LAB 1

WATER BUDGET OF MONO LAKE: PRECIPITATION AND EVAPORATION

PURPOSE: Familiarize you with components of the hydrologic cycle, hydrologic data sources, and techniques for analyzing these data. Become familiar with hydrologic units in metric units, which are convenient, and American (or English) units, which are necessary in the United States. This first lab will deal with precipitation and evaporation.

OBJECTIVES: Analyze hydrographic data to determine quantitative values for precipitation and evaporation.

PROBLEM: Determine the average annual groundwater flow into Mono Lake, CA.

APPROACH: Analyze the water budget for Mono Lake. Determine precipitation and evaporation.

MATERIALS: You will need a straightedge, compass (with pencil), calculator, and access to the Internet (can be done before lab). A spreadsheet program will make calculations easier.

ASSIGNMENT: Read *Hydrology of Mono Basin* below. Additional information is available in *Case Study: Mono Lake*, Fetter, 2001, pp. 9–11.[1]

Before or during lab, access the Internet to retrieve precipitation data for Table 1.1 (see *Climate* section that follows).

HYDROLOGY OF MONO BASIN

Location

Mono Basin is an intermontane, closed drainage basin in central Mono County, CA, and Mineral County, NV (Fig. 1.1). The basin is about 300 kilometers east of San Francisco and forms part of the eastern boundary of Yosemite National Park. Lee Vining and June Lake, CA, are the only two towns within the basin.

Basin Morphometry

The shape of the Mono Basin is slightly elongate northeast–southwest, with dimensions of about 50 km by 30 km (30 mi by 20 mi). The enclosed area is 1748 km^2 (675 mi^2), including Mono Lake (215 km^2, 83 mi^2). The lake is fairly elliptical, about 22 km (13 mi) east–west by about 16 km (10 mi) north–south (Fig. 1.1).

The basin floor is relatively flat, sloping gently upward from Mono Lake at 1948 m (6390 ft) to the base of the surrounding rim of mountains at about 2200 m (7200 ft) (Fig. 1.2). The Bodie Hills to the north rise fairly steeply to elevations of about 2500 m (8200 ft), and in the south, the narrow arcuate chain of the Mono Craters, about 2700 m (9000 ft), extend northward to within 1.5 km of the lake.

West of Mono Lake, the Sierra Nevadas rise abruptly from the lake and culminate in snowy crests at elevations near 4000 m (Mt. Lyell, 3997 m, 13,114 ft; Mt. Dana, 3979 m, 13,053 ft; Mt. Gibbs, 3890 m, 12,764 ft). In this region, the Sierra Nevada Divide is the western drainage boundary of the Mono Basin. The mountains exhibit rugged relief

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[1] Some references are made to C.W. Fetter, 2001, *Applied Hydrogeology*, 4th edition: Prentice-Hall, Upper Saddle River, NJ.

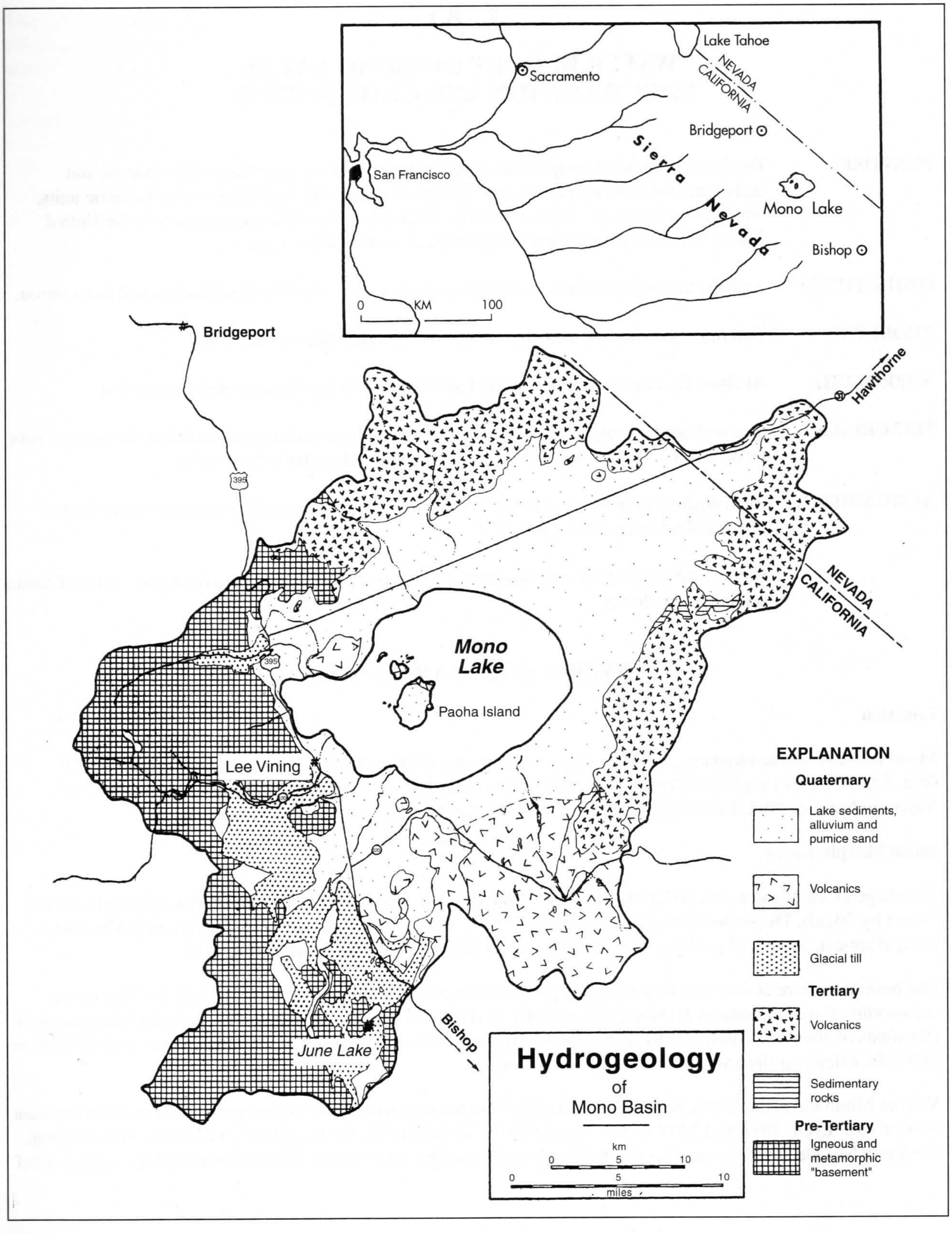


Figure 1.1—Index map and hydrogeologic map of the Mono Basin (Lee, 1969, Figure 6).

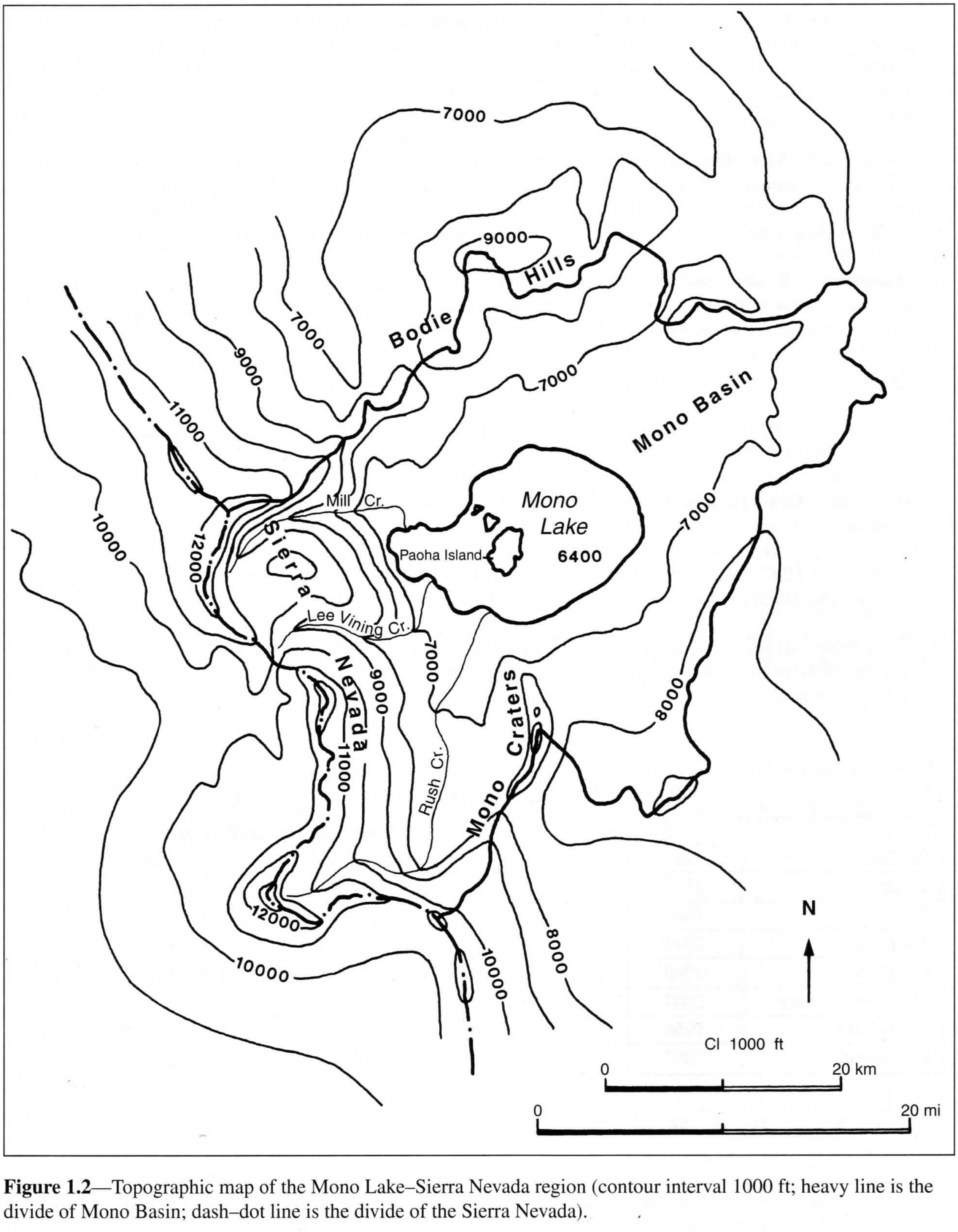


Figure 1.2—Topographic map of the Mono Lake–Sierra Nevada region (contour interval 1000 ft; heavy line is the divide of Mono Basin; dash–dot line is the divide of the Sierra Nevada).

characteristic of glacially sculpted mountains, with deep, narrow, U-shaped valleys and horn-shaped peaks. The steep eastern flank of the Sierras is accentuated by a very steep scarp (500 m/km, 2600 ft/mi) immediately alongside Mono Lake.

Climate

The climate of the Mono Basin is continental, with cold winters, during which most of the annual precipitation occurs, and dry summers with hot days and cool nights. The basin lies in an area of strong gradients; elevations rise precipitously from the basin floor to the crest of the Sierra Nevadas, and as a consequence, mean annual temperatures drop with increasing elevation (environmental lapse rate is $-5.8°C/1000$ m).

The United States Weather Bureau (USWB, now Environmental Data Services of NOAA) records meteorological observations at three stations within the Mono Basin and at several stations nearby. In addition, the Los Angeles Department of Water and Power maintains a station at Cain Ranch. These stations are shown on the map in Figure 1.3. Pertinent data are summarized in Table 1.1, *except for Ellery Lake, for which you will need to retrieve precipitation data from the Internet.*

1. Go to the California Data Exchange Center, maintained by the California Department of Water Resources as the access point to hydrologic data, at: http://cdec.water.ca.gov.
2. From the "CDEC Quick Search," select "Station Information" to find the 3-letter code for the Ellery Lake station.
3. From the "CDEC Quick Search," select "Download CSV Data," use the "Monthly Data Sorted By Years" form, and retrieve data from the entire period of record (sensor number is 2).
4. Drop these data into a spreadsheet for quick calculation of average precipitation. Calculate average monthly precipitation for the period of record, and sum these values to obtain the mean annual precipitation for the period of record.

Table 1.1—PRECIPITATION, MONO BASIN AREA

	Elevation		**Average Annual Precipitation**		
Station	**m**	**ft**	**cm**	**in.**	**from records of**
Bodie	2551	8370	41.1	16.2	1965–1968, 1996–1999 (8)
Benton	1661	5450	19.3	7.6	1965–1968 (4)
Ellery Lake	2940	9645			1924–2000 (75)
Gem Lake	2760	9054	53.3	21.0	1924–2000 (75)
Mark Twain Camp	2204	7230	17.3	6.8	1950–1955 (4)
Mono Lake	1966	6450	34.3	13.5	1951–1980, 1982–1988 (36)
Cain Ranch	2097	6880	28.1	11.1	1921–1964 (34)

WATER BUDGET

Write a continuity equation for the water budget of Mono Lake, including all components that you think might possibly be significant (the continuity equation is also known as the law of mass conservation and is referred to as the *hydrologic equation* by Fetter). Consider addition to the lake as positive and removal as negative.

PRECIPITATION

Arithmetic Average Method

Precipitation is measured at recording stations that provide point data of linear depth. In order to determine the volume of precipitation falling within a basin, these point data somehow must be extrapolated over an area that they represent (the *effective uniform depth* of Fetter). The easiest way of doing this is the arithmetic averaging method, in which one simply multiplies the average of the point data by the area of the entire basin.

1. Determine the average annual precipitation (m^3) by averaging the precipitation data for stations within the Mono Basin (Table 1.1). Calculate precipitation in the Mono Basin and, separately, on Mono Lake.

Thiessen Method

A more accurate method for determining basin precipitation, the Thiessen method, accounts for nonuniform distribution of recording stations by weighting each data point differently, according to the percentage of the basin the station represents. The method assumes that the precipitation at any point in the basin is that of the nearest station, or (another way of saying this) the precipitation is assumed to vary linearly between stations. A description of the Thiessen method is available in most textbooks (e.g., Fetter, 2001, pp. 34–37).

2. Determine the average annual precipitation on Mono Lake (m^3) by the Thiessen method (do this for the *lake only*), using the map in Figure 1.3. Areas within each polygon normally are measured with a planimeter, but for the sake of this exercise, you can estimate the areas by "counting squares," using quad-ruled paper.

Compare your result with precipitation calculated by the averaging method (No. 1).

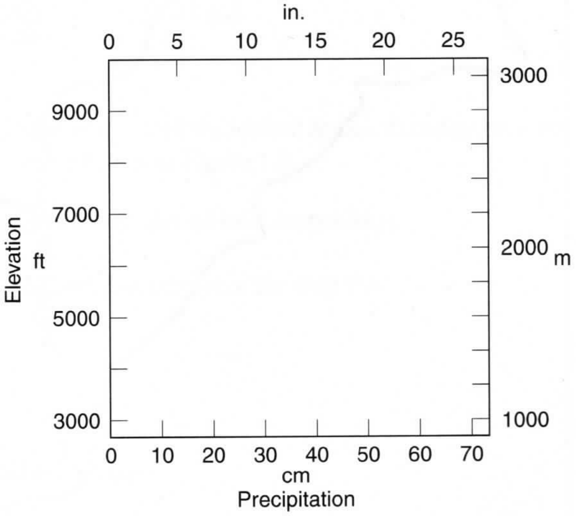
Isohyetal Method

Where orographic effects are significant, the isohyetal method gives a more accurate estimate because it accounts for topography. The method takes into account not only a nonuniform distribution of stations, but it allows for nonlinear variations in precipitation as well, as might be expected along a mountain range.

3. Plot precipitation as a function of elevation on the graph. Does there appear to be an orographic effect?

   Estimate a regression line, and determine the precipitation gradient.

Here in the rain shadow of the Sierras, where gradients are strong, the isohyetal method gives the most effective estimate of precipitation.



Using the isohyetal method, precipitation values are plotted at each station and contoured with lines of equal precipitation, or isohyets, taking into account the topography and using your knowledge of prevailing wind directions and orographic precipitation. After the isohyetal map is completed, precipitation is determined by measuring the areas between successive isohyets and multiplying each area by the average precipitation between its bounding contours.

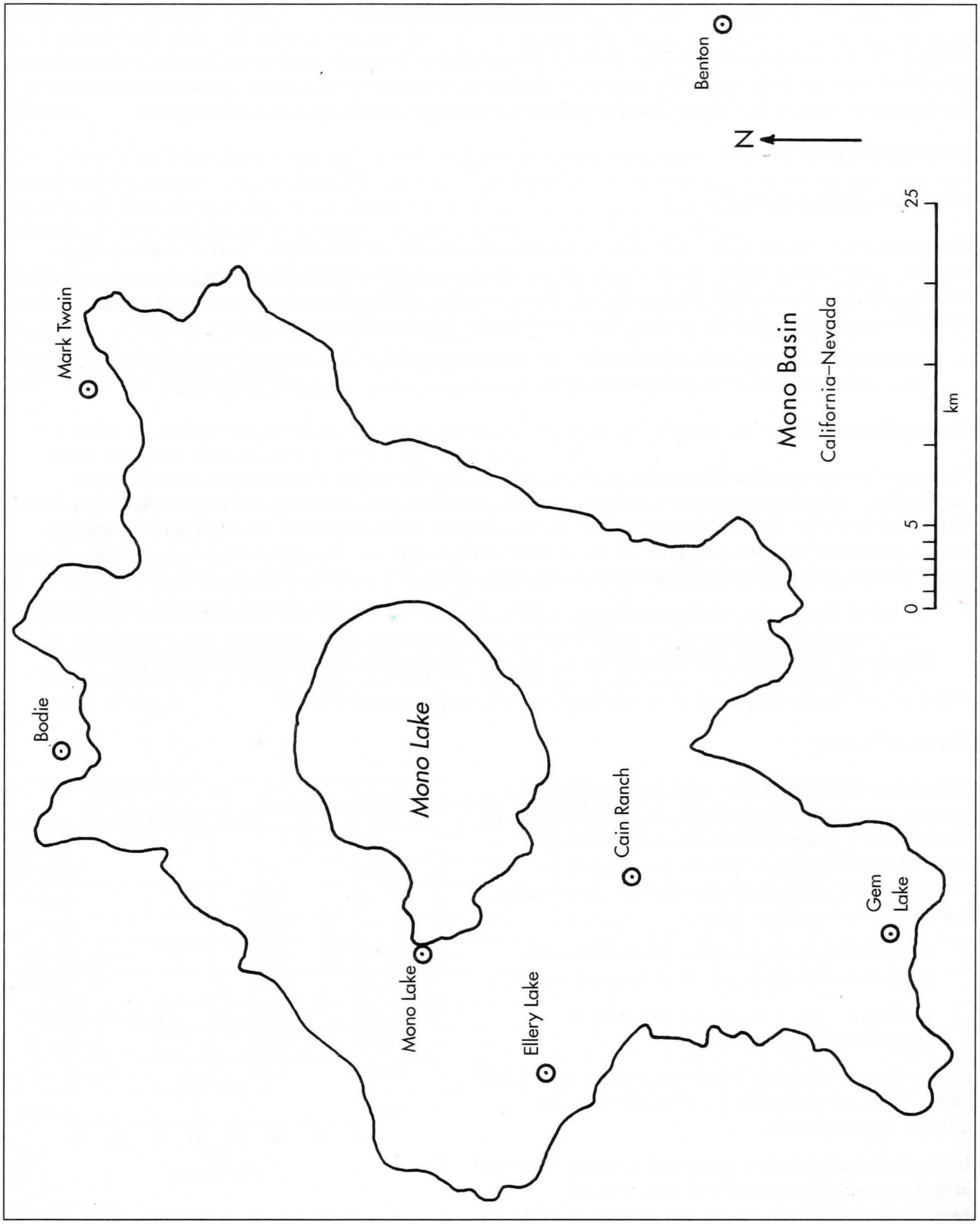


Figure 1.3—Precipitation stations in and around Mono Basin.

4. Construct an isohyetal map of the Mono Basin on Figure 1.4, making reference to the topographic map in Figure 1.2. Compute the average annual precipitation on Mono Lake by this method. Compare your result with precipitation determined by the other two methods (Nos. 1 and 2).

EVAPORATION

You will estimate the evaporation at Mono Lake in two ways: (1) by referring to a published map and (2) by reducing data from an evaporation pan at Cain Ranch.

1. Estimate average annual evaporation, or lake evaporation (m), by viewing the evaporation map in Figure 1.5. For conversion tables from American units to SI units, refer to your textbook (e.g., Fetter, 2001, Appendices 7–9).

The data for the lake evaporation map compiled by Kohler and others (1959) were derived from measurements of water evaporated from a standardized pan: a 4-ft-diameter, galvanized pan known as the Class A land pan. These measurements of pan evaporation are shown on the map in Figure 1.6.

Because evaporation pans have greater evaporation rates than lakes, typically about 140 percent, they must be corrected by applying an empirically derived pan coefficient. The variation in pan coefficients is shown on a similar map in Figure 1.7. In effect, the lake evaporation map you used (Fig. 1.5) is a derivative of the other two maps—measured pan evaporation (Fig. 1.6) multiplied by a pan coefficient (Fig. 1.7).

2. The following pan data were recorded at Cain Ranch.

Cain Ranch Station

Elevation: 6880 ft

Class A evaporation pan, water level held constant by float valve; volume of water needed to recharge pan (corrected for precipitation) is recorded.

May	33.71 gal	August	73.94 gal
June	51.41 gal	September	49.41 gal
July	94.10 gal	October	33.51 gal

(a) Calculate the pan evaporation (m) for this period.

(b) Data for the winter months are usually not recorded because in much of the United States, freezing prevents measurement. Extrapolate for annual pan evaporation using the map in Figure 1.8.

(c) Correct for the pan effect, using the map in Figure 1.7 to determine annual lake evaporation.

(d) How does this measurement compare with the reading you took directly from the map (No. 1)?

3. Calculate the annual evaporation (m^3) from Mono Lake.

LAB REPORT

Prepare a lab report summarizing the analysis to date, showing all calculations.

For all quantitative values, ensure that you report significant figures (significant digits) only (e.g., see Fetter, 2001, p. 19).

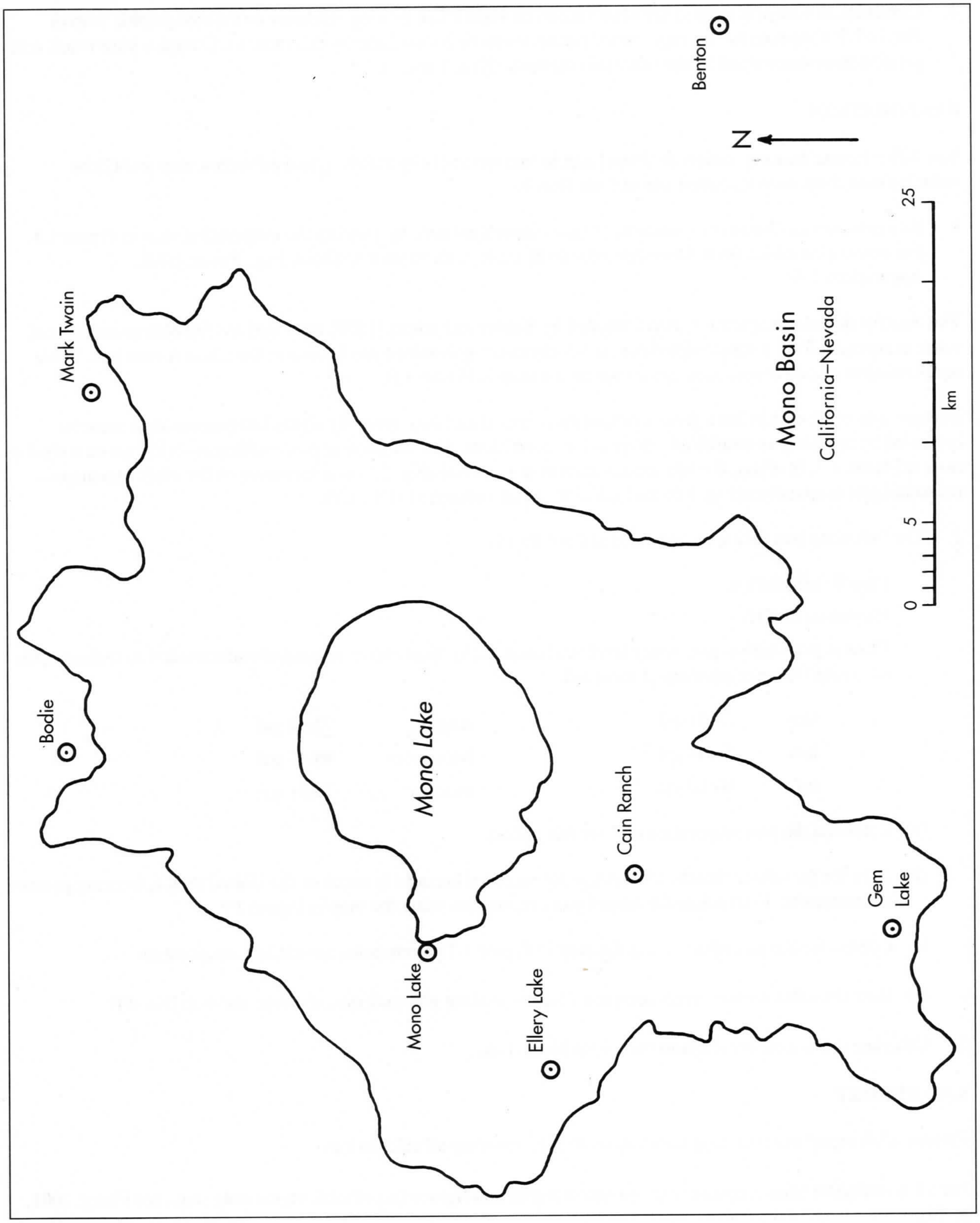


Figure 1.4—Precipitation stations in and around Mono Basin.

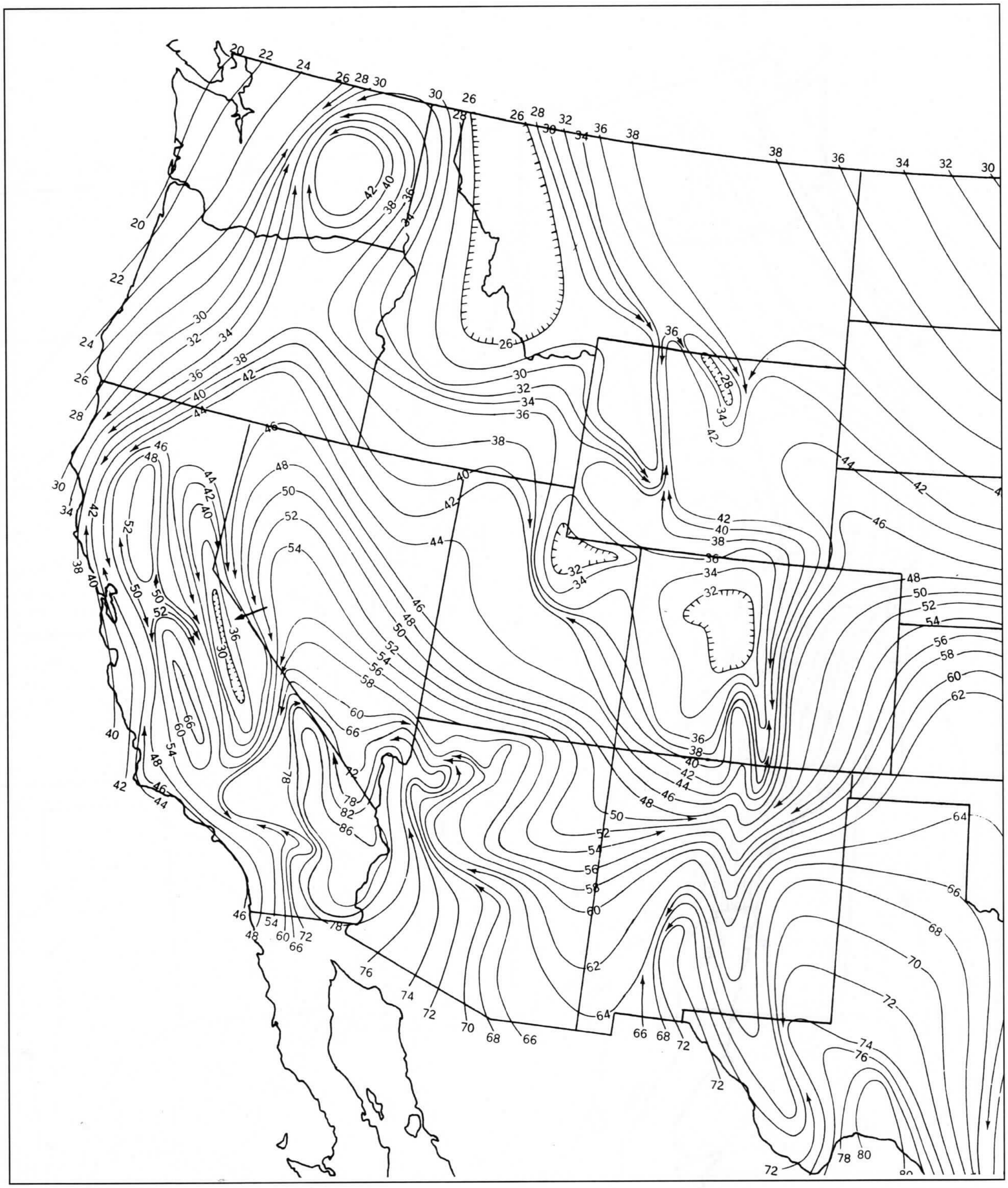


Figure 1.5—Average annual lake evaporation (in inches) in the western United States for the period 1946–1955 (from Kohler et al., 1959, Plate 2).

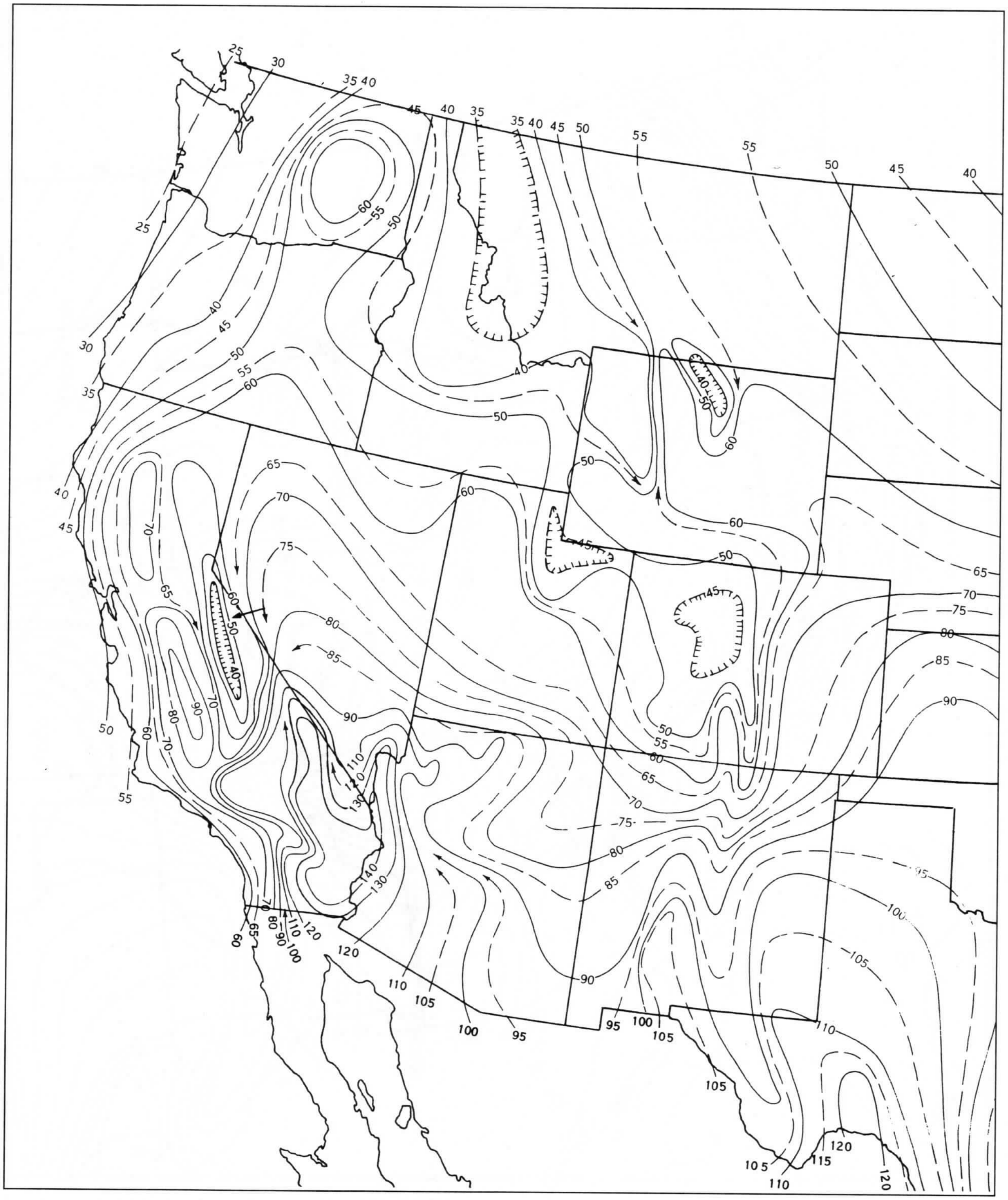


Figure 1.6—Average annual Class A pan evaporation (in inches) in the western United States (from Kohler et al., 1959, Plate 1).

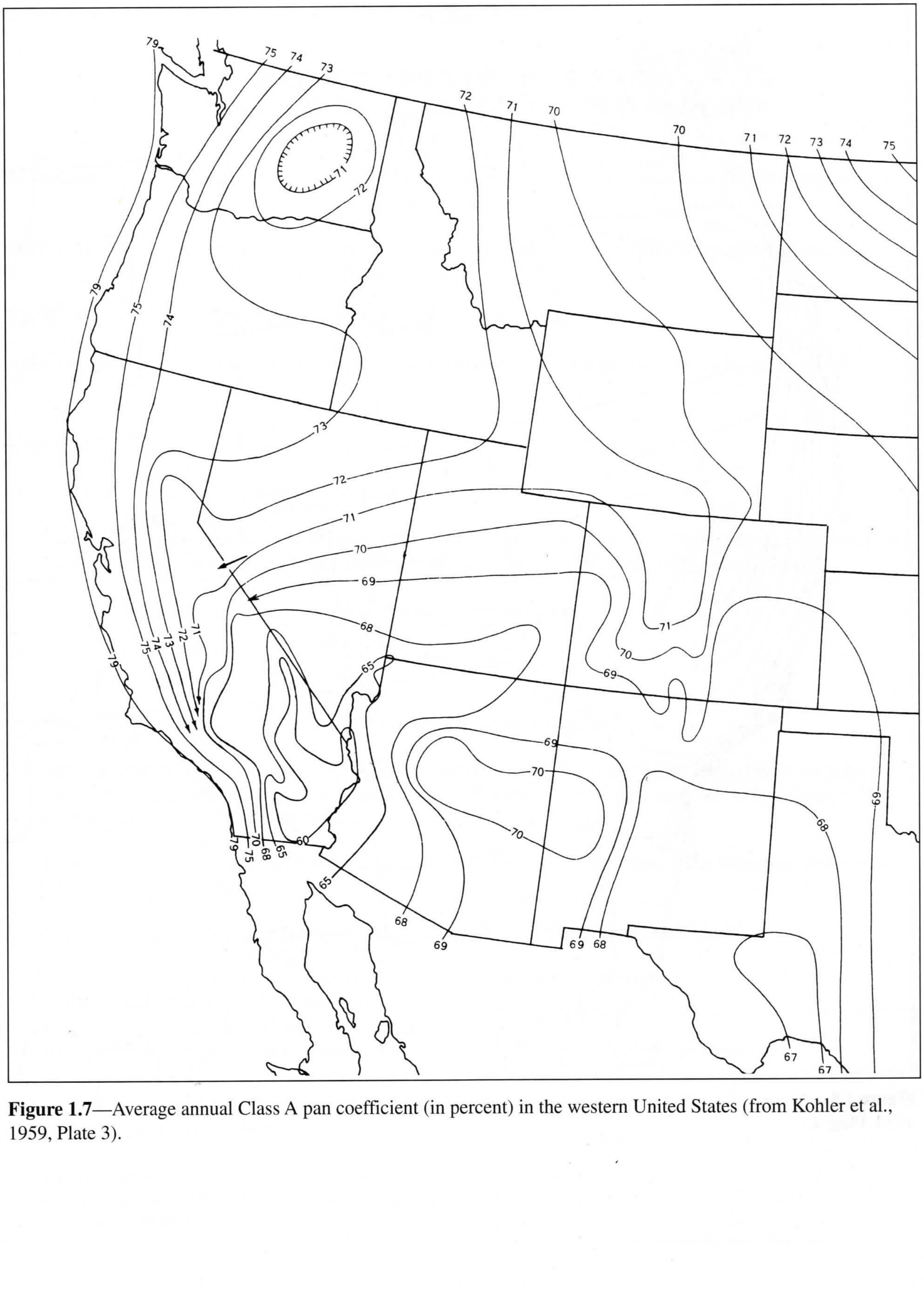


Figure 1.7—Average annual Class A pan coefficient (in percent) in the western United States (from Kohler et al., 1959, Plate 3).

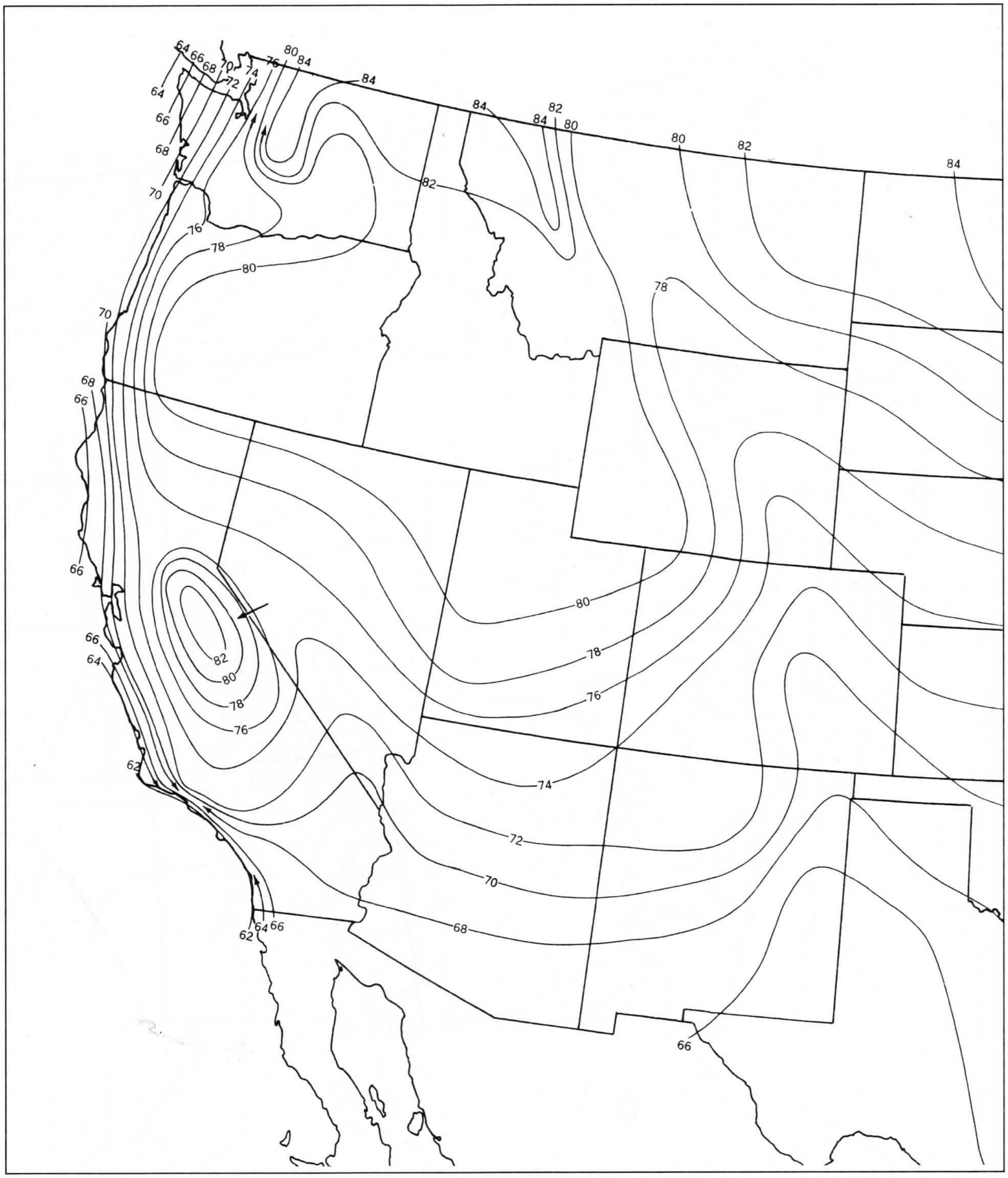


Figure 1.8—Average May–October evaporation (percent of annual) in the western United States (from Kohler et al., 1959, Plate 4.)