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A Study of Evaporation and Evapotranspiration in Peru

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A STUDY OF EVAPORATION AND EVAPOTRANSPIRATION IN PERU

by

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Fernando Chanduví-Acuña

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ABSTRACT

A Study of Evaporation and Evapotranspiration

In Perú

by

Fernando Chanduvi-Acuña, Master of Science

Utah State University, 1969

Major Professor: Jerald E. Christiansen
Department: Irrigation and Drainage Engineering

Twenty-four equations for estimating evaporation and/or evapotranspiration were compared with measured Piche evaporation. At least 1728 months of records from 12 Peruvian stations were analyzed in this study.

Computer programs were developed to work this study and the results were compared by plotting.

It has been found that the equation that best fits the Piche evaporation in the low elevation stations in Peru is Christiansen's formula (ET2) which was used as a base for his formula for Class A pan evaporation (EVC).

(95 pages)

INTRODUCTION

Geographic situation, area, and population

Perú is located in the central west coast of South America, on the Pacific Ocean side. Lima, with a population of about 2,000,000 people, is the capital.

Perú has the following coordinates in the extreme points:

$00^{\circ}00'00''$ S latitude

$18^{\circ}24'00''$ S latitude

$81^{\circ}36'00''$ W longitude

$68^{\circ}36'00''$ W longitude

The country borders on the Pacific Ocean on the west, Brazil and Bolivia on the east, Ecuador and Colombia on the north, and Chile on the south.

Perú has an area of approximately 1,285,215 square kilometers (496,222 square miles), and a population of more than 11,000,000 inhabitants. It is the third largest of the Latin American republics, and is exceeded in size only by Brazil and Argentina.

Geographical regions and climate

The topography of the country, its location near the equator, and the presence of the Peruvian current of Humboldt, produce a climatic complexity. The coastal area near the Pacific Ocean is very arid, and in some locations rainfall never occurs.

Three principal regions are well defined in the country as shown in Figure 1.

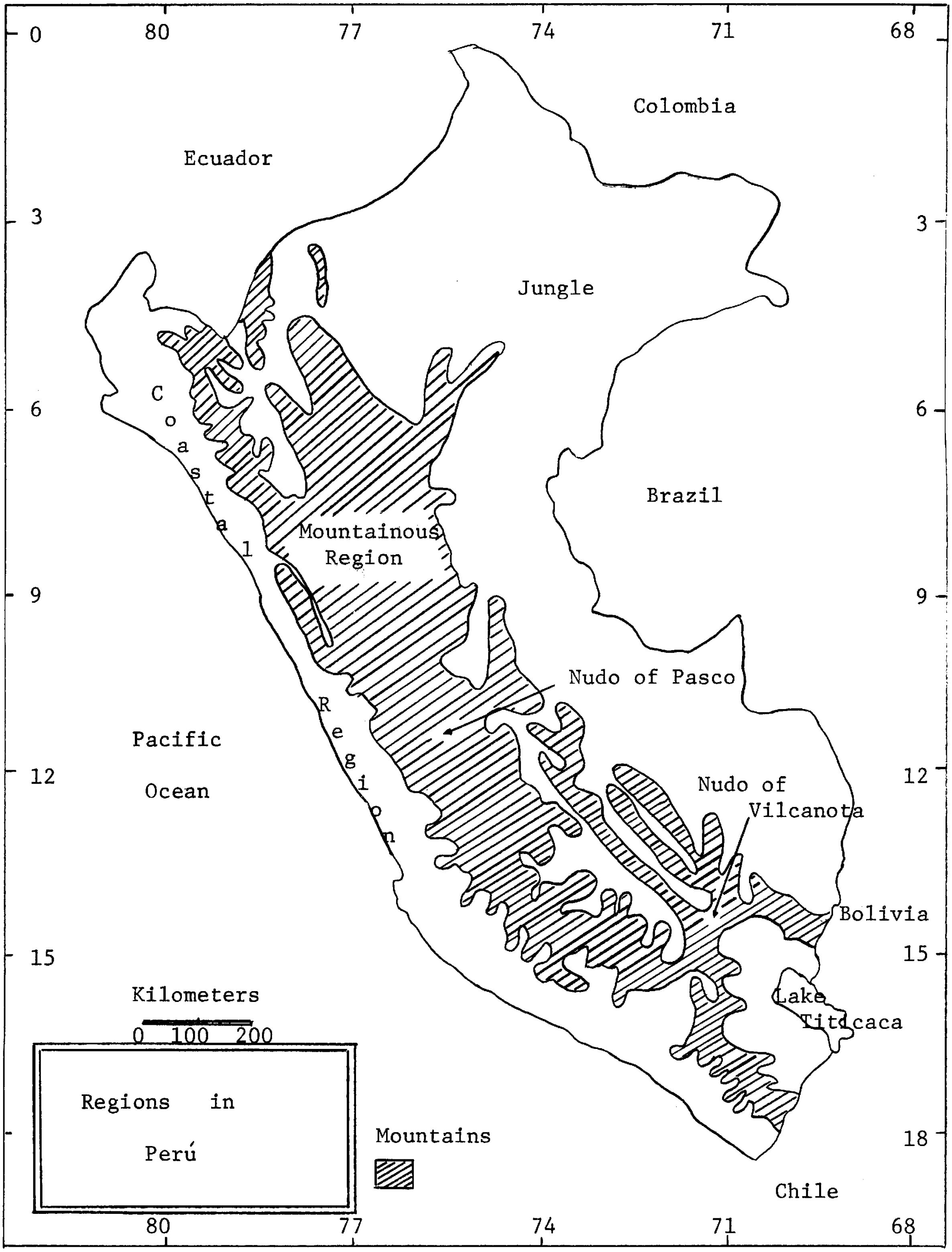

Figure 1. Map of Perú.

The coastal zone. This region is a narrow strip along the west side of the country. It is a dry zone where the agriculture practiced is based on irrigation from the seasonal discharge of the rivers. Its average width is 80 kilometers (43.7 miles) and its length is 2,250 kilometers (1,400 miles).

Irrigation is vital because the coastal region is almost rainless. Only a few of the rivers flowing into the Pacific Ocean from the Andes carry water all the year around. Because of the steep gradient of the rivers there are only a few storage reservoirs.

Most of the important cities of the country, Lima, Piura, Chiclayo, Chimbote, Ica, and Tacna, are located in this zone. With only 11 percent of the area of the country, it contains about 35 percent of the inhabitants.

The mountainous zone. This region, also known as the Sierra, comprises all the Andean highlands and valleys over 6,500 feet. Its average altitude is at about 13,000 feet. Three great mountain chains (Cordilleras) run longitudinally through the country from northwest to southeast. In addition to agriculture and livestock, the most profitable economic activity of the region is mining, because most of Perú's valuable mineral deposits are located in the Sierra.

The Sierra covers about 26 percent of the total area of Perú and has 51 percent of the total population. The principal towns in the Sierra are Arequipa and Cuzco (the old Inca capital) in the south, Huancayo and Ayacucho in the center, and Cajamarca in the north.

The jungle (selva). The remainder of the national territory, about 63 percent, lies to the east of the Andes and extends into the Amazon Basin. In the hot, wet valleys and uplands, tea, cacao, cocoanuts, and

tobacco are being cultivated.

The tropical forest and impenetrable undergrowth make difficult the development of this region, but the abundance of forest products, the land suitability for growing a variety of crops, and the improvements of roads are slowly making possible the development of the jungle.

Objectives

The objectives of this study are:

1. To compare measured Piche evaporation with values computed from the more commonly used formulas for estimating evaporation and/or evapotranspiration in order to better understand its relationship to water requirements of crops.

2. To determine the effect of altitude on Piche evaporation.

3. To determine what kind of additional work on evaporation and/or evapotranspiration should be undertaken in order to more reliably estimate water requirements.

DEFINITION OF TERMS

Evaporation

Evaporation is the natural process by which water is changed from a liquid to a vapor. Evaporation from an exposed water surface is subject to the effect of many varying climatic and other factors. The resulting evaporation is a complex process, difficult to analyze and difficult to correlate with measurements of the individual factors that affect its rate. Many attempts have been made to correlate evaporation data with climatic parameters, and to derive mathematical expressions for evaporation in terms of one or more of these factors. In most instances only a few parameters are considered, and, therefore, the equations do not accurately reflect the influence of all of the factors that make up the climate.

Evaporation from pans and lakes

Pan evaporation is the evaporation measured with a standard pan, such as the Class A pan adopted by the U.S. Weather Bureau. This pan has a diameter of 4 feet, a height of 10 inches, and is installed 6 inches above the ground surface. The depth of water in the pan is kept at about 7.5 inches.

Lake evaporation has been related to Class A pan evaporation by a coefficient which has an annual value of about 0.70. Monthly values vary appreciably depending on the heat capacity of the lake.

Australian tank evaporimeter

The Australian tank evaporimeter, which is referred to in this study, consists of a cylindrical copper tank 3 feet in diameter and 3 feet deep, set in an outer tank 4 feet in diameter and 2 feet 10 inches deep. The outer tank is set flush with the ground. The depth of water in the inner tank is measured with a micrometer screw and float and is allowed to vary over a range from 1½ to 3 inches below the rim.

Piche evaporation

The Piche evaporation is the evaporation measured in a graduated tube, 30 cm long, with the lower end covered by a paper disk held in place by a metallic device. The tube is filled with water and turned upside down. The water evaporates from the wetted paper disk. Water loss is read on the scale on the tube as a measurement of evaporation, and is usually reported in millimeters (mm) per day or per month.

Fuess evaporimeter

The Fuess evaporimeter, or evaporigraph, is a device for measuring evaporation. It is placed in a shelter to avoid the effects of direct radiation and wind. The evaporimeter consists of 250-cm^2 metal pan, 1 cm high. A plastic bottle containing the water supply is supported above the pan to maintain a constant water level in the pan. As the water evaporates from the pan, the change in weight actuates a needle which plots the evaporation on a graduated chart on a metal drum, which is moved by a clock mechanism. The drum makes one revolution in 24 hours.

Atmospheric pressure

Atmospheric pressure refers to the weight of a column of the atmosphere of unit cross section above the point of observation. This pressure has been expressed most frequently as the height of a column of mercury of equivalent weight. Atmospheric pressure at sea level is normally the equivalent of about 30 inches of mercury, or about 14.7 pounds per square inch.

A standard atmosphere is a pressure of 760 mm or 76 cm and equals 29.92 inches of mercury. It is also customary to express atmospheric pressure in the cgs units of force per unit area. For this purpose the unit is the bar. One bar is the force of 10^6 dynes/cm^2, and the millibar is 10^3 dynes/cm^2. One bar is approximately 1 atmosphere (1.032) standard atmospheres).

Humidity

Humidity refers to water vapor in the atmosphere. Since water vapor exerts its own partial pressure exactly in the manner of each of the other gases which constitute the atmosphere, the humidity can be expressed in terms of the partial pressure of water vapor, in millibars. However, other units for expressing humidity are more convenient for many practical uses.

Relative humidity is the ratio e/e_m, expressed as a percentage, where e is the vapor pressure and e_m is the saturation vapor pressure at the existing temperature. The saturation vapor pressure is the maximum vapor pressure which can exist in the atmosphere at a given temperature. Any further increase of e beyond e_m leads to supersaturation and the condensation from the air of the excess vapor. The

saturation vapor pressure, e_m, is a known function of the temperature alone.

The relative humidity influences the rate of evaporation into the air. It is measured by the cooling produced by such evaporation, as shown by the difference between the wet bulb and the dry bulb temperature. The wet bulb temperature is the temperature registered by a thermometer whose bulb is covered by a wet cloth and exposed to a ventilation sufficient to insure a maximum rate of evaporation, or cooling. The dry bulb temperature is the temperature as measured by a standard thermometer which is exposed to the same ventilation as the wet bulb. From the depression of the wet bulb temperature below the observed dry bulb temperature, the relative humidity may be obtained from standard tables. The vapor pressure e may be obtained from similar tables, since e_m is a function of the dry bulb temperature alone.

Dewpoint is the temperature to which the air must be cooled at constant pressure in order to become saturated, i.e., the temperature for which e_m is the same as the prevailing vapor pressure e, and for which the relative humidity is 100 percent.

Radiation

Radiation may be described as energy which travels in the form of electromagnetic wave motion and which produces heating wherever it is absorbed.

The solar constant is the intensity of the solar radiation at the outer limit of the atmosphere on a surface perpendicular to the solar beam. Its value is about 2.00 cal/cm^2/min when the earth is at its mean distance from the sun.

REVIEW OF LITERATURE

The knowledge of the amount of water needed to be applied to the soil for crop production is very important. At the same time, evaporation losses from reservoirs are also important.

Many methods and procedures have been used for determining both evaporation and evapotranspiration. Such determinations have also been correlated with various climatic parameters, and many formulas have been developed and proposed for estimating both evaporation and evapotranspiration using climatic data.

Various methods of measuring evaporation include the use of an instrument and/or equipment such as Class A pans, sunken pans, Australian tanks, Fuess evaporimeters, and atmometers.

Most of the formulas proposed are reliable for the location for which they have been developed but may not be reliable when used for locations with different climatic conditions. For these and other reasons, much research has been done on evaporation and/or potential evapotranspiration, and still there is much to be done on this subject.

Evapotranspiration is difficult to measure directly but can be determined by a number of procedures. Tanner (1967), p. 535, says:

> Measurements of E_t can be divided into three classes for convenience: first, the water balance or hydrologic methods; second, micrometeorological methods; and third, empirical methods. The methods of the first two classes have a rational basis whereas empirical methods, if reasonable confidence is obtained, must be "calibrated" by relating the empirical E_t indexes to actual E_t measurements.

Most formulas for estimating evapotranspiration, although rational in form, have one or more empirical coefficients.

Symbols used for evaporation and evapotranspiration

The symbols used in some of the formulas given in this literature review have been changed in the interest of uniformity and to avoid repetition of definitions. They are:

E_{vt} is a general term which may be either evaporation or evapotranspiration,

E_t is evapotranspiration,

E_{tp} is potential evapotranspiration, assuming that soil moisture and crop cover are not limiting factors,

E_v is Class A pan evaporation,

PEV is Piche evaporation,

E_{vc} is computed Class A pan evaporation, and

E_{vau} is Australian tank evaporation.

Water balance methods

The water balance methods include natural catchment hydrology, soil water depletion sampling, and tank or lysimeter experiments. These methods have been described by Patil (1962), Al-Barrak (1964), Guillen (1967), and Pardo (1968).

Micrometeorological measurement methods

Micrometeorological methods provide a measurement of the flux density of water vapor in the boundary layer of the atmosphere. These methods have limitations as to where and how they can be used as well as instrumental difficulties. They also have important advantages. When applicable, micrometeorological methods can measure evapotranspiration over very short time periods and can provide environment information important to plant studies (e.g., temperature, humidity, etc.).

Empirical methods for estimating evaporation and/or evapotranspiration

Empirical methods for estimating evapotranspiration can be grouped into four classes, those depending primarily on: 1) The relation of evapotranspiration to radiation, 2) The relation of evapotranspiration to temperature, 3) The relation of evapotranspiration to humidity or vapor pressure deficit, and 4) The relation of evapotranspiration to evaporation as measured by various types of evaporimeters. It is emphasized that these formulas are best suited to potential (not actual) evapotranspiration. Many workers have applied coefficients to potential evapotranspiration or to measured evaporation to estimate actual evapotranspiration.

Christiansen and graduate students working at Utah State University, Logan, Utah, have developed a method for estimating evaporation and evapotranspiration which is rational and dimensionally sound. They use extraterrestrial (global) radiation and empirically derived coefficients for the climatic factors such as temperature, sunshine, humidity, wind, elevation, etc. This method for estimating evapotranspiration will be discussed in detail later.

Relation of Piche evaporation to pan evaporation

Fleming (1964) reported that at Griffith, Australia, the relationship between the cumulative Piche evaporation and the Australian tank was

$$\Sigma\ PEV = 1.14\ \Sigma\ E_{vau}$$

He further found that the relation between the Class A pan and the Australian tank was

$$\Sigma\ E_{v} = 1.22\ \Sigma\ E_{vau}$$

From these relationships, one can deduce that the relation between Piche evaporation and Class A pan evaporation was

$$\Sigma \text{ PEV} = 0.935 \; \Sigma \; E_v$$

Fleming (1964) also says that Prescott and Stirk (1951) obtained a relationship between the cumulative Piche evaporation and cumulative Australian tank evaporation, which can be written

$$\Sigma \text{ PEV} = 1.075 \; \Sigma \; E_{vau}$$

They state that for various installations in Australia the factor on a monthly basis varied from 0.73 to 3.12.

From Fleming's relationship between the Class A pan and the Australian tank this would give

$$\Sigma \text{ PEV} = 0.88 \; \Sigma \; E_v$$

Fleming also states that Parthasarathy and Misra (1955) have reported results from the New Delhi area of the Ganges Plain in India, where Piche evaporation was compared with a U.S. Class A pan. They found different conditions

(a) Wet season PEV = 0.71 E_v

(b) Dry season PEV = 1.14 E_v

Israelsen and Hansen (1965) suggested that multiplying Piche readings by 0.7 gives average comparable values of evaporation; rewriting this relation one obtains

$$\text{PEV} = 1.43 \; E_v$$

Hargreaves (1953) suggested that

$$PEV = 1.25\ E_v$$

Shahin[1] says that "according to Egyptian standards, evaporation from a free water surface is usually taken as half of the Piche evaporation." He does not define "evaporation from a free water surface," but implies that it would be the same as for the Class A pan. If, however, it is assumed that it is for a large lake and that annual lake evaporation is 0.7 Class A pan evaporation, then

$$PEV = 1.4\ E_v$$

From these relationships between Piche evaporation and Class A pan evaporation, it appears that the ratio varies quite widely and depends on climatic conditions, especially humidity.

Blaney and Morin formula

Blaney and Morin (1942) developed an expression for computing evaporation or consumptive use, which is

$$E_{vt} = k\ t\ p\ (1.14 - h_m)/100 = k\ c \qquad (1)$$

in which

E_{vt} is the monthly evaporation or evapotranspiration in inches,

k is a monthly empirical coefficient, which has different values for pan evaporation and consumptive use,

t is the mean monthly temperature in degrees F,

p is the monthly percentage of daytime hours of the year, and

---

[1] Personal communication to Prof. J. E. Christiansen, July 16, 1966.

h_m is the mean monthly humidity, expressed decimally.

They have differentiated a "climatic factor"

$$c = t\ p\ (1.14 - h_m)/100$$

The computer symbol used for E_{vt} in this formula is ETBM.

<u>Blaney-Criddle method</u>

The Blaney-Criddle formula (Blaney and Criddle, 1966) was developed for estimating consumptive use, but also has been used for estimating evaporation (Blaney 1958).

$$E_{vt} = k\ p\ t/100 = k\ f \quad . . . . (2)$$

where

$$f = p\ t/100$$

in which

f is a monthly consumptive-use factor and all other terms are as previously defined.

Therefore, the seasonal consumptive use is given by

$$E_t = \Sigma\ k\ E_{vt} = K\ F$$

in which

E_t is the seasonal consumptive use of water by the crop, in inches,

K is an empirical consumptive use crop coefficient for the irrigation season, or growing period (this has been reported to be approximately reasonably constant for all areas),

F is the sum of the monthly consumptive-use factors for the period (sum of the products of mean monthly temperature and monthly percent of daytime hours of the year).

The Blaney-Criddle formula in metric units can be written

$$E_{vt} = k\ p\ (4.57\ t_c + 81.3) \qquad (3)$$

in which

E_{vt} is the monthly consumptive use or evaporation, in millimeters,

t_c is the monthly temperature, in degrees Centigrade.

The computer symbol used for evapotranspiration in this formula is ETBC.

Hargreaves method

The Hargreaves method (Hargreaves 1956, 1966) is based upon the following assumptions: 1) The evaporation of water is a physical process and can be computed from climatic data, and 2) That an empirical relationship exists between computed evaporation and consumptive use of water by various crops. The relationship between evaporation, temperature, and length of day is given by the equation

$$E_{vc} = m\ (t - 32) \qquad (4)$$

in which

E_{vc} is the monthly evaporation in inches, and

m is an empirical factor which is assumed to be $m = c\ d$

in which

c is a climatic factor depending upon humidity,

d is a monthly daytime coefficient depending upon latitude,

d $= 0.12\ p$ (p of the Blaney-Criddle equation),

c $= 0.38\ (1 - h_n)$,

where

h_n is the mean monthly relative humidity at noon expressed decimally.

The original equation then becomes

$$E_{vc} = 0.38\ d(1 - h_n)\ (t - 32) \quad . . . . (5)$$

Hargreaves' formula in metric units is

$$E_{vc} = 17.37\ d\ t_c\ (1 - h_n) \quad . . . . (6)$$

in which

E_{vc} is the monthly evaporation in millimeters, and

t_c is the mean monthly temperature in degrees centigrade.

For evapotranspiration, E_t, he applied a coefficient K to the computed pan evaporation

$$E_t = K\ E_v \quad . . . . (7)$$

The seasonal evapotranspiration, or consumptive use, is taken as the sum of the monthly values of E_t for the crop growing period.

The computer symbol used for E_{vc} in this formula is ETHA.

Hargreaves modified formula

Christiansen has suggested that Hargreaves formula (Hargreaves 1967) could be improved by modifying the humidity factor $(1 - h_n)$, and incorporating factors for wind, sunshine, and elevation as follows. The modified equation in metric units can then be written

$$E_{vc} = 17.37\ d\ t_c\ F_H\ F_W\ F_S\ F_E \quad . . . . (8)$$

in which

$F_H = 0.59 - 0.55\ h_n^2$,

$F_W = 0.75 + 0.0255\ \sqrt{WKD}$, or

$F_W = 0.75 + 0.125 \sqrt{W2M}$

$F_S = 0.478 + 0.58\ S,$

$F_E = 0.950 + 0.0001\ E,$

where

WKD is the mean wind velocity in km/day at a height of 2 meters, or

W2M is the mean wind velocity in km/hour at a height of 2 meters,

S is the sunshine percentage, expressed decimally, e.g., S = 80% = 0.8, and

E is the elevation in meters.

Sometimes published data for noon humidity are not available, but either mean humidity, h_m, or mean maximum humidity, h_x, and mean minimum humidity, h_i, are available. Noon relative humidity can be estimated with reasonable accuracy from the expressions

$h_n = 0.36\ h_m + 0.64\ h_m^2$, or

$h_n = 0.10\ h_x + 0.40\ h_i + 0.18\ h_m + 0.32\ h_m^2$, or

$h_n = 1.13 - 0.045\ (\Delta t)$, from Mathison (1963)

where

Δt is the difference in the mean maximum and mean minimum temperatures in degrees F.

The sunshine percentage S, expressed decimally, may be estimated from the sky cover, SC, by use of the equation given by Christiansen (Hargreaves 1967) as follows

$$S = 1.0 - 0.016\ SC - 0.0084\ SC^2$$

when sky cover values are reported on a scale of 0 to 8, adjusted values of SC may be obtained by multiplying by 1.25.

Hargreaves' equations are based upon data considered to be fairly representative of evaporation and evapotranspiration from irrigated areas. Computed values are, therefore, believed to be a better index of irrigation requirements than Class A pan evaporation from arid, dry-land locations. The computer symbol used for E_{vc} in this formula is ETH2.

Hargreaves-Christiansen formula

In 1968, Hargreaves and Christiansen (personal communication) suggested a formula for E_{tp} for Davis, California, which is

$$E_{tp} = 8.38\ d\ t_c\ F_E\ C_{HH}\ C_{HW}\ C_{HS} \quad \ldots\ldots\ldots\ldots \quad (9)$$

in which

E_{tp} is potential evapotranspiration in mm/day,

F_E is as in Hargreaves'modified equation,

$C_{HH} = 0.464 + 1.661\ (h_m/0.6) - 1.125\ (h_m/0.6)^2$,

$C_{HW} = 0.439 + 0.850\ (W2M/10) - 0.289\ (W2M/10)^2$, and

$C_{HS} = 0.475 + 0.964\ (S/0.8) - 0.439\ (S/0.8)^2$.

In these equations, d, t_c, h_m, and S are as previously defined. The computer symbol used for E_{tp} in this formula is ETHC.

Penman equation

Penman (1948) proposed a vapor transfer equation for evaporation from an open water surface

$$E_{vc} = 0.35\ (1 + 0.01\ W2MP)\ (e_s - e_d) \quad \ldots\ldots\ldots \quad (10)$$

in which

E_{vc} is evaporation, in millimeters per day,

W2MP is the wind velocity, in miles per day, measured 2 meters above the surface,

e_s is the vapor pressure of the evaporating surface, in millimeters of mercury,

e_d is the vapor pressure in the atmosphere, in millimeters of mercury.

Assuming that the mean air temperature is the same as the water surface temperature, expressing the saturated vapor pressure of the atmosphere as e_a, and designating the evaporation from a water surface computed on this basis as E_{vc}, Penman gives for E_{vc}

$$E_{vc} = 0.35(e_a - e_d)(1.0 + 0.0098\ W2MP) \quad . \ . \ . \ . \ . \ . \ . \ (11)$$

Combining the concept of a heat budget and vapor transfer equation, he developed the formula for evapotranspiration from a grassed surface

$$E_{tp} = (H + 0.27\ E_a)/(\Delta + 0.27) \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ (12)$$

in which

H is daily heat budget at the surface, in millimeters of water per day, given by the equation

$$H = R_A\ (1 - r)\ (0.18 + 0.55\ n/N) - \sigma\ T_a^4\ (0.56 - 0.092\ e_d)\ (0.10 + 0.90\ n/N) \ . \ . \ . \ . \ (13)$$

in which

R_A is the mean monthly extraterrestrial radiation in millimeters of water per day,

r is the reflection coefficient of the surface, taken as 0.25 for a grass cover.

n is the actual duration of bright sunshine,

N is the maximum possible duration of bright sunshine,

σ is Boltzman's constant = 2.01×10^{-9} millimeters per day,

e_d is the saturation vapor pressure at the mean dewpoint (i.e., actual vapor pressure in the air), in millimeters of mercury,

e_a is the saturation vapor pressure at mean air temperature in millimeters of mercury,

E_{vc} is evaporation in millimeters of water per day from the vapor transfer equation,

E_{tp} is the potential evapotranspiration, in millimeters of water per day, for grass, and

Δ is the slope of saturated vapor pressure curve of air at absolute temperature, T_a, in degrees F (mm Hg/F).

Wind measurements taken at other heights, h_a, can be corrected to the 2-meter elevation by use of the formula

$$W2MP = WA \log 6.6/\log h_a \quad . \quad . \quad . \quad (14)$$

in which

WA is measured wind speed in miles per day at height h_a, in feet.

The ratio n/N = S, the sunshine percentage expressed decimally as used in other formulas.

The computer symbol used for E_{tp} in this formula is ETPE.

Kohler, Nordenson, and Fox formula

Kohler, Nordenson, and Fox (1955) developed a revised equation for estimating Class A pan evaporation, E_{vc} in inches per day. Using the same notation as for Penman's formula, this equation can be written

$$E_{vc} = 0.37\ (1.0 + 0.0114\ W)\ \left[(e_a - e_d)/25.4\right]^{0.88} \quad . \quad . \quad (15)$$

in which

W is the wind velocity in miles per day as measured at a standard Class A pan (0.6 m above ground surface).

For annual lake evaporation, expressed in mean inches per day, they used the Penman formula (Eq. 12), with a factor of 0.70 and substituted E_p for E_a and Q_n for H/25.4. In order to evaluate H, an albedo factor, r, equal to 0.06 was assumed. The annual lake evaporation, in inches per day, can then be written

$$E_L = 0.70\ (Q_n + 0.27\ E_p)/(\Delta + 0.27)\ .\ .\ .\ .\ .\ .\ .\ .\ (16)$$

In the computer program, this value of E_L is compared with evapotranspiration from other formulas. The computer symbol used for E_L in this formula is ELKO.

Turc formula

Turc (1961) presented a formula for potential evapotranspiration, E_{tp}, in mm per day that can be written

$$E_{tp} = 0.013\ t_c\ (R_s + 50)/(t_c + 15)\ .\ .\ .\ .\ .\ .\ .\ .\ (17)$$

in which

R_s is the mean incoming radiation in langleys/day (calories/cm^2/day).

Darlot and Lecarpienter (1963) modified this formula by proposing an equation for estimating R_s from the theoretical radiation, R, reaching the earth's atmosphere, and the sunshine percentage expressed decimally. This equation can be written

$$R_s = R\ (0.18 + 0.62\ S)\ .\ .\ .\ .\ .\ .\ .\ .\ .\ .\ .\ (18)$$

The computer symbol used for E_{tp} is ETTU in this formula.

Papadakis formula

Papadakis (1961), in Argentina, computed potential evapotranspiration using his equation, which can be written

$$E_{tp} = 0.1875\ (e_{am} - e_{dm}) \quad \text{. . . . .} \quad (19)$$

in which

e_{am} is the saturation vapor pressure at the average daily maximum temperature of the month, in millibars,

e_{dm} is the saturation vapor pressure at the temperature of dew point, in millibars.

The computer symbol used for E_{tp} is ETPA in this formula.

Jensen's formula

Jensen's formula was suggested in a personal communication to Professor J. E. Christiansen. It is understood that it was based on a study of lysimeter data from Professor W. O. Pruitt, University of California. The equation can be written as follows

$$E_{tp} = R_s \left[\sqrt{e_{df}} / (9\sqrt{e_{df}} + 247) \right] (t_c - 3.47 + 42.07/\sqrt{e_{df}}) \quad \text{. .} \quad (20)$$

in which

$$e_{df} = e_{am} - e_{dm}$$

The computer symbol used for E_{tp} is ETJE in this formula.

Jensen and Haise formula

Jensen and Haise (1963) developed a formula for computing the potential evapotranspiration based on the mean air temperature and solar radiation. Their formula is

$$E_{tp} = (0.014\ t - 0.37)\ R_s \quad \text{. . . . .} \quad (21)$$

in which

R_s is the incoming solar radiation in the same units as E_{tp}.

The solar radiation for a given month and latitude is affected primarily by the degree of cloud cover and sunshine. The computer symbol used for E_{tp} in this formula is ETJH.

Linacre's formula

Linacre (1967) has presented a formula to compute potential evapotranspiration, which can be written

$$E_{tp} = R_s \left[4.7\ t_c + 110(e_a - e_d)/t_c - 9.6\ (1+4\ S)\right] / (6\ t_c + 75) \quad ..(22)$$

in which

S is sunshine, expressed decimally.

The computer symbol used for E_{tp} in this formula is ETLI.

Investigations at Utah State University

Christiansen (1966, 1968), working at Utah State University, developed several formulas for estimating evaporation and evapotranspiration. The primary objective of his studies was to develop a practical formula for determining water requirements in connection with the development of irrigation projects, especially in foreign countries where actual data on evapotranspiration are very limited.

The objective was to develop formulas that would:

1. Take into consideration most of the climatic parameters that affect evaporation and evapotranspiration.

2. Use climatic data of the type published in the U.S. Weather Bureau's State climatological data, or similar data published in other countries.

3. Be easy to apply using tables that have been computed for the climatic coefficients, and that could be used even though some of the desired climatic data were missing.

His basic formula can be written

$$E_{vt} = K\,R\,C \qquad (23)$$

in which

K is a dimensionless constant, determined from the analysis of many data,

R is the theoretical or extraterrestrial solar radiation reaching the earth's outer atmosphere, expressed in the same units as E_{vt},

C is an empirical coefficient, which is the product of any number of subcoefficients, each expressing the effect of a given climatic or other factor. Thus,

$$C = C_T\,C_H\,C_W\,C_S\,C_E \text{ etc} \qquad (24)$$

in which T, H, W, S, and E are mean monthly values of temperature, humidity, wind, sunshine, and elevation, etc.

Each coefficient has generally been expressed as a second degree equation of the form

$$C_X = A + BX + CX^2 \qquad (25)$$

except where the data suggested a different form of equation. In this equation, X represents parameters of climatic or other factors.

Christiansen revised formula for Class A pan evaporation

Christiansen (1966, 1968) developed a formula which can be written

$$E_{vc} = K\ R\ C_T\ C_W\ C_S\ C_E\ C_M \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \qquad (26)$$

in which

E_{vc} is the pan evaporation which may be expressed in any desired units of length and time. The most commonly used units are mm/month and mm/day,

K = 0.473 based on a solar constant of 1.94 cal/cm^2/min and equal to 0.459 when a solar constant of 2 cal/cm^2/min is used,

R is the solar radiation at the top of the atmosphere expressed in the same units as E_{vc},

C_T $= 0.393 + 0.559\ (t_c/20) + 0.048\ (t_c/20)^2$,

C_W $= 0.708 + 0.328\ (W/60) - 0.036\ (W/60)^2$; W is the mean wind velocity in miles per day measured at 0.6 meters above the ground or 6 inches above the rim of the pan,

C_{Hn} $= 1.250 - 0.348\ (h_n/0.4) + 0.120\ (h_n/0.4)^2 - 0.022\ (h_n/0.4)^4$ or where mean humidity is available,

C_{Hm} $= 1.250 - 0.212\ (h_m/.4) - 0.038\ (h_m/0.4)^5$,

C_S $= 0.542 + 0.640\ (S/0.8) - 0.499(S/0.8)^2 + 0.317(S/0.8)^3$,

C_E $= 0.970 + 0.030\ (E/305)$; E is the elevation in meters, and

C_M = monthly coefficient, tabulated for many regions.

Calculation of subcoefficients might appear to be tedious and time consuming, but in practice, when once determined, the subcoefficients and their logarithms can be tabulated for a convenient range of values of each parameter. The value of E_{vc} is determined by simply adding the

logarithms of all terms involved in the formulas and taking the antilogarithm. The computer symbol used for E_{vc} in this formula is EVC.

From data obtained from Professor Pruitt at the University of California, Davis, California, Christiansen developed another formula for pan evaporation which is designated in the computer programs as EVC1. This formula did not agree with Class A pan evaporation in Venezuela and is not considered reliable for use in Peru.

Christiansen and Hargreaves (1969) presented three equations for computing potential evapotranspiration which may be written

$$E_{tp} = 0.755\, E_v\, C_{T2}\, C_{S2}\, C_{H2}\, C_{W2} \quad . . . . \quad (27)$$

$$E_{tp} = 0.324\, R\, C_{TT}\, C_{ST}\, C_{HT}\, C_E\, C_{WT} \quad . . . . \quad (28)$$

$$E_{tp} = 0.492\, R_s\, C_{TT}\, C_{HT}\, C_{WT} \quad . . . . \quad (29)$$

in which

$C_{T2} = 0.862 + 0.179\ (t_c/20) - 0.041\ (t_c/20)^2$,

$C_{S2} = 0.904 + 0.008\ (S/0.8) + 0.088\ (S/0.8)^2$,

$C_{H2} = 0.499 + 0.620\ (h_m/0.6) - 0.119\ (h_m/0.6)^2$,

$C_{TT} = 0.463 + 0.425\ (t_c/20) + 0.112\ (t_c/20)^2$,

$C_{ST} = 0.340 + 0.856\ (S/0.8) - 0.196\ (S/0.8)^2$, and

$C_{HT} = 1.035 + 0.240\ (h_m/0.6)^2 - 0.275\ (h_m/0.6)^3$.

In applying these equations to the data from Perú, the coefficients for wind, C_{W2} and C_{WT} were omitted because wind data were not available.

The computer symbols used for E_{tp} in these formulas are ET2, ET3, and ET5C for formulas (27), (28), and (29), respectively.

In order to apply equation (29) to Peruvian data, it was first necessary to estimate the incoming radiation, R_s. For this purpose, R_s

was computed from the equation developed by Pizarro (1967) which is designated as R_c.

$$R_s = 0.622\ R\ C_{sp}\ C_E \quad \ldots\ldots\ldots\ldots \quad (30)$$

in which

$$C_{sp} = 0.320 + 0.85\ S$$

Mathison formulas

Mathison (1963), using 3232 months of records for 40 stations in the western states and Texas, USA, obtained the following formula for estimating evaporation from a standard Weather Bureau Class A pan.

$$E_v = C_R\ C_T\ C_W\ C_{\Delta T}\ C_S\ C_E\ C_{(L-D)}\ C_M \quad \ldots\ldots\ldots \quad (31)$$

The equations for the coefficients, some of which have been converted to a dimensionless form, with temperature in degrees F, are

$$C_R = 0.20\ R + 0.015\ R^2,$$

$$C_T = -0.260 + 1.576\ (t/65) - 0.316\ (t/65)^2,$$

$$C_W = 0.800 + 0.210\ (W/60) - 0.01\ (W/60),$$

$$C_{\Delta T} = 0.450 + 0.700\ (\Delta t/27)^2 - 0.150\ (\Delta t/27)^4,\ \Delta t = {}^oF,$$

$$C_{(L-D)} = 1.160 + 0.420\ \cos(L-D) + 0.7\ \left[\cos(L-E)\right]^2, \text{ and}$$

$$C_E = 0.967 + 0.035\ (E/305) - 0.002\ (E/305)^2.$$

in which

R is the radiation at the top of the atmosphere expressed in equivalent evaporation in inches per month.

Δt is the difference between the mean maximum and minimum temperature, $\Delta t = t(max) - t(min)$ in ^oF,

L is the latitude, in degrees,

D is the mean declination of sun for the month, in degrees.

He found that the monthly coefficient could be expressed approximately by the equation

$$C_M = 1.00 + 0.00155\ (L-D)\ \cos\left[\pi(N+1)/6\right]$$

where N is the number of the month, (January = 1).

Since three of these coefficients are functions of the latitude and the month only, they were combined into a single coefficient, C_c, thus

$$C_c = C_R\ C_{(L-D)}\ C_M$$

Mathison computed and tabulated values of C_R, $C_{(L-D)}$, C_M and C_c for each month and each 5 degrees of latitude from 60°S to 60°N. The computer symbol used for E_v in this formula is EVM.

Lopez and Mathison formulas for E_{tp}

Lopez and Mathison (1965) suggested a regression equation for computing potential evapotranspiration

$$E_{tp} = 0.865\ E_v - 0.832 \quad \text{. . . . .} \quad (32)$$

In this formula E_{tp} and E_v are expressed in mm/day.

Grassi formulas

Grassi (1967) developed three formulas for evapotranspiration computations. His first formula, which was somewhat similar to Mathison's, can be written,

$$E_t = 5.46\ C_{RG}\ C_{TD}\ C_{CLC}\ C_{TG1}\ F_G \quad \text{. . . . .} \quad (33)$$

in which

C_{RG} = 0.1824 + 1.46 R_d, (where R_d is the solar radiation received at the top of the atmosphere, expressed in inches per day),

C_{TD} = 0.9361 + 0.00767 (Δt),

C_{CLC} = 1.15 - 0.05 SKC, where SKC is the sky cover, scale of 0 to 10,

C_{TG1} = 0.036 + 1.489 (t/68) - 0.525 $(t/68)^2$, and

F_G is the mean value of a factor for each crop for which data were available.

Alfalfa	1.09	Cotton	1.08
Beans	0.98	Oats	0.89
Corn	1.00	Potatoes	1.02
Sugar beets	1.00	Sorghum	1.16
		Winter wheat	1.10

Grassi's second and third equations are:

$$E_t = 0.537\ R_s\ C_{TG2}\ F_G \qquad (34)$$

$$E_t = 0.968\ E_v\ C_{TG3}\ F_G \qquad (35)$$

in which

C_{TG2} = 0.620 + 0.380 (t/68),

C_{TG3} = 1.754 - 0.754 (t/68).

The computer symbols used for E_t in these formulas are ETG1, ETG2, and ETG3 for formulas (33), (34), and (35), respectively.

DATA AND COMPUTER PROGRAMS

Piche evaporation and climatological data were obtained from the "Servicio de Agrometeorologia o Hidrologia" bulletins published by the Ministerio de Agricultura, Perú. Twelve stations were selected from the network, according to the number of years of records, the completeness of the data, and the continuity of the observations. For the twelve stations, a total of 1728 months of record were included. The computer symbols used were:

NST or ST	Station number
MO	Month (1,2,3,etc.)
LA,LM	Latitude in degrees and minutes
XLO,XLOM	Longitude in degrees and minutes
EL	Elevation in meters
TX	Maximum temperature, Centigrade
TI	Minimum temperature, Centigrade
TM	Average temperature, Centigrade
HX	Maximum relative humidity, expressed decimally
HI	Minimum relative humidity, expressed decimally
HM	Average relative humidity, expressed decimally
VP7	Vapor pressure at 7 a.m., millibars (mb)
VP13	Vapor pressure at 1 p.m., millibars
VP18	Vapor pressure at 6 p.m., millibars
SHM	Sunshine hours per month
CC7	Cloud cover at 7 a.m., in eighths
CC13	Cloud cover at 1 p.m., in eighths

CC18	Cloud cover at 6 p.m., in eighths
PM	Monthly precipitation in millimeters
PD	Monthly precipitation expressed in millimeters per day
PEVM	Monthly Piche evaporation in millimeters
PEV	Monthly Piche evaporation expressed in millimeters per day

The names of the stations, the number assigned to each one, and the period of record are given in Table 1.

Venezuelan climatological data for the Shell Foundation Station at Cagua, Aragua, were studied for the purpose of comparing measured pan evaporation, and fuess evaporation as measured in a shelter, with the formulas of Christiansen, Penman, Mathison, Kohler, Blaney-Criddle, and Hargreaves. This was done to verify the validity of the formulas. The data included:

Latitude	10^{o} 11' N
Longitude	67^{o} 30' W
Altitude	430 meters above sea level

Temperature (max., min., and mean), relative humidity (max, min., and mean), wind in kilometers per hour, sunshine, days of precipitation, fuess evaporation and pan evaporation.

The computer symbols used for the measured pan evaporation and fuess evaporation are EVP and EVF, respectively.

Table 1. Peruvian meteorological stations

Station number	Location	Latitude in degrees	Elevation in meters	Years
1	Lambayeque	6.70	18	1928/60
2	Chiclayo	6.78	31	1944/48
3	Cartavio	7.90	51	1944/60
4	Paramonga	10.67	75	1938/60
5	Isla Guañape	8.53	5	1954/60
6	Huaraz	9.53	3,207	1949/60
7	Huánuco	9.97	1,800	1965/66
8	Puno	15.82	3,820	1965/66
9	Kcayra	13.57	3,400	1965/66
10	Tarapoto	6.48	356	1965/66
11	Cayaltí	7.07	150	1935/60
12	Zorritos	3.67	7	1943/60

Data from other sources

Theoretical radiation, R. The theoretical extra atmospheric radiation received at the top of the atmosphere was computed from the equation:

$$R = 120 \left[DL \sin(LA) \sin(DE) + 7.6394 \cos(LA) \cos(DE) \sin(OM) \right] / ES \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (36)$$

in which

$$OM = \text{Arc tan} \left[\frac{\sqrt{1 - \tan^2(LA) \tan^2(DE)}}{\tan(LA) \tan(DE)} \right] \quad . \; . \; . \; . \qquad (37)$$

R = extraterrestrial radiation, in langleys per day,

DL = day length (theoretical sunshine, in hours),

LA = latitude, in radians,

DE = mean monthly declination of the sun, in radians, and

ES = square of the monthly relative values of the distance from the earth to the sun, dimensionless.

This equation was developed for computer calculations by Christiansen from an equation given by Frank and Lee (1966).

Radiation at the earth's surface. The solar radiation reaching the earth's surface was calculated from the formula developed by Pizarro (1967).

$$R_s = 0.622 \, R \, C_{sp} \, C_E \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (30)$$

in which

R_s = radiation at the earth's surface, in langleys per day,

R = theoretical radiation at the top of the atmosphere, in langleys per day, and

C_{sp} = sunshine coefficient; in which S is the sunshine ratio (sunshine hours/theoretical daytime hours).

Heat of vaporization, HV. The heat of vaporization was computed from the equation

$$HV = 595.9 - 0.55\ t_c \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (38)$$

in which

HV = heat of vaporization in calories/gram.

This relation was used to express both theoretical and incoming radiation in equivalent depth of evaporation in millimeters by the expression

$$R\ (\text{millimeters per day}) = 10\ R_{LD}/HV \quad . \ . \ . \ . \ . \ . \quad (39)$$

in which

R_{LD} = radiation in langleys (cal/cm^2) per day. The factor 10 converts from centimeters to millimeters.

Day length, DL. The theoretical mean day length or daytime hours, for each month was estimated from the equation

$$DL = OM/0.1309 \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (40)$$

in which

DL = day length in hours, and

OM = as formerly defined.

Sunshine ratio, S. The sunshine ratio was computed from the expression

$$S = SH/DL \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (41)$$

in which

SH = mean sunshine hours per day, and

DL = as formerly defined.

In the Penman formula, S is expressed as n/N, in which n = actual duration of bright sunshine and N = maximum possible duration of bright sunshine.

Wind velocity. Wind velocity data were not available in most cases. An average value of 6.7 km/hour (100 miles/day) was used in all the computations as the value for wind measured at 2 meters above the ground, and a value of 60 miles/day was taken for the wind measured at 2 feet above the ground.

Computer programs

Computer program #50. This program was developed in order to compute evaporation and/or potential evapotranspiration with the following formulas:

1. E(3) = ETJE Jensen
2. E(4) = ETJH Jensen and Haise
3. E(5) = ELKO Kohler Lake Evaporation
4. E(6) = ETLI Linacre
5. E(7) = ETTU Turc
6. E(8) = ETPA Papadakis
7. E(9) = ETBC Blaney & Criddle
8. E(10) = ETBM Blaney & Morin
9. E(11) = ETHA Hargreaves
10. E(12) = ETH2 Hargreaves modified
11. E(13) = ETHC Hargreaves & Christiansen
12. E(14) = ETPE Penman

Computer program #52. This program was developed in order to compute evaporation and/or potential evapotranspiration with the following formulas:

1. E(3) = EVC Christiansen computed pan evaporation in mm/day
2. E(4) = EVC1 Computed pan evaporation, Davis (Pruitt)

3. E(5) = EVM Mathison pan evaporation
4. E(6) = ET2 Christiansen
5. E(7) = ET3 Christiansen
6. E(8) = ET5C Christiansen
7. E(9) = ET6 Christiansen ET2 using EVC1 for E_V
8. E(10) = ETMA Lopez and Mathison computed from EVM
9. E(11) = ETMC Lopez and Mathison computed from EVC
10. E(12) = ETG1 Grassi
11. E(13) = ETG2 Grassi
12. E(14) = ETG3 Grassi computed from Christiansen EVC

Computer program #51. This program was developed to obtain certain values for comparison and checking, i.e., this program computed average temperature from the maximum and minimum temperature and compared it with the actual given average temperature.

Computer program #53. This program was developed to compute the extraterrestrial radiation for latitudes from the Equator to 25° south. The computed values of extraterrestrial radiation were expressed as equivalent evaporation in mm/day.

Computer program #216C. This program was prepared to compare measured and computed pan evaporation for one Venezuelan station (Shell Foundation Station). The formulas used in this program are:

1. E(5) = EVC Christiansen
2. E(7) = EVM Mathison
3. E(9) = EVPE Penman
4. E(11) = EVKO Kohler
5. E(13) = EVBC Blaney & Criddle
6. E(15) = EVHA Hargreaves

PROCEDURE

The Piche evaporation and the climatological data for the twelve Peruvian stations were punched into the data cards. The values punched were the averages for each station for each month for the given period.

For use with some of the formulas considered here, data in metric units were converted to English units in the computer programs used.

The Peruvian data were analyzed with computer programs #50 and #52.

The Venezuelan data were analyzed with computer program #216C.

All the programs were run at the Computer Terminal Center, Engineering Building, Utah State University, using the Univac system.

RESULTS

1. Tables 3, 4, 5, 6, 7, 8, 9, and 10 show the computed values for evaporation and/or potential evapotranspiration for twelve Peruvian stations. See Appendix B.

2. Figures 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17 show the evaporation and/or potential evapotranspiration for the Peruvian stations #1, 3, 7, and 8.

3. Tables 11, 12, and 13 show the computed pan evaporation values for Shell Foundation Station (Venezuela). See Appendix B.

4. Figures 18A and 18B show the comparison of formulas for estimating pan evaporation with actual measured pan evaporation for Shell Foundation Station.

5. Table 14 shows the computed extraterrestrial radiation for latitudes from the Equator to 25 degrees south. See Appendix B.

6. Tables 15, 16, 17, and 18 show the comparison between measured and computed values for temperature, vapor pressure, and the theoretical radiation received at the top of the atmosphere and the computed radiation reaching the earth's surface. See Appendix B.

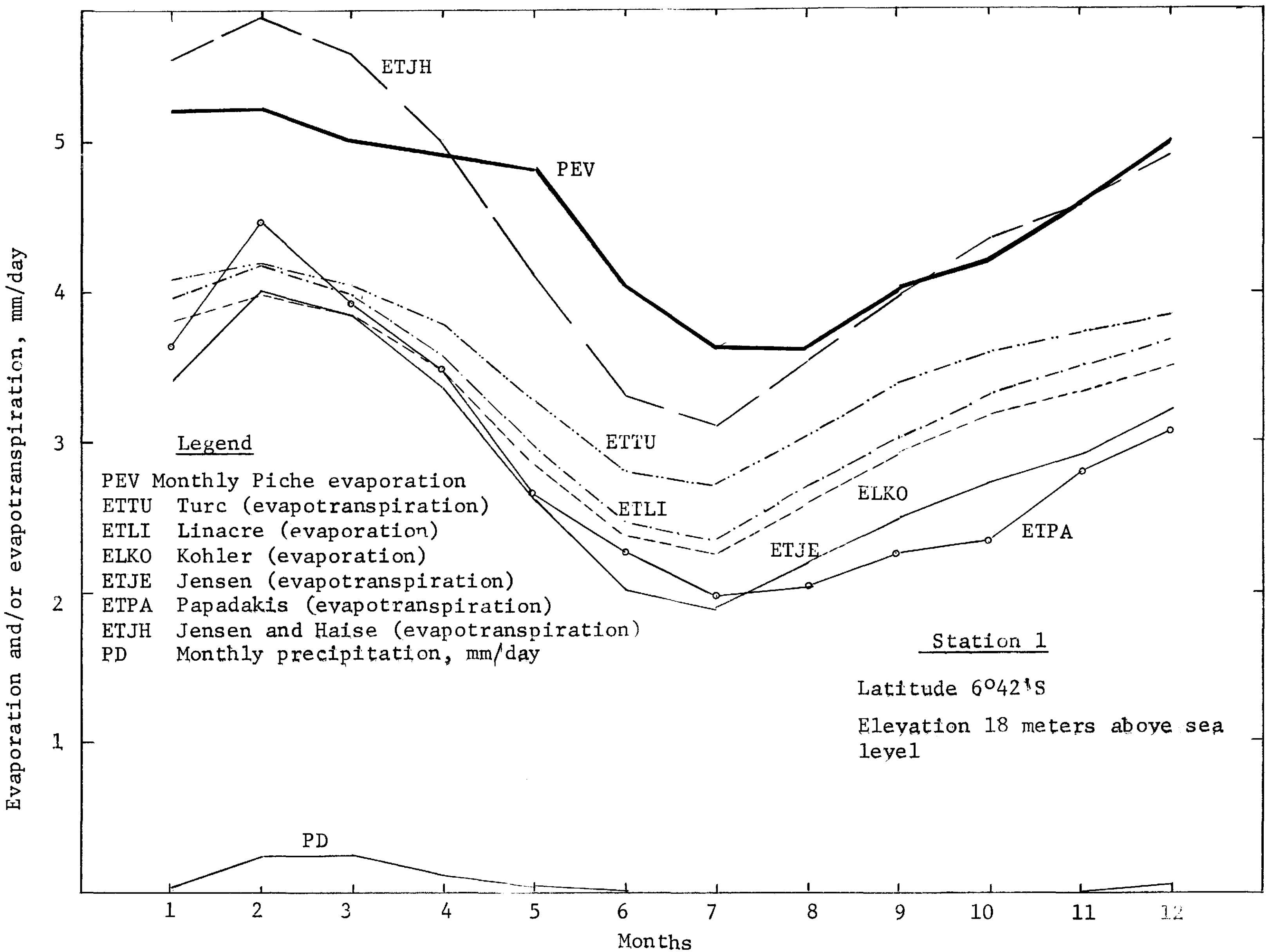

Figure 2. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

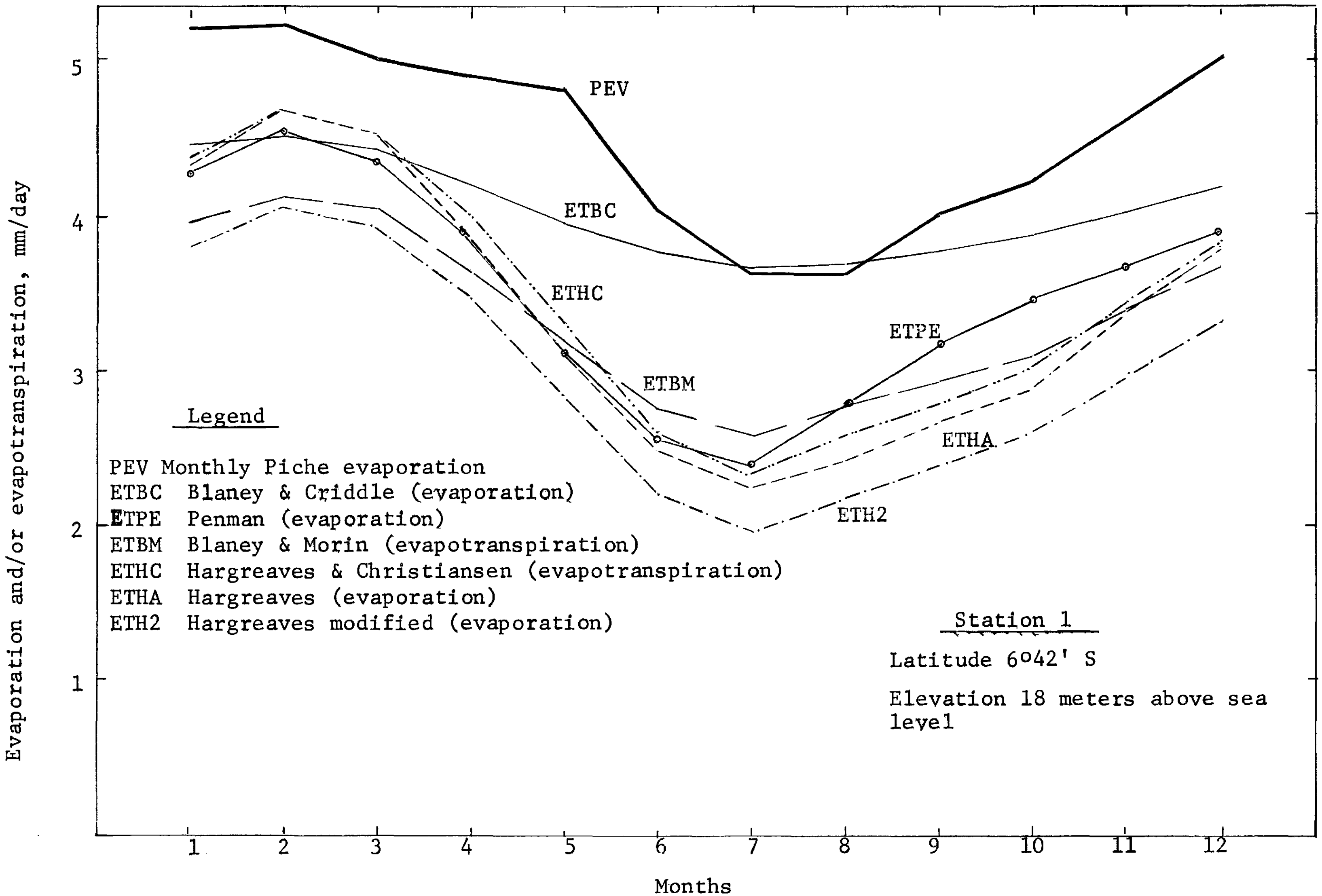

Figure 3. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

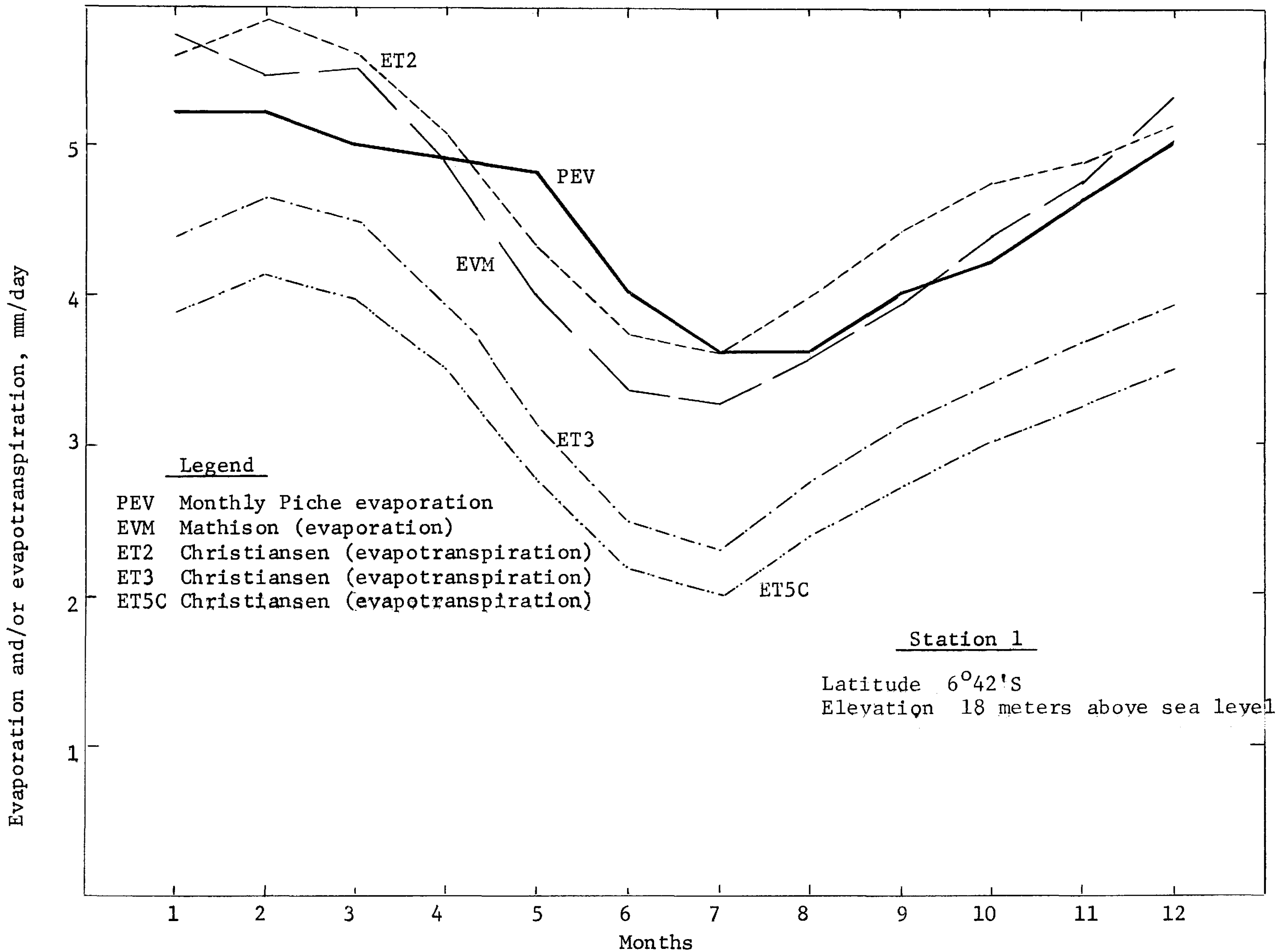

Figure 4. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

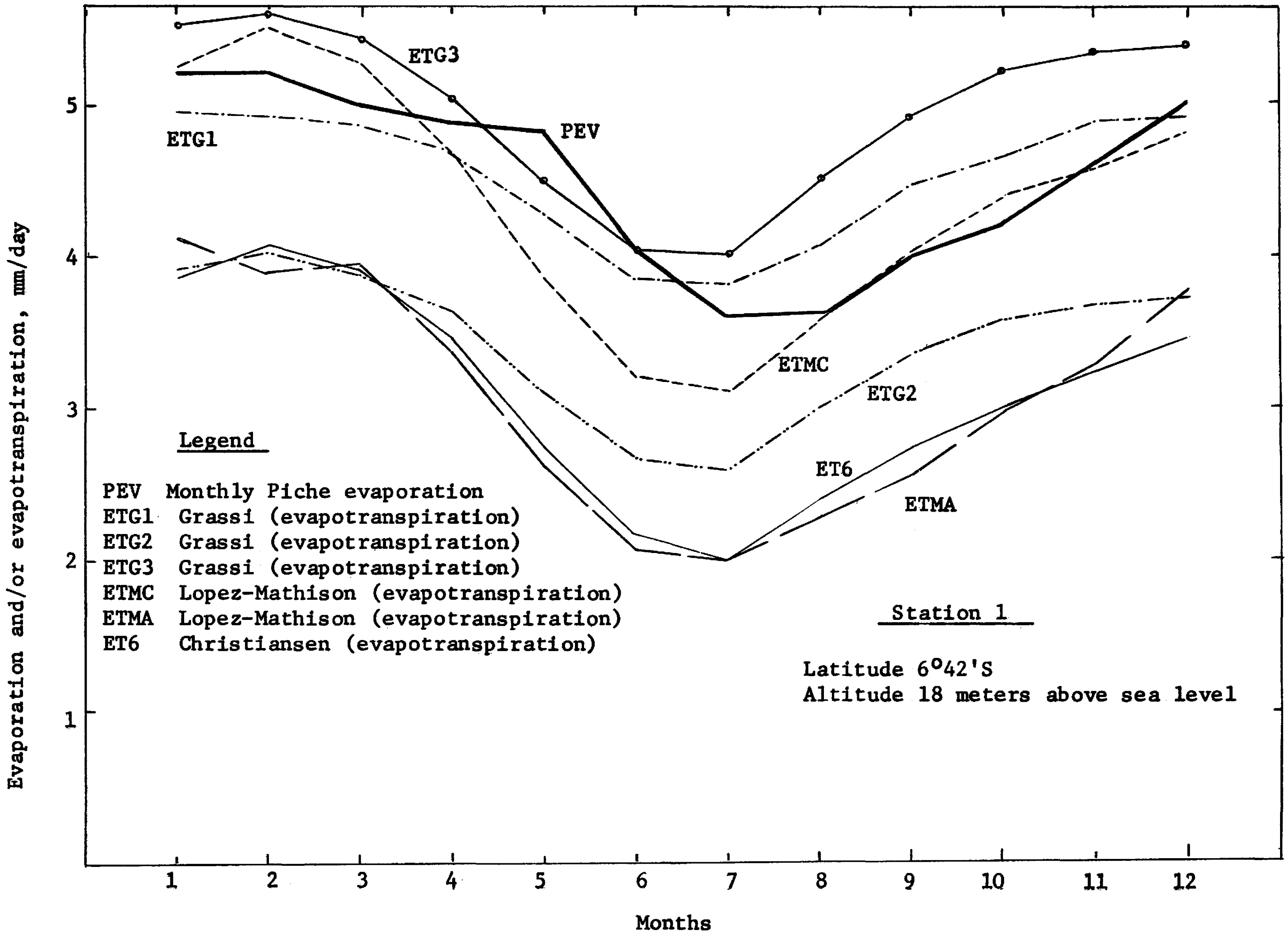

Figure 5. Comparison of formulas for estimating evapotranspiration with actual measured Piche evaporation.

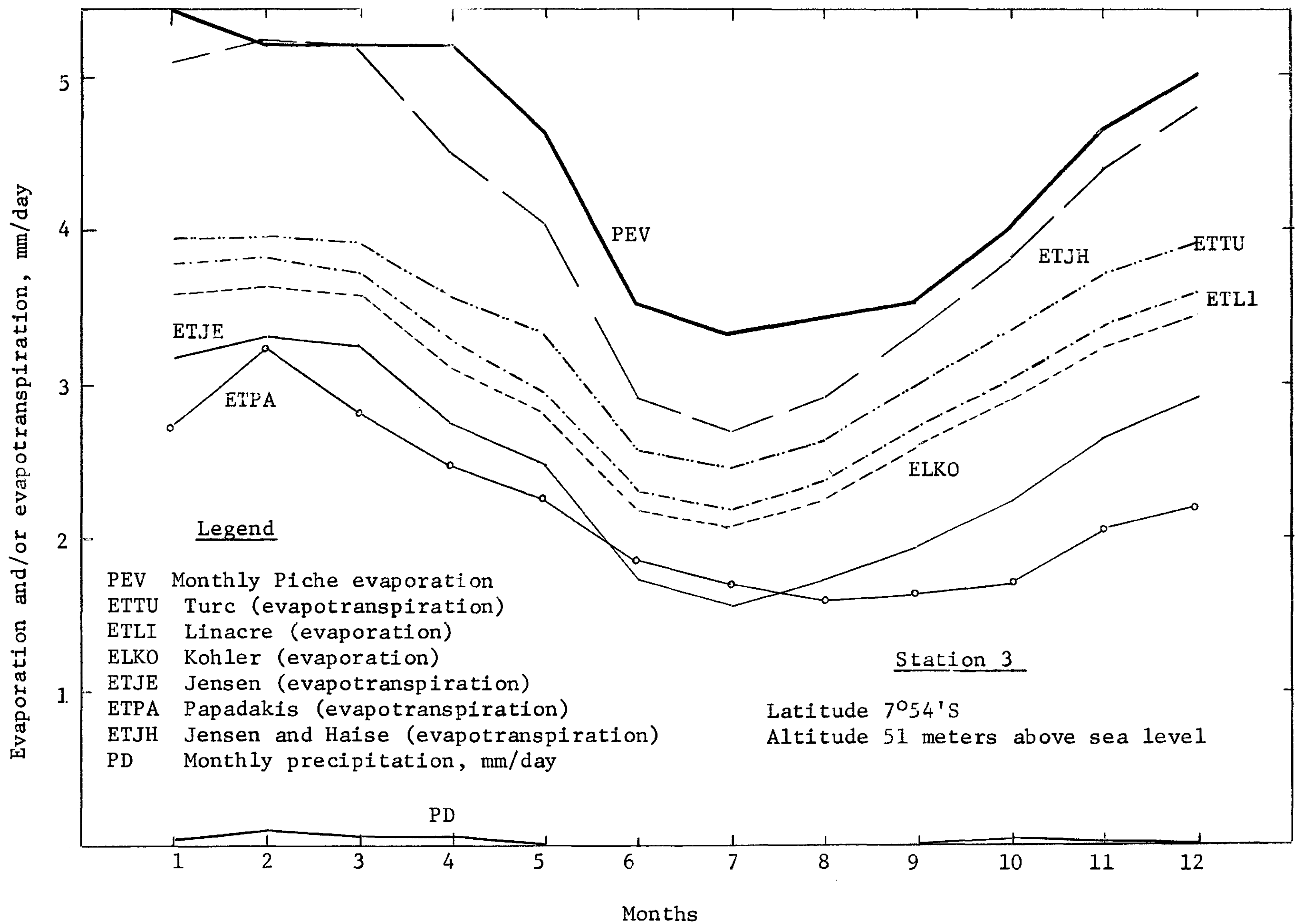

Figure 6. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

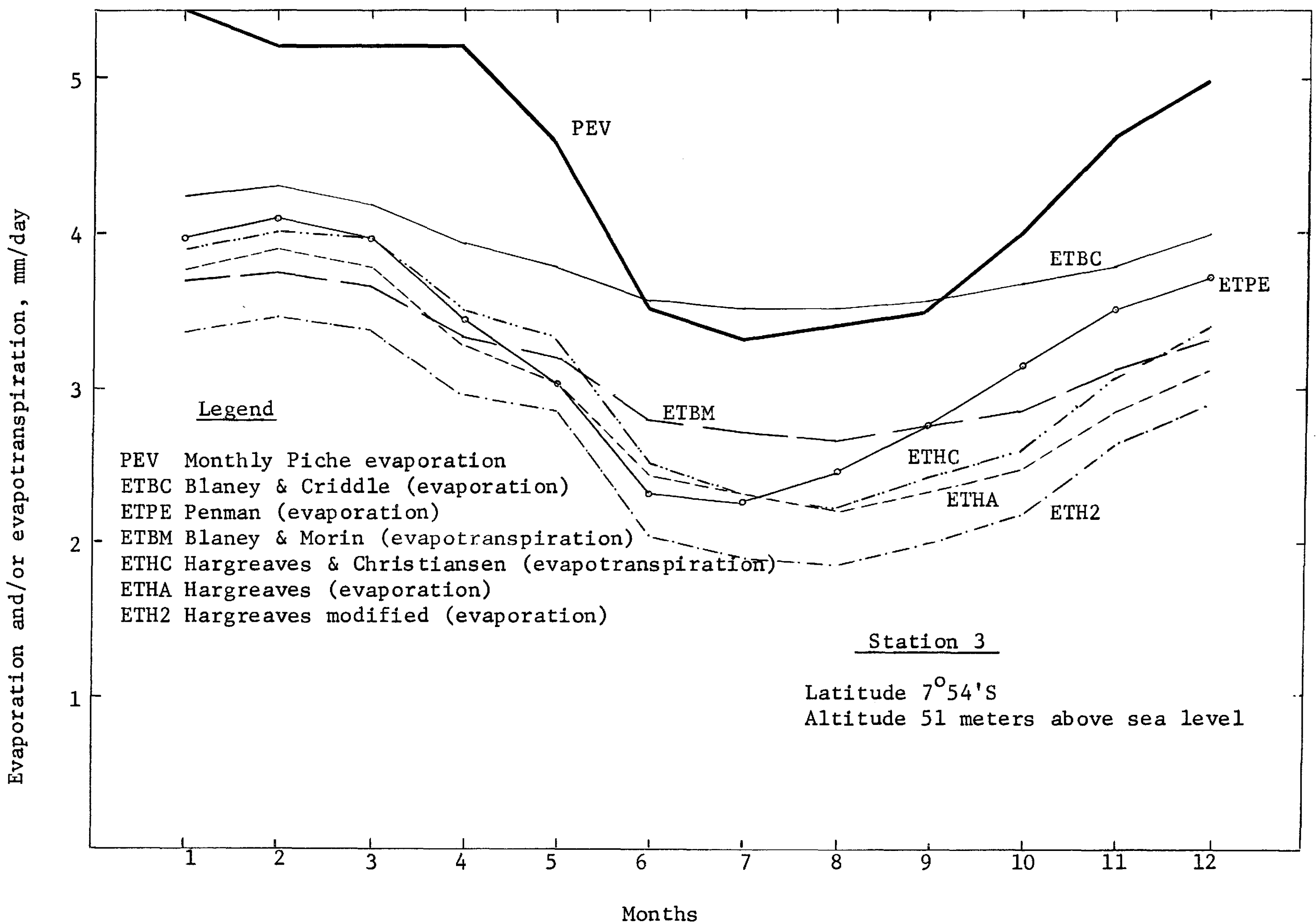

Figure 7. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

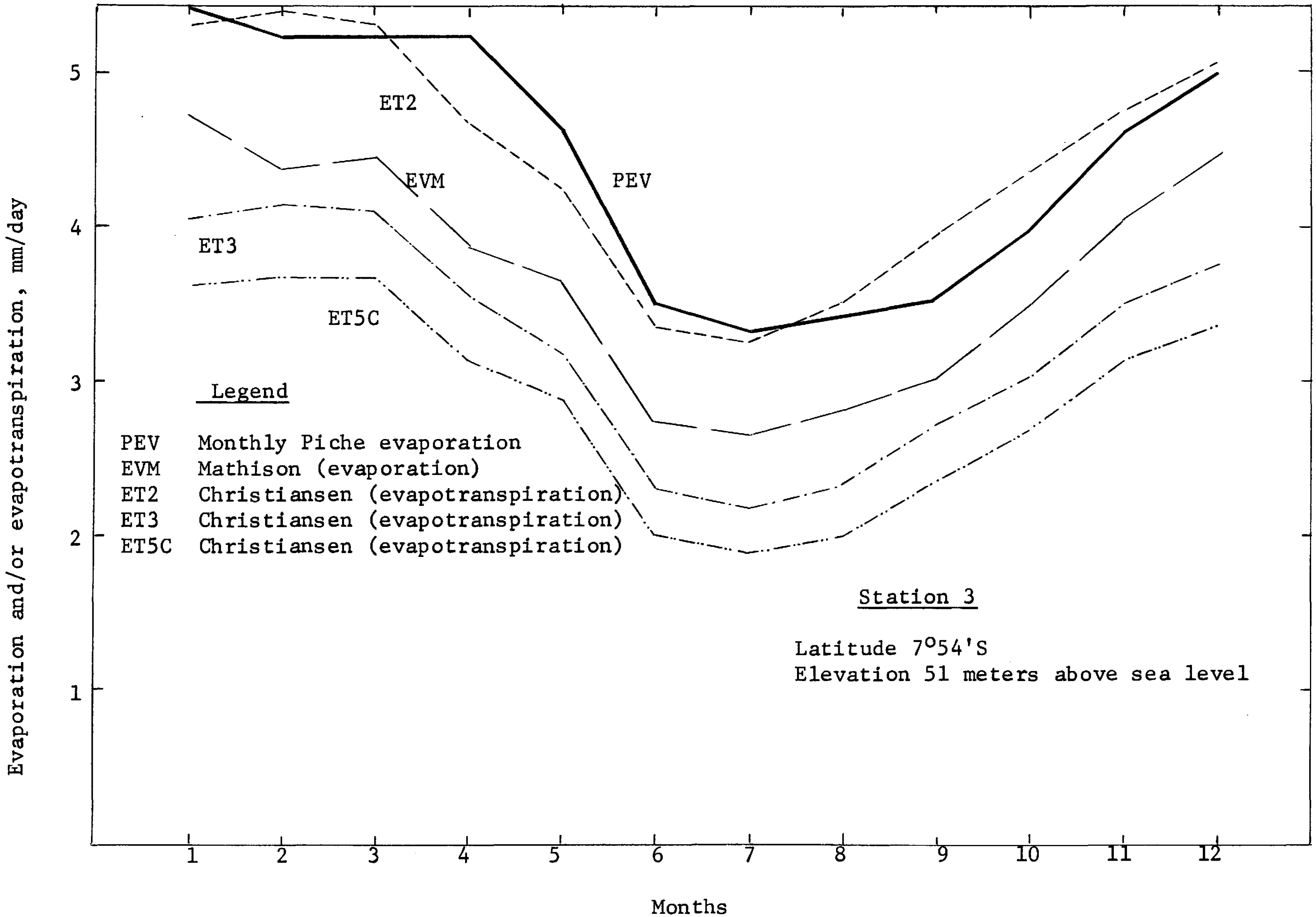

Figure 8. Comparison of formulas for estimating evaporation and/or evapotranspiration with measured Piche evaporation.

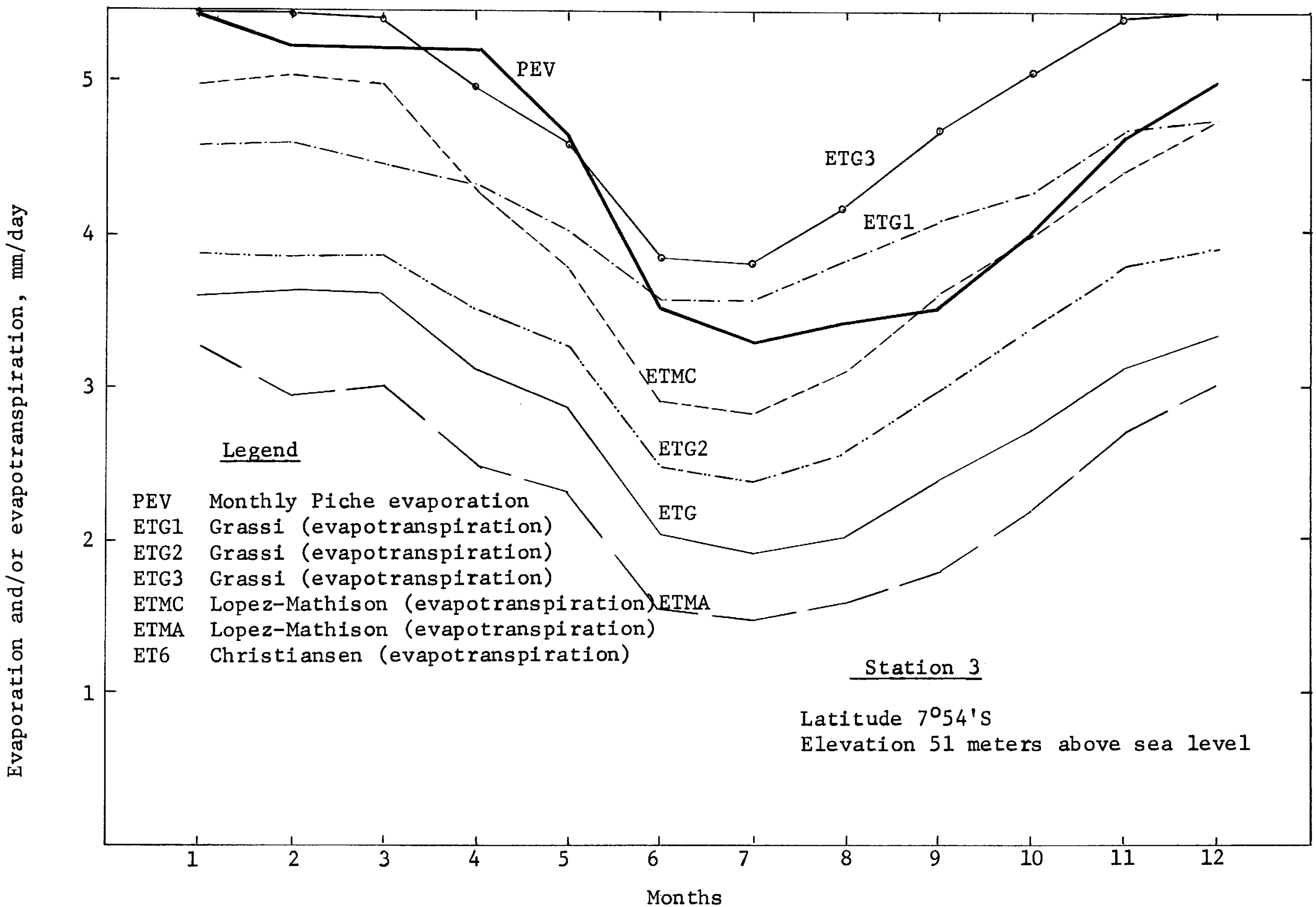

Figure 9. Comparison of formulas for estimating evapotranspiration with actual measured Piche evaporation.

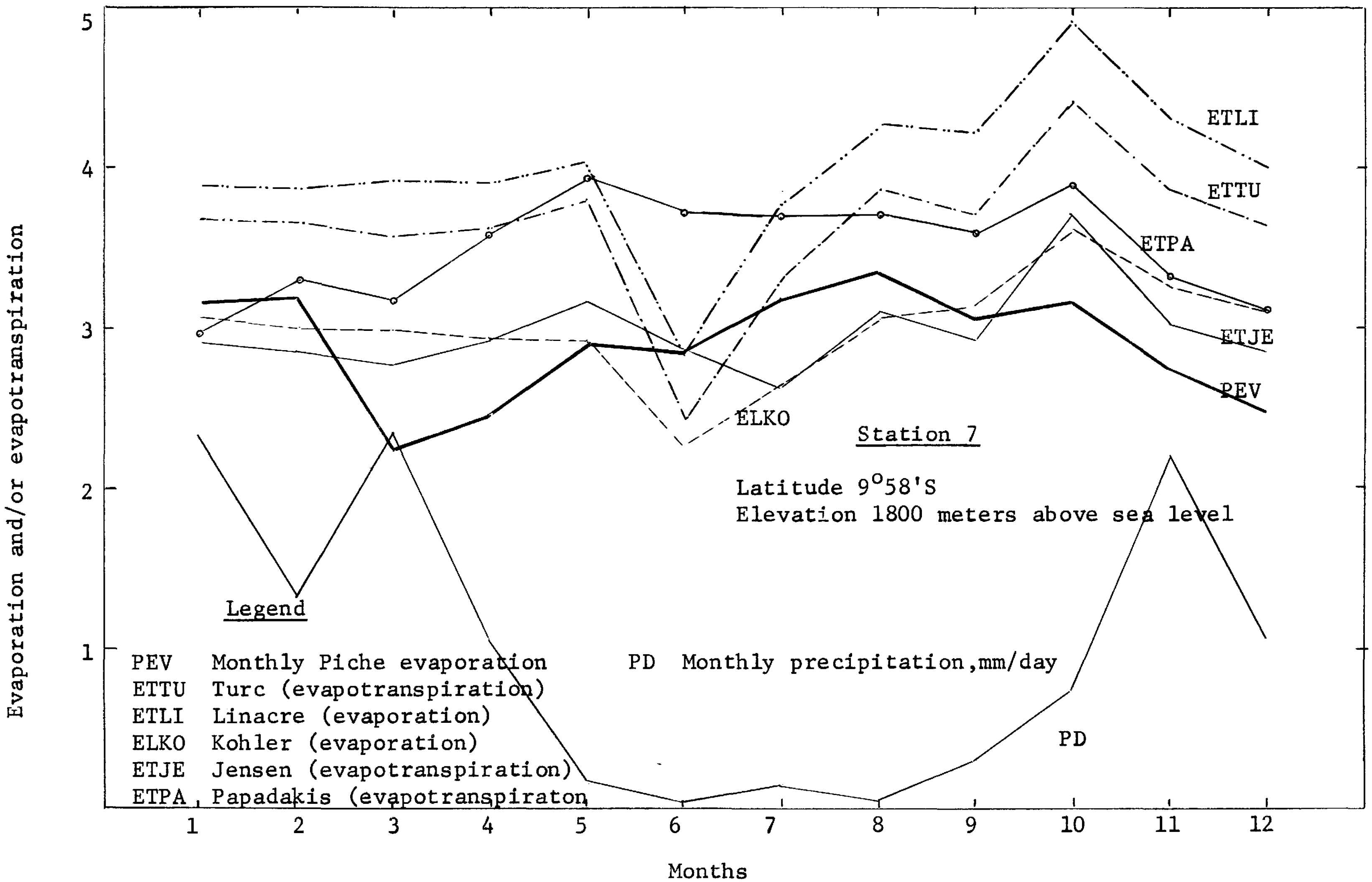

Figure 10. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

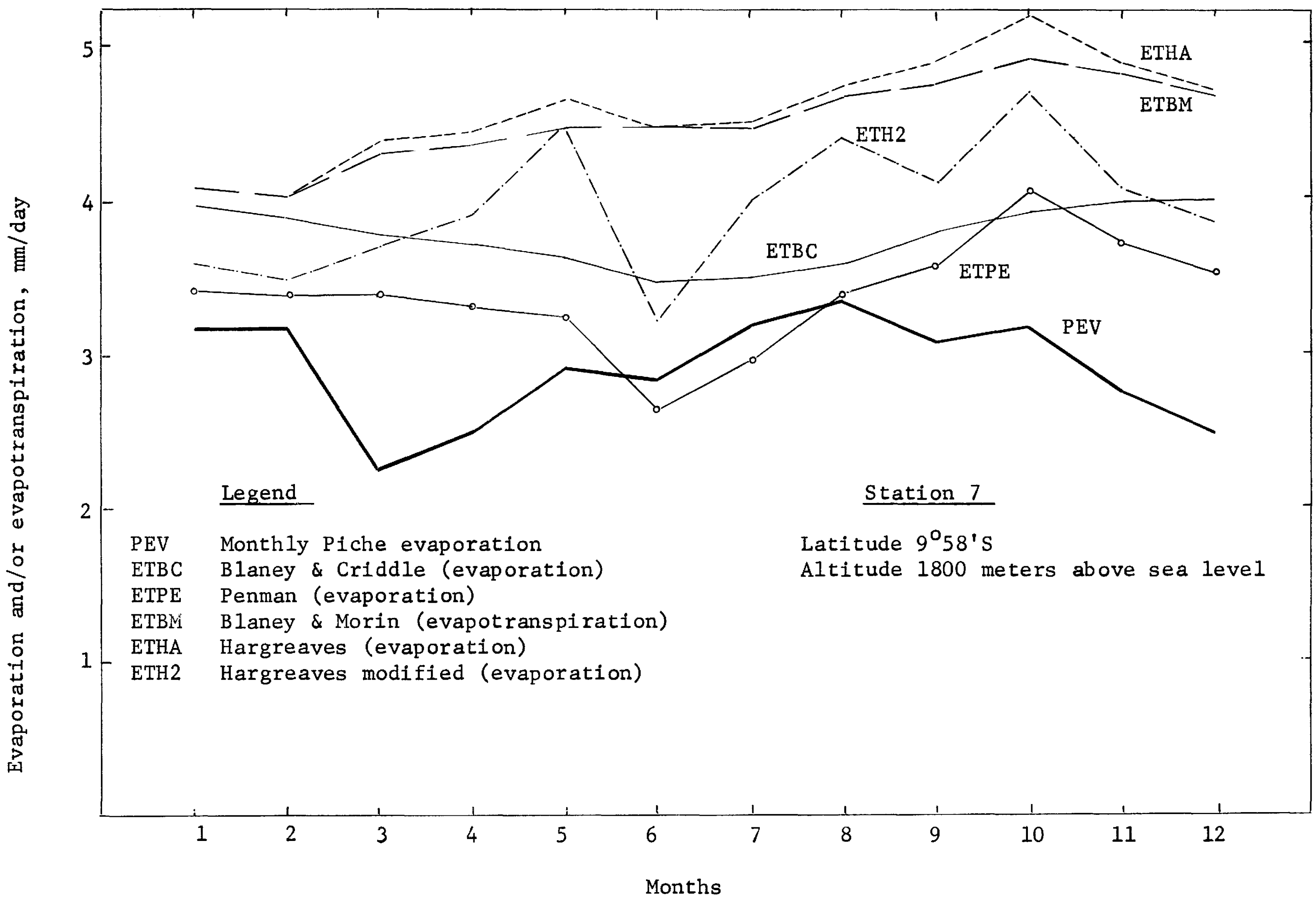

Figure 11. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

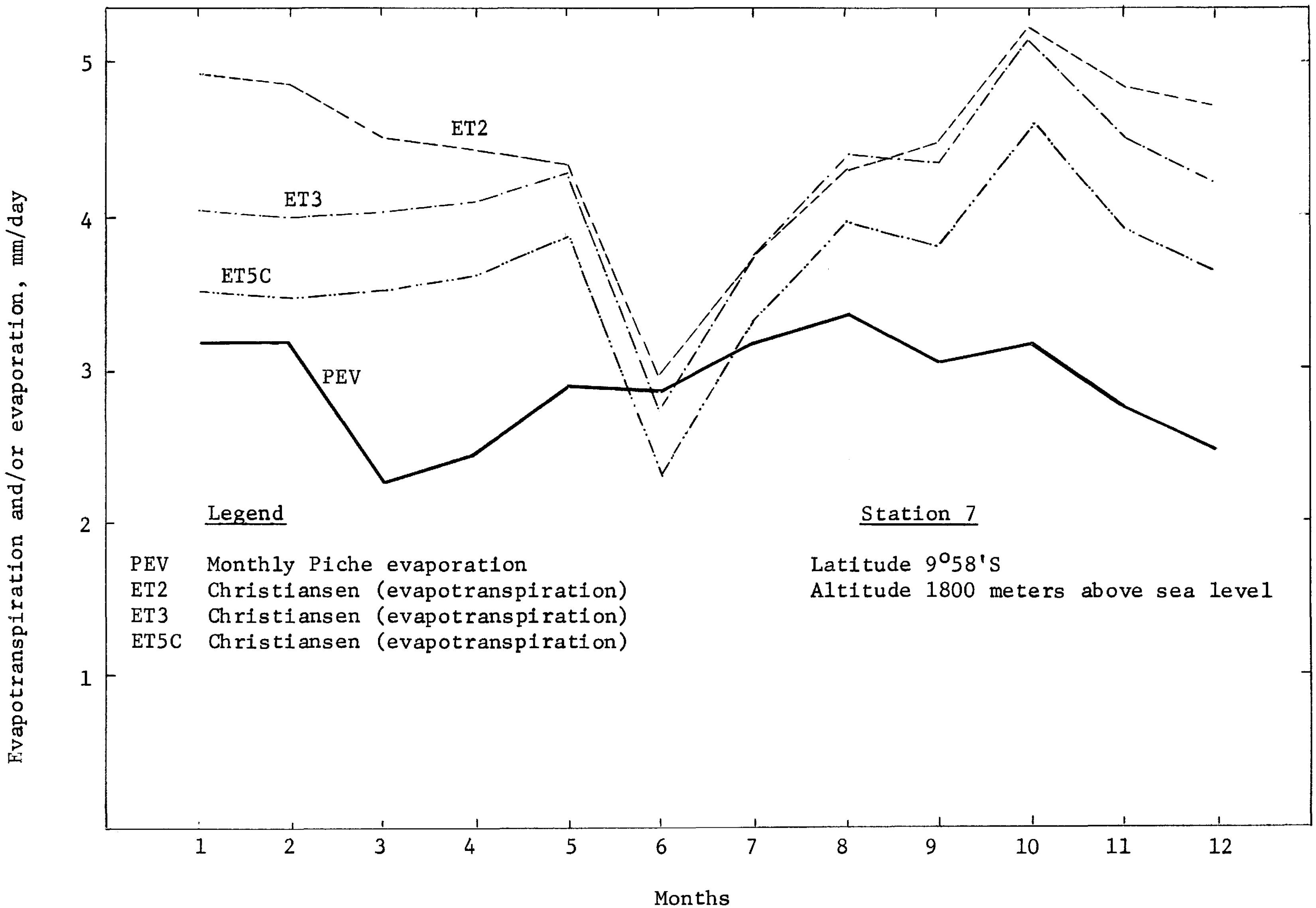

Figure 12. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

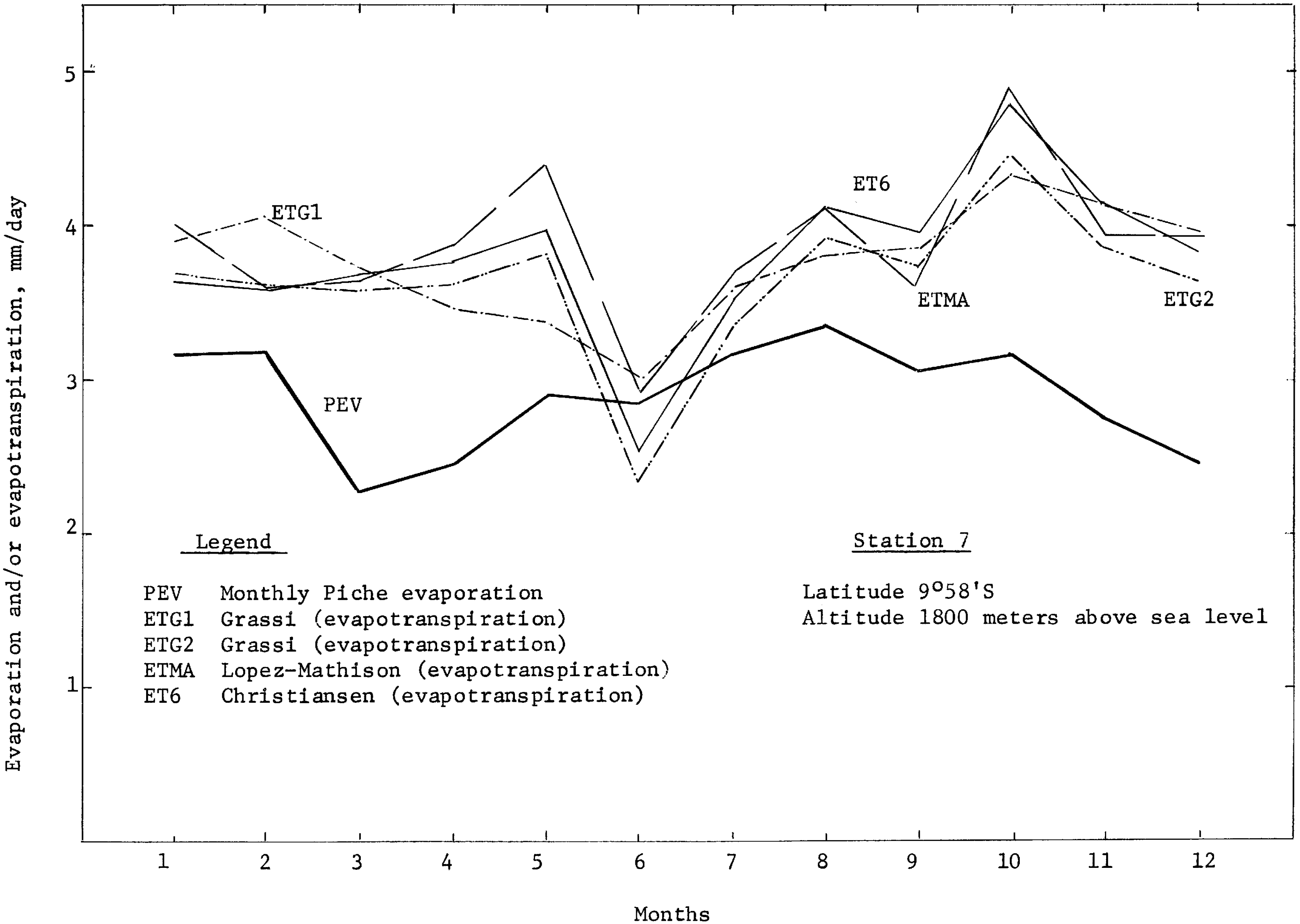

Figure 13. Comparison of formulas for estimating evapotranspiration with actual measured Piche evaporation.

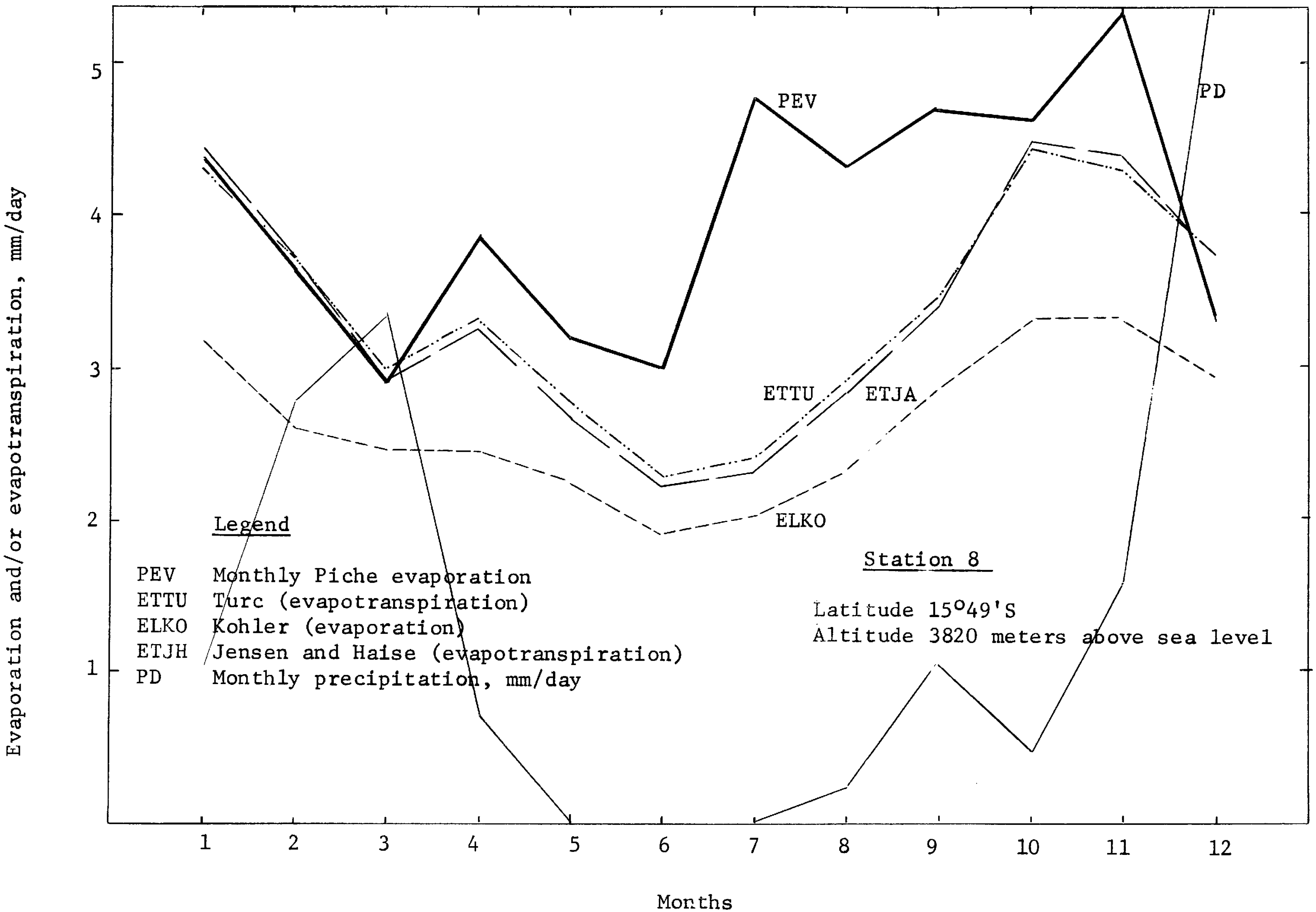

Figure 14. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

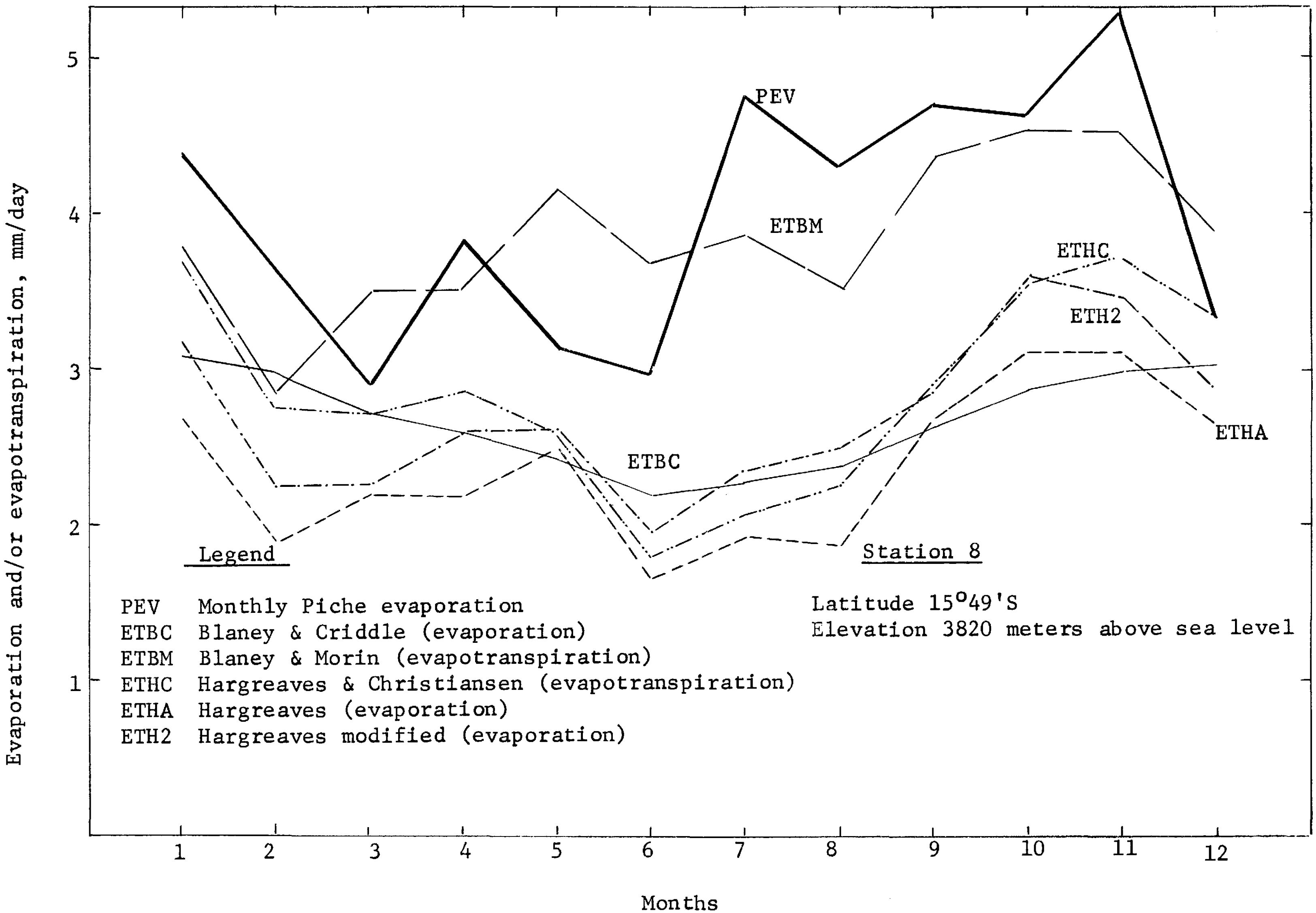

Figure 15. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

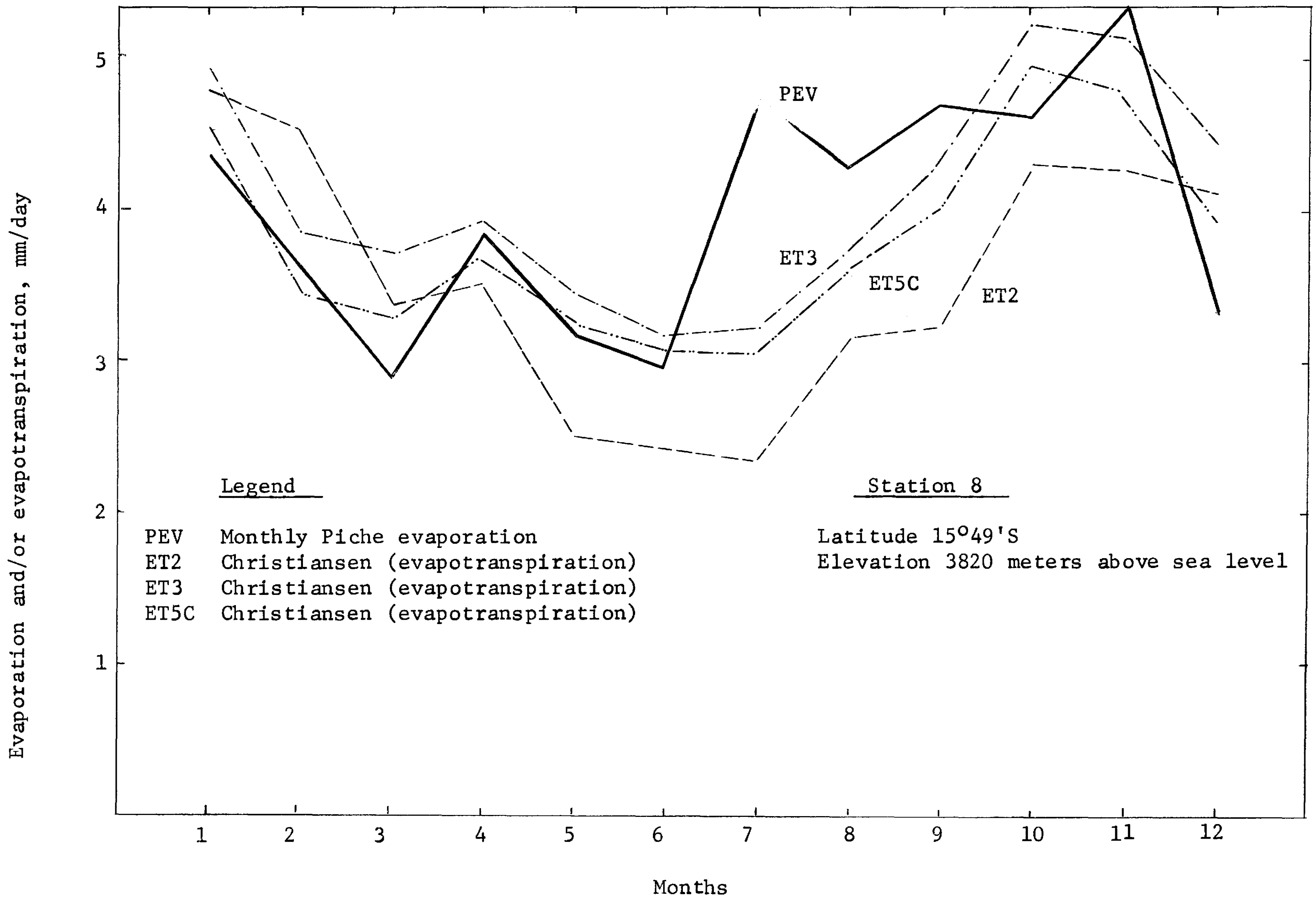

Figure 16. Comparison of formulas for estimating evaporation and/or evapotranspiration with actual measured Piche evaporation.

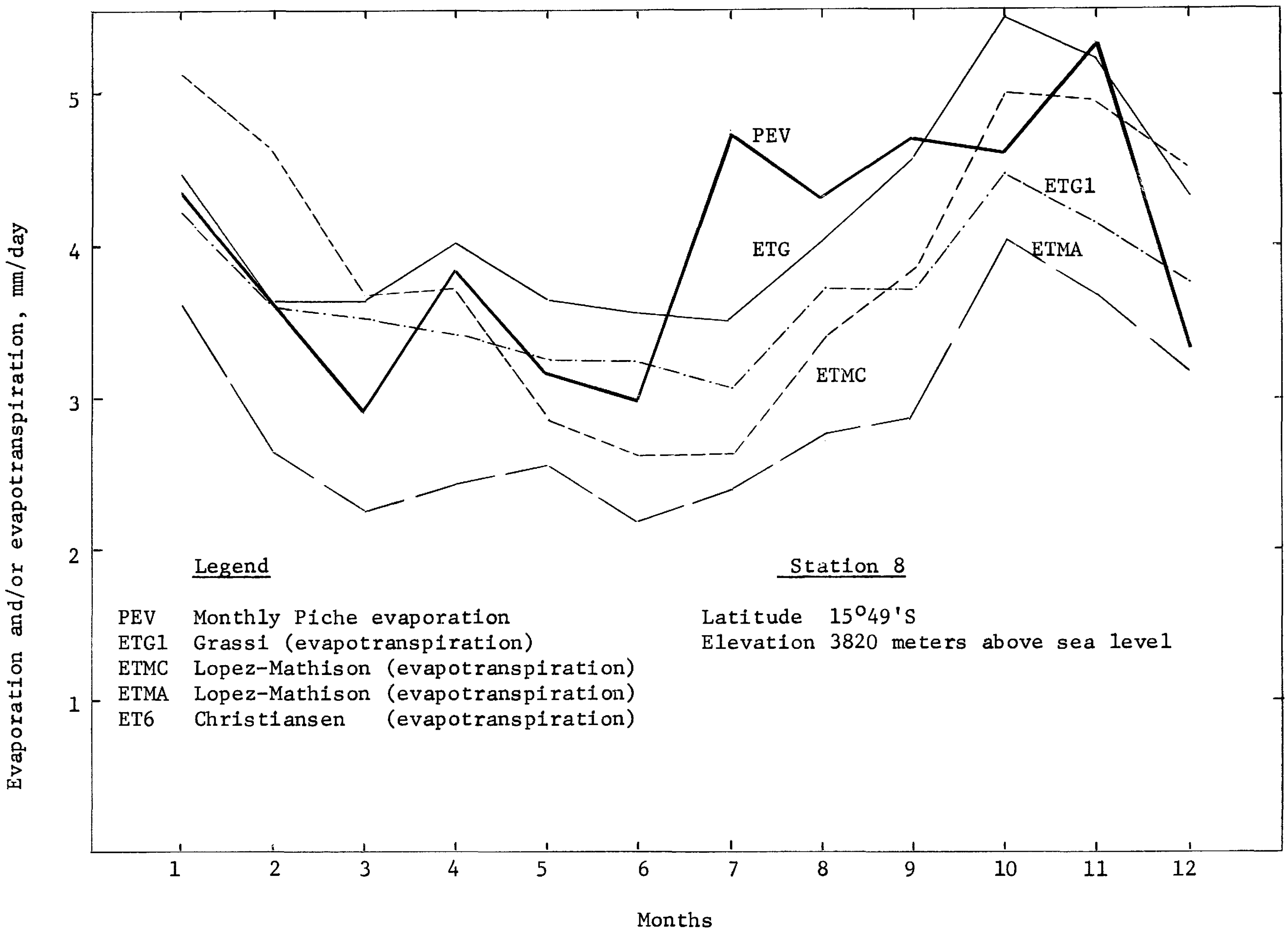

Figure 17. Comparison of formulas for estimating evapotranspiration with actual measured Piche evaporation.

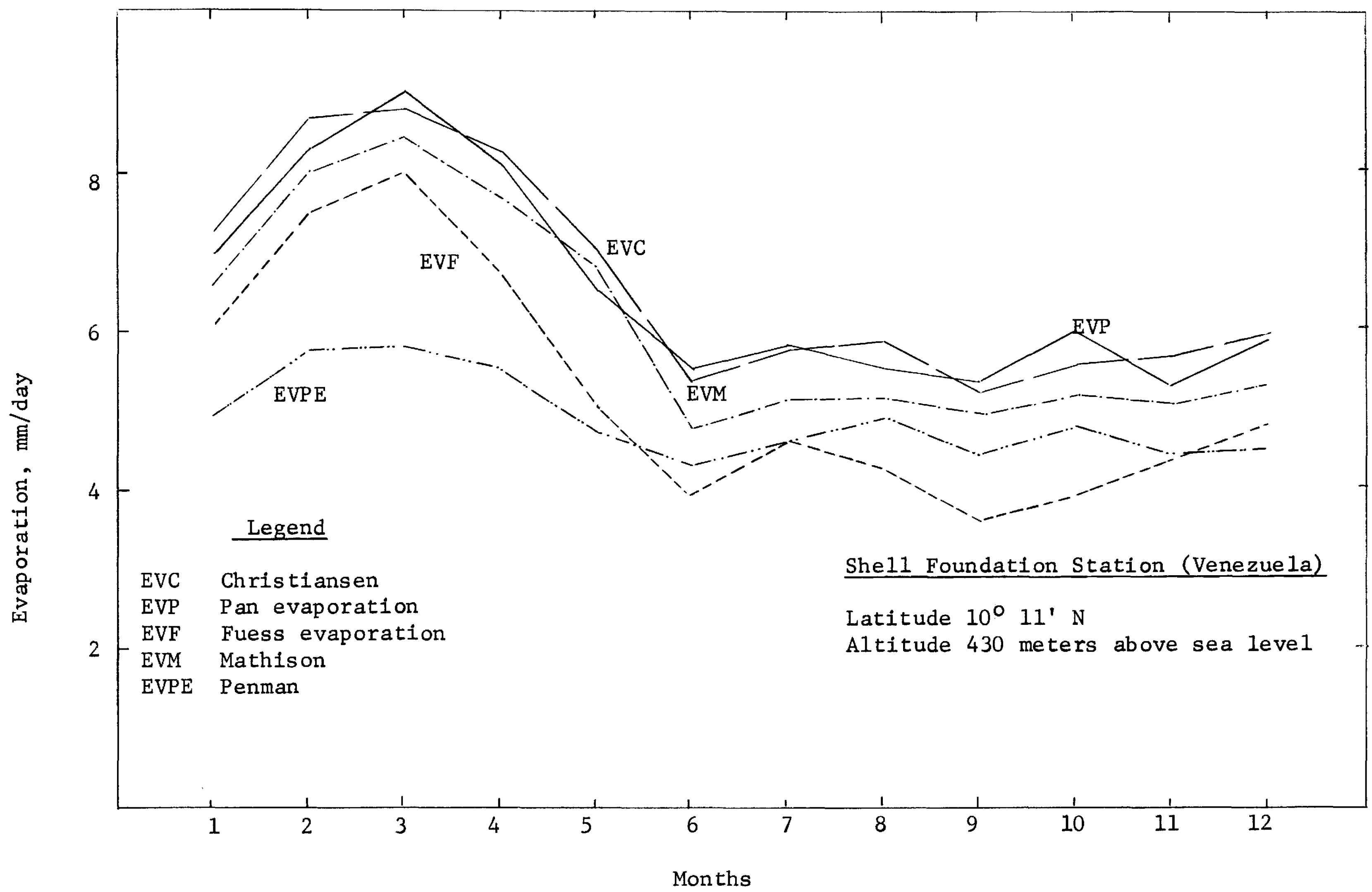

Figure 18A. Comparison of formulas for estimating pan evaporation with actual measured pan evaporation.

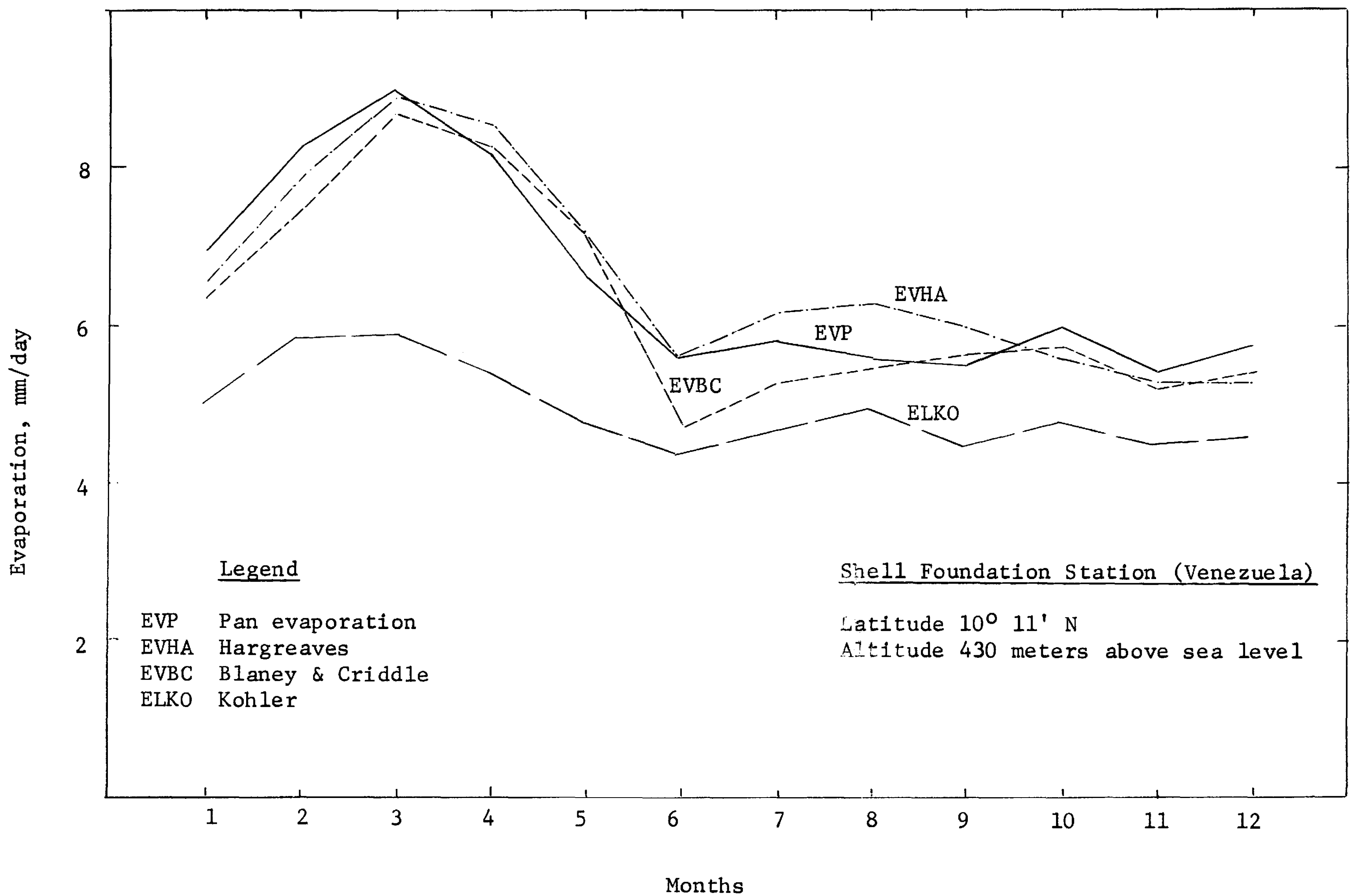

Figure 18B. Comparison of formulas for estimating pan evaporation with actual measured pan evaporation.

DISCUSSION OF RESULTS

1. From the graphs for Station 1 (18 meters above sea level), it can be seen that the equations that best fit the Piche evaporation values are Jensen and Haise (ETJH), Mathison's (EVM), and Christiansen's (ET2) which used as a base his formula for Class A pan evaporation (EVC). The other formulas give lower values except Grassi's equation (ETG3). It must be remembered that none of these formulas were developed for the purpose of estimating Piche evaporation. Mathison's (EVM) is for Class A pan evaporation, and Christiansen's (ET2) and Grassi's (ETG3) are for estimating potential evapotranspiration and actual evapotranspiration, respectively.

2. The formulas that best fit the Piche evaporation values for Station 3 (51 meters above sea level) are Jensen and Haise's (ETJH) and Christiansen's (ET2). Jensen and Haise's (ETJH) was also for estimating actual evapotranspiration.

3. In general, it can be said that Christiansen's formula (ET2) fits quite well the Piche evaporation in the low elevation stations.

4. The best fit for Station 7 (1800 meters above sea level) was obtained with Jensen's formula. It should be noted that for this high elevation station all the formulas computed higher values than the Piche evaporation. The Jensen formula was for potential evapotranspiration.

5. The Piche evaporation is quite variable in Station 8 (3820 meters above sea level) and none of the formulas computed satisfactory values for the Piche evaporation. For the months March, April, May, and June, the Piche evaporation was sometimes less than given by some of the formulas,

but for July through November, it was generally higher than given by any of the formulas except Grassi's (ETG2) and Mathison's (EVM). This latter period is one of low precipitation, but so was May and June when the Piche evaporation was low.

6. From Figure 18A, for Shell Foundation Station, Venezuela, it can be seen that there exists a good relation between the measured pan evaporation and Christiansen's formula (EVC). Hargreaves' (EVHA) and Mathison's formulas give fair results.

7. The basic purpose of these studies, however, was to estimate Class A pan evaporation and/or evapotranspiration for Peruvian climatological conditions. Unfortunately, however, no data on either Class A pan evaporation or evapotranspiration were available from which the estimates from the different formulas could be compared. The climatic conditions in Perú, especially in the coastal regions,are somewhat different from most places in the world because of the relatively high humidities but almost complete absence of precipitation. It would be highly desirable to be able to check these formulas with actual data to verify the results, but it was of interest to compare the estimates with Piche evaporation since this is the only measurement of evaporation available.

8. As shown in Figure 19, there appears to be no direct relationship between Piche evaporation and elevation. This may be expected, however. There is a wide range of annual values of Piche evaporation for the coastal stations with intermediate values for the intermediate and high elevation zones.

Since evaporation is largely dependent on temperature, and according to some formulas, Hargreaves' for instance, is approximately proportional

to mean temperature in ^{o}C, the ratio of PEV/t_c was plotted against elevation.

For nine of the 12 stations, the ratio PEV/t_c was in the range of 0.139 to 0.297. Two of the others were much lower, 0.049 and 0.073, and the other at the highest elevation was higher, 0.458.

The ratio of $PEV/\left[t_c(1-h_m)\right]$ was also plotted. In this instance, eight of the values were in the range 0.738 to 1.090 with a mean value of 0.932. The other four were much lower, 0.292 to 0.527.

The data from which these values were plotted are given in Table 2.

From these comparisons, it would appear that there is no consistent relationship between PEV and elevation when temperature and humidity are also considered. It would also appear that the mean annual PEV values for four of the stations selected are much lower than would be expected from the temperature and humidity data. Three of those stations have relatively high mean annual precipitation values.

Three of these latter four stations have mean annual values of precipitation in the range of 0.976 to 3.037 mm per day, but the other one has the lowest mean precipitation of the 12 stations, 0.011 mm per day. Only two stations, 8 and 9, at elevations of 3820 and 3400 meters, have relatively high precipitation, 1.406 and 1.829 mm/day, and relatively high values of the ratio $PEV/t_c(1-h_m)$, 0.915 and 0.815. This might indicate that when temperature, humidity and precipitation are considered, the PEV values are relatively high at high elevations.

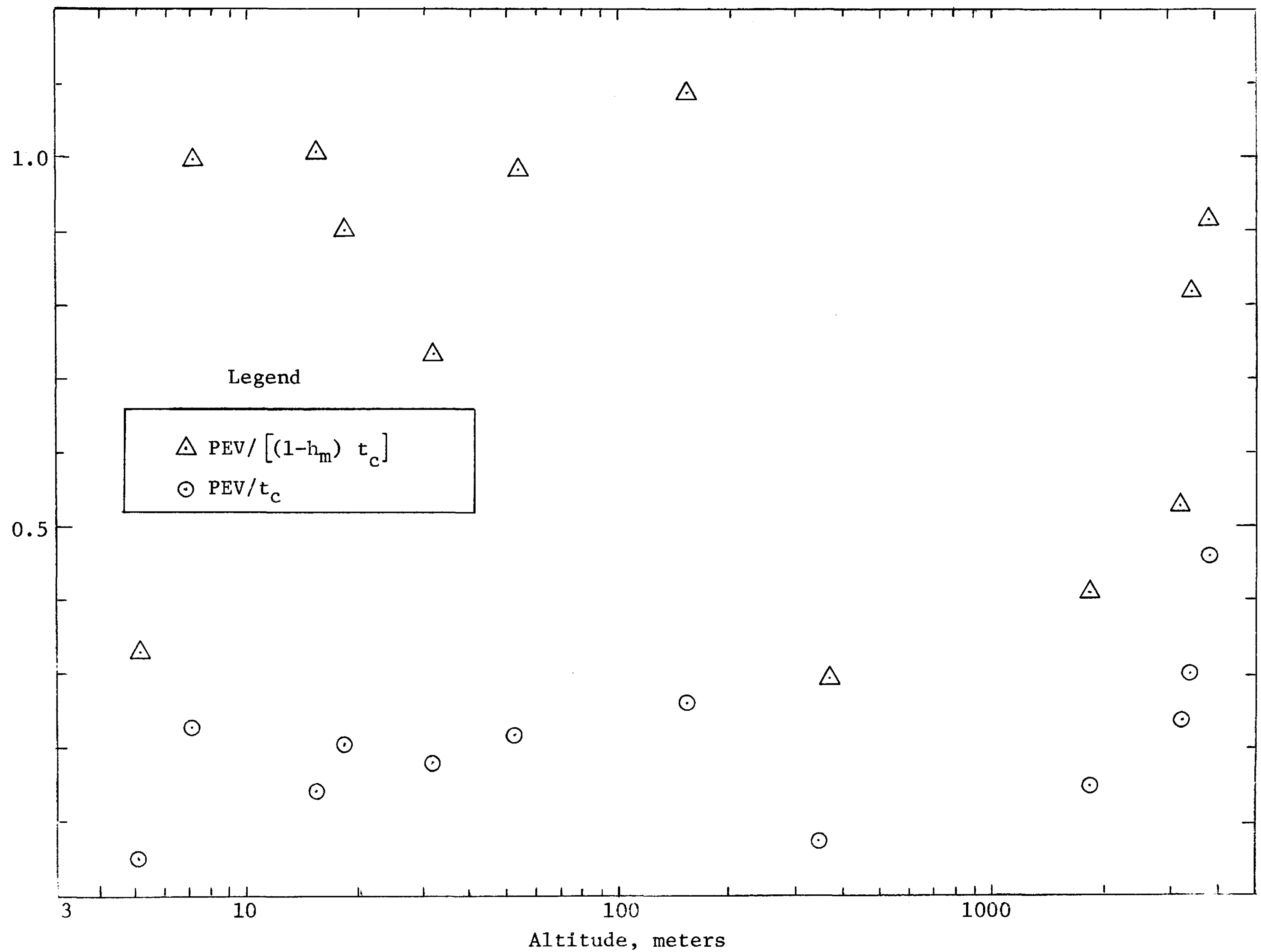

Figure 19. Relation of Piche evaporation to altitude.

Table 2. Comparison of mean annual values of temperature, humidity, and Piche evaporation with elevation.

Station	Elevation meters	Temperature t_c	Humidity	Precipitation mm/day	PEV mm/day	PEV/t_c	PEV/$[(1-h_m)t_c]$
1	18	22.4	0.777	0.066	4.51	0.201	0.902
2	31	21.8	0.760	0.032	3.86	0.177	0.738
3	51	20.4	0.780	0.028	4.41	0.216	0.982
4	15	18.7	0.864	0.028	2.59	0.139	1.020
5	5	20.1	0.851	0.011	0.98	0.049	0.330
6	3207	13.8	0.548	2.041	3.27	0.238	0.527
7	1800	19.7	0.644	0.976	2.88	0.146	0.411
8	3820	8.7	0.499	1.406	3.98	0.458	0.915
9	3400	11.4	0.636	1.829	3.39	0.297	0.815
10	356	26.9	0.750	3.037	1.97	0.073	0.292
11	150	22.2	0.761	0.094	5.79	0.260	1.090
12	7	24.7	0.775	0.361	5.56	0.225	1.000

SUMMARY AND CONCLUSIONS

1. The objectives of this study were:

   (a) To determine which formula best fits Peruvian climatic data in order to estimate evaporation and/or potential evapotranspiration.

   (b) To compare the measured Piche evaporation with the values given by the formulas above mentioned.

   (c) To determine the effect of altitude on the computed evaporation, since there are many agricultural areas at high altitudes in Perú.

2. Climatic data from 12 stations in Perú were analyzed. Some unavailable climatic factors were estimated in order to use these formulas.

3. A total of 24 formulas for computing evaporation and/or potential evapotranspiration were used in this study.

4. The reliability of these formulas was checked with actual pan evaporation data using data from Shell Foundation Station, Venezuela.

5. Table 13 was prepared in order to have available computed values of extraterrestrial radiation for latitudes from the Equator to 25^{o} south.

6. This study indicates that Christiansen's (ET2) and Mathison's (EVM) give the best estimates of Piche evaporation. Until data can be obtained from stations where both Class A pan evaporation and Piche evaporation are measured, it will not be possible to say how well these two measurements agree, or which formulas give the best estimates of Class A pan evaporation for Peruvian climatic conditions. Studies by Christiansen

(personal communication) indicate that his formula for Class A pan evaporation (EVC) gives the best estimate of pan evaporation for Venezuelan conditions of all the formulas used in this study.

7. It may be possible to develop a new formula, or modify one or more of those used in this study, to obtain better estimates of Class A pan evaporation. Reliable estimates of potential evapotranspiration can be made from Class A pan evaporation and climatic data using Christiansen's formula (ET2). Actual evapotranspiration can then be estimated by applying a crop cover factor to these values.

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APPENDIXES

Appendix A

Computer Programs

```
C      PROGRAM 50 TO COMPUTE EVAPORATION AND POTENTIAL EVAPOTRANSPIRATION
C      FOR PERUVIAN DATA
C      PEV= MEASURED PICHE EVAPORATION IN MM/DAY
C      PEVM= MEASURED PICHE EVAPORATION IN MM/MONTH
       DIMENSION DEC(15),ES(15),DER(15),E(15),SU(15),SUM(15),AV(15),A(15)
      1,DM(15)
   102 FORMAT (12F6.3)
       READ (5,102) (DEC(M),M=1,12)
   100 FORMAT(12F6.0)
       READ(5,100)(DM(MO),MO=1,12)
   103 FORMAT (12F6.5)
       READ (5,103) (ES(M),M=1,12)
       DO 20 I=1,15
    20 SUM(I) = 0.
       DO 25 L=1,4
   108 FORMAT(115H1                 TABLE       COMPARISON OF PD, PEV, AND COMP
      1UTED VALUES OF EVAPOTRANSPIRATION FOR 12 PERUVIAN STATIONS.     ,/)
       WRITE (6,108)
   113 FORMAT(130H0STA ELEV  MO      PD     PEV    ETJE    ETJH    ELKO    ETLI
      1   ETTU   ETPA   ETBC   ETBM   ETHA   ETH2   ETHC   ETPE   MEAN
      2                                         ,/)
       WRITE (6,113)
       DO 25 K=1,3
       DO 23 I=1,15
    23 SU(I)=0.
       DO 27 M=1,12
   106 FORMAT(I2,I5,I3,I3,I2,F3.0,F2.0,F5.0,F4.1,2F3.1,F3.2,2F2.2,F4.1,
      12F3.1,F6.2,F3.1,2F2.1,2F5.1                 )
       READ(5,106)NST,NY,MO,LA,LM,XLO,XLOM,EL,TX,TI,TM,HX,HI,HM,VP7,VP13,
      1VP18,SHM,CC7,CC13,CC18,PM,PEVM
       IF(VP7)10,10,11
    10 VPA=VP18
       GO TO 14
    11 VPA=(VP7+VP13+VP18)/3.
    14 CONTINUE
       TF = 1.8 * TM + 32.
       PD=PM/DM(MO)
       E(1)=PD
       PEV=PEVM/DM(MO)
       E(2)=PEV
       XLM  = LM
       XLA  = LA
       XLM  = XLM/60.
       XLA=-(XLA+XLM)
       XLOM=XLOM/60.
       XLOD=XLO+XLOM
       HV   = 595.9 - 0.55*TM
       DER(M)=(DEC(M))/57.2958
       Z= -TAN(XLA/57.2958)*TAN(DER(M))
       AZ   = ABS(Z)
       OM   = ATAN(SQRT(1.0-Z*Z)/AZ)
       DL   = OM/0.1309
       IF (Z) 12,13,13
    12 DL   = 24.-DL
    13 SINO = SIN(OM)
       RLD=120.*(DL*SIN(XLA/57.2958)*SIN(DER(M))+3.8197*COS(XLA/57.2958)*
      1COS(DER(M))*2.*SINO)/ES(M)
       RMD=10.*RLD/(595.9-0.55*TM)
       RID = RMD/25.4
       CE   = 0.97 + 0.000098*EL
       S=SHM/(DM(MO)*DL)
       CS1 = 0.320 + 0.85 * S
       RC = 0.622 * RMD * CE * CS1
    16 RSL = 0.1 * RC * HV
    15 RS = 10.0 * RSL/HV
       WMD=60.
       W2M=6.7
       W2MP=100.
       XTCM = 17.765 -  5320./(TM+273.16)
       XTCX = 17.765-5320./(TX+273.16)
       XTCI = 17.765-5320./(TI+273.16)
       VPIN =0.5*(EXP(XTCX)*HI+EXP(XTCI)*HX)
       VPMM = 25.4*VPIN
       VPINS= EXP(XTCM)
       VPMMS= 25.4*VPINS
       VPMMD= VPMMS-VPMM
       WFP = 1.0 + 0.0098 * W2MP
       EAP = 0.35 * VPMMD * WFP
       EA=EXP(47.226-6463./(273.+TM)-3.927*ALOG(273.+TM))
       DEL=(EA/(273.+TM))*((6463./(273.+TM))-3.927)/1.8
       APP  = RMD *0.75*(0.18+0.55*S)
       TK=TM+273.16
       B    = 2.01E-09*TK**4
       C    = (0.56-0.092*(VPMM)**0.5)*(0.1+0.9*S)
       HP   = APP-B*C
       ETPE = (DEL*HP+0.27*EAP)/(DEL +0.27)
       E(14)=ETPE
       EI = 33.86 * EXP(XTCI)
       EX = 33.86 * EXP(XTCX)
       ETJE=RS*SQRT(EX-EI)/(9.*SQRT(EX-EI)+247.)*(TM-3.47+42.07/SQRT(EX-E
      1I))
       E(3)  = ETJE
       ETJH = RS * (0.014 * TF - 0.37)
       E(4)  = ETJH
       EM = 33.86 * VPIN
       VPIND= VPINS-VPIN
       WFK = 0.37 + 0.0041 * WMD
       AK = RMD * 0.94 * (0.18 + 0.55 * S)
       EAK = (VPIND**0.89) * WFK
       QN = (AK - B * C)/25.4
       DELK = DEL/25.4
       EVK  = (QN*DELK + 0.0105*EAK)/(DELK + 0.0105)
       ELKO = 25.4*EVK
       ELKO = 0.70 * ELKO
       E(5)  = ELKO
       ETLI= RS*(4.7*TM+110.*VPMMD/TM-9.6*(1.+4*S))/(6.*TM+75.)
```

```
      E(6)  = ETLI
      ETTU = 0.013 * TM * (RSL + 50.)/(TM + 15.)
      E(7)  = ETTU
      ETPA = 5.625 * (EX - EM)/DM(MO)
      E(8)  = ETPA
      DH = (DL/12.) * DM(MO)/30.417
      PX = DH/0.12
      FB   = 25.4*PX*TF/100.
      EVBC = FB/DM(MO)
      ETBC = 0.8 * EVBC
      E(9)  = ETBC
      ETBM = FB * (1.14 - HM)/DM(MO)
      ETBM = 1.83 * ETBM
      E(10)  = ETBM
      HN = 0.1 * HX + 0.4 * HI + 0.18 * HM + 0.32 * HM**2
      IF (HX)  46,45,46
   45 HN = 0.4 * HM + 0.6 * HM**2
   46 CONTINUE
      EVH  = 17.37*DH*TM*(1.0-HN)
      EVHA = EVH/DM(MO)
      ETHA = 0.80 * EVHA
      E(11) = ETHA
      FE = 0.950 + 0.0001 * EL
      FH = 0.59 - 0.55 * HN**2
      FW = 0.75 + 0.125 * SQRT(W2M)
      FS = 0.478 + 0.58 * S
      EVHA2 = 17.37 * DH * TM * FH * FW * FS * FE
      ETHA2 = 0.85 * EVHA2
      E(12) = ETHA2/DM(MO)
      CHH = 0.464 + 1.661 * (HM/0.60) - 1.125 * (HM/0.60)**2
      CHW = 0.439 + 0.850 * (W2M/10.) - 0.289 * (W2M/10.)**2
      CHS = 0.475 + 0.964 * (S/0.80) - 0.439 * (S/0.80)**2
      ETHC = 8.38 * DH * TM * FE * CHH * CHW * CHS
      E(13) = ETHC/DM(MO)
      E(15)=(E(3)+E(4)+E(5)+E(6)+E(7)+E(8)+E(9)+E(10)+E(11)+
     1E(12)+E(13)+E(14))/12.
      DO 32  I = 1,15
   32 SU(I) = SU(I) + E(I)
      LE=EL
  104 FORMAT(I4,I5,I4,15F7.3)
      WRITE(6,104) NST,LE,MO,(E(I),I=1,15)
   27 CONTINUE
      DO 26 I= 1,15
   26 A(I)=SU(I)/12.
      DO 28  I = 1,15
   28 SUM(I) = SUM(I) + SU(I)
  114 FORMAT (/,I4,9H MEANS    ,15F7.3,/)
      WRITE(6,114) NST,(A(I),I=1,15)
   25 CONTINUE
      DO 29 I= 1,15
   29 AV(I)= SUM(I)/144.
  124 FORMAT(13HOMEANS         ,15F7.3)
      WRITE(6,124) (AV(I),I=1,15)
      STOP
      END

END OF UNIVAC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)

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 3 0   0      3      0     799     $    87.52
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```
C      PROGRAM 51  TO OBTAIN CERTAIN VALUES FOR COMPARISON AND CHECKING
C      PEV= MEASURED PICHE EVAPORATION IN MM/DAY
C      PEVM= MEASURED PICHE EVAPORATION IN MM/MONTH
       DIMENSION DEC(15),ES(15),DER(15),E(18),SU(18),SUM(18),A(18),DM(18)
       READ (5,102) (DEC(M),M=1,12)
   102 FORMAT (12F6.3)
       READ(5,100)(DM(MO),MO=1,12)
   100 FORMAT(12F6.0)
   103 FORMAT (12F6.5)
       READ (5,103) (ES(M),M=1,12)
       DO 20 I=1,16
    20 SUM(I) = 0.
       DO 80 L=1,4
   108 FORMAT(115H1                    TABLE      COMPARISON OF TM, VPA, H
      1M, PEV, AND OTHER COMPUTED VALUES FOR 12 PERUVIAN STATIONS.     ,/)
       WRITE(6,108)
   301 FORMAT(130HOST YEAR MO ELEV   LAT   LONG   DL      S   TM  TMA   TF
      1  VPA VPCA    DH    HM   H18    HN  CCA     PD     PEV     RMD      R
      2C   ETPE                                                       ,/)
       WRITE(6,301)
       DO 80 K=1,3
       DO 23 I=1,16
    23 SU(I)=0.
       DO 27 M=1,12
   106 FORMAT(I2,I5,I3,I3,I2,F3.0,F2.0,F5.0,F4.1,2F3.1,F3.2,2F2.2,F4.1,
      12F3.1,F6.2,F3.1,2F2.1,2F5.1              )
       READ(5,106)NST,NY,MO,LA,LM,XLO,XLOM,EL,TX,TI,TM,HX,HI,H8,VP7,VP13,
      1VP18,SHM,CC7,CC13,CC18,PM,PEVM
       IF(VP7)10,10,11
    10 VPA=VP18
       GO TO 14
    11 VPA=(VP7+VP13+VP18)/3.
    14 CONTINUE
       E(5)=VPA
       E(2)=TM
       TF = 1.8 * TM + 32.
       E(4)=TF
       PD=PM/DM(MO)
       E(12)=PD
       LE=EL
       HM=(HX+HI+H8)/3.
       E(8)=HM
       E(9)=H8
       IF(CC7)30,30,31
    31 CCA=(CC7+CC13+CC18)/3.
       GO TO 32
    30 CCA=CC18
    32 CONTINUE
       E(11)=CCA
       TMA=(TX+TI)/2.
       E(3)=TMA
       PEV=PEVM/DM(MO)
       E(13)=PEV
       XLM  = LM
       XLA  = LA
       XLA= -(XLA+XLM/60.)
       XLOD=XLO+XLOM/60.
       DER(M)=(DEC(M))/57.2958
       Z= -TAN(XLA/57.2958)*TAN(DER(M))
       AZ   = ABS(Z)
       OM   = ATAN(SQRT(1.D-Z*Z)/AZ)
       DL   = OM/0.1309
       IF (Z) 12,13,13
    12 DL   = 24.-DL
    13 SINO = SIN(OM)
       RLD=120.*(DL*SIN(XLA/57.2958)*SIN(DER(M))+3.8197*COS(XLA/57.2958)*
      1COS(DER(M))*2.*SINO)/ES(M)
       RMD=10.*RLD/(595.9-0.55*TM)
       E(14)=RMD
       RID = RMD/25.4
       CE   = 0.97 + 0.000098*EL
       S=SHM/(DM(MO)*DL)
       E(1)=S
       CS1 = 0.320 + 0.85 * S
       RC = 0.622 * RMD * CE * CS1
       E(15)=RC
       W2MP=100.
       XTCM = 17.765 -  5320./(TM+273.16)
       XTCX = 17.765-5320./(TX+273.16)
       XTCI = 17.765-5320./(TI+273.16)
       VPIN =0.5*(EXP(XTCX)*HI+EXP(XTCI)*HX)
       VPCA=33.86*VPIN
       E(6)=VPCA
       VPMM = 25.4*VPIN
       VPINS= EXP(XTCM)
       VPMMS= 25.4*VPINS
       VPMMD= VPMMS-VPMM
       WFP = 1.0 + 0.0098 * W2MP
       EAP = 0.35 * VPMMD * WFP
       EA=EXP(47.226-6463./(273.+TM)-3.927*ALOG(273.+TM))
       DEL=(EA/(273.+TM))*((6463./(273.+TM))-3.927)/1.8
       APP  = RMD *0.75*(0.18+0.55*S)
       B    = 2.01E-09*((TM+273.16)**4)
       C    = (0.56-0.092*(VPMM)**0.5)*(0.1+0.9*S)
       HP   = APP-B*C
       ETPE = (DEL*HP+0.27*EAP)/(DEL +0.27)
       E(16)=ETPE
       DH = (DL/12.) * DM(MO)/30.417
       E(7)=DH
       HN = 0.1 * HX + 0.4 * HI + 0.18 * HM + 0.32 * HM**2
       E(10)=HN
       DO 37 I =1,16
    37 SU(I) = SU(I) + E(I)
   300 FORMAT(2(I3,I5),3F6.2,F6.3,5F5.1,4F6.3,F5.1,5F7.3)
       WRITE(6,300)NST,NY,MO,LE,XLA,XLOD,DL,(E(I),I=1,16)
    27 CONTINUE
       DO 26 I= 1,16
    26 A(I)=SU(I)/12.
   330 FORMAT(/,I3,31H   MEAN ANNUAL VALUES      12.00   ,F6.3,5F5.1,4F6.3
      1,F5.1,5F7.3,/)
       WRITE(6,330)NST,(A(I),I=1,16)
    80 CONTINUE
       STOP
       END

CARDS IN  267   CARDS OUT    0   PAGES    11  ELAPSED TIME  0  0  6
0   0     3     0     699    $    89.53
```

```
C     PROGRAM 52 TO COMPUTE EV AND ET FROM USU FORMULAS FOR PERUVIAN DATA
C     PEVM= MEASURED PICHE EVAPORATION IN MM/MONTH
C     PEV = MEASURED PICHE EVAPORATION IN MM/DAY
C     EVC = CHRISTIANSEN  COMPUTED PAN EVAPORATION IN MM/DAY.
C     EVC1 = COMPUTED PAN EVAPORATION DAVIS (PRUITT) DATA.
C     ET2, 3, 5C = CHRISTIANSEN  ET, ETMA = MATHINSON  COMPUTED FROM EVM
C     ETMC = MATHINSON  COMPUTED FROM CHRISTIANSEN EVC
C     ETG1 AND ETG2 = GRASSI EQUATIONS 1 AND 2
C     ETG3 = GRASSI COMPUTED FROM CHRISTIANSEN EVC
      DIMENSION DEC(15),ES(15),DER(15),E(15),SU(15),SUM(15),AV(15),A(15)
     1,DM(15)
      READ (5,102) (DEC(M),M=1,12)
  102 FORMAT (12F6.3)
      READ(5,100)(DM(MO),MO=1,12)
  100 FORMAT(12F6.0)
  103 FORMAT (12F6.5)
      READ (5,103) (ES(M),M=1,12)
      DO 20 I=1,15
   20 SUM(I) = 0.
      DO 25 L=1,4
  109 FORMAT(115H1TABLE        COMPARISON OF PD, PEV AND COMPUTED EV AND E
     1T FROM USU FORMULAS FOR 12 PERUVIAN STATIONS.                    ,/)
      WRITE (6,109)
  113 FORMAT(118H0STA ELEV  MO      PD     PEV      EVC    EVC1     EVM     ET2
     1     ET3    ET5C     ET6    ETMA    ETMC    ETG1    ETG2    ETG3   MEAN,/)
      WRITE (6,113)
      DO 25 K=1,3
      DO 23 I=1,15
   23 SU(I)=0.
      DO 27 M=1,12
  106 FORMAT(I2,I5,I3,I3,I2,F3.0,F2.0,F5.0,F4.1,2F3.1,F3.2,2F2.2,F4.1,
     12F3.1,F6.2,F3.1,2F2.1,2F5.1             )
      READ(5,106)NST,NY,MO,LA,LM,XLO,XLOM,EL,TX,TI,TM,HX,HI,HM,VP7,VP13,
     1VP18,SHM,CC7,CC13,CC18,PM,PEVM
      TF = 1.8 * TM + 32.
      PD=PM/DM(MO)
      E(1)=PD
      PEV=PEVM/DM(MO)
      E(2)=PEV
      XLM  = LM
      XLA  = LA
      XLM  = XLM/60.
      XLA=-(XLA+XLM)
      HV   = 595.9 - 0.55*TM
      DER(M)=(DEC(M))/57.2958
      Z= -TAN(XLA/57.2958)*TAN(DER(M))
      AZ   = ABS(Z)
      OM   = ATAN(SQRT(1.0-Z*Z)/AZ)
      DL   = OM/0.1309
      IF (Z) 12,13,13
   12 DL   = 24.-DL
   13 SINO = SIN(OM)
      RLD=120.*(DL*SIN(XLA/57.2958)*SIN(DER(M))+3.8197*COS(XLA/57.2958)*
     1COS(DER(M))*2.*SINO)/ES(M)
      RMD=10.*RLD/(595.9-0.55*TM)
      RID = RMD/25.4
      S=SHM/(DM(MO)*DL)
      CE    = 0.97 + 0.000098*EL
      CS1 = 0.320 + 0.85 * S
      RC = 0.622 * RMD * CE * CS1
      HN = 0.1 * HX + 0.4 * HI + 0.18 * HM + 0.32 * HM**2
      IF (HX)  46,45,46
   45 HN = 0.4 * HM + 0.6 * HM**2
   46 CONTINUE
      IF(CC7)30,30,31
   31 CCA=(CC7+CC13+CC18)/3.
      GO TO 34
   30 CCA=CC18
   34 CONTINUE
      XK = 0.459
      CT    = 0.3932 + 0.5592 * (TM/20.) + 0.0476 * (TM/20.)**2
      CH = 1.250 - 0.3482*(HN/.40)+0.120*(HN/.40)**2-0.0218*(HN/.40)**4
      CS = 0.542+0.640*(S/.80) - 0.4994*(S/.80)**2 +0.3174*(S/.80)**3
   33 EVC  = XK*RMD*CT**CH*CS*CE
      E(3) = EVC
      CTV = 0.493 + 0.116*(TF/68.) +0.391*(TF/68)**2
      CSV = 0.388 + 0.782 * (S/.80) - 0.170 * (S/.80)**2
      CHV = 1.734 - 0.595 * (HM/.60) - 0.139 * (HM/.60)**2
      EVC1 = 0.412 * RMD * CE * CSV * CTV * CHV
      E(4)=EVC1
      DT=1.8*(TX-TI)
      EF    = 3.281*EL/1000.
      RIN   = RMD/25.4
      RINM=DM(MO)*RIN
      CRM   = 0.20*RINM+0.015*RINM**2
      CTM=-0.260+1.576*(TF/65.)-0.316*(TF/65.)**2
      CDEL=0.450+0.700*(DT/27.)**2-0.150*(DT/27.)**4
      XLAR = XLA/57.2958
      CCOS = 1.16+0.42*COS(XLAR-DER(M))-0.7*(COS(XLAR-DER(M)))**2
      CSM   = 0.622+0.5875*S-0.11*S**2
      CEM   = 0.967+0.035*EF-0.00156*EF**2
      XM    = MO
      CMM   = 1. +0.00155*(XLA-DEC(M))*COS(0.5236*(XM+1.))
      EVMM = CRM*CTM*CMM*CDEL*CCOS*CSM*CEM
      EVMD = EVMM/DM(MO)
      EVM   = 25.4*EVMD
      E(5)=EVM
      CT2 = 0.862 + 0.179*(TM/20.) - 0.041*(TM/20.)**2
      CH2 = 0.499 + 0.620 * (HM/.6) - 0.119 * (HM/.6)**2
      CS2 = 0.904 + 0.008 * (S/.8) + 0.088 * (S/.8)**2
      ET2 = 0.749 * EVC * CT2 * CS2 * CH2
      E(6)=ET2
      CT3 = 0.463 + 0.425*(TM/20.) + 0.112*(TM/20.)**2
      CH3 = 1.035 + 0.240*(HM/.6)**2 - 0.275 * (HM/.6)**3
      CS3 = 0.340 + 0.856 * (S/.8) - 0.196 * (S/.8)**2
      ET3 = 0.324 * RMD * CT3 * CS3 * CH3 * CE
      E(7)=ET3
      ET5C = 0.492 * RC * CT3 * CH3
      E(8) = ET5C
      ET6 = 0.755 * EVC1 * CT2 * CS2 * CH2
```

```
      E(9)=ETG
      ETMA = 0.865 * EVM - 0.832
      E(10) = ETMA
      ETMC = 0.865 * EVC - 0.832
      E(11)=ETMC
      TDC = TX - TM
      CTD = 0.9361 + 0.00767 * TDC
      CTG1=0.036+1.489*(TF/68.)-0.525*(TF/68.)**2
      CRG = 0.1824 + 1.46 * RID
      SKC=CCA*1.25
      CCLC = 1.15 - 0.05 * SKC
      FG = 0.90
      ETG1 = 5.46 * CRG * CTG1 * CCLC * CTD * FG
      E(12) = ETG1
      CTG2=0.620+0.380*(TF/68.)
      ETG2 = 0.537 * RC * CTG2 * FG
      E(13) = ETG2
      CTG3=1.754-0.754*(TF/68.)
      ETG3 = 0.9678 * EVC * CTG3 * FG
      E(14) = ETG3
      E(15)=(E(6)+E(7)+E(8)+E(9)+E(10)+E(11)+E(12)+E(13)+E(14))/9.
      DO 32  I = 1,15
   32 SU(I) = SU(I) + E(I)
      LE = EL
  104 FORMAT (I4,I5,I4,15F7.3)
      WRITE(6,104) NST,LE,MO,(E(I),I=1,15)
   27 CONTINUE
      DO 26 I= 1,15
   26 A(I)=SU(I)/12.
  114 FORMAT (/,I4,9H  MEANS  ,15F7.3,/)
      WRITE(6,114) NST,(A(I),I=1,15)
      DO 28  I = 1,15
   28 SUM(I) = SUM(I) + SU(I)
   25 CONTINUE
      DO 29 I= 1,15
   29 AV(I)= SUM(I)/144.
  124 FORMAT(8H  MEANS    ,5X,15F7.3)
      WRITE(6,124) (AV(I),I=1,15)
      STOP
      END
```

END OF UNIVAC 1108 FORTRAN V COMPILATION.   0 *DIAGNOSTIC* MESSAGE(S)

PROJECT 686900   CARDS IN   301   CARDS OUT   0   PAGES   11 ELAPSED TIME 0 0 6
0   301   2 0   0   2   0   699 $ 91.84

```
C      PROGRAM  53. TO COMPUTE EXTRATERRESTRIAL RADIATION FOR LATITUDES
C      FROM THE EQUATOR TO 25 DEGREES SOUTH.
       DIMENSION OM(12),DEC(12),ES(12),RLD(12),RMD(12)
   301 FORMAT (12F6.0)
       READ (5,301)(OM(MO), MO = 1,12)
   102 FORMAT (12F6.3)
       READ (5,102)(DEC(MO),  MO = 1,12)
   103 FORMAT (12F6.5)
       READ (5,103) (ES(MO),  MO = 1,12)
   320 FORMAT(65H1TABLE       MEAN MONTHLY VALUES OF EXTRATERRESTRIAL RADI
      1ATION        )
       WRITE(6,320)
   321 FORMAT(90HOLATITUDE              EXPRESSED AS EQUIVALENT EVAPORATION
      1 IN MILLIMETERS PER DAY. *                                        )
       WRITE(6,321)
   322 FORMAT(93HODEG. S.  JAN.   FEB.   MAR.   APR.   MAY    JUNE   JULY
      1   AUG.   SEP.   OCT.   NOV.   DEC.     */)
       WRITE(6,322)
       XLA = 1.
       DO 30  I = 1,26
       XLA = XLA - 1.
       DO 20 MO = 1,12
       DER=(DEC(MO))/57.2958
       Z= -TAN(XLA/57.2958)*TAN(DER)
       AZ    = ABS(Z)
       IF(Z)7,8,7
     7 OM    = ATAN(SQRT(1.0-Z*Z)/AZ)
       GO TO 9
     8 OM=1.5708
     9 DL    = OM/0.1309
       IF (Z) 12,13,13
    12 DL    = 24.-DL
    13 SINO = SIN(OM)
       RLD(MO)=120.*(DL*SIN(XLA/57.2958)*SIN(DER)+3.8197*COS(XLA/57.2958)
      1*COS(DER)*2.*SINO)/ES(MO)
       RMD(MO)=0.017097*RLD(MO)
    20 CONTINUE
       LAT = ABS(XLA)
   323 FORMAT (I5, F9.2, 11F7.2)
   324 FORMAT    (I5, F9.2, 11F7.2,/)
       IF(LAT.EQ.0.OR.LAT.EQ.5.OR.LAT.EQ.10.OR.LAT.EQ.15.OR.LAT.EQ.20.OR.
      1LAT.EQ.25)  GO TO 50
       WRITE(6,323)LAT,(RMD(MO), MO = 1,12)
       GO TO 30
    50 WRITE(6,324)LAT,(RMD(MO), MO = 1,12)
    30 CONTINUE
   104 FORMAT(90HO*BASED ON A SOLAR RADIATION CONSTANT OF 2 CAL/CM2/MIN A
      1T THE TOP OF THE ATMOSPHERE.                                    )
       WRITE(6,104)
       STOP
       END

END OF UNIVAC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)


PROJECT 686900   CARDS IN   58   CARDS OUT   0   PAGES    6  ELAPSED TIME  0  0  3
   0    58     1 0   0      1      0      399     $    88.90
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```
C      PROGRAM 216C. TO COMPARE MEASURED AND COMPUTED PAN EVAPORATION
C      FOR ONE VENEZUELAN STATION (SHELL FOUNDATION STATION)
C      PD= AVERAGE DAILY PRECIPITATION IN MILLIMETERS.
C      EVP = MEASURED PAN EVAPORATION IN MILLIMETERS PER DAY.
C      EVF = FUESS EVAPORATION IN MILLIMETERS PER DAY
C      EVC = PAN EVAPORATION COMPUTED FROM CHRISTIANSENS FORMULA.
C      EVM = PAN EVAPORATION COMPUTED FROM MATHISONS FORMULA.
C      EVPE = PAN EVAPORATION COMPUTED FROM PENMANS FORMULA.
C      EVKO = PAN EVAPORATION COMPUTED FROM KOHLERS FORMULA.
C      EVBC = PAN EVAPORATION COMPUTED FROM THE BLANEY-CRIDDLE FORMULA.
C      EVHA = PAN EVAPORATION COMPUTED FROM HARGREAVES FORMULA.
C      CM AND K VALUES ARE RATIOS OF MEASURED TO COMPUTED EVAPORATION.
       DIMENSION DEC(15),ES(15),DER(15),E(18),SU(18),SUM(18),AV(18),A(18)
      1,ER(18),SER(18),AER(18),SUER(18),AVER(18)
   102 FORMAT(12F6.3)
       READ(5,102) (DEC(M),M=1,12)
   103 FORMAT(12F6.5)
       READ(5,103)(ES(M),M=1,12)
       DO 21 I=1,16
    21 SUM(I)=0.
       DO 80 L= 1,3
   108 FORMAT(117H1TABLE    COMPARISON OF MEASURED AND COMPUTED PAN EVAPO
      1RATION FOR SHELL FOUNDATION STATION (VENEZUELA).
      1                                                  ./)
       WRITE(6,108)
   109 FORMAT(130HDST MO YEAR      PD     EVP     EVF     CMF     EVC     CMC
      1 EVM     CMM    EVPE    CMPE    EVKO    CMKO    EVBC    BC-K    EVHA    CM
      2HA                                                                  ./)
       WRITE(6,109)
       DO 25 K=1,4
       DO 23 I=1,16
       SER(I)=0.
    23 SU(I)=0.
   142 DO 27 J=1,5
       LA=10
       LM=11
       EL=430.
   106 FORMAT(I2,3F5.1,3F4.2,F5.2,F4.1,F6.1,F4.0,2F4.1,F3.0,3X,I2)
       READ(5,106)MO,TX,TI,TM,HX,HI,HM,WA,SH,P,DP,EVF,EVP,DM,NYR
       NST=31
       ZA=2.
       M=MO
       XM=MO
       TF=1.8*TM+32.
       E(1)=P
       E(2)=EVP
       E(3)=EVF
       IF(EVF)75,76,75
    76 E(4)=0.
       GO TO 77
    75 E(4)=EVP/E(3)
    77 CONTINUE
       XLM=LM
       XLA=LA
       XLM=XLM/60.
       XLA=XLA+XLM
       DER(M)=(DEC(M))/57.2958
       Z= -TAN(XLA/57.2958)*TAN(DER(M))
       AZ    = ABS(Z)
       OM    = ATAN(SQRT(1.0-Z*Z)/AZ)
       DL    = OM/0.1309
       IF (Z) 12,13,13
    12 DL    = 24.-DL
    13 SINO = SIN(OM)
       RLD=120.*(DL*SIN(XLA/57.2958)*SIN(DER(M))+3.8197*COS(XLA/57.2958)*
      1COS(DER(M))*2.*SINO)/ES(M)
       RMD=10.*RLD/(595.9-0.55*TM)
       RID=RMD/25.4
       RIM=DM*RID
       CE=0.97+0.030*(EL/305.)
       S=SH/DL
       CS1=0.320+0.85*S
       RC=0.622*RMD*CE*CS1
    40 W2M=WA
       IF(W2M-3.83)50,51,51
    50 W6=0.40*W2M+0.0525*W2M**2
       GO TO 14
    51 W6=0.792*W2M-0.730
    14 WMD=14.91*W6
       XK=0.459
       HN=0.1*HX+0.4*HI+0.18*HM+0.32*HM**2
       IF(HX)46,45,46
    45 HN=0.4*HM+0.6*HM**2
    46 CONTINUE
       CT=0.3932+0.5592*(TM/20.)+0.0476*(TM/20.)**2
       CW=0.7084+0.3276*(WMD/60.)-0.0360*(WMD/60.)**2
       CH=1.265-0.249*(HM/0.60)-0.016*(HM/0.60)**6
       CS=0.542+0.640*(S/0.80)-0.4994*(S/0.80)**2+0.3174*(S/0.80)**3
       CDP=1.03-0.02*(DP/10.)**2-0.01*(DP/10.)**3
    33 EVC=XK*RMD*CT*CW*CH*CS*CE*CDP
       E(5)=EVC
       E(6)=EVP/E(5)
       DT=1.8*(TX-TI)
       EF=3.281*EL/1000.
       CRM=0.20*RIM+0.015*RIM**2
       CTM=-0.260+1.576*(TF/65.)-0.316*(TF/65.)**2
       CWM=0.8+0.0035*WMD-0.27E-05*WMD**2
       CDEL=0.450+0.700*(DT/27.)**2-0.150*(DT/27.)**4
       XLAR = XLA/57.2958
       CCOS=1.16+0.42*COS(XLAR-DER(M))-0.7*(COS(XLAR-DER(M)))**2
       CSM=0.622+0.5875*S-0.11*S**2
       CEM=0.967+0.035*EF-0.00156*EF**2
       CMM=1.+0.00155*(XLA-DEC(M))*COS(0.5236*(XM+1.))
       EVMM=CRM*CTM*CWM*CDEL*CCOS*CSM*CEM*CMM
       EVMD=EVMM/DM
```

```
      EVM=25.4*EVMD
      E(7)=EVM
      E(8)=EVP/E(7)
      TK=TM+273.16
      XTCM=17.765-5320./TK
      XTCX=17.765-5320./(TX+273.16)
      XTCI=17.765-5320./(TI+273.16)
      VPIN=0.5*(EXP(XTCX)*HI+EXP(XTCI)*HX)
      VPMM=25.4*VPIN
      VPINS=EXP(XTCM)
      VPMMS=25.4*VPINS
      VPMMD=VPMMS-VPMM
      W2MP=14.91*W2M
      WFP=1.0+0.0098*W2MP
      EAP=0.35*VPMMD*WFP
      EA=EXP(47.226-6463./(273.+TM)-3.927*ALOG(273.+TM))
      DEL=(EA/(273.+TM))*((6463./(273.+TM))-3.927)/1.8
      APP=RMD*0.95*(0.18+0.55*S)
      B=2.01E-09*TK**4
      C=(0.56-0.092*(VPMM)**0.5)*(0.1+0.9*S)
      HP=APP-B*C
      EVPE=(DEL*HP+0.27*EAP)/(DEL+0.27)
      E(9)=EVPE
      E(10)=EVP/E(9)
      EM=33.86*VPIN
      VPIND=VPINS-VPIN
      WFK=0.37+0.0041*WMD
      AK=RMD*0.94*(0.18+0.55*S)
      EAK=(VPIND**0.88)*WFK
      QN=(AK-B*C)/25.4
      DELK=DEL/25.4
      EVK=(QN*DELK+0.0105*EAK)/(DELK+0.0105)
      EVKO=25.4*EVK
      E(11)=EVKO
      E(12)=EVP/E(11)
      DH=(DL/12.)*DM/30.417
      PX=DH/0.12
      FB=PX*TF/100.
      EVBC=25.4*FB/DM
      E(13)=EVBC
      E(14)=EVP/E(13)
      EVH=17.37*DH*TM*(1.0-HN)
      EVHA=EVH/DM
      E(15)=EVHA
      E(16)=EVP/E(15)
      ER(1)=ABS(EVP-E(3))
      ER(2)=ABS(EVP-E(5))
      ER(3)=ABS(EVP-E(7))
      ER(4)=ABS(EVP-E(9))
      ER(5)=ABS(EVP-E(11))
      ER(6)=ABS(EVP-E(13))
      ER(7)=ABS(EVP-E(15))
  104 FORMAT(2I3,I4,1X,16F7.3)
      WRITE(6,104)NST,MO,NYR,(E(I),I=1,16)
      DO 24 I=1,16
      SER(I)=SER(I)+ER(I)
   24 SU(I)=SU(I)+E(I)
   27 CONTINUE
      DO 26 I=1,16
      SUM(I)=SUM(I)+SU(I)
   26 A(I)=SU(I)/5.
      DO 28 I=1,7
      SUER(I)=SUER(I)+SER(I)
   28 AER(I)=SER(I)/SU(2)
  114 FORMAT(11H0MEANS          ,16F7.3)
      WRITE(6,114)(A(I),I=1,16)
  134 FORMAT(25H0MEAN ABS. RELATIVE ERROR                         ,7F14.3,/)
      WRITE(6,134)(AER(I),I=1,7)
   25 CONTINUE
  144 FORMAT(65H0*LATITUDE = 10.18 DEGREES N, ELEVATION= 430  METERS.
     1                                    ,/)
      WRITE(6,144)
   80 CONTINUE
      DO 29 I=1,16
   29 AV(I)=SUM(I)/59.
      DO 19 I=1,7
   19 AVER(I)=SUER(I)/SUM(2)
  124 FORMAT(11H MEANS          ,16F7.3)
      WRITE(6,124)(AV(I),I=1,16)
      WRITE(6,134)(AVER(I),I=1,7)
      STOP
      END

END OF UNIVAC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)
```

Appendix B

Tables 3 - 18

TABLE 3. COMPARISON OF PD, PEV, AND COMPUTED VALUES OF EVAPOTRANSPIRATION FOR 12 PERUVIAN STATIONS.

STA	ELEV	MO	PD	PEV	ETJE	ETJH	ELKO	ETLI	ETTU	ETPA	ETBC	ETBM	ETHA	ETH2	ETHC	ETPE	MEAN
1	18	1	.039	5.200	3.733	5.503	3.797	3.959	4.075	3.613	4.420	3.943	4.294	3.774	4.348	4.256	4.143
1	18	2	.232	5.200	4.017	5.808	3.982	4.164	4.180	4.444	4.507	4.124	4.660	4.053	4.642	4.511	4.424
1	18	3	.213	5.000	3.842	5.568	3.829	3.995	4.039	3.928	4.422	4.046	4.511	3.906	4.518	4.331	4.245
1	18	4	.113	4.900	3.346	5.005	3.436	3.573	3.777	3.460	4.195	3.647	3.845	3.455	4.008	3.821	3.797
1	18	5	.035	4.800	2.592	4.093	2.838	2.953	3.261	2.621	3.964	3.173	3.128	2.820	3.298	3.101	3.153
1	18	6	.023	4.000	2.047	3.307	2.351	2.458	2.797	2.225	3.753	2.747	2.470	2.193	2.599	2.530	2.623
1	18	7	.003	3.600	1.895	3.078	2.239	2.339	2.687	1.983	3.637	2.579	2.227	1.951	2.303	2.395	2.443
1	18	8	.003	3.600	2.185	3.537	2.581	2.681	3.049	2.020	3.649	2.754	2.409	2.163	2.571	2.765	2.697
1	18	9	.017	4.000	2.479	3.985	2.923	3.032	3.364	2.239	3.744	2.912	2.640	2.367	2.785	3.160	2.969
1	18	10	.026	4.200	2.720	4.339	3.171	3.293	3.598	2.318	3.854	3.085	2.888	2.591	3.026	3.447	3.194
1	18	11	.027	4.600	2.911	4.569	3.319	3.486	3.700	2.754	4.006	3.390	3.374	2.955	3.418	3.642	3.460
1	18	12	.055	5.000	3.207	4.896	3.485	3.669	3.824	3.065	4.196	3.647	3.798	3.312	3.819	3.862	3.732
1 MEANS			.066	4.508	2.915	4.474	3.162	3.300	3.529	2.889	4.029	3.337	3.354	2.962	3.445	3.485	3.407
2	31	1	.016	6.000	3.865	5.769	4.024	4.398	4.371	3.708	4.267	4.392	4.820	4.294	4.823	4.495	4.435
2	31	2	.071	5.200	4.060	5.909	4.064	4.344	4.322	4.434	4.406	4.334	4.855	4.267	4.869	4.594	4.537
2	31	3	.045	4.900	4.246	6.049	4.136	4.508	4.432	4.376	4.322	4.449	5.123	4.556	5.035	4.663	4.658
2	31	4	.077	4.000	3.887	5.826	3.883	4.101	4.346	3.664	4.175	3.820	4.278	4.148	4.408	4.290	4.235
2	31	5	.006	3.268	3.138	4.969	3.272	3.365	3.889	2.622	3.943	3.157	3.170	3.268	3.520	3.520	3.486
2	31	6	.010	2.900	2.401	3.940	2.669	2.775	3.278	2.190	3.722	2.810	2.625	2.593	2.899	2.829	2.894
2	31	7	.010	2.300	2.071	3.455	2.447	2.554	2.987	1.861	3.606	2.557	2.261	2.141	2.429	2.592	2.580
2	31	8	.006	2.700	2.402	3.952	2.763	2.786	3.382	1.857	3.618	2.483	2.122	2.137	2.389	2.913	2.734
2	31	9	.013	2.900	2.855	4.615	3.198	3.127	3.859	2.041	3.714	2.464	2.128	2.247	2.419	3.387	3.005
2	31	10	.013	3.600	3.201	5.088	3.602	3.679	4.178	2.396	3.824	3.149	3.001	2.985	3.288	3.873	3.522
2	31	11	.057	3.700	3.437	5.405	3.800	3.928	4.391	2.719	3.914	3.313	3.260	3.285	3.530	4.101	3.756
2	31	12	.055	4.800	3.880	5.912	4.042	4.227	4.587	3.128	4.135	3.878	4.021	3.959	4.302	4.411	4.207
2 MEANS			.032	3.856	3.287	5.074	3.492	3.649	4.001	2.916	3.970	3.400	3.472	3.323	3.659	3.805	3.671
3	51	1	.042	5.400	3.166	5.091	3.587	3.775	3.946	2.698	4.224	3.672	3.741	3.331	3.899	3.974	3.759
3	51	2	.096	5.200	3.279	5.216	3.639	3.812	3.954	3.212	4.286	3.725	3.906	3.427	4.002	4.059	3.876
3	51	3	.045	5.200	3.235	5.173	3.575	3.728	3.946	2.807	4.184	3.637	3.749	3.374	3.944	3.963	3.776
3	51	4	.040	5.200	2.723	4.472	3.127	3.277	3.578	2.483	3.929	3.325	3.256	2.968	3.484	3.414	3.336
3	51	5	.006	4.600	2.445	4.038	2.803	2.960	3.326	2.258	3.770	3.191	3.031	2.832	3.318	3.016	3.082
3	51	6	.013	3.500	1.683	2.887	2.155	2.286	2.560	1.830	3.566	2.774	2.433	2.060	2.488	2.314	2.420
3	51	7	.010	3.300	1.564	2.682	2.070	2.188	2.439	1.657	3.491	2.715	2.295	1.883	2.300	2.222	2.292
3	51	8	.003	3.400	1.682	2.894	2.248	2.361	2.616	1.587	3.509	2.649	2.199	1.830	2.223	2.418	2.351
3	51	9	.007	3.500	1.927	3.340	2.586	2.704	2.970	1.616	3.563	2.771	2.316	1.981	2.415	2.787	2.581
3	51	10	.042	4.000	2.215	3.804	2.898	3.014	3.316	1.683	3.659	2.846	2.466	2.186	2.595	3.126	2.817
3	51	11	.013	4.600	2.619	4.373	3.227	3.345	3.703	2.041	3.797	3.127	2.843	2.619	3.059	3.482	3.186
3	51	12	.023	5.000	2.875	4.775	3.423	3.575	3.885	2.164	4.001	3.295	3.119	2.907	3.381	3.727	3.427
3 MEANS			.028	4.408	2.451	4.062	2.945	3.085	3.353	2.170	3.832	3.144	2.946	2.617	3.092	3.208	3.075

TABLE 4. COMPARISON OF PD, PEV, AND COMPUTED VALUES OF EVAPOTRANSPIRATION FOR 12 PERUVIAN STATIONS.

STA	ELEV	MO	PD	PEV	ETJE	ETJH	ELKO	ETLI	ETTU	ETPA	ETBC	ETBM	ETHA	ETH2	ETHC	ETPE	MEAN
4	15	1	.019	3.339	3.028	5.048	3.458	3.372	4.048	1.856	4.085	2.804	2.350	2.401	2.832	3.718	3.250
4	15	2	.014	3.364	3.100	5.214	3.514	3.418	4.099	2.056	4.112	2.728	2.294	2.383	2.785	3.790	3.291
4	15	3	.000	3.152	2.937	4.928	3.299	3.208	3.917	1.818	3.988	2.554	2.098	2.210	2.561	3.537	3.088
4	15	4	.007	2.763	2.342	4.052	2.733	2.706	3.372	1.566	3.751	2.317	1.775	1.848	2.179	2.889	2.627
4	15	5	.016	2.277	1.464	2.571	1.851	1.921	2.349	1.235	3.479	2.069	1.434	1.295	1.579	1.944	1.933
4	15	6	.023	2.260	1.008	1.826	1.471	1.519	1.799	1.106	3.336	2.060	1.427	1.108	1.319	1.568	1.629
4	15	7	.035	1.942	1.004	1.806	1.464	1.509	1.795	1.013	3.304	1.965	1.301	1.021	1.206	1.556	1.579
4	15	8	.094	1.935	1.061	1.910	1.558	1.598	1.896	.936	3.297	1.961	1.241	.977	1.172	1.657	1.605
4	15	9	.080	1.930	1.341	2.407	1.908	1.935	2.303	.976	3.379	1.932	1.218	1.043	1.246	2.025	1.809
4	15	10	.026	2.339	1.729	3.039	2.363	2.380	2.785	1.177	3.535	2.264	1.609	1.412	1.721	2.519	2.211
4	15	11	.010	2.723	2.088	3.585	2.700	2.725	3.151	1.494	3.743	2.568	1.971	1.768	2.176	2.895	2.572
4	15	12	.006	3.016	2.602	4.365	3.106	3.063	3.663	1.674	3.926	2.605	2.077	2.046	2.428	3.323	2.906
4 MEANS			.028	2.587	1.975	3.396	2.452	2.446	2.932	1.409	3.661	2.319	1.733	1.626	1.934	2.619	2.375
5	5	1	.019	.800	2.411	4.230	2.979	2.999	3.454	1.570	4.049	2.593	2.104	1.981	2.370	3.227	2.831
5	5	2	.018	1.000	2.875	5.011	3.364	3.312	3.862	1.922	4.221	2.704	2.248	2.247	2.695	3.662	3.177
5	5	3	.042	1.100	2.571	4.568	3.097	3.082	3.594	1.640	4.084	2.616	2.161	2.107	2.532	3.361	2.951
5	5	4	.003	1.100	2.443	4.422	2.946	2.886	3.594	1.447	3.845	2.375	1.852	1.976	2.308	3.128	2.768
5	5	5	.006	1.000	2.080	3.756	2.516	2.530	3.164	1.358	3.683	2.359	1.836	1.899	2.252	2.540	2.506
5	5	6	.000	1.100	1.798	3.167	2.209	2.298	2.727	1.627	3.651	2.506	2.098	1.940	2.315	2.342	2.390
5	5	7	.013	1.000	1.504	2.702	2.018	2.105	2.408	1.442	3.597	2.468	2.059	1.722	2.049	2.167	2.187
5	5	8	.000	.900	1.507	2.706	2.096	2.175	2.442	1.376	3.571	2.451	2.003	1.624	1.927	2.262	2.179
5	5	9	.003	.900	1.733	3.120	2.385	2.429	2.817	1.254	3.522	2.336	1.790	1.580	1.889	2.542	2.283
5	5	10	.019	.900	2.026	3.512	2.564	2.531	3.099	1.377	3.643	2.417	1.812	1.657	2.031	2.720	2.449
5	5	11	.000	1.000	2.328	4.106	2.996	2.986	3.519	1.482	3.775	2.590	2.091	2.010	2.377	3.202	2.788
5	5	12	.006	1.300	2.307	4.083	2.898	2.885	3.425	1.411	3.929	2.517	1.944	1.868	2.261	3.107	2.720
5 MEANS			.011	.983	2.132	3.782	2.672	2.685	3.176	1.492	3.798	2.494	2.000	1.984	2.251	2.863	2.602
6	3207	1	3.903	2.471	3.128	4.648	3.234	5.223	4.304	2.835	3.304	4.006	3.696	3.833	4.197	3.544	3.829
6	3207	2	4.589	2.496	2.965	4.490	3.118	4.897	4.176	2.805	3.246	3.861	3.469	3.607	4.025	3.401	3.672
6	3207	3	4.419	2.681	3.183	4.738	3.197	5.146	4.382	2.806	3.190	3.868	3.543	3.852	4.143	3.470	3.793
6	3207	4	2.643	2.703	3.337	4.888	3.127	5.136	4.494	3.184	3.139	3.877	3.626	4.184	4.253	3.350	3.883
6	3207	5	.774	3.258	3.260	4.772	2.955	5.307	4.419	3.128	3.050	4.117	3.812	4.518	4.278	3.134	3.896
6	3207	6	.097	3.247	3.206	4.456	2.751	5.127	4.191	3.955	2.963	4.135	3.757	4.456	4.092	2.886	3.831
6	3207	7	.003	4.403	3.244	4.440	2.832	5.532	4.221	4.045	2.918	4.405	3.834	4.423	3.990	2.986	3.906
6	3207	8	.100	4.829	3.696	5.049	3.223	6.270	4.691	4.303	3.044	4.804	4.278	4.791	4.337	3.461	4.329
6	3207	9	.837	3.513	3.921	5.446	3.525	6.436	4.933	4.305	3.221	4.789	4.498	4.864	4.761	3.856	4.546
6	3207	10	1.845	2.758	3.599	5.146	3.536	6.376	4.706	3.687	3.262	4.776	4.445	4.516	4.669	3.918	4.386
6	3207	11	3.050	3.767	3.303	4.781	3.378	5.809	4.427	3.419	3.280	4.502	4.094	4.122	4.447	3.734	4.108
6	3207	12	2.229	3.142	3.358	4.880	3.388	5.736	4.487	3.266	3.340	4.355	4.071	4.182	4.497	3.739	4.103
6 MEANS			2.041	3.272	3.350	4.811	3.189	5.583	4.453	3.478	3.163	4.291	3.927	4.279	4.307	3.457	4.024

TABLE 5. COMPARISON OF PD, PEV, AND COMPUTED VALUES OF EVAPOTRANSPIRATION FOR 12 PERUVIAN STATIONS.

STA	ELEV	MO	PD	PEV	ETJE	ETJH	ELKO	ETLI	ETTU	ETPA	ETBC	ETBM	ETHA	ETH2	ETHC	ETPE	MEAN
7	1800	1	2.310	3.161	2.910	4.458	3.038	3.888	3.679	2.961	3.979	4.096	4.095	3.550	4.287	3.415	3.696
7	1800	2	1.321	3.179	2.865	4.375	3.002	3.848	3.631	3.295	3.898	4.013	4.022	3.472	4.173	3.374	3.664
7	1800	3	2.368	2.245	2.765	4.231	2.987	3.921	3.556	3.138	3.765	4.306	4.381	3.674	4.373	3.379	3.706
7	1800	4	1.057	2.447	2.914	4.330	2.935	3.892	3.611	3.548	3.707	4.325	4.424	3.921	4.636	3.292	3.794
7	1800	5	.139	2.900	3.154	4.538	2.922	4.051	3.780	3.918	3.614	4.464	4.658	4.448	4.988	3.236	3.981
7	1800	6	.067	2.813	1.825	2.676	2.242	2.813	2.427	3.688	3.462	4.435	4.427	3.209	3.765	2.618	3.132
7	1800	7	.148	3.158	2.608	3.811	2.636	3.661	3.303	3.633	3.477	4.455	4.479	3.986	4.583	2.940	3.631
7	1800	8	.074	3.332	3.089	4.537	3.038	4.261	3.843	3.667	3.567	4.651	4.717	4.353	4.907	3.377	4.000
7	1800	9	.273	3.060	2.929	4.447	3.114	4.202	3.698	3.557	3.759	4.729	4.882	4.101	4.826	3.542	3.982
7	1800	10	.732	3.148	3.694	5.417	3.587	4.909	4.373	3.860	3.908	4.917	5.185	4.673	5.376	4.048	4.495
7	1800	11	2.183	2.723	3.029	4.665	3.245	4.299	3.840	3.326	3.951	4.790	4.868	4.074	4.887	3.687	4.055
7	1800	12	1.045	2.448	2.835	4.375	3.080	4.008	3.624	3.107	3.987	4.651	4.675	3.831	4.639	3.502	3.860
7	MEANS		.976	2.885	2.885	4.321	2.986	3.979	3.614	3.475	3.756	4.486	4.568	3.941	4.620	3.367	3.833
8	3820	1	1.052	4.358	2.956	4.433	3.155	4.999	4.330	1.916	3.073	3.795	2.688	3.188	3.661	3.363	3.463
8	3820	2	2.754	3.629	2.443	3.684	2.609	3.637	3.660	1.645	2.967	2.851	1.872	2.256	2.761	2.745	2.761
8	3820	3	3.339	2.881	2.014	2.917	2.432	4.177	3.003	1.586	2.696	3.515	2.163	2.256	2.711	2.602	2.673
8	3820	4	.717	3.827	2.261	3.235	2.426	4.138	3.307	1.777	2.585	3.489	2.155	2.593	2.847	2.500	2.776
8	3820	5	.026	3.161	1.929	2.643	2.219	5.240	2.754	2.266	2.426	4.162	2.468	2.608	2.572	2.340	2.802
8	3820	6	.000	2.973	1.768	2.192	1.914	5.353	2.272	1.953	2.163	3.661	1.636	1.954	1.792	1.884	2.378
8	3820	7	.019	4.745	1.785	2.296	2.011	5.178	2.405	2.063	2.253	3.865	1.904	2.136	2.055	2.043	2.500
8	3820	8	.279	4.271	2.152	2.820	2.324	4.933	2.919	1.937	2.356	3.503	1.845	2.273	2.254	2.352	2.639
8	3820	9	1.073	4.677	2.421	3.384	2.820	6.266	3.456	2.235	2.604	4.349	2.672	2.859	2.867	3.020	3.246
8	3820	10	.452	4.600	3.113	4.468	3.322	6.448	4.423	2.415	2.858	4.511	3.100	3.565	3.549	3.550	3.777
8	3820	11	1.590	5.327	2.964	4.351	3.296	6.142	4.297	2.253	2.977	4.494	3.096	3.434	3.691	3.557	3.713
8	3820	12	5.619	3.313	2.499	3.725	2.921	5.022	3.716	1.830	3.019	3.868	2.659	2.834	3.346	3.166	3.217
8	MEANS		1.406	3.980	2.359	3.346	2.621	5.128	3.378	1.990	2.665	3.839	2.355	2.663	2.842	2.760	2.995
9	3400	1	2.526	3.161	2.778	4.063	2.774	3.953	3.855	2.363	3.276	3.148	2.519	2.768	3.261	2.975	3.144
9	3400	2	6.114	2.568	2.386	3.584	2.492	3.547	3.425	2.287	3.230	2.807	2.233	2.358	2.766	2.687	2.817
9	3400	3	2.890	2.703	2.218	3.300	2.209	2.809	3.252	1.659	2.985	2.458	1.628	1.893	2.355	2.298	2.422
9	3400	4	1.770	2.840	2.320	3.295	2.352	3.526	3.275	2.522	2.831	3.109	2.339	2.606	2.996	2.467	2.803
9	3400	5	.187	2.890	2.128	2.865	2.209	3.950	2.937	3.085	2.601	3.570	2.485	2.689	2.917	2.307	2.812
9	3400	6	.000	2.947	2.014	2.627	2.102	4.402	2.739	3.370	2.424	3.770	2.319	2.566	2.548	2.150	2.753
9	3400	7	.013	4.000	1.810	2.390	1.662	1.910	2.511	2.390	2.457	2.586	1.478	1.809	2.132	1.599	2.061
9	3400	8	.000	4.574	2.183	2.939	2.425	4.661	3.006	3.232	2.642	3.747	2.686	2.730	2.951	2.608	2.984
9	3400	9	1.020	3.813	2.272	3.230	2.576	4.351	3.216	2.777	2.886	3.829	2.918	2.820	3.261	2.817	3.079
9	3400	10	1.881	4.113	3.052	4.354	3.112	5.213	4.088	3.214	3.205	4.472	3.760	3.740	4.242	3.430	3.823
9	3400	11	1.367	4.187	2.964	4.307	3.051	4.848	4.040	2.950	3.299	4.226	3.505	3.527	4.140	3.347	3.684
9	3400	12	4.184	2.868	2.273	3.411	2.604	3.978	3.274	2.335	3.318	3.795	3.073	2.812	3.398	2.893	3.097
9	MEANS		1.829	3.389	2.367	3.364	2.464	3.929	3.302	2.682	2.930	3.460	2.579	2.693	3.081	2.632	2.957

TABLE 6. COMPARISON OF PD, PEV, AND COMPUTED VALUES OF EVAPOTRANSPIRATION FOR 12 PERUVIAN STATIONS.

STA	ELEV	MO	PD	PEV	ETJE	ETJH	ELKO	ETLI	ETTU	ETPA	ETBC	ETBM	ETHA	ETH2	ETHC	ETPE	MEAN
10	356	1	3.297	1.810	3.698	5.204	3.513	3.695	3.724	4.103	4.653	4.151	4.541	3.736	4.501	4.016	4.128
10	356	2	2.182	2.093	3.817	5.215	3.583	3.826	3.738	5.133	4.596	4.310	4.937	3.942	4.652	4.126	4.323
10	356	3	1.390	1.942	3.321	4.614	3.280	3.472	3.356	4.513	4.532	4.666	5.187	3.810	4.662	3.815	4.102
10	356	4	3.780	1.910	3.315	4.588	3.185	3.355	3.344	4.550	4.454	4.178	4.655	3.662	4.404	3.667	3.946
10	356	5	3.413	1.361	2.603	3.657	2.655	2.724	2.759	4.153	4.378	3.805	4.229	3.135	3.677	3.080	3.405
10	356	6	3.087	1.387	2.428	3.510	2.530	2.619	2.704	3.833	4.262	3.509	3.813	2.954	3.440	2.903	3.209
10	356	7	3.713	2.226	3.194	4.423	3.033	3.246	3.283	4.423	4.303	4.035	4.573	3.815	4.468	3.462	3.855
10	356	8	1.348	2.832	4.031	5.402	3.520	3.746	3.938	4.583	4.320	4.151	4.470	4.100	4.852	3.943	4.255
10	356	9	4.220	2.200	3.260	4.601	3.221	3.421	3.392	4.279	4.424	3.947	4.418	3.477	4.090	3.699	3.852
10	356	10	2.987	1.865	3.839	5.240	3.555	3.756	3.741	4.532	4.592	4.097	4.629	3.779	4.456	4.078	4.191
10	356	11	2.877	1.400	3.145	4.463	3.112	3.253	3.281	4.022	4.588	3.988	4.261	3.254	3.930	3.570	3.733
10	356	12	4.155	2.658	3.743	5.076	3.548	3.805	3.631	4.939	4.687	4.932	5.649	4.271	5.155	4.127	4.464
10	MEANS		3.037	1.974	3.366	4.666	3.228	3.410	3.407	4.422	4.482	4.147	4.613	3.661	4.357	3.707	3.956
11	150	1	.077	6.500	4.585	6.134	4.134	4.461	4.521	4.781	4.396	4.022	4.652	4.326	4.648	4.625	4.607
11	150	2	.271	6.500	4.763	6.268	4.214	4.556	4.519	5.755	4.460	4.285	5.058	4.558	4.981	4.759	4.848
11	150	3	.303	6.600	4.815	6.311	4.208	4.555	4.531	5.286	4.413	4.240	5.033	4.611	4.985	4.752	4.812
11	150	4	.153	6.500	4.185	5.591	3.737	4.012	4.172	4.847	4.192	3.836	4.333	4.075	4.427	4.155	4.297
11	150	5	.061	5.700	3.427	4.755	3.144	3.311	3.746	3.801	3.929	3.235	3.361	3.327	3.606	3.397	3.587
11	150	6	.013	4.800	2.609	3.768	2.531	2.654	3.162	3.067	3.697	2.706	2.515	2.462	2.752	2.676	2.883
11	150	7	.006	4.800	2.400	3.508	2.433	2.556	3.027	2.751	3.602	2.636	2.378	2.259	2.560	2.568	2.723
11	150	8	.010	4.800	2.710	3.932	2.790	2.933	3.366	2.943	3.615	2.812	2.658	2.523	2.791	2.970	3.004
11	150	9	.033	5.400	3.246	4.641	3.297	3.482	3.865	3.408	3.734	3.160	3.148	2.996	3.271	3.550	3.483
11	150	10	.052	5.700	3.571	5.062	3.596	3.830	4.143	3.528	3.846	3.343	3.456	3.285	3.527	3.901	3.757
11	150	11	.060	5.900	3.897	5.417	3.763	3.974	4.332	3.934	3.991	3.560	3.695	3.560	3.857	4.091	4.006
11	150	12	.090	6.310	4.329	5.894	4.010	4.304	4.532	4.328	4.192	3.836	4.229	4.070	4.323	4.410	4.372
11	MEANS		.094	5.792	3.712	5.107	3.488	3.719	3.993	4.036	4.006	3.473	3.710	3.504	3.811	3.821	3.865
12	7	1	.565	6.000	2.972	5.071	3.558	3.677	3.690	2.938	4.516	4.236	4.493	3.673	4.515	4.055	3.950
12	7	2	1.993	5.500	3.063	5.045	3.509	3.572	3.655	3.283	4.521	3.930	4.125	3.396	4.155	3.988	3.854
12	7	3	1.058	5.900	3.362	5.516	3.770	3.851	3.943	3.049	4.506	4.020	4.230	3.667	4.466	4.275	4.054
12	7	4	.567	5.800	3.237	5.141	3.515	3.597	3.768	3.220	4.368	3.797	3.984	3.500	4.186	3.949	3.855
12	7	5	.013	6.100	2.843	4.629	3.168	3.238	3.463	2.819	4.287	3.727	3.718	3.272	4.045	3.539	3.562
12	7	6	.017	4.700	1.997	3.721	2.676	2.760	2.931	1.989	4.134	3.593	3.350	2.757	3.565	2.992	3.039
12	7	7	.032	5.100	1.953	3.263	2.299	2.348	2.671	2.123	4.022	3.220	2.814	2.245	2.918	2.515	2.699
12	7	8	.016	4.900	1.847	3.278	2.384	2.438	2.694	1.763	4.016	3.124	2.672	2.092	2.711	2.630	2.637
12	7	9	.007	4.700	2.270	4.065	2.855	2.906	3.247	1.800	4.050	2.964	2.529	2.212	2.812	3.127	2.903
12	7	10	.006	5.500	2.351	4.156	2.977	3.056	3.277	2.037	4.145	3.318	3.045	2.516	3.173	3.302	3.113
12	7	11	.027	6.100	2.812	4.968	3.438	3.524	3.833	2.244	4.184	3.541	3.400	3.083	3.760	3.786	3.548
12	7	12	.029	6.400	3.095	5.463	3.682	3.735	4.048	2.378	4.371	3.800	3.749	3.481	4.238	4.083	3.844
12	MEANS		.361	5.558	2.650	4.526	3.152	3.225	3.435	2.470	4.260	3.606	3.509	2.991	3.712	3.520	3.421
MEANS			.826	3.599	2.787	4.244	2.988	3.678	3.548	2.786	3.713	3.500	3.230	3.012	3.426	3.270	3.348

TABLE 7. COMPARISON OF PD, PEV AND COMPUTED EV AND ET FROM USU FORMULAS FOR 12 PERUVIAN STATIONS.

STA	ELEV	MO	PD	PEV	EVC	EVC1	EVM	ET2	ET3	ETSC	ET6	ETMA	ETMC	ETG1	ETG2	ETG3	MEAN
1	18	1	.039	5.200	7.024	4.792	5.709	5.573	4.376	3.901	3.832	4.107	5.244	4.955	3.935	5.495	4.602
1	18	2	.232	5.200	7.323	5.081	5.449	5.812	4.646	4.144	4.065	3.881	5.503	4.882	4.020	5.564	4.724
1	18	3	.213	5.000	7.067	4.896	5.506	5.593	4.468	3.976	3.906	3.931	5.281	4.850	3.872	5.394	4.586
1	18	4	.113	4.900	6.382	4.285	4.844	5.087	3.930	3.510	3.443	3.358	4.689	4.650	3.626	5.049	4.149
1	18	5	.035	4.800	5.427	3.403	3.978	4.325	3.136	2.777	2.734	2.609	3.863	4.269	3.116	4.463	3.477
1	18	6	.023	4.000	4.691	2.694	3.345	3.716	2.476	2.164	2.151	2.062	3.226	3.838	2.667	4.013	2.924
1	18	7	.003	3.600	4.556	2.526	3.251	3.587	2.302	2.003	2.005	1.980	3.109	3.795	2.590	4.000	2.819
1	18	8	.003	3.600	5.074	3.022	3.575	3.988	2.730	2.398	2.394	2.261	3.557	4.065	3.008	4.481	3.209
1	18	9	.017	4.000	5.616	3.441	3.891	4.416	3.105	2.737	2.727	2.534	4.026	4.464	3.343	4.921	3.586
1	18	10	.026	4.200	6.002	3.777	4.391	4.723	3.407	3.014	2.996	2.966	4.360	4.620	3.580	5.207	3.875
1	18	11	.027	4.600	6.211	4.075	4.719	4.868	3.659	3.240	3.220	3.250	4.541	4.834	3.650	5.280	4.060
1	18	12	.055	5.000	6.484	4.334	5.289	5.102	3.916	3.474	3.438	3.743	4.777	4.895	3.728	5.332	4.267
1	MEANS		.066	4.508	5.988	3.860	4.496	4.733	3.512	3.112	3.076	3.057	4.348	4.510	3.428	4.933	3.856
2	31	1	.016	6.000	7.234	5.581	5.892	5.633	4.846	4.416	4.381	4.264	5.425	4.720	4.295	5.848	4.870
2	31	2	.071	5.200	7.392	5.462	5.555	5.806	4.865	4.386	4.324	3.973	5.562	4.709	4.193	5.744	4.840
2	31	3	.045	4.900	7.458	5.721	6.149	5.853	5.024	4.587	4.526	4.487	5.619	4.869	4.315	5.822	5.011
2	31	4	.077	4.000	7.076	4.977	5.208	5.760	4.529	4.200	4.083	3.673	5.289	4.543	4.244	5.622	4.660
2	31	5	.006	3.268	6.131	3.919	4.361	5.071	3.644	3.377	3.268	2.940	4.471	4.137	3.806	5.063	3.975
2	31	6	.010	2.900	5.160	3.158	3.507	4.182	2.912	2.634	2.580	2.202	3.632	3.952	3.208	4.441	3.305
2	31	7	.010	2.300	4.824	2.773	3.223	3.856	2.543	2.256	2.234	1.956	3.341	3.762	2.938	4.261	3.016
2	31	8	.006	2.700	5.393	3.058	3.612	4.370	2.823	2.537	2.498	2.292	3.833	4.215	3.396	4.791	3.417
2	31	9	.013	2.900	6.118	3.395	4.112	5.041	3.171	2.886	2.820	2.725	4.460	4.319	3.911	5.393	3.859
2	31	10	.013	3.600	6.606	4.350	4.800	5.328	3.925	3.601	3.536	3.320	4.883	4.739	4.239	5.766	4.371
2	31	11	.057	3.700	6.900	4.629	5.167	5.598	4.170	3.867	3.786	3.638	5.136	4.785	4.444	5.974	4.600
2	31	12	.055	4.800	7.332	5.285	5.898	5.908	4.701	4.381	4.292	4.270	5.511	4.872	4.581	6.106	4.958
2	MEANS		.032	3.856	6.469	4.359	4.790	5.200	3.929	3.594	3.527	3.312	4.763	4.469	3.964	5.403	4.240
3	51	1	.042	5.400	6.678	4.478	4.719	5.271	4.056	3.608	3.563	3.250	4.945	4.581	3.855	5.469	4.289
3	51	2	.096	5.200	6.809	4.538	4.373	5.383	4.138	3.669	3.617	2.951	5.058	4.597	3.830	5.445	4.299
3	51	3	.045	5.200	6.674	4.482	4.450	5.297	4.087	3.646	3.586	3.017	4.941	4.439	3.830	5.372	4.246
3	51	4	.040	5.200	5.900	3.897	3.852	4.670	3.530	3.149	3.109	2.500	4.272	4.310	3.487	4.934	3.774
3	51	5	.006	4.600	5.330	3.549	3.622	4.227	3.195	2.869	2.834	2.301	3.779	4.009	3.246	4.550	3.445
3	51	6	.013	3.500	4.323	2.574	2.738	3.349	2.295	1.994	2.010	1.536	2.907	3.550	2.463	3.826	2.659
3	51	7	.010	3.300	4.208	2.465	2.665	3.227	2.169	1.874	1.906	1.474	2.808	3.548	2.363	3.789	2.573
3	51	8	.003	3.400	4.560	2.614	2.798	3.509	2.309	1.995	2.027	1.588	3.112	3.813	2.578	4.130	2.785
3	51	9	.007	3.500	5.104	3.060	2.999	3.931	2.697	2.347	2.376	1.762	3.583	4.084	2.987	4.632	3.155
3	51	10	.042	4.000	5.580	3.411	3.479	4.340	3.031	2.662	2.674	2.178	3.995	4.245	3.363	5.035	3.503
3	51	11	.013	4.600	6.043	3.942	4.061	4.739	3.506	3.128	3.116	2.681	4.395	4.602	3.757	5.369	3.921
3	51	12	.023	5.000	6.367	4.144	4.449	5.049	3.744	3.352	3.312	3.016	4.676	4.708	3.875	5.468	4.133
3	MEANS		.028	4.408	5.631	3.596	3.684	4.416	3.230	2.858	2.844	2.355	4.039	4.207	3.303	4.835	3.565

TABLE 8. COMPARISON OF PD, PEV AND COMPUTED EV AND ET FROM USU FORMULAS FOR 12 PERUVIAN STATIONS.

STA	ELEV	MO	PD	PEV	EVC	EVC1	EVM	ET2	ET3	ETSC	ET6	ETMA	ETMC	ETG1	ETG2	ETG3	MEAN
4	15	1	.019	3.339	6.615	3.747	4.450	5.415	3.525	3.166	3.091	3.018	4.890	4.560	4.033	5.624	4.147
4	15	2	.014	3.364	6.704	3.707	4.016	5.537	3.531	3.175	3.086	2.642	4.967	4.559	4.053	5.595	4.127
4	15	3	.000	3.152	6.364	3.426	4.033	5.271	3.270	2.940	2.860	2.656	4.673	4.383	3.865	5.344	3.918
4	15	4	.007	2.763	5.479	2.840	3.325	4.493	2.685	2.392	2.347	2.045	3.907	3.691	3.321	4.734	3.290
4	15	5	.016	2.277	4.141	1.925	2.543	3.276	1.759	1.515	1.535	1.368	2.750	3.292	2.257	3.722	2.386
4	15	6	.023	2.260	3.403	1.494	1.935	2.630	1.312	1.121	1.164	.842	2.112	3.069	1.670	3.124	1.894
4	15	7	.035	1.942	3.440	1.456	1.958	2.660	1.275	1.089	1.135	.862	2.143	3.112	1.685	3.187	1.905
4	15	8	.094	1.935	3.724	1.571	2.040	2.867	1.364	1.166	1.219	.932	2.389	3.063	1.833	3.496	2.037
4	15	9	.080	1.930	4.395	1.889	2.332	3.418	1.672	1.430	1.481	1.185	2.970	3.627	2.311	4.126	2.469
4	15	10	.026	2.339	5.035	2.500	2.935	3.922	2.234	1.925	1.963	1.707	3.523	3.881	2.835	4.666	2.962
4	15	11	.010	2.723	5.506	2.968	3.481	4.316	2.680	2.329	2.345	2.179	3.931	4.366	3.182	4.978	3.367
4	15	12	.006	3.016	6.098	3.317	4.187	4.915	3.078	2.727	2.695	2.790	4.443	4.467	3.686	5.365	3.796
4	MEANS		.028	2.587	5.075	2.570	3.103	4.060	2.365	2.081	2.077	1.852	3.558	3.839	2.894	4.497	3.025
5	5	1	.019	.800	5.969	3.091	3.705	4.813	2.905	2.538	2.512	2.373	4.331	4.339	3.380	5.075	3.585
5	5	2	.018	1.000	6.523	3.471	3.669	5.368	3.338	2.953	2.879	2.342	4.810	4.397	3.751	5.296	3.904
5	5	3	.042	1.100	6.113	3.219	3.519	4.993	3.074	2.704	2.650	2.212	4.456	4.216	3.478	5.027	3.646
5	5	4	.003	1.100	5.789	3.025	3.242	4.795	2.886	2.590	2.526	1.972	4.176	4.182	3.533	4.922	3.509
5	5	5	.006	1.000	5.070	2.709	2.971	4.146	2.548	2.276	2.233	1.738	3.553	3.822	3.098	4.398	3.090
5	5	6	.000	1.100	4.511	2.476	2.709	3.600	2.289	2.006	1.991	1.511	3.070	3.503	2.613	3.914	2.722
5	5	7	.013	1.000	4.225	2.207	2.463	3.308	2.002	1.725	1.741	1.299	2.823	3.480	2.282	3.717	2.486
5	5	8	.000	.900	4.419	2.267	2.514	3.432	2.032	1.744	1.775	1.342	2.990	3.614	2.350	3.949	2.581
5	5	9	.003	.900	4.942	2.569	2.683	3.865	2.311	2.001	2.025	1.489	3.443	3.856	2.833	4.520	2.927
5	5	10	.019	.900	5.383	2.833	3.233	4.240	2.570	2.236	2.249	1.965	3.825	4.088	3.128	4.876	3.242
5	5	11	.000	1.000	5.855	3.266	3.516	4.673	2.992	2.646	2.628	2.210	4.232	4.437	3.566	5.232	3.624
5	5	12	.006	1.000	5.843	3.040	3.633	4.695	2.831	2.482	2.463	2.311	4.222	4.396	3.402	5.099	3.544
5	MEANS		.011	.983	5.387	2.848	3.155	4.327	2.648	2.325	2.306	1.897	3.828	4.028	3.118	4.669	3.238
6	3207	1	3.903	2.471	6.814	6.482	6.407	4.766	4.791	4.312	4.571	4.710	5.062	3.606	4.923	6.657	4.822
6	3207	2	4.589	2.496	6.674	6.228	5.285	4.677	4.632	4.149	4.399	3.740	4.941	3.438	4.779	6.533	4.588
6	3207	3	4.419	2.681	6.789	6.491	6.012	4.808	4.813	4.396	4.634	4.368	5.040	3.502	5.018	6.633	4.801
6	3207	4	2.643	2.703	6.786	6.530	6.269	4.899	4.832	4.541	4.752	4.691	5.038	3.576	5.128	6.607	4.885
6	3207	5	.774	3.258	6.592	6.668	6.333	4.724	4.713	4.576	4.816	4.646	4.870	3.648	5.080	6.453	4.836
6	3207	6	.097	3.247	6.228	6.458	6.817	4.424	4.451	4.368	4.624	5.065	4.556	3.758	4.885	6.161	4.699
6	3207	7	.003	4.403	6.259	6.976	7.157	4.279	4.556	4.486	4.808	5.359	4.582	3.864	5.022	6.257	4.802
6	3207	8	.100	4.829	6.969	8.008	7.869	4.652	5.135	5.026	5.388	5.974	5.196	4.313	5.480	6.870	5.337
6	3207	9	.837	3.513	7.394	8.206	7.952	4.996	5.524	5.242	5.588	6.047	5.564	4.341	5.607	7.148	5.562
6	3207	10	1.845	2.758	7.162	7.994	7.549	4.749	5.394	4.973	5.343	5.697	5.363	3.959	5.373	6.961	5.313
6	3207	11	3.050	3.767	6.882	7.306	7.078	4.622	5.075	4.602	4.946	5.291	5.121	3.878	5.089	6.736	5.040
6	3207	12	2.229	3.142	6.989	7.081	7.349	4.809	5.073	4.605	4.906	5.525	5.214	3.763	5.119	6.805	5.091
6	MEANS		2.041	3.272	6.795	7.036	6.840	4.700	4.916	4.607	4.898	5.084	5.046	3.804	5.125	6.652	4.981

TABLE 9. COMPARISON OF PD, PEV AND COMPUTED EV AND ET FROM USU FORMULAS FOR 12 PERUVIAN STATIONS.

STA	ELEV	MO	PD	PEV	EVC	EVC1	EVM	ET2	ET3	ETSC	ET6	ETMA	ETMC	ETG1	ETG2	ETG3	MEAN
7	1800	1	2.310	3.161	6.710	4.896	5.593	4.925	4.057	3.509	3.623	4.006	4.972	3.871	3.665	5.809	4.271
7	1800	2	1.321	3.179	6.611	4.826	5.107	4.846	3.991	3.451	3.566	3.585	4.886	4.065	3.621	5.747	4.195
7	1800	3	2.368	2.245	6.335	5.094	5.148	4.516	4.036	3.500	3.660	3.621	4.648	3.692	3.561	5.562	4.088
7	1800	4	1.057	2.447	6.148	5.160	5.421	4.411	4.094	3.596	3.732	3.857	4.486	3.467	3.608	5.365	4.068
7	1800	5	.139	2.900	6.016	5.456	6.043	4.341	4.252	3.849	3.969	4.395	4.372	3.388	3.806	5.272	4.183
7	1800	6	.067	2.813	4.413	3.705	4.330	2.974	2.717	2.328	2.517	2.913	2.985	2.993	2.341	3.959	2.859
7	1800	7	.148	3.158	5.310	4.945	5.227	3.705	3.727	3.315	3.478	3.689	3.761	3.596	3.333	4.764	3.708
7	1800	8	.074	3.332	6.125	5.831	5.702	4.299	4.384	3.951	4.125	4.101	4.466	3.795	3.926	5.463	4.279
7	1800	9	.273	3.060	6.407	5.659	5.108	4.466	4.327	3.784	3.977	3.586	4.710	3.828	3.705	5.591	4.219
7	1800	10	.732	3.148	7.350	6.642	6.610	5.218	5.143	4.580	4.754	4.885	5.526	4.302	4.425	6.338	5.019
7	1800	11	2.183	2.723	6.850	5.786	5.512	4.820	4.499	3.912	4.103	3.936	5.094	4.089	3.849	5.943	4.472
7	1800	12	1.045	2.448	6.643	5.329	5.518	4.702	4.192	3.621	3.802	3.941	4.914	3.974	3.609	5.763	4.280
7	MEANS		.976	2.885	6.243	5.277	5.443	4.435	4.118	3.616	3.775	3.876	4.568	3.755	3.621	5.465	4.137
8	3820	1	1.052	4.358	6.903	6.973	5.143	4.762	4.927	4.501	4.849	3.617	5.139	4.209	5.519	7.104	4.959
8	3820	2	2.754	3.629	6.299	4.999	4.001	4.536	3.855	3.422	3.629	2.629	4.616	3.583	4.671	6.516	4.162
8	3820	3	3.339	2.881	5.179	5.566	3.545	3.356	3.681	3.252	3.636	2.234	3.648	3.503	4.143	5.510	3.663
8	3820	4	.717	3.827	5.259	5.977	3.740	3.513	3.924	3.655	4.025	2.403	3.717	3.409	4.629	5.604	3.875
8	3820	5	.026	3.161	4.264	6.168	3.896	2.495	3.442	3.211	3.639	2.538	2.857	3.237	4.016	4.604	3.338
8	3820	6	.000	2.973	3.970	5.821	3.447	2.392	3.154	3.082	3.535	2.150	2.602	3.221	4.134	4.452	3.191
8	3820	7	.019	4.745	3.968	5.913	3.705	2.330	3.215	3.058	3.500	2.373	2.600	3.068	4.004	4.394	3.171
8	3820	8	.229	4.271	4.870	6.212	4.114	3.157	3.743	3.609	4.059	2.727	3.381	3.703	4.741	5.360	3.831
8	3820	9	1.073	4.677	5.403	7.545	4.227	3.227	4.319	4.025	4.542	2.825	3.841	3.698	4.986	5.796	4.140
8	3820	10	.452	4.600	6.768	8.565	5.656	4.296	5.223	4.959	5.480	4.061	5.023	4.452	5.924	7.084	5.167
8	3820	11	1.590	5.327	6.694	8.188	5.210	4.259	5.142	4.746	5.251	3.675	4.959	4.131	5.658	6.971	4.977
8	3820	12	5.619	3.313	6.209	6.463	4.603	4.111	4.410	3.920	4.314	3.149	4.539	3.755	4.844	6.466	4.390
8	MEANS		1.406	3.980	5.482	6.533	4.274	3.536	4.086	3.787	4.205	2.865	3.910	3.664	4.772	5.822	4.072
9	3400	1	2.526	3.161	6.571	5.009	6.400	4.775	3.981	3.501	3.669	4.704	4.852	3.584	4.477	6.511	4.450
9	3400	2	6.114	2.568	6.172	4.151	4.887	4.522	3.375	2.922	3.065	3.395	4.507	3.303	3.910	6.095	3.899
9	3400	3	2.890	2.703	5.799	3.834	4.699	4.281	3.117	2.724	2.852	3.233	4.185	3.332	3.899	5.878	3.722
9	3400	4	1.770	2.840	5.286	4.769	5.466	3.729	3.547	3.178	3.391	3.896	3.740	3.227	4.029	5.413	3.794
9	3400	5	.187	2.890	4.545	5.205	5.839	2.995	3.421	3.140	3.458	4.219	3.099	3.410	3.875	4.780	3.600
9	3400	6	.000	2.947	4.237	5.552	5.342	2.673	3.322	3.151	3.530	3.789	2.833	3.558	3.962	4.567	3.487
9	3400	7	.013	4.000	4.209	3.846	5.115	2.979	2.792	2.543	2.744	3.593	2.809	3.202	3.549	4.522	3.193
9	3400	8	.000	4.574	4.699	5.553	5.865	3.024	3.575	3.245	3.602	4.241	3.233	3.610	3.975	4.943	3.716
9	3400	9	1.020	3.813	5.298	5.545	5.383	3.463	3.759	3.314	3.653	3.824	3.751	3.596	3.950	5.425	3.859
9	3400	10	1.881	4.113	6.525	6.971	6.978	4.284	4.756	4.247	4.614	5.204	4.812	3.928	4.726	6.432	4.778
9	3400	11	1.367	4.187	6.638	6.509	6.639	4.478	4.637	4.102	4.427	4.911	4.910	3.818	4.652	6.532	4.719
9	3400	12	4.184	2.868	5.989	4.975	5.391	4.086	3.658	3.147	3.422	3.832	4.348	3.369	3.721	5.914	3.944
9	MEANS		1.829	3.389	5.497	5.160	5.667	3.774	3.662	3.268	3.536	4.070	3.923	3.495	4.060	5.584	3.930

TABLE 10. COMPARISON OF PD, PEV AND COMPUTED EV AND ET FROM USU FORMULAS FOR 12 PERUVIAN STATIONS.

STA	ELEV	MO	PD	PEV	EVC	EVC1	EVM	ET2	ET3	ETSC	ET6	ETMA	ETMC	ETG1	ETG2	ETG3	MEAN
10	356	1	3.297	1.810	7.040	4.592	6.005	5.507	4.202	3.651	3.621	4.362	5.258	3.695	3.516	5.226	4.338
10	356	2	2.182	2.093	7.104	4.792	5.938	5.500	4.320	3.753	3.740	4.304	5.313	3.726	3.532	5.286	4.386
10	356	3	1.390	1.942	6.654	4.650	5.534	4.998	4.028	3.466	3.521	3.955	4.924	4.467	3.125	4.952	4.160
10	356	4	3.780	1.910	6.366	4.250	5.382	4.909	3.817	3.303	3.303	3.823	4.674	4.119	3.114	4.748	3.973
10	356	5	3.413	1.361	5.437	3.270	4.670	4.208	2.959	2.535	2.551	3.208	3.871	4.138	2.494	4.074	3.338
10	356	6	3.087	1.387	5.131	3.015	4.197	4.008	2.763	2.373	2.375	2.798	3.606	3.736	2.448	3.925	3.115
10	356	7	3.713	2.226	5.861	4.042	5.223	4.561	3.644	3.195	3.171	3.686	4.238	4.338	3.061	4.453	3.816
10	356	8	1.348	2.832	6.748	4.891	6.434	5.321	4.405	3.952	3.888	4.733	5.005	4.323	3.766	5.162	4.506
10	356	9	4.220	2.200	6.469	4.138	5.205	5.020	3.750	3.239	3.236	3.670	4.764	3.787	3.176	4.904	3.950
10	356	10	2.987	1.865	7.087	4.617	6.235	5.547	4.229	3.675	3.643	4.561	5.298	4.433	3.532	5.249	4.463
10	356	11	2.877	1.400	6.519	3.975	5.458	5.054	3.607	3.095	3.107	3.889	4.807	4.048	3.052	4.996	3.951
10	356	12	4.155	2.658	7.047	5.123	6.570	5.303	4.439	3.844	3.886	4.851	5.264	3.944	3.414	5.207	4.461
10	MEANS		3.037	1.974	6.455	4.280	5.571	4.995	3.847	3.340	3.337	3.987	4.752	4.063	3.186	4.840	4.038
11	150	1	.077	6.500	7.570	5.318	7.984	6.083	4.839	4.412	4.308	6.074	5.716	5.143	4.421	5.962	5.217
11	150	2	.271	6.500	7.731	5.611	7.393	6.148	5.060	4.590	4.498	5.563	5.856	5.134	4.392	5.941	5.243
11	150	3	.303	6.600	7.703	5.596	7.696	6.161	5.059	4.617	4.512	5.825	5.832	4.999	4.400	5.893	5.255
11	150	4	.153	6.500	6.894	4.851	6.992	5.542	4.409	4.026	3.931	5.216	5.131	4.663	4.051	5.453	4.714
11	150	5	.061	5.700	5.966	3.899	6.143	4.857	3.591	3.285	3.199	4.482	4.328	4.335	3.653	4.937	4.074
11	150	6	.013	4.800	5.038	2.994	4.947	4.065	2.766	2.478	2.435	3.447	3.526	3.930	3.088	4.354	3.343
11	150	7	.006	4.800	4.881	2.881	4.783	3.888	2.630	2.335	2.314	3.305	3.390	3.862	2.983	4.311	3.224
11	150	8	.010	4.800	5.386	3.370	5.288	4.278	3.039	2.723	2.698	3.742	3.827	4.151	3.378	4.785	3.624
11	150	9	.033	5.400	6.151	4.136	5.985	4.882	3.689	3.346	3.309	4.345	4.488	4.778	3.906	5.400	4.238
11	150	10	.052	5.700	6.609	4.535	6.747	5.255	4.039	3.681	3.635	5.004	4.885	4.990	4.190	5.745	4.603
11	150	11	.060	5.900	6.928	4.838	7.396	5.533	4.315	3.956	3.894	5.565	5.161	5.111	4.355	5.914	4.867
11	150	12	.090	6.310	7.339	5.190	8.062	5.903	4.661	4.298	4.208	6.141	5.516	5.178	4.501	6.048	5.162
11	MEANS		.094	5.792	6.516	4.435	6.618	5.216	4.008	3.646	3.578	4.893	4.805	4.690	3.943	5.395	4.464
12	7	1	.565	6.000	6.712	4.634	3.997	5.220	4.179	3.659	3.633	2.626	4.974	4.310	3.492	5.076	4.130
12	7	2	1.993	5.500	6.729	4.357	3.828	5.298	4.013	3.499	3.458	2.479	4.988	4.459	3.450	5.054	4.077
12	7	3	1.058	5.900	7.031	4.757	4.165	5.577	4.385	3.874	3.803	2.770	5.250	4.605	3.754	5.257	4.364
12	7	4	.567	5.800	6.572	4.374	4.161	5.231	4.039	3.578	3.509	2.767	4.853	4.578	3.585	5.028	4.130
12	7	5	.013	6.100	5.981	3.975	3.844	4.740	3.655	3.229	3.176	2.493	4.341	4.197	3.268	4.627	3.747
12	7	6	.017	4.700	5.190	3.337	2.841	4.031	3.013	2.616	2.613	1.625	3.657	3.886	2.725	4.142	3.145
12	7	7	.032	5.100	4.870	2.842	3.086	3.783	2.571	2.211	2.225	1.838	3.381	3.821	2.471	3.988	2.921
12	7	8	.016	4.900	5.045	2.826	2.877	3.917	2.554	2.189	2.212	1.657	3.532	3.990	2.503	4.158	2.968
12	7	9	.007	4.700	5.760	3.253	3.156	4.570	3.018	2.620	2.602	1.898	4.151	3.973	3.105	4.747	3.403
12	7	10	.006	5.500	5.941	3.555	3.432	4.650	3.246	2.810	2.805	2.137	4.307	4.486	3.120	4.834	3.599
12	7	11	.027	6.100	6.484	4.261	3.792	5.146	3.896	3.461	3.409	2.448	4.776	4.518	3.719	5.264	4.071
12	7	12	.029	6.400	6.851	4.627	4.057	5.487	4.262	3.820	3.736	2.677	5.094	4.697	3.906	5.360	4.338
12	MEANS		.361	5.558	6.097	3.900	3.603	4.804	3.569	3.131	3.098	2.284	4.442	4.293	3.258	4.794	3.742
MEANS			.826	3.599	5.970	4.488	4.770	4.516	3.658	3.280	3.355	3.294	4.332	4.068	3.723	5.241	3.941

TABLE 11. COMPARISON OF MEASURED AND COMPUTED PAN EVAPORATION FOR SHELL FOUNDATION STATION (VENEZUELA)*.

ST	MO	YEAR	PD	EVP	EVF	CMF	EVC	CMC	EVM	CMM	EVPE	CMPE	EVKO	CMKO	EVBC	BC-K	EVHA	CMHA
31	1	64	.000	7.400	5.000	1.480	7.895	.937	6.499	1.139	5.445	1.359	5.519	1.341	5.112	1.448	5.938	1.246
31	1	65	15.800	7.200	3.500	2.357	5.835	1.234	5.568	1.293	4.343	1.658	4.436	1.623	4.980	1.446	4.041	1.782
31	1	66	.000	6.600	3.700	1.784	6.543	1.009	5.775	1.143	4.888	1.350	4.928	1.339	5.159	1.279	6.380	1.035
31	1	67	.000	6.300	3.900	1.615	6.651	.947	5.826	1.081	4.764	1.322	4.840	1.302	4.980	1.265	5.754	1.095
31	1	68	.000	7.100	4.100	1.732	7.313	.971	6.468	1.098	5.144	1.380	5.199	1.366	5.064	1.402	6.681	1.063
MEANS			3.160	6.920	4.040	1.734	6.847	1.020	6.027	1.151	4.917	1.414	4.984	1.394	5.059	1.368	5.759	1.244
MEAN ABS. RELATIVE ERROR						.416		.072		.129		.289		.280		.269		.168
31	2	64	.000	8.800	5.600	1.571	8.505	1.035	6.711	1.311	5.836	1.508	5.888	1.494	5.332	1.650	6.869	1.281
31	2	65	.000	7.800	4.600	1.696	7.470	1.044	6.156	1.267	5.186	1.504	5.291	1.474	5.150	1.515	4.865	1.603
31	2	66	1.200	8.400	4.600	1.826	8.443	.995	6.811	1.233	5.885	1.427	5.921	1.419	5.284	1.590	7.114	1.181
31	2	67	.000	8.300	5.000	1.660	8.746	.949	6.747	1.230	5.983	1.387	6.022	1.378	5.211	1.593	7.433	1.117
31	2	68	.000	8.100	4.400	1.841	8.551	.947	7.252	1.117	5.923	1.368	5.957	1.360	5.271	1.537	7.309	1.108
MEANS			.240	8.280	4.840	1.719	8.343	.994	6.735	1.232	5.762	1.439	5.816	1.425	5.250	1.577	6.718	1.258
MEAN ABS. RELATIVE ERROR						.415		.038		.187		.304		.298		.366		.189
31	3	64	.000	9.500	6.300	1.508	7.313	1.299	6.023	1.577	4.775	1.990	4.842	1.962	5.529	1.718	6.887	1.379
31	3	65	.000	9.500	5.600	1.696	9.621	.987	8.767	1.084	6.515	1.458	6.566	1.447	5.492	1.730	6.899	1.377
31	3	66	.000	9.400	5.100	1.843	9.810	.958	8.104	1.160	6.545	1.436	6.550	1.435	5.541	1.696	8.647	1.087
31	3	67	.000	7.600	4.500	1.689	8.558	.888	6.754	1.125	5.950	1.277	5.970	1.273	5.367	1.416	7.982	.952
31	3	68	3.500	8.900	4.500	1.978	8.161	1.091	6.753	1.318	5.524	1.611	5.561	1.600	5.442	1.636	7.832	1.136
MEANS			.700	8.980	5.200	1.743	8.692	1.045	7.280	1.253	5.862	1.554	5.898	1.543	5.474	1.639	7.649	1.186
MEAN ABS. RELATIVE ERROR						.421		.098		.189		.347		.343		.390		.165
31	4	64	40.300	8.100	4.500	1.800	6.963	1.163	5.254	1.542	4.530	1.788	4.588	1.766	5.675	1.427	7.402	1.094
31	4	65	4.100	8.700	4.900	1.776	9.116	.954	7.660	1.136	6.120	1.421	6.157	1.413	5.700	1.526	7.720	1.127
31	4	66	14.800	8.800	4.900	1.796	8.240	1.068	6.270	1.404	5.595	1.573	5.588	1.575	5.764	1.527	8.938	.985
31	4	67	66.200	6.900	4.100	1.683	7.982	.864	6.252	1.104	5.604	1.231	5.631	1.225	5.649	1.221	7.667	.900
31	4	68	72.500	8.200	3.600	2.278	7.458	1.099	5.568	1.473	5.095	1.609	5.135	1.597	5.662	1.448	7.420	1.105
MEANS			39.580	8.140	4.400	1.866	7.952	1.030	6.201	1.331	5.389	1.525	5.420	1.515	5.690	1.430	7.829	1.042
MEAN ABS. RELATIVE ERROR						.459		.097		.238		.338		.334		.301		.083

*LATITUDE = 10.18 DEGREES N. ELEVATION= 430 METERS.

TABLE 12. COMPARISON OF MEASURED AND COMPUTED PAN EVAPORATION FOR SHELL FOUNDATION STATION (VENEZUELA)*.

ST	MO	YEAR	PD	EVP	EVF	CMF	EVC	CMC	EVM	CMM	EVPE	CMPE	EVKO	CMKO	EVBC	BC-K	EVHA	CMHA
31	5	64	95.000	6.800	4.300	1.581	6.588	1.032	5.615	1.211	4.321	1.574	4.385	1.551	5.825	1.167	7.203	.944
31	5	65	135.600	6.800	2.700	2.519	6.284	1.082	5.301	1.283	4.520	1.504	4.577	1.486	5.786	1.175	6.452	1.054
31	5	66	104.200	6.500	1.900	3.421	7.005	.928	5.639	1.153	5.072	1.281	5.104	1.274	5.799	1.121	7.466	.871
31	5	67	76.800	7.000	3.800	1.842	7.638	.916	6.077	1.152	5.494	1.274	5.517	1.269	5.760	1.215	7.770	.901
31	5	68	143.600	5.400	1.900	2.842	5.075	1.064	4.360	1.238	4.216	1.281	4.265	1.266	5.617	.961	5.514	.979
MEANS			111.040	6.500	2.920	2.441	6.518	1.005	5.398	1.207	4.725	1.383	4.770	1.369	5.757	1.128	6.881	.950
MEAN ABS. RELATIVE ERROR						.551		.068		.169		.273		.266		.128		.080
31	6	64	157.800	5.800	2.200	2.636	5.318	1.091	4.487	1.293	4.408	1.316	4.460	1.300	5.619	1.032	5.991	.968
31	6	65	195.700	6.000	1.800	3.333	4.363	1.375	3.857	1.556	3.675	1.633	3.738	1.605	5.579	1.075	4.798	1.251
31	6	66	183.400	5.000	1.800	2.778	4.954	1.009	4.399	1.137	4.282	1.168	4.329	1.155	5.671	.882	5.393	.927
31	6	67	186.800	6.400	2.500	2.560	5.378	1.190	4.668	1.371	4.573	1.399	4.615	1.387	5.671	1.128	6.474	.989
31	6	68	188.500	4.600	1.600	2.875	4.668	.985	4.292	1.072	4.404	1.045	4.448	1.034	5.579	.824	5.029	.915
MEANS			182.440	5.560	1.980	2.836	4.936	1.130	4.341	1.286	4.268	1.312	4.318	1.296	5.624	.988	5.537	1.010
MEAN ABS. RELATIVE ERROR						.644		.117		.219		.232		.223		.107		.082
31	7	64	373.600	6.500	1.600	4.062	4.909	1.324	4.678	1.390	4.527	1.436	4.582	1.419	5.544	1.172	4.065	1.599
31	7	65	77.300	5.700	2.200	2.591	5.912	.964	5.126	1.112	4.691	1.215	4.752	1.200	5.622	1.014	5.584	1.021
31	7	66	208.900	5.200	1.600	3.250	4.285	1.214	4.438	1.172	4.350	1.195	4.398	1.182	5.596	.929	4.677	1.112
31	7	67	150.000	5.700	2.300	2.478	5.391	1.057	4.440	1.284	4.484	1.271	4.538	1.256	5.583	1.021	5.606	1.017
31	7	68	111.600	5.800	2.300	2.522	5.909	.982	4.918	1.179	5.011	1.157	5.054	1.148	5.583	1.039	5.627	1.031
MEANS			184.280	5.780	2.000	2.981	5.281	1.108	4.720	1.227	4.613	1.255	4.665	1.241	5.586	1.035	5.112	1.156
MEAN ABS. RELATIVE ERROR						.654		.108		.183		.202		.193		.061		.116
31	8	64	155.900	6.100	1.700	3.588	5.088	1.199	4.319	1.412	4.896	1.246	4.943	1.234	5.570	1.095	4.118	1.481
31	8	65	196.200	5.700	2.000	2.850	5.868	.971	5.200	1.096	4.907	1.162	4.960	1.149	5.506	1.035	5.326	1.070
31	8	66	190.600	5.200	1.600	3.250	4.939	1.053	4.660	1.116	4.602	1.130	4.647	1.119	5.480	.949	4.808	1.082
31	8	67	64.600	5.600	2.300	2.435	6.384	.877	5.233	1.070	5.119	1.094	5.157	1.086	5.519	1.015	6.089	.920
31	8	68	86.300	5.200	2.200	2.364	5.595	.929	4.848	1.073	4.906	1.060	4.938	1.053	5.544	.938	6.030	.862
MEANS			138.720	5.560	1.960	2.897	5.575	1.006	4.852	1.153	4.886	1.138	4.929	1.128	5.524	1.006	5.274	1.083
MEAN ABS. RELATIVE ERROR						.647		.094		.127		.121		.114		.051		.146

*LATITUDE = 10.18 DEGREES N. ELEVATION= 430 METERS.

TABLE 13. COMPARISON OF MEASURED AND COMPUTED PAN EVAPORATION FOR SHELL FOUNDATION STATION (VENEZUELA)*.

ST	MO	YEAR	PD	EVP	EVF	CMF	EVC	CMC	EVM	CMM	EVPE	CMPE	EVKO	CMKO	EVBC	BC-K	EVHA	CMHA
31	9	64	182.000	5.500	1.500	3.667	4.214	1.305	4.482	1.227	4.506	1.221	4.551	1.208	5.383	1.022	3.460	1.590
31	9	65	164.700	5.500	1.800	3.056	4.761	1.155	4.510	1.219	3.938	1.396	3.990	1.379	5.433	1.012	4.683	1.175
31	9	66	83.600	5.200	1.600	3.250	5.072	1.025	4.645	1.119	4.523	1.150	4.563	1.140	5.408	.962	5.234	.993
31	9	67	174.300	5.600	1.700	3.294	5.033	1.113	4.786	1.170	4.672	1.199	4.712	1.188	5.370	1.043	5.215	1.074
31	9	68	135.200	5.400	1.800	3.000	5.044	1.071	4.606	1.172	4.527	1.193	4.568	1.182	5.370	1.006	5.421	.996
MEANS			147.960	5.440	1.680	3.253	4.825	1.134	4.606	1.182	4.433	1.232	4.477	1.219	5.393	1.009	4.803	1.166
MEAN ABS. RELATIVE ERROR						.691		.113		.153		.185		.177		.024		.121
31	10	64	121.000	5.800	1.800	3.222	5.491	1.056	5.186	1.118	4.956	1.170	5.000	1.160	5.304	1.093	4.238	1.369
31	10	65	137.500	6.000	2.100	2.857	5.424	1.106	5.066	1.184	4.735	1.267	4.774	1.257	5.353	1.121	5.080	1.181
31	10	66	208.600	6.400	1.800	3.556	5.159	1.240	5.142	1.245	4.638	1.380	4.675	1.369	5.280	1.212	5.209	1.229
31	10	67	136.800	6.000	1.600	3.750	4.682	1.281	4.891	1.227	4.345	1.381	4.388	1.367	5.267	1.139	4.928	1.218
31	10	68	134.200	5.600	2.400	2.333	6.086	.920	5.334	1.050	5.118	1.094	5.141	1.089	5.366	1.044	6.041	.927
MEANS			147.620	5.960	1.940	3.148	5.369	1.121	5.124	1.165	4.759	1.258	4.796	1.248	5.314	1.122	5.099	1.185
MEAN ABS. RELATIVE ERROR						.674		.132		.140		.202		.195		.108		.174
31	11	64	34.500	5.800	2.800	2.071	5.902	.983	5.041	1.150	4.700	1.234	4.755	1.220	5.233	1.108	4.753	1.220
31	11	65	126.800	5.300	1.900	2.789	4.815	1.101	4.526	1.171	4.060	1.305	4.109	1.290	5.137	1.032	4.790	1.106
31	11	66	35.000	4.500	1.400	3.214	4.221	1.066	4.166	1.080	3.760	1.197	3.812	1.180	5.125	.878	4.350	1.034
31	11	67	27.800	5.200	2.500	2.080	5.753	.904	5.404	.962	4.601	1.130	4.641	1.120	5.161	1.008	5.750	.904
31	11	68	21.900	5.900	2.900	2.034	6.449	.915	5.876	1.004	5.033	1.172	5.062	1.166	5.197	1.135	6.311	.935
MEANS			49.200	5.340	2.300	2.438	5.428	.994	5.003	1.074	4.431	1.208	4.476	1.195	5.171	1.032	5.191	1.040
MEAN ABS. RELATIVE ERROR						.569		.074		.078		.170		.162		.079		.100
31	12	64	.000	6.000	3.100	1.935	5.933	1.011	5.769	1.040	4.443	1.350	4.521	1.327	4.966	1.208	4.565	1.314
31	12	65	6.300	5.700	2.900	1.966	5.877	.970	5.215	1.093	4.524	1.260	4.578	1.245	5.109	1.116	5.385	1.059
31	12	66	57.200	5.000	2.200	2.273	4.870	1.027	4.663	1.072	4.019	1.244	4.068	1.229	4.990	1.002	5.008	.998
31	12	67	3.600	6.400	3.300	1.939	6.144	1.042	5.466	1.171	4.549	1.407	4.614	1.387	5.074	1.261	5.378	1.190
31	12	67	7.800	6.200	3.900	1.590	6.840	.906	6.090	1.018	5.084	1.220	5.109	1.213	5.121	1.211	6.732	.921
MEANS			14.980	5.860	3.080	1.941	5.933	.991	5.441	1.079	4.524	1.296	4.578	1.280	5.052	1.160	5.414	1.096
MEAN ABS. RELATIVE ERROR						.474		.043		.072		.228		.219		.138		.113

*LATITUDE = 10.18 DEGREES N. ELEVATION= 430 METERS.

MEANS			86.434	6.637	3.080	2.457	6.415	1.066	5.570	1.215	4.963	1.357	5.011	1.344	5.499	1.228	6.039	1.137
MEAN ABS. RELATIVE ERROR						.536		.086		.162		.252		.245		.190		.131

TABLE 14. MEAN MONTHLY VALUES OF EXTRATERRESTRIAL RADIATION

LATITUDE EXPRESSED AS EQUIVALENT EVAPORATION IN MILLIMETERS PER DAY. *

DEG. S.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
0	15.07	15.53	15.71	15.27	14.47	13.97	14.19	14.95	15.61	15.66	15.23	14.90
1	15.23	15.63	15.73	15.20	14.34	13.81	14.04	14.85	15.59	15.73	15.37	15.07
2	15.38	15.72	15.74	15.13	14.20	13.64	13.88	14.75	15.56	15.80	15.51	15.24
3	15.53	15.81	15.75	15.05	14.06	13.47	13.72	14.64	15.53	15.86	15.64	15.40
4	15.67	15.90	15.75	14.96	13.91	13.29	13.56	14.52	15.50	15.91	15.77	15.56
5	15.81	15.98	15.75	14.88	13.76	13.12	13.39	14.41	15.46	15.96	15.89	15.72
6	15.95	16.06	15.75	14.78	13.60	12.94	13.22	14.28	15.42	16.01	16.01	15.87
7	16.08	16.13	15.73	14.69	13.45	12.75	13.05	14.16	15.37	16.05	16.13	16.02
8	16.21	16.20	15.72	14.59	13.28	12.56	12.87	14.03	15.32	16.09	16.24	16.16
9	16.33	16.27	15.70	14.48	13.12	12.37	12.69	13.90	15.26	16.12	16.35	16.30
10	16.45	16.33	15.67	14.37	12.95	12.18	12.51	13.76	15.20	16.15	16.45	16.44
11	16.57	16.38	15.64	14.26	12.78	11.98	12.32	13.62	15.13	16.17	16.55	16.57
12	16.68	16.43	15.61	14.14	12.60	11.78	12.13	13.47	15.06	16.19	16.64	16.70
13	16.78	16.47	15.57	14.02	12.42	11.58	11.94	13.32	14.99	16.20	16.73	16.83
14	16.89	16.51	15.52	13.89	12.24	11.38	11.74	13.17	14.91	16.21	16.81	16.94
15	16.98	16.55	15.48	13.76	12.06	11.17	11.54	13.01	14.82	16.21	16.89	17.06
16	17.08	16.58	15.42	13.62	11.87	10.96	11.34	12.85	14.73	16.21	16.97	17.17
17	17.16	16.61	15.36	13.48	11.68	10.75	11.14	12.69	14.64	16.21	17.04	17.28
18	17.25	16.63	15.30	13.34	11.48	10.53	10.93	12.52	14.54	16.20	17.10	17.38
19	17.33	16.65	15.23	13.20	11.29	10.32	10.72	12.35	14.44	16.18	17.16	17.48
20	17.40	16.66	15.16	13.05	11.09	10.10	10.51	12.17	14.33	16.16	17.22	17.57
21	17.47	16.66	15.08	12.89	10.88	9.88	10.30	11.99	14.22	16.14	17.27	17.66
22	17.54	16.67	15.00	12.73	10.68	9.65	10.08	11.81	14.11	16.11	17.32	17.75
23	17.60	16.66	14.92	12.57	10.47	9.43	9.86	11.63	13.99	16.07	17.36	17.83
24	17.66	16.66	14.83	12.41	10.26	9.20	9.64	11.44	13.86	16.03	17.40	17.90
25	17.71	16.65	14.73	12.24	10.05	8.97	9.42	11.25	13.73	15.99	17.43	17.97

*BASED ON A SOLAR RADIATION CONSTANT OF 2 CAL/CM2/MIN AT THE TOP OF THE ATMOSPHERE.

TABLE 15. COMPARISON OF TM, VPA, HM, PEV, AND OTHER COMPUTED VALUES FOR 12 PERUVIAN STATIONS.

ST	YEAR	MO	ELEV	LAT	LONG	DL	S	TM	TMA	TF	VPA	VPCA	DH	HM	H18	HN	CCA	PD	PEV	RMD	RC	ETPE
1	2860	1	18	-6.70	79.92	12.34	.559	25.1	25.1	77.2	21.4	22.9	1.048	.750	.750	.636	4.2	.039	5.200	16.121	7.744	4.256
1	2860	2	18	-6.70	79.92	12.22	.562	26.4	26.3	79.5	21.8	24.0	.937	.737	.740	.618	4.6	.232	5.200	16.210	7.814	4.511
1	2860	3	18	-6.70	79.92	12.04	.551	26.2	26.1	79.2	17.6	23.9	1.023	.740	.740	.624	4.4	.213	5.000	15.831	7.542	4.331
1	2860	4	18	-6.70	79.92	11.85	.568	24.6	24.5	76.3	16.9	22.6	.974	.760	.760	.654	4.0	.113	4.900	14.780	7.172	3.821
1	2860	5	18	-6.70	79.92	11.70	.526	22.8	22.8	73.0	16.0	21.3	.993	.790	.790	.692	3.9	.035	4.800	13.529	6.272	3.101
1	2860	6	18	-6.70	79.92	11.62	.454	20.9	20.8	69.6	15.1	19.6	.955	.817	.820	.730	4.5	.023	4.000	12.818	5.469	2.530
1	2860	7	18	-6.70	79.92	11.65	.423	19.6	19.7	67.3	14.2	18.4	.990	.823	.830	.739	4.7	.003	3.600	13.093	5.381	2.395
1	2860	8	18	-6.70	79.92	11.78	.483	19.3	19.2	66.7	13.9	17.7	1.001	.810	.810	.722	4.6	.003	3.600	14.188	6.267	2.765
1	2860	9	18	-6.70	79.92	11.96	.501	19.7	19.6	67.5	13.3	17.7	.983	.797	.800	.703	4.3	.017	4.000	15.382	6.937	3.160
1	2860	10	18	-6.70	79.92	12.15	.520	20.2	20.1	68.4	13.0	18.0	1.032	.787	.790	.689	4.4	.026	4.200	16.043	7.392	3.447
1	2860	11	18	-6.70	79.92	12.31	.525	21.2	21.3	70.2	13.7	18.6	1.011	.763	.770	.656	4.0	.027	4.600	16.113	7.462	3.642
1	2860	12	18	-6.70	79.92	12.38	.535	22.8	22.8	73.0	15.1	20.1	1.052	.757	.760	.644	4.0	.055	5.000	16.018	7.502	3.862
1	MEAN ANNUAL VALUES					12.00	.517	22.4	22.4	72.3	16.0	20.4	1.000	.777	.780	.676	4.3	.066	4.508	15.010	6.913	3.485
2	4448	1	31	-6.78	79.83	12.35	.658	23.6	23.5	74.5	.0	18.8	1.049	.683	.690	.561	4.7	.016	6.000	16.109	8.576	4.495
2	4448	2	31	-6.78	79.83	12.22	.611	25.4	25.3	77.7	.0	21.7	.937	.707	.710	.587	5.0	.071	5.200	16.201	8.229	4.584
2	4448	3	31	-6.78	79.83	12.04	.666	25.2	25.1	77.4	.0	20.4	1.023	.683	.690	.552	4.3	.045	4.900	15.815	8.484	4.663
2	4448	4	31	-6.78	79.83	11.85	.730	24.4	24.3	75.9	.0	21.1	.974	.737	.740	.609	4.3	.077	4.000	14.769	8.409	4.290
2	4448	5	31	-6.78	79.83	11.69	.727	22.6	22.5	72.7	.0	20.6	.993	.787	.790	.683	4.3	.006	3.268	13.513	7.674	3.520
2	4448	6	31	-6.78	79.83	11.61	.626	20.6	20.6	69.1	.0	18.9	.955	.807	.810	.709	4.0	.010	2.900	12.799	6.598	2.829
2	4448	7	31	-6.78	79.83	11.65	.534	19.3	19.3	66.7	.0	17.7	.989	.817	.830	.726	4.7	.010	2.300	13.075	6.122	2.592
2	4448	8	31	-6.78	79.83	11.78	.597	19.0	19.0	66.2	.0	17.7	1.001	.827	.840	.741	4.0	.006	2.700	14.173	7.097	2.913
2	4448	9	31	-6.78	79.83	11.96	.653	19.4	19.4	66.9	.0	18.3	.983	.833	.850	.747	4.7	.013	2.900	15.373	8.141	3.387
2	4448	10	31	-6.78	79.83	12.15	.687	19.9	19.8	67.8	.0	17.2	1.032	.770	.780	.667	4.0	.013	3.600	16.042	8.780	3.873
2	4448	11	31	-6.78	79.83	12.31	.730	20.3	20.3	68.5	.0	17.0	1.012	.743	.770	.640	4.0	.057	3.700	16.109	9.167	4.101
2	4448	12	31	-6.78	79.83	12.39	.749	22.2	22.2	72.0	.0	18.7	1.052	.730	.730	.616	4.0	.055	4.800	16.021	9.274	4.411
2	MEAN ANNUAL VALUES					12.00	.664	21.8	21.8	71.3	.0	19.0	1.000	.760	.769	.653	4.3	.032	3.856	15.000	8.046	3.805
3	4460	1	51	-7.90	79.22	12.41	.548	23.0	22.9	73.4	.0	20.4	1.054	.757	.760	.653	5.0	.042	5.400	16.244	7.742	3.974
3	4460	2	51	-7.90	79.22	12.26	.532	24.1	24.1	75.4	.0	21.9	.940	.757	.760	.650	5.1	.096	5.200	16.258	7.611	4.059
3	4460	3	51	-7.90	79.22	12.05	.562	23.8	23.8	74.8	.0	21.7	1.023	.760	.760	.657	5.2	.045	5.200	15.777	7.632	3.963
3	4460	4	51	-7.90	79.22	11.83	.562	22.0	22.0	71.6	.0	19.8	.972	.770	.770	.671	4.5	.040	5.200	14.623	7.072	3.414
3	4460	5	51	-7.90	79.22	11.64	.593	21.0	21.0	69.8	.0	18.7	.989	.770	.770	.674	4.3	.006	4.600	13.313	6.650	3.016
3	4460	6	51	-7.90	79.22	11.55	.416	19.2	19.2	66.6	.0	17.3	.949	.797	.800	.709	5.0	.013	3.500	12.573	5.138	2.314
3	4460	7	51	-7.90	79.22	11.59	.374	18.3	18.3	64.9	.0	16.5	.984	.800	.800	.716	5.1	.010	3.300	12.866	4.974	2.222
3	4460	8	51	-7.90	79.22	11.74	.377	18.0	18.0	64.4	.0	16.3	.998	.807	.810	.724	5.0	.003	3.400	14.016	5.443	2.418
3	4460	9	51	-7.90	79.22	11.96	.424	17.9	17.8	64.2	.0	16.0	.983	.800	.800	.716	5.0	.007	3.500	15.294	6.313	2.787
3	4460	10	51	-7.90	79.22	12.18	.480	18.2	18.1	64.8	.0	16.1	1.034	.793	.800	.703	5.1	.042	4.000	16.058	7.088	3.126
3	4460	11	51	-7.90	79.22	12.36	.563	19.0	19.0	66.2	.0	16.6	1.016	.777	.780	.680	4.3	.013	4.600	16.213	7.854	3.482
3	4460	12	51	-7.90	79.22	12.45	.579	20.7	20.4	69.3	.0	18.1	1.057	.777	.780	.680	4.2	.023	5.000	16.161	7.963	3.727
3	MEAN ANNUAL VALUES					12.00	.501	20.4	20.4	68.8	.0	18.3	1.000	.780	.782	.686	4.8	.028	4.408	14.950	6.790	3.208

TABLE 16. COMPARISON OF TM, VPA, HM, PEV, AND OTHER COMPUTED VALUES FOR 12 PERUVIAN STATIONS.

ST	YEAR	MO	ELEV	LAT	LONG	DL	S	TM	TMA	TF	VPA	VPCA	DH	HM	H18	HN	CCA	PD	PEV	RMD	RC	ETPE
4	3860	1	15	-10.67	77.82	12.55	.594	21.2	21.2	70.2	.0	20.9	1.066	.843	.840	.770	5.0	.019	3.339	16.548	8.246	3.718
4	3860	2	15	-10.67	77.82	12.35	.599	22.1	22.1	71.8	.0	22.2	.947	.850	.850	.779	5.0	.014	3.364	16.394	8.212	3.790
4	3860	3	15	-10.67	77.82	12.07	.599	21.8	21.8	71.2	.0	22.1	1.025	.857	.860	.788	5.0	.000	3.152	15.680	7.854	3.537
4	3860	4	15	-10.67	77.82	11.77	.555	20.4	20.4	68.7	.0	20.4	.967	.867	.870	.803	6.0	.007	2.763	14.300	6.843	2.889
4	3860	5	15	-10.67	77.82	11.52	.345	18.4	18.4	65.1	.0	18.4	.978	.880	.880	.822	6.0	.016	2.277	12.817	4.746	1.944
4	3860	6	15	-10.67	77.82	11.39	.199	17.3	17.3	63.1	.0	16.9	.936	.870	.870	.810	6.0	.023	2.260	12.019	3.553	1.568
4	3860	7	15	-10.67	77.82	11.44	.192	16.8	16.7	62.2	.0	16.5	.972	.880	.880	.822	6.0	.035	1.942	12.344	3.602	1.556
4	3860	8	15	-10.67	77.82	11.65	.188	16.1	16.1	61.0	.0	16.0	.990	.883	.880	.829	7.0	.094	1.935	13.613	3.948	1.657
4	3860	9	15	-10.67	77.82	11.94	.265	16.1	16.1	61.0	.0	16.0	.982	.887	.890	.831	6.0	.080	1.930	15.101	4.976	2.025
4	3860	10	15	-10.67	77.82	12.24	.356	16.8	16.8	62.2	.0	16.2	1.040	.860	.860	.794	6.0	.026	2.339	16.116	6.061	2.519
4	3860	11	15	-10.67	77.82	12.49	.416	18.1	18.0	64.6	.0	17.2	1.027	.843	.840	.773	5.0	.010	2.723	16.484	6.712	2.895
4	3860	12	15	-10.67	77.82	12.61	.527	19.5	19.5	67.1	.0	18.9	1.071	.847	.850	.776	5.0	.006	3.016	16.522	7.666	3.323
4	MEAN ANNUAL VALUES					12.00	.403	18.7	18.7	65.7	.0	18.5	1.000	.864	.864	.800	5.7	.028	2.587	14.828	6.035	2.619
5	5460	1	5	-8.53	78.95	12.44	.450	21.2	21.1	70.2	.0	21.0	1.056	.857	.860	.788	5.4	.019	.800	16.295	6.910	3.227
5	5460	2	5	-8.53	78.95	12.28	.521	23.4	23.4	74.1	.0	24.3	.942	.860	.860	.794	5.5	.018	1.000	16.289	7.505	3.662
5	5460	3	5	-8.53	78.95	12.05	.490	22.8	22.8	73.0	.0	23.4	1.024	.857	.860	.791	5.6	.042	1.100	15.750	7.000	3.361
5	5460	4	5	-8.53	78.95	11.81	.591	21.2	21.2	70.2	.0	21.4	.971	.867	.870	.803	4.6	.003	1.100	14.546	7.223	3.128
5	5460	5	5	-8.53	78.95	11.61	.568	20.2	20.1	68.4	.0	20.0	.986	.860	.860	.794	4.6	.006	1.000	13.199	6.398	2.640
5	5460	6	5	-8.53	78.95	11.51	.467	20.2	20.2	68.4	.0	19.4	.946	.837	.840	.761	5.2	.000	1.100	12.465	5.395	2.342
5	5460	7	5	-8.53	78.95	11.56	.348	19.5	19.5	67.1	.0	18.5	.981	.837	.840	.758	5.4	.013	1.000	12.767	4.746	2.167
5	5460	8	5	-8.53	78.95	11.72	.312	18.7	18.7	65.7	.0	17.6	.996	.837	.840	.758	5.7	.000	.900	13.941	4.927	2.262
5	5460	9	5	-8.53	78.95	11.95	.392	17.5	17.5	63.5	.0	16.6	.983	.847	.850	.773	5.6	.003	.900	15.253	6.012	2.542
5	5460	10	5	-8.53	78.95	12.19	.424	18.0	18.5	64.4	.0	17.9	1.036	.853	.850	.786	5.6	.019	.900	16.076	6.606	2.720
5	5460	11	5	-8.53	78.95	12.39	.519	18.7	18.6	65.7	.0	17.6	1.018	.837	.840	.761	4.7	.000	1.000	16.277	7.476	3.202
5	5460	12	5	-8.53	78.95	12.49	.469	19.9	19.9	67.8	.0	19.7	1.061	.860	.860	.794	5.0	.006	1.000	16.236	7.045	3.107
5	MEAN ANNUAL VALUES					12.00	.463	20.1	20.1	68.2	.0	19.8	1.000	.851	.852	.780	5.2	.011	.983	14.925	6.437	2.863
6	4960	1	3207	-9.53	77.52	12.49	.604	13.9	13.9	57.0	.0	8.4	1.061	.620	.610	.447	6.8	3.903	2.471	16.304	10.852	3.544
6	4960	2	3207	-9.53	77.52	12.31	.582	13.8	13.8	56.8	.0	8.9	.944	.640	.620	.475	7.2	4.589	2.496	16.204	10.546	3.401
6	4960	3	3207	-9.53	77.52	12.06	.668	13.9	13.9	57.0	.0	8.4	1.024	.613	.610	.447	6.7	4.419	2.681	15.596	11.062	3.470
6	4960	4	3207	-9.53	77.52	11.79	.782	14.1	14.1	57.4	.0	8.1	.969	.600	.600	.427	5.7	2.643	2.703	14.342	11.280	3.350
6	4960	5	3207	-9.53	77.52	11.57	.898	13.8	12.9	56.8	.0	6.6	.982	.553	.550	.375	4.2	.774	3.258	12.954	11.209	3.134
6	4960	6	3207	-9.53	77.52	11.45	.934	13.2	13.2	55.8	4.1	6.0	.941	.527	.530	.346	3.2	.097	3.247	12.193	10.850	2.886
6	4960	7	3207	-9.53	77.52	11.50	.946	12.6	12.6	54.7	4.0	5.1	.977	.473	.480	.302	3.0	.003	4.403	12.504	11.226	2.984
6	4960	8	3207	-9.53	77.52	11.69	.926	13.4	13.3	56.1	3.8	5.1	.993	.447	.450	.281	2.7	.100	4.829	13.737	12.146	3.461
6	4960	9	3207	-9.53	77.52	11.95	.817	14.5	14.5	58.1	5.8	6.2	.982	.493	.490	.320	4.0	.837	3.513	15.151	12.282	3.856
6	4960	10	3207	-9.53	77.52	12.22	.707	14.2	14.1	57.6	6.6	6.3	1.038	.500	.500	.327	5.7	1.845	2.758	16.049	11.807	3.918
6	4960	11	3207	-9.53	77.52	12.44	.638	13.8	13.9	56.8	5.5	7.1	1.022	.540	.540	.374	6.0	3.050	3.767	16.306	11.230	3.734
6	4960	12	3207	-9.53	77.52	12.55	.642	14.1	14.1	57.4	6.4	7.5	1.066	.570	.570	.396	6.4	2.229	3.142	16.288	11.261	3.739
6	MEAN ANNUAL VALUES					12.00	.762	13.8	13.7	56.8	3.0	7.8	1.000	.548	.546	.376	5.1	2.041	3.272	14.802	11.313	3.457

TABLE 17. COMPARISON OF TM, VPA, HM, PEV, AND OTHER COMPUTED VALUES FOR 12 PERUVIAN STATIONS.

ST	YEAR	MO	ELEV	LAT	LONG	DL	S	TM	TMA	TF	VPA	VPCA	DH	HM	H18	HN	CCA	PD	PEV	RMD	RC	ETPE
7	5556	1	1800	-9.97	76.25	12.51	.382	20.3	20.2	68.5	15.3	16.2	1.063	.710	.690	.589	7.0	2.310	3.161	16.453	7.561	3.415
7	5556	2	1800	-9.97	76.25	12.32	.380	20.1	20.0	68.2	15.1	15.9	.945	.710	.690	.586	6.3	1.321	3.179	16.325	7.484	3.374
7	5556	3	1800	-9.97	76.25	12.06	.402	19.6	19.6	67.3	10.4	14.2	1.025	.663	.640	.527	7.0	2.368	2.245	15.668	7.397	3.379
7	5556	4	1800	-9.97	76.25	11.78	.481	19.9	19.9	67.8	10.3	14.3	.968	.660	.630	.522	7.0	1.057	2.447	14.372	7.473	3.292
7	5556	5	1800	-9.97	76.25	11.55	.630	19.7	19.7	67.5	9.6	13.1	.981	.627	.600	.477	6.3	.139	2.900	12.952	7.899	3.236
7	5556	6	1800	-9.97	76.25	11.43	.290	18.5	18.5	65.3	8.8	12.0	.939	.617	.580	.471	7.0	.067	2.813	12.169	4.917	2.618
7	5556	7	1800	-9.97	76.25	11.48	.548	18.5	18.5	65.3	8.6	11.9	.975	.613	.580	.465	5.0	.148	3.158	12.494	7.002	2.940
7	5556	8	1800	-9.97	76.25	11.68	.610	18.8	18.8	65.8	8.6	11.9	.992	.603	.570	.454	5.3	.074	3.332	13.747	8.223	3.377
7	5556	9	1800	-9.97	76.25	11.95	.456	19.9	19.9	67.8	9.5	13.3	.982	.617	.590	.476	6.3	.273	3.060	15.200	7.674	3.542
7	5556	10	1800	-9.97	76.25	12.23	.554	20.5	20.5	68.9	10.0	13.6	1.038	.613	.590	.470	5.7	.732	3.148	16.155	9.110	4.048
7	5556	11	1800	-9.97	76.25	12.46	.421	20.2	20.2	68.4	10.4	14.3	1.024	.640	.610	.509	6.3	2.183	2.723	16.448	7.947	3.687
7	5556	12	1800	-9.97	76.25	12.57	.371	20.2	20.2	68.4	10.7	15.0	1.068	.660	.630	.534	6.7	1.045	2.448	16.440	7.452	3.502
7	MEAN ANNUAL VALUES					12.00	.461	19.7	19.7	67.4	10.6	13.8	1.000	.644	.617	.507	6.3	.976	2.885	14.869	7.512	3.367
8	5556	1	3820	-15.82	70.00	12.83	.669	10.9	10.9	51.6	8.0	7.6	1.090	.587	.600	.488	4.3	1.052	4.358	16.914	12.569	3.363
8	5556	2	3820	-15.82	70.00	12.52	.538	10.6	10.6	51.1	9.1	9.1	.961	.713	.720	.625	6.0	2.754	3.629	16.430	10.675	2.745
8	5556	3	3820	-15.82	70.00	12.10	.512	8.9	8.9	48.0	4.9	6.7	1.028	.587	.570	.482	5.0	3.339	2.881	15.273	9.650	2.602
8	5556	4	3820	-15.82	70.00	11.65	.748	8.8	8.8	47.8	4.8	6.3	.957	.563	.550	.455	4.0	.717	3.827	13.506	10.793	2.500
8	5556	5	3820	-15.82	70.00	11.27	.753	8.0	8.0	46.4	3.3	3.9	.957	.380	.390	.277	3.0	.026	3.161	11.770	9.451	2.340
8	5556	6	3820	-15.82	70.00	11.08	.920	5.6	5.6	42.1	2.9	3.8	.911	.427	.400	.319	1.0	.000	2.973	10.853	10.002	1.884
8	5556	7	3820	-15.82	70.00	11.16	.825	6.4	6.4	43.5	2.9	3.9	.948	.403	.390	.306	2.7	.019	4.745	11.235	9.597	2.043
8	5556	8	3820	-15.82	70.00	11.48	.874	6.8	6.8	44.2	3.9	4.7	.975	.477	.490	.373	1.3	.229	4.271	12.722	11.311	2.352
8	5556	9	3820	-15.82	70.00	11.91	.750	8.4	8.4	47.1	3.5	4.2	.979	.397	.410	.293	3.7	1.073	4.677	14.590	11.680	3.020
8	5556	10	3820	-15.82	70.00	12.36	.819	9.9	9.9	49.8	4.5	5.1	1.050	.430	.450	.326	2.7	.452	4.600	16.062	13.644	3.550
8	5556	11	3820	-15.82	70.00	12.74	.711	10.2	10.1	50.4	4.7	5.7	1.047	.463	.480	.366	4.3	1.590	5.327	16.797	12.987	3.557
8	5556	12	3820	-15.82	70.00	12.92	.544	10.2	10.1	50.4	5.5	6.9	1.098	.563	.580	.461	5.7	5.619	3.313	16.994	11.118	3.166
8	MEAN ANNUAL VALUES					12.00	.722	8.7	8.7	47.7	4.8	5.7	1.000	.499	.502	.397	3.6	1.406	3.980	14.429	11.123	2.760
9	5556	1	3400	-13.57	71.88	12.71	.487	13.1	13.1	55.6	10.9	10.5	1.079	.713	.720	.598	7.0	2.526	3.161	16.734	9.954	2.975
9	5556	2	3400	-13.57	71.88	12.44	.391	13.3	13.3	55.9	11.5	11.0	.955	.743	.760	.635	7.7	6.114	2.568	16.394	8.674	2.687
9	5556	3	3400	-13.57	71.88	12.09	.451	11.8	11.8	53.2	8.4	11.1	1.027	.797	.780	.711	6.7	2.890	2.703	15.426	8.792	2.298
9	5556	4	3400	-13.57	71.89	11.70	.583	11.2	11.2	52.2	6.6	8.5	.962	.680	.660	.543	6.0	1.770	2.840	13.830	9.146	2.467
9	5556	5	3400	-13.57	71.89	11.38	.689	9.6	9.6	49.3	4.8	6.1	.966	.587	.540	.428	3.7	.187	2.890	12.202	8.954	2.307
9	5556	6	3400	-13.57	71.88	11.22	.815	8.1	8.2	46.6	3.6	4.7	.922	.510	.460	.354	1.7	.000	2.947	11.340	9.313	2.150
9	5556	7	3400	-13.57	71.88	11.28	.656	8.3	8.3	46.9	6.5	8.4	.958	.697	.680	.596	3.7	.013	4.000	11.697	8.323	1.599
9	5556	8	3400	-13.57	71.88	11.56	.641	9.6	9.6	49.3	4.5	5.3	.981	.547	.520	.378	3.7	.000	4.574	13.106	9.187	2.608
9	5556	9	3400	-13.57	71.88	11.93	.502	11.2	11.1	52.2	5.7	7.0	.980	.577	.560	.435	5.3	1.020	3.813	14.819	8.966	2.817
9	5556	10	3400	-13.57	71.88	12.31	.567	13.4	13.3	56.1	6.1	7.8	1.046	.547	.530	.410	5.7	1.881	4.113	16.108	10.474	3.430
9	5556	11	3400	-13.57	71.88	12.63	.520	13.5	13.5	56.3	6.9	8.8	1.038	.590	.580	.466	6.3	1.367	4.187	16.673	10.299	3.347
9	5556	12	3400	-13.57	71.88	12.79	.337	13.3	13.2	55.9	7.4	9.5	1.086	.643	.640	.527	7.7	4.184	2.868	16.788	8.256	2.893
9	MEAN ANNUAL VALUES					12.00	.553	11.4	11.4	52.5	6.9	8.2	1.000	.636	.619	.507	5.4	1.829	3.389	14.593	9.195	2.632

TABLE 18. COMPARISON OF TM, VPA, HM, PEV, AND OTHER COMPUTED VALUES FOR 12 PERUVIAN STATIONS.

ST	YEAR	MO	ELEV	LAT	LONG	DL	S	TM	TMA	TF	VPA	VPCA	DH	HM	H18	HN	CCA	PD	PEV	RMD	RC	ETPE
10	5556	1	356	-6.48	76.43	12.33	.414	27.4	27.3	81.3	25.2	27.0	1.047	.767	.750	.658	8.0	3.297	1.810	16.127	6.771	4.016
10	5556	2	356	-6.48	76.43	12.21	.414	27.3	27.2	81.1	24.5	25.5	.937	.743	.730	.620	8.0	2.182	2.093	16.208	6.808	4.126
10	5556	3	356	-6.48	76.43	12.04	.339	27.3	27.3	81.1	18.0	25.3	1.023	.720	.690	.604	5.7	1.390	1.942	15.850	6.024	3.815
10	5556	4	356	-6.48	76.43	11.86	.386	27.2	27.2	81.0	18.5	26.0	.975	.747	.730	.632	6.0	3.780	1.910	14.837	6.009	3.667
10	5556	5	356	-6.48	76.43	11.71	.290	27.0	27.0	80.6	19.1	26.2	.994	.763	.760	.651	5.0	3.413	1.361	13.617	4.822	3.080
10	5556	6	356	-6.48	76.43	11.63	.319	26.1	26.0	79.0	18.8	25.1	.956	.777	.780	.668	5.7	3.087	1.387	12.921	4.771	2.903
10	5556	7	356	-6.48	76.43	11.66	.471	26.4	26.4	79.5	18.0	24.2	.991	.740	.730	.616	4.0	3.713	2.226	13.216	5.951	3.462
10	5556	8	356	-6.48	76.43	11.79	.590	26.1	26.1	79.0	17.9	24.7	1.001	.747	.720	.636	5.0	1.348	2.832	14.306	7.343	3.943
10	5556	9	356	-6.48	76.43	11.97	.373	26.5	26.5	79.7	18.6	24.9	.983	.753	.750	.636	7.3	4.220	2.200	15.491	6.169	3.695
10	5556	10	356	-6.48	76.43	12.15	.416	27.5	27.5	81.5	19.5	26.7	1.032	.760	.750	.643	6.0	2.987	1.865	16.145	6.796	4.078
10	5556	11	356	-6.48	76.43	12.30	.311	26.9	26.9	80.4	19.2	26.8	1.011	.777	.760	.673	7.0	2.877	1.400	16.175	5.904	3.570
10	5556	12	356	-6.48	76.43	12.37	.393	27.6	27.6	81.7	18.0	25.0	1.051	.710	.680	.584	7.3	4.155	2.658	16.059	6.562	4.127
10	MEAN ANNUAL VALUES					12.00	.393	26.9	26.9	80.5	19.6	25.6	1.000	.750	.736	.635	6.2	3.037	1.974	15.079	6.161	3.707
11	3560	1	150	-7.07	79.57	12.36	.660	24.8	24.7	76.6	.0	21.1	1.050	.733	.740	.597	3.9	.077	6.500	16.164	8.726	4.62
11	3560	2	150	-7.07	79.57	12.23	.639	25.9	25.9	78.6	.0	22.1	.938	.720	.720	.580	4.1	.271	6.500	16.228	8.579	4.75
11	3560	3	150	-7.07	79.57	12.04	.665	26.1	26.0	79.0	.0	22.2	1.023	.717	.720	.577	4.2	.303	6.600	15.825	8.578	4.75
11	3560	4	150	-7.07	79.57	11.85	.667	24.6	24.5	76.3	.0	21.3	.974	.740	.740	.609	4.2	.153	6.500	14.743	8.012	4.15
11	3560	5	150	-7.07	79.57	11.68	.675	22.5	22.5	72.5	.0	20.4	.992	.777	.780	.662	3.9	.061	5.700	13.467	7.372	3.39
11	3560	6	150	-7.07	79.57	11.60	.583	20.4	20.4	68.7	.0	19.1	.953	.817	.820	.718	4.3	.013	4.800	12.744	6.364	2.67
11	3560	7	150	-7.07	79.57	11.63	.540	19.3	19.2	66.7	.0	17.9	.988	.820	.820	.722	4.6	.006	4.800	13.026	6.216	2.56
11	3560	8	150	-7.07	79.57	11.77	.583	19.0	19.0	66.2	.0	16.8	1.000	.797	.800	.685	4.5	.010	4.800	14.137	7.061	2.97
11	3560	9	150	-7.07	79.57	11.96	.638	19.6	19.7	67.3	.0	16.7	.983	.770	.770	.647	3.6	.033	5.400	15.362	8.114	3.55
11	3560	10	150	-7.07	79.57	12.16	.660	20.1	20.2	68.2	.0	16.7	1.033	.757	.760	.626	3.6	.052	5.700	16.056	8.661	3.90
11	3560	11	150	-7.07	79.57	12.32	.684	21.0	21.0	69.8	.0	17.8	1.013	.753	.750	.627	3.5	.060	5.900	16.151	8.921	4.09
11	3560	12	150	-7.07	79.57	12.40	.707	22.7	22.7	72.9	.0	18.9	1.053	.737	.740	.603	3.5	.090	6.310	16.071	9.068	4.41
11	MEAN ANNUAL VALUES					12.00	.642	22.2	22.2	71.9	.0	19.3	1.000	.761	.763	.638	4.0	.094	5.792	14.998	7.973	3.82
12	4360	1	7	-3.67	80.65	12.19	.463	26.6	26.7	79.9	.0	24.9	1.035	.727	.730	.634	5.7	.565	6.000	15.725	6.776	4.05
12	4360	2	7	-3.67	80.65	12.12	.438	26.9	27.0	80.4	.0	26.4	.930	.757	.760	.665	5.5	1.993	5.500	15.976	6.675	3.98
12	4360	3	7	-3.67	80.65	12.02	.514	27.1	27.1	80.8	.0	26.2	1.021	.747	.750	.657	5.0	1.058	5.900	15.858	7.249	4.27
12	4360	4	7	-3.67	80.65	11.92	.527	26.1	26.3	79.0	.0	25.1	.980	.753	.760	.659	4.5	.567	5.800	15.078	6.988	3.94
12	4360	5	7	-3.67	80.65	11.84	.512	25.6	25.7	78.1	.0	24.8	1.005	.760	.760	.678	4.8	.013	6.100	14.032	6.401	3.53
12	4360	6	7	-3.67	80.65	11.79	.410	24.2	23.8	75.6	.0	22.8	.969	.777	.760	.703	5.0	.017	4.700	13.406	5.410	2.99
12	4360	7	7	-3.67	80.65	11.81	.332	23.0	23.6	73.4	.0	23.6	1.003	.810	.790	.742	5.5	.032	5.100	13.650	4.962	2.51
12	4360	8	7	-3.67	80.65	11.88	.297	22.7	22.8	72.9	.0	22.8	1.009	.820	.800	.754	5.5	.016	4.900	14.599	5.043	2.63
12	4360	9	7	-3.67	80.65	11.98	.407	22.7	22.8	72.9	.0	22.7	.985	.823	.820	.758	6.2	.007	4.700	15.552	6.254	3.12
12	4360	10	7	-3.67	80.65	12.08	.387	23.3	23.5	73.9	.0	22.6	1.026	.790	.790	.716	5.0	.006	5.500	15.943	6.248	3.30
12	4360	11	7	-3.67	80.65	12.17	.542	23.4	23.7	74.1	.0	22.1	1.000	.770	.770	.686	4.8	.027	6.100	15.779	7.441	3.78
12	4360	12	7	-3.67	80.65	12.21	.585	25.1	25.3	77.2	.0	24.3	1.037	.763	.760	.681	4.3	.029	6.400	15.584	7.688	4.08
12	MEAN ANNUAL VALUES					12.00	.451	24.7	24.9	76.5	.0	24.0	1.000	.775	.771	.694	5.1	.361	5.558	15.099	6.428	3.52

DATA CARDS IGNORED - FIRST IS LISTED BELOW

VITA

Fernando Chanduvi-Acuña

Candidate for the Degree of

Master of Science

Thesis: Study of Evaporation and Evapotranspiration in Perú

Major Field: Irrigation and Drainage Engineering

Biographical Information:

Personal Data: Born at Lima, Perú, August 28, 1939, son of Apolinario Chanduví and Petronila Acuña; married Hilda Coronado, September 10, 1966; two children, Walter and Beatriz.

Education: Attended elementary school in Lima, Perú; attended secondary education at the Gran Unidad Escolar "Ricardo Palma," Lima, Perú; received the Agricultural Engineering degree from Universidad Agraria "La Molina" in December 1964; completed requirements for the Master of Science degree, majoring in Irrigation and Drainage at Utah State University, July 1969.

Professional Experience: 1964, made the topographical survey for the new campus of the Agrarian University "La Molina," Lima, Perú; 1965-67, worked as part of the Irrigation Department staff in the Agricultural Engineering Faculty, Agrarian University Lima, Perú and half of this time was spent on a drainage investigation in Piura Valley, Perú; 1968, spent three months in California attending the "Salinity and Soil Reclamation" course taught at the Salinity Laboratory in Riverside, California, and made some trips to Imperial and Coachella Valley.