UNIVERSITY
OF NEVADA
RENO

MACKAY SCHOOL OF MINES

NEVADA BUREAU OF MINES AND GEOLOGY
REPORT 48

# STATEWIDE POTENTIAL EVAPOTRANSPIRATION MAPS FOR NEVADA

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1996

## ABSTRACT

Values of evapotranspiration are required throughout the state of Nevada as part of work being conducted to rank abandoned mine sites for their potential to cause adverse environmental impacts. Measured temperature and the calculated ratio of total to vertical radiation (after the work of Behnke and Maxey (1969)) were used to estimate monthly potential evapotranspiration (PET) at 125 weather stations in Nevada, most of which are near valley floors at elevations ranging from 393 to 2,287 m. The calculated values were found to be well correlated ($R^2$ = 0.909 to 0.990, slopes near 1.0) with monthly pan evaporation measurements at eight sites in Nevada.

In order to extrapolate these values to areas without temperature measurements and sites at higher elevations, the state was divided into five regions based on latitude, and linear regressions of PET versus elevation were calculated for each of these regions. These extrapolated PET values compare well with the pan evaporation measurements ($R^2$ = 0.936 to 0.985, slopes near 1.0). The estimated values are generally somewhat lower than pan measurements, in part because the effects of wind are not explicitly considered in the calculations, and near freezing temperatures result in a calculated PET of zero. April though October calculated PET values are 84 to 100% of the measured pan evaporation values. Poorer agreement is obtained in October through March, with calculated values being 36 to 65% of measured pan evaporation values. Using Digital Elevation Models in a geographic information system (GIS), calculated values were adjusted for slope and aspect, and the data were used to construct a series of maps of monthly PET. The resultant maps show a realistic distribution of regional variations in PET throughout Nevada which inversely mimics topography.


## INTRODUCTION

Evapotranspiration (ET) varies regionally as a function of time (month), temperature, latitude, and elevation. Local variability in ET results from variations in soil type, moisture content, vegetation cover and type, and wind speed, among other factors. When conducting regional water studies, the majority of these factors are not known, and, due to the high cost of acquiring these data, these parameters are generally only obtained when site specific local data are required for a particular study. However, data such as temperature, time, latitude, and elevation are available, or can be extrapolated, on a regional scale and can be used to empirically estimate potential ET (PET) such that information on relative values between locations can be obtained.

Knowledge of the variability in regional and monthly ET rates is needed to address a variety of water quality and water quantity problems. As an example, the results described here have been used as part of a model to rank abandoned mine sites by their potential to result in water quality degradation (Shevenell and others, 1996; Shevenell and Christensen, 1996). For instance, leaching of exposed waste rock dumps is more likely to occur in areas with high precipitation and low PET than in areas with high PET and low precipitation. Other applications for these types of PET data include identifying preferable sites to locate landfills and evaluating the yearly water budgets on a regional scale.

Because these types of PET data were not available for Nevada, and they would have wide applicability to a number of hydrogeologic studies, the work described here was conducted. The purpose of this report is to document the development of models to calculate PET in the arid and semiarid state of Nevada and to present PET contour maps of the state which can be useful to hydrologic researchers as well as state and local water planning agencies. In addition, the digital data at 1-km grid spacing are made available on an anonymous ftp site at nbmg.unr.edu in the subdirectory /pub/ET, and a web page is planned where color maps can be viewed (http://www.nbmg.unr.edu). The methods described here could be applied in other arid western states (for example, New Mexico and Arizona) to obtain statewide maps of PET on a regional scale.

## METHODS

An empirical method was sought that could be used to estimate potential evapotranspiration for the state of Nevada. Limited data are available in Nevada from which PET can be estimated. Few weather stations have sufficient data on parameters such as average wind speed, vapor pressure and relative humidity to use approaches such as those described by Penman (Penman, 1948; Ivanov, 1954; Penman, 1956; Penman and Schofield, 1951; Turc, 1961; Jensen and Haise, 1963; Papadakis, 1966; Priestley and Taylor, 1972). Hence, a less rigorous method is employed to estimate PET based solely on average monthly temperature measurements. Although the Thornthwaite (1948) method uses only temperature and latitude to estimate PET, it “should not be used in areas that are not similar to the east central United States” (Jensen, 1973). Hence, a method previously utilized specifically in the arid state of Nevada is selected.

Behnke and Maxey (1969) described a method of estimating PET from monthly temperature measurements in Nevada, and show that this method provides reasonable estimates for selected stations in Nevada. It is assumed that with sufficient air circulation, PET should be primarily dictated by temperature (which is a function of solar radiation reaching the earth’s surface) and vapor deficit. Based on work in Egypt and the Sudan (Keeling, 1909), Olivier (1964) found that the mean annual pan evaporation for the year (in mm/day) divided by the mean annual wet bulb depression (in °C) is close to one. Oliver (1964) noted that deviations from the ratio of one followed a cyclic pattern which appeared to be associated with variations in the vertical component of radiation, and that the amplitude of the variation changed with latitude. Hence, Olivier (1964) suggested that wet bulb depression readings (because they measure evaporation from all directions) should be corrected with the ratio of vertical to total radiation in order to approximate evaporation. On a clear day, the vertical component of radiation ($R_v$) is calculated with

$$R_v = R\sin(h) \qquad (1)$$

where R = total radiation and sin(h) = the angular distance of the sun above the horizon, and is defined by

$$\sin(h) = \sin(ø)\sin(d) + \cos(ø)\cos(d)\cos(t) \qquad (2)$$

where ø is the latitude of the observation location, d = the angular distance of the sun above or below the equator (declination), and t = the hour angle (the angle between the meridian plane through the observation location and the meridian plane through the sun). Values for t and D are obtained from the American Ephemeris and Nautical Almanac (or Astronomical Almanac after 1982) for the 15th of each month to obtain average monthly values. Using the ratio $R/R_v$ (total divided by vertical radiation), Behnke and Maxey (1969) derived an expression to estimate PET in Nevada:

$$PET = \frac{T°C}{1.9} \times \frac{L_o}{L^2} \qquad (3)$$

where $L_o$ is the average monthly ratio between total and vertical radiation for a particular year ($\overline{R/R_v}$), L = the monthly value of $R/R_v$, and T/1.9 is the simulated wet bulb depression curve empirically determined by Behnke and Maxey (1969) for Nevada data between April and October, and PET is in mm/d. This expression only applies under clear sky and direct sun, and would be in error under cloudy skies and low sun angles. However, these conditions are generally met in Nevada which has a high percentage of sunshine and ample dry air circulation. In addition, Behnke and Maxey (1969) found that PET calculated with the above expression correlated well with lysimeter and adjusted pan evaporation calculated for several stations in Nevada.

Average monthly temperature data for all stations in Nevada through 1994 were obtained from the Western Regional Climate Center in Reno. Data from all stations, whether active or inactive, were obtained for the entire period of record for the station. Any stations with less than 10 years of temperature data were eliminated from the dataset, resulting in a total of 124 stations throughout Nevada. The average elevation for which calculated PET values are available is 1,494 ± 382 m (4,900 ± 1,252 feet). Approximately half of the stations are at elevations 393 to 1,494 m (1,290 to 4,900 feet; 61 stations), whereas approximately half are at elevations between >1,494 and 2,287 m (>4,900 and 7,500 feet; 63 stations).

Using the latitude of each station, $R/R_v$ was calculated for each month, and estimated monthly PET was calculated based on equation (3). Any values of PET < 0 were assumed equal to zero and these values correspond to below freezing average temperatures, where PET is expected to be minimal (except from snowpacks subject to high winds). It is assumed that if average temperatures are below freezing, and snow is on the ground, that no percolation of water into the subsurface occurs. Hence, although evaporation from snow does occur, it is not relevant to the processes of percolation or runoff being considered here.

Most weather stations in Nevada from which temperature and precipitation data are available are located in valleys rather than on ridge tops. Hence, direct construction of regional PET contours based solely on the station data does not adequately account for topographic effects. The PET values calculated at the stations based on solar radiation were, hence, extrapolated to other elevations and locations. This was accomplished by making linear regression analyses on a month by month basis between these calculated PET values and the station elevations. Known elevations throughout the state were then inserted into the linear regression equations to obtain PET at 1-km grid spacing (described in greater detail in later sections). Digital Elevation Model (DEM) data for the state of Nevada were used in conjunction with these monthly linear regression equations to estimate PET as a function of elevation throughout the state. Elevation values used in the calculation of statewide evapotranspiration are from U.S. Geological Survey (USGS) 1-degree Digital Elevation Models (DEM). Elevation points are spaced every 3 arc-seconds (for details on the structure and limitations of DEMs, see USGS, 1990). The point data were converted into raster data in the Universal Transverse Mercator projection, producing a cell size of 90 m. The 90-m grid was resampled at a resolution of 1 km. From these data, a single elevation is assigned to each 1-km grid cell based on the average value from the 90-m grids. Hence, the assigned elevation of a grid cell is not identical to the elevation of a weather station contained in the grid cell, and the GIS calculated PET values will not exactly equal calculated values using the actual elevation of a particular station. Nevertheless, these data provide an estimate of PET that accounts for regional topographic effects obtained on a grid with 1-km cells.

This regional view of PET for the state required additional manipulation to account for the direction in which a slope faces (aspect), with north-facing slopes clearly having lower PET than south-facing slopes at the same elevation. This results in contours of PET around mountain ranges that are not symmetrical. A particular PET contour value is at a higher elevation on south slopes than on the north slopes.

In order to account for the variability of PET with aspect, the variations in the angle at which solar radiation intersects a slope was qualitatively evaluated. Most stations for which temperature measurements are available for use in calculating PET are on valley floors, and hence on flat surfaces. The Olivier (1964) method does not account for variations from a flat surface. If a slope is facing south, the angle at which radiation intersects the slope differs from that of a corresponding flat slope. For instance, if radiation is incident on a flat surface at an angle of 70° from horizontal, the radiation on a south-facing 20° slope on the same day will intersect that slope at a 90° angle. Perhaps this greater angle of incidence would result in increased radiation as a function of the sine of the slope angle (for example, 1 + sin(theta)). If the average angle of the south-facing slope is 15°, then the radiation, and ultimately PET, may be greater than that on a flat slope by a factor on the order of 1 + sin(15°), or 1.26. Similarly, the radiation incident on a north-facing slope may be less by a factor on the order of 1 - sin(15°), or 0.74. The radiation incident on a plane will vary with slope and aspect, and it is expected that slopes facing in directions other than directly south or north would have factors intermediate between these example values of 0.74 to 1.26.

The west- and east-facing slopes should have different weighting factors even though they are exposed to sunshine nearly the same amount of time per day. The distinction is made because air temperatures are higher in the afternoon when the west-facing slopes are more exposed to the sun. Hence, west-facing slopes generally undergo greater heating than east-facing slopes which receive morning sun during times of cooler air temperatures. Both west- and east- facing slopes are likely to have greater PET than slopes containing a north-facing component, and less PET than slopes containing a south-facing component. Hence, a slope facing directly south should be given the highest weighting, and a north-facing slope the lowest weighting. The magnitude of the weighting factors can be gauged by considering the example 15° slope discussed previously which suggests weighting factors

may lie in the range of 0.74 and 1.26. In order to obtain conservative (rather than extreme) PET estimates as a function of aspect, a smaller range in weighting factors was selected for this work. Although it is believed that the following weighting factors are conservative, there is some uncertainty regarding their values and additional research is needed to quantify how PET varies at particular elevations on different aspects at different angles from horizontal. Nevertheless, for the purposes of this work, the following weighting factors were applied for the values of aspect noted without explicit consideration of the angle of the slope from horizontal:

| Aspect | Direction | Weighting Factor |
|---|---|---|
| >15 to 75° | NE | 0.95 |
| >75 to 105° | E | 0.98 |
| >105 to 165° | SE | 1.03 |
| >165 to 195° | S | 1.10 |
| >195 to 255° | SW | 1.05 |
| >255 to 285° | W | 1.02 |
| >285 to 345° | NW | 0.97 |
| >345 to 15° | N | 0.90 |

A slope is considered flat and given a weighting factor of 1.0 if its angle from horizontal is less than 2°.

The direction in which a slope faces is directly calculated by GRID (Environmental Systems Research Institute, Inc., 1991) as a degree value. Although GRID automatically identifies a slope as flat when there is a slope of zero, changes were made so that a slope was considered to be flat if it changed by ≤2° over a distance of 1 km. In these cases, the grid cell is likely to be on a valley floor, which is the location where many temperature measurements were available for calculation of PET. Hence, a weighting factor of one is applied to these locations.

The previously described manipulations, including calculation of PET at grid locations based on the linear regressions for the five regions of the state, and adjustment for aspect were conducted in a GIS format using Arc/Info 6.1.1 and the accompanying raster modeling package GRID (ESRI, 1991). Contouring of the data was subsequently conducted using Arc/Info 6.1.1, resulting in the final GIS overlay coverages.

## RESULTS

Some weather stations in Nevada measure evaporation using pan evaporation measurements (J. Ashby, personal commun., 1995), and table 1 lists these values and the equation (3) calculated PET. The two values agree reasonably well as indicated by the coefficients of determination ($R^2$) These $R^2$ were calculated without use of values followed by "*" or "+" because few (≤3) or no evapotranspiration measurements were made during the particular month in any year. In general, the calculated PET values are somewhat less than the measured pan evaporation values. Hence, the calculated PET values are somewhat more realistic because evaporation measured from pans is generally greater than from nearby vegetated areas. For instance, reference crop evaporation is typically lowered by multiplying the pan evaporation value by 0.4 to 0.856 depending on wind speed, and the fetch of wet versus dry crop (see Maidment, 1993, p. 4.22).

Calculated PET values are likely to be lower than measured pan evaporation values for two reasons. First, average temperatures are used in calculating PET, and this tends to smooth the extreme values. Temperature can vary by about 22°C (40°F) per day, and an average value of 18.3°C (65°F) could be representative of some days with temperatures as high as the 27°C, during which time evaporation would be much higher than it would be at a temperature of 18.3°C. Of course, this is partially offset because much lower than average temperatures also occur in the course of any given month. The second possibility for the discrepancy between measured pan evaporation and calculated PET values is that the wind speed is not explicitly considered in the calculated values. Most stations in Nevada are subject to a moderate amount of wind as the model assumes, yet winds vary daily from virtually no wind to high winds which tend to increase the rate of evaporation from a pan over that which would be calculated based solely on solar radiation and the assumption of constant moderate winds. In addition, pan measurements may be affected by an oasis effect resulting in higher measured PET than in other more typical arid settings. Note that the PET calculated from either pan evaporation or the Behnke and Maxey (1969) method is the amount of PET that would occur if water were not a limiting factor, which it is in most locations in Nevada. For the purposes for which these PET are to be used (that is, in a relative sense between different portions in a region), the Behnke and Maxey calculated values are suitable. PET and precipitation at one site can be compared to those at other sites in Nevada to determine which site is more likely to result in either leachate generation from abandoned mines or proposed landfills. In this case, actual values of ET are somewhat less important, but the relative values are very important because the goal is to evaluate sites in a relative manner.

Data from selected stations in figures 1 (1,299 m) and 2 (768 m) and table 1 illustrate the types of precipitation and ET variability expected in the southern and northern portions of the state. The Boulder City plot shows typical responses for the southern stations where rain is high and ET is low in January. A second high in precipitation occurs in August, yet at a time when ET is very high. Similarly for the Imlay station located near the Eugene Mountains in north-central Nevada, February precipitation is relatively high when ET is relatively low. Table 2 shows calculations of precipitation minus ET to illustrate which months have the highest and lowest potential for recharge. When precipitation minus ET values are among the lower values, this is indicative of the least potential for recharge/percolation to occur. When precipitation minus ET

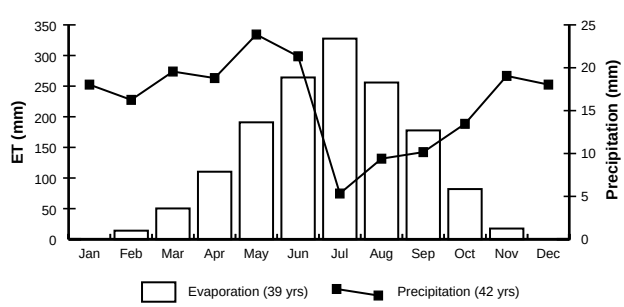


**Figure 1—Average annual evapotranspiration and precipitation versus time at the Imlay weather station.**

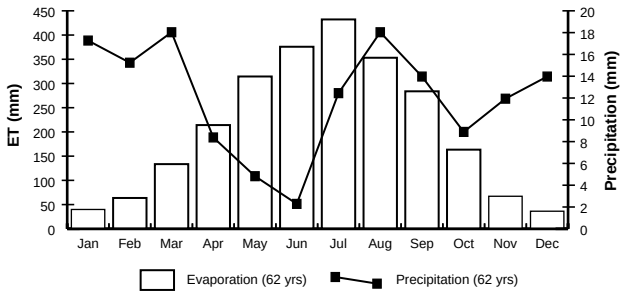


**Figure 2—Average annual evapotranspiration and precipitation versus time at the Boulder City weather station.**

values are among the higher values, this is indicative of the greatest potential for recharge/percolation to occur.

During January, February, November, and December, the Imlay station (similar to other northern Nevada stations) shows a water surplus (positive values), and hence, a high likelihood that sufficient water is available to result in percolation in suitable geologic settings. During no month does precipitation exceed evaporation in the southern Nevada stations, although the calculated deficits in January and December (22 mm) are considerably lower than those in July (420 mm). However, the surplus during the cold months in northern Nevada is generally attributable to snow, and percolation would not occur during these months, but would occur later during snowmelt and runoff.

Most weather stations in Nevada from which temperature and precipitation data are available are located in valleys rather than on ridge tops, and direct construction of regional contours based solely on the station data does not account for topographic effects. When pan evaporation data are plotted versus elevation, a broadly linear trend in the data exists, although with some scatter. Very limited data are available for the higher elevation stations from which to make generalizations. Data from Ruby Lake (elevation = 1,832 m) appear in table 2 for comparison, and this is the station at the highest elevation for which there are any measured pan evaporation data. No pan evaporation data were collected for the months labeled with “0+.” When comparing Ruby Lake with the lower elevation Imlay station, it is clear that the precipitation for all months is somewhat higher, and the pan evaporation values are lower at the higher elevations. A linear regression analysis was made on average monthly PET values from the eight stations with measured pan evaporation values at elevations between 768 and 1,832 m. All months show a decrease in pan evaporation values with increasing elevation (in meters). For instance, note the following:

January:

$$PET(mm) = -0.066(Elev) + 114.46, \quad R^2 = 0.65 \qquad (4)$$

February:

$$PET(mm) = -0.098(Elev) + 185.18, \quad R^2 = 0.64 \qquad (5)$$

When pan evaporation data and elevation are compared between a small number of stations located near one another, correlations are generally poor and slopes and intercepts vary with position in the state. When calculated, average monthly PET values from all 125 stations in Nevada are used, $R^2$ values are somewhat better, and the results of the linear regressions follow.

January:

$$PET(mm) = -0.023(Elev) + 37.02, \quad R^2 = 0.56 \qquad (6)$$

February:

$$PET(mm) = -0.039(Elev) + 73.96, \quad R^2 = 0.75 \qquad (7)$$

March:

$$PET(mm) = -0.079(Elev) + 162.54, \quad R^2 = 0.80 \qquad (8)$$

April:

$$PET(mm) = -0.102(Elev) + 251.07, \quad R^2 = 0.81 \qquad (9)$$

May:

$$PET(mm) = -0.118(Elev) + 362.46, \quad R^2 = 0.81 \qquad (10)$$

June:

$$PET(mm) = -0.118(Elev) + 423.65, \quad R^2 =\sim 0.77 \qquad (11)$$

July:

$$PET(mm) = -0.112(Elev) + 478.18, \quad R^2 = 0.74 \qquad (12)$$

August:

$$PET(mm) = -0.095(Elev) + 386.64, \quad R^2 = 0.73 \qquad (13)$$

September:

$$PET(mm) = -0.089(Elev) + 306.71, \quad R^2 = 0.71 \qquad (14)$$

October:

$$PET(mm) = -0.062(Elev) + 175.97, \quad R^2 = 0.68 \qquad (15)$$

November:

$$PET(mm) = -0.036(Elev) + 73.08, \quad R^2 = 0.68 \qquad (16)$$

December:

$$PET(mm) = -0.020(Elev) + 32.67, \quad R^2 = 0.57 \qquad (17)$$

Coefficients of determination ($R^2$) range from 0.56 to 0.81 with the poorest correlations occurring during the winter months (January, February, December). The poorer correlations during these months can be directly attributed to the fact that higher elevation stations have average monthly temperatures below freezing, resulting in calculated PET values of zero for the month. Hence a large number of the stations have 0 mm/month PET.

The slopes, and particularly the intercepts, vary with latitude within the state because stations at higher latitudes have lower overall ET than those at lower latitudes, and a statewide equation could be expected to yield poor estimates in many, if not most, parts of the state. Hence, several other linear regressions were attempted to account for this effect. Division of the state into the five regions depicted in figure 3 resulted in the best correlations in the data when only those PET values which were estimated based on ≥20 years of temperature measurements were utilized in the calculation. The points on figure 3 show the locations of the stations with temperature measurements. Table 3 lists the slopes, intercepts, and $R^2$ for the PET-elevation relationships in the five regions. In some regions during some months (that is, February for region 1, fig. 4), a change in slope occurs in the PET vs elevation plot. Hence, two segments resulting in positive values of PET are obtained. Similarly, for winter months which may have a large percentage of freezing weather, a PET of 0 is assigned over particular elevations, primarily based on the regression equations, but also based on snowpack data (table 4). The calculated PET of a winter month regression equation approaches zero with increasing elevation. Elevation cut-offs noted in table 3 are not necessarily the precise elevation at which a value of zero would be calculated with the respective regression equation, but is an elevation value in the neighborhood of a calculated PET value of zero. The exact elevation value is not noted because (1) the precise value is not known and will certainly vary year to year, (2) the elevations were rounded because the cut-off between positive and zero PET should not be specified precisely, (3) the noted elevations were selected to assure a

**Table 1—Calculated PET and measured pan evaporation at Nevada Stations. Values are in millimeters.**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual | $R^2$ | Slope |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boulder City, 35°59′N, 114°51′W | | | | | | | | | | | | | | | |
| Calculated | 39.9 | 63.6 | 133.5 | 214.1 | 314.4 | 375.8 | 432.2 | 353.1 | 283.8 | 163.4 | 67.2 | 36.3 | 2478 | 0.985 | 1.168 |
| Measured | 88.1 | 113.5 | 184.7 | 261.4 | 336.3 | 404.6 | 402.3 | 348.2 | 281.9 | 193.0 | 115.8 | 83.1 | 2813 | | |
| Silver Peak, 37°40′N, 117°35′W | | | | | | | | | | | | | | | |
| Calculated | 0.8 | 23.2 | 74.1 | 140.1 | 238.2 | 308.3 | 363.3 | 289.2 | 209.7 | 99.3 | 25.0 | 0.0 | 1771 | 0.978 | 0.909 |
| Measured | 0* | 97.5 | 184.4 | 256.3 | 346.5 | 408.7 | 449.8 | 397.8 | 283.7 | 172.5 | 74.7 | 0* | 2672 | | |
| Topaz Lake, 38°42′N, 119°31′W | | | | | | | | | | | | | | | |
| Calculated | 2.5 | 16.2 | 42.9 | 86.3 | 168.9 | 232.7 | 289.5 | 233.7 | 162.2 | 76.5 | 20.1 | 3.6 | 1335 | 0.981 | 1.274 |
| Measured | 0* | 0* | 0* | 181.6 | 231.4 | 277.9 | 322.1 | 293.6 | 223.5 | 151.1 | 70.87+ | 0* | 1681 | | |
| Central Nevada Field LA, 39°23′N, 117°19′W | | | | | | | | | | | | | | | |
| Calculated | 0.0 | 0.1 | 21.8 | 57.0 | 145.1 | 206.1 | 268.4 | 209.3 | 140.2 | 52.4 | 9.5 | 0.0 | 1110 | 0.975 | 1.143 |
| Measured | 0* | 0* | 75.69+ | 151.1 | 220.7 | 266.4 | 310.9 | 287.3 | 205.2 | 124.0 | 43.94+ | 0* | 1566 | | |
| Fallon Experiment Station, 39°27′N, 118°47′W | | | | | | | | | | | | | | | |
| Calculated | 0.0 | 15.1 | 55.8 | 114.5 | 193.8 | 250.9 | 311.9 | 246.1 | 172.1 | 81.0 | 19.5 | 0.9 | 1462 | 0.962 | 1.384 |
| Measured | 34.0 | 56.6 | 111.5 | 156.2 | 194.6 | 225.0 | 249.2 | 217.2 | 153.7 | 98.8 | 58.2 | 31.5 | 1586 | | |
| Beowawe U of N Ranch, 39°54′N, 116°35′W | | | | | | | | | | | | | | | |
| Calculated | 0.0 | 0.5 | 31.9 | 81.0 | 153.1 | 220.4 | 279.0 | 220.8 | 150.3 | 64.6 | 9.4 | 0.0 | 1211 | 0.952 | 1.187 |
| Measured | 0* | 0* | 0* | 91.4 | 191.3 | 228.9 | 263.4 | 235.5 | 175.3 | 112.5 | 0* | 0* | 1298 | | |
| Ruby Lake, 40°12′N, 115°30′E | | | | | | | | | | | | | | | |
| Calculated | 0.0 | 0.0 | 23.3 | 81.4 | 157.9 | 222.4 | 286.8 | 227.5 | 151.8 | 65.5 | 10.3 | 0.0 | 1227 | 0.990 | 1.290 |
| Measured | 0* | 0* | 0* | 0+ | 180.1 | 225.0 | 267.2 | 237.0 | 165.9 | 101.6 | 0* | 0* | 1177 | | |
| Rye Patch Dam, 40°28′N, 118°18′W | | | | | | | | | | | | | | | |
| Calculated | 0.0 | 13.0 | 48.2 | 106.9 | 190.4 | 255.7 | 317.0 | 248.9 | 173.7 | 78.5 | 17.9 | 0.0 | 1450 | 0.949 | 1.398 |
| Measured | 0* | 0* | 0+ | 163.1 | 187.7 | 236.0 | 283.7 | 252.2 | 176.0 | 111.0 | 0+ | 0* | 1410 | | |

0* indicates that no evaporation measurements were made for that month at the station.
0+ indicates that only one to three evaporation measurements were made for that month at the station.
*Note:* Measured values are reported to two significant figures. Calculated values are listed with two significant figures for comparative purposes.
The $R^2$ and slopes are calculated omitting the values followed by * or + because few or no evaporation measurements were made for those months.

**Table 2—Measured values of pan evaporation, precipitation, and temperature at three stations in Nevada.**

| | Boulder City | | | | Imlay | | | | Ruby Lake | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elev (ft) | 2,520 | | | | 4,260 | | | | 6,010 | | | |
| Elev (m) | 768 | | | | 1299 | | | | 1832 | | | |
| Lat | 35.9833° | | | | 40.6500° | | | | 40.2000° | | | |
| Long | 114.8500° | | | | 118.1500° | | | | 114.8500° | | | |
| | Evap (mm) | Precip (mm) | Temp (°C) | Precip - Evap | Evap (mm) | Precip (mm) | Temp (°C) | Precip - Evap | Evap (mm) | Precip (mm) | Temp (°C) | Precip - Evap |
| JAN | 88.14 | 17.27 | 7.88 | -70.87 | 0.00 | 18.03 | -1.16 | 18.03 | * | 34.04 | -3.15 | ? |
| FEB | 113.54 | 15.24 | 10.49 | -98.30 | 14.04 | 16.26 | 2.66 | 2.22 | * | 30.23 | -0.74 | ? |
| MAR | 184.66 | 18.03 | 13.86 | -166.63 | 50.32 | 19.56 | 5.62 | -30.76 | * | 33.53 | 2.58 | ? |
| APR | 261.37 | 8.38 | 18.51 | -252.99 | 110.28 | 18.80 | 9.53 | -91.48 | 129.79 | 26.67 | 7.03 | -103.12 |
| MAY | 336.30 | 4.83 | 23.19 | -331.47 | 190.91 | 23.88 | 14.00 | -167.03 | 180.09 | 33.27 | 11.58 | -146.81 |
| JUN | 404.62 | 2.29 | 28.40 | -402.33 | 264.15 | 21.34 | 19.27 | -242.82 | 225.04 | 20.83 | 16.28 | -204.22 |
| JUL | 402.34 | 12.45 | 31.66 | -389.89 | 327.58 | 5.33 | 23.58 | -322.25 | 267.21 | 12.95 | 20.68 | -254.25 |
| AUG | 348.23 | 18.03 | 30.63 | -330.20 | 255.88 | 9.40 | 22.16 | -246.48 | 236.98 | 17.53 | 19.69 | -219.46 |
| SEP | 281.94 | 13.97 | 26.98 | -267.97 | 177.71 | 10.16 | 17.35 | -167.55 | 165.86 | 19.30 | 14.78 | -146.56 |
| OCT | 193.40 | 8.89 | 20.53 | -184.51 | 81.95 | 13.46 | 11.29 | -68.49 | 101.60 | 24.89 | 8.94 | -76.71 |
| NOV | 115.82 | 11.94 | 12.96 | -103.88 | 17.51 | 19.05 | 4.01 | 1.54 | * | 35.81 | 2.33 | ? |
| DEC | 83.06 | 13.97 | 8.57 | -69.09 | 0.00 | 18.03 | -0.14 | 18.03 | * | 36.58 | -2.34 | ? |

* no evaporation measurements.

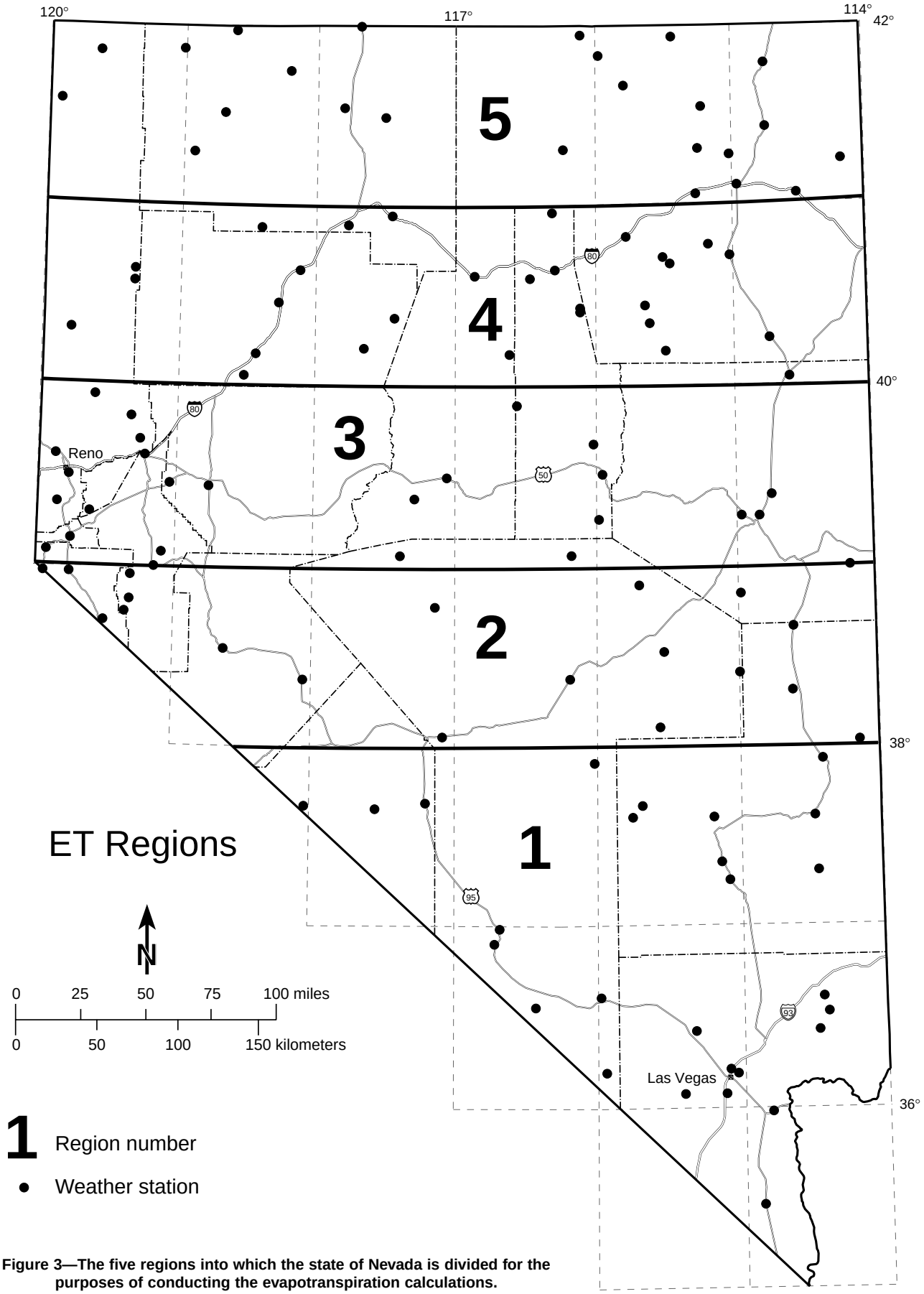


**Figure 3—The five regions into which the state of Nevada is divided for the purposes of conducting the evapotranspiration calculations.**

**Table 3—Linear regression calculated for the estimation of PET (in millimeters) as a function of elevation (in meters) for the five regions in Nevada.**

**PET = A(Elevation) + b**

| | Region 1 | | | | Region 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | A | b | $R^2$ | Elevation (m) | A | b | $R^2$ | Elevation (m) |
| | # stations = 27 | | | | # stations = 22 | | | |
| January | | | | | | | | |
| line 1 | -0.0153 | 43.933 | 0.3691 | ≤1082 | | | | |
| line 2 | -0.0794 | 110.413 | 0.7985 | >1082 - 1341 | | | | |
| line 3 | 0 | 0 | | 1341 - 3827 | | | | |
| February | | | | | | | | |
| line 1 | -0.0434 | 87.100 | 0.764 | <1463 | -0.0259 | 51.934 | 0.698 | ≤2000 |
| line 2 | -0.0241 | 51.314 | 0.517 | 1463 - 2125 | 0 | 0 | | >2000 - 3850 |
| line 3 | 0 | 0 | | >2125 - 3827 | | | | |
| March | | | | | | | | |
| line 1 | -0.0772 | 174.473 | 0.904 | ≤2259 | -0.0572 | 135.200 | 0.786 | ≤2287 |
| line 2 | 0 | 0 | | >2259 - 3827 | 0 | 0 | | >2287 - 3850 |
| line 3 | | | | | | | | |
| April | | | | | | | | |
| line 1 | -0.0971 | 264.690 | 0.889 | ≤2723 | -0.0695 | 210.332 | 0.739 | ≤3024 |
| line 2 | 0 | 0 | | >2723 | 0 | 0 | | >3024 - 3850 |
| line 3 | | | | | | | | |
| May | | | | | | | | |
| line 1 | -0.1073 | 371.478 | 0.815 | <1463 | -0.0785 | 303.333 | 0.589 | ≤3850 |
| line 2 | -0.1013 | 353.867 | 0.427 | 1463 - 3491 | | | | |
| line 3 | 0 | 0 | | >3491 - 3827 | | | | |
| June | | | | | | | | |
| line 1 | -0.1079 | 435.739 | 0.846 | ≤3827 | -0.0723 | 358.481 | 0.413 | ≤3850 |
| line 2 | | | | | | | | |
| July | | | | | | | | |
| line 1 | -0.1061 | 490.653 | 0.831 | ≤3827 | -0.0710 | 415.104 | 0.357 | ≤3850 |
| line 2 | | | | | | | | |
| August | | | | | | | | |
| line 1 | -0.0942 | 405.410 | 0.859 | ≤3827 | -0.0580 | 332.943 | 0.396 | ≤3850 |
| line 2 | | | | | | | | |
| September | | | | | | | | |
| line 1 | -0.0917 | 329.611 | 0.856 | <1341 | -0.0480 | 246.339 | 0.442 | ≤3850 |
| line 2 | -0.0756 | 318.055 | 0.691 | 1341 - 3827 | | | | |
| line 3 | | | | | | | | |
| October | | | | | | | | |
| line 1 | -0.0664 | 195.479 | 0.836 | <1463 | -0.0316 | 130.362 | 0.554 | ≤3850 |
| line 2 | -0.0260 | 125.629 | 0.181 | 1463 - 3827 | | | | |
| line 3 | | | | | | | | |
| November | | | | | | | | |
| line 1 | -0.0394 | 85.478 | 0.832 | <1299 | -0.0179 | 46.555 | 0.528 | ≤2604 |
| line 2 | -0.0299 | 78.616 | 0.572 | 1299 - 2774 | 0 | 0 | | >8540 - 12,628 |
| line 3 | 0 | 0 | | >2774 - 3827 | | | | >2604 - 3850 |
| December | | | | | | | | |
| line 1 | -0.0281 | 48.278 | 0.791 | <1299 | -0.0282 | 41.959 | 0.508 | ≤1485 |
| line 2 | 0 | 0 | | 1299 - 3827 | 0 | 0 | | >1485 - 3850 |

| | Region 3 | | | | Region 4 | | | |
|---|---|---|---|---|---|---|---|---|
| | A | b | $R^2$ | Elevation (m) | A | b | $R^2$ | Elevation (m) |
| | # stations = 27 | | | | # stations = 29 | | | |
| January | | | | | | | | |
| line 1 | | | | | | | | |
| line 2 | | | | | | | | |
| line 3 | | | | | | | | |
| February | | | | | | | | |
| line 1 | -0.0205 | 42.073 | 0.801 | ≤1951 | -0.0204 | 37.366 | 0.616 | ≥1835 |
| line 2 | 0 | 0 | | >1951 - 3850 | 0 | 0 | | >1835 - 3351 |
| line 3 | | | | | | | | |
| March | | | | | | | | |
| line 1 | -0.0539 | 125.184 | 0.852 | ≤2287 | -0.0510 | 112.225 | 0.751 | ≤2201 |
| line 2 | 0 | 0 | | >2287 - 3850 | 0 | 0 | | >2201 - 3351 |
| line 3 | | | | | | | | |
| April | | | | | | | | |
| line 1 | -0.0734 | 208.504 | 0.799 | ≤2838 | -0.1194 | 258.499 | 0.888 | ≤1652 |
| line 2 | 0 | 0 | | >2838 - 3850 | -0.0656 | 188.083 | 0.765 | >1652 - 2805 |
| line 3 | | | | | 0 | 0 | | >2805 - 3351 |
| May | | | | | | | | |
| line 1 | -0.0821 | 300.185 | 0.822 | ≤3655 | -0.1463 | 377.957 | 0.790 | ≤1652 |
| line 2 | 0 | 0 | | >3655 - 3850 | -0.0827 | 295.112 | 0.707 | >1652 - 3351 |
| line 3 | | | | | | | | |

**Table 3—Linear regression calculated for the estimation of PET (in millimeters) as a function of elevation (in meters) for the five regions in Nevada (continued).**

| | Region 3 | | | | Region 4 | | | |
|---|---|---|---|---|---|---|---|---|
| | A | b | $R^2$ | Elevation (m) | A | b | $R^2$ | Elevation (m) |
| | # stations = 27 | | | | # stations = 29 | | | |
| June | | | | | | | | |
| line 1 | -0.0738 | 350.836 | 0.728 | ≤3850 | -0.0800 | 356.229 | 0.625 | ≤3351 |
| line 2 | | | | | | | | |
| July | | | | | | | | |
| line 1 | -0.0708 | 407.096 | 0.599 | ≤3850 | -0.1504 | 513.950 | 0.588 | ≤1655 |
| line 2 | | | | | -0.0758 | 416.297 | 0.482 | 1655 - 3351 |
| August | | | | | | | | |
| line 1 | -0.0538 | 320.344 | 0.556 | ≤3850 | -0.1176 | 402.588 | 0.619 | ≤1655 |
| line 2 | | | | | -0.0507 | 314.878 | 0.388 | 1655 - 3351 |
| September | | | | | | | | |
| line 1 | -0.0461 | 235.708 | 0.587 | ≤3850 | -0.0537 | 241.125 | 0.484 | ≤3351 |
| line 2 | | | | | | | | |
| line 3 | | | | | | | | |
| October | | | | | | | | |
| line 1 | -0.0316 | 123.972 | 0.611 | ≤3850 | -0.0882 | 190.979 | 0.812 | ≤1652 |
| line 2 | | | | | -0.0316 | 117.220 | 0.457 | >1652 - 3351 |
| line 3 | | | | | | | | |
| November | | | | | | | | |
| line 1 | -0.0180 | 44.313 | 0.580 | ≤2454 | -0.0363 | 63.097 | 0.687 | ≤1652 |
| line 2 | 0 | 0 | | >2454 - 3850 | -0.0197 | 41.245 | 0.653 | >1652 - 2095 |
| line 3 | | | | | 0 | 0 | | >2095 - 3351 |
| December | | | | | | | | |
| line 1 | -0.0105 | 16.272 | 0.146 | ≤1418 | -0.0359 | 44.250 | 0.126 | ≤1232 |
| line 2 | 0 | 0 | | >1418 - 3850 | 0 | 0 | | >1232 - 3351 |

| | Region 5 | | | |
|---|---|---|---|---|
| | A | b | $R^2$ | Elevation (m) |
| | # stations = 24 | | | |
| January | | | | |
| line 1 | | | | |
| line 2 | | | | |
| line 3 | | | | |
| February | | | | |
| line 1 | -0.0548 | 80.760 | 0.501 | ≤1463 |
| line 2 | 0 | 0 | | >1463 - 3195 |
| line 3 | | | | |
| March | | | | |
| line 1 | -0.0895 | 158.239 | 0.661 | ≤1723 |
| line 2 | -0.0630 | 120.778 | 0.790 | >1723 - 1915 |
| line 3 | 0 | 0 | | >1915 - 3195 |
| April | | | | |
| line 1 | -0.0704 | 183.852 | 0.788 | ≤2607 |
| line 2 | 0 | 0 | | >2607 - 3195 |
| line 3 | | | | |
| May | | | | |
| line 1 | -0.0921 | 297.000 | 0.777 | ≤3195 |
| line 2 | | | | |
| line 3 | | | | |
| June | | | | |
| line 1 | -0.0999 | 373.784 | 0.761 | ≤3195 |
| line 2 | | | | |
| July | | | | |
| line 1 | -0.0957 | 431.310 | 0.614 | ≤3195 |
| line 2 | | | | |
| August | | | | |
| line 1 | -0.0738 | 337.770 | 0.601 | ≤3195 |
| line 2 | | | | |
| September | | | | |
| line 1 | -0.0515 | 225.850 | 0.496 | ≤3195 |
| line 2 | | | | |
| line 3 | | | | |
| October | | | | |
| line 1 | -0.0392 | 120.631 | 0.496 | <1838 |
| line 2 | -0.0417 | 131.118 | 0.084 | 1838 - 3146 |
| line 3 | 0 | 0 | | >3146 - 3195 |
| November | | | | |
| line 1 | -0.0215 | 40.764 | 0.526 | ≤1893 |
| line 2 | 0 | 0 | | >1893 - 3195 |
| line 3 | | | | |
| December | | | | |
| line 1 | 0 | 0 | | ≥1277 |
| line 2 | | | | |

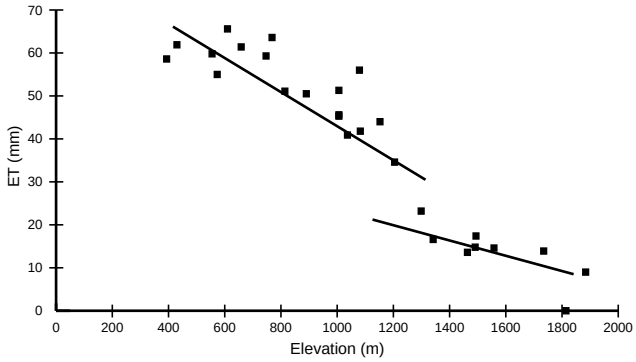


**Figure 4—Evapotranspiration versus elevation for February in region 1 showing a change in slope. This change in slope has also been observed in other regions and months.**

positive PET value was calculated at the lower elevations (that is, to assure round-off errors did not result in negative PET values at the lower elevations).

Note that very poor correlations occur for some months, for some of the segments. However, for many of the months, correlations are generally fairly good. In the southern part of the state, the $R^2$ values for January through April for the segments of the PET-elevation relationships which show the best correlation range from 0.764 to 0.904 (0.369 to 0.517 for the less well correlated segments). In the northern part of the state, the $R^2$ values for February through May range from 0.501 to 0.888. Numerous scenarios were attempted to estimate PET in the northern part of the state in region 5, yet the estimates for the eastern half of the region are poor regardless of the method of calculation. For instance, splitting region 5 into an east and west half produced no improvements in the PET estimates, and hence, it is retained here as one region. Because of the relatively poor estimates in the eastern half of region 5, discontinuities in the PET trends between the eastern halves of regions 4 and 5 are obtained for some months, and these data should be used with caution. However, when the average yearly PET are calculated, correlations improve and this discontinuity is subdued significantly. Nevertheless, during modeling and extrapolating PET from lower to higher elevations, the equations listed in table 3 are assumed to reasonably represent the variability of PET on a regional scale. In order to determine if the original elevation cut-offs identified by a change in slope in the PET-elevation relationships were reasonable, snowpack data were consulted (table 4) and compared with these initial values. table 5 lists the original elevations over which PET was calculated as zero, the snow depth at the minimum reported elevation, the calculated PET value at the highest elevation calculated using temperature measurements (prior to making the linear regression analysis of the data), the PET value which would be calculated at the noted snow elevation based on the linear regression equations, and a new elevation to account for any discrepancies. The new elevation row is omitted when no changes were made. The final, revised regression equations accounting for the changes in the elevation cut-offs noted in table 5 are incorporated into table 3. When the value is <0 in the PET calc @ snow elevation column, it indicates that the regression calculation of PET at the indicated elevation cut-off is reasonable. Although not all values in this row are <0, most are very close to zero in January through March and November and December, when snow is accumulating. Greater discrepancies occur in April and May, and all regions show that the PET calculated at the point of the lowest snowpack elevation is >0. Although snowpack remains at the higher elevations during these months, it is melting at that time. Hence, temperatures are above freezing, ET is positive, but percolation is also likely to occur from the snowmelt. The calculated PET values are, therefore, reasonable for these months because it is sufficiently warm for ET to occur, and there is water available for evaporation.

Table 6 lists measured pan evaporation and calculated PET values at stations for which pan evaporation measurements are available. Data labelled “Calc 1” represent the values calculated from Equation (3) using temperature and solar radiation, whereas Calc 2 represents values calculated from the linear regression equations in table 3. The $R^2$ and slopes are for linear regression between the Calc 1 values and measured pan evaporation values (first entries), and the Calc 2 and measured pan evaporation values (second entries). The $R^2$ varies from 0.942 to 0.990 (slopes = 0.909 to 1.398) for the Calc 1 data, and that for the Calc 2 data ranges from 0.942 to 0.985 (slopes = 0.942 to 1.342). Hence, correlations are generally good, and slopes approach a value of one indicating that the calculated Calc 2 values will provide reasonable estimates on the regional variability of PET in Nevada.

Table 6 also lists a comparison between measured pan evaporation, and final GIS calculated PET based on slope and aspect. Good agreement between the calculated and measured values are seen in all regions during the summer months. Poorer agreement is observed in the winter months, due in part to less available data, and a large number of zero PET values. In addition, during the winter months there is greater cloud cover and the Behnke-Maxey method is more applicable to cloudless skies. Hence, during the summer months, when plant consumptive use and irrigation issues are important, the calculated PET values are very good and can be used in regional water planning. The values calculated for the winter months, on the other hand, appear to be approximately 50% of the measured pan evaporation value, and this trend should be recognized in use of these data.

Figures 5, 6, 7, and 8 illustrate the difference between measured pan evaporation and calculated PET at two sites. The data labelled Measured are the pan evaporation data; the data labeled Solar are the PET values obtained from the Behnke and Maxey (1969) method (equation 3); those labeled Region were calculated using the linear regression equations for each month (table 3) and the station elevation; and the GIS data were calculated using the table 3 equations, the weighting factors for the grid, and the average grid cell elevations. The curves are very similar in figures 7 and 8, yet there is some disagreement in the colder months at the Beowawe University of Nevada Ranch weather station because of insufficient pan evaporation data having been collected at the station during these months. Figures 5 and 6 show measured pan evaporation versus calculated PET points and linear regression lines for these data. The Beowawe data show that the GIS PET is, on average, lower than the other calculated data for the station. This results because the GIS calculated PET is for a 1-km grid cell, over which elevation varies. The GIS grid averages the elevations over the grid cell, and in this case, the elevation used in the calculations is 1,779 m (5,834 feet), whereas the

**Table 4—Data on snowpacks compiled from Greenlee (1994).**

| | Data Type* | State | Elev (m) | Lat (degrees) | Long (degrees) | Measured Snowpack Depth (values in centimeters) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| **Region 1** | | | | | | | | | | | | | | | | | |
| Rainbow Canyon 2 | 2 | NV | 2470 | 36.25 | 115.633 | | | 32.3 | 37.8 | | | | | | | | |
| Kyle Canyon | 2 | NV | 2500 | 36.267 | 115.667 | | | 24.1 | 22.6 | | | | | | | | |
| Lee Canyon 3 | 2 | NV | 2591 | 36.283 | 115.683 | | | 19.8 | 19.6 | | | | | | | | |
| Lee Canyon 2 | 2 | NV | 2805 | 36.317 | 115.667 | | | 22.4 | 24.4 | | | | | | | | |
| Tioga Pass | 2 | CA | 3018 | 37.917 | 119.25 | | 43.7 | 48.8 | 65.3 | 49.3 | | | | | | | |
| **Region 2** | | | | | | | | | | | | | | | | | |
| Spratt Creek | 1 | CA | 1845 | 38.667 | 119.817 | 9.4 | 14.5 | 7.9 | 2.3 | 0 | 0 | 0 | 0 | 0 | 0 | 1.5 | 4.3 |
| Fallen Leaf | 1 | CA | 1921 | 38.933 | 120.05 | 8.6 | 11.4 | 9.9 | 4.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 5.3 |
| Upper Truckee | 2 | CA | 1951 | 38.867 | 119.983 | | 16.5 | 21.3 | 20.1 | | | | | | | | |
| Richardsons 2 | 2 | CA | 1982 | 38.917 | 120.05 | 13.7 | 25.7 | 35.8 | 40.1 | | | | | | | | |
| Leavitt Meadows | 1 | CA | 2195 | 38.333 | 119.55 | 13.7 | 20.3 | 20.1 | 11.4 | 4.1 | 0 | 0 | 0 | 0 | 0 | 1.3 | 8.4 |
| Freel Bench | 2 | CA | 2226 | 38.85 | 119.95 | | 20.3 | 25.7 | 25.1 | | | | | | | | |
| Echo Summit | 2 | CA | 2271 | 38.833 | 120.033 | | 53.3 | 69.9 | 83.1 | 67.3 | | | | | | | |
| Echo Peak | 1 | CA | 2378 | 38.85 | 120.067 | 52.8 | 73.9 | 92.7 | 85.1 | 46.7 | 8.9 | 0 | 0 | 0 | 0.5 | 7.4 | 30.5 |
| Poison Flat | 1 | CA | 2409 | 38.5 | 119.633 | 27.9 | 41.4 | 54.9 | 35.3 | 11.9 | 0 | 0 | 0 | 0 | 0 | 3.3 | 15.5 |
| Blue Lakes | 1 | CA | 2439 | 38.6 | 119.917 | 31.8 | 62 | 83.1 | 90.4 | 68.8 | 18.5 | 0.8 | 0 | 0 | 1 | 9.7 | 27.2 |
| Blue Lakes | 2 | CA | 2439 | 38.6 | 119.917 | | 60.5 | | 89.2 | 82.6 | | | | | | | |
| Hagan's Meadow | 1 | CA | 2439 | 38.85 | 119.933 | 22.1 | 32.3 | 38.4 | 31.8 | 11.2 | 0 | 0 | 0 | 0 | 0 | 3.3 | 11.9 |
| Lake Lucille | | CA | 2500 | 38.867 | 120.117 | | | | | | | | | | | | |
| Willow Flat | 2 | CA | 2515 | 38.267 | 119.45 | | 17.3 | 26.4 | | | | | | | | | |
| Carson Pass, Upper | 2 | CA | 2622 | 38.7 | 119.983 | | 53.6 | 75.7 | 89.2 | 78.7 | | | | | | | |
| Ebbetts Pass | 1 | CA | 2652 | 38.55 | 119.8 | 47.5 | 63.8 | 88.4 | 90.9 | 58.4 | 16 | 0 | 0 | 0 | 0 | 9.4 | 25.4 |
| Sawmill Ridge | 2 | CA | 2668 | 38.117 | 119.35 | | | | 47 | | | | | | | | |
| Sonora Pass | 1 | CA | 2683 | 38.317 | 119.6 | 33 | 47.5 | 65.8 | 69.6 | 40.6 | 3.8 | 0 | 0 | 0 | 0.5 | 5.6 | 17.5 |
| Sonora Pass Bridge | | CA | 2683 | 38.317 | 119.6 | | | | | | | | | | | | |
| Heavenly Valley | 1 | CA | 2698 | 38.933 | 119.933 | 33.3 | 48.8 | 68.1 | 68.6 | 37.8 | 4.1 | 0 | 0 | 0 | 0.8 | 6.6 | 19.6 |
| Virginia Lakes Ridge | 1 | CA | 2805 | 38.083 | 119.25 | 22.1 | 31 | 45.5 | 47.8 | 30.7 | 3 | 0 | 0 | 0 | 0.3 | 4.8 | 12.2 |
| Virginia Lakes Ridge | 2 | CA | 2805 | 38.083 | 119.25 | | | | 49.8 | | | | | | | | |
| Lobdell Lake | 1 | CA | 2805 | 38.433 | 119.367 | 21.1 | 30 | 40.6 | 39.6 | 19.6 | 0.5 | 0 | 0 | 0 | 0 | 4.1 | 11.2 |
| Leavitt Lake | 2 | CA | 2866 | 38.267 | 119.617 | 50.8 | 73.4 | 102.6 | 125.5 | 134.1 | | | | | | | |
| White River 1 | 2 | NV | 2268 | 38.933 | 115.383 | | | 7.1 | 4.6 | | | | | | | | |
| Baker Creek 1 | 2 | NV | 2424 | 38.967 | 114.25 | | 11.7 | 13.2 | 16.3 | | | | | | | | |
| Corduroy Flat | 2 | NV | 2659 | 38.983 | 115.417 | | | 11.9 | 11.2 | | | | | | | | |
| Baker Creek 2 | 2 | NV | 2729 | 38.967 | 114.267 | | | 29 | 37.1 | | | | | | | | |
| Baker Creek 3 | 2 | NV | 2820 | 38.967 | 114.267 | | | 31.8 | 43.4 | | | | | | | | |
| **Region 3** | | | | | | | | | | | | | | | | | |
| Truckee 2 | 1 | CA | 1951 | 39.25 | 120.05 | 21.6 | 32.8 | 38.4 | 26.2 | 11.4 | 0 | 0 | 0 | 0 | 0 | 1.8 | 11.2 |
| Truckee 2 | 2 | CA | 1951 | 39.25 | 120.05 | 0 | 22.9 | 30 | 34.3 | | | | | | | | |
| Fordyce Lake | | CA | 1982 | 39.35 | 120.5 | | | | | | | | | | | | |
| Independence Creek | 1 | CA | 1982 | 39.483 | 120.283 | 18 | 28.7 | 36.1 | 18.8 | 4.8 | 0 | 0 | 0 | 0 | 0 | 2 | 9.1 |
| Independence Creek | 2 | CA | 1982 | 39.483 | 120.283 | 0 | | | 31.8 | | | | | | | | |
| Furnace Flat | 2 | CA | 2043 | 39.35 | 120.5 | | 66.8 | 94.5 | 120.1 | 113.5 | | | | | | | |
| Tahoe City Cross | 1 | CA | 2058 | 39.167 | 120.15 | 23.4 | 31.2 | 32 | 16.8 | 7.4 | 0 | 0 | 0 | 0 | 0 | 3 | 12.4 |
| Ward Creek 3 | 1 | CA | 2058 | 39.133 | 120.233 | 35.3 | 53.6 | 84.8 | 81.5 | 48.8 | 22.6 | 0 | 0 | 0 | 0 | 4.6 | 18.5 |
| Ward Creek 3 | 2 | CA | 2058 | 39.133 | 120.233 | | | | 98.6 | | | | | | | | |

*continued*

**Table 4—Data on snowpacks compiled from Greenlee (1994) (continued).**

| | Data Type* | State | Elev (m) | Lat (degrees) | Long (degrees) | Measured Snowpack Depth (values in centimeters) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Donner Summit | 2 | CA | 2104 | 39.283 | 120.333 | 41.9 | 59.9 | 80.5 | 94.7 | 78.7 | 74.4 | | | | | | |
| Central Sierra Snow Lab | 1 | CA | 2104 | 39.317 | 120.383 | 44.2 | 59.2 | 72.6 | 55.9 | 16.8 | 0 | 0 | 0 | 0 | 0 | 7.6 | 27.2 |
| Ward Creek 2 | 2 | CA | 2134 | 39.133 | 120.217 | | 63.2 | 83.8 | 101.1 | | | | | | | | |
| Independence Camp | 1 | CA | 2134 | 39.45 | 120.283 | 26.9 | 40.6 | 54.6 | 43.9 | 15.7 | 0.3 | 0 | 0 | 0 | 0 | 3 | 13.2 |
| Independence Camp | 2 | CA | 2134 | 39.45 | 120.283 | | | | 55.1 | | | | | | | | |
| Webber Lake | 2 | CA | 2134 | 39.483 | 120.433 | | | | 79.5 | | | | | | | | |
| Castle Creek | 2 | CA | 2256 | 39.317 | 120.35 | | 83.8 | 106.4 | 132.1 | 111.8 | 100.8 | | | | | | |
| Rubicon 2 | 1 | CA | 2287 | 39 | 120.133 | 32.5 | 49.8 | 66.3 | 66.5 | 36.6 | 2.5 | 0 | 0 | 0 | 0.5 | 4.6 | 19.1 |
| Squaw Valley 2 | 2 | CA | 2287 | 39.183 | 120.25 | | 78 | 103.1 | 126.2 | | | | | | | | |
| Webber Peak | 2 | CA | 2439 | 39.483 | 120.433 | | | | 110.2 | | | | | | | | |
| Rubicon1 | | CA | 2470 | 39 | 120.133 | | | | | | | | | | | | |
| Squaw Valley Gold Coast | 1 | CA | 2500 | 39.183 | 120.25 | 60.7 | 88.4 | 114 | 116.3 | 76.5 | 31 | 3.6 | 0 | 0 | 1 | 10.4 | 35.8 |
| Independence Lake | 1 | CA | 2576 | 39.417 | 120.317 | 50 | 71.4 | 96.8 | 112.5 | 105.7 | 55.9 | 11.7 | 0 | 0 | 0.8 | 9.7 | 28.4 |
| Independence Lake | 2 | CA | 2576 | 39.417 | 120.317 | | | | 107.7 | | | | | | | | |
| Little Valley | 2 | NV | 1921 | 39.25 | 119.883 | | 11.2 | 20.1 | 15 | | | | | | | | |
| Big Creek Campground | | NV | 2012 | 39.367 | 117.133 | | | | | | | | | | | | |
| Glenbrook #2 | 2 | NV | 2104 | 39.083 | 119.917 | 9.9 | 18.8 | 24.6 | 29.2 | | | | | | | | |
| Murray Summit | 2 | NV | 2210 | 39.233 | 114.967 | | | 7.4 | 4.8 | | | | | | | | |
| Clear Creek | 2 | NV | 2226 | 39.117 | 119.9 | | 18.3 | 26.4 | 29 | | | | | | | | |
| Kalamazoo Creek | 2 | NV | 2256 | 39.567 | 114.667 | | | 17.8 | 20.1 | | | | | | | | |
| Bird Creek | 2 | NV | 2287 | 39.467 | 114.65 | | | 9.4 | 6.9 | | | | | | | | |
| Big Creek Mine | | NV | 2317 | 39.333 | 117.117 | | | | | | | | | | | | |
| Robinson Summit | 2 | NV | 2317 | 39.4 | 115.1 | | | 5.1 | 2 | | | | | | | | |
| Marlette Lake | 1 | NV | 2439 | 39.15 | 119.9 | 27.2 | 38.9 | 53.1 | 50.5 | 23.6 | 2.5 | 0 | 0 | 0 | 0.5 | 4.1 | 16.5 |
| Marlette Lake | 2 | NV | 2439 | 39.15 | 119.9 | | | | 56.9 | | | | | | | | |
| Silver Creek 2 | 2 | NV | 2439 | 39.233 | 114.25 | | | 13 | 12.2 | | | | | | | | |
| Diamond Peak | 1 | NV | 2451 | 39.567 | 115.85 | 10.2 | 14.2 | 13.5 | 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 1.3 | 4.8 |
| Big Meadow | 1 | NV | 2530 | 39.45 | 119.95 | 25.4 | 35.8 | 52.3 | 42.9 | 12.7 | 0 | 0 | 0 | 0 | 0 | 3.6 | 16.8 |
| Big Creek Summit | 1 | NV | 2652 | 39.317 | 117.117 | 20.6 | 27.2 | 35.6 | 42.4 | 25.7 | 0 | 0 | 0 | 0 | 0.5 | 2.3 | 11.7 |
| Mt Rose Ski Area | 1 | NV | 2744 | 39.317 | 119.883 | 56.1 | 77 | 103.4 | 111 | 77.7 | 29.7 | 0.5 | 0 | 0 | 0.8 | 13.2 | 37.3 |
| Mt Rose Ski Area | 2 | NV | 2744 | 39.317 | 119.883 | | | | 107.7 | | | | | | | | |
| Mt Rose | | NV | 2744 | 39.35 | 119.883 | | | | | | | | | | | | |
| Berry Creek | 1 | NV | 2774 | 39.35 | 114.65 | 16 | 22.6 | 29.7 | 34.8 | 24.9 | 7.9 | 0 | 0 | 0 | 1.5 | 4.1 | 9.4 |
| Defiance Mines | 2 | NV | 2805 | 39.083 | 114.95 | | | 39.1 | 45.2 | | | | | | | | |
| Ward Mountain | 1 | NV | 2805 | 39.133 | 114.817 | 14.2 | 20.8 | 27.2 | 22.1 | 8.6 | 0 | 0 | 0 | 0 | 0.8 | 3 | 8.6 |
| **Region 4** | | | | | | | | | | | | | | | | | |
| Corral Canyon | 1 | NV | 2591 | 40.283 | 115.533 | 23.4 | 31.2 | 42.2 | 50.5 | 25.4 | 0 | 0 | 0 | 0 | 1 | 4.1 | 14.5 |
| Harrison Pass 1 | 2 | NV | 2012 | 40.3 | 115.533 | | 21.3 | 9.9 | 7.1 | | | | | | | | |
| Green Mountain | 1 | NV | 2439 | 40.383 | 115.533 | 25.7 | 34 | 38.4 | 30 | 17.5 | 0 | 0 | 0 | 0 | 0.5 | 4.6 | 16.5 |
| Smith Creek | 2 | NV | 2317 | 40.45 | 115.517 | | | 29.5 | 37.1 | | | | | | | | |
| American Beauty | 2 | NV | 2378 | 40.517 | 115.433 | | 16.8 | 22.4 | 25.7 | | | | | | | | |
| Lamoille 5 | 2 | NV | 2652 | 40.6 | 115.367 | | 45 | 58.4 | 73.7 | | | | | | | | |
| Lamoille 3 | 1 | NV | 2348 | 40.633 | 115.4 | 20.3 | 27.4 | 35.3 | 26.9 | 10.2 | 0 | 0 | 0 | 0 | 0.3 | 3.6 | 12.4 |
| Lamoille 1 | 2 | NV | 2165 | 40.65 | 115.45 | | 15.2 | 21.6 | 23.1 | | | | | | | | |
| Robinson Lake | 2 | NV | 2805 | 40.733 | 115.267 | | 53.6 | 72.4 | 78 | | | | | | | | |
| Dry Creek | 2 | NV | 1982 | 40.85 | 115.2 | | 12.7 | 10.2 | 5.6 | | | | | | | | |
| Pole Canyon 2 | 2 | NV | 2348 | 40.85 | 115.117 | | | 36.1 | 41.1 | | | | | | | | |

**Table 4—Data on snowpacks compiled from Greenlee (1994) (continued).**

| | Data Type* | State | Elev (m) | Lat (degrees) | Long (degrees) | Measured Snowpack Depth (values in centimeters) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Dorsey Basin | 1 | NV | 2470 | 40.883 | 115.2 | 21.1 | 29.7 | 37.1 | 33.3 | 16 | 0 | 0 | 0 | 0 | 0.5 | 3 | 11.9 |
| Golconda #2 | 2 | NV | 1829 | 40.9 | 117.567 | | | 14 | 9.7 | | | | | | | | |
| Tent Mountain, Upper | 2 | NV | 2546 | 40.95 | 115.167 | | 39.1 | 49 | 57.9 | | | | | | | | |
| Hole-in-mountain | 1 | NV | 2409 | 40.967 | 115.05 | 19.1 | 26.4 | 32.3 | 29.5 | 19.1 | 0 | 0 | 0 | 0 | 0.3 | 2.5 | 10.4 |
| Tent Mountain, Lower | 2 | NV | 2134 | 40.967 | 115.167 | | 21.3 | 23.1 | 31.5 | | | | | | | | |
| **Region 5** | | | | | | | | | | | | | | | | | |
| Barber Creek | 2 | CA | 1982 | 41.233 | 120.117 | | 20.8 | | 29 | | | | | | | | |
| Dismal Swamp | 1 | CA | 2149 | 41.967 | 120.167 | 38.4 | 53.6 | 67.3 | 64.5 | 37.6 | 4.8 | 0 | 0 | 0 | 0.5 | 6.6 | 24.9 |
| Cedar Pass | 1 | CA | 2165 | 41.583 | 120.3 | 22.9 | 32.8 | 44.7 | 42.2 | 18.5 | 0 | 0 | 0 | 0 | 0.3 | 3.6 | 14.2 |
| Cedar Pass | 2 | CA | 2165 | 41.583 | 120.3 | 18.5 | 26.9 | 34.5 | 43.4 | 35.1 | | | | | | | |
| lamance Creek | 1 | NV | 1829 | 41.517 | 117.633 | 23.6 | 32.8 | 33.5 | 11.7 | 0 | 0 | 0 | 0 | 0 | 0.3 | 4.3 | 14.7 |
| Mt. Bidwell | 2 | CA | 2195 | 41.967 | 120.183 | | 38.9 | 51.1 | 66.8 | 79.5 | | | | | | | |
| Tremewan Ranch | 2 | NV | 1738 | 41.3 | 115.75 | 2.8 | 3.8 | 4.6 | 0.5 | | | | | | | | |
| Fortynine Mountain | 2 | NV | 1829 | 41.567 | 119.817 | | 8.1 | | 7.4 | | | | | | | | |
| Little Bally Mountain | 2 | NV | 1829 | 41.85 | 119.883 | | 6.6 | 8.4 | 7.6 | | | | | | | | |
| Taylor Canyon | 1 | NV | 1890 | 41.233 | 115.983 | 7.1 | 10.7 | 11.4 | 5.8 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0.3 | 3.8 |
| Quinn Ridge | 2 | NV | 1921 | 41.967 | 117.333 | | 4.3 | 4.6 | 2.5 | | | | | | | | |
| Hays Canyon | 2 | NV | 1951 | 41.3 | 119.933 | | 6.6 | | 6.4 | | | | | | | | |
| Disaster Peak | 1 | NV | 1982 | 41.967 | 118.2 | 20.8 | 28.4 | 26.9 | 16.8 | 0.8 | 0 | 0 | 0 | 0 | 0 | 1.3 | 12.7 |
| O'Neil Creek | 2 | NV | 1994 | 41.867 | 115.067 | | | 19.8 | 16 | | | | | | | | |
| Gold Creek | 2 | NV | 2012 | 41.767 | 115.717 | | 9.9 | 13.2 | 12.2 | | | | | | | | |
| Columbia Basin | 2 | NV | 2027 | 41.667 | 116.05 | | 18.5 | 21.8 | 17.3 | | | | | | | | |
| Big Bend | 1 | NV | 2043 | 41.767 | 115.717 | 13.2 | 19.6 | 22.4 | 16.3 | 2 | 0 | 0 | 0 | 0 | 0 | 0.8 | 6.9 |
| Fry Canyon | 2 | NV | 2043 | 41.583 | 115.917 | | 14.2 | 17.3 | 15.7 | | | | | | | | |
| Laurel Draw | 1 | NV | 2043 | 41.783 | 116.033 | 13.2 | 18.5 | 20.8 | 13.2 | 2.3 | 0 | 0 | 0 | 0 | 0 | 1.3 | 7.9 |
| Buckskin, Lower | 1 | NV | 2043 | 41.75 | 117.533 | 13.5 | 19.8 | 23.1 | 17 | 7.1 | 0 | 0 | 0 | 0 | 0 | 2 | 9.1 |
| Bald Mountain | | NV | 2049 | 41.783 | 119.617 | | | | | | | | | | | | |
| Rodeo Flat | 2 | NV | 2073 | 41.583 | 115.95 | | 11.9 | 15.7 | 15.2 | | | | | | | | |
| Jack Creek, Lower | | NV | 2073 | 41.533 | 116.033 | | | | | | | | | | | | |
| Trout Creek, Lower | 2 | NV | 2104 | 41.083 | 115.033 | | | 9.9 | 8.1 | | | | | | | | |
| Jakes Creek | 2 | NV | 2134 | 41.55 | 114.983 | | 12.2 | 14.2 | 24.6 | | | | | | | | |
| Merrit Mountain | 2 | NV | 2134 | 41.883 | 115.867 | | 13.7 | 17 | 14.7 | | | | | | | | |
| Fawn Creek | 1 | NV | 2149 | 41.817 | 116.1 | 25.4 | 35.8 | 45.7 | 49.3 | 20.8 | 0 | 0 | 0 | 0 | 0.5 | 4.1 | 16.3 |
| Seventysix Creek | 1 | NV | 2165 | 41.7 | 115.467 | 16 | 22.1 | 27.7 | 21.3 | 4.6 | 0 | 0 | 0 | 0 | 0 | 3.8 | 9.4 |
| Midas | | NV | 2195 | 41.267 | 116.833 | | | | | | | | | | | | |
| Jack Creek, Upper | 1 | NV | 2210 | 41.55 | 116.017 | 25.7 | 36.1 | 47 | 51.8 | 20.6 | 1 | 0 | 0 | 0 | 0.5 | 3.6 | 15 |
| Snowstorm Mountain | 2 | NV | 2256 | 41.333 | 116.983 | | 21.3 | 38.1 | 39.9 | | | | | | | | |
| Draw Creek | 1 | NV | 2271 | 41.65 | 115.317 | 20.3 | 26.2 | 31 | 18.5 | 1.5 | 0 | 0 | 0 | 0 | 0 | 2.3 | 13.2 |
| Toe Jam | 2 | NV | 2348 | 41.317 | 116.033 | | 16.8 | 22.1 | 22.9 | | | | | | | | |
| Stag Mountain | 2 | NV | 2378 | 41.417 | 115.45 | | 11.2 | 14.2 | 16.8 | | | | | | | | |
| Bear Creek | 1 | NV | 2378 | 41.833 | 115.45 | 24.4 | 37.6 | 49.8 | 56.4 | 39.9 | 0 | 0 | 0 | 0 | 0 | 3.3 | 12.7 |
| Granite Peak | 1 | NV | 2378 | 41.65 | 117.567 | 27.9 | 40.4 | 54.6 | 65.8 | 46.2 | 14 | 0 | 0 | 0 | 0.3 | 4.1 | 17.3 |
| Pole Creek Ranger Station | 1 | NV | 2540 | 41.867 | 115.25 | 25.4 | 35.8 | 46.7 | 53.8 | 35.3 | 0 | 0 | 0 | 0 | 0 | 6.1 | 15 |
| Jacks Peak | 2 | NV | 2567 | 41.533 | 116.017 | | 38.1 | 51.6 | 68.3 | | | | | | | | |
| Trout Creek, Upper | 2 | NV | 2591 | 41.067 | 115.033 | | | | 48.3 | | | | | | | | |

* 1 = SNOTEL data, 2 = Snow Course data.

**Table 5—Elevations at which PET is assumed zero due to below freezing temperatures or presence of snow.**

| | | Region 1 | Region 2 | Region 3 | Region 4 | Region 5 |
|---|---|---|---|---|---|---|
| January | Original Elevation (m)* | 1,341 | | | | |
| | Snow Depth (cm) | No data | | | | |
| | PET Value (mm)** | 0 | | | | |
| | PET elevation (m) | 1,341 | | | | |
| February | Original Elevation (m)* | 2,125 | 2,000 | 2,049 | 1,835 | 1,463 |
| | Snow Depth (cm) | 43.7 | 11.7 | 11.2 | 12.7 | 3.8 |
| | Snow Elevation (m) | 3,018 | 2,424 | 1,921 | 1,982 | 1,738 |
| | PET Value (mm)** | 9 | 0 & 1.3 | 0 & 8.8 | 0 & 18 | 0 |
| | PET elevation (m) | 1,860 | 1514 & 2082 | 1515 & 1933 | 1540 & 1655 | ≥1494 |
| | PET calc @ Snow Elev. | -21.5 | -11 | 2.6 | -3 | -14.5 |
| | New Elevation (m)+ | same | same | 1,951 | same | same |
| March | Original Elevation (m)* | 2,259 | 2,363 | 2,323 | 2,201 | 1,915 |
| | Snow Depth (cm) | 32.3 | 7.1 | 18.8 | 14 | 33.5 |
| | Snow Elevation (m) | 2,470 | 2,268 | 2,104 | 1,829 | 1,829 |
| | PET Value (mm)** | 39 | 13 | 0 & 13.4 | 14.3 | 0 & 13 |
| | PET elevation (m) | 1,884 | 2,183 | 2085 & 2183 | 6,520 | 1704 & 1881 |
| | PET calc @ Snow Elev. | -16 | 5.5 | 11.9 | 19 | 5.5 |
| | New Elevation (m)+ | same | 2,287 | 2,287 | same | same |
| April | Original Elevation (m)* | 2,723 | 3,024 | 2,838 | 2,866 | 2,607 |
| | Snow Depth (cm) | 37.8 & 24.4 | 4.6 | 29.2 | 9.7 | 11.7 |
| | Snow Elevation (m) | 2470 & 3018 | 2,268 | 2,104 | 1,829 | 1,829 |
| | PET Value (mm)** | 100 | 55.7 | 3.9 | 60.1 | 38.7 |
| | PET elevation (m) | 1,884 | 2,183 | 2,287 | 1,988 | 1,985 |
| | PET calc @ Snow Elev. | 24.6 | 52.7 | 52.1 | 68 | 54.9 |
| | New Elevation (m)+ | same | same | same | 2,805 | same |
| May | Original Elevation (m)* | 3,491 | >3850 | 3,655 | >3351 | 0 |
| | Snow Depth (cm) | No data | 4.1 | 15 | 10.2 | 3.8 |
| | Snow Elevation (m) | | 2,195 | 1,921 | 2,348 | 1,738 |
| | PET Value (mm)** | 184 | 127.6 | 91 | 138.8 | 0 |
| | PET elevation (m) | 1,884 | 2,183 | 2,287 | 1,988 | >1494 |
| | PET calc @ Snow Elev. | | 131 | 142.5 | 34.5 | 98.9 |
| November | Original Elevation (m)* | 2,774 | 2,604 | 2,454 | 2,095 | 1,893 |
| | Snow Depth (cm) | No data | No data | 4.1 | 3.6 | 14.7 |
| | Snow Elevation (m) | | | 2,439 | 2,348 | 1,829 |
| | PET Value (mm)** | 21 | 6.2 | 0 & 3.4 | 6.5 | 0 & 5.3 |
| | PET elevation (m) | 1,884 | 2,183 | 2085 & 2287 | 1,988 | 1829 & 1985 |
| | PET calc @ Snow Elev. | | ? | 0.3 | -4.9 | 1.4 |
| December | Original Elevation (m)* | 1,299 | 1,485 | 1,543 | 1,232 | 1,277 |
| | Snow Depth (cm) | No data | 4.3 (CA) | 16.5 | 12.4 | 14.7 |
| | Snow Elevation (m) | | 1,845 | 2,439 | 2,348 | 1,829 |
| | PET Value (mm)** | 0 | 0 & 3.6 | 0 & 3.6 | 0 & 1.3 | 0 |
| | PET elevation (m) | >1299 | 1457 & 1530 | 1280 & 1951 | 1204 & 1655 | 1,277 |
| | PET calc @ Snow Elev. | | -10.1 | -9.4 | -40 | 0 |
| | New Elevation (m)+ | same | same | 1,418 | same | same |

*Note:* The snow elevation is generally the lowest elevation for which a snow pack is reported.
* Elevation for which calculated PET approaches zero. PET assumed equal to zero above this elevation.
** PET value calculated from measured temperature at the highest elevation weather station in each region.
\+ New elevation over which PET is assumed equal to zero based on known snow depths.

**Table 6—Calculated PET and measured pan evaporation at Nevada stations with slope and aspect corrections incorporated. PET values are in millimeters. Measured elevations are in italics and GIS grid cell elevations are in bold (both values are in meters).**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual | $R^2$ | Slope |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Region 1** | | | | | | | | | | | | | | | |
| Boulder City | | | *768.3* | **858.3** | | | | | | | | | | | |
| Calc 1 | 39.9 | 63.6 | 133.5 | 214.1 | 314.4 | 375.8 | 432.2 | 353.1 | 283.8 | 163.4 | 67.2 | 36.3 | 2478 | 0.985 | 1.168 |
| Calc 2 | 32.1 | 53.8 | 115.3 | 190 | 289.1 | 352.8 | 409.3 | 333.1 | 259.1 | 144.3 | 55.2 | 26.6 | 2261 | 0.982 | 1.121 |
| GIS | 31.7 | 52.7 | 113.2 | 187.5 | 286.2 | 349.9 | 406.4 | 330.6 | 256.6 | 142.5 | 54.2 | 25.8 | 2237 | 0.981 | 1.114 |
| Measured | 88.1 | 113.5 | 184.7 | 261.4 | 336.3 | 404.6 | 402.3 | 348.2 | 281.9 | 193 | 115.8 | 83.1 | 2813 | | |
| Silver Peak | | | *1298.8* | **1340.2** | | | | | | | | | | | |
| Calc 1 | 0.8 | 23.2 | 74.1 | 140.1 | 238.2 | 308.3 | 363.3 | 289.2 | 209.7 | 99.3 | 25 | 0 | 1771 | 0.978 | 0.909 |
| Calc 2 | 7.3 | 30.9 | 74.4 | 138.6 | 232.2 | 295.6 | 353.1 | 283.1 | 210.3 | 109 | 39.9 | 0 | 1774 | 0.968 | 0.846 |
| GIS | 0 | 28.6 | 70.4 | 133.6 | 226.6 | 290 | 347.6 | 278.3 | 216 | 105.6 | 38.3 | 0 | 1735 | 0.962 | 0.837 |
| Measured | 0* | 97.5 | 184.4 | 256.3 | 346.5 | 408.7 | 449.8 | 397.8 | 283.7 | 172.5 | 74.7 | 0* | 2672 | | |
| **Region 2** | | | | | | | | | | | | | | | |
| Topaz Lake | | | *1530.5* | **1649.5** | | | | | | | | | | | |
| Calc 1 | 2.5 | 16.3 | 42.9 | 86.3 | 168.9 | 232.7 | 289.5 | 233.7 | 162.2 | 76.5 | 20.1 | 3.6 | 1335 | 0.981 | 1.274 |
| Calc 2 | 0 | 12.3 | 47.9 | 103.9 | 183.4 | 248 | 306.2 | 244.1 | 173 | 82.2 | 18.9 | 0 | 1420 | 0.985 | 1.303 |
| GIS | 0 | 9 | 41.3 | 97.3 | 177.9 | 245.4 | 305.4 | 243.3 | 171.5 | 80.2 | 17 | 0 | 1388 | 0.983 | 1.322 |
| Measured | 0* | 0* | 0* | 181.6 | 231.4 | 277.9 | 322.1 | 293.6 | 223.5 | 151.1 | 70.9+ | 0* | 1752 | | |
| **Region 3** | | | | | | | | | | | | | | | |
| Central Nevada Field LA | | | *1817.1* | **1798.5** | | | | | | | | | | | |
| Calc 1 | 0 | 0.1 | 21.8 | 57 | 145.1 | 206.1 | 268.4 | 209.3 | 140.2 | 52.4 | 9.5 | 0 | 1110 | 0.975 | 1.143 |
| Calc 2 | 0 | 4.5 | 27.4 | 75 | 151.2 | 216.7 | 278.4 | 222.6 | 151.7 | 66.6 | 11.5 | 0 | 1206 | 0.977 | 1.115 |
| GIS | 0 | 4.9 | 28.4 | 76.4 | 152.7 | 218.1 | 279.7 | 223.6 | 152.5 | 67.3 | 11.7 | 0 | 1215 | 0.977 | 1.117 |
| Measured | 0* | 0* | 74.7+ | 151.1 | 220.7 | 266.4 | 310.9 | 287.3 | 205.2 | 124 | 43.9+ | 0* | 1685 | | |
| Fallon Experiment Station | | | *1210.4* | **1210.4** | | | | | | | | | | | |
| Calc 1 | 0 | 15.1 | 55.8 | 114.5 | 193.8 | 250.9 | 311.9 | 246.1 | 172.1 | 81 | 19.5 | 0.9 | 1462 | 0.942 | 1.304 |
| Calc 2 | 0 | 17.1 | 60.1 | 119.6 | 200.9 | 261.5 | 321.3 | 255.2 | 179.7 | 85.9 | 22.5 | 3.6 | 1527 | 0.942 | 1.341 |
| GIS | 0 | 17.1 | 60.1 | 119.6 | 201 | 261.5 | 321.4 | 255.3 | 179.8 | 85.9 | 22.5 | 3.6 | 1528 | 0.942 | 1.342 |
| Measured | 34 | 56.6 | 111.5 | 156.2 | 194.6 | 225 | 249.2 | 217.2 | 153.7 | 98.8 | 58.2 | 1.2 | 1556 | | |
| Beowawe U of N Ranch | | | *1750* | **1778.5** | | | | | | | | | | | |
| Calc 1 | 0 | 0.5 | 31.9 | 81 | 153.1 | 220.4 | 279 | 220.8 | 150.3 | 64.6 | 9.4 | 0 | 1211 | 0.952 | 1.187 |
| Calc 2 | 0 | 5.9 | 31 | 79.9 | 156.7 | 221.7 | 283.1 | 226.2 | 154.8 | 68.8 | 12.7 | 0 | 1241 | 0.959 | 1.204 |
| GIS | 0 | 5.2 | 28.6 | 75.5 | 149.7 | 213 | 272.7 | 217.9 | 148.9 | 65.9 | 11.9 | 0 | 1189 | 0.96 | 1.165 |
| Measured | 0* | 0* | 0* | 91.4 | 191.3 | 228.9 | 263.4 | 235.5 | 175.3 | 112.5 | 0* | 0* | 1298 | | |
| **Region 4** | | | | | | | | | | | | | | | |
| Ruby Lake | | | *1832.3* | **2044.6** | | | | | | | | | | | |
| Calc 1 | 0 | 0 | 23.3 | 81.4 | 157.9 | 222.4 | 286.8 | 227.5 | 151.8 | 65.5 | 10.3 | 0 | 1227 | 0.99 | 1.29 |
| Calc 2 | 0 | 0.1 | 19.1 | 67.9 | 143.7 | 209.6 | 277.5 | 221.7 | 142.6 | 59.5 | 5.2 | 0 | 1147 | 0.988 | 1.279 |
| GIS | 0 | 0 | 6.4 | 50.7 | 120.8 | 186.1 | 253.6 | 205 | 128.7 | 50.7 | 0.3 | 0 | 1002 | 0.978 | 1.197 |
| Measured | 0* | 0* | 0* | 0+ | 180.09 | 225.04 | 267.21 | 236.98 | 165.86 | 101.6 | 0* | 0* | 1177 | | |
| Rye Patch Dam | | | *1259.1* | **1280.4** | | | | | | | | | | | |
| Calc 1 | 0 | 13 | 48.2 | 106.9 | 190.4 | 255.7 | 317 | 248.9 | 173.7 | 78.5 | 17.9 | 0 | 1450 | 0.949 | 1.398 |
| Calc 2 | 0 | 11.8 | 48.2 | 108.2 | 193.8 | 255.5 | 324.4 | 254.3 | 173.4 | 79.9 | 17.3 | 0 | 1467 | 0.953 | 1.429 |
| GIS | 0 | 11.3 | 47.1 | 105.6 | 190.7 | 253.8 | 321.2 | 251.8 | 172.3 | 78 | 16.5 | 0 | 1448 | 0.952 | 1.424 |
| Measured | 0* | 0* | 0+ | 163.1 | 187.7 | 236 | 283.7 | 252.2 | 176 | 111 | 0+ | 0* | 1410 | | |

0* indicates that no evaporation measurements were made for that month at the station
0+ indicates that only one to three evaporation measurements were made for that month at the station
*Note:* Measured values are reported to two significant figures. Calculated values are listed with two significant figures for comparative purposes.
The first number on the station name line in italics is the reported weather station elevation, and the second number in bold is the GIS grid elevation.
Calc 1 refers to the PET calculated with the Behnke and Maxey (1969).
Calc 2 refers to PET calculated using linear regression equations between PET and elevation which appear in table 3.
GIS refers to the PET calculated using Calc 2 equations on GIS, the grid elevations, and the weighting factors.
The $R^2$ and slopes are for the comparison between Calc 1, Calc 2 and GIS and the measured pan evaporation values.
The $R^2$ and slopes are calculated omitting the values followed by * or + because few or no evaporation measurements were made for those months.

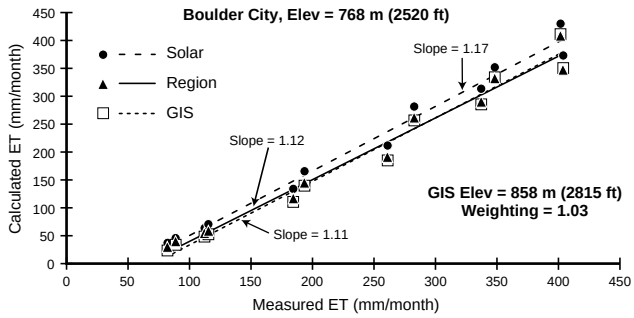


**Figure 5—Measured pan evaporation versus calculated PET points and linear regressions for PET calculated from solar radiation, from linear regressions with elevation, and final PET calculated using the GIS model.**

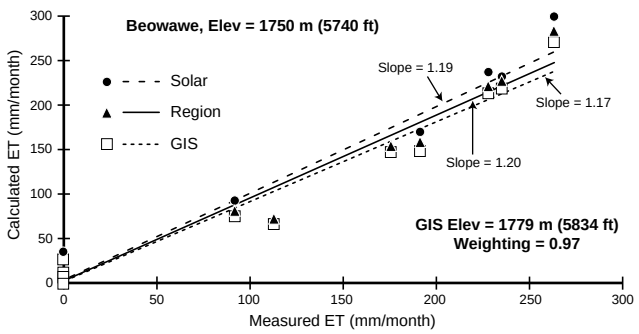


**Figure 6—Measured pan evaporation versus calculated PET points and linear regressions for PET calculated from solar radiation, from linear regressions with elevation, and final PET calculated using the GIS model.**

station elevation is 1,750 m (5,740 feet). Hence, with a higher elevation, plus a weighting factor of 0.97, GIS calculated PET for the station is lower than the measured pan evaporation, or other calculated values. Boulder City, on the other hand, shows good agreement between the Region and GIS calculated PET-elevation relationships due to a grid cell elevation of 858 m (2,815 feet; versus station elevation of 768.3 m) which tends to lower the PET, and a weighting factor (1.03) which tends to increase the PET. Nevertheless, the final GIS calculated values are somewhat lower than measured pan evaporation values or those calculated using solar radiation. Similar relationships are seen at the other eight stations in part due to the grid cell elevations being different than the station elevations. Of the eight stations with measured pan evaporation data, four sites had a weighting factor of 1.0 (Silver Peak, Central Nevada Field Station, Fallon and Rye Patch Dam).

Figures 9 through 21 are maps of the results of the PET data compilation for January through December, and for the average yearly PET with 10, 20, 40, 80 and 300 mm contour intervals as appropriate. Except for January and December, supplemental contours are drawn within each of the shaded areas. For instance, the light gray shaded area labelled >0 - 20 in February indicates the lower contour in contact with the white region has a value of 0 mm; the intermediate contour within the gray shading has a value of 10 mm; and the upper contour in contact with the darker gray shading has a value of 20 mm. The arrangement of the patterns varies from map to map for ease of viewing in order to avoid shading large segments of the state in black, and in order to most easily distinguish between the shades of gray. The January (fig. 9) and December (fig. 20) maps show similar patterns and indicate that in most of the state, average temperatures are below freezing and PET values are equal to zero. In comparing the January to December data, there is a larger area in southern Nevada with higher (31 to 40 mm) PET in January than there is in December.

The February (fig. 10) and November (fig. 19) maps are also similar to one another although greater portions of the state have PET = 0 mm in February. Note the dramatic discontinuity in figure 19 of the November map boundary between regions 1 and 2. Clearly, extreme caution should be used in application of the November data in the vicinity of this boundary. Additional data is needed to obtain better estimates of PET in this region. Additional data would also be useful during other months in various parts of the state. For instance, the previously noted discontinuity between the eastern parts of regions 4 and 5 is clearly visible on the February plot. This is

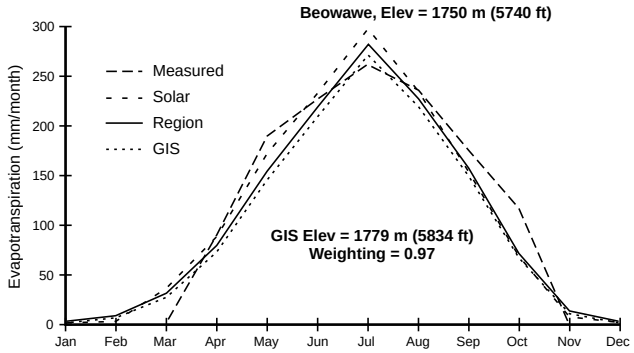


**Figure 7—Comparison of measured pan evaporation and PET calculated from solar radiation, from linear regressions with elevation, and final PET calculated using the GIS model for January through December.**

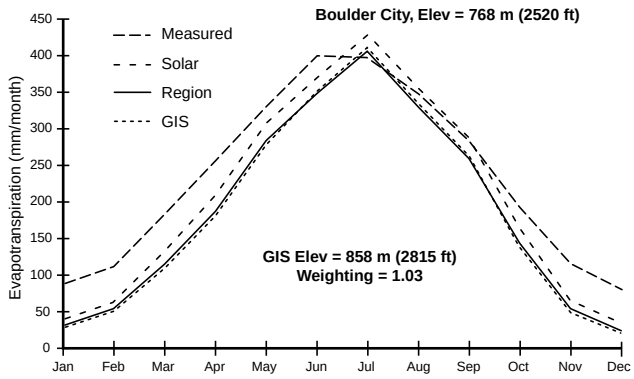


**Figure 8—Comparison of measured pan evaporation and PET calculated from solar radiation, from linear regressions with elevation, and final PET calculated using the GIS model for January through December.**

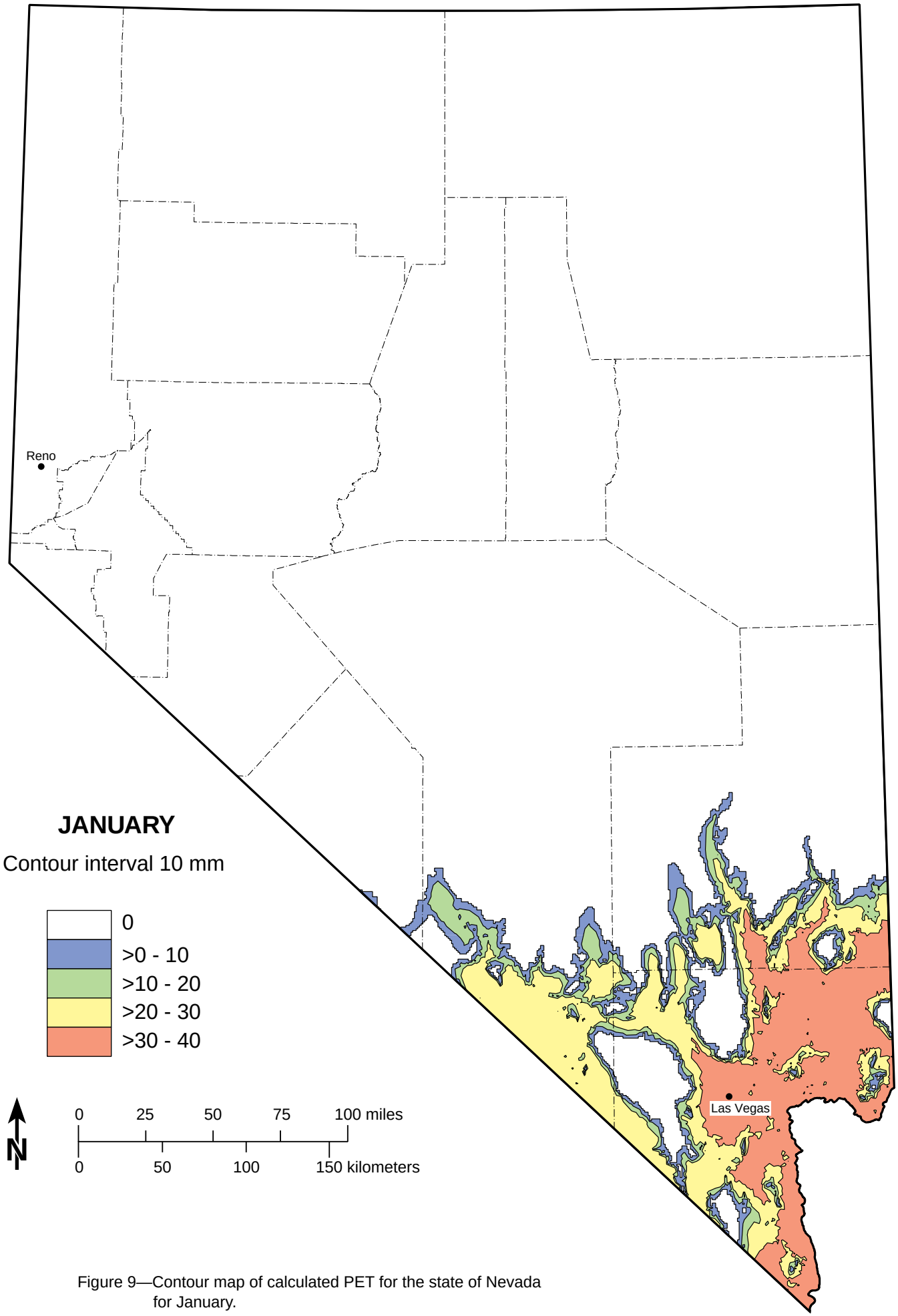


Figure 9—Contour map of calculated PET for the state of Nevada for January.

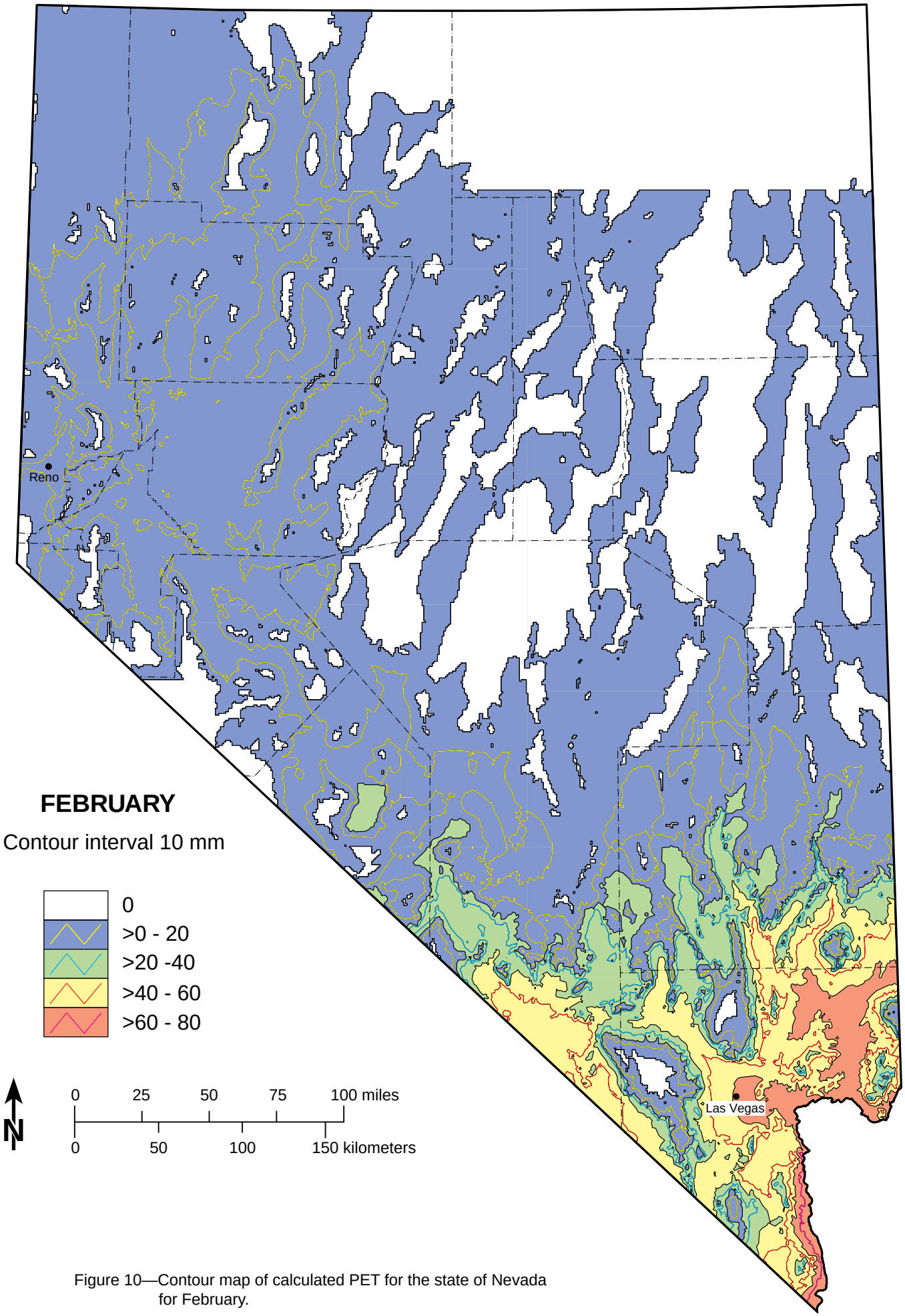


Figure 10—Contour map of calculated PET for the state of Nevada for February.

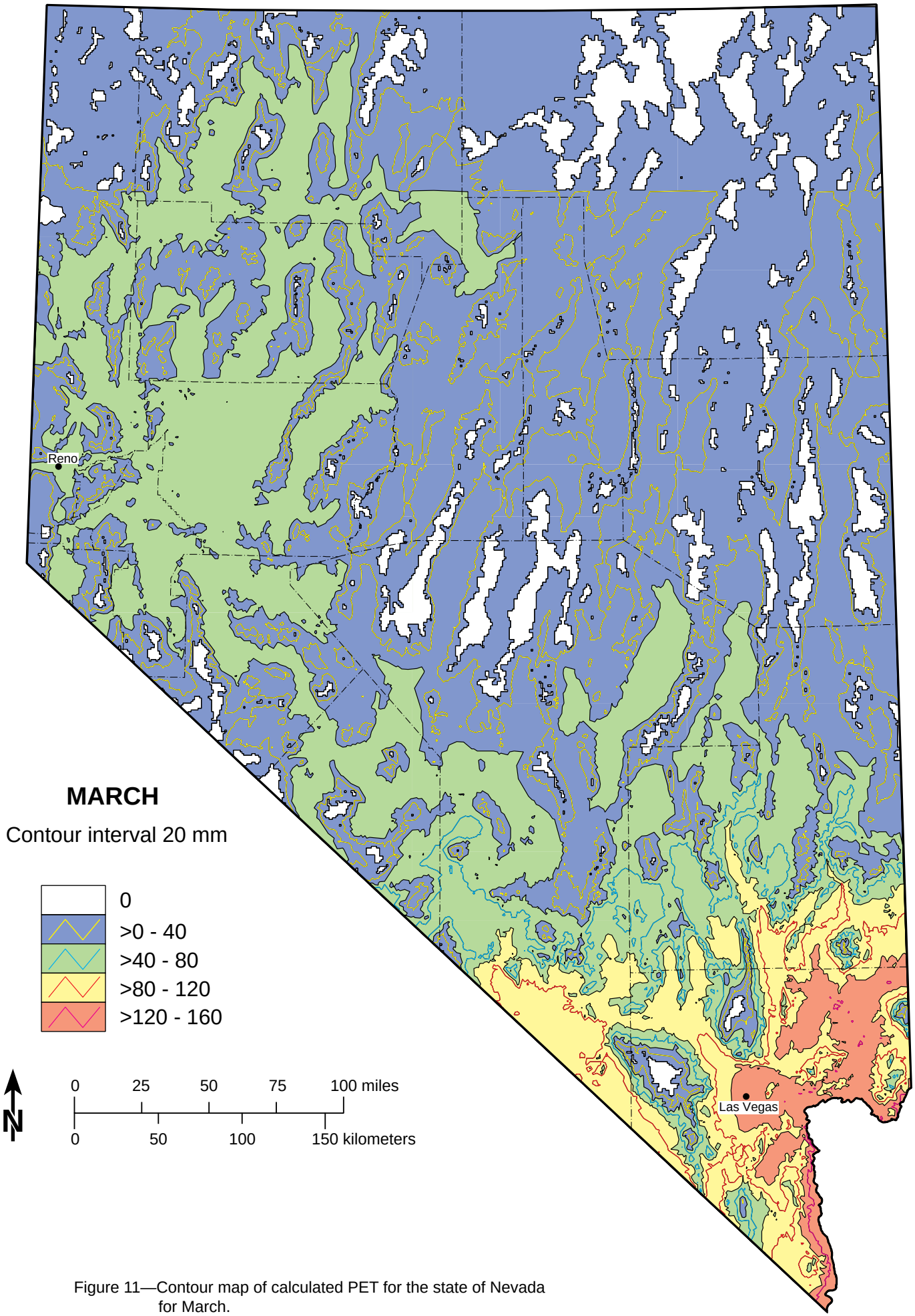


Figure 11—Contour map of calculated PET for the state of Nevada for March.

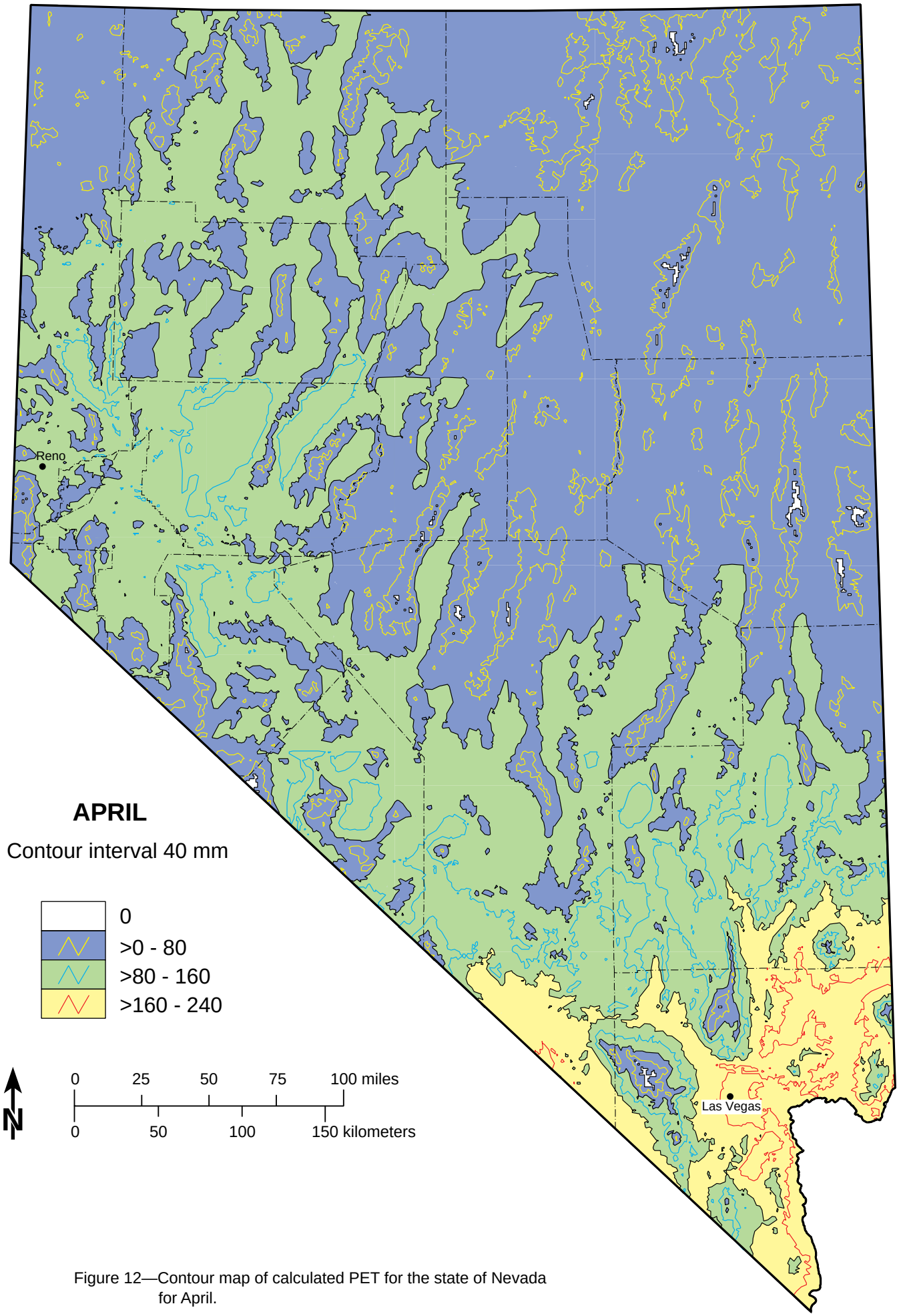


Figure 12—Contour map of calculated PET for the state of Nevada for April.

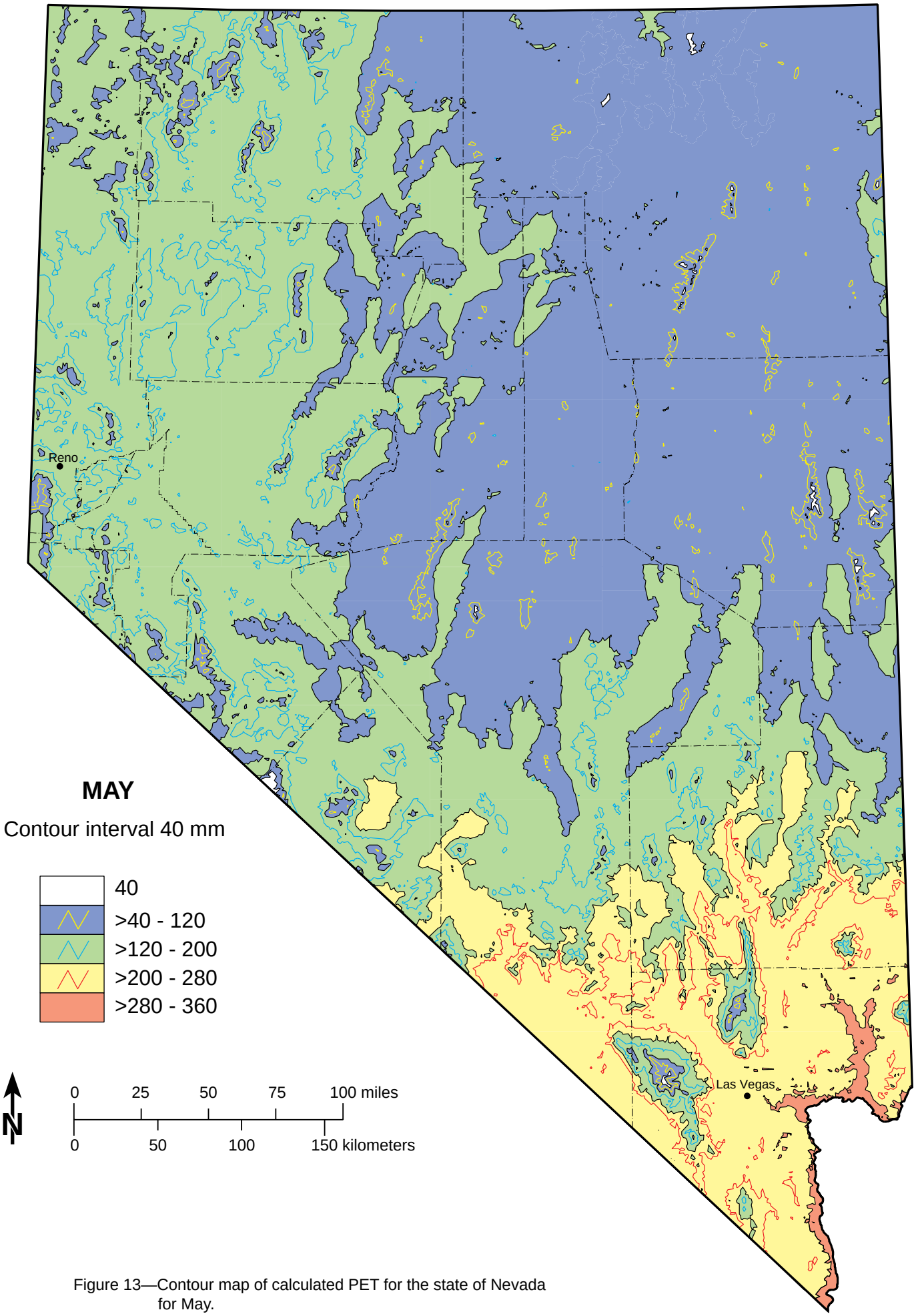


Figure 13—Contour map of calculated PET for the state of Nevada for May.

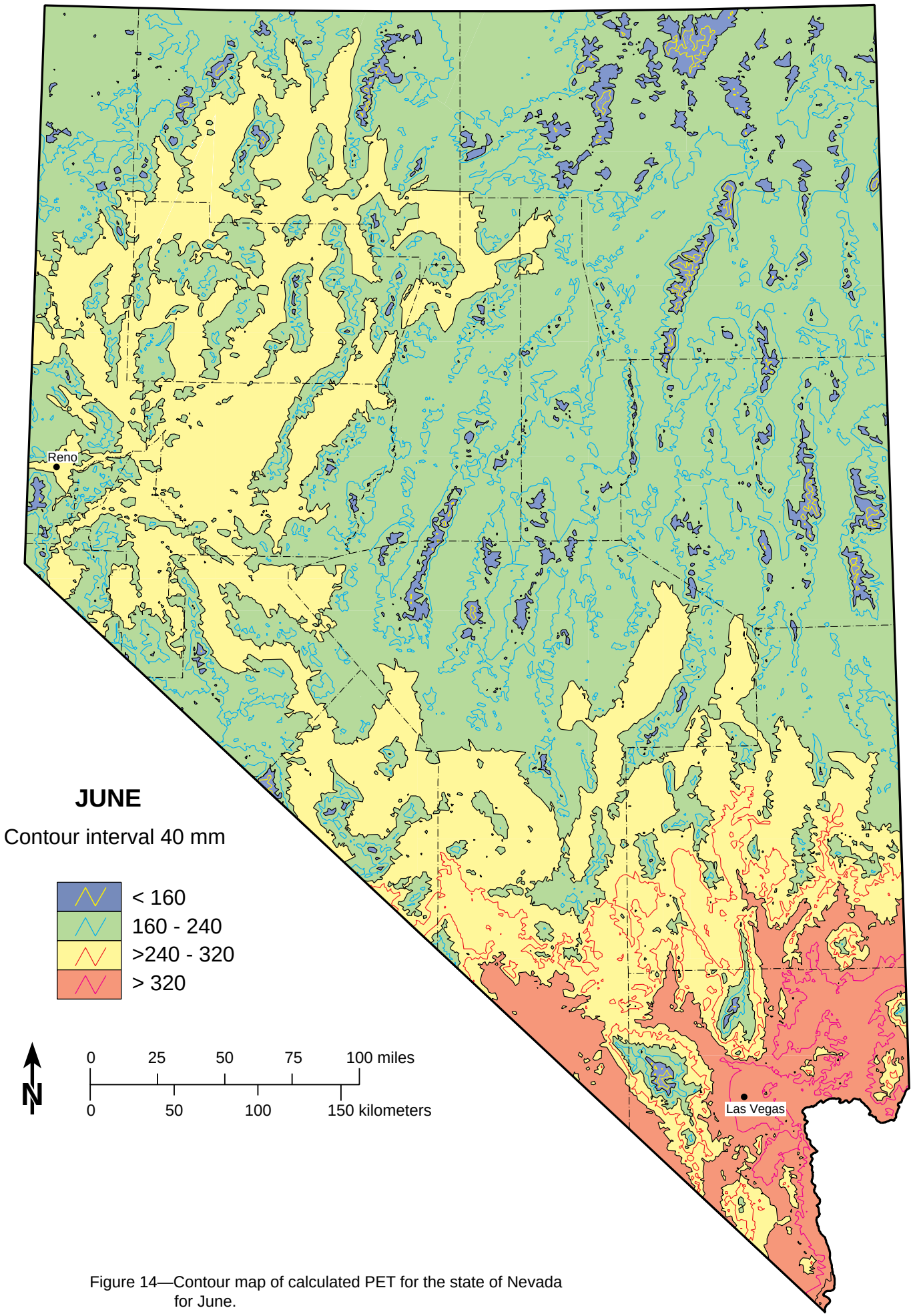


Figure 14—Contour map of calculated PET for the state of Nevada for June.

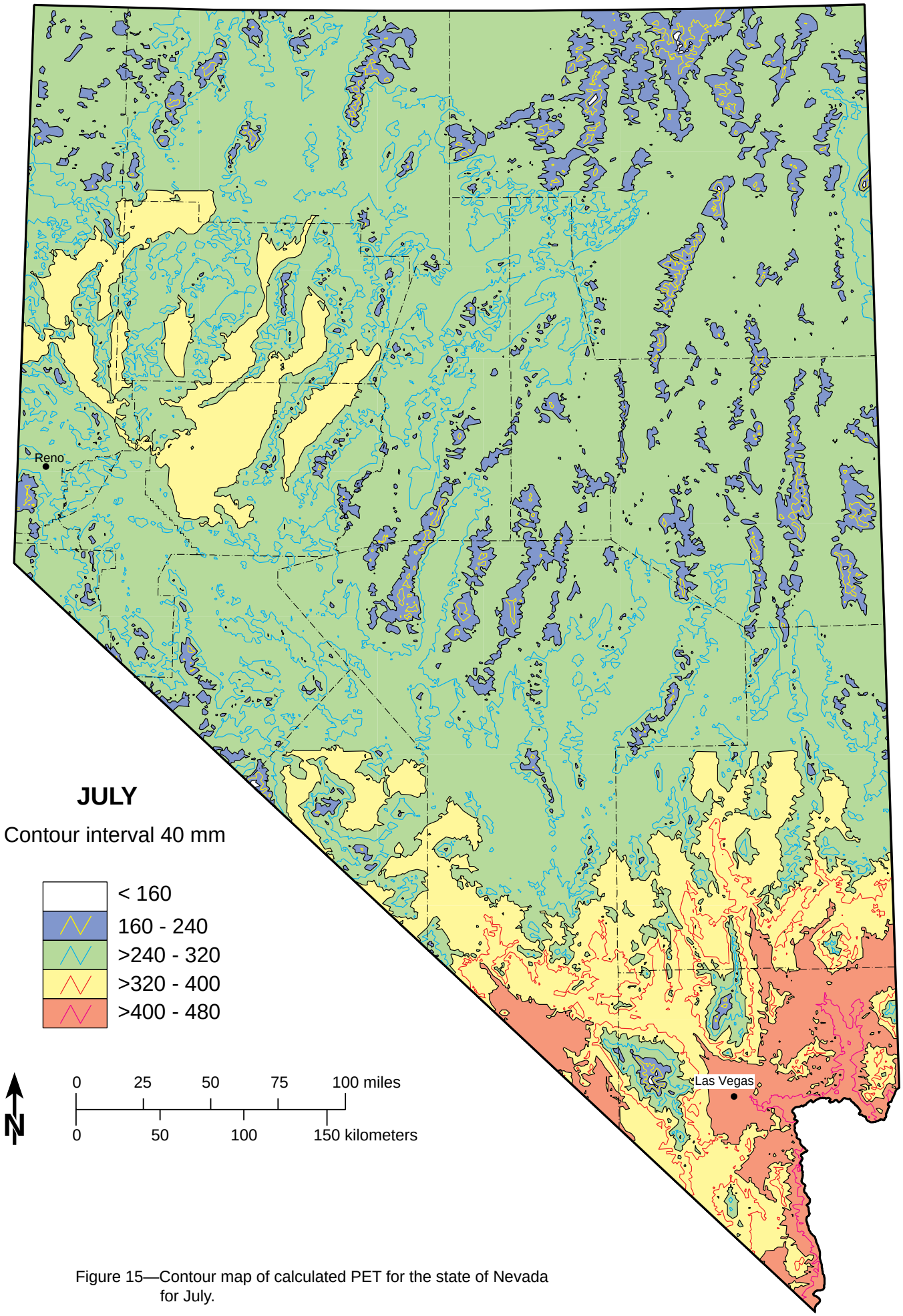


Figure 15—Contour map of calculated PET for the state of Nevada for July.

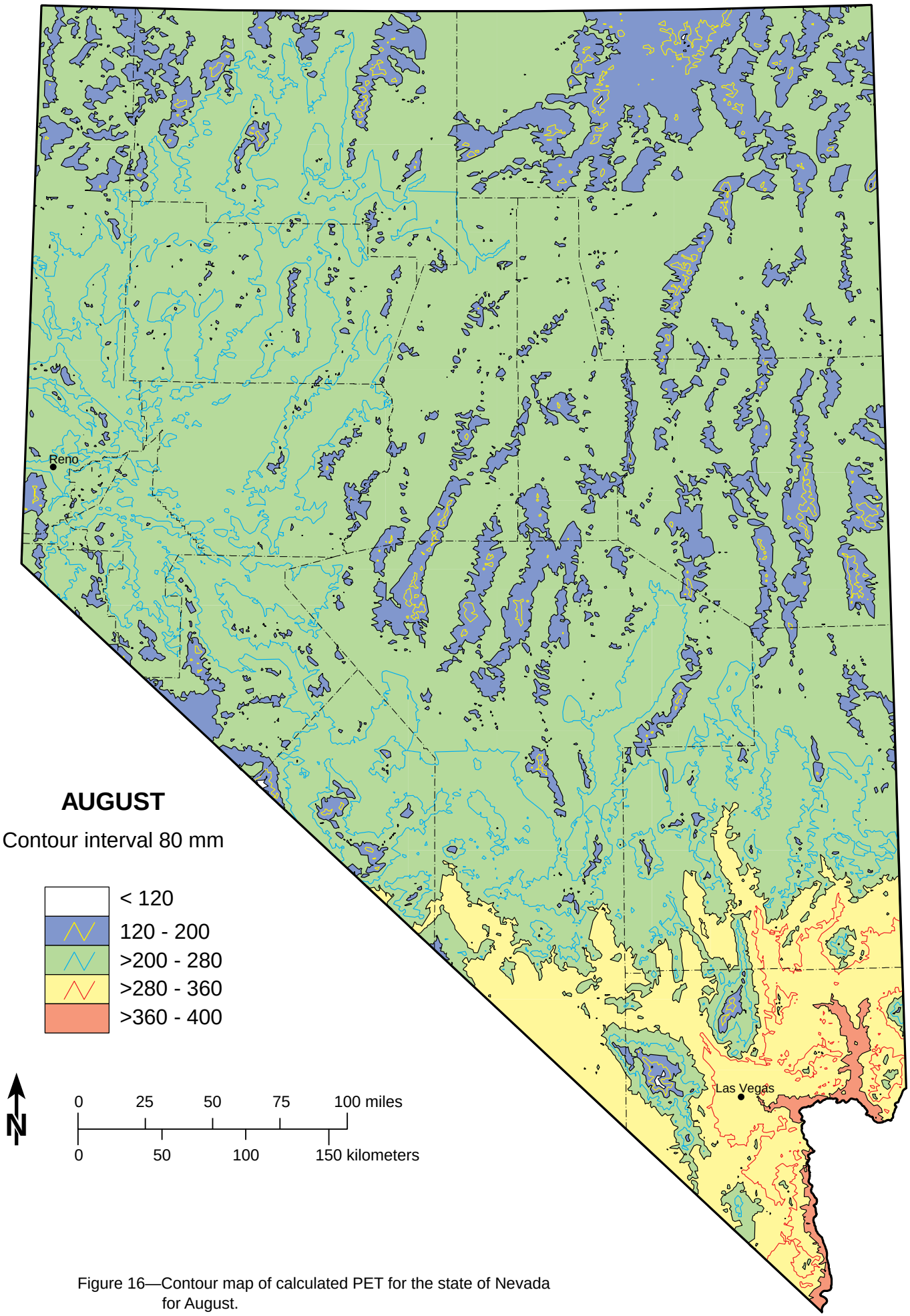


Figure 16—Contour map of calculated PET for the state of Nevada for August.

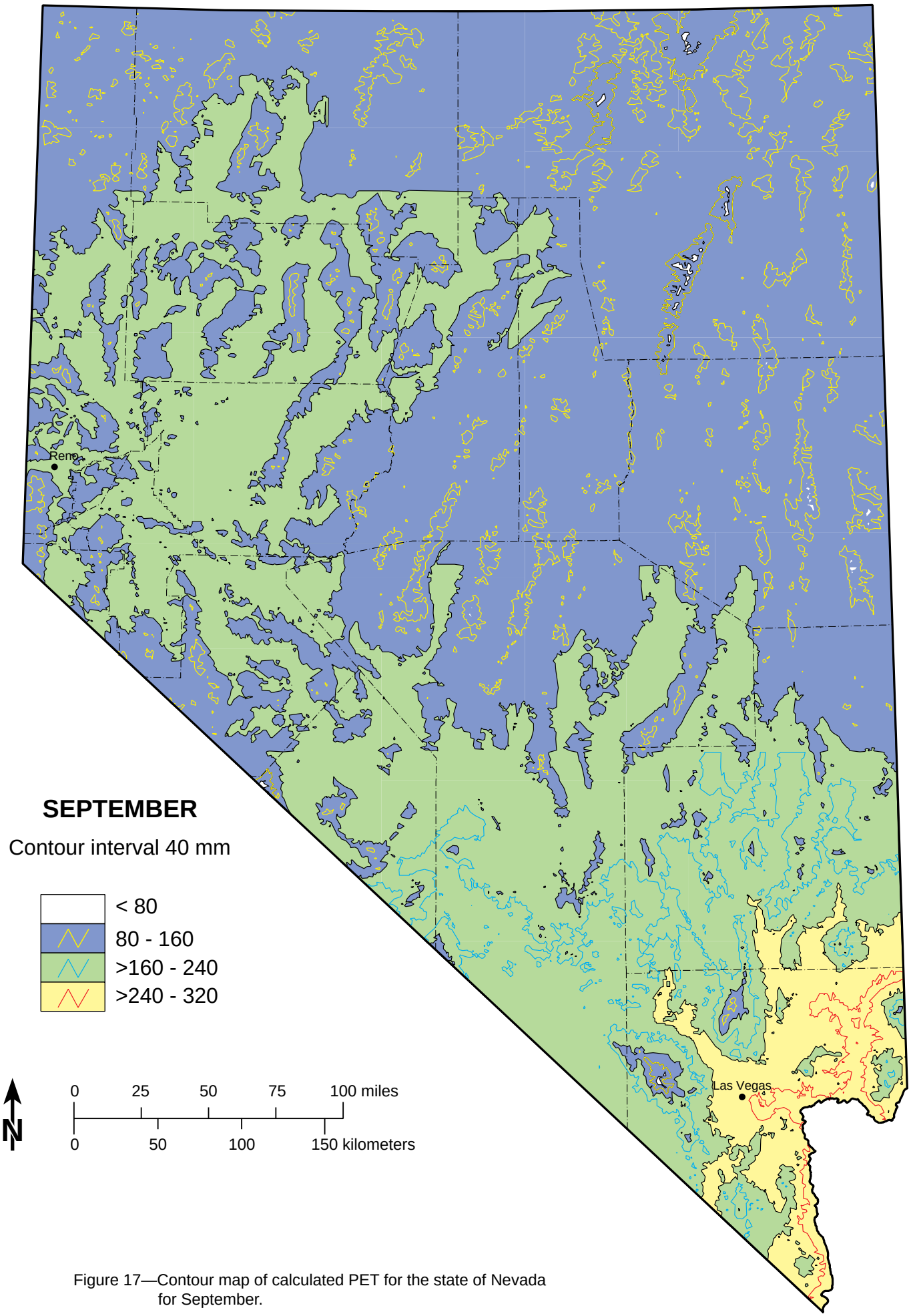


Figure 17—Contour map of calculated PET for the state of Nevada for September.

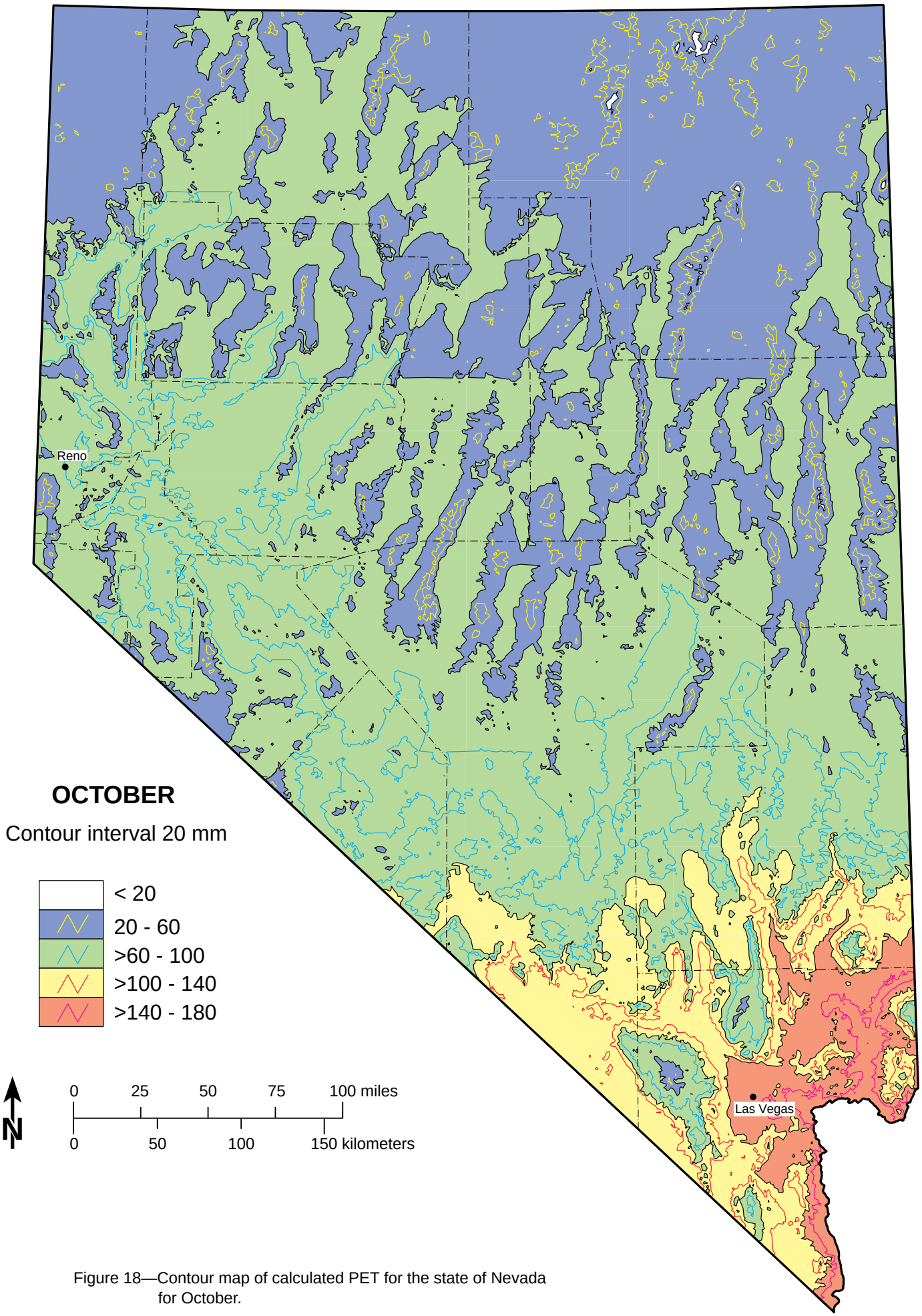


Figure 18—Contour map of calculated PET for the state of Nevada for October.

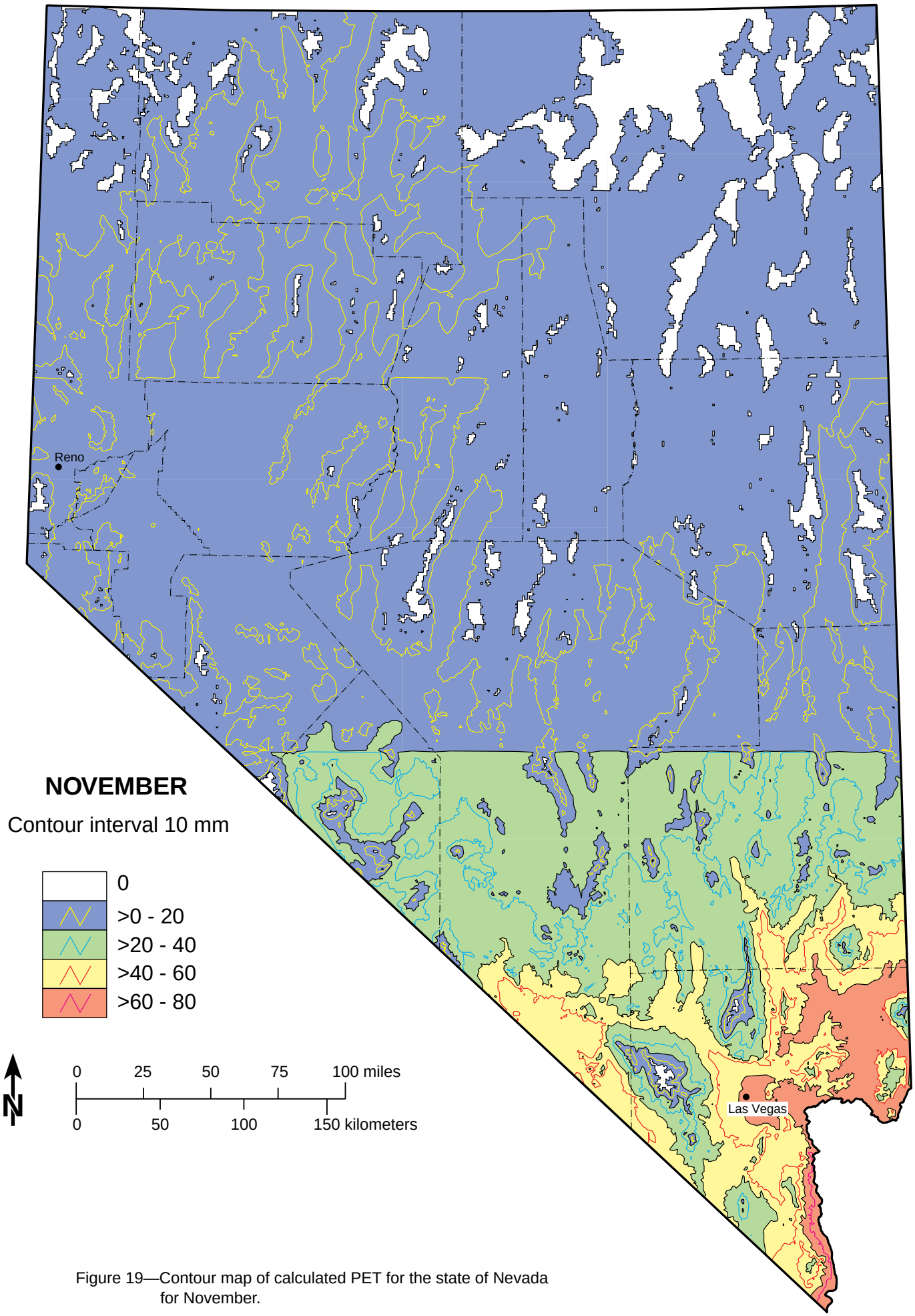


Figure 19—Contour map of calculated PET for the state of Nevada for November.

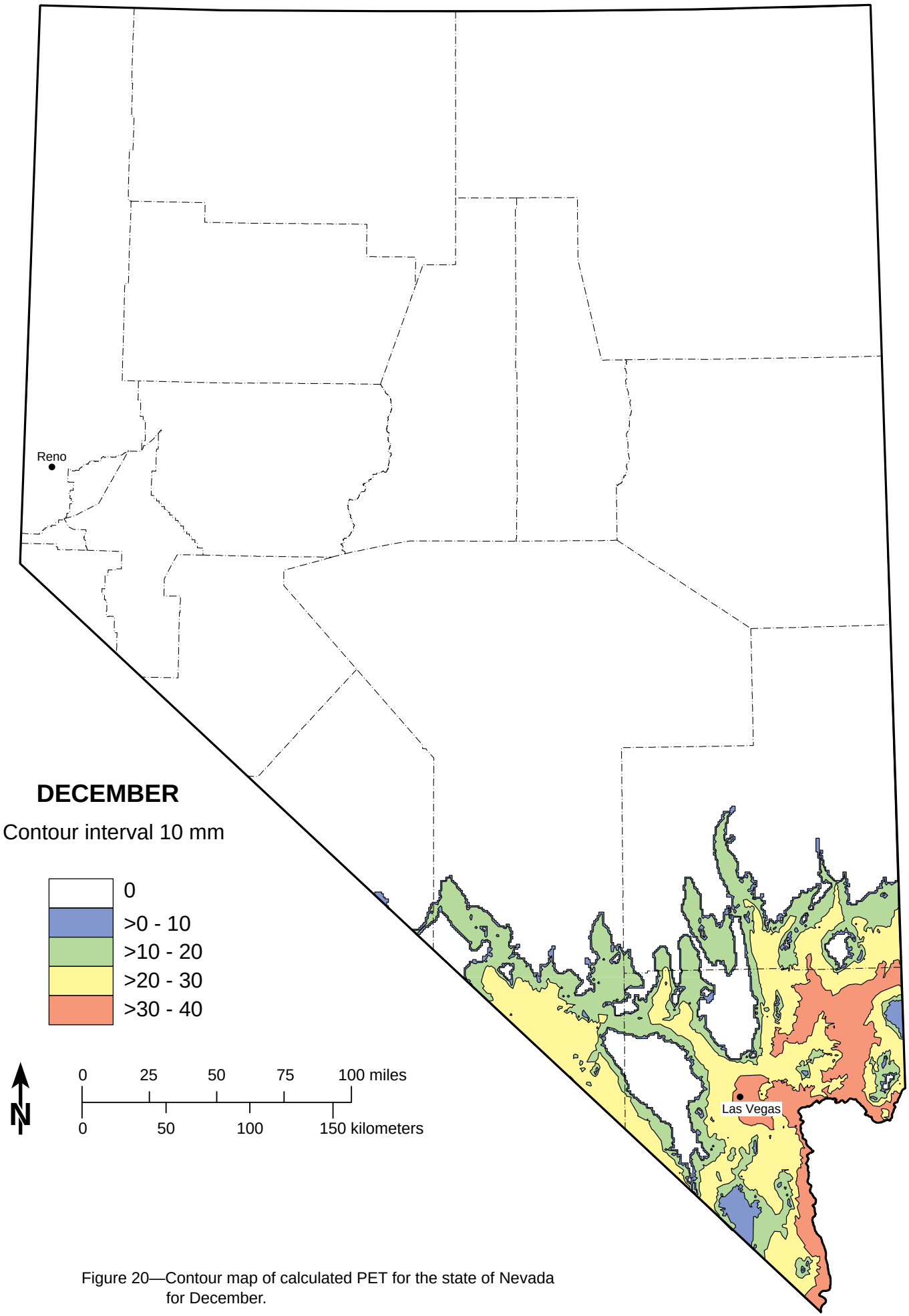


Figure 20—Contour map of calculated PET for the state of Nevada for December.

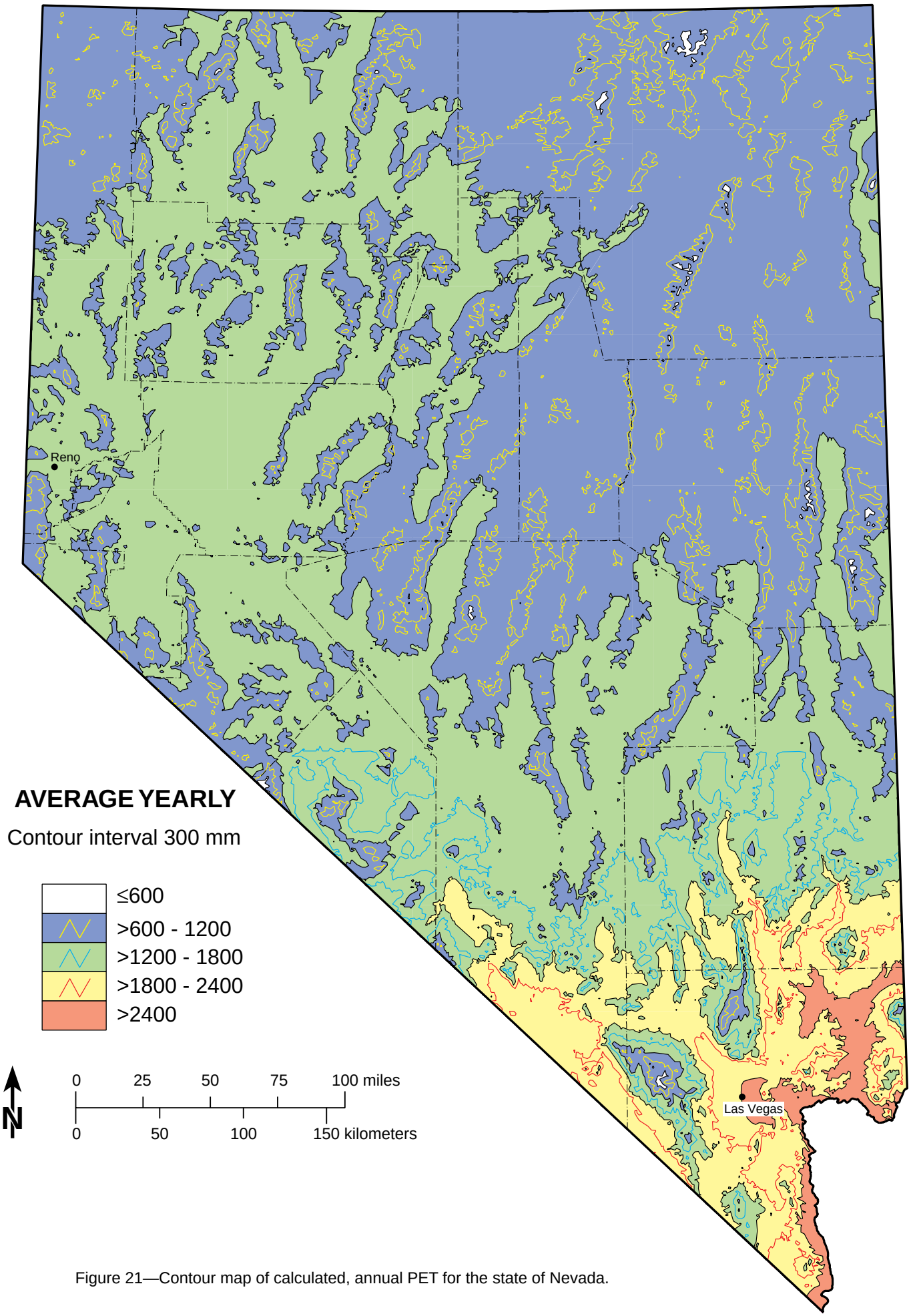


Figure 21—Contour map of calculated, annual PET for the state of Nevada.

due to the fact that all average measured temperatures in the eastern half of region 5 are less than freezing. There are likely to be some areas in valleys with temperatures above freezing and the light gray shading from valleys in region 4 should extend into region 5.

The March and October PET maps are illustrated in figures 11 and 18. As the months get warmer, the discontinuity between the eastern half of regions 4 and 5 becomes less apparent and values associated with mountain ranges straddle the boundary. Similar PET patterns are seen in March and October, yet because temperatures are higher in October, PET values are higher throughout the state. In using the data from October, the intermittent discontinuity between regions 3 and 4 should be recognized.

Similar PET patterns are seen in April (fig. 12) and September (fig. 17), yet because temperatures are higher in September, PET values are higher throughout the state. In using the data from both these months, the intermittent discontinuity between regions 2 and 3 should be recognized.

The maps for the months with the most reliable data (May through August) appear in figures 13 through 16. A small discontinuity occurs in the eastern part of the state between regions 2 and 3 in the May data, whereas a prominent discontinuity occurs between regions 1 and 2 in the June and July data, with August having remarkably few boundary discontinuities. As with all of the PET maps, the area surrounding Lake Mead consistently has the highest PET values. In June (fig. 14) and July (fig. 15), high PET associated with the Carson Sink is also evident.

Figure 21 shows the generalized pattern of yearly averaged PET throughout the state. Due to the more generalized nature of this map which show a large range in PET values, discontinuities seen during the individual month maps are subdued. This map shows that the average PET varies dramatically throughout the state. Areas near Lake Mead experience >2,400 mm of PET per year, whereas higher elevations in several parts of the state have considerably lower average yearly PET (<600 mm).

## DISCUSSION

The PET data mimic the topography, with lower PET occurring at the higher elevations. This is in contrast to precipitation data in which higher precipitation is associated with higher elevation. The resulting contour maps of PET for the state provide realistic regional views of the variability of PET in the state by latitude and elevation. The most accurate regional maps are produced for the summer months when there is a large percentage of clear sky days, ample wind, and high sun angles. Caution should be exercised with using PET data from the eastern half of region 5, and in other areas in which discontinuities are apparent at region boundaries. Perhaps in future work, the regression equations from both regions along a boundary should be used to calculate the PET and the average value placed at the boundary. This change may improve the reliability of PET values at the boundaries.

The best PET estimates in comparison to pan evaporation measurements are obtained for the months June, July, and August. For these months, the average ratios (calculated PET/PAN values) for all eight stations of the calculated PET to measured pan evaporation values are 0.920, 1.008 and 0.914. These ratios for the months of May and September are fairly good and are equal to 0.841 and 0.896, and those for the cooler months of April and October are worse at 0.663 and 0.646. Only about 50% of the pan evaporated value is estimated with the calculations for March and November, whereas only 20 to 30% of the measured pan evaporation value is estimated for February and December. This results because: (1) the absolute evaporation values are much smaller for these colder months, and smaller differences in the two values can result in much larger calculated percentage differences than in warmer months; (2) solar radiation is likely to be less important than wind speed in the cooler months, and wind speed is not explicitly considered in the calculations; (3) few pan evaporation measurements are available for the coldest months; and (4) calculated PET based on solar radiation is expected to be somewhat in error during times of low sun angles (Olivier, 1964) as occurs during the winter months.

Lysimeter (planted with alfalfa) data in the Fallon area over the course of one year consistently show much lower PET when using water balance equations than do the measurements from a nearby evaporation pan (Neyshabouri, 1976). Table 7 summarizes these data and shows monthly data for the Olivier method (similar to the method employed in the current work), pan measurements, and PET from three lysimeters. These data show that the pan evaporation values are consistently higher than the lysimeter PET values for all months, and they are much higher than the lysimeter values for the colder months. For instance, January pan data suggest almost 31 mm of evaporation, yet all three lysimeters indicate <6.6 mm for the same area. In contrast, although there is variability month to month, the Olivier method estimates PET which is very close to that obtained for the three lysimeters, averaged over the entire year (ratio of 1.01, table 7). These data suggest that the pan measurements overestimate evaporation, particularly in the cooler months, and that estimates from Olivier or the current method are likely to be more realistic than pan measurements during the cooler months, but less accurate in comparison to lysimeter data. Note that relatively poor agreement between pan and the current method's PET is partially a reflection of the amount of data available for pan evaporation data. At the Fallon site, 41 to 43 years of record are available for the months of April through October, yet only 26, 5, 3, and 18 years of record are available for the months of November, December, January, and February, respectively. This is also the case for other stations noted in table 6. Relatively few evaporation measurements are available for the winter months at any of the stations, and hence, it is difficult to determine the degree to which the current PET calculated values differ from long term pan evaporation measurements.

Although the percentage differences between the current work PET and pan evaporation data are often small, the current work overestimates PET in the summer months for the Fallon station. PET is also overestimated during July at other stations (Boulder City, Beowawe, and Rye Patch Dam). However, the current method generally underestimates PET relative to the pan evaporation values (which overestimate actual ET) at the stations for the other months (table 6).

It should be emphasized that the measured pan evaporation and calculated values of PET are potential evaporation, assuming sufficient water is available for unimpeded evaporation to occur. In addition, elevated winds at higher elevations, and the presence of conifers, will tend to increase evaporation

**Table 7—Pan evaporation and lysimeter data near Fallon (summarized from Neyshabouri, 1976). ET in mm per month.**

| | Oliv | Pan | Lys A | Lys B | Lys C | Ave Lys | Calc PET current work | Ave Annual ET (Pan) | Ratios | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Oliv/Pan | Oliv/Lys | Pan/Lys |
| Jan | 15.75 | 30.99 | 6.60 | -7.37 | -3.56 | -1.44 | 0.00 | 34.04 | 0.51 | -10.94 | -21.53 |
| Feb | 35.56 | 57.15 | 1.02 | 2.29 | -0.25 | 1.02 | 17.06 | 56.64 | 0.62 | 35.00 | 56.25 |
| Mar | 70.87 | 104.14 | 33.78 | 33.53 | 33.78 | 33.70 | 60.08 | 111.51 | 0.68 | 2.10 | 3.09 |
| Apr | 91.95 | 135.64 | 59.69 | 69.85 | 76.96 | 68.83 | 119.58 | 156.21 | 0.68 | 1.34 | 1.97 |
| May | 194.82 | 234.44 | 205.49 | 216.41 | 199.14 | 207.01 | 200.94 | 194.56 | 0.83 | 0.94 | 1.13 |
| Jun | 194.56 | 241.55 | 194.49 | 160.02 | 194.82 | 183.05 | 261.51 | 225.04 | 0.81 | 1.06 | 1.32 |
| Jul | 212.09 | 256.03 | 216.92 | 215.39 | 204.47 | 212.26 | 321.34 | 249.17 | 0.83 | 1.00 | 1.21 |
| Aug | 262.13 | 288.80 | 249.17 | 208.53 | 235.71 | 231.14 | 255.24 | 217.17 | 0.91 | 1.13 | 1.25 |
| Sep | 153.16 | 170.69 | 172.21 | 140.97 | 158.50 | 157.23 | 179.73 | 153.67 | 0.90 | 0.97 | 1.09 |
| Oct | 90.93 | 114.30 | 104.65 | 92.96 | 104.39 | 100.67 | 85.78 | 98.81 | 0.80 | 0.90 | 1.14 |
| Nov | 50.29 | 72.14 | 2.29 | 12.45 | 17.02 | 10.58 | 22.48 | 58.17 | 0.70 | 4.75 | 6.82 |
| Dec | 24.38 | 29.46 | 10.41 | 7.37 | 8.89 | 8.89 | 3.57 | 31.50 | 0.83 | 2.74 | 3.31 |
| Sum/Ave: | 1396.49 | 1735.33 | 1256.54 | 1152.40 | 1229.87 | 1381.42 | 1527.30 | 1586.48 | 0.80 | 1.01 | 1.26 |

*Note:* Lysimeter and the first Pan measurements were taken between December 1974 and January 1976.
The Ave Annual ET (Pan) column lists the average data for Fallon for up to 43 years of record.

over that calculated in comparison to the ET which would occur with similar temperatures at lower elevations.

## CONCLUSIONS

An existing method was modified to provide estimates of monthly and annual evapotranspiration for the entire state of Nevada over a grid spacing of 1 km. The influence of different latitudes, elevations, slopes, and aspect of mountain ranges are considered in the model. There is some uncertainty in the values selected for weighting potential evapotranspiration for aspect, and additional research is needed to quantify specifically how PET varies at particular elevations on different slope faces at different angles from horizontal. Nevertheless, the results of this effort provide values for evapotranspiration on a regional scale, and the calculated values are very close to measured pan evaporation values at several stations in Nevada at different elevations and with different aspects. The best agreement between calculated PET and measured pan evaporation values is during the summer months. These data can be used for a variety of research and water planning activities. For instance, when combined with digital precipitation data, maps can be constructed showing which portions of the state are more prone to percolation of water through surficial deposits. This type of information can be useful in the siting of landfills where minimal percolation is desirable. In addition, these data have been used as one component in ranking abandoned mine sites for their potential to result water quality degradation (Shevenell and Christensen, 1996).

## Acknowledgments

Funding was provided for this work by the U.S. Bureau of Land Management under Agreement 1422F950A0001, Task Order No. 5. The author gratefully acknowledges the helpful suggestions of three reviewers: Scott Tyler (Desert Research Institute), Michael Turnipseed (Nevada State Engineer), and Randy Pahl (Nevada Division of Water Planning). All GIS constructed maps (figs. 9 through 21) were compiled by Lindsay Christensen and Gary Johnson at the Nevada Bureau of Mines and Geology where archived files are maintained. Additional cartographic work was done on the evapotranspiration maps by Robert Chaney. Editing of this document was done by Dick Meeuwig and typesetting was done by Rayetta Buckley. The contributions of each of these Nevada Bureau of Mines and Geology employees is greatly appreciated.

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