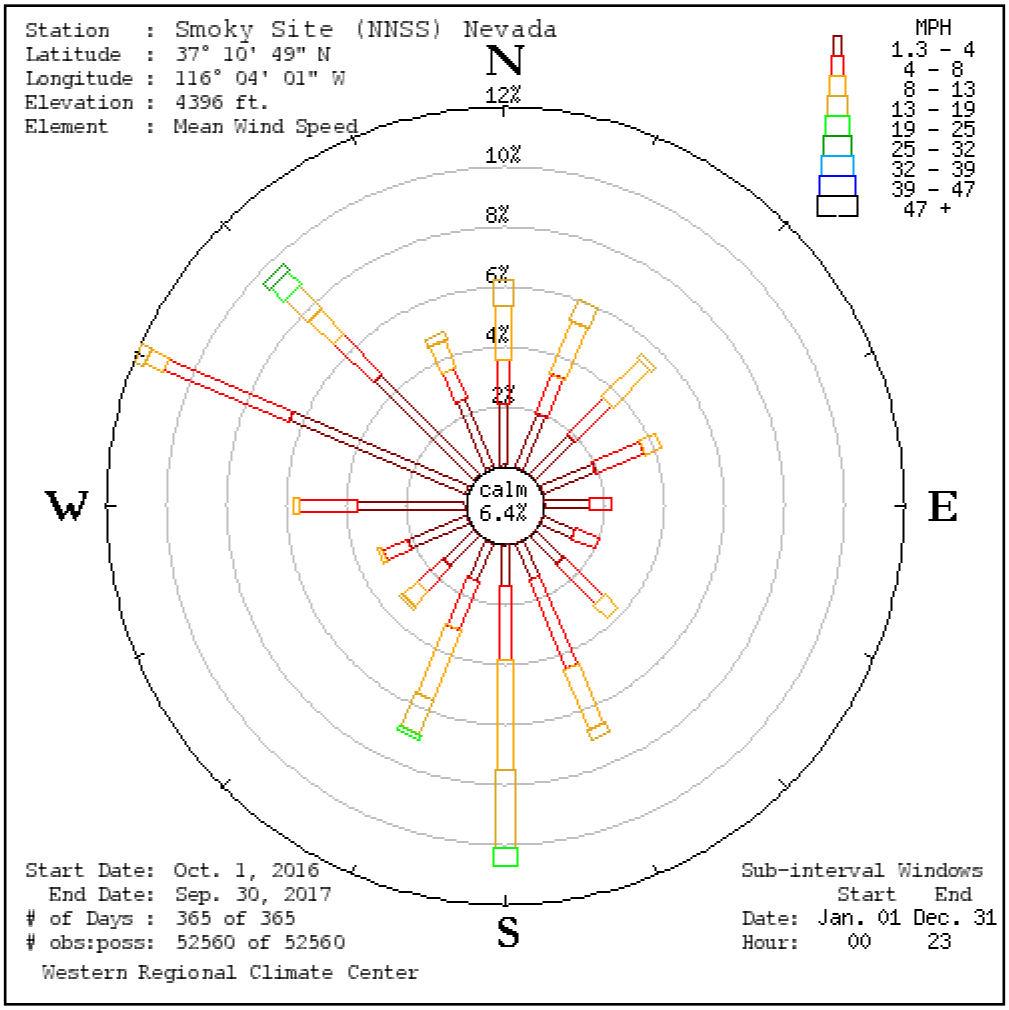

Figure A-5. The FY2017 wind rose for the Smoky Site meteorological station shows that stronger winds tend to come from the northwest quadrant and from the south. Winds from these directions are also the most frequent.

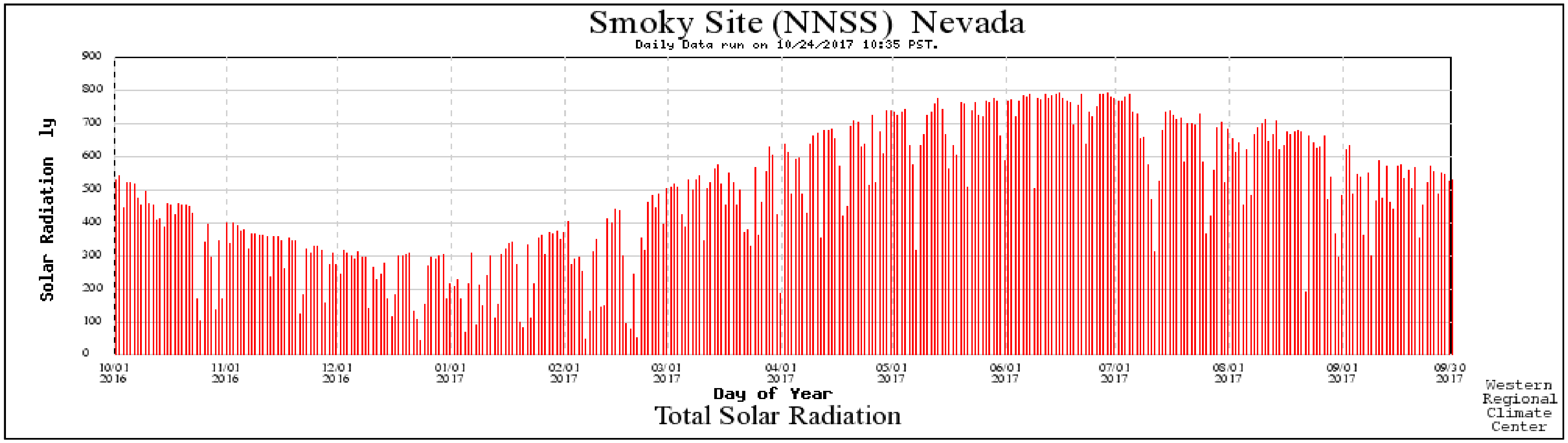

Figure A-6. Total daily solar radiation at the Smoky Site during FY2017 exhibits the expected annual trend with the greatest radiation occurring in the late spring and summer, and the lowest radiation occurring the late fall and winter. Occasions of unseasonably low solar radiation suggest cloud cover, which may be indicative of storm conditions and may occur at any time throughout the year.

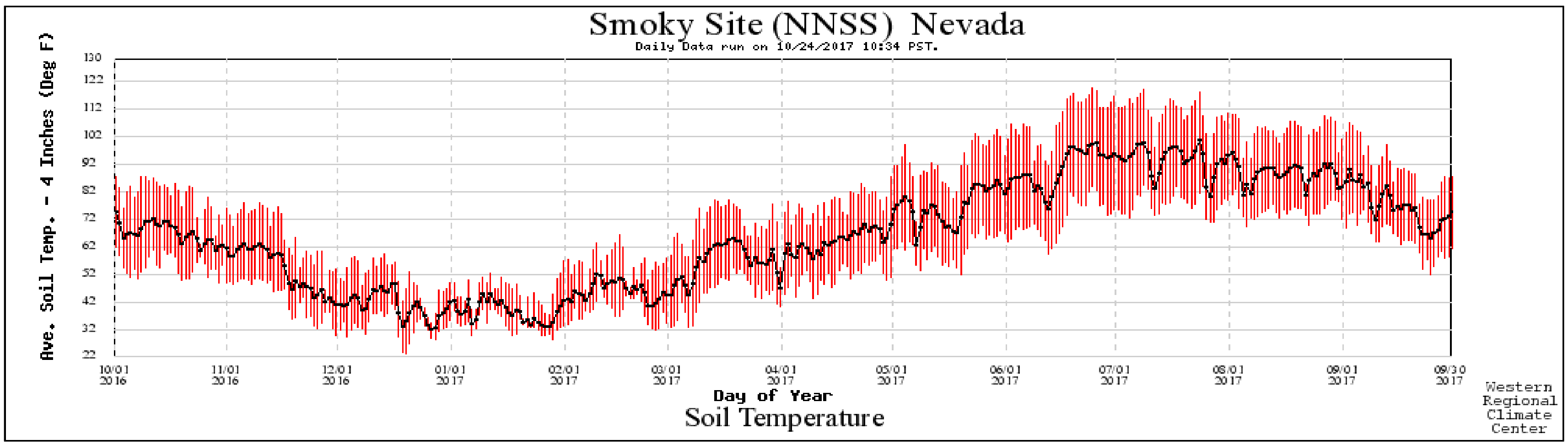

Figure A-7. Daily average (blakc ticks), maximum, and minimum (ends of verticle red bars) soil temperature measured at a depth of four inches (10.16 cm) at the Smoky Site meteorological station reflect a seasonal pattern similar to the air temperature.

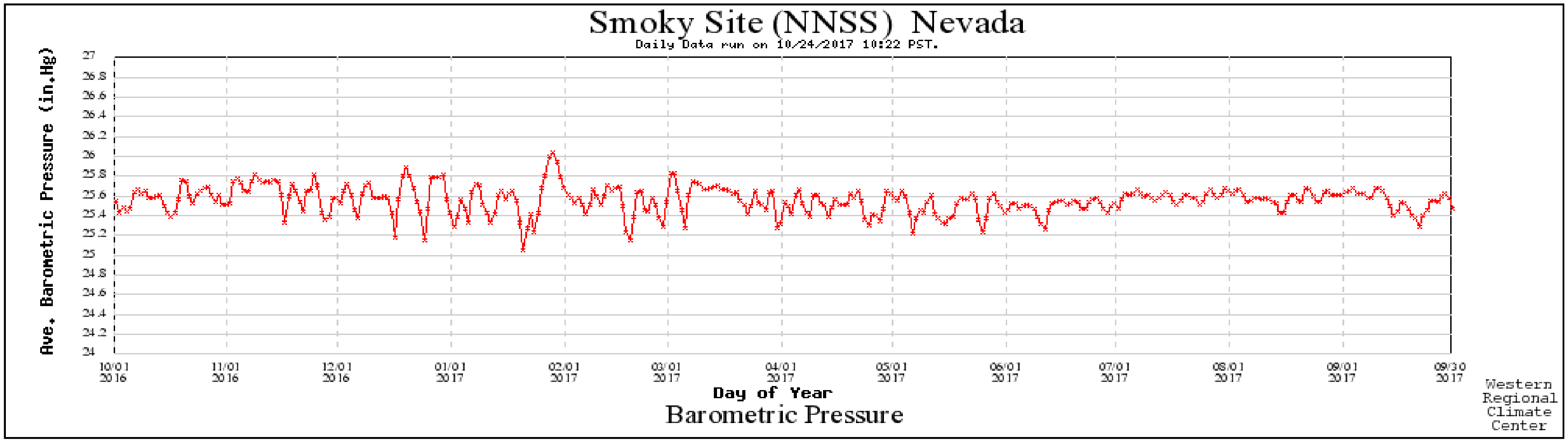

Figure A-8. Barometric pressure recorded at the Smoky Site meteorological station during FY2017 fluctuated between 25 and 26 in (63.5 and 66.04 cm) of mercury.

APPENDIX B: HISTORY OF MONITORING ACTIVITIES AND METEOROLOGICAL AND HYDROLOGICAL OBSERVATIONS AT THE SMOKY SITE, JULY 2011 TO PRESENT

Table B-1. Smoky Site monitoring activities and meteorological and hydrological observations, July 2011 to present.

Date	Description
FY2011	
7/14/2011 and 7/15/2011	**Meteorological station** installed with datalogger and GOES transmitter adjacent to the Smoky Site CA.
7/14/2011	**Data collection initiated.**
7/19/2011	**Flume installed** with satellite datalogger and radio communication to meteorological datalogger; **data collection initiated 7/20/2011.**
FY2012	
7/26/2012	Quarterly datalogger download and routine maintenance at meteorological station.
7/30/2012	**Download datalogger at flume satellite station**; single bedload sample collected below flume.
8/23/2012	Quarterly datalogger download and routine maintenance at meteorological station.
9/19/2012	Quarterly datalogger download and routine maintenance at meteorological station.
FY2013	
4/19/2013	Quarterly datalogger download and routine maintenance at meteorological station.
7/26/2013	Quarterly datalogger download and routine maintenance at meteorological station.
7/28/2013	**Flume washed out** by high flow event; precipitation events recorded on 7/24 and 7/28.
8/15/2013	**Download datalogger at flume satellite station;** Field personnel noted flume was moved from point of installation; collect sediment samples from channel in CA.

Table B-1. Smoky Site monitoring activities and meteorological and hydrological observations, July 2011 to present (continued).

Date	Description
FY2014	
10/9/2013	Quarterly datalogger download and routine maintenance at meteorological station.
1/24/2014	Quarterly datalogger download and routine maintenance at meteorological station.
3/4/2014	**Flume reinstalled**; **datalogger program revised** to record temperature at pressure transducer and perform temperature compensation using meteorological-station datalogger panel temperature; pressure sensor field tested; **flume was NOT functional 7/28/2013 through 3/4/2014.**
4/1/2014 (2130) to 4/18/2014 (1920)	Datalogger recorded “out of range” data probably because of dry zero drift.
4/4/2014	Quarterly datalogger download and routine maintenance at meteorological station.
4/19/2014 (1010 through 1350)	Sensor malfunction, unknown cause.
7/6/2014 (1850 through 2120)	**Flow event**; flume mouth plugged, **flume overtopped**; sensor stilling well packed with sediment.
7/6/2014 (2130) to 7/15/2014 (1200)	Datalogger recorded “out of range” values, **flume plugged at throat** causing malfunction of sensor reading.
7/15/2014	Quarterly datalogger download and routine maintenance at meteorological station.
7/15/2014	**Second datalogger program** modification installed to apply temperature compensation to the pressure sensor output using pressure sensor temperature; stilling well cleaned, sensor tested and reinstalled.
8/3 (1450) through 8/4/2014 (1850)	**Major flow event**; flume mouth plugged, **flume overtopped**; sensor stilling well packed with sediment.
8/4/2014 (1900) to 8/20/2014 (1130)	Datalogger recorded “out of range” values; **flume plugged at throat** causing malfunction of sensor reading.
8/20/2014	**Flume rebuilt**, stabilized; transducer stilling well cleaned and reinstalled; download datalogger at flume satellite station AND at meteorological station; collected channel sediment samples.

Table B-1. Smoky Site monitoring activities and meteorological and hydrological observations, July 2011 to present (continued).

Date	Description
FY2015	
1/16/2015	Quarterly datalogger download and routine maintenance at meteorological station.
Week of 3/29/2015	Quarterly datalogger download and routine maintenance at meteorological station.
5/15/2015	New batteries were installed at the meteorological station
7/1/2015	0.2 in precipitation at met station; 18.27 in water depth at flume.
7/2/2015 to 7/3/2015	0.18 in precipitation at met station; 15.96 in water depth at flume.
8/1/2015	0.52 in precipitation at met station; 35.7 in water depth at flume.
Week of 8/9/2015	Quarterly datalogger download and routine maintenance at meteorological station.
8/23/2015	**Water depth pressure sensor failed** because of animal damage.
9/24/2015	Battery at flume datalogger appears to be failing.
FY2016	
10/1/2015	Quarterly datalogger download and routine maintenance at meteorological station.
11/30/2015	**Repair Geokon water depth pressure sensor** and solar power; Flume reinforced with sandbags.
1/5/2016	0.02 in precipitation at met station; 10.34 in water depth at flume.
1/16/2016	Quarterly datalogger download and routine maintenance at meteorological station.
1/23/2016	0.04 in precipitation at met station; 9.89 in water depth at flume.
1/31/2016	0.04 in precipitation at met station; 12.39 in water depth at flume.
4/3/2016	Quarterly datalogger download and routine maintenance at meteorological station.
5/15/2016	Batteries preemptively replaced at meteorological station; no data were lost.
6/7/2016	Quarterly datalogger download and routine maintenance at meteorological station.
7/14/2016	Quarterly datalogger download and routine maintenance at meteorological station.
8/17/2016	**Geokon pressure sensor failed** because of animal damage, **repaired on 1/24/2017.**

Table B-1. Smoky Site monitoring activities and meteorological and hydrological observations, July 2011 to present (continued).

Date	Description
FY2017	
10/21/2016	Quarterly datalogger download and routine maintenance at meteorological station.
11/21/2016	**Repair water depth pressure sensor** at flume malfunction because of animal damage.
1/6/2017	Quarterly datalogger download and routine maintenance at meteorological station.
1/24/2017	**Repair water depth pressure sensor** at flume malfunction because of animal damage on 8/17/2016 and 11/22/2016.
3/24/2017	Quarterly datalogger download and routine maintenance at meteorological station.
7/7/2017	Quarterly datalogger download and routine maintenance at meteorological station.
10/6/2017	Quarterly datalogger download and routine maintenance at meteorological station.

STANDING DISTRIBUTION LIST

Robert Boehlecke
EM NV Program Manager
Nevada Field Office
National Nuclear Security Administration
U.S. Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518
Robert.Boehlecke@nnsa.doe.gov

Bill Wilborn
EM NV Deputy Program Manager, Operations
Nevada Field Office
National Nuclear Security Administration
U.S. Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518
Bill.Wilborn@nnsa.doe.gov

Kevin Cabble
Soils Activity Lead
Nevada Field Office
National Nuclear Security Administration
U.S. Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518
Kevin.Cabble@nnsa.doe.gov

Tiffany Lantow
Long-Term Monitoring Activity Lead
Nevada Field Office
National Nuclear Security Administration
U.S. Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518
Tiffany.Lantow@nnsa.doe.gov

Peter Sanders
Nevada Field Office
National Nuclear Security Administration
U.S. Department of Energy
P.O. Box 98518
Las Vegas, NV 89193-8518
Peter.Sanders@nnsa.doe.gov

Sarah Hammond, Contracting Officer
Office of Acquisition Management
NNSA Service Center
Pennsylvania and H Street, Bldg. 20388
P.O. Box 5400
Albuquerque, NM 87185-5400
Sarah.Hammond@nnsa.doe.gov

Jenny Chapman
DOE Program Manager
Division of Hydrologic Sciences
Desert Research Institute
755 E. Flamingo Road
Las Vegas, NV 89119-7363
Jenny.Chapman@dri.edu

Julianne Miller
DOE Soils Activity Manager
Division of Hydrologic Sciences
Desert Research Institute
755 E. Flamingo Road
Las Vegas, NV 89119-7363
Julie.Miller@dri.edu

Pat Matthews
Navarro, LLC
P.O. Box 98952
M/S NSF167
Las Vegas, NV 89193-8952
Patrick.Matthews@nv.doe.gov

Reed Poderis
National Security Technologies, LLC
P.O. Box 98521
M/S NLV082
Las Vegas, NV 89193-8521
poderirj@nv.doe.gov

*****Nevada State Library and Archives
State Publications
100 North Stewart Street
Carson City, NV 89701-4285

Archives Getchell Library
University of Nevada, Reno
1664 N. Virginia St.
Reno, NV 89557
tradniecki@unr.edu

DeLaMare Library 262
University of Nevada, Reno
1664 N. Virginia St.
Reno, NV 89557
tradniecki@unr.edu

Document Section, Library
University of Nevada, Las Vegas
4505 Maryland Parkway
Las Vegas, NV 89154
sue.wainscott@unlv.edu

†Library
Southern Nevada Science Center
Desert Research Institute
755 E. Flamingo Road
Las Vegas, NV 89119-7363

‡Nuclear Testing Archive
ATTN: Martha DeMarre
National Security Technologies, LLC
Mail Stop 400
PO Box 98521
Las Vegas, NV 89193-8521
demarrme@nv.doe.gov
(2 CDs)

§Office of Scientific and Technical Information
U.S. Department of Energy
P.O. Box 62
Oak Ridge, TN 37831-9939

All on distribution list receive one electronic PDF copy, unless otherwise noted.

***** 12 paper copies
† 3 paper copies; CD with pdf (from which to print)
‡ compact disc only
§ electronic copy (pdf) only