Meteorological Data for Water Years 1988–94 from Five Weather Stations at Yucca Mountain, Nevada

by Alan L. Flint and William J. Davies

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CONVERSION FACTORS

Multiply	By	To obtain
millimeter (mm)	0.03937	inch
meter (m)	3.28	foot
watt (w)	3.412	BTU per hour
joule	9.48×10^{-4}	BTU, British thermal unit
kilometer (km)	0.6214	mile (mi)
square kilometer (km^2)	0.3861	square mile (mi^2)
watts (w/m^2) per square meter	0.319	BTU per square foot per hour
megaJoules per square meter (MJ/m^2)	1141.77	BTU per square foot
kilopascal (kPa)	0.145	pound-force per square inch

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

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Abstract

This report describes meteorological data collected from five weather stations at Yucca Mountain, Nevada, from as early as April 1987 through September 1994. The measurements include solar radiation, temperature, relative humidity, wind speed, wind vector magnitude, wind direction, wind vector direction, barometric pressure, and precipitation. Measurements were made every 10 seconds and averaged every 15 minutes. The data were collected as part of the geologic and hydrologic site-characterization studies of Yucca Mountain, a potential repository for high-level radioactive waste.

Precipitation at the site ranged from a low of 12 millimeters total for water year 1989 to a high of 312 millimeters total for water year 1993. Air temperature ranged from a low of 15.1 degrees Celsius in December 1990 (water year 1991) to a high of 41.9 degrees Celsius in July 1989 (water year 1989). The weather station network also provides information on the spatial variability of precipitation and temperature.

INTRODUCTION

Yucca Mountain, Nevada, is being evaluated as a potential site for the storage of high-level radioactive waste in a geologic repository (U.S. Department of Energy, 1988). As part of this study, the U.S. Geological Survey (USGS) is collecting meteorological data. Meteorological data are needed to help characterize present net infiltration rates and to develop models for predicting changes in infiltration rates in response to potential changes in climate and surface characteristics. The data from this study are intended to support studies of precipitation, infiltration, and evapotranspiration to help characterize the surface-water budget for Yucca Mountain. The purpose of this report is to describe the data collected since 1987, for water year 1988. A water year is the continuous 12-month period that begins October 1 and ends September 30, designated by the calendar year in which it ends.

Study Area Description

Yucca Mountain, Nevada, is a north-south-trending block-faulted ridge located within the southern part of the Basin and Range physiographic province and within the northern part of the Mojave Desert. It is located in the rain shadow of the Sierra Nevada and is considered one of the driest locations in the United States. The Mojave Desert is classified as a warm desert, receiving most of its precipitation as rain. There are two distinctly different storm patterns affecting the desert climate in this area, one in winter, the other in summer. Winter precipitation tends to be of low intensity and long duration (days) and covers large areas. In contrast, most summer rains result from convective thunderstorms of high intensity and short duration (hours) that cover less than 2–3 km^2. Less than 48 km to the north is the southern boundary of the Great Basin Desert, a cold desert. Conditions may arise that allow winter storms to move south from the Great Basin Desert toward the study area, bringing snow and cold temperatures in the winter. Because the study area is near the boundary of two distinctly different desert systems, meteorological conditions may vary considerably. The area of interest in this study is the potential repository and surrounding area encompassed by the weather stations shown in figure 1.

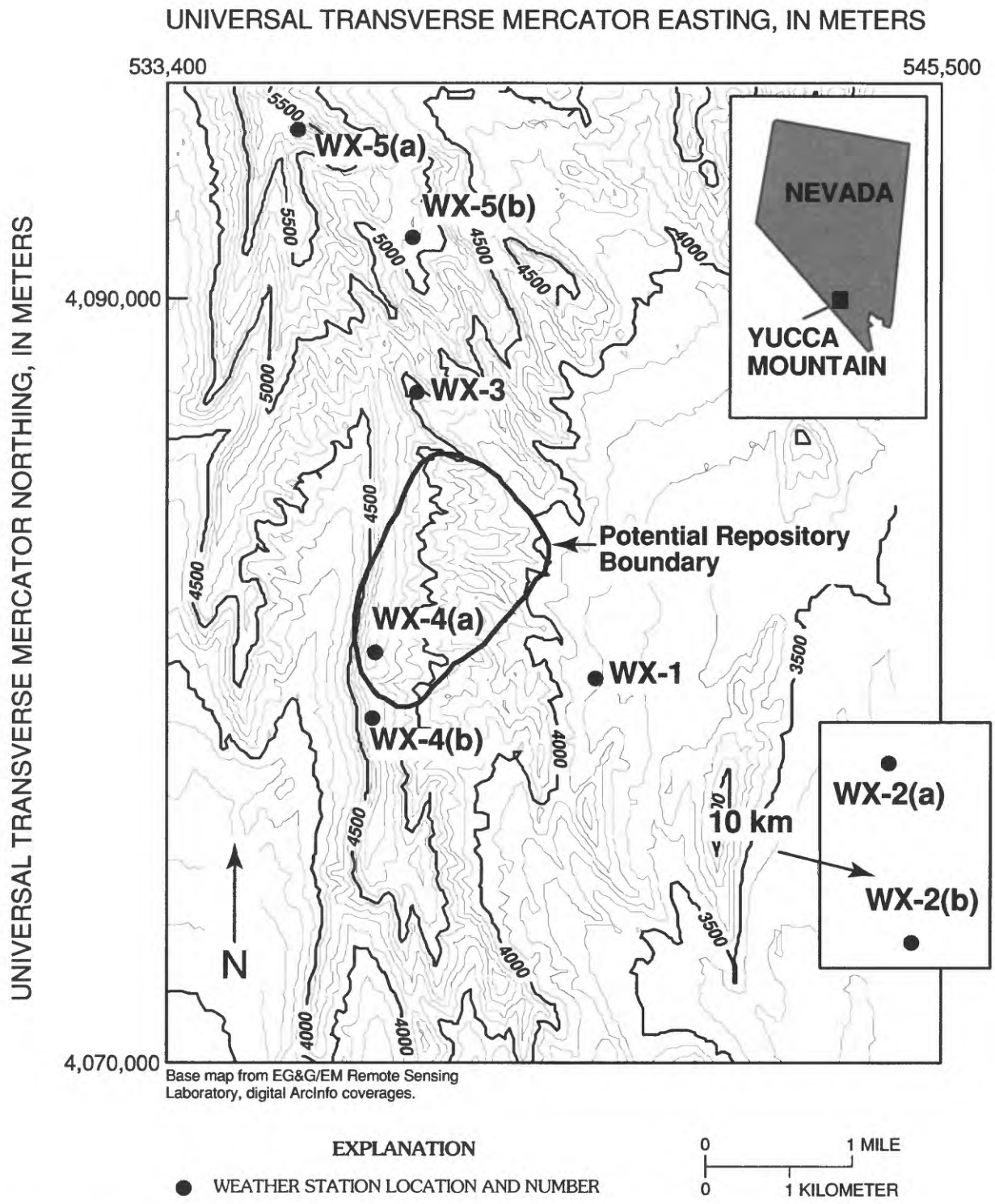

Figure 1. Locations of eight weather station sites at Yucca Mountain, Nevada.

Instrumentation

Two weather stations were installed in early 1983 and 1984 to monitor environmental conditions during drilling activities. In 1987, these two weather stations were rebuilt at the same location with new instruments, and two additional weather stations were added to the network (table 1). In 1988, a final weather station was added. The weather station instrumentation was chosen for two purposes: (1) To provide local information on solar radiation, temperature, relative humidity, wind speed, wind direction, barometric pressure, and precipitation; and (2) to provide the minimal information necessary to make estimates of potential and actual evapotranspiration using the Penman equation or the Priestley-Taylor equation (Monteith and Unsworth, 1990; Flint and Childs, 1991).

All instruments for each weather station were attached to a tripod except for the tipping-bucket rain gage. The rain gage was located on the ground away from, but within 5 m of the station to minimize wind effects around the weather station. A data logger was used to sample the sensors every 10 seconds and to average the measurements every 15 minutes. The tipping-bucket rain gage was event-driven with the counter checked every 10 seconds. If tips occurred, then the time of the tip was recorded (to within 10 seconds). During high-intensity precipitation events, multiple tips could be recorded. The manufacturer, model, and accuracy for each instrument is given in table 2 (barometric pressure was recorded only at weather station WX-3). In addition to the 15-minute data, a daily record was generated. The daily record consists of total solar radiation data, minimum and maximum air temperature and relative-humidity data, and the time of collection of minimum and maximum air temperature and relative-humidity data. These data were derived from the data collected every 10 seconds. Although the weather station numbers remained the same, they were sometimes relocated from one site to another during the study.

METEOROLOGICAL DATA

The data are presented in four types of files and are available as ASCII files from the USGS (Denver) repository site on the Internet. These data are available online (via anonymous ftp) at **ympbsrv1.cr.usgs.gov** or from the Chief, Earth Science Investigations Program. A daily file consists of the ninety-six 15-minute records of time (Pacific standard time), temperature (°C), relative humidity (percent), solar radiation (w/m^2), wind speed (m/s), wind vector magnitude (m/s), wind direction (azimuthal degrees) or wind vector (azimuthal degrees), and barometric pressure (kPa). The daily files are designated as WX#_DOY.0YR, where WX# is the weather station number, DOY is the three-digit day of year (001–366), and YR is the last two digits of the calendar year.

Prior to mid-January 1990, the wind direction was recorded as the average of ninety 10-second readings. After mid-January, wind vector direction was calculated instead. The wind vector direction is the wind direction linearly weighted by the wind speed. The higher the wind speed over a 10-second reading, the more weight given to the wind direction. When the wind speed is zero, the wind direction is not counted. The wind vector magnitude is the average magnitude of the wind speed for that wind vector direction. To keep the data files as consistent as possible, a column was created for wind vector magnitude for all daily data files. A -99 appears in that column if the data were not yet collected. (Note: -99 is used to denote missing or bad data in all cases). When the weather station program was changed to collect wind vector magnitude and wind vector direction, the data in the wind direction column changes to wind vector direction. An example of a daily-data file is presented in table 3.

The temperature and relative-humidity sensor was placed in an R.M. Young self-aspirated radiation shield at 2 m above land surface. The relative-humidity data tended to drift over the 1-year field life; at low humidities (<50 percent), the measured relative humidity was insensitive to small changes in humidity. When the calibration data differed between pre-installation and post-installation, a linear drift was assumed and the data were corrected. Data were not adjusted for insensitivity. Insensitivity to small changes can be seen in the daily data files as slowly changing relative humidity at low humidities. The overall trend of humidity appears to be correct when compared with the other weather stations.

Barometric pressure was collected only at weather station WX-3. The horizontal variability barometric pressure probably is small over the study area, but the effects of differences in elevation should be accounted for. For 2 weeks (days 241–254, 1987),

Table 1. Location, elevation, and date of coverage for each weather station

[Weather stations WX-1, WX-2, WX-4, and WX-5 were moved during the time of data collection and are indicated by (a) for first location and (b) for second location; Northing and Easting are in Universal Transverse Mercator (NAD 27) coordinates]

	Locations (Universal Transverse Mercator[1])				
Weather station ID	Northing (meters)	Easting (meters)	Elevation (meters)	Beginning date	Ending date
WX-1	4,076,521	550,424	1,163	01/01/88	09/30/94
WX-2(a)	4,075,931	564,332	1,154	04/18/87	03/07/89
WX-2(b)	4,071,986	563,430	1,055	03/07/89	09/30/94
WX-3	4,080,316	548,038	1,351	07/16/87	09/30/94
WX-4(a)	4,076,856	547,504	1,498	07/01/87	06/08/90
WX-4(b)	4,075,990	547,481	1,489	06/08/90	09/30/94
WX-5(a)	4,083,775	546,453	1,789	06/23/88	10/04/93
WX-5(b)	4,082,370	547,984	1,563	10/04/93	09/30/94

[1]Nevada State Coordinates are used to identify location of weather stations cited in this report. These coordinates are for the central zone of Nevada and are based on a Transverse Mercator projection. The origin of this projection for the central zone of Nevada is latitude 34°45' N., and the central meridian is at longitude 116°40' W. The coordinates listed in this report are in meters north of the baseline and in meters east of the central meridian.

Table 2. Instrumentation used for each weather station

[°C, Celsius; m/s, meters per second; kPa, kilopascals; N/A, not applicable]

Instrument	Manufacturer	Model	Manufacturers' stated accuracy[1]
Pyranometer	Li-Cor	LI-200SZ	5 percent
Temperature	Campbell Scientific	207	0.4°C
Relative humidity	Campbell Scientific	207	5 percent
Wind speed	Met-One	024A	0.11 m/s
Wind direction	Met-One	014A	5 degrees
Rain gage	Sierra Misco	2501	2 percent
Barometric pressure	Setra	270	0.02 kPa
Data logger	Campbell Scientific	21X	N/A

[1]The actual accuracies may vary depending on each individual instrument calibration. The values reported here are for reference only. Actual instrument calibration data can be requested from the Chief, Earth Science Investigations Program, U.S. Geological Survey, Box 25046, MS-421, Denver, CO 80225).

Table 3. Daily meteorological data from weather station WX-3 for June 21, 1994

[Time of day in Pacific standard time; °C, degrees Celsius; w/m^2, watts per square meter; m/s, meters per second; deg, degrees; kPa, kilopascals]

Time of day	Air temperature (°C)	Relative humidity (percent)	Solar radiation (w/m^2)	Mean wind speed (m/s)	Mean wind vector magnitude (m/s)	Wind vector direction (azimuthal deg)	Barometric pressure (kPa)
0015	21.0	27	0	2.2	2.1	319	86.654
0030	20.9	28	0	2.1	2.0	311	86.647
0045	21.0	29	0	1.7	1.4	302	86.650
0100	20.6	29	0	1.9	1.8	313	86.652
0115	20.6	29	0	1.8	1.7	309	86.657
0130	20.5	30	0	2.0	2.0	305	86.654
0145	20.6	30	0	1.8	1.8	308	86.650
0200	20.7	30	0	1.7	1.3	330	86.651
0215	20.5	31	0	1.7	1.5	313	86.650
0230	20.2	32	0	1.9	1.8	309	86.650
0245	19.8	33	0	1.9	1.8	321	86.650
0300	20.1	33	0	2.0	1.9	318	86.645
0315	20.1	33	0	1.6	1.5	305	86.653
0330	20.3	33	0	1.8	1.7	307	86.653
0345	20.1	34	0	1.7	1.7	313	86.659
0400	19.7	35	0	2.1	2.1	314	86.663
0415	19.4	36	0	2.1	2.0	317	86.667
0430	19.2	37	1	2.1	2.0	321	86.676
0445	19.0	38	4	2.1	2.0	306	86.680
0500	19.0	39	8	2.2	2.2	321	86.685
0515	19.1	39	16	1.9	1.8	317	86.692
0530	19.5	39	34	1.8	1.8	308	86.702
0545	20.2	38	61	1.4	1.3	296	86.700
0600	21.4	37	83	1.1	1.0	337	86.705
0615	22.3	36	73	0.7	0.3	339	86.721
0630	23.0	35	64	1.5	1.5	114	86.731
0645	23.5	35	236	1.3	1.3	115	86.733
0700	25.5	33	396	2.3	2.2	133	86.735
0715	26.3	32	448	2.5	2.4	126	86.751
0730	26.8	31	504	2.0	1.9	125	86.759
0745	27.6	29	570	1.9	1.6	138	86.755
0800	28.1	29	554	2.2	2.0	140	86.752
0815	28.1	28	615	2.6	2.4	136	86.753
0830	28.2	27	595	2.4	2.2	114	86.755
0845	28.4	26	775	2.5	2.2	112	86.751
0900	28.6	26	817	3.9	3.6	139	86.749

Table 3. Daily meteorological data from weather station WX-3 for June 21, 1994—Continued

[Time of day in Pacific standard time; °C, degrees Celsius; w/m^2, watts per square meter; m/s, meters per second; deg, degrees; kPa, kilopascals]

Time of day	Air temperature (°C)	Relative humidity (percent)	Solar radiation (w/m^2)	Mean wind speed (m/s)	Mean wind vector magnitude (m/s)	Wind vector direction (azimuthal deg)	Barometric pressure (kPa)
0915	28.9	25	838	2.9	2.6	119	86.753
0930	29.2	24	859	3.3	2.9	127	86.756
0945	29.5	23	885	3.9	3.8	134	86.755
1000	29.6	19	917	4.1	3.8	132	86.757
1015	29.9	18	939	4.0	3.7	125	86.748
1030	30.3	17	965	4.1	3.8	129	86.750
1045	30.6	17	984	2.9	2.5	121	86.747
1100	30.8	15	999	3.4	3.0	127	86.742
1115	30.8	13	1013	4.2	3.9	124	86.735
1130	31.2	12	1022	4.3	4.2	129	86.725
1145	31.6	12	1026	3.5	3.2	123	86.709
1200	31.9	12	1027	4.1	3.8	132	86.695
1215	32.2	11	1028	3.7	3.3	127	86.686.
1230	32.5	11	1022	4.3	3.9	124	86.669
1245	32.9	11	1016	3.1	2.6	122	86.661
1300	33.1	11	1002	3.7	2.5	109	86.648
1315	33.2	11	987	4.1	3.5	121	86.629
1330	33.1	11	970	2.6	0.8	132	86.625
1345	33.0	11	947	4.1	3.1	100	86.614
1400	33.1	10	916	2.6	1.4	139	86.599
1415	33.5	10	885	3.7	2.7	103	86.5.69
1430	33.5	10	851	2.8	1.8	107	86.557
1445	34.0	10	817	3.5	2.9	114	86.539
1500	33.6	10	780	3.2	2.3	104	86.529
1515	33.6	10	736	4.3	3.1	89	86.513
1530	33.3	10	697	3.0	2.2	122	86.500
1545	33.9	10	654	3.5	1.8	87	86.4.94
1600	33.9	10	606	2.9	1.7	100	86.4.82
1615	33.5	10	556	3.9	2.7	78	86.4.69
1630	33.1	10	506	3.1	2.4	56	86.4.58
1645	33.3	9	454	3.4	2.5	80	86.4.54
1700	33.3	9	401	3.2	1.8	48	86.4.55
1715	32.9	10	345	3.1	1.6	71	86.4.53
1730	32.5	10	96	2.7	1.9	11	86.4.50
1745	31.1	10	24	2.2	1.7	14	86.4.47
1800	30.5	10	22	2.0	1.1	47	86.4.41

Table 3. Daily meteorological data from weather station WX-3 for June 21, 1994—Continued

[Time of day in Pacific standard time; °C, degrees Celsius; w/m^2, watts per square meter; m/s, meters per second; deg, degrees; kPa, kilopascals]

Time of day	Air temperature (°C)	Relative humidity (percent)	Solar radiation (w/m^2)	Mean wind speed (m/s)	Mean wind vector magnitude (m/s)	Wind vector direction (azimuthal deg)	Barometric pressure (kPa)
1815	30.4	11	19	2.0	1.6	14	86.4.45
1830	30.0	11	16	1.5	0.8	61	86.4.50
1845	29.7	11	12	1.6	1.3	119	86.4.45
1900	29.1	11	8	1.1	0.5	158	86.4.49
1915	27.2	12	4	1.7	1.6	309	86.4.56
1930	25.5	12	1	2.4	2.4	310	86.4.65
1945	25.0	13	0	2.3	2.2	320	86.4.82
2000	24.9	13	0	2.4	2.4	305	86.4.93
2015	24.9	13	0	2.0	1.9	307	86.505
2030	25.0	13	0	2.0	2.0	304	86.527
2045	24.7	13	0	2.2	2.2	304	86.544
2100	24.5	13	0	2.2	2.2	309	86.553
2115	24.0	13	0	2.4	2.3	311	86.560
2130	23.6	14	0	2.4	2.4	309	86.566
2145	23.2	14	0	2.4	2.3	311	86.574
2200	23.0	14	0	2.6	2.5	311	86.580
2215	23.0	14	0	2.4	2.4	310	86.583
2230	22.6	15	0	2.4	2.4	312	86.589
2245	22.6	15	0	2.4	2.4	305	86.589
2300	22.4	15	0	2.4	2.4	304	86.590
2315	22.3	15	0	2.2	2.2	309	86.587
2330	22.3	15	0	2.1	2.1	309	86.590
2345	22.0	15	0	2.2	2.1	302	86.590
2400	22.2	15	0	2.3	2.3	296	86.592

the sensitivity of the data logger was improperly set, and small changes in pressure were not recorded, which can be seen in the daily data files.

The rain gage was a 1-mm-resolution tipping bucket. The high-volume bucket makes the gage insensitive to small amounts of precipitation (<1 mm) but considerably reduces errors due to high-intensity storms. The data are available as yearly files designated as WX#_PPT.0YR, where WX# is the weather station number and YR is the last two digits of the calendar year.

A yearly weather-station file is also available. These files are designated was WX#_DAY.0YR, where WX# is the weather station number and YR is the last two digits of the calendar year. The data consist of day of year, solar radiation (MJ/m^2), maximum temperature (°C), mean temperature (°C), minimum temperature (°C), maximum relative humidity (percent), mean relative humidity (percent), minimum relative humidity (percent), maximum wind speed (m/s), mean wind speed (m/s), minimum wind speed (m/s), and total daily precipitation (mm). The data were based on the 15-minute averages. If data were missing for any part of the day, then -99 appears. In addition to the three types of data files, there is also a header file, WX#_HDR.0YR, which provides information needed to identify the columns in each type of data file.

Two data summaries are presented. One summarizes the spatial distribution of selected properties; the other summarizes the yearly distribution at one location. The spatial variability of temperature in any one month is generally small (table 4), whereas the month-to-month variability is considerably higher (tables 4 and 6). The temporal variability of precipitation is high relative to the spatial variability (table 5). Precipitation in water year 1992 ranged from 160 mm to 279 mm, due in large part to localized summer precipitation and elevation effects during winter precipitation (Hevesi and others, 1992a,b; Hevesi, J.A., Ambos, D.S. and Flint, A.L., U.S. Geological Survey, written commun., 1996; Ambos and others, 1995). Annual precipitation at weather station WX-3 ranged from 12 mm in water year 1989, to 312 mm in water year 1993 (table 7).

The period of record for data in this report includes May 3, 1989, the date on which the USGS began working under an approved quality-assurance program. Data collected before that date were rigorously collected and are scientifically valid but should not be assumed to be supportable for purposes for which the approved quality-assurance program is mandatory.

Table 4. Maximum and minimum monthly air temperature for five weather stations for water year 1992

[Max, maximum air temperature; Min, minimum air temperature]

Weather station		Air temperature (degrees Celsius)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
WX-1	Max	34.0	27.6	18.9	20.3	21.7	21.7	31.1	32.5	37.4	38.5	39.7	34.8
	Min	-1.6	-2.3	-3.2	-2.8	-0.8	3.8	5.9	9.4	7.9	13.2	14.6	13.5
WX-2	Max	34.7	27.6	18.4	20.5	22.9	23.1	32.4	33.5	38.3	39.9	41.1	35.9
	Min	-2.3	-5.3	-8.0	-3.5	-1.6	0.8	4.4	9.0	6.6	10.9	11.0	13.3
WX-3	Max	32.8	25.9	17.8	18.4	21.1	20.7	29.4	30.7	36.0	37.8	38.4	33.9
	Min	-2.7	-4.1	-4.7	-3.2	-1.9	2.0	2.7	8.4	7.2	11.6	13.7	12.7
WX-4	Max	31.3	25.2	16.0	16.9	19.5	19.4	29.3	31.1	37.4	38.0	38.4	33.5
	Min	-2.8	-5.1	-6.2	-3.0	-1.9	1.4	6.0	10.5	7.7	12.0	15.8	11.6
WX-5	Max	29.2	22.5	14.0	14.8	17.4	17.8	26.5	26.1	31.1	33.8	35.8	30.6
	Min	-4.3	-7.7	-7.9	-6.5	-4.6	-0.1	3.8	7.8	8.8	9.7	13.9	13.0

Table 5. Total monthly precipitation for five weather stations for water year 1992

[--, missing data]

Weather station	Precipitation (millimeters)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
WX-1	2	0	28	37	81	76	0	4	0	0	2	0
WX-2	4	3	19	24	50	59	0	1	0	0	0	0
WX-3	2	0	22	36	102	88	0	4	0	3	0	18
WX-4	0	0	18	29	79	86	0	3	0	28	35	1
WX-5	--	0	21	38	109	81	1	--	0	25	--	0

Table 6. Maximum and minimum monthly air temperature for weather station WX-3 for water years 1988–94

[Max, maximum air temperature; Min, minimum air temperature]

Weather station		Air temperature (degrees Celsius)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1988	Max	34.2	20.2	14.7	16.7	21.1	26.1	27.1	31.8	37.1	41.4	36.9	37.4
	Min	6.5	-2.7	-8.2	-9.1	-3.7	-2.3	1.9	0.0	4.4	15.9	15.2	8.2
1989	Max	32.0	25.9	21.5	20.0	23.5	24.1	32.5	33.3	37.6	41.9	37.9	33.6
	Min	12.0	-2.2	-14.2	-8.2	-14.3	-5.5	-0.8	2.2	14.5	16.7	14.5	7.2
1990	Max	30.8	25.7	22.8	20.9	22.6	26.4	29.5	30.8	39.0	39.5	39.5	35.3
	Min	-2.4	-2.7	-4.6	-5.0	-8.8	-4.0	3.8	7.2	8.0	15.8	12.3	12.7
1991	Max	28.5	25.4	18.0	16.5	21.7	18.0	24.5	29.6	36.1	40.2	36.0	35.9
	Min	4.5	-6.1	-15.1	-6.2	-1.8	-3.3	-1.5	0.1	8.8	16.4	12.9	9.4
1992	Max	32.8	25.9	17.8	18.4	21.1	20.7	29.4	30.7	36.0	37.8	38.4	33.9
	Min	-2.7	-4.1	-4.7	-3.2	-1.9	2.0	2.7	8.4	7.2	11.6	13.7	12.7
1993	Max	31.7	22.7	15.5	16.7	15.6	23.6	28.0	29.7	37.3	38.3	40.8	38.1
	Min	5.8	-4.6	-7.1	-9.6	-3.4	-2.7	1.8	7.3	3.7	13.7	13.1	8.7
1994	Max	33.6	23.2	16.6	22.5	17.7	25.5	19.8	33.0	40.3	38.5	38.5	33.9
	Min	5.8	-6.1	-3.5	-4.2	-6.0	-1.3	-0.9	1.8	10.8	17.2	17.2	7.8

Table 7. Total monthly precipitation values for weather station WX-3 for water years 1988–94

Weather station	Precipitation (millimeters)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1988	25	40	22	5	14	1	50	13	0	3	9	12
1989	0	1	2	1	8	0	0	0	0	0	0	0
1990	0	0	0	12	3	2	8	12	0	4	13	9
1991	0	3	0	3	24	61	0	14	2	0	18	7
1992	2	0	22	36	102	88	0	4	0	3	0	18
1993	17	0	76	79	83	25	1	0	22	0	7	2
1994	10	11	10	14	27	21	19	11	0	1	0	4

SUMMARY

Meteorological data were collected from five weather stations on and around Yucca Mountain, Nevada, from April 1987 through September 1994. The measurements include solar radiation, temperature, relative humidity, wind speed, wind vector magnitude, wind direction, wind vector direction, barometric pressure, and precipitation. The range of air temperature and precipitation was presented to indicate the differences between water years at a single location and between weather station locations for a single year.

Precipitation at one site (WX-3) ranged from a low of 12 mm in water year 1989 to a high of 312 mm in water year 1993. At the same location, air temperature ranged from a low of -15.1°C in December 1990 (water year 1991) to a high of 41.9°C in July 1989 (water year 1989). The weather station network also provides information on spatial variability of meteorological conditions over the site.

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