CALIFORNIA GEOGRAPHICAL SOCIETY
Vol. XXXIV, 1994

PRECIPITATION DISTRIBUTION IN YOSEMITE NATIONAL PARK: A TWENTY-YEAR LOOK

Donald L. Morgan
William F. Slusser

Editor's Note: *Foremost among the stated goals of this journal is the diffusion of geographical knowledge, but equally important is the commitment to education. The following paper meets both of these goals. Not only does it provide basic information relating to the physical geography of one of the more remote parts of the state, but it also illustrates the dedication geographical practitioners have demonstrated over the years in the pursuit of basic knowledge. In an era when we depend more and more on weather data from sensors orbiting the earth, and earth-bound sensors are frequently totally automated and even report via satellite or radio link, it is well to remind ourselves of what was involved in collecting the basic data we so blithely utilize, even as recently as the period covered in this paper.*

In the fall of 1967 the Atmospheric Water Resources Research (AWRR)—Fresno State College directed by Merlin C. Williams applied for use permits for the installation of three 4.6-meter (15-foot) fiberglass precipitation storage gages in the Yosemite National Park and for one gage in the Inyo National Forest. These gages were to collect data to be used as a part of a weather modification research project in the Central Sierra Nevada sponsored by the U.S. Department of the Interior.

Donald Morgan is Emeritus Professor of Geography at California State University, Fresno.
William Slusser is the Instructional Technician in the Department of Geography, California State University, Fresno.

The use permits were granted on October 13, 1967 for the Yosemite sites and on October 27, 1967 for the Inyo location. Installation followed and data were gathered beginning with the summer of 1968. For five years the research study moved forward with the installation of a variety of weather equipment, the hiring of a dozen meteorologists and many technicians. In 1973 the priorities of the government shifted and the AWRR along with many other Weather modification projects being sponsored by the Department of the Interior were closed down.

With the closing of the AWRR personnel were scattered, the data lost and the equipment for the most part was absorbed into other ongoing projects. It was at this time that the Department of Geography was asked if it would like to take over the four precipitation gages. In 1973 William Slusser and Donald Morgan began servicing these gages and collecting the annual precipitation data.

Data

The locations of these gages were set up to be in a southwest to northeast transect across the higher elevations of the park. Each of these sites was selected keeping in mind protection from the public, representative exposure, and accessibility (Figure 1).

The most southwesterly site is at the northeast end of Tenaya Lake at an elevation of 2,480 meters (8,136 feet) MSL. This site is in an open stand of Lodgepole pine. The second site is at Gaylor Creek with an elevation of 2,804 meters (9,200 feet). This site is on the north edge of a small meadow. The third site is about 0.16 kilometers (one tenth mile) up the hill to the west of the entrance station at Tioga Pass on a narrow grassy bench among a stand of Lodgepole pine. The site is at 3,042 meters (9,980 feet) elevation. The fourth site is about one half kilometer (one third mile) north of the north end of Saddleback Lake in an open stand of Lodgepole pine at an elevation of 3,090 meters (10,140 feet).

The precipitation storage gages are made of fiberglass molded into a cylinder 4.6 meters tall and about a one third meter in diameter narrowing near the top to a standard 20.5-centimeter (8-inch) diameter orifice. There is a valve at the bottom of the cylindric gage mounted on the side which is used to empty the catch. There is also a bung about one meter above the bottom of the gage mounted on the side through which a charge of antifreeze and oil is put into the gage upon servicing. On the side of the gage is a vertical translucent strip "window" running upwards about three meters. Imbedded into this fiberglass window is a tape measure scale to aid in reading the depth of the catch. The units on

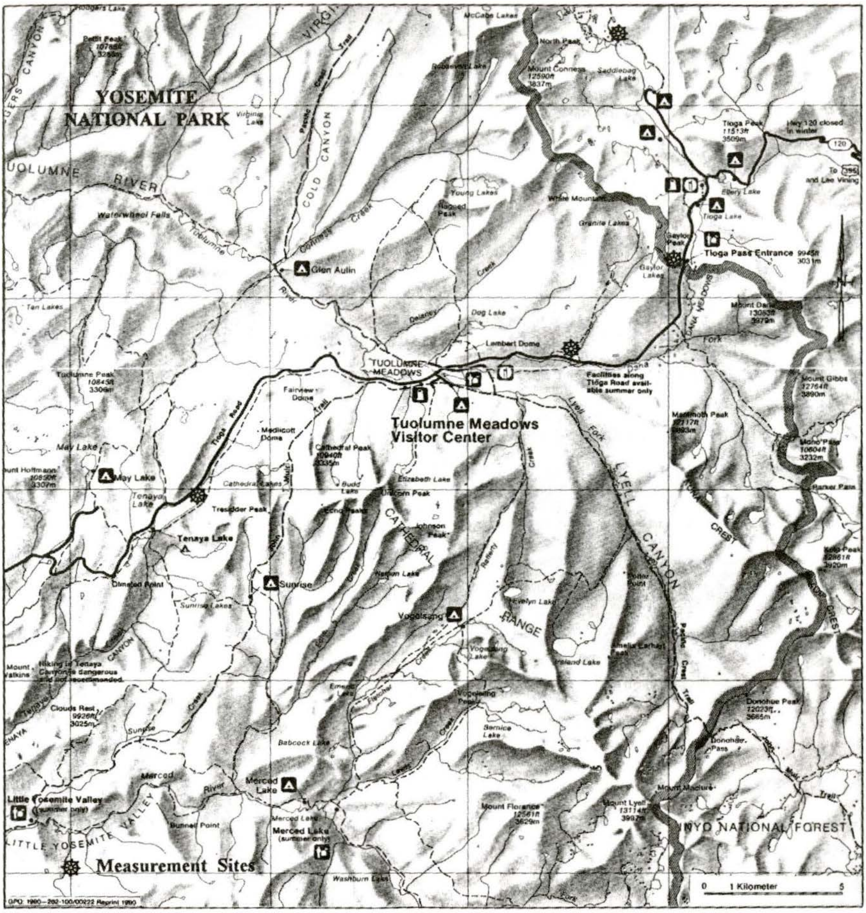

Figure 1. Precipitation gage locations
in Yosemite National Park

this scale are in inches. Each of these gages is equipped with a U.S. National Weather Service wind shield, which is designed to shelter the orifice catchment area of the gage against wind eddied insuring a representative catch.

To determine the gage catch the following procedure is used. The depth is measured by reading the top of the fluid in the gage through the side window or by climbing to the gage top and using a 5-meter dipstick. These are referred to as "depth" readings. When the initial charge depth is subtracted from the current depth reading and this difference is multiplied by 1.44 it will give the catch in inches of precipitation.

Next the gage content is drained through the bottom valve one bucket at a time with each bucket being weighed before emptying it. The sum of these weights minus the weight of the initial charge multiplied by 0.64 will give the catch in inches. This measure is referred to as a "weight" derived reading.

Finally, the gage is recharged with several gallons of antifreeze, to prevent splitting of the gage by the freezing of its contents, and a quart of motor oil, to prevent evaporation of its catch. The weight of the recharge contents is noted as is the depth so that upon the next reading these can be accounted for.

In comparing the "depth" derived readings with the "weight" derived readings it was found that generally they are within less than 4% of each other with the weight reading being the smaller. This is most likely due to the difficulty of emptying and weighting the gage contents without loss by spillage.

Analysis

Table 1 lists the twenty years of annual precipitation data for each of the four sites described above with the mean and standard deviation for each site indicated at the bottom of its respective column.

The 1972 season (precipitation year) begins in July of 1972 and ends in June 1973. The same pattern is true for the other 19 seasons with the last season representing the July 1991 through June 1992 precipitation year. A note in the data column indicates missing or unreliable data due to gage leakage or wind shield slippage down the gage exposing the orifice to wind eddies. In the case of the first three seasons for the Saddleback Lake site a three year total catch of 344.6 centimeters (134.4 inches) was reported, which if entered into the data set would have made the statistics invalid.

The data used in this table are depth derived values in centimeters of water equivalent snow melt or rainfall. The mean and standard deviation values at the bottom of each column were calculated using a QuatroPro computer program.

Upon examining the mean values for these sites it would appear that there are two local rainshadows in this part of the park. Since the prevailing wind direction of the overhead moisture bearing storm winds is generally from the west through south, the Tenaya Lake site with 113.1 cm (44.1 in) average annual precipitation is on the windward of the Cathedral Range. The Galor Creek site is to the leeward of this range and appears to be in its rainshadow with 77.9 cm (30.4 in) of annual pre-

Table 1. Precipitation in centimeters of water equivalent

SEASON	TENAYA LAKE	GAYLOR CREEK	TIOGA PASS	SADDLEBACK LAKE
1972-73	—	—	—	—
1973-74	116.1	99.5	109.5	—
1974-75	119.5	90.5	103.3	344.6 (3 yrs.)
1975-76	68.7	63.3	60.5	72.8
1976-77	55.4	49.0	76.7	56.4
1977-78	140.5	129.2*	95.9	109.1
1978-79	117.9	83.8	98.5	91.5
1979-80	154.1	105.1	124.1	128.2
1980-81	92.3	73.8	69.5	78.7
1981-82	184.4	111.8*	157.2	126.4
1982-83	207.7	146.9*	170.0	N/D
1983-84	121.3	110.8	125.6	86.9
1984-85	89.7	62.8	47.9	80.5
1985-86	168.2	117.4	120.5	145.9
1986-87	77.2	57.2*	65.9	62.6
1987-88	66.4	60.3	73.1	65.4
1988-89	96.4	63.6	73.7	67.7
1989-90	86.6	66.4	69.5	69.0
1990-91	95.9	65.6	70.3	70.8
1991-92	83.1	59.0	N/D	62.8
MEAN	113.1	77.9	95.1	85.9
STD	41.3	20.8	33.1	26.4

Statistics do not include questionable data or multiple-year data as indicated in the table above.
*Indicates that the wind screen had slipped downward on the gage making the exposure of the top nonstandard and the catch therefore uncertain. The wind screen position was adjusted each time during the servicing visit and was permanently fixed in 1987 with a pin placed through the gage below the screen brace.
N/D Indicates that the gage had been leaking at one of the fixtures. These leaks were repaired during the servicing visit.

cipitation. The second rainshadow effect occurs northeastward with the Tioga Pass site having an average of 95.1 cm (37.1 in) on the windward of the Conness Range and the Saddleback Lake site having a 85.9 cm (33.5 in) average in the Conness Range rainshadow.

The less intense rainshadow effect represented by the Saddleback Lake site compared to the Galor Creek site may be due to the difference in distance of these sites downwind from their respective ranges. Snow will be blown over the crest of a mountain range and can be carried some distance on the wind into the lee area. An extreme example of this carryover or blowover of snow is found in the Mammoth Lakes area with drifting snow being a problem over Highway 395 some eleven kilometers downwind from the Sierra crest. The Galor Creek site is eight kilometers downwind from the Cathedral Range while the Saddlebag Lake site is only four kilometers downwind of the Conness Range crest.

The other feature that shows up in the mean data is the decrease in average annual precipitation with an increase in elevation. The Tenaya Lake site at 2,480 meters (8,136 feet) elevation receives 113.1 cm (44.1 in) annually while the Tioga Pass site at 3,042 meters (9,980 feet) receives an average of 95.1 cm (37.1 in). This sixteen per cent decrease in average annual precipitation with a 600 meter increase in elevation is due to the decrease of absolute moisture content with increasing altitude and decreasing temperature in the air masses flowing over the Sierra. It is generally thought that there is less water available to be snowed or rained out as the elevation increases above the 1,500-1,800 meter elevation range in the central Sierra where the maximum precipitation occurs.

Looking at the standard deviation the most meaningful value occurs for the Tanaya Lake site with the complete data set. If one assumes a normal distribution of precipitation data, then this site will receive between 72 and 154 centimeters of precipitation sixty-seven per cent of the time or two out of three years. This is a rather large variation reflecting the extremely wet El Niño year of 1982 with 208 centimeters. These are thought to be once in 100 year events.

Another interesting feature shown in the Tenaya Lake data is the dramatic change that can occur from one year to the next. This is exemplified by the drought year of 1976 with 55.4 cm followed by 1977 with 149,7 cm and the wet year of 1985 with 167.9 cm being followed by 1986 with 77.2 cm. This wide variation from year to year reflects the high degree of variability in the precipitation producing mechanisms associated with the Mediterranean type climate. It seems almost by chance that the right combination of elements come together on occasion to produce precipitation.

So much depends on the position of the moisture-bearing subtropical jet stream and the cold-bearing polar jet stream. When these currents converge over central California copious amounts of rain and snow occur. But when these vagrant jet streams do not come close to meeting over California, and that seems to be most of the time, drought is the usual result.

Conclusion

The twenty-year record of precipitation used in this study seems adequate to give representative mean and standard deviation statistics in light of the "Joseph Principle" of seven years being thought minimum to give a first approximation. However, with the National Weather Service using a 30-year base for their statistics it would seem desirable to extend the period of observation for these four sites.

With four precipitation monitoring sites in this 1036 square kilometers (400 square miles) area of the Yosemite National Park only very general patterns of precipitation distribution can be determined. The transect design for locating these four gage sites has, however, allowed the observation of two expected and explainable patterns. First is the occurrence of local rainshadows downwind of subranges within the Sierra range itself and second is the decrease of precipitation with increasing elevation above about 2,500 meters (8,000 feet).

These two characteristics of precipitation distribution associated with topographic features could be further verified, quantified and expanded within the park by including more precipitation measuring sites. Some such sites might be Crane Flat, Gin Flat, Toulumne Meadows, Ellery Lake, Lee Vining and Ostrander Lake with data being collected by the California Department of Water Resources, the Los Angeles Department of Water and Power and other agencies.