

Weather Data Inventory, Devils Postpile National Monument

Natural Resource Data Series NPS/SIEN/NRDS—2010/113



ON THE COVER

Soda Springs Meadow weather station, Devils Postpile National Monument. NPS photo.

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Acronyms and Abbreviations

%vwc	percent volumetric water content
CDEC	California Data Exchange Center
CDWR	California Department of Water Resources
cm	centimeters
CRREL	U.S. Army Cold Regions Research and Engineering Lab
CUES	CRREL UCSB Eastern Sierra
deg	degrees
DEPO	Devils Postpile National Monument
FMU	Fire Management Unit
ft	feet
GMP	General Management Plan
I&M	Inventory & Monitoring
in	inches
km	kilometers
LADWP	City of Los Angeles Department of Water and Power
m	meters
mbar	millibars
mi	miles
MMSA	Mammoth Mountain Ski Area
mph	miles per hour
n/a	not available
NIFC	National Interagency Fire Center
NPS	National Park Service
RAWS	Remote Automated Weather Station
SCEC	Southern California Edison Company
Scripps	Scripps Institution of Oceanography at the University of California San Diego
SEKI	Sequoia and Kings Canyon National Parks
SIEN	Sierra Nevada Network
UCSB	University of California at Santa Barbara
USBR	U.S. Bureau of Reclamation
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
W/m ²	watts per square meter
WRCC	Western Regional Climate Center
YOSE	Yosemite National Park

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1 Introduction

1.1 Background

Climate is a major driver of Sierra Nevada ecosystems. The cumulative effects of past and present climates, in concert with geologic factors (such as soil type) and processes (such as fire), largely determine current hydrology and species distribution patterns in the Sierra Nevada. Accelerated climatic change related to anthropogenic influences is expected to result in significant ecosystem effects in western montane systems, including reduced snowpack, altered fire regimes, and modified species vulnerability (CIRMOUNT Committee 2006). In the Sierra Nevada, atmospheric warming is resulting in an increase in the fraction of rain to snow, a decrease in maximum snowpack water content, and earlier snowmelt (Cayan et al. 2001; Dettinger 2005). Climate scientists expect climatic change to interact with and exacerbate other ecosystem stressors, such as altered fire regimes, air pollution, and non-native species invasions (IPCC 2007)—stressors that already rank among the most threatening to Sierra Nevada ecosystem resilience (Mutch et al. 2008).

The National Park Service (NPS) is particularly concerned about the influence of climate change on the presence and character of the natural and cultural resources it is charged with protecting (NPS 2010). The primary method by which a national park can track the local expression of broader climatic phenomena is by monitoring weather. Many parks monitor weather through cooperative arrangements with other programs and as part of air quality monitoring and fire management programs. Weather and climate monitoring have also been identified as a high priority by the NPS Inventory & Monitoring (I&M) program. The I&M program was established to provide funding, technical assistance, and coordination for more than 270 parks to complete basic natural resource inventories and to monitor the status and trends of park natural resources (NPS 2009b; Fancy et al. 2009). To plan and implement this program, the NPS created networks of parks linked by geography and by shared natural resource characteristics. The Sierra Nevada Inventory & Monitoring Network (SIEN) includes Devils Postpile National Monument (DEPO), Sequoia and Kings Canyon National Parks (SEKI), and Yosemite National Park (YOSE), all located on the west slope of the Sierra Nevada (Figure 1.1). Weather and climate monitoring were identified as high priorities in the SIEN Monitoring Plan (Mutch et al 2008).

While SIEN is still in the process of developing its weather and climate monitoring protocol, the network's strategy is to augment, enhance, and extend the existing weather monitoring infrastructure in SIEN parks. In 2006, DEPO, SEKI, and SIEN collaborated with the California Department of Water Resources (CDWR) and the Scripps Institution of Oceanography at the University of California San Diego (Scripps) to establish a meteorological monitoring station at DEPO. The purpose of this report is to document the data being collected by this station, as well as all additional known, long-term records of weather observations taken at and near DEPO.

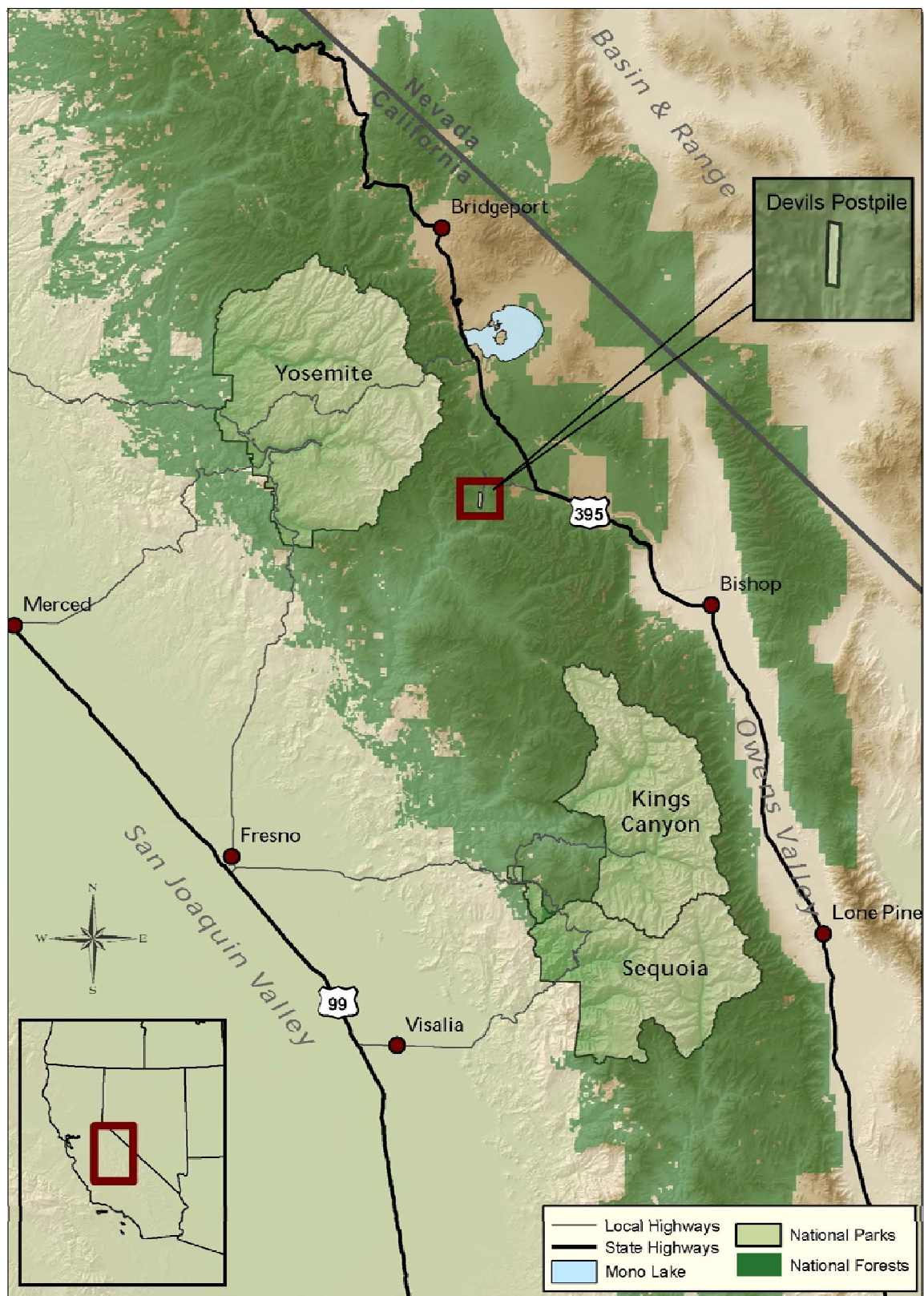


Figure 1.1. Map of the Sierra Nevada I&M Network.

Weather data are useful for calculating long-term climate trends, as well as for providing information for specific park management needs. Park rangers at DEPO use current weather information for interpretation and visitor safety. The superintendent requires baseline climate information in a management context for understanding current weather variability, the potential consequences of future climate changes, and the interrelations between climate and other focal resources under NPS stewardship. The SIEN needs baseline data and data quality information to develop and implement specific natural resource monitoring programs, including its weather and climate monitoring protocol, which will serve as a regional monitoring plan for its constituent parks. Collaborating researchers would benefit from a more complete understanding of the various sources and relative value of weather datasets. This report documents existing datasets for use in park management, monitoring, and research.

1.2 Project scope

The goal of this report is to document sources of weather data that are directly relevant to resource management and interpretation at Devils Postpile National Monument. A weather and climate inventory report for SIEN parks (Davey et al. 2007) presented a list of local weather station locations but did not provide specific descriptions or data evaluations of individual stations in the context of management utility. This report builds on that inventory report by describing individual datasets that are relevant to management, monitoring, research, and interpretation; by assessing the character and quality of these datasets; and by making recommendations for their use.

The specific objectives of this report are as follows:

- Summarize relevant weather data sources in and near DEPO, including their temporal extent, parameters, sampling interval, data quality and completeness, metadata, and data access.
- Assess usefulness of each dataset and make recommendations for future analyses. Major datasets include:

Dataset	Assessment goal
Soda Springs Meadow	Document the 2005 installation of this weather station, provide metadata about its two separate sensor arrays, make recommendations regarding NPS support of its long-term operation.
Remote Automated Weather Station	Provide accurate metadata and a temporal data completeness summary.
Daily ranger logs	Assess data quality and usefulness for quantitative and qualitative weather analyses.
Other nearby stations and short-term research efforts	Assess potential usefulness for weather analyses related to DEPO's resource management and interpretation needs.

- Provide long-term weather and climate monitoring recommendations and justification regarding specific datasets, monitoring, and additional watershed-wide instrumentation.

This report is not an assessment of local or regional climate history, nor does it present new technical analyses of the weather data. This report can serve as a useful reference for these and other specific lines of investigation.

The terms weather and climate bracket two overlapping segments of the same continuum. Weather describes short-term atmospheric conditions—what one experiences at a moment or over a few days. Weather data are instantaneous or short-term observations of current conditions (e.g., the current temperature or cloudiness, today’s maximum temperature, yesterday’s total precipitation). The science of meteorology is the study of atmospheric phenomena, including surface weather. Climate refers generally to long-term statistical characterizations of atmospheric conditions. Climatology is the science concerned with studying long-term climate. One must establish spatial and temporal bounds to define climate because variability is inherent in both weather and climate. For example, weather observations collected at a particular site on a daily basis can be used over a sufficient length of time (e.g., 30 years) to develop a sound characterization of the climate at that site.

1.3 Physical context

1.3.1 Devils Postpile National Monument

President Taft established Devils Postpile National Monument in 1911, to preserve “the natural formations known as the Devils Postpile and Rainbow Falls” for their scientific interest and for public inspiration and interpretation (NPS 1982). The Devils Postpile formation is an outcrop of columnar volcanic rock whose top has been smoothed by the passage of Pleistocene glaciers. Rainbow Falls is a waterfall on the Middle Fork of the San Joaquin River created by differential weathering of volcanic rock strata.

The monument is located in the Sierra Nevada Mountains, southeast of Yosemite National Park, in Madera County, California. The unit is east of the crest of the Sierra Nevada Mountains but in a watershed that drains off the west slope of the range. The monument is small, at 324 ha in size (798 ac; 1.25 mi²), but is surrounded by the large Inyo National Forest (263,000 ha, 650,000 ac), administered by the U.S. Forest Service. Ninety-four percent of DEPO is part of the Ansel Adams Wilderness Area. The monument’s elevation ranges from 2,200 to 2,500 m (7,200–8,200 ft). Approximately half of the surface geology is volcanic rock from four separate flows; the other half is porphyritic quartz monzonite similar to that found in the Cathedral Peaks suite in Yosemite National Park. Additionally, DEPO contains a variable thickness of pumice erupted from nearby Deadman Pass. Upland vegetation reflects both eastern and western slope influences. Riparian woodland and meadows flank the river.

The monument is located in the center of the Middle Fork watershed of the San Joaquin River (see Figure 1.3.1). The headwaters of the San Joaquin River are located in a unique part of the Sierra Nevada where the crest of the range is not congruent with the range’s hydrologic divide. Though the San Joaquin flows south, then west to California’s Central Valley, DEPO is located east of the physical mountain crest, resulting in weather patterns that can be similar to those of the east slope. The Middle Fork is divided into three sixth-level Hydrologic Unit Code units: the Upper Middle Fork, the Middle Middle Fork, and the Lower Middle Fork. The Upper Middle Fork (27,980 ac) lies immediately north and upstream of DEPO. The monument itself lies at the upper edge of the Middle Middle Fork (21,786 ac), where King Creek, Boundary Creek, and a creek from Red’s Meadow contribute to the Middle Fork within or near the monument. The Lower Middle Fork lies downstream of DEPO, and is contained within the Sierra National Forest, adjacent to the Inyo National Forest. DEPO’s administrative planning boundary includes the upper and middle forks of the Middle Fork. The Mammoth Mountain Ski Area and resort community of Mammoth Lakes are located 10 kilometers (six miles) east of DEPO, in an adjacent watershed.



Watersheds surrounding Devils Postpile National Monument

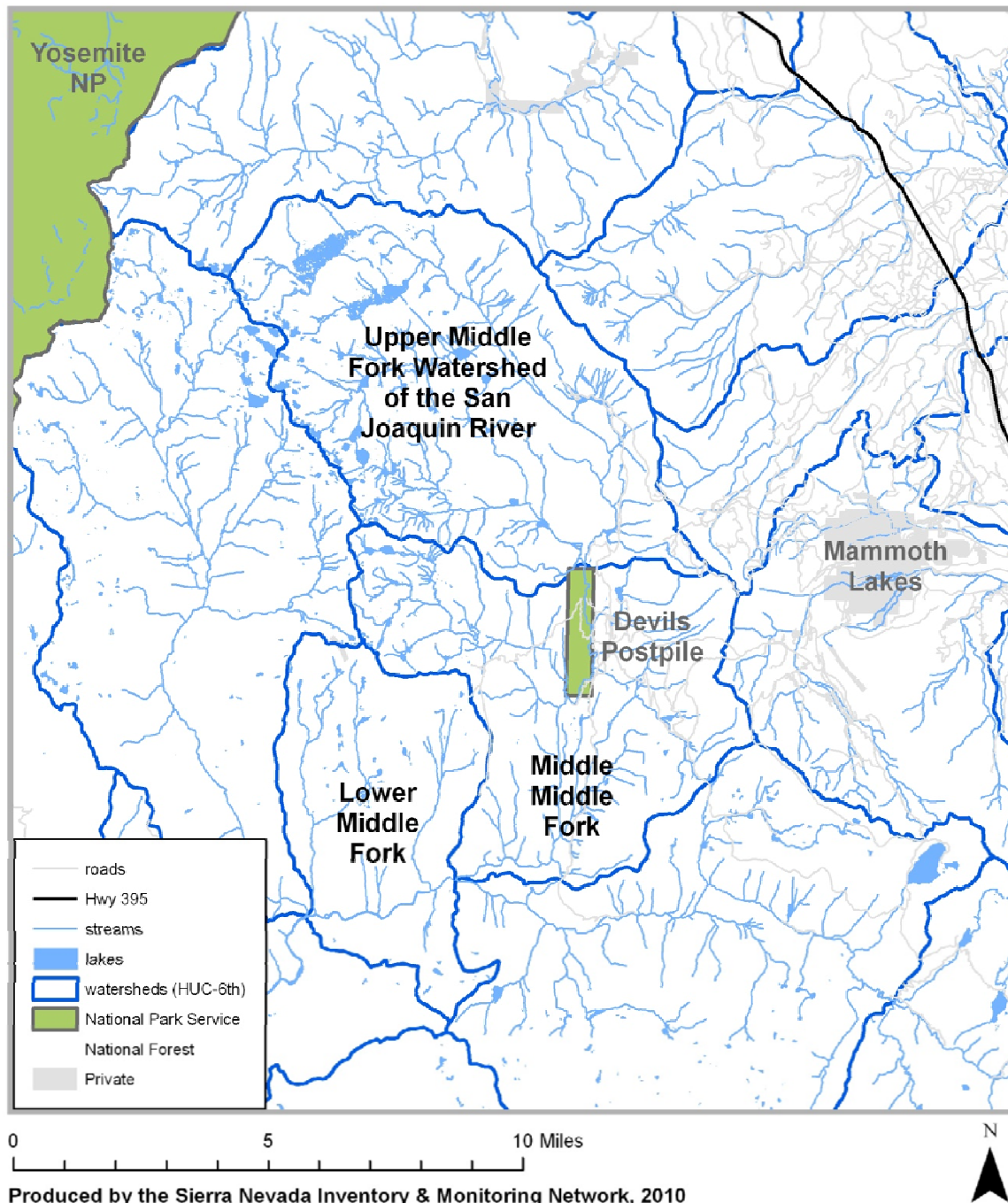


Figure 1.3.1. Map of watersheds near DEPO.

1.3.2 Regional climate characterization

Due to its elevation, seasonal precipitation regime, and aspect to solar insolation, the climate at DEPO technically classifies as lower boreal (also called microthermal), though it shares some characteristics with the upper Mediterranean classification (Edwards and Redmond, in prep). In general, winters are cold and wet; summers are warm and mostly dry. During winter storms, temperatures usually remain below or near freezing, both day and night. Between storms, daytime highs can rise to above 15°C (60°F) even in January, but nighttime lows are almost always well below freezing, occasionally dipping below -18°C (0°F). Summer days are warm but nights are cool; skies are usually clear and the humidity is usually low. High-level winds tend to be directed eastward over the Sierra Nevada, but lower, more local winds tend to be directed along the axis of the San Joaquin River canyon, coming either from the south or north. During fall and winter, the monument can experience adiabatic rain shadow winds, locally called Mono winds, coming from the north or sometimes from the northeast or east. Combined with low ambient humidity, these winds can create a severe fire hazard (NPS 2005).

Hemispheric cycles, such as the El Niño Southern Oscillation, and regional influences, such as the southwestern summer monsoon and cyclonic storms, influence the variability in local climate at DEPO. The monsoon is responsible for a significant portion of summer precipitation, as warm, wet air masses create afternoon convective storms from late June to mid-September. Such thunderstorms often produce spotty and intense localized precipitation, flash flooding, high winds, and wildfire ignitions. During winter, cyclonic storms produce widespread precipitation. The prevailing westerly winds create a rain shadow at DEPO, even though the range crest curls east of the monument. Drought, a multi-scalar phenomenon driven by many atmospheric factors, also figures into local climate fluctuation (Edwards and Redmond, in prep).

1.4 Identifying resource management priorities at DEPO

DEPO is currently in the public scoping phase of its first General Management Plan (GMP), from which its first Resource Stewardship Strategy will follow. Consequently, there are few published documents offering park-specific guidance for managing resources. The monument's enabling legislation cites "Rainbow Falls" and "scientific interest" as two important values (NPS 1982). Theoretically, weather data can be linked to these values—hydrologic measurements of streamflow over Rainbow Falls are presumably closely linked to local precipitation data, and weather data are undoubtedly of scientific value—but this is an imprecise justification for the usefulness of weather data to park management. There are three documents with more specific relevance to the rank of weather data in the hierarchy of resource management priorities.

The first relevant document is the Fundamental Resources and Values statement (NPS 2009a, 5), an informal listing of eight values developed by NPS staff and other team members during Phase I of the GMP process. It presents eight broad topics of management and interpretive interest to the monument. Three of these values—"the San Joaquin River and corridor," "component of larger ecosystem," and "opportunities for science and learning"—are supported by weather monitoring activities in the monument. First, the San Joaquin River and its riparian corridor are sensitive to the magnitude of and variability in streamflow, which is directly and inextricably tied to measurable weather parameters, such as precipitation (rain and snowfall) and air temperature. Weather also directly impacts the plants and animals that live in or depend on the river corridor. Second, DEPO, a relatively small NPS unit, has a history of close collaboration with the U.S. Forest Service, which manages the vast surrounding wilderness (the "larger ecosystem" of which DEPO is a component). Integrating knowledge gained from DEPO weather observations into a larger regional climate context and downscaling regional analyses to the scale of the monument, thereby situating DEPO climate in a landscape ("larger ecosystem") context, are management-related uses of weather data. Third, DEPO and SIEN have already capitalized on one

major opportunity for science and learning by supporting the construction of the Soda Springs Meadow weather station. DEPO interprets the station and its accessible data to monument visitors with two interpretive wayside signs (see Appendix C) and interpretive talks.

The second relevant document is the DEPO vital signs workshop report (NPS 2002), a summary of monitoring priorities developed during the scoping process for the SIEN vital signs monitoring plan and integrated into its selection of vital signs (or indicators) of ecosystem condition. Though developed for the network, the priorities identified by the scoping group reflect the scientific consensus about important management concerns at DEPO. Weather and climate were not identified as vital signs for DEPO during this initial scoping workshop. However, numerous other vital signs on the list—wetlands extent, vegetation and invertebrates, flow of the Middle Fork of the San Joaquin River, and bird populations—are sensitive to intra- and interannual weather fluctuations. The availability of local weather and climate data are important to analysis and interpretation of status and trends in these vital signs. Weather and climate were identified as an important vital sign for all SIEN parks during the network-level scoping process in 2005 (Mutch et al. 2008, Appendix G). The development of a SIEN weather and climate protocol will contribute to the discussion of how climate datasets can be used to support park management.

The third relevant document is the DEPO fire and fuels management plan (NPS 2005), which provides long-term direction for achieving goals related to human safety and ecosystem management. Though the plan does not explicitly detail the importance of weather monitoring at DEPO, it does make recommendations based on the characterization of the DEPO Fire Management Unit (FMU) and refers to this characterization as “the cornerstone for managing the wildland fire program.” Weather and climate monitoring at DEPO can provide information on short- and long-term trends that can aid in assessing fire danger and updating management strategies.

2 Extant Data Sources

This section describes three sets of weather data, from the Soda Springs Meadow weather station, the DEPO Remote Automated Weather Station (RAWS) station, and the monument's daily ranger logs. The Soda Springs Meadow weather station is the only weather station currently operating in the monument. Erected in 2005 and fully operational by August 2006, its installation and operation is documented in detail in this report (see Appendix A). From 1993 to 2004, a now-decommissioned RAWS station operated in the housing area northeast of Soda Springs Meadow. The third dataset is an archive of paper reports, called daily ranger logs, that contain weather observations. Other weather stations operating nearby are also mentioned.

A search of NPS publication search engines—NPS Library (<http://library.nps.gov/>), NPS Technical Information Center (<http://etic.nps.gov/>), and Natural Resource Information Portal (<http://nrinfo/Home.mvc>, which superseded NatureBib)—revealed only one citation relevant to weather and climate at DEPO, an anonymous source from 1947 (this citation appears to be an erroneous entry and is described later in this report).

2.1 Scripps/CDWR Soda Springs Meadow station, 2005–present

On August 17, 2005, the National Park Service and a team of partner agencies began construction of a new weather and river stage monitoring station at Soda Springs Meadow, located in the Middle Fork floodplain near the DEPO ranger station. The multi-agency collaboration included NPS staff from DEPO and SIEN, and representatives from the Scripps, the U.S. Geological Survey (USGS), and the California Cooperative Snow Surveys (part of the CDWR). The station features two separate arrays of sensors, data loggers, and transmission equipment, operated separately by Scripps and CDWR. Sensor maintenance and data delivery to public websites are also separate. (The operator is sometimes listed as “National Park Service.” DEPO personnel are not, however, involved in station maintenance). See Appendix A, for installation details and initial sensor specifications.

2.1.1 *Agency objectives for the Soda Springs Meadow Station*

The various agencies participating in the establishment of the Soda Springs Meadow weather station have substantially different but complementary objectives for collecting weather data. The objectives of each contributing group are provided below to help explain the maintenance priorities, quality controls, and end-user needs of each operating agency.

2.1.1.1 *Devils Postpile National Monument*

The monument permitted and supported installation of the Soda Springs Meadow Station because of its relevance to water resources and climate change in the context of management, research, and visitor interpretation (NPS 2006). Park staff incorporates the station into interpretive programs and are beginning to use the data in resource projects and management decisions.

2.1.1.2 *Sierra Nevada Network*

Installation of the Meadow station supports Sierra Nevada Network vital signs monitoring as identified in the SIEN vital signs monitoring plan (Mutch et al. 2008). SIEN will use the station's data to monitor seasonal, annual, and long-term status and trends in weather and climate as both a qualitative complement and quantitative covariate to other vital signs monitoring. SIEN also supports related weather/climate research in the park and the dissemination of local weather data to the public (notes from Andi Heard, April 12, 2005). SIEN's weather and climate monitoring program (in development) supports the collection of high-quality data that can be used for long-term monitoring of temperature, precipitation

(including snowfall), snowpack, and other secondary parameters, such as humidity, wind and solar radiation (SIEN, in prep).

2.1.1.3 Scripps Institution of Oceanography at the University of California San Diego

Scripps invested in the installation to augment its regional network of stations supporting long-term climate research. Regular maintenance and data quality control procedures ensure a high standard of completeness and precision of the data coming from the Scripps suite of sensors. Real-time data access offers important efficiencies but is not the highest priority in this research context; high temporal resolution and data quality are of greater priority. At the time of this document's publication, Douglas Alden was responsible for the Scripps investment.

2.1.1.4 California Department of Water Resources

The CDWR Cooperative Snow Surveys office uses station data as a weather forecasting and early warning tool in the San Joaquin River system as the river flows west toward a series of dammed reservoirs. This station is part of a regional network of real-time stations providing snowpack, streamflow, and meteorological data to forecasters. High temporal resolution data and real-time access are of highest value to CDWR. At the time of this document's publication, Frank Gehrke was responsible for the CDWR investment.

2.1.1.5 U.S. Geological Survey

Since the installation, USGS researchers have added temporary temperature sensors to the tower to augment snowpack and cold air drainage research in the Middle Fork Valley. At the time of this document's publication, Mike Dettinger (USGS) and Dan Cayan (USGS and Scripps) were responsible for the USGS investment.

2.1.2 Data descriptions

2.1.2.1 Scripps data

Due to budget constraints, the full period-of-record dataset from Scripps sensors was not readily available to the public at the time of this publication. Some current data are intermittently available online, and Scripps has shared the full dataset with SIEN (Tables 2.1.2.1, 2.1.2.2).¹ The website has basic data display tools for viewing recent data. SIEN and Scripps are currently attempting to establish a periodic data transfer agreement with Western Regional Climate Center (WRCC) to guarantee data access.

¹ Soda Springs Meadow station data from Scripps sensors are (limited and intermittently) available at: http://meteora.ucsd.edu/weather/observations/sio_other/sites/stn_32.html

Table 2.1.2.1a. Parameters of Scripps-operated sensors, Soda Springs Meadow weather station.

Sensor description	Units	Height (m)	Interval (minutes)	Data available
Precipitation, accumulated (PrTot)	inches	6	1	Aug 31, 2005–present
Air temperature (Temp0)	°C	3.5	1	Aug 31, 2005–present
Air temperature (Temp1)	°C	8	1	Aug 31, 2005–present
Relative humidity (RH)	%	8	1	Aug 31, 2005–present
Barometric pressure (station pressure)	mbar	6	1	Aug 31, 2005–present
Solar radiation (Solar)	W/m ²	6	1	Aug 31, 2005–present
Fuel moisture	%	0.2	60	Jul 21, 2007–present
Fuel temperature	°C	0.2	60	Jul 21, 2007–present
Soil moisture	%vwc	-0.1	60	Jun 22, 2008–present
Soil temperature	°C	-0.1	60	Jun 22, 2008–present
Soil moisture	%vwc	-0.5	60	Jun 22, 2008–present
Soil temperature	°C	-0.5	60	Jun 22, 2008–present

Data provided by Douglas Alden.

mbar = millibars

W/m² = watts per square meter

%vwc = percent volumetric water content

Table 2.1.2.1b. Scripps-operated sensors on stream gauge in Middle Fork of San Joaquin River.

Sensor Description	Units	Height	Interval (minutes)	Data Available
River stage	cm	varies	30	Aug 29, 2004–present
Water temperature	°C	varies	30	Aug 29, 2004–present

Data provided by Douglas Alden.

2.1.2.2 CDWR data

The full period-of-record uncorrected data from CDWR sensors on the Soda Springs Meadow weather station are available online at the California Data Exchange Center (CDEC) (Table 2.1.2.2).² CDEC is a clearinghouse for weather and water data and does not conduct any quality checks on the data it serves. Real-time viewing tools help with visualization, but downloading historical data is tedious and slow because of the way the database query is structured. Sensor error values are inconsistently recorded (some are confusingly recorded as “0”; see air temperature during the summer of 2008) which demands some attention by raw data users. Precipitation values are cumulative, requiring careful manipulation of the raw data before analysis. The CDWR does not currently measure river stage despite the presence of a reporting field. The anemometer malfunctioned for a significant length of time. Also, either the temperature sensor does not measure below 0°F (-18°C) or the server will not plot negative temperature values, though these sub-zero data can be obtained from the Scripps temperature dataset. As a whole, the data are relatively complete, of high quality, and available in real-time making them useful not only to the CDWR but to the monument’s staff and visitors.

² Soda Springs Meadow station data from CDWR sensors are available through CDEC at: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=DPO

Table 2.1.2.2. Parameters of CDWR-operated sensors, Soda Springs Meadow weather station.

Sensor description	Units	Height	Interval		Data collection	Data available			
			Measured	Reported					
Snow depth	inches	0 m	n/a	daily	computed	October 1, 2007–present			
Snow, water content									
Snow, water content (revised)									
Snow depth			unknown	hourly	raw via satellite	August 4, 2006–present			
Snow, water content									
Precipitation, accumulated			event						
Relative humidity	%	6 m	hourly						
Temperature, air	°F								
Atmospheric pressure	inches		unknown						
Wind, speed	mph	10 m	2 seconds						
Wind, direction	deg								
Wind, peak gust	mph								
Wind, direction of peak gust	deg								
Solar radiation avg	W/m ²	6 m	10 seconds						
Solar radiation max	W/m ²								
Solar radiation min	W/m ²								
Net solar radiation avg	W/m ²								
Net solar radiation max	W/m ²								
Net solar radiation min	W/m ²								
Irradiance average	W/m ²								
Irradiance maximum	W/m ²								
Irradiance minimum	W/m ²								
Reflected irradiance avg	W/m ²								
Reflected irradiance max	W/m ²								
Reflected irradiance min	W/m ²								
Battery voltage	volts	n/a	n/a						

Parameters downloaded August 4, 2009, from http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=DPO. Additional data provided by Frank Gehrke. Soil moisture listed on installed sensor list but no soil moisture data is available online. When units listed on the website disagreed with units listed on the installation notes, this table used website units and assumed that either the datalogger or the CDEC database was making the proper conversion.

2.2 RAWS station, 1993–2004

2.2.1 Dataset description

From November 15, 1993 to August 6, 2004, the Inyo National Forest operated a RAWS station called “Devils Post Pile” (*sic*). This type of weather station originally served the wildfire community, but RAWS stations are deployed throughout the United States, and the data are widely utilized by resource managers, scientists, and others for meteorological and climatological purposes (see Appendix B for RAWS network description). Daily data are available online (<http://raws.dri.edu/cgi-bin/rawMAIN.pl?caCDPP>); the WRCC supplied SIEN with the complete hourly dataset.

The station was first located on a topographical bench on the west side of the San Joaquin River, outside of the monument (Kelly Redmond, personal communication). These original coordinates are maintained in the metadata file by the National Interagency Fire Center (NIFC). At some unknown time, the station was moved to a forested and sheltered locale. Current superintendent Deanna Dulen and former park manager Wymond Eckhardt have verified the station’s approximate location there, on NPS property, and these coordinates are used to locate the RAWS station in Figure 1.3.1. Unfortunately, there are no known photographs of the RAWS station at either location.

The dataset has several shortcomings. There is a data gap from December 31, 1993 to June 24, 1994. However, the dataset is relatively complete for the rest of the period of record for precipitation, air and fuel temperatures, humidity, solar radiation, and wind (Table 2.2.1). The station also recorded precipitation as a cumulative value restarted at zero after station maintenance visits, rather than at the start of a new calendar or water year. This means one must translate the raw data available online into periodic sums (daily, monthly, annual) prior to analysis. Anecdotal evidence suggests that pine needles often clogged the snow cup and rain gauge, introducing an unquantifiable loss in precipitation-measurement accuracy.

Table 2.2.1. Parameters measured by the decommissioned Devils Post Pile RAWS weather station, 1993–2004.

Sensor description	Units	Interval	Data available
Accumulated precipitation	inches	hourly	November 15, 1993–August 6, 2004 (with gap from December 31, 1993–June 24, 1994)
Air temperature	°F		
Fuel temperature	°F		
Relative humidity	%		
Solar radiation	W/m ²		
Average wind speed	mph		
Wind direction	deg		
Max hourly wind gust	mph		
Direction of max wind gust	deg		

Full hourly dataset provided by Jim Ashby, Western Regional Climate Center, on 13 August 2009. Daily data can be accessed at this site <<http://raws.dri.edu/cgi-bin/rawMAIN.pl?caCDPP>>.



Weather Stations in and near Devils Postpile National Monument

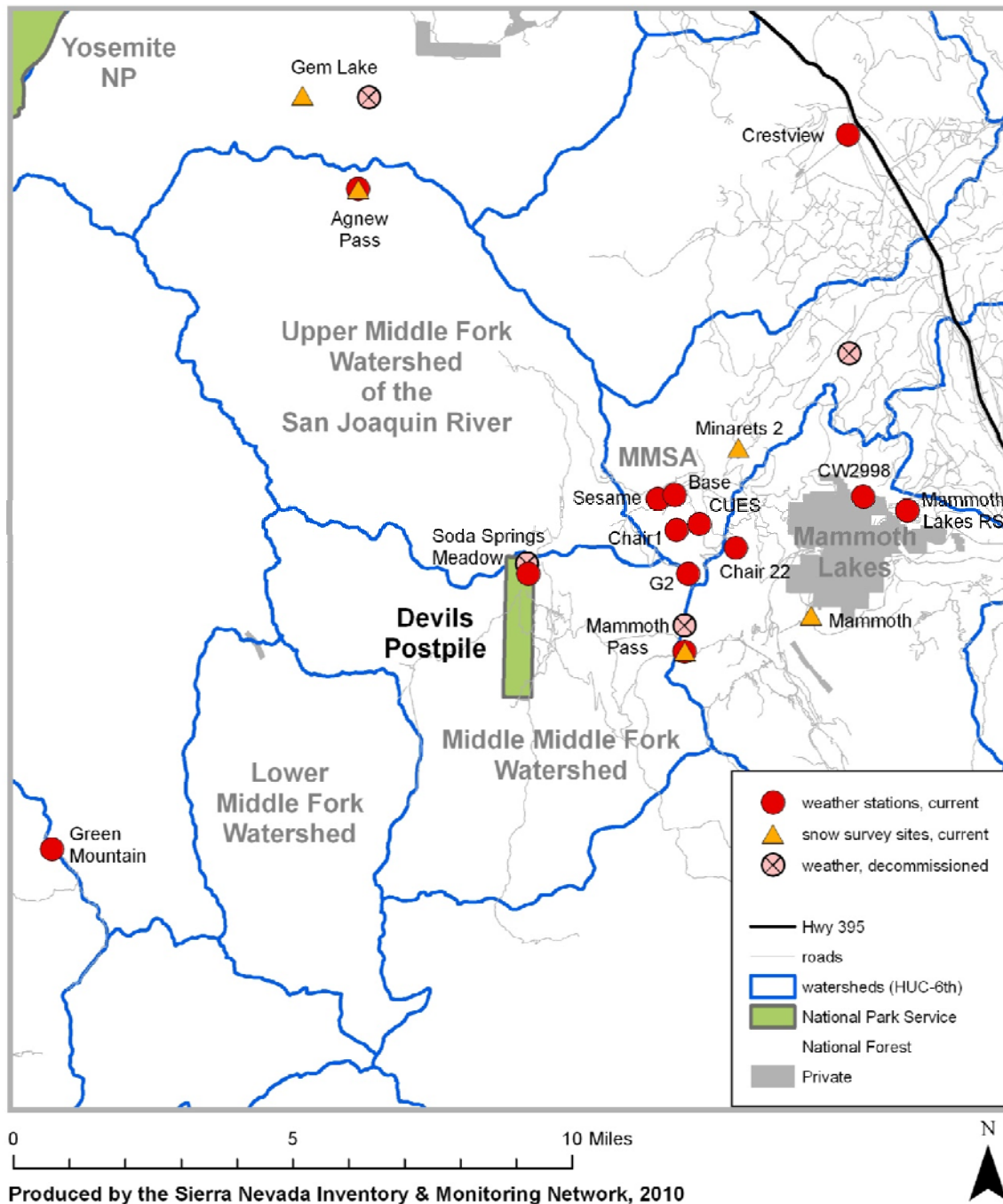


Figure 2.2.1. Map of area weather stations.

2.3 DEPO Daily ranger logs, 1972–2003

2.3.1 Dataset description

The DEPO daily ranger logs are daily records kept by rangers on duty at the monument. The logs contain some information on daily weather as well as all manner of administrative information irrelevant to weather. Rangers still keep these daily records and their usefulness extends far beyond their relevance as a weather record. At the time of this publication, DEPO held digital and hard copies and the Sequoia National Park Archives at Ash Mountain held the original logs spanning 32 operating seasons (1972–2003). We did not intend to conduct a full inventory of existing logs, and although more recent logs exist, we concerned our investigation with this time period because these logs were easily accessible.

Physically, the logs are a combination of formal daily datasheets and handwritten records of the day's activities (Figure 2.3.1). There are multiple versions of the datasheet but all contain space for recording the daily high and low temperature, temperature at time of observation, precipitation, and miscellaneous weather comments. Some of the handwritten sheets also contain this information.

We briefly reviewed the ranger logs to estimate their temporal extent, completeness, and quality, and to assess their relevance to scientific understanding of local weather and climate.

DAILY LOG		Thursday July 21 1977	
DEVILS POSTPILE NATIONAL MONUMENT		DAY	DATE YEAR
WEATHER		INTERPRETATION - VISITOR SERV.	
Temp: hi <u>90°</u> ; low <u>40°</u>		Naturalist walks _____	
at obs/time <u>55° / 8am</u>		Info. desk _____	
Precip: _____ in. Description <u>clear am sks</u>		Campfire program _____	
<u>patchy clouds - no precip.</u>		Casual contacts _____	
COUNT		Special pres. _____	
USE: Tents <u>5</u> ; Rec.Veh. <u>13</u> ; Parking <u>33</u>		Natl. Hist. Assoc. -- to be ordered _____	
Travel: End <u>66454</u> Road closures: _____		Order sent: _____	
Start <u>66010</u>		Natl. Hist. Assoc. remittance _____	
2 <u>444</u>		Natl. Hist. sightings _____	
CARS <u>222</u>		_____	
X <u>3.5(3.7)</u>		_____	
VISITORS <u>777</u>		_____	
Picnics: 10 a <u>3</u> ; 12 N <u>25</u> ; 2 p <u>10</u> ; 4 p <u>8</u>		_____	
SERVICES: Campfire program _____		_____	
Interpret. walks: 11 a <u>52</u> ; 2 p <u>45</u> ; Casual <u>20</u>		_____	
Special interpret. presentation _____		_____	
Natl. Hist. Assoc. sales \$ <u>55.39</u>		_____	
Campground fees collected \$ <u>34.09</u> Nos. <u>#26</u>		_____	
Wilderness permits issued <u>34.09</u>		_____	
Ranger Station hours <u>8-5</u> ; contacts <u>300</u>		_____	
ADMINISTRATION		_____	
PERSONNEL: Savoy <u>8</u> Medeiros <u>8</u>		_____	
Nachtigal <u>8</u> Hoffmann, W <u>8</u>		_____	
Eckhardt, W <u>8</u> Kennedy, J <u>8</u>		_____	
PROCUREMENT: Permits <u>8</u> McCullough <u>8</u>		_____	
DI-1's submitted _____		_____	
Warehouse _____		_____	
Inventory _____		_____	
DFF brochures on hand _____		_____	
Campground fee remittance \$ _____		_____	
Administrative project _____		_____	

DEPO Log

Temp. hi 64, low 30 Tuesday 11, Oct. 77
@ obs/time 30/8am

Description: clear skies in am

Use: Tents _____ RV 5 Parking 2

Travel: End 4755
start 4628
31 127

Cars 64
X 3.5

Visitors 222

Campground fees \$ 7.50 #11

Personnel:
Nachtigal 8
Hoffmann 8

Figure 2.3.1. Pages from DEPO ranger logs—datasheets and handwritten.

2.3.2 Data quality and completeness

Rangers recorded weather data for 32 of 34 operating seasons between 1972 and 2005 in coherent sets of formal (templated) or informal (handwritten) logs. We ignored one additional season of substantial extant logs (1978) because the logs were not in chronological order. Five additional seasons (1976, 2001, 2004) lacked logs of any sort (though there are other administrative documents for these seasons). Although ranger logs for these missing intermediate seasons or others may well be squirreled away at the park, we did not seek them out and their status does not affect the recommendations of this report.³ The logs span the summer ranger seasons at the monument, roughly June through October (Figure 2.3.2), though the start and end dates vary widely. We did not inventory the sporadic wintertime logs recorded when rangers occasionally skied into the monument during the off-season. We digitized a few representative days from 1977 (Table 2.3.2) to illustrate the incomplete nature of the weather data found in the logs.

Though there is no documentation of the data collection procedure, former DEPO park manager Wymond Eckhardt (1972-1999) provided us some insight on the credibility of ranger-log weather data. He reported that rangers recorded precipitation from a rain gage located on the porch of the superintendent cabin, and temperature from a Taylor brand high/low thermometer attached to the north-facing side of a large lodgepole pine tree just south of the cabin, about 100 feet from the ranger station (Wymond Eckhardt, pers. comm.). Rangers may have gleaned some of their weather data from the RAWs station while it was operating (1993–2004) instead of by direct measurement (Deanna Dulen, pers. comm.; Davey et al. 2007⁴); however, confidence in manual measurement data during the tenure of Mr. Eckhardt is relatively high. The academic background of Eckhardt and his staff, and the high level of interest and supervision Eckhardt conveyed to us, indicate that he likely produced rigorous data. Data collection has recently become much less reliable. For example, during the 2009 season, rangers recorded the National Weather Service’s forecasted daily high and low temperatures for Mammoth Lakes (*not* Devils Postpile) on the daily ranger logs. Furthermore, it is unknown on which days rangers recorded data in this manner.

In general, the quality of weather-related data in these logs is highly variable. As it pertains to scientific analysis of weather, the overall quality of the dataset is poor because the logs are far from complete. Logs span less than half of each calendar year due to winter seasonal closure. Precipitation is rarely recorded as zero; rather, it is left blank, which is not adequate evidence of lack of precipitation. Temperatures are often omitted as well, and no formal documentation describes where or how rangers recorded their weather measurements. Many summer-season periods of the logs are relatively complete and there does seem to be a high level of day-to-day consistency and quality during the tenure of Park Manager Wymond Eckhardt.

3 The only indication that there may be more records was a confusing NatureBib entry, now accessible in NRInfo under Legacy ID 130863. We believe that this entry was submitted in 1997, given the mention of “50 years” of ranger logs and the document date of 1947. The entry does not appear to be an actual publication but rather a documentation of existing weather records—the ranger logs and the RAWs weather station. We have found no evidence that there are, in fact, ranger logs extending back to 1947. If such records are someday found, it may be worth examining the pre-RAWs logs for weather data.

4 This information was recorded on an unpublished form, “Requested Metadata for Inventory,” that is archived as supporting data for the inventory. Appendix G (page 86) of the inventory (Davey et al 2007) lists an incorrect hyperlink; the correct link is http://www.wrcc/dri.edu/nps/pubs/sien/metadata/SIEN_NPS.tar.gz.

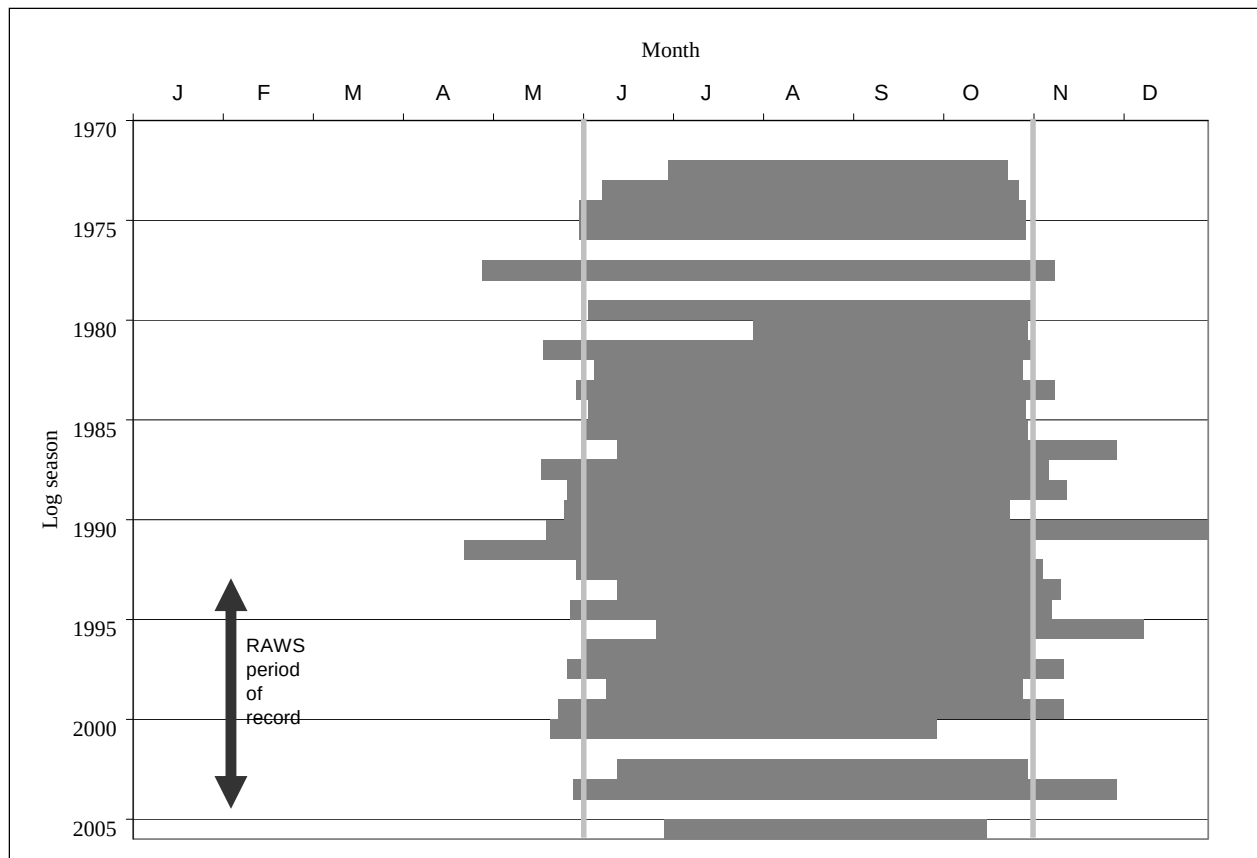


Figure 2.3.2. Daily ranger log timeline, 1972–2005. (Note: Logs for 1978 are not inventoried here)

Table 2.3.2. Example daily ranger log weather observations, June 1977.

Date	Temperature (°F)			Precip (in)	Comments
	High	Low	at Obs Time*		
6/1/1977					
6/2/1977					
6/3/1977	76	35			
6/4/1977	85	41	47		
6/5/1977	87	40			high clouds, overcast, no rain
6/6/1977	76	44			overcast, high clouds, light drizzle during late afternoon and night, no measureable
6/7/1977	71	43			clear skies with scattered clouds
6/8/1977	70	43			overcast with light sprinkles
6/9/1977	48	40		1.95	overcast, drizzles all day, snow in afternoon at 9000 ft level reported by backpackers
6/10/1977	70	36			fairly clear in morning, some scattered clouds later on
6/11/1977	73	32		0	clear and crisp
6/12/1977	76	32			
6/13/1977	72	36			clear skies late morning and afternoon cloud cover, afternoon winds
6/14/1977	77	32	44		clear in morning skies, afternoon winds about 15 mph
6/15/1977	79	36	46		clear skies in morning and afternoon
6/16/1977	76	36	50		clear morning skies
6/17/1977	73	37	41		scattered clouds, wind gusting, cool morning
6/18/1977	76	33	46		clear, afternoon cloudiness
6/19/1977	63	36	47	0.08	clear morning, afternoon thundershowers
6/20/1977	66	35	49	trace	patchy morning clouds, afternoon thundershowers
6/21/1977	86	42	56 (8:30 a.m.)		clear skies AM, scattered clouds 10am, 4pm
6/22/1977	86	42	54		clear skies in morning
6/23/1977	90	44	58		clear morning, few afternoon cumulus clouds
6/24/1977	79	46	59	0.23	clear morning, afternoon thunder showers, 2pm, continued heavy through night
6/25/1977	73	46	52	trace	clear morning, afternoon build up 2pm, light showers 4pm
6/26/1977	78	44	60 (9:00 a.m.)		patchy morning clouds, afternoon cover, but no rain
6/27/1977	76	45	57	trace	clear morning, afternoon thunder, clouds, slight rain in late afternoon
6/28/1977	77	50	60	0.05	clear AM skies, afternoon thunder shower
6/29/1977	72	50	56	trace	high cloud cover in AM, late afternoon showers
6/30/1977	89	43	54		clear skies, afternoon winds

*8:00 a.m. unless otherwise noted

2.4 Other Weather Datasets

A few datasets outside the monument boundary are worth mentioning in this report because of their close proximity to DEPO and/or their long periods of record and, therefore, potential usefulness in assessing local climate variability. Metadata for each of these datasets, including hyperlinks to data, are included in this report (Table 2.4). Using nearby datasets to infer weather status and climate trends in and near DEPO is an objective-specific endeavor. Any such analysis would require selection and exclusion of certain datasets by the analyst based on each station's relevancy to the specified goal(s). The list below is a summary of the options available for such an endeavor.

2.4.1 Mammoth Pass (*LADWP, USBR, decommissioned COOP*)

Two stations are located at Mammoth Pass (2,835 m; 9,300 ft), five kilometers (three miles) south-southeast of and 510 m (1,730 ft) above the Soda Springs Meadows station. The U.S. Bureau of Reclamation (USBR) operates a site with meteorological and snow data (some parameters since 1994).⁵ The City of Los Angeles Department of Water and Power (LADWP) has operated a snow survey site since 1928.⁶ These stations are relevant to DEPO weather because they are some of the closest stations to the monument. Pass observations may closely correlate, historically and currently, with actual weather in DEPO, though this has not yet been formally demonstrated. Differences between these stations and the Soda Springs Meadow station may provide insight on the patterns of cold-air pooling in the Middle Fork valley. The site of a decommissioned Mammoth Pass COOP station (station #045284, 1948–1976) is located near Mammoth Pass.

2.4.2 Agnew Pass (*CDWR*)

The CDWR operates a weather (since 2005) and snow (since 1930) monitoring station at Agnew Pass (2,880 m, 9,450 ft), at the northern head of the Upper Middle Fork San Joaquin watershed, approximately 12 kilometers (7.5 mi) to the north-northwest and 575 m (1,890 feet) above the Soda Springs Meadow station.⁷ The period of record for standard weather parameters is short but relevant because of its location at the headwaters of the Middle Fork watershed and, thus, may be of use in estimating upstream snowpack and snowmelt.

2.4.3 Gem Lake (*decommissioned SCEC*)

The Southern California Edison Company (SCEC) operated a station at Gem Lake from 1924 to 2006.⁸ This station has the longest precipitation record of any nearby, and could serve as an historical proxy for general conditions in the area. There is not enough overlap with the Soda Springs Meadow station to assess similarity, however. Gem Lake is located 15 kilometers (9 mi) north of DEPO, at 2,734 m (8,970 ft), 424 m (1,390 ft) above the Soda Springs Meadow station.

2.4.4 Snow surveys (*DWR, NPS-DEPO*)

The California Cooperative Snow Surveys operate numerous snow monitoring sites in the Sierra Nevada, some with records beginning around 1930, taking monthly measurements each winter.⁹ Although there are no accompanying continuous (year-round) precipitation or temperature records for most of these sites

5 Mammoth Pass (USBR) metadata and data: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=MHP

6 Mammoth Pass (LADWP) metadata and data: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=MAM

7 Agnew Pass (CDWR) metadata and data: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=AGP

8 Gem Lake (SCEC) metadata and data: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=GLK

9 The California Cooperative Snow Surveys, part of the Department of Water Resources (CDWR) <http://cdec.water.ca.gov/snow/>

and periods of record, these data have proven critical to an understanding of local and regional snowpack and climate. We mention snow records only briefly here, but these sites are of significant regional importance. Additional data on nearby stations—Mammoth, Minarets 2, Green Mountain, and others—can be found at the CDEC website.

On January 29, 2010, DEPO staff began conducting snow survey measurements along a transect crossing Soda Springs Meadow, close to the weather station. Staff conduct the surveys following California Cooperative Snow Survey protocols with the intent of comparing manually collected data to the automated data collected at the station's snow pillow (the CDWR instrument measuring snow-water equivalent). The data are stored in DEPO's resource management files, with copies sent to Frank Gehrke (CDWR). DEPO completed monthly snow surveys at Soda Springs Meadow through spring 2010, and may continue in future seasons, qualified staff and funding permitting.

Table 2.4. Metadata for weather stations near Devils Postpile NM with data served through CDEC.

Station Information				
Station name	<u>Agnew Pass</u>	<u>Devil's Postpile</u>	<u>Mammoth Pass (LADWP)</u>	<u>Mammoth Pass (USBR)</u>
Station ID	AGP	DPO	MAM	MHP
Operator	CA Dept of Water Resources	National Park Service (CDWR sensors on Soda Springs Meadow station)	City of Los Angeles Dept of Water and Power	U.S. Bureau of Reclamation
Established (precip)	1995	2006	none	1994
Latitude	37.7244°N	37.6294°N	37.6100°N	37.6100°N
Longitude	119.1430°W	119.0847°W	119.0330°W	119.0330°W
Elevation	9,450'	7,569'	9,300'	9,300'
River basin	San Joaquin R	San Joaquin R	Owens R	Owens R
Hydrologic area	San Joaquin River	San Joaquin River	South Lahontan	South Lahontan
County	Madera	Mono	Mono	Mono
Nearby city	Mammoth Lakes	Mammoth Lakes	Mammoth Lakes	Mammoth Lakes
Data collection	Satellite	Satellite	Satellite	Satellite

Table 2.4. Metadata for weather stations near Devils Postpile NM with data served through CDEC, cont.

Snow Course Information

Station name	Agnew Pass	Devil's Postpile	Mammoth Pass (LADWP)	Mammoth Pass (USBR)
Course num	189		205	
Station ID	AGP		MAM	
Measure agency	Southern California Edison Company, Bishop		City of Los Angeles Dept of Water and Power	
Established	1930		1928	
Measured Month(s)	Feb Mar Apr		Feb Mar Apr May	
April 1 avg.	31.8"		41.9"	
Aspect	Southwest	none	south	none
Exposure	open scattered sage brush		open timber	
Points	10		10	
Wild area	Y		N	
Enable average	Y		Y	
Start year	N/A		N/A	
End year	N/A		N/A	
Abandon	N/A		N/A	

Snow Sensor Information

Station name	Agnew Pass	Devil's Postpile	Mammoth Pass (LADWP)	Mammoth Pass (USBR)
Snow sensor no.	189			205
Station ID	AGP			MHP
Operator	CA Dept of Water Resources			U.S. Bureau of Reclamation
Established	1989			1970
Scheduled Month(s)	Feb Mar Apr May			Feb Mar Apr May
April 1 avg.	32.3"	none	none	42.4"
Aspect	east			south
Exposure	open scattered brush			open timber
Wild area	Y			N
Other sensors	T			TP
Precip gage type	N/A			N/A
Abandon	N/A			N/A

Data collected at these weather station and snow survey sites in and near DEPO are served on the CDEC website (<http://cdec.water.ca.gov>). The station "DPO" is the CDWR's portion of the Soda Springs Meadow weather station. Note that the Operator for DPO is listed as the National Park Service.

2.4.5 Weather data from the Mammoth Mountain Ski Area

The Mammoth Mountain Ski Area (MMSA) and the University of California at Santa Barbara (UCSB), in collaboration with the U.S. Army Cold Regions Research and Engineering Lab (CRREL), collect weather and snowpack data at multiple stations on the flanks of Mammoth Mountain. The MMSA Ski Patrol uses current weather condition data during the ski season; UCSB manages and serves both current and period-of-record data¹⁰. The ski area and its weather stations sprawl across the north and east slopes of Mammoth Mountain, five kilometers (3 mi) east and well above DEPO (Figure 2.4.5, Table 2.4.5).

The U.S. Forest Service collected daily manual measurements at the McCoy/mid-gondola station (2,935 m; 9,630 ft) from 1968 until March 1995. They recorded daily maximum and minimum air temperature, total and new snow depth, and precipitation during the ski season only. The length of the seasons varied significantly from year to year. The MMSA Ski Patrol reports quality concerns in these data that further limit its usefulness as a historical climate record. This data is not available online but is available upon request from the MMSA Ski Patrol.

In the mid 1980s, the U.S. Army and UCSB established an energy balance monitoring station near the McCoy/mid-gondola station called the CRREL UCSB Eastern Sierra (CUES) Snow Study Site. The CUES station received a major overhaul during summer 2009, and there are now more than 30 sensors on the station.

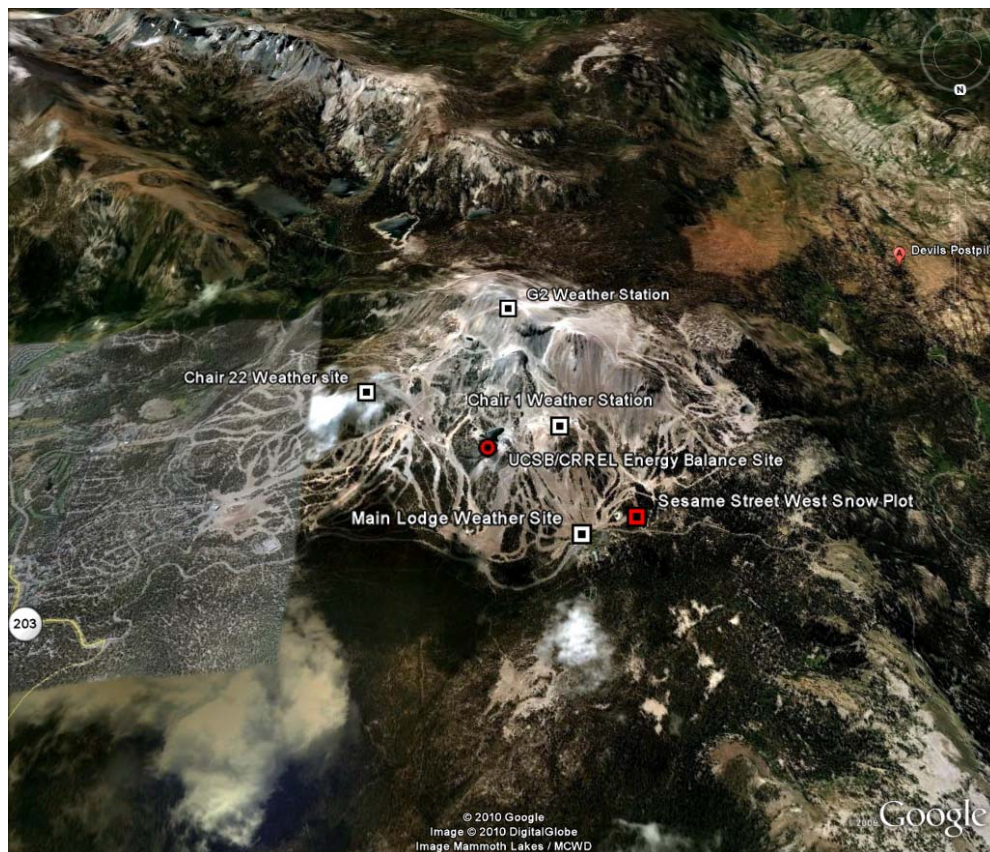


Figure 2.4.5. Weather stations on Mammoth Mountain, California.

10 Mammoth Mountain Ski Area weather data served by UCSB: <http://dub-snow.icess.ucsb.edu/mmsa>

Table 2.4.5. Metadata for weather stations near Devils Postpile NM, operated by Mammoth Mountain Ski Area and partners.

Station name	USFS Mid-Mountain	CUES	SESAME (Sesame Street Snow Study Plot)	BASE	CHAIR_1	CHAIR_22	G2
Location	Approximately 75–100 m south of the current CUES location	Approximately 75–100 m east of gondola mid-station	Slightly north of Main Lodge, off the ski run Sesame Street West	Top of Main Lodge	Top of Chairlift 1	Top of Chairlift 22	Summit of Mammoth Mountain
Operator	USFS	UCSB	Ski Patrol	Ski Patrol	Ski Patrol	Ski Patrol	Ski Patrol
Latitude	near CUES	37.6430	37.6494	37.6505	37.6415	37.6370	37.6302
Longitude	near CUES	-119.0292	-119.0429	-119.0375	-119.0366	-119.0172	-119.0325
Elevation	~9,630'	~9,630'	9,000'	8,900'	9,950'	10,150'	11,053'
Aspect	unknown	SW	NW	N	SW	W	summit
Data collection	Manual observations, and at times automated snow pillow	Real-time automated	Manual observations (1982–present), real-time automated (1999–present)	Manual observations (1982–present), real-time automated (1999–present)	Real-time automated	Real-time automated	Real-time automated
Start year	1968	mid-1980s	1982	1982	1999	1999	1999
End year	1995	present	present	present	present	present	present
Interval	Daily	Varies by sensor	Averaged hourly, minute data (since 2008) available as CSV files	Averaged hourly, minute data (since 2008) available as CSV files	Averaged hourly, minute data (since 2008) available as CSV files	Averaged hourly, minute data (since 2008) available as CSV files	Averaged hourly, minute data (since 2008) available as CSV files
Temperature	min/max	yes	yes	yes	yes	yes	yes
Relative humidity	no	yes	yes	yes	yes	yes	yes
Precipitation	yes	no	yes	no	no	no	no
Snow	Total depth, total new depth	Total depth at 3 locations	Total depth, total new depth	no	no	no	no

Table 2.4.5. Metadata for weather stations near Devils Postpile NM, operated by Mammoth Mountain Ski Area and partners, cont.

Station name	USFS Mid-Mountain	CUES	SESAME (Sesame Street Snow Study Plot)	BASE	CHAIR_1	CHAIR_22	G2
Wind		Speed and direction at ~2 m, ~12 m above the surface	no	Average speed, gust, average direction	Average speed, gust, average direction	Average speed, gust, average direction	Average speed, gust, average direction
Other parameters	none	Soil temp and moisture, multiple radiant flux, solar irradiance, snow melt	none	none	none	none	none
Annual duration	Ski season only	Year-round	Ski season; started limited year-round measurements in 2008	Ski season	Ski season	Ski season	Ski season

Data collected at weather stations and observation sites in the Mammoth Mountain Ski Area, managed by the Mammoth Mountain Ski Patrol and the CRREL UCSB Eastern Sierra (CUES) Study Site collaboration between the University of California at Santa Barbara and the U.S. Army Cold Regions Research and Engineering Lab. Metadata provided by Alex Clayton (MMSA Snow and Avalanche Analyst), current as of January 26, 2010. All data can be queried online (<http://dub-snow.icess.ucsb.edu/mmsa/>) except for the former USFS site, which has no known online data access.

In 1982, the ski patrol began manual collection and management of weather data, during ski season only, at the Sesame Street West site (2,743 m; 9,000 ft). In autumn 1999, it established five automated weather stations: G2 (at Mammoth Mountain Summit), Chair 1, Chair 22, Base (at the Main Lodge), and Sesame Street West (replacing the manual site, which was approximately 75 m farther downhill). These stations range in elevation from 2,441 m (8,900 feet) at the Main Lodge to 3,369 m (11,053 feet) at the summit of Mammoth Mountain, and generally operate only during the winter ski season, though limited summer data became available in 2008. The past day of data for each station is readily available at UCSB's website, where one can also query the full period of record. Qualitative information about weather collection history is also available from the database metadata record.¹¹

Additionally, the MMSA maintains many anemometers along chair lift lines throughout the mountain. The purpose of these anemometers is to slow or halt chair lifts during strong wind gusts. Only some of this data is logged, and it is not particularly relevant to DEPO.

Though located in a different regional watershed, the data from MMSA make for a nearby and higher-elevation analog to data collected at DEPO. In particular, the proximity of MMSA to DEPO, which is similar to Mammoth Pass stations but higher in elevation, makes it valuable for understanding how elevation and topography influence weather and climate near DEPO.

2.4.6 Ongoing microclimate research at DEPO

The only other weather observations known to the authors is a dataset that USGS and Scripps scientists are collaborating with NPS personnel to collect. The purpose of this endeavor is to investigate the presence, magnitude, and extent of cold-air pooling in the Middle Fork valley and determine whether it may create unique temperature constraints affecting plant and animal presence, abundance, or diversity. Anecdotes from employees and visitors, and informal weather data analysis, suggest that DEPO, situated at the valley bottom, exhibits colder temperatures than surrounding areas, including areas much higher in elevation. Jessica Lundquist (University of Washington) and colleagues used a modeling approach to show the potential for cold-air pooling throughout the central Sierra Nevada (Lundquist et al. 2008; Westfall 2009) and Bob Westfall (USFS-PSW) used the same model to show potential for cold-air pooling around DEPO. A USGS investigator (Mike Dettinger) intends to test the model with field data collected by DEPO staff.

The methods include short-term, intensive (in time and space) instrumentation to capture local weather phenomena. In October 2008, 38 self-contained temperature loggers (Onset Tidbits) were deployed in trees at elevation intervals of 50 meters along five east–west transects spanning DEPO and along Minaret Road from DEPO to the Minaret Summit.¹² The loggers recorded temperature every 30 minutes and operated for one year. DEPO purchased 65 additional loggers for a future deployment into the surrounding Inyo National Forest and/or with increased sampling resolution within DEPO. Increased resolution will more precisely define temperature gradient slope and determine diurnal or seasonal variation of this gradient. The scientists involved will report on this short-term research project's results when complete.

11 See the database metadata file for a qualitative historic record of weather-related information at: http://dub-snow.icess.ucsb.edu/mmsa/mdata_mmsp.html

12 Specifications for Onset Tidbits available at: <http://www.onsetcomp.com>

3 Recommendations

3.1 Actions regarding Soda Springs Meadow Station

The Soda Springs Meadow weather station provides real-time online weather data of excellent interpretive value. The installation of this station reestablished continuous weather monitoring in the monument with an expanded range of parameters. Keeping this station active is of high interpretive and natural resource management value for the monument, even in the absence of specific resource management priorities. The park needs a weather dataset of adequate length and quality to permit quantitative assessment of variability in a temporal and regional context and permit correlations with other resource vital signs. Analyzing weather data, along with stream discharge, spring discharge, water quality, soil moisture, plant community, and animal dynamics data, can deepen understanding of these critical resources.

The top priority from the NPS perspective is to ensure consistent and complete collection, rigorous quality checking, and timely public access of basic weather parameters—daily minimum and maximum temperature, daily precipitation and snow water equivalent. Station operators already recognize data completeness and quality of these parameters as a priority. The best support DEPO staff can provide is regular communication with the station operators regarding timely maintenance, careful quality control, and regular archiving (of Scripps data) with the WRCC. Park staff can also continue to provide on-the-ground feedback on the condition of station hardware and report any malfunction to the operators.

While the Scripps data will be rigorously reviewed before transmission to the WRCC, the CDWR data served on CDEC will not. Timely quality review of real-time data served on CDEC is probably not a realistic expectation since such review takes time and expertise and could detract from a major use of the data, which is near-term forecasting. However, the CDWR data uses inconsistent and confusing null value codes, which lead to misleading graphical displays and require careful user attention to process. Working with CDWR and CDEC to make raw data more user-friendly is a reasonable endeavor and one that the monument could help initiate. We also recommend that Scripps and CDWR add more calculated fields to their data access sites (e.g., daily/monthly precipitation sum, monthly average temperature) to increase utility for end users.

Park staff should consider augmenting automatic data collection with co-located manual measurements. This would guarantee continuous data collection and sensor accuracy, at least during the summer season. Such an effort would involve reading daily data from a min/max thermometer, rain bucket, and perhaps a snow-depth staff gage (when applicable) in Soda Springs Meadow. These manual measurements could then be submitted to the operating agencies as verification data. The daily ranger logs could easily accommodate these data. We recommend using standard procedures, such as those published by the National Weather Service's Cooperative Observer Program, as a guide.¹³

As we write this report, the station is gaining more sensors to address specific research questions and interpretive needs. Soil moisture sensors and a webcam may be added soon. As long as the station is measuring basic parameters consistently and accurately, the addition of new sensors can only benefit resource understanding in the monument.

¹³ NWS Cooperative Observer Program: <http://www.weather.gov/om/coop/>

3.2 RAWS station data

The dataset from the decommissioned RAWS station is now a stand-alone dataset that is permanently archived and accessible. The park does not need to take any action regarding this dataset. From a scientific perspective, these data can be used for date-specific research questions.

3.3 Daily ranger logs

The value of the weather information contained within the daily ranger logs lies in its relevance at the time of recording to both staff and visitors and as historical context for other contemporaneous activities. The quality of weather-related data in these logs is variable due to incompleteness at both the day-to-day and seasonal scale. Though relatively high confidence exists in methods for data collected during the tenure of Park Manager Wymond Eckhardt (1972–1999), we cannot assume a standard measurement procedure or location for data outside this period. The recent practice of recording forecasted instead of real data shows that although ranger log data are useful for immediate purposes, these data are not appropriate as a long-term record.

A few simple recommendations will help maintain the integrity and increase the utility of past and future logs. The original logs should remain at the Sequoia National Park Archives to guarantee their preservation; the information they contain is more significant for administrative than daily-weather records. Regular transfer of current and future logs to the archives should occur annually after copies are made for the monument's files. A trained archivist should review the logs to assess what management and administrative history purposes they might serve. Finally, we do not see a need to digitize the weather data in the logs at this time. If there were a particular day(s) of interest to which some qualitative measure of weather would be relevant (e.g., the date of a significant natural phenomenon, such a flood, or weather-related visitor incident), there would be use for small chunks of these data. The full dataset will not augment the long-term climate record; hence, our recommendation.

The ranger-log weather data may well develop significant value in the future. If manual measurements dating to before the RAWS station are uncovered, DEPO staff should revisit the above recommendations. Should the monument determine that digitization would be valuable, we suggest that the digitization process include the following steps. First, all of the extant weather data should be entered, including affirmative documentation of days within the period of record when rangers did not record data, followed by independent verification. Second, the digital data should be permanently archived at the WRCC. Third, the entire process—digitization, data quality issues, what the data can and cannot be used for, permanent archiving—should be formally reported in a published document.

3.4 Combining data from the Soda Springs Meadow weather station with other datasets

In certain situations, when data collection at two or more different stations is conducted in a documented manner with overlapping time series, one may be able to generate a quantitative transfer function permitting the estimation of one dataset from another, thereby extending the continuous record of one station by appending an adjusted version of a nearby station. For instance, if the daily maximum air temperature was statistically determined to be an average of two degrees warmer at the RAWS than at the Meadow station with little deviation, one could subtract two degrees from all maximum temperatures taken at the RAWS during its entire period of record and append them to the Meadow data for analysis purposes. Such a transfer function would enable the extension of the local weather record and thus be of great benefit because DEPO has only small, fragmented weather datasets.

Unfortunately, statistical transformation between the Soda Springs Meadow and RAWS stations is not a practical endeavor because the periods of record do not overlap. The RAWS and logs data overlap, but

the logs were partially taken from reported RAWS data, confounding a comparison. The logs are also significantly incomplete, invalidating the extrapolation of any quantitative comparison to the entire period of record. The Meadow station, therefore, is even more vital to the monument as the only local operating source of weather data; the other two datasets exist as solitary, independent datasets of reduced value. One possibility for record extension might be to correlate the Meadow station data with a long-standing station located outside the San Joaquin Valley. We will leave consideration of this possibility to a climatologist.

3.5 Microclimate research

The USGS, Scripps, and NPS project underway to document and analyze microclimate temperature patterns in the monument should yield detailed information (M. Dettinger, in progress). This project has the potential to inform interpretation and resource management at DEPO, and may provide a significant advance in scientific understanding of cold-air pooling in general. This information may be useful for downscaling global or regional circulation models and for determining the connection, if any, between small-scale temperature patterns and species presence, abundance, or diversity.

3.6 Hydrological monitoring

Although this report deals primarily with atmospheric weather data, discharge patterns in the San Joaquin River are inextricably tied to weather in the Middle Fork watershed. Historical river stage data are available in fisheries reports by Deinstadt and others (1995) and Rowan and others (1996), and in the supporting documentation and field notes for these reports. Scripps has collected stage measurements upstream of the meadow since the weather station's installation in 2005. During the fall of 2009, the USGS installed a stream gaging station on the Middle Fork. The monument intends to find funding to establish a discharge rating curve by a USGS hydrologist. This would be the single best use of limited time and effort toward monitoring the hydrology and riparian ecology of the San Joaquin River and corridor, a stated Fundamental Resource and Value (NPS 2009a).

3.7 Conclusion

Continued collection of high-quality weather data at DEPO supports three of the eight Fundamental Resources and Values identified in the monument's GMP process: (1) Upper Middle Fork of the San Joaquin River and Corridor; (2) Component of Larger Ecosystem; and (3) Opportunities for Science and Learning (NPS 2009a).

3.7.1 Upper Middle Fork of the San Joaquin River and corridor

Continued weather monitoring provides information about climate drivers that influence the critical surface water and groundwater resources at DEPO, and the biological communities that depend on them. The functioning and resilience of water-dependent features and communities at DEPO are closely tied to local and regional climate and water dynamics.

3.7.2 Component of larger ecosystem

Weather monitoring at the Soda Springs Meadow weather station, used in conjunction with additional local long- and short-term monitoring efforts, can provide spatial and temporal hydroclimatic inference for the entire Middle Fork of the San Joaquin watershed. Climate is also an important determinant of the three bioregions that converge at DEPO. Continued weather monitoring provides insight into this regional intersection.

3.7.3 Opportunities for science and learning

The existence of a highly visible weather station and online real-time weather data present excellent opportunities for interpretation of weather, climate, climate change, snowpack, streamflow, and other focal topics for the monument's visitors and neighboring communities.

DEPO is fortunate to have an engaged, collaborative community of weather/climate and hydrology scientists working for its benefit. DEPO is a small NPS unit, and depends upon outside collaboration to achieve its management goals. The monument will benefit from maintaining these relationships as long as they directly support park management priorities. Active participation in these relationships involves facilitating frequent communication among the parties, prompt maintenance of instruments and related equipment, regular Scripps data transfer to the WRCC, and periodic analysis and reporting. The creation of a specific plan for data analysis as a complement to or component of the SIEN weather and climate monitoring protocol would help define the direct application of weather data to resource issues, identify knowledge gaps, and steer research toward the most useful avenues. As the GMP process progresses, the network of scientific partners already in place will enhance DEPO's ability to clearly define its resource concerns, effectively map a route to sustainable management, and grapple with the challenges of climate change.

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Appendix A: Installation and Sensor Array, Soda Springs Meadow Weather Station

This appendix details the August 2005 installation of a weather station at Soda Springs Meadow in Devils Postpile National Monument, California. Below is a list of the agencies involved (Table A.1), a summary of the installation process, a description of the two separate sensor arrays, and tables listing sensor specifications. This information was collected from notes and documents produced at the time of installation. Equipment added to the station in the years since installation is documented with the operating agencies, but not in this report.

A.1 Agencies

Interagency collaboration between the SIEN, Scripps, USGS, CDWR Cooperative Snow Surveys Program, and DEPO made this installation possible (Table A.1). Scripps, the USGS, and CDWR, with partial support from a grant from the NPS, provided the funding for the equipment.

Table A.1. Contributors to the Soda Springs Meadow weather station.

Name	Title	Organization	Role
Frank Gehrke	California Snow Survey Coordinator	DWR	Planning, equipment purchasing, coordination with NPS, installation, maintenance, data management
Colin Leslie	Maintenance worker	DEPO	Installation
Deanna Dulen	Superintendent	DEPO	Planning, equipment purchasing, coordination with Scripps and DWR
John Fernandes	Maintenance Mechanic	DEPO	Installation
Melissa Rosenberg	Student Conservation Association Intern	DEPO	Installation
Pete Lundberg	Park Ranger	DEPO	Installation
Dan Cayan	Climate Researcher	Scripps	Planning, coordination with NPS and DWR
Douglas Alden	Senior Development Engineer	Scripps	Planning, equipment purchasing, coordination with NPS, installation, maintenance, data management
Spencer Kawamoto	Assistant Development Engineer	Scripps	Logger firmware and sensor interfacing, logger/sensor maintenance, data processing
Linda Mutch	Network Coordinator	SIEN	Planning, equipment purchasing, coordination with Scripps and DWR, installation
Andi Heard	Physical Scientist	SIEN	Planning, equipment purchasing, coordination with Scripps and DWR, installation
Annie Esperanza	Air Quality Specialist	SEKI	Planning, environmental compliance, installation
Hassan Basagic	Physical Science Technician	SEKI, SIEN	Equipment purchasing, installation
Mike Dettinger	Climate Researcher	USGS	Planning, equipment purchasing, installation of snow temp sensors

A.2 Installation

The staff listed in Table A.1 installed the station on August 17, 2005. The sensor tower is a 10-m high steel structure. The base of the tower extends four feet below ground, encased by a 4' × 4' × 4' cement footing. The station is located south of a stand of lodgepole pine trees (*Pinus contorta* var. *murrayana*) approximately 40 m south of the ranger station. Logistical advantages of this location include electrical power service directly from the ranger station, maintenance accessibility, and the presence of National Park Rangers to discourage vandalism.

A.2.1 Equipment maintained by Scripps

A DL4-Met Environmental data logger collects basic weather parameters every minute, including humidity, barometric pressure, solar radiation, soil moisture, and two air temperature measurements at different heights. Soil temperature, fuel moisture, and fuel temperature are measured hourly, and precipitation events are measured with a heated rain gauge. All data are recorded on flash memory and are periodically manually downloaded during maintenance trips by Scripps staff. The logger transmits a subset of the internally recorded data every half-hour via RS-232 serial cable to a computer in the ranger

station. Each transmission consists of six frames of data filled at five-minute intervals during the previous half hour.

Approximately 100 m north of the ranger station, a DL4-GP data logger records stage and water temperature of the San Joaquin River every 30 minutes. The DL4-GP transmits data via a DigiXStream RF modem to the computer in the ranger station, which maintains and uploads data from both loggers to a server located at Scripps every hour. A cellular router installed on the weather station tower provides internet connectivity.

Data are stored on a server at Scripps. The most recent 30 days of transmitted data are available on the Scripps Hydroclimate Weather Observation Program website (<http://hcn.ucsd.edu>). The online interface allows users to display current and past weather data in the form of 3-day, 7-day, and 30-day graphs. Users may also download the past seven days of data in tabular format. The direct address for the DEPO data is: http://meteora.ucsd.edu/weather/observations/sio_other/sites/stn_32.html.

Table A-2: Specifications of Soda Springs Meadow weather station sensors installed by the Scripps Institution of Oceanography.

DL1 Sensors (August 2005 to June 2007)

Precipitation

Sensor	TR-525USW Rain Gauge and Tipping Bucket Specifications:
Reference	http://www.campbellsci.com/te525ws-l
Temperature	0° to +50°C
Resolution	1 tip
Rainfall per tip	Rainfall per tip: 0.01" (0.254 mm)
Orifice diameter	8" (20.3 cm)
Height	10.5" (26.7 cm)
Weight	2.5 lbs. (1.1 kg)
Accuracy	
up to 1 in/hr	± 1%
up to 2 in/hr	+ 0, -2.5%
up to 3 in/hr	+ 0, -3.5%

Temperature

Sensor	YSI 44018 Thermistor with Resistor Set 44303
Reference	http://www.ysitemperature.com/
Max. operating temp.	105°C
Accuracy	± 0.15°C
Time constant max. (Time to indicate 63% of new Temp.)	10s
Dissipation constant, min.(Power to raise 1°C above surroundings)	1mW/°C
Storage temperature	-80°C to 105°C
Resistance vs. temperature	-30°C to 50°C

Temperature

Sensor	ThermX YPT8-3.5-33T-20-SX
Reference	http://www.thermx.com/
Sheath diameter	0.188 in
Sheath length	3.5 in
Sheath material	316SS Tubing, Max. 200°C
Circuit type	3 Wire Single
Leadwire insulation	Teflon ®
Leadwire length	20 ft

Table A-2: Specifications of Soda Springs Meadow Weather Station Sensors installed by the Scripps Institution of Oceanography, cont.

Termination	2 in Split Leads
Humidity	
Sensor	Sensirion Humidity Sensor SHT75
Reference	http://www.sensirion.com/
Packaging	4-pin Single in line/ for 1.27 mm sockets
Measurement range	0 – 100% Relative Humidity (RH)
Absolute RH accuracy	± 1.8% RH (20...80% RH)
Repeatability RH	± 0.1% RH
Temp. accuracy	± 0.3°C (at 25°C)
Response time	< 4 sec
Operating temperature	-20°C – 100°C
Typical power	20µW
Supply voltage	2.4-5.5V
Pressure	
Sensor	Intersema Barometer Module MS5534A
Reference	http://www.intersema.ch/
Absolute pressure range	300 – 1100 mbar
Operating temperature	-10 - 60°C
Packaging	Silicon, 3-wire interface for 15 bit ADC, RoHS compatible
Calibration	Six coefficients for software calibration
Supply voltage	2.2 – 3.6 V
Standby current	3.1µA
Conversion current	1mA
Master clock	32.768 kHz
Radiation	
Sensor	LI-Cor Pyranometer LI-200
Reference	http://www.licor.com/env/Products/Sensors/200/li200_description.jsp
Calibration	Calibrated against an Eppley Precision Spectral Pyranometer (PSP) under natural daylight conditions.
Calibration Error	Typical error under these conditions is ± 5%.
Sensitivity	Typically 90 µA per 1000 W m ⁻² .
Linearity	Maximum deviation of 1% up to 3000 W m ⁻² .
Stability	< ± 2% change over a 1 year period.
Response time	10 µs.
Temperature dependence	0.15% per °C maximum.
Cosine correction	Cosine corrected up to 80° angle of incidence.
Azimuth	< ± 1% error over 360° at 45° elevation.

Table A-2: Specifications of Soda Springs Meadow Weather Station Sensors installed by the Scripps Institution of Oceanography, cont.

Tilt	No error induced from orientation.
Operating temperature	- 40 to 65 °C.
Relative humidity	0 to 100%.
Detector	High stability silicon photovoltaic detector (blue enhanced).
Sensor housing	Weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware.
Size	2.38 Dia. x 2.54 cm H (0.94" x 1.0").
Weight	28 g (1 oz).
Cable length	3.0 m (10 ft).

DL4-GP Sensors (June 2007 to present)

River Stage (height of water) and Water Temperature

Sensor	Solinst 3001 Levellogger
Reference	http://www.solinst.com/
Materials	316 Stainless Steel
Battery life	8-10 years
Clock accuracy	Better than 1sec/day
Operating temp.	-20°C – 80°C
Communication	RS232 (optical infrared)
Max No. of readings	2x24,000 linear; 2x19,000 event or log
Measurement range	0.5 sec to 99hrs; 19hr, 116hr, 228 day log event-based
Level sensor	Ceramic transducer
Accuracy	0.1%FS (-10°C – 40°C)
Resolution	0.01ft/.3cm
Temperature sensor	Spreading resistance silicon
Accuracy	0.1°C
Resolution	0.01°C

Soil Moisture

Sensor	Decagon ECH20
Reference	ECH2O-TE/EC-TM Probe Operator's Manual
Dimensions	10cm (l) x 3.2cm (w) x 0.7cm (d)
Prong Length	5.2cm
Power Requirement	3-15VDC, 0.3mA quiescent, 10 mA for 9 ms measurement
Dielectric measurement freq	70 MHz
Volumetric water content	
Range	0-100%VWC
Resolution	
Mineral	Soil: 0.1% VWC

Table A-2: Specifications of Soda Springs Meadow Weather Station Sensors installed by the Scripps Institution of Oceanography, cont.

Accuracy	
Mineral	Soil: $\pm 3\%$ VWC, up to 8 dS/m ($\pm 1\text{-}2\%$ with soil specific calibration)
<i>Temperature</i>	
Range	-40° to $+50^{\circ}\text{C}$
Resolution	0.1°C
Accuracy	$\pm 1^{\circ}\text{C}$
<i>Electrical Conductivity</i>	
Range	0 to 50 dS/m (Bulk)
Resolution	0.01 dS/m from 0 to 10 dS/m
Accuracy	$\pm 10\%$ 0 to 6 dS /m (bulk)
Fuel Moisture	
Sensor	CS505-L Fuel Moisture Specifications:
Reference	http://www.campbellsci.com/cs505-l
Operating Range	0 to 70% moisture content
Fuel Moisture Accuracy	
range	worst case
0 to 10%	$\pm 2\%$
10 to 20%	$\pm 3\%$
20 to 30%	$\pm 5\%$
30 to 40%	$\pm 8\%$
40 to 70%	$\pm 12\%$ (est)
Power	9 to 18VDC
Enable Voltage	1.3 to 20 VDC
Current Use	70mA active; 10uA quiescent
Output Signal	$\pm 2.5\text{Vdc}$ square wave with an output frequency of 600 to 1500 Hz
Weight	0.4 lbs plus 0.4lbs per 10ft length of cable
Dimensions	7.1cm x 10.9cm x 2.3 cm
Fuel Temperature	
Sensor	CS205 10-Hour Fuel Temperature Stick Specifications:
Reference	http://www.campbellsci.com/documents/product-brochures/b_cs505.pdf
Material	Ponderosa Pine
Length	11.4 cm
Diameter	1.3 cm
Weight	9.07 g
Accuracy	$\pm 0.15^{\circ}\text{C}$
Resistance vs. temperature	-30°C to 50°C

Note that Scripps deployed the DL1-Met array from August 2005 to June 2007, then deployed the DL4-Met array from June 2007 to present.

A.2.2 Equipment maintained by CDWR

The California Snow Surveys group uses a Vaisala 555C Data Collection Platform to log data. The Vaisala 555C collects data on humidity, pressure, temperature, soil moisture, precipitation, short-wave solar radiation, net radiation, snow depth, and snow water content. The rain gauge and the radiation, humidity, and temperature sensors are mounted 6 m above the ground. The wind sensor is mounted 10 m above ground. Snow pillows are shallowly buried approximately 10 m from the tower.

The Vaisala 555C samples radiation every 10 seconds, wind every 2 seconds, and snow depth, snow water content, humidity, and air temperature every hour. Precipitation is logged according to accumulation. The Vaisala 555C internally logs the data and transmits data hourly to a GOES satellite operated by the National Oceanic and Atmospheric Administration. The California Data Exchange Center (CDEC) receives and ingests the satellite data and provides a public internet interface with basic graphing and download functions: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=DPO.

Table A-3: Specifications of Soda Springs Meadow weather station sensors installed by the California Department of Water Resources.

Vaisala 555C Sensors (maintained by California Department of Water Resources)

Temperature and Humidity

Sensor	RH/AT Sensor HMP45DUS
Sensor	Humidity Sensor : HUMICAP 180
Sensor	Temperature Sensor: Pt 1000 IEC 751
Reference	http://www.vaisala.com/
Housing	ABS plastic
Power	<4mA
Supply voltage	7-35 VDC
Settling time	500ms
RH range	.8 to 100% RH
RH output scale	0...100%RH equals 0...1VDC
RH accuracy at +20°C	± 2%
RH temp. dependence	± .05 % RH/°C
AT range	-39.2°C...60°C
AT output scale	-40...60°C equals 0...1VDC
AT accuracy at +20°C	± .2°C

Wind

Sensor	Vaisala heated Ultrasonic Wind Sensor WS425:
Reference	http://www.vaisala.com/
Material	Stainless steel (AISI 316) w/ silicon rubber transducers
Operating power	10...15 VDC, 12 mA
Operating temperature	-40...55°C
Max reading rate	1 per/sec
Wind speed	
Measurement range	0...65 m/s
Resolution	0.1 m/s
Accuracy	± 0.135 m/s or 3%
Wind Direction	
Measurement Range	0...360°
Resolution	1°
Accuracy	± 2°

Table A-3: Specifications of Soda Springs Meadow Weather Station Sensors installed by the California Department of Water Resources, cont.

Precipitation

Sensor	Vaisala Heated Precipitation Sensor RG13H
Reference	http://www.vaisala.com/
Material	Aluminum alloy
Diameter of aperture	400 cm ²
Rainfall capacity	Unlimited
Sensativity	.2mm
Dimensions	390 300 mm
Heater	38 W / 40 VAC
Thermostat operation	Open at 11°C, closed at 4°C

Soil Moisture (no soil moisture data is available online)

Sensor	Vaisala Soil Moisture Sensor 438B
Reference	http://www.vaisala.com/
Sensor Element	Concentric electrodes in porous matrix
Operating Temperature	-55 to 65°C
Element Output Impedence	.5 to 30 Kohms
Amplifier Output	0 to 5 V
Power	9 to 25 V, 6ma nominal
Size	.8inDX1.1inL

Pressure

Sensor	Vaisala Barometric Pressure Sensor 555A/C/D 557152
Reference	http://www.vaisala.com/
Pressure sensor	Ceramic Capacitor
Measurement range	600mb – 1100mb
Analog signal	Linear response; 0.000...5.000 V DC
Accuracy	± .05%
Power	24 VDC, supplied by switched circuit SW1

Radiation

Sensor	LICOR Pryanometer LI-200
Reference	http://www.licor.com/env/Products/Sensors/200/li200_description.jsp
Calibration	Calibrated against an Eppley Precision Spectral Pyranometer (PSP) under natural daylight conditions.
Calibration Error	Typical error under these conditions is ± 5%.
Sensitivity	Typically 90 µA per 1000 W m-2.

Table A-3: Specifications of Soda Springs Meadow Weather Station Sensors installed by the California Department of Water Resources, cont.

Linearity	Maximum deviation of 1% up to 3000 W m ⁻² .
Stability	< ± 2% change over a 1 year period.
Response time	10 µs.
Temperature dependence	.15% per °C maximum.
Cosine correction	Cosine corrected up to 80° angle of incidence.
Azimuth	< ± 1% error over 360° at 45° elevation.
Tilt	No error induced from orientation.
Operating temperature	- 40 to 65 °C.
Relative humidity	0 to 100%.
Detector	High stability silicon photovoltaic detector (blue enhanced).
Sensor housing	Weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware.
Size	2.38 Dia. x 2.54 cm H (0.94" x 1.0").
Weight	28 g (1 oz).
Cable length	3.0 m (10 ft).

Radiation

Sensor	LICOR Quantum Sensor LI-190
Reference	http://www.licor.com/env/Products/Sensors/190/li190_description.jsp
Absolute Calibration	± 5% traceable to the National Institute of Standards and Technology (NIST)
Sensitivity	Typical 5µA per 1000 µmol s ⁻¹ m ⁻² .
Linearity	Maximum deviation of 1% up to 10,000 µmol s ⁻¹ m ⁻² .
Stability	< ± 2% change over a 1 year period.
Response time	10µs.
Temperature dependence	.15% per °C maximum.
Cosine correction	Cosine corrected up to 80° angle of incidence.
Azimuth	< ± 1% error over 360° at 45° elevation.
Tilt	No error induced from orientation.
Operating temperature	- 40 to 65 °C.
Relative humidity	0 to 100%.
Detector	High stability silicon photovoltaic detector (blue enhanced).
Sensor housing	Weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware.
Size	2.38 Dia. x 2.54 cm H (0.94" x 1.0").

Table A-3: Specifications of Soda Springs Meadow Weather Station Sensors installed by the California Department of Water Resources, cont.

Weight	28g (1 oz).
Cable length	3.0 m (10 ft).
Snow Pillows	
Material	Stainless steel filled with 50 gal total; 83/17 denatured ethyl alcohol and propylene glycol
Dimensions	4 ft x 5ft x 1/2"
Snow Pillows	
Sensor	Pressure Transducer GE PMP 317-8693
Reference	http://www.gesensing.com/products/resources/datasheets/pdsa118jan02.pdf
Material	Stainless steel 316L and Hastelloy C276
Measurement range	68mbar – 6200 mbar
Accuracy	± .15%
Operating temperature	-54°C-120°C
Excitation Voltage	7-30 VDC

Appendix B: Description of the Remote Automated Weather Station (RAWS) Network

Adapted from Appendix G, Section 11, SIEN Weather and Climate Inventory Report (Davey et al. 2007).

Purpose of network: RAWS provides near-real-time (hourly or near-hourly) measurements of meteorological variables for use in fire weather forecasts and climatology. RAWS data are also used for natural resource management, flood forecasting, natural hazard management, and air quality monitoring. The RAWS network was one of the first automated weather station networks to be installed in the United States. There are approximately 1,100 real-time sites in this network and about 1,800 historic sites (some were decommissioned or moved).

- Primary network management agency: National Interagency Fire Center
- Individual station operation agencies: NPS, USFS (in the case of DEPO's station), BLM, FWS, BIA, and others
- Primary data management agency: Western Regional Climate Center
- Data website: <http://www.raws.dri.edu/>
- Measured weather parameters:
 - air temperature
 - precipitation
 - relative humidity
 - wind speed
 - wind direction
 - wind maximum gust speed
 - wind gust direction
 - solar radiation
 - soil temperature
 - soil moisture
- Sampling frequency: 1 or 10 minutes, element-dependent
- Reporting frequency: usually hourly, some stations report every 15 or 30 minutes
- Estimated station cost: \$1,200 annually with satellite telemetry (\$8,000 without satellite telemetry); maintenance costs are around \$2,000 annually
- Network strengths:
 - metadata records are usually complete
 - sites are located in remote areas
 - sites are generally well-maintained
 - entire period of record available online (at least daily data; contact WRCC for entire hourly dataset)
- Network weaknesses:
 - focused largely on fire management needs (formerly focused only on fire needs)
 - some stations are not in ideal locations for climatology purposes
 - frozen precipitation is not measured reliably because automated precipitation gages do not have heaters
 - station operation is not always continuous
 - data transmission is completed via one-way telemetry; data are therefore recoverable either in real-time or not at all

Appendix C: Photos of the Met Station Installation

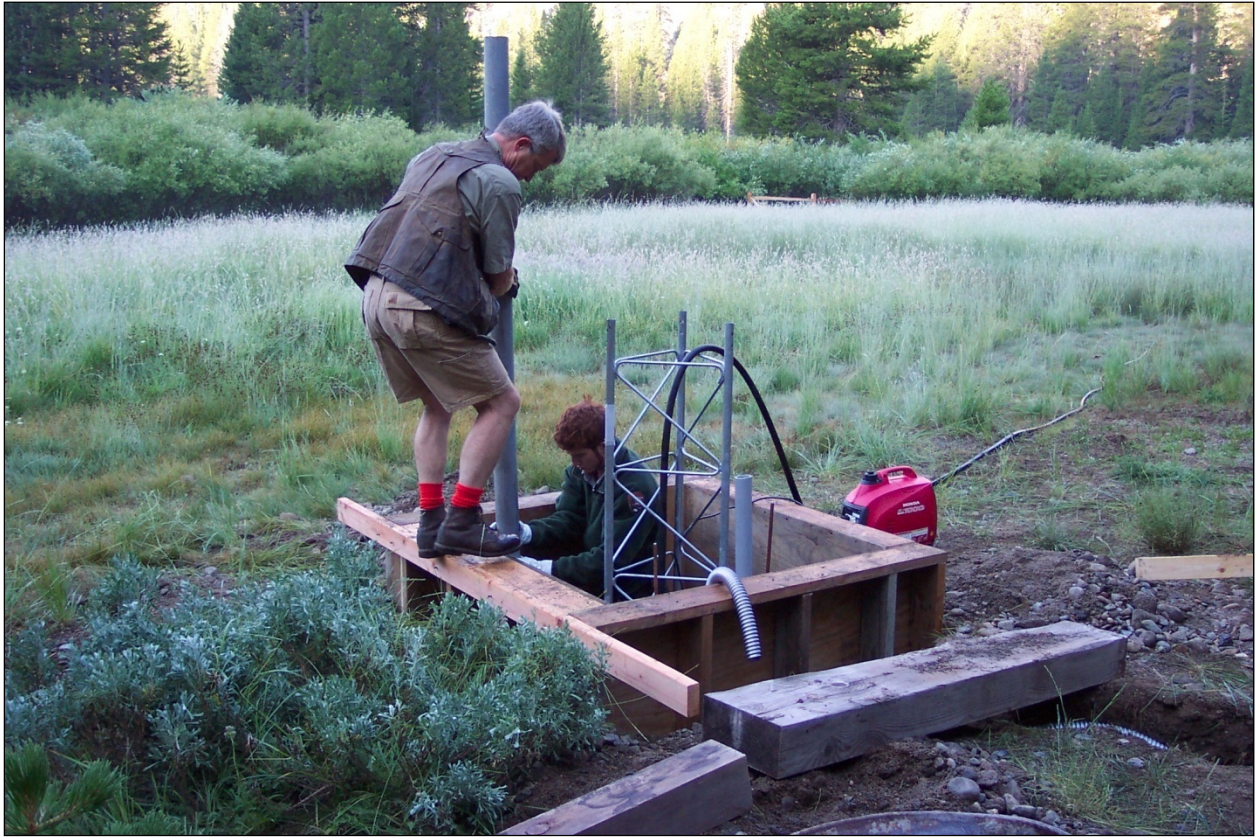


Figure C-1. Frank Gehrke (left) and Colin Leslie (right) securing the foundation for the Soda Springs weather station, Devils Postpile NM. 17 August 2005.



Figure C-2. DEPO staff carting concrete for the footing of the Soda Springs weather station, Devils Postpile NM. Note the travel boards used to reduce impact to the surrounding area. 17 August 2005



Figure C-3. DEPO maintenance worker Colin Leslie pours one of the dozens of loads of concrete needed to create the footing for the Soda Springs weather station, Devils Postpile NM. 17 August 2005



Figure C-4. Deanna Dulen, Dan Cayan, and Hassan Basagic standing next to the snow pillows at the DEPO weather station. 31 August 2005.



Figure C-5. Frank Gehrke putting the final touches on the snow pillows at the Soda Springs weather Station, Devils Postpile NM. Note the minimal amount of instrumentation on the tower. 28 September 2008.

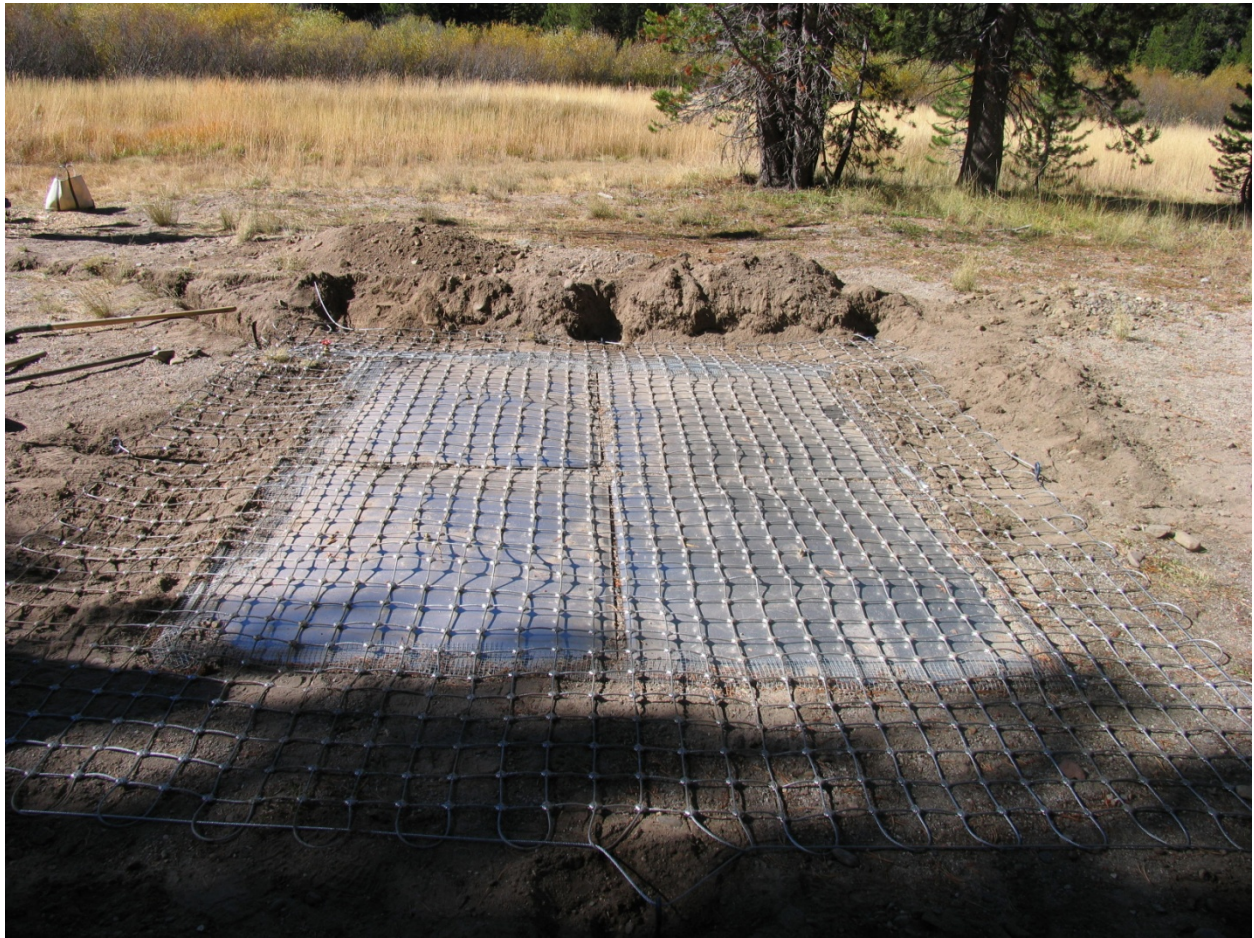


Figure C-6. Wire mesh was secured over the snow pillows to discourage bears or other large animals from tearing into the pillows. 29 September 2005.



Figure C-7. Frank Gehrke installing additional instrumentation to the Soda Springs weather station, Devils Postpile NM. 31 September 2005.

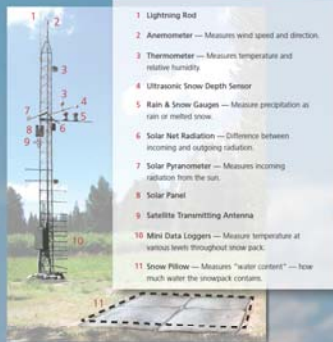


Why Measure Weather and Water?

Understanding our climate is more important than ever. Climate change and increasing demand for water affect us all. We need more information about regional climate and global warming to plan for the future. To better understand the Sierra Nevada's climate and local effects of global warming, several partners worked together to create this climate monitoring station: Scripps Institution of Oceanography, National Park Service, U.S. Geological Survey, California Department of Water Resources, and California Energy Commission.

Watering a Thirsty State

Much of California's water begins as snow falling in these mountains. During winter, snow builds up to form a snowpack. When this melts it fills streams, nourishes the forest and provides water for farms and cities downstream. Years of low snowpack, and therefore less water, contribute to stressful conditions for plants, animals and people.



Measuring Weather and Water

This fully automated weather station takes several different measurements every hour and transmits them to a data collection center. Weather information is available online at www.nps.gov/depo

- 1 Lightning Rod
- 2 Anemometer — Measures wind speed and direction.
- 3 Thermometer — Measures temperature and relative humidity.
- 4 Ultrasonic Snow Depth Sensor
- 5 Rain & Snow Gauges — Measure precipitation as rain or melted snow.
- 6 Solar Net Radiation — Difference between incoming and outgoing radiation.
- 7 Solar Pyranometer — Measures incoming radiation from the sun.
- 8 Solar Panel
- 9 Satellite Transmitting Antenna
- 10 Mini Data Loggers — Measure temperature at various levels throughout snow pack.
- 11 Snow Pillow — Measures "water content" — how much water the snowpack contains.

From Snow to Water

Air temperature, wind, humidity and, most importantly, the sun's energy determine how quickly snow melts. Measuring these factors helps to predict when snow will turn to water, forecast flood potential, and manage reservoir levels.

All Snow is not Created Equal

"Water content" tells how much water is in the snow. Water content varies with each storm depending on where the storm comes from. For example, many snow storms in the Sierra Nevada originate in moist air over the Pacific Ocean. Snow from these storms holds more water than storms from the drier air over interior Canada. Measuring snow water content helps to predict how much water it will yield as it melts.

Instruments on this station monitor long-term climate trends.

Scientists use this information to detect changes in climate that are affecting snowpack, wildlife, vegetation and fire patterns at Devils Postpile.

Climate Change in the Sierra Nevada

Global warming is affecting snow levels in the Sierra Nevada. Snow levels are rising and snowmelt starts earlier, leaving less water for late summer and fall.



Air is colder at high altitudes. The higher the altitude, the more likely it is to snow than to rain. High, cold mountains store the snowpack until spring's warmer temperatures start to melt it.



Global warming causes warmer temperatures at all altitudes. As a result, in the mountains, rain falls rather than snow. Snowpack builds up only at higher elevations.

Illustrations by Justin McManis

Figure C-8. This interpretive panel explains the purpose of the Soda Springs weather station. This panel was put on display in 2007, at the start of the Devils Postpile trail where visitors can view the station from the trail.



Figure C-9. This interpretive panel explains the location of the Soda Springs weather station. This panel was put on display in 2007, along the Devils Postpile trail where visitors can view the station from the trail.

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

NPS 120/106124, November 2010

National Park Service
U.S. Department of the Interior



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