Micrometeorological Measurements at Ash Meadows and Corn Creek Springs, Nye and Clark Counties, Nevada, 1986-87

By Michael J. Johnson

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	*By*	*To obtain*
acre-foot (acre-ft)	1,233	cubic meter
foot (ft)	0.3048	meter
inch (in)	25.4	millimeter
mile (mi)	1.609	kilometer
mile per hour (mi/h)	1.609	kilometer per hour

Note: The metric system is used in U.S. Geological Survey reports for evapotranspiration units of measure.

For temperature, degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the formula °F = [(1.8)(°C)] + 32. Degrees Fahrenheit can be converted to degrees Celsius by using the formula °C = 0.556 (°F - 32). Degrees Kelvin (°K) can be converted to degrees Fahrenheit by using the formula °F = [(°K - 273.15)(1.8)] + 32.

SEA LEVEL

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of both the United States and Canada.

DEFINITIONS OF SYMBOLS USED IN THIS REPORT

C_p	Specific heat of air, in joules per gram per degree Celsius
d	Zero-plane displacement, in meters
E	Quantity of water evaporated (water-vapor flux density), in grams per square meter per second
$f(u)$	Empirical wind function for the Penman equation, in joule-meters per gram per second
G	Soil-heat flux, in watts per square meter
H	Sensible-heat flux, in watts per square meter
h	Average crop height, in meters
K	Von Karman constant equal to 0.4, dimensionless
p_a	Density of air, in grams per cubic meter
p_s	Saturated water-vapor pressure, in kilopascals
Q	Specific humidity, unitless
RH	Relative humidity
R_{n}	Net radiation, in watts per square meter
r_{H}	Sensible-heat transport resistance, in seconds per meter
r_v	Vapor-transport resistance, in seconds per meter
S	Slope of the saturated vapor-density function, in grams per cubic meter per degree Celsius
T	Temperature of air, in degrees Celsius
T_c	Temperature, in degrees Celsius
T_k	Temperature, in kelvin
$\overline{u}$	Mean windspeed at height Z, in meters per second
V	Vapor density of air, in grams per cubic meter
W	Vertical wind velocity, in meters per second
Z	Height of measurements above soil surface, in meters
Z_h	Roughness parameter for heat, equal to 0.2 Z_m, in meters
Z_m	Roughness parameter for momentum, equal to 0.13 h (where h is average crop-canopy height), in meters
γ	Thermodynamic psychrometer constant, in grams per cubic meter per degree Celsius
γ^*	Apparent psychrometer constant
λ	Latent heat of vaporization, equal to 2,450 joules per gram at 20°C
λE	Latent-heat flux, in watts per square meter
λE_p	Potential latent-heat flux, in watts per square meter
ρ_v	Water-vapor density, in grams per cubic meter
ρ_{v_s}	Saturated water-vapor density at existing temperature, in grams per cubic meter
$'$	Instantaneous deviation from the mean

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ABSTRACT

Micrometeorological data were collected at Ash Meadows and Corn Creek Springs, Nye and Clark Counties, Nevada, from October 1, 1986, through September 30, 1987. The data include accumulated measurements recorded hourly or every 30 minutes, at each site, for the following climatic variables: air temperature, windspeed and direction, relative humidity, precipitation, solar radiation, net radiation, and soil-heat flux. Periodic sampling of sensible-heat flux and latent-heat flux were also recorded using 5-minute intervals of accumulated data. Evapotranspiration was calculated by both the eddy-correlation method and the Penman-combination method. Documentation includes files containing field data, processed data tables, and the computer programs used to process the data. The files, in American International Standard Code for Information Interchange (ASCII), are compressed and stored on three 3.5-inch diskettes. The decompressed files require approximately 15 megabytes of disk space on an IBM-compatible microcomputer using the MS-DOS operating system.

INTRODUCTION

In 1985, the U.S. Geological Survey began an intensive study of the carbonate-rock aquifer systems of eastern and southern Nevada, in cooperation with the State of Nevada, other federal agencies, and the Las Vegas Valley Water District, to better understand these large, regional aquifers and to explore their potential for water supply. The carbonate-rock aquifer study includes a general evaluation of the effects of both short- and long-term development on discharge from the carbonate aquifers (fig. 1). Discharge processes include subsurface flow from one topographic basin to another, spring discharge, and evapotranspiration (*ET*). Because a major source of natural ground-water loss in arid regions is by evapotranspiration from both spring discharge and shallow ground water through bare soil and plants, part of the carbonate-aquifer study includes an investigation of the mechanisms and rates of *ET* discharge. This part of the carbonate-aquifer study to evaluate *ET* was a cooperative effort between the Geological Survey and the State of Nevada.

The accuracy with which *ET* discharge can be determined, directly affects the validity of water budgets prepared for the region and will help to identify the effects that discharge from the carbonate aquifers has on the natural environment. Although discharge from carbonate aquifers that surfaces at springs can be measured directly, shallow ground water from carbonate aquifers that evaporates in lower parts of the topographic basin or adjacent to areas with springs is more difficult to evaluate and to separate from *ET* derived from noncarbonate water sources. These noncarbonate sources can include ground water from basin-fill deposits, soil moisture derived from overland flow or local precipitation, and water, stored in the vegetation or soil, derived from the absorption of water vapor present in the air. A limited *ET* study was made in southern Nevada and data were collected to obtain initial *ET* rates for evaluating the discharge component of the water budget.

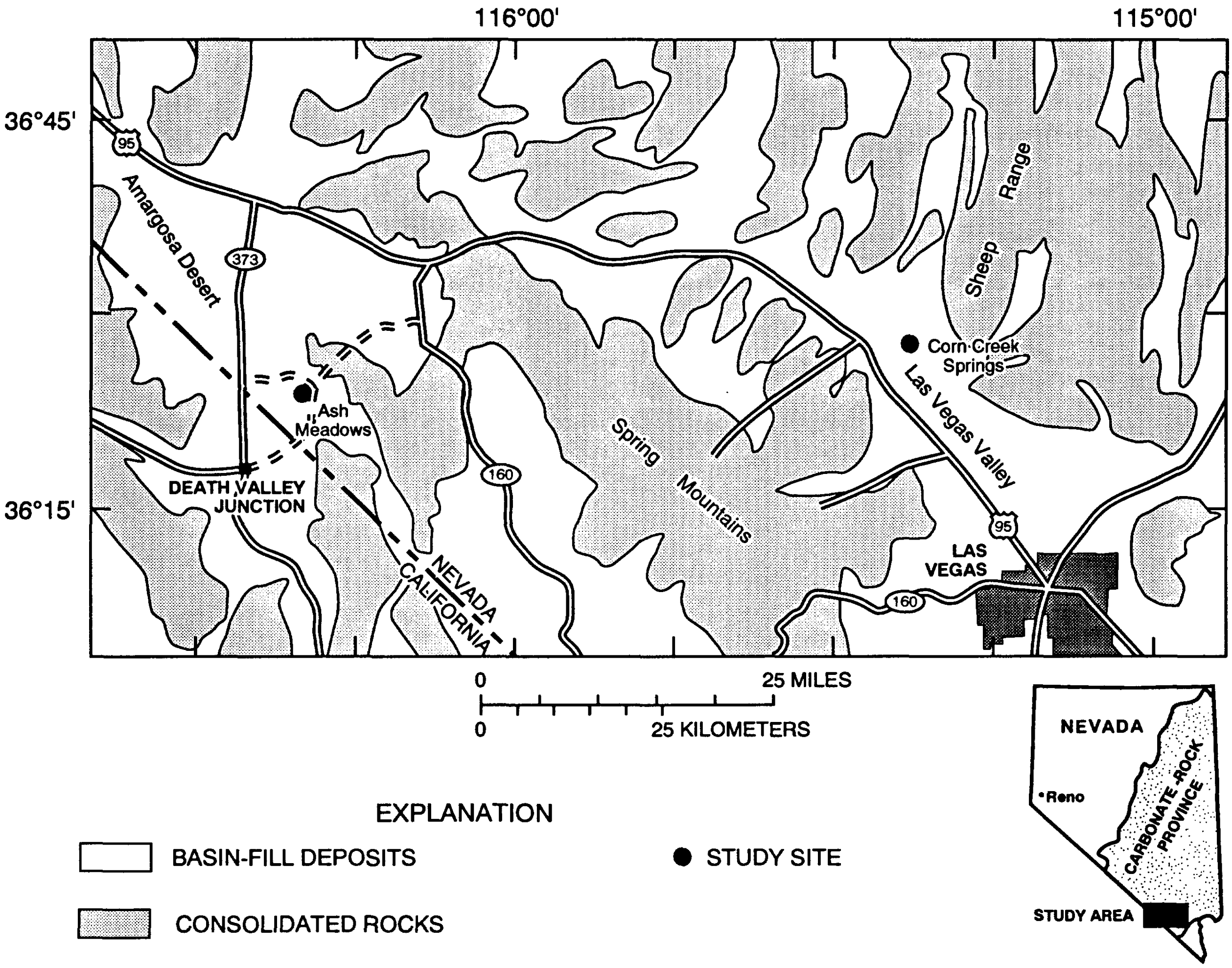

FIGURE 1.--Location of study sites.

Two micrometeorological data-collection stations were installed, one at Ash Meadows in the southern part of the Amargosa Desert, about 70 miles west of Las Vegas, and another at Corn Creek Springs in the northern part of Las Vegas Valley, about 25 miles northwest of the city (fig. 1). Both the Ash Meadows and the Corn Creek Springs sites are located within the carbonate-rock province of the Basin and Range in southeastern Nevada (Hess and Mifflin, 1978, page 2).

This report outlines the data that were collected for the *ET* study during the 1987 water year (October 1, 1986, to September 30, 1987) and presents the processing and subsequent format in which the data are stored on three 3.5-inch diskettes at the back of this report. Examples of the information obtained are shown in tables 1-4 of this report. The field parameters that were monitored for calculating potential *ET* using the Penman-combination method include solar radiation, soil-heat flux, air temperature, relative humidity, windspeed and direction, precipitation, and net radiation. The additional parameters monitored for directly measuring *ET* in the field using the eddy-correlation method include measurements of sensible-heat flux and latent-heat flux. A data logger was used onsite to periodically interogate the field instruments, collect and process the measurements, and record them on cassette tapes for later transfer to a computer file.

The Ash Meadows site is at longitude 116°20'29" W., latitude 36°25'11" N., at an altitude of 2,165 feet above sea level. The Corn Creek Springs site is at longitude 115°24'11" W., latitude 36°28'26" N., at an altitude of 2,990 feet above sea level. Both sites are in arid desert climates characterized by short, mild winters and long, hot, dry summers. Diurnal temperature changes can be large. Occasionally, winter daytime temperatures start in the 20's and reach the 70's (°F), while summer daytime temperatures may start in the low 60's and rise to 110°F or higher. More typical diurnal ranges are 30-40°F. The mean daily maximum temperature from mid-May to mid-September is nearly 100°F. Annual precipitation is generally less than 3 to 4 inches with regional, winter storm fronts supplying the most consistent source of convective, "rain-band" precipitation. Locally, high precipitation totals are possible from intense, microscale, convective, air-mass thunderstorms. Occasionally, in late spring or early autumn, tropical storms move inland from the Pacific Ocean across southern Nevada. These storms can produce locally heavy rains of as much as 2 inches on the valley floors and even heavier rains in the mountains. Overland flow and arroyo flooding are common with such storms and several days of thunder activity generally follow a storm until water vapor dissipates.

Ash Meadows is a major spring-discharge area along the southwestern edge of the carbonate-rock province, with an estimated average annual discharge of 17,000 acre-feet (Walker and Eakin, 1963, p. 21). In contrast, Corn Creek Springs, with an annual discharge of about 200 acre-feet (Pupacko and others, 1989), represents an isolated, smaller spring site typically found within the carbonate-rock province. The Ash Meadows data station was located in a large meadow containing moist subsoils, a dense, short grass understory, and sparse, low-lying shrubs. The Corn Creek Springs data station was located on bare, dry soil, about a fourth of which is covered with low-lying forbs and shrubs.

DATA COLLECTION

Equipment Used

Data were collected at both sites between October 1, 1986, and September 30, 1987. Vapor-flux data were collected periodically from April through September 1987. Penman-combination field instruments were sampled every minute, whereas eddy-correlation instruments were sampled every 0.1 second, using a 21X micrologger from Campbell Scientific, Inc. (CSI). The data were then compiled, processed through a computer program, and placed in intermediate storage using mathematical algorithms stored in the data logger's memory. Computations include totals, means, and covariances of the voltages measured from the different instruments and converted to engineering units. Processed Penman-combination data were then transmitted every 30 minutes to cassette tape recorders for final onsite storage; eddy-correlation data were transmitted every 5 minutes.

Temperature and relative humidity were measured by a combined probe made by CSI and designed for use with the CSI 21X micrologger. The Model 207 probe contains a Phys-Chemical Research PCRC-11 RH sensor and a Fenwal Electronics UU51J1 thermistor. The temperature was measured in degrees Celsius at 4 feet above land surface with an instrument accuracy of typically ± 0.2°C. The relative humidity (*RH*) was measured as a percentage of saturation with an overall sensor accuracy of better than ± 5 percent at vapor densities greater than 2.76 grams per cubic meter (g/m^3), corresponding to a lower limit of 12 percent *RH* at 25°C, or 6 percent *RH* at 40°C. The ± 5 percent sensor accuracy is maintained from these lower limits up to 100 percent *RH*, and the probe's resistors are electronically compensated for temperature changes when making *RH* measurements. However, during field monitoring it was observed that the desert climate required the humidity sensor to operate generally at or near the low end of the instrument's capabilities (and some times beyond) where greater nonlinear responses are present and can induce larger errors. At temperatures of 40°C and with *RH* below 10 percent, an aspirated psychrometer would be a better instrument to measure low values of *RH*.

Windspeed was measured in meters per second using a Sierra Misco, Inc., wind sensor. The model 1036-HM is a general purpose sensor for monitoring windspeed and wind direction. It is designed to give accurate ac voltage readings of ± 1 percent of full scale from a threshold windspeed of 1.5 to an upper limit of 200 miles per hour. Windspeed was measured 9 feet above land surface.

Precipitation was measured with a Sierra Misco, Inc., 2501 tipping-bucket rain gage. Rainfall was recorded, in millimeters, during the accumulation period. The gage was calibrated at the factory to an accuracy of ± 4 percent by volume, at a precipitation rate of 1-6 inches per hour, and recalibration was found to be unnecessary.

Incoming short-wave radiation was measured with a Li-Cor pyranometer, model LI-200SZ-05, mounted 7 to 8 feet above the ground. The pyranometer is an instrument for measuring solar radiation plus sky radiation received from a whole hemisphere. The spectral response of the silicon photodiode is in the wave-length range from 0.4 to 1.2 micrometers (μm), but does not extend uniformly over the full solar radiation range. Besides having a nonlinear response to solar radiation, the pyranometer is slightly temperature dependent, introducing an error of ± 0.15 percent per degree Celsius. The pyranometer is calibrated against an Eppley precision spectral pyranometer under natural daylight conditions giving an absolute error of ± 5 percent, with a true cosine response for angles less than 80 degrees from the normal axis of the sensor. Output is in microamps per 1,000 watts per square meter (W/m^2), but is converted to millivolts per 1,000 W/m^2 through the use of a precision resistor for voltage monitoring with the data logger. Final output with the data logger is in units of radiant-flux density, in watts per square meter. For a noon reading of 1,200 W/m^2, the maximum error at ± 5 percent would be ± 60 W/m^2.

Net radiation was measured approximately 3 feet above the ground with a model 6211 Fritchen Net Radiometer with heavy-duty domes. It is a miniature net radiometer that is shielded, temperature compensated between 10 and 50°C, and sensitive to solar and terrestrial radiation in the wave-length range from 0.3 to 60 micrometers, and has a nominal sensitivity of 50 microvolts per W/m^2. Output is in millivolts with conversion in the data logger to radiant-flux density, in watts per square meter, using a typical factor of 200 W/m^2 per millivolt. The net radiometer is not temperature compensated below 10°C; for example, at zero degrees the reading error would be 2.3 percent. Below 10°C, the correction to be applied is +0.23 percent per degree Celsius.

The soil-heat-flux density was measured with a Thornwaite soil-heat-flux plate placed 5 mm below the soil surface. Storage of heat in the soil above the plate was not measured. The plate attains a temperature difference that is sensed by an encapsulated thermopile. Output is in millivolts. Each plate has its own calibration constant to convert to radiant-flux density, in watts per square meter, within the data logger. The soil-heat-flux plate can accommodate flux changes in excess of 140 W/m^2.

The sensible-heat flux is obtained from the covariance of vertical windspeed and air temperature. The vertical windspeed was measured with a CSI sonic anemometer that has an acoustical path length of 100 mm, a calibration factor of 1 volt d.c. per meter per second, and an effective range of ± 4 volts. The sonic anemometer also contains a 0.0127-mm diameter chromel-constantan thermocouple for monitoring air temperature. The thermocouple has a calibration factor of 0.25 volt per degrees Celsius and a range of ± 4 volts.

The vapor-flux measurements needed for obtaining direct values of latent-heat flux were obtained by using a CSI model-220 Lyman-alpha hygrometer. The hygrometer is calibrated against an aspirated wet-and-dry-bulb psychrometer in a closed environment by varying vapor density while monitoring voltage output. Calibration of the hygrometer varies, being dependent on path length and the source tube in use. A typical calibration value of 0.5 volt per g/m^3 might be obtained for a given path length and source tube. The useful range of the hygrometer depends on the voltage-gain adjustment attainable for a given path length and for a given source tube to accommodate the resolution limitations of the recording electronics. As vapor density increases, the Lyman-alpha source-to-detector radiation drops, possibly causing measured voltages to drop below detectable limits if the voltage gain is not increased. Likewise, as vapor density decreases, there is greater source-to-detector radiation and a high-gain setting might saturate the amplifier. A voltage-gain adjustment does not affect the calibration or resolution of vapor density because the voltage reading is divided by the mean voltage term in the calibration expression.

Equipment Maintenance

The accuracy of the data depended largely upon the proper maintenance of the equipment. The Lyman-alpha hygrometer required specific voltage-gain adjustment between dry and moist weather conditions to avoid saturation of the electronic amplifier or deterioration of signals below detectable limits. Typically, the voltage gain is set for dry weather conditions; manual adjustments are made when weather conditions change. Because of the distance to the remote micrometeorological sites, manual adjustments were generally made only during scheduled daily service runs. Should an unexpected convection storm occur between visits, the dry setting could cause saturation of the electronic amplifier in the hygrometer and subsequent data loss. These storms also caused some moisture penetration onto internal electronic circuits, which led to some shorting and corrosion of electronic components, although a desiccant (moisture remover) normally limited such problems. The Lyman-alpha hygrometer proved to be mechanically fragile and developed either electrical-connection problems at tube terminal pins or source-tube deterioration caused by transportation vibration enroute to remote station sites. In addition, the surfaces of both the source and detector tubes are required to be extremely clean to maintain detectable voltage signals, even in moderately dry conditions. CSI has since developed the KH-20 Krypton hygrometer that in subsequent studies overcame many of the Lyman-alpha service problems.

When using the sonic anemometer, any deformation of the silver dishes on the acoustical sensors or misalignment of the acoustical dishes caused poor or no response to fluctuations of air movement. During normal use, the acoustical sensors were cleaned as needed to remove oxidation accumulations that could cause electrical shorting between copper disks attached to the silver dishes. When the acoustical sensors became wet from rains or heavy dew, they had to be dried and cleaned before accurate data could be collected again. Rain tends to cause initial large offsets to the wind signal and eventual electrical shorts. Whenever the acoustical sensors were cleaned or changed, the zero offset levels were recalibrated. Winter storms also caused significant data loss because moisture penetrated the control box and affected the electronic circuitry. New desiccant was inadequate in stopping corrosion on the printed circuit boards, which subsequently caused open leads and shorted-out components. Plastic bags over the control boxes, however, were effective in keeping rain from reentering the sonic anemometer after factory repair.

The fine-wire thermocouple is extremely fragile and, therefore, was checked daily during service runs. Wind-driven dust particles, spider webs attached to the fine wire and pulled by the wind, or heavy rain would break the 0.0127-mm diameter wire.

The temperature and humidity probes functioned properly during the spring and summer of 1987. During the autumn and winter of 1986, however, considerable data were lost because of electrical wiring problems, particularly with the humidity probe. In addition, the desert climate required the humidity sensor to operate generally at or near the low end of (and some times beyond) the instruments' capabilities, where greater nonlinear responses are present and could induce larger errors. At temperatures of 40°C and with RH below 10 percent, an aspirated psychrometer would be a more effective instrument to measure low values of RH. Dust slows the response, but does not affect the performance of the sensors. However, oil and sulfate does, and for this reason the sensors were always handled with cloth gloves to reduce transfer of contaminants like body oils and powdery, sulfate-rich evaporite deposits (from springs in the area) that might be on a person's hands.

The soil-heat-flux plates worked adequately unless the wire leads were chewed through by rodents, possibly tasting human body salts and oils on the wires. All ground wires were run through polyvinyl-chloride (PVC) pipes or the leads were wrapped in steel wool to reduce this problem.

In this study, no soil-temperature thermistors were used, so outgoing long-wave radiation was estimated using air temperature instead of the preferred surface-soil temperature. This introduced significant error to the net radiation estimate when the net radiometer was not in operation and a temperature-based estimate of the radiation had to be made. In future studies, if a soil-temperature thermistor were to be used with the soil-heat-flux plate, better estimates of long-wave radiation should result when the net radiometer is not functioning.

The net radiometer and the silicone pyranometer required their sensors to be level with the horizon and their surfaces to be clean for accurate measurements. The silicon pyranometer would at times become covered by dust or bird droppings and, with extended use, the pin connections in the net radiometer oxidized, causing increased electrical resistance or open circuits that resulted in skewed or lost data.

The wind sensors were prone to data error and loss introduced by mounting hardware and set screws which at times became loose and allowed the fixed potentiometers or counting sensors to move during data collection. Vertical and directional alignments were checked at various intervals to limit this error.

The tipping-bucket rain gage remained calibrated, but at times rodents chewed the wires or the gage was upended by wild horses or burros.

Occasionally, static electricity from wind-blown dry air or thunderstorms caused data loss within the 21X micrologger despite the fact that it was properly grounded. Static charges created instrument problems within the electronic-chip circuitry, causing the micrologger to malfunction. To clear the problem, the micrologger needed to be shut off and reprogrammed. With only daily to monthly visits, this static problem could cause the potential loss of a significant period of record. Data loss due to static problems tended to occur only when the additional eddy equipment was hooked up with the Penman equipment to the same recorder, which increased the antenna effect of the system. At these times, sites were visited every 24-48 hours, thereby limiting the data loss. Other than this hardware problem caused by static charges, the 21X micrologger worked flawlessly.

The output data were stored on a hand-held cassette recorder that generally functioned adequately when (1) the tape heads were properly aligned and (2) the volume control was set at a level above signal threshold, but not high enough to distort or clip the data signal. Winter air temperatures were not low enough to cause the recording system to malfunction at these sites.

DATA PROCESSING

Field-Data File Formats

Data were collected and processed in the field with a CSI 21X micrologger, input to a Tandy CCR-82 computer cassette recorder, then transferred in the office to a Prime computer file through a CSI model C20 cassette interface. The field data were collected and processed in the field using CSI 21X micrologger field programs (see appendix A). The field data from the micrologger were stored in the office by a Prime computer in card-image format as shown in table 1. Subsequently, these files were transferred to a microcomputer and compressed so they would fit on 3.5-inch diskettes included as part of this report.

The 21X micrologger used two processing programs to produce two types of card-image formats (table 1). The basic data, which were recorded continually and used in the Penman-combination method to estimate potential *ET* (see section "Equations used"), were processed through program 2 of the 21X micrologger. The card-image format consists of 14 data columns extending over 2 lines and output every 30 minutes (table 1A). The first two digits of each column identify the column number. The remaining digits represent the recorded data for that column. Columns 1 through 3 identify the card image (Penman-combination or eddy-correlation), Julian day, and hour-minute. Columns 4 through 9 record the average solar radiation, soil-heat flux, air temperature, relative humidity, windspeed and direction. Column 10 records total rainfall. Columns 11 and 12 measure average net radiation and data-logger battery voltage. Maximum and minimum air temperatures are recorded in columns 13 and 14, respectively.

Results of periodic sampling of the sensible-heat flux and latent-heat flux using the eddy-correlation method (see section "Equations Used") were processed through the 21X micrologger program 1. It had the highest priority and was executed before program 2 on the 21X micrologger by switching on at specified times and interrupting the continual output of program 2. Its card-image format consists of eight data columns on one card image (or data line) and is output every 5 minutes. As shown in table 1B, when the flux data (for measured *ET*) are collected, six card images are output from the 21X micrologger program 1 for every one output from the 21X micrologger program 2 during each 30-minute interval. Columns 1 through 3 (table 1B) identify the card image, Julian day, and hour-minute. Columns 4 through 6 show the five 5-minute mean values of the wind, air temperature, and vapor signals, in volts. Columns 7 and 8 record the covariances of the wind-temperature and the wind-vapor signals, in volts.

These field-data files are stored on the 3.5-inch diskettes; the data were screened first to remove recording noise and format errors incurred during data transmission. In addition, errors produced by known equipment malfunctions have been removed. However, users of these field-data files need to evaluate the adequacy of the data with regard to the accuracy and performance of the equipment, before using the data in interpretive studies.

TABLE 1.--*Example of file format of field data*

A. Micrometeorological data, from Program 2, potential evapotranspiration (Appendix A)

01+0210	02+0177	03+1030	04+0731	05+17.20	06+34.33	07+10.37	08+1.916
09+21.79	10+0.000	11+226.8	12+12.74	13+35.26	14+33.92		
01+0210	02+0177	03+1100	04+404.1	05+17.21	06+34.42	07+10.44	08+1.238
09+0.0	10+0.000	11+130.2	12+12.74	13+35.18	14+33.45		
01+0210	02+0177	03+1130	04+591.2	05+19.90	06+34.25	07+10.91	08+0.185
09+13.82	10+0.000	11+210.0	12+12.74	13+35.73	14+33.44		
01+0210	02+0177	03+1200	04+1250	05+29.03	06+37.36	07+08.66	08+0.898
09+66.29	10+0.000	11+419.8	12+12.75	13+38.16	14+35.88		
01+0210	02+0177	03+1230	04+1377	05+29.76	06+37.13	07+08.67	08+1.930
09+127.2	10+0.000	11+478.4	12+12.75	13+37.96	14+36.45		
01+0210	02+0177	03+1300	04+0779	05+29.00	06+37.18	07+08.64	08+2.518
09+145.5	10+0.000	11+394.4	12+12.75	13+37.72	14+36.76		
01+0210	02+0177	03+1330	04+1290	05+33.38	06+38.11	07+08.24	08+3.015
09+145.7	10+0.000	11+486.6	12+12.75	13+38.64	14+37.32		
01+0210	02+0177	03+1400	04+487.2	05+21.84	06+36.52	07+08.74	08+2.096
09+154.2	10+0.000	11+125.8	12+12.74	13+37.29	14+36.21		

B. Micrometeorological data, from Programs 1 and 2, potential and measured evapotranspiration (Appendix A)

01+0101	02+0178	03+0735	04-0.056	05-2.476	06+0.991	07+.02211	08-.00341
01+0101	02+0178	03+0740	04+0.006	05-2.519	06+0.984	07+.03592	08-.00636
01+0101	02+0178	03+0745	04-0.062	05-2.671	06+0.980	07+.03560	08-.00647
01+0101	02+0178	03+0750	04-0.078	05-2.829	06+1.011	07+.02544	08-.00532
01+0101	02+0178	03+0755	04-0.100	05-2.948	06+0.999	07+.03282	08-.00599
01+0101	02+0178	03+0800	04-0.052	05-3.149	06+0.988	07+.02709	08-.00608
01+0210	02+0178	03+0800	04+647.2	05+5.777	06+30.93	07+13.74	08+0.304
09+085.2	10+0.000	11+252.2	12+12.64	13+31.39	14+30.11		
01+0101	02+0178	03+0805	04-0.109	05-3.515	06+1.015	07+.04276	08-.00692
01+0101	02+0178	03+0810	04-0.110	05-3.603	06+1.011	07+.04273	08-.00793
01+0101	02+0178	03+0815	04-0.028	05-3.746	06+0.984	07+.03753	08-.00665
01+0101	02+0178	03+0820	04-0.065	05-4.056	06+1.020	07+.05202	08-.00856
01+0101	02+0178	03+0825	04-0.007	05-3.918	06+0.998	07+.05672	08-.00908
01+0101	02+0178	03+0830	04-0.027	05-3.876	06+1.003	07+.05408	08-.00692
01+0210	02+0178	03+0830	04+0932	05+10.02	06+32.17	07+12.16	08+0.960
09+073.7	10+0.000	11+315.2	12+12.65	13+32.71	14+31.43		
01+0101	02+0178	03+0835	04-0.035	05-3.483	06+0.986	07+.05786	08-.00856
01+0101	02+0178	03+0840	04-0.021	05-3.707	06+0.992	07+.05298	08-.00744
01+0101	02+0178	03+0845	04-0.025	05-3.924	06+0.976	07+.07228	08-.01064
01+0101	02+0178	03+0850	04+0.012	05-4.009	06+0.968	07+.03989	08-.00594
01+0101	02+0178	03+0855	04+0.027	05-3.982	06+0.929	07+.05527	08-.01014
01+0101	02+0178	03+0900	04-0.074	05-4.605	06+1.004	07+.04858	08-.00737
01+0210	02+0178	03+0900	04+1156	05+13.78	06+33.70	07+11.11	08+0.924
09+66.19	10+0.000	11+378.1	12+12.65	13+34.74	14+32.73		
01+0101	02+0178	03+0905	04+0.006	05-4.495	06+0.941	07+.07662	08-.01279
01+0101	02+0178	03+0910	04-0.020	05-4.945	06+0.980	07+.04302	08-.00683
01+0101	02+0178	03+0915	04-0.077	05-4.795	06+0.995	07+.05915	08-.01088
01+0101	02+0178	03+0920	04-0.034	05-5.007	06+0.973	07+.06284	08-.01126
01+0101	02+0178	03+0925	04+0.014	05-5.202	06+0.967	07+.06105	08-.01046
01+0101	02+0178	03+0930	04+0.019	05-5.724	06+0.993	07+.04133	08-.00930
01+0210	02+0178	03+0930	04+1285	05+16.11	06+35.26	07+09.99	08+0.655
09+083.8	10+0.000	11+457.7	12+12.66	13+36.03	14+34.73		

Equations Used

The net transfer of energy into and out of any given system at the surface of the Earth can be expressed in terms of an energy budget. The energy available at the ground surface is the difference between total upward and total downward radiation fluxes. This net-radiation flux is composed of the algebraic sum of the short-wave radiation from the Sun, in the form of direct or atmospherically diffused radiation minus its reflected short-wave component, and the incoming, long-wave radiation from the atmosphere minus the upwelling long-wave terrestrial radiation from the surface of the Earth.

The importance of net radiation is that it is the fundamental quantity of energy available at the surface of the Earth to enable evapotranspiration (latent-heat flux), to warm the air (sensible-heat flux), and to heat the soil (soil-heat flux), as well as to perform other smaller, energy-consuming processes. Excluding the minor amount of energy expended for photosynthesis, plant respiration, and heat storage in the crop canopy, the energy budget at the Earth's surface can be expressed by the following equation:

$$R_n - G = H + \lambda E \tag{1}$$

where

R_n is net radiation, in watts per square meter;
G is soil-heat flux, in watts per square meter;
H is sensible-heat flux, in watts per square meter;
λE is latent-heat flux, in watts per square meter;
λ is latent heat of vaporization, equal to 2,450 joules per gram at 20°C; and
E is quantity of water evaporated (water-vapor flux density), in grams per square meter per second.

In determining the components of an energy budget, net radiation and soil-heat storage can be measured without much difficulty. The quantity $R_n - G$ is known as the available energy. Sensible- and latent-heat fluxes are somewhat more difficult to measure. One method used to measure the turbulent fluxes of sensible and latent heat from covariances is the eddy-correlation method (Brutsaert, 1982, p. 190).

Eddy-Correlation Method

In the eddy-correlation method, the latent- and sensible-heat fluxes are calculated independently of the other energy-budget components (net radiation and soil-heat flux). Latent-heat flux, a direct measurement of actual *ET*, is calculated from the covariance of vapor density and vertical windspeed. Sensible-heat flux is calculated from the covariance of vertical windspeed and air temperature. The eddy-correlation flux equations are presented by Campbell (1977, p. 35):

$$\lambda E = \overline{V'W'}\,\lambda \;=\; LHF \tag{2}$$

and

$$H = \overline{W'T'}\,\rho_a C_p \;=\; SHF \tag{3}$$

where

- $'$ is the instantaneous deviation from the mean;
- $\overline{}$ is the average for a given time period (5 minutes);
- V is vapor density of air, in grams per cubic meter;
- W is vertical wind velocity, in meters per second;
- T is temperature of air, in degrees celsius;
- ρ_a is density of air, in grams per cubic meter; and
- C_p is specific heat of air, in joules per gram per degree Celsius.

For this study the vapor density was obtained with field instruments that monitored signal output in volts, which were converted to grams per meter by using a Lyman-alpha calibration coefficient. The Lyman-alpha calibration coefficient, in grams per cubic meter per volt, accounts for the deviation in vapor density per deviation in signal output for any flux-measurement interval.

The sum of the two turbulent fluxes shown in equations (2) and (3), theoretically, should equal the available energy as defined in the energy-budget equation (1). Due to errors in measuring the components, the energy-budget equation does not always balance. To measure the relative balance, or closure, Duell (1985, p. 45) and Duell and Nork (1985, p. 163) suggest calculating the ratio of the turbulent fluxes to the available energy, which is termed the energy-budget closure (***EBC***):

$$EBC = \frac{\lambda E + H}{R_n - G} \times 100 \ . \tag{4}$$

Because the latent- and sensible-heat flux are calculated independent of the net radiation and the soil-heat flux, the actual *ET* also can be estimated from the energy-budget equation by measuring sensible-heat flux, net radiation, and soil-heat flux, and by calculating the latent-heat flux as a residual (***LHFR***):

$$LHFR = \lambda E = R_n - G - H \ . \tag{5}$$

The measurements collected in this study allow for the calculation of actual *ET* using direct measurements of the ***LHF*** and of the ***LHFR***. The data also permit the calculation of the ***EBC***. The ***LHF*** values, in watts per square meter, are converted to *ET*, in millimeters per each 30 minutes, by dividing the ***LHF*** by the latent heat of vaporization, then multiplying by the appropriate unit.

Penman-Combination Method

Estimates for potential *ET* were also calculated. Many equations are available for estimating potential *ET* from climatic data. One equation that considers the factors of both energy supply and turbulent transport of water vapor away from the evaporating surface is the Penman-combination equation. The form of this equation used to calculate potential *ET* in this report was presented by Campbell (1977, p. 138):

$$\lambda E_p = \frac{S}{S+\gamma}(R_n - G) + \frac{\gamma}{S+\gamma} f(u)\,(\rho_{v_s} - \rho_v), \tag{6}$$

where

- λE_p is the potential latent-heat flux;
- S is the slope of the saturated-vapor density function;
- γ is the thermodynamic psychrometer constant;
- $f(u)$ is the empirical wind function for the Penman equation;
- ρ_{v_s} is saturated water-vapor density at the existing temperature; and
- ρ_v is water-vapor density.

The slope of the saturated vapor density (S) is calculated by cubic regression analysis of data presented by Campbell (1977), giving the following equation:

$$S = 0.337569 + 0.02067\,T_c + 0.000427\,T_c^2 + 0.000011\,T_c^3 \tag{7}$$

where T_c is temperature in degrees Celsius.

The thermodynamic psychrometer constant (γ) is equal to the density of air (ρ_a) times the specific heat of air (C_p) divided by the latent heat of vaporization (λ). Therefore,

$\lambda = \rho_a C_p / \lambda$ and

$$\rho_a = (1{,}292\ \mathrm{g/m^3}) \left(\exp\left(-\frac{altitude\ in\ meters}{8{,}230}\right)\right) \left(\frac{273.16}{273.16+T_c}\right), \tag{8}$$

in grams per cubic meter; and

$$C_p = 1.005(1.0 - 0.85\ Q), \tag{9}$$

in joules per gram per degree Celsius,

where $Q = \dfrac{\rho_v}{\rho_a + \rho_v}$ is the specific humidity (dimensionless).

The saturated water-vapor density of air (ρ_{v_s}) is derived from the saturated water-vapor pressure (p_s) and the temperature, in degrees Kelvin (T_k), by the following equation:

$$\rho_{v_s} = \frac{P_s}{4.62 \times 10^{-4} T_k}, \tag{10}$$

where p_s is an exponential function of temperature, in degrees Kelvin (Campbell, 1977, p. 22) assuming saturated conditions (100 percent relative humidity at the recorded temperature), and is expressed as:

$$P_s = \exp(52.57633 - \frac{6790.4985}{T_k} - 5.02808\ \ln\ T_k)\ . \tag{11}$$

The actual water-vapor density of air (ρ_v) is a function of the relative humidity (RH) and the saturated water-vapor pressure (ρ_{v_s}), as shown by the following equation:

$$\rho_v = \frac{RH}{100}\,\rho_{v_s}\ . \tag{12}$$

The wind function $f(u)$ is equal to the latent heat of vaporization (λ) divided by the sensible-heat transport resistance (r_H), or:

$f(u) = \lambda / r_H$, in joule-meters per gram per second, where

$\lambda = 2{,}502 - 2.40\ T_c$, and

$$r_H = \frac{\ln\left(\frac{Z-d+Z_h}{Z_h}\right)\ \ln\left(\frac{Z-d+Z_m}{Z_m}\right)}{K^2 \bar{u}}$$

(Campbell, 1977, p. 138),

where

- Z is height of measurements above soil surface;
- Z_m is roughness parameter for momentum equal to $0.13h$, where h is the average canopy height;
- Z_h is roughness parameter for heat, ($0.2\ Z_m$);
- d is zero-plane displacement, where $\log d = 0.9793 \log h - 0.1536$ (Stanhill, 1969 p. 513);
- K is the von Karman constant; and
- $\bar{u}$ is mean windspeed at height Z.

An improvement to the Penman-combination equation is the Penman-Monteith combination equation in which the thermodynamic psychrometer constant is replaced by the apparent psychrometer constant, $\gamma^* = \gamma r_v / r_H$. The Penman-combination equation assumes that the canopy resistance to atmospheric sensible heat and vapor transport are equal, so $r_v = r_H$. This assumption is valid only for dense, well-watered crop canopies where the heat-exchange surface is the vapor-exchange surface. As a vegetated surface dries, the vapor-transport resistance is not equal to, but is greater than, the resistance to heat transport. The Penman-Monteith combination equation accounts for the effects of drying, thus giving an estimate of actual *ET* rather than potential *ET* (Monteith, 1973). An estimate of r_v can be obtained in the Penman-Monteith combination equation, by using directly measured latent-heat flux, or the latent-heat flux residual along with the sensible-heat transport resistance. Thus, if r_v is a predictable function, the Penman-Monteith combination equation could be used to extrapolate estimates of actual *ET* when direct measurements are not available. The vapor-transport resistance was calculated from the field data collected using the measured latent-heat flux.

The Fortran processing program that used the above equations to calculate the actual and potential *ET* from the field data files, along with other calculated parameters, such as the vapor transport resistance, is presented in appendix B. The output of the Fortran program is in the form of processed output files and is discussed in the next section.

Processed Output-File Formats

The processed output files consist of reformatted micrometeorological data, including calculated potential *ET* and field-measured *ET*. Files were processed on a Prime computer using the field data files and the Fortran processing program (Appendix B) and equations discussed in the previous section. These output files were then transferred to a microcomputer and compressed so that they would fit on three 3.5-inch diskettes included as part of this report.

TABLE 2.--*Example of a table in "30-minute" files*

[YR, year; MO, month; DAY, day; TIME, time; TMAX, maximum air temperature; TMIN, minimum air temperature; WD, wind direction; DENA, density of air; WVP, water-vapor pressure; DENSWV, density of the saturated water vapor; DENAWV, density of the actual water vapor; SHTR, sensible-heat transport resistance; VTR, vapor-transport resistance; TPC, thermodynamic psychrometer constant; APC, apparent psychrometer constant; S, slope function; FU, wind function; MWVFF, maximum water-vapor flux; ENERGY, Penman-combination energy-supply term; TURBUL, Penman-combination turbulent-transport term; and LHFR, latent-heat flux residual. Symbols and abbreviations: °, degree; °C, degree Celsius; g, gram; m, meter; kPa, kilopascal; s, second; J, joule; W, watt]

YR	MO	DAY	TIME	TMAX (°C)	TMIN (°C)	WD (°)	DENA (g/m^3)	WVP (kPa)	DENSWV (g/m^3)	DENAWV (g/m^3)	SHTR (s/m)	VTR (s/m)	TPC ($g/m^3/°C$)	APC ($g/m^3/°C$)	S	FU (Jm/g/s)	MWVFF (W/m^2)	ENERGY (W/m^2)	TURBUL (W/m^2)	LHFR (W/m^2)
87	6	27	30	21.2	20.6	8.	1,107.6	2.48	18.23	3.62	322	0	0.4528	0.00	1.06	7.62	0.0	-77.6	33.4	-101.8
87	6	27	100	20.9	20.0	7.	1,109.7	2.39	17.64	3.59	95	4,226	0.4534	20.11	1.03	25.74	8.0	-75.9	110.7	-99.9
87	6	27	130	20.3	19.7	28.	1,110.6	2.36	17.40	3.75	1,361	0	0.4536	0.00	1.02	1.80	8.0	-73.6	7.6	-97.4
87	6	27	200	19.5	17.5	11.	1,117.3	2.12	15.71	4.62	3,629	0	0.4552	0.00	0.93	0.68	8.0	-63.4	2.5	-80.8
87	6	27	230	17.9	17.0	19.	1,120.5	2.01	14.94	4.75	351	2,222,217	0.4561	288.62	0.89	7.00	0.0	-60.7	24.2	-84.5
87	6	27	300	19.3	18.0	24.	1,115.5	2.18	16.15	5.49	96	41	0.4544	0.20	0.95	25.67	637.0	-59.7	88.3	-69.3
87	6	27	330	19.4	18.7	19.	1,115.3	2.19	16.20	4.60	394	0	0.4547	0.00	0.96	6.24	637.0	-64.7	23.3	-89.6
87	6	27	400	19.1	17.6	13.	1,117.7	2.10	15.59	4.62	449	0	0.4554	0.00	0.92	5.48	637.0	-63.4	19.8	-87.1
87	6	27	430	19.8	18.3	13.	1,114.4	2.22	16.41	4.46	199	0	0.4545	0.00	0.97	12.33	637.0	-65.5	47.2	-74.3
87	6	27	500	18.2	16.2	24.	1,122.1	1.96	14.58	5.33	322	0	0.4564	0.00	0.87	7.65	637.0	-45.5	24.3	-59.3
87	6	27	530	0.0	0.0	3.	1,119.8	2.03	15.09	5.97	309	9,422	0.4555	13.90	0.90	7.96	2.0	14.2	24.4	25.9
87	6	27	600	23.7	19.9	4.	1,103.8	2.64	19.34	7.01	130,645	2,526,554	0.4505	8.71	1.11	0.04	0.0	87.1	0.1	25.8
87	6	27	630	27.7	23.8	61.	1,089.2	3.34	24.18	6.60	1,765	1,403	0.4464	0.35	1.35	1.38	30.0	50.7	6.0	64.0
87	6	27	700	27.6	26.6	107.	1,085.0	3.58	25.78	5.58	479	704	0.4455	0.66	1.43	5.09	69.0	95.2	24.5	114.9
87	6	27	730	30.0	27.7	80.	1,077.8	4.02	28.81	4.90	4,839	6,907	0.4436	0.63	1.57	0.50	8.0	171.2	2.6	199.4
87	6	27	800	31.4	30.1	85.	1,071.2	4.48	31.86	4.38	430	728	0.4419	0.75	1.71	5.65	91.0	195.8	31.9	214.4
87	6	27	830	32.7	31.4	74.	1,066.8	4.80	34.04	4.14	136	349	0.4407	1.13	1.81	17.82	207.0	245.4	104.3	254.3
87	6	27	900	34.7	32.7	66.	1,061.5	5.23	36.90	4.10	141	398	0.4392	1.24	1.94	17.12	199.0	297.1	103.7	306.4
87	6	27	930	36.0	34.7	84.	1,056.1	5.70	40.03	4.00	199	427	0.4377	0.94	2.08	12.12	203.0	364.8	75.9	380.9
87	6	27	1000	37.0	36.0	21.	1,051.2	6.17	43.09	3.96	660	1,694	0.4363	1.12	2.21	3.66	55.0	407.1	23.6	427.4
87	6	27	1030	38.6	37.0	12.	1,047.7	6.53	45.48	3.99	1,320	1,425	0.4352	0.47	2.32	1.83	70.0	402.3	12.0	411.5
87	6	27	1100	39.0	38.2	34.	1,044.7	6.85	47.54	3.89	137	396	0.4344	1.25	2.41	17.54	265.0	429.4	117.0	433.1
87	6	27	1130	39.2	38.4	0.	1,044.1	6.92	47.99	3.84	146	603	0.4343	1.79	2.43	16.47	176.0	473.6	110.4	504.5
87	6	27	1200	39.7	38.9	24.	1,042.5	7.10	49.17	3.81	142	419	0.4338	1.28	2.48	17.01	260.0	505.7	115.0	531.0
87	6	27	1230	40.5	39.6	0.	1,039.9	7.40	51.15	3.75	126	536	0.4331	1.83	2.56	19.02	212.0	514.4	130.4	543.0

TABLE 2.--***Example of a table in "30-minute" files***--Continued

YR	MO	DAY	TIME	TMAX (°C)	TMIN (°C)	WD (°)	DENA (g/m^3)	WVP (kPa)	DENSWV (g/m^3)	DENAWV (g/m^3)	SHTR (s/m)	VTR (s/m)	TPC ($g/m^3/°C$)	APC ($g/m^3/°C$)	S	FU (Jm/g/s)	MWVFF (W/m^2)	ENERGY (W/m^2)	TURBUL (W/m^2)	LHFR (W/m^2)
87	6	27	1300	40.4	40.0	65.	1,039.6	7.44	51.38	3.72	89	433	0.4330	2.10	2.57	26.99	264.0	466.8	185.5	496.6
87	6	27	1330	40.6	40.1	60.	1,039.0	7.51	51.82	3.69	91	211	0.4328	1.01	2.59	26.55	548.0	407.0	183.0	412.8
87	6	27	1400	40.6	40.2	69.	1,039.0	7.51	51.85	3.67	39	247	0.4328	2.72	2.59	61.16	468.0	402.9	422.0	417.0
87	6	27	1430	40.9	40.4	51.	1,037.9	7.64	52.68	3.63	75	284	0.4325	1.63	2.62	31.86	415.0	396.4	221.1	417.7
87	6	27	1500	41.4	40.8	10.	1,036.5	7.81	53.82	3.61	78	429	0.4321	2.37	2.67	30.68	281.0	325.0	214.5	363.6
87	6	27	1530	41.2	40.6	5.	1,037.3	7.72	53.18	3.61	79	296	0.4324	1.62	2.65	30.45	402.0	272.3	212.1	307.7
87	6	27	1600	41.3	40.3	12.	1,037.6	7.67	52.89	3.61	57	348	0.4325	2.64	2.63	42.14	340.0	184.3	292.9	234.0
87	6	27	1630	40.2	38.8	11.	1,041.7	7.19	49.74	3.59	53	579	0.4337	4.77	2.50	45.75	191.0	106.9	312.1	164.5
87	6	27	1700	39.9	39.5	12.	1,041.2	7.25	50.14	3.59	42	372	0.4335	3.82	2.52	57.07	301.0	94.7	390.2	154.3
87	6	27	1730	39.5	39.3	12.	1,042.1	7.15	49.49	3.58	59	599	0.4338	4.44	2.49	41.11	184.0	92.5	280.0	150.6
87	6	27	1800	39.4	38.5	15.	1,043.6	6.97	48.36	3.58	72	493	0.4342	2.98	2.44	33.50	218.0	-8.8	226.5	38.6
87	6	27	1830	38.4	35.6	17.	1,050.1	6.28	43.84	3.54	331	0	0.4361	0.00	2.25	7.30	218.0	-61.5	47.8	-57.7
87	6	27	1900	35.4	33.4	16.	1,060.2	5.34	37.62	3.48	14,516	0	0.4390	0.00	1.97	0.17	218.0	-98.4	1.0	-94.9
87	6	27	1930	33.7	31.9	11.	1,065.0	4.95	35.00	3.39	130,645	[a]10,952,886	0.4404	36.92	1.85	0.00	0.0	-108.7	0.0	-138.1
87	6	27	2000	32.9	28.9	0.	1,070.1	4.56	32.39	3.36	1,199	0	0.4419	0.00	1.74	2.02	0.0	-106.7	11.9	-121.2
87	6	27	2030	31.2	28.8	55.	1,076.1	4.13	29.54	3.28	71	357	0.4437	2.22	1.60	34.13	178.0	-103.8	194.3	-39.5
87	6	27	2100	31.4	29.6	0.	1,071.7	4.44	31.62	3.34	189	0	0.4424	0.00	1.70	12.82	178.0	-108.2	74.9	-99.2
87	6	27	2130	29.6	28.0	41.	1,080.0	3.88	27.85	3.26	137	0	0.4448	0.00	1.52	17.75	178.0	-101.4	98.6	-90.7
87	6	27	2200	29.6	28.0	58.	1,078.5	3.98	28.50	3.34	46	779	0.4444	7.49	1.55	52.62	78.0	-102.9	294.3	-34.8
87	6	27	2230	29.4	27.3	58.	1,079.1	3.94	28.24	3.35	78	850	0.4445	4.85	1.54	31.27	71.0	-104.0	174.1	-75.7
87	6	27	2300	27.3	24.8	17.	1,089.2	3.34	24.18	3.29	211	0	0.4475	0.00	1.35	11.58	71.0	-95.0	60.2	-112.8
87	6	27	2330	25.3	24.3	0.	1,092.5	3.17	23.01	3.30	104	1,113	0.4484	4.82	1.29	23.59	43.0	-91.3	119.7	-99.0
87	6	27	0	24.2	22.5	0.	1,099.4	2.83	20.69	3.55	234	0	0.4504	0.00	1.18	10.47	43.0	-84.1	49.6	-94.4

[a] Large numbers are indicative of instability in deriving a calculated value and should not be used in further calculations.

TABLE 3.--*Example of a table in "day" files*

[JU, Julian day; YR, year; MO, month; DAY, day; TIME, time; TEMP, air temperature; WIND, windspeed; REL-HUM, relative humidity; RAIN, rainfall; VAP-DEN, actual water-vapor density; SOL-RAD, solar radiation; NET-RAD, net radiation; SOIL-HEAT, soil-heat flux; SHF, sensible-heat flux; LHF, latent-heat flux; EBC, energy-balance closure; LHF-P, potential latent-heat flux using Penman combination equation; ET, measured evapotranspiration using the eddy-correlation method; ET-P, potential evapotranspiration using the Penman-combination equation; and ET-R, estimated evapotranspiration using the latent-heat flux residual from the energy equation. Symbols and abbreviations: °C, degree Celsius; m, meter; s, second; %, percent; mm, millimeter; g, gram; W, watt]

JU	YR	MO	DAY	TIME	TEMP (°C)	WIND (m/s)	REL-HUM (%)	RAIN (mm)	VAP-DEN (g/m^3)	SOL-RAD (W/m^2)	NET-RAD (W/m^2)	SOIL-HEAT (W/m^2)	SHF (W/m^2)	LHF (W/m^2)	EBC (%)	LHF-P (W/m^2)	ET (mm)	ET-P (mm)	ET-R (mm)
178	87	6	27	30	20.9	0.41	19.9	0.0	3.620	0.2	-115.6	-4.8	-9.0	4.2	4.3	-44.2	0.00	-0.03	-0.07
178	87	6	27	100	20.4	1.37	20.4	0.0	3.594	0.3	-115.0	-5.6	-9.5	2.4	6.5	34.8	0.00	0.03	-0.07
178	87	6	27	130	20.1	0.10	21.6	0.0	3.754	0.2	-112.8	-6.4	-9.0	3.9	4.8	-66.0	0.00	-0.05	-0.07
178	87	6	27	200	18.4	0.04	29.4	0.0	4.622	0.2	-101.5	-7.1	-13.6	9.9	3.9	-60.9	0.01	-0.04	-0.06
178	87	6	27	230	17.5	0.37	31.8	0.0	4.750	0.2	-99.2	-7.4	-7.3	-0.2	8.2	-36.5	0.00	-0.03	-0.06
178	87	6	27	300	18.8	1.37	34.0	0.0	5.494	0.0	-94.9	-6.7	-18.8	35.1	-18.5	28.6	0.03	0.02	-0.05
178	87	6	27	330	18.9	0.33	28.4	0.0	4.601	0.0	-102.6	-7.0	-5.9	4.9	1.1	-41.4	0.00	-0.03	-0.07
178	87	6	27	400	18.3	0.29	29.6	0.0	4.616	0.0	-101.6	-7.0	-7.5	5.1	2.5	-43.5	0.00	-0.03	-0.06
178	87	6	27	430	19.1	0.66	27.2	0.0	4.458	1.7	-102.8	-6.4	-22.1	11.8	10.7	-18.4	0.01	-0.01	-0.05
178	87	6	27	500	17.1	0.41	36.6	0.0	5.335	21.1	-76.0	-6.6	-10.1	5.4	6.8	-21.3	0.00	-0.02	-0.04
178	87	6	27	530	17.7	0.42	39.6	19.7	5.972	118.4	16.3	-5.1	-4.6	3.5	-5.0	38.6	0.00	0.03	0.02
178	87	6	27	600	22.0	0.00	36.2	0.0	7.011	244.2	119.9	-2.5	-3.4	13.9	8.5	87.2	0.01	0.06	0.09
178	87	6	27	630	25.9	0.07	27.3	0.0	6.597	387.0	67.4	-0.1	3.5	59.8	93.8	56.8	0.04	0.04	0.05
178	87	6	27	700	27.0	0.27	21.7	0.0	5.583	530.3	126.2	1.3	10.0	107.6	94.2	119.7	0.08	0.09	0.08
178	87	6	27	730	29.1	0.03	17.0	0.0	4.904	712.0	222.9	3.3	20.2	158.9	81.6	173.9	0.12	0.13	0.15
178	87	6	27	800	30.9	0.30	13.7	0.0	4.377	647.2	252.2	5.8	32.0	199.3	93.9	227.7	0.15	0.17	0.16
178	87	6	27	830	32.2	0.96	12.2	0.0	4.139	932.0	315.2	10.0	50.9	267.8	104.4	349.7	0.20	0.26	0.19
178	87	6	27	900	33.7	0.92	11.1	0.0	4.099	1156.0	378.1	13.8	57.9	300.2	98.3	400.7	0.22	0.30	0.23
178	87	6	27	930	35.3	0.65	10.0	0.0	3.999	1285.0	457.7	16.1	60.7	367.7	97.0	440.7	0.27	0.33	0.28
178	87	6	27	1000	36.7	0.20	9.2	0.0	3.964	1395.0	507.9	20.6	60.0	342.4	82.6	430.7	0.26	0.32	0.32
178	87	6	27	1030	37.8	0.10	8.8	0.0	3.994	1486.0	503.6	25.7	66.4	409.2	99.5	414.3	0.31	0.31	0.31
178	87	6	27	1100	38.6	0.95	8.2	0.0	3.893	1554.0	537.0	30.0	73.8	424.2	98.2	546.5	0.32	0.41	0.32
178	87	6	27	1130	38.8	0.89	8.0	0.0	3.839	1599.0	591.4	33.1	53.9	396.0	80.6	583.9	0.30	0.44	0.38
178	87	6	27	1200	39.3	0.92	7.7	0.0	3.806	1620.0	629.0	34.7	63.3	480.3	91.5	620.7	0.36	0.46	0.40
178	87	6	27	1230	40.1	1.03	7.3	0.0	3.755	1619.0	637.3	35.9	58.4	439.2	82.7	644.8	0.33	0.48	0.41

TABLE 3.--*Example of a table in "day" files*--Continued

JU	YR	MO	DAY	TIME	TEMP (°C)	WIND (m/s)	REL-HUM (%)	RAIN (mm)	VAP-DEN (g/m^3)	SOL-RAD (W/m^2)	NET-RAD (W/m^2)	SOIL-HEAT (W/m^2)	SHF (W/m^2)	LHF (W/m^2)	EBC (%)	LHF-P (W/m^2)	ET (mm)	ET-P (mm)	ET-R (mm)
178	87	6	27	1300	40.2	1.47	7.2	0.0	3.715	1585.0	582.7	37.2	48.9	419.1	85.8	652.4	0.31	0.49	0.37
178	87	6	27	1330	40.3	1.44	7.1	0.0	3.695	1531.0	511.3	36.3	62.3	495.6	117.4	590.0	0.37	0.44	0.31
178	87	6	27	1400	40.3	3.32	7.1	0.0	3.666	1456.0	502.9	32.6	53.3	469.3	111.1	824.9	0.35	0.62	0.31
178	87	6	27	1430	40.7	1.73	6.9	0.0	3.629	1339.0	494.5	32.8	44.0	443.9	105.7	617.5	0.33	0.46	0.31
178	87	6	27	1500	41.1	1.67	6.7	0.0	3.607	1247.0	410.6	33.0	13.9	332.4	91.7	539.5	0.25	0.40	0.27
178	87	6	27	1530	40.9	1.65	6.8	0.0	3.611	1042.0	347.7	30.8	9.1	349.3	113.1	484.4	0.26	0.36	0.23
178	87	6	27	1600	40.8	2.29	6.8	0.0	3.614	895.0	243.0	28.4	-19.5	277.4	120.2	477.2	0.21	0.36	0.18
178	87	6	27	1630	39.5	2.48	7.2	0.0	3.586	581.1	146.6	21.2	-39.1	169.0	103.6	419.0	0.13	0.31	0.12
178	87	6	27	1700	39.7	3.10	7.2	0.0	3.595	632.3	129.9	18.9	-43.3	225.8	164.4	484.9	0.17	0.36	0.12
178	87	6	27	1730	39.4	2.23	7.2	0.0	3.583	497.1	125.7	17.0	-42.0	157.2	106.0	372.6	0.12	0.28	0.11
178	87	6	27	1800	39.0	1.82	7.4	0.0	3.583	341.0	4.2	14.5	-48.9	115.5	-645.2	217.7	0.09	0.16	0.03
178	87	6	27	1830	37.0	0.39	8.1	0.0	3.543	93.8	-64.7	8.7	-15.7	14.8	1.3	-13.7	0.01	-0.01	-0.04
178	87	6	27	1900	34.1	0.01	9.2	0.0	3.476	26.3	-117.5	2.7	-25.3	25.5	-0.1	-97.3	0.02	-0.07	-0.07
178	87	6	27	1930	32.7	0.00	9.7	0.0	3.388	3.8	-135.5	-1.0	3.6	-6.4	2.1	-108.7	0.00	-0.08	-0.10
178	87	6	27	2000	31.2	0.11	10.4	0.0	3.362	0.7	-135.8	-2.0	-12.6	12.0	0.5	-94.7	0.01	-0.07	-0.09
178	87	6	27	2030	29.5	1.83	11.1	0.0	3.276	0.6	-134.1	-1.6	-93.0	48.4	33.7	90.4	0.04	0.07	-0.03
178	87	6	27	2100	30.8	0.69	10.6	0.0	3.339	0.3	-135.7	0.7	-37.2	13.4	17.4	-33.3	0.01	-0.02	-0.07
178	87	6	27	2130	28.5	0.95	11.7	0.0	3.256	0.3	-132.7	-1.7	-40.3	17.7	17.3	-2.8	0.01	0.00	-0.07
178	87	6	27	2200	28.9	2.83	11.7	0.0	3.337	0.3	-132.3	0.0	-97.5	42.3	41.7	191.4	0.03	0.14	-0.03
178	87	6	27	2230	28.7	1.68	11.9	0.0	3.349	0.3	-131.9	2.1	-58.2	21.8	27.2	70.1	0.02	0.05	-0.06
178	87	6	27	2300	25.9	0.62	13.6	0.0	3.286	0.4	-127.8	-1.3	-13.7	3.2	8.3	-34.8	0.00	-0.03	-0.08
178	87	6	27	2330	25.0	1.26	14.3	0.0	3.299	0.4	-126.1	-3.1	-24.0	8.1	12.9	28.4	0.01	0.02	-0.07
179	87	6	27	0000	23.1	0.56	17.2	0.0	3.554	0.4	-119.7	-3.6	-21.8	7.4	12.4	-34.5	0.01	-0.03	-0.07
TOTAL					--	--	--	19.7	4.065	--	--	--	--	--	--	--	5.76	7.85	4.34
AVERAGE					30.7	0.98	15.3			553.8	132.2	9.6	1.9	160.7	39.2	218.9	0.12	0.16	0.09

NUMBER OF OBSERVATIONS FOR DAY PENMAN-COMBINATION DATA: 48 EDDY-CORRELATION DATA: 48

	ET	ET-P	ET-R
DAILY TOTAL OF ALL POSITIVE VALUES:	5.76	8.41	5.74
30 MINUTE AVERAGE OF POSITIVE VALUES:	0.12	0.18	0.12

TABLE 4.--*Example of a table in "month" files*

[YR, year; MO, month; DAY, day; AVERAGE TEMP, average air temperature; AVERAGE WIND, average windspeed; AVERAGE REL-HUM, average relative humidity; TOTAL RAIN, total rainfall; AVERAGE VAP-DEN, average water-vapor density; AVERAGE SOL-RAD, average solar radiation; AVERAGE NET-RAD, average net radiation; AVERAGE SOIL-HEAT, average soil-heat flux; AVERAGE SHF, average sensible-heat flux; AVERAGE LHF, average latent-heat flux; AVERAGE EBC, average energy-balance closure; AVERAGE LHF-P, average latent-heat flux using Penman-combination equation; TOTAL ET, total measured evapotranspiration using the eddy-correlation method; TOTAL ET-P, total potential evapotranspiration using the Penman-combination equation; and COUNT PEN/EDDY, the total number of 30-minute Penman-combination values used in each day to calculate the total potential *ET*, compared to the total number of 30-minute eddy-correlation values used in each day to obtain the total measured *ET*. Symbols and abbreviations: °C, degree Celsius; m, meter; s, second; %, percent; mm, millimeter; g, gram; W, watt]

YR	MO	DAY	AVERAGE TEMP (°C)	AVERAGE WIND (m/s)	AVERAGE REL-HUM (%)	TOTAL RAIN (mm)	AVERAGE VAP-DEN (g/m^3)	AVERAGE SOL-RAD (W/m^2)	AVERAGE NET-RAD (W/m^2)	AVERAGE SOIL-HEAT (W/m^2)	AVERAGE SHF (W/m^2)	AVERAGE LHF (W/m^2)	AVERAGE EBC (%)	AVERAGE LHF-P (W/m^2)	TOTAL ET (mm)	TOTAL ET-P (mm)	COUNT PEN/ EDDY
87	6	1	25.6	0.97	16.2	0.0	3.443	553.7	344.0	10.1	0.0	0.0	0.0	372.9	0.00	13.30	48/0
87	6	2	27.2	1.63	12.3	0.0	3.054	568.3	349.0	10.9	0.0	0.0	0.0	447.3	0.00	15.95	48/0
87	6	3	26.7	0.92	13.3	0.0	3.100	557.4	341.0	9.9	0.0	0.0	0.0	378.4	0.00	13.53	48/0
87	6	4	27.0	1.95	15.7	0.0	3.419	368.1	183.7	7.5	0.0	0.0	0.0	374.3	0.00	13.39	48/0
87	6	5	28.6	2.87	15.6	2.0	4.196	311.4	142.0	10.3	0.0	0.0	0.0	406.7	0.00	14.49	48/0
87	6	6	20.9	2.12	62.5	4.0	11.075	207.8	111.5	2.1	0.0	0.0	0.0	168.6	0.00	5.97	48/0
87	6	7	23.0	1.44	45.5	0.0	7.877	466.7	310.3	6.2	0.0	0.0	0.0	365.7	0.00	13.00	48/0
87	6	8	25.2	1.75	25.6	0.0	5.381	377.3	214.6	7.2	0.0	0.0	0.0	337.9	0.00	12.02	48/0
87	6	9	25.6	0.86	22.6	0.0	4.742	490.0	303.4	9.2	0.0	0.0	0.0	316.6	0.00	11.28	48/0
87	6	10	27.0	1.91	18.3	0.0	4.069	412.1	228.3	7.4	0.0	0.0	0.0	400.9	0.00	14.32	48/0
87	6	11	28.3	2.27	12.2	0.0	3.272	473.2	269.5	7.4	0.0	0.0	0.0	468.5	0.00	16.73	48/0
87	6	12	28.7	0.83	13.6	0.0	3.477	494.6	289.4	9.5	0.0	0.0	0.0	331.4	0.00	11.86	48/0
87	6	13	30.0	0.97	14.8	0.0	3.893	480.6	279.9	10.9	0.0	0.0	0.0	340.9	0.00	12.22	48/0
87	6	14	30.5	3.84	10.7	0.0	3.223	493.9	282.5	7.7	0.0	0.0	0.0	669.7	0.00	23.93	48/0
87	6	15	25.9	5.35	11.9	0.0	2.857	512.9	301.6	5.1	0.0	0.0	0.0	775.5	0.00	27.53	48/0
87	6	16	25.0	2.20	13.3	0.0	2.961	485.0	280.9	6.1	0.0	0.0	0.0	450.6	0.00	16.02	48/0
87	6	17	27.1	3.79	12.4	0.0	3.135	312.6	133.2	7.1	0.0	0.0	0.0	495.1	0.00	17.60	48/0
87	6	18	26.5	1.58	12.9	0.0	3.145	321.7	142.2	8.9	0.0	0.0	0.0	265.5	0.00	9.44	48/0
87	6	19	27.7	1.93	12.3	0.0	3.191	286.1	110.3	7.6	0.0	0.0	0.0	296.7	0.00	10.58	48/0
87	6	20	27.2	1.94	12.5	0.0	3.166	297.8	120.8	7.9	0.0	0.0	0.0	296.8	0.00	10.57	48/0
87	6	21	28.3	3.85	11.7	0.0	3.168	306.0	126.0	7.1	0.0	0.0	0.0	511.7	0.00	18.22	48/0
87	6	22	27.1	2.12	11.8	0.0	2.989	307.2	126.4	10.1	0.0	0.0	0.0	314.0	0.00	11.17	48/0
87	6	23	26.9	0.70	12.8	0.0	3.043	347.4	161.3	8.1	0.0	0.0	0.0	211.4	0.00	7.56	48/0
87	6	24	30.2	0.68	12.2	0.0	3.443	400.0	206.0	9.9	0.0	0.0	0.0	244.4	0.00	8.75	48/0
87	6	25	31.0	1.52	11.5	0.0	3.350	392.3	196.7	10.1	0.0	0.0	0.0	338.1	0.00	12.11	48/0
87	6	26	29.7	0.68	13.3	0.0	3.777	289.4	29.3	7.7	-8.6	91.7	3.0	97.0	2.59	3.40	47/38
87	6	27	30.7	0.98	15.3	19.7	4.065	553.8	132.2	9.6	1.9	160.7	39.2	218.9	5.76	7.85	48/48
87	6	28	29.9	1.42	13.5	0.0	3.789	472.9	97.7	9.2	-12.5	139.1	45.3	235.2	4.97	8.41	48/48
87	6	29	29.2	1.19	13.1	0.0	3.557	549.9	129.6	8.1	15.9	151.0	58.1	239.6	5.40	8.57	48/48
87	6	30	30.0	2.08	11.3	0.0	3.317	563.8	135.7	6.6	3.7	176.3	71.3	348.6	6.30	12.47	48/48
TOTAL			--	--	--	25.7	--	--	--	--	--	--	--	--	25.02	382.24	
AVERAGE			27.6	1.88	16.7		3.906	421.8	202.6	8.2	0.1	143.7	43.4	357.3	5.00	12.74	

NUMBER OF OBSERVATIONS IN MONTHLY AVERAGE PENMAN-COMBINATION DATA: 30 EDDY-CORRELATION DATA: 5

TOTAL OF ALL DAILY POSITIVE VALUES: 25.05 395.40

AVERAGE DAILY POSITIVE VALUES: 5.01 13.18

The processed output files are stored (see next section) in the form of tables. Three data-table categories are used: 30-minute, day, and month. Examples of these data-tables are shown in tables 2, 3, and 4. The "30-minute" table (table 2) presents the calculated parameters used every 30 minutes during a given day to generate values for the day table, along with some field data that are not used to generate *ET* estimates. It consists of 21 columns. The "day" table (table 3) lists the principal micrometeorological data collected on a given day to generate *ET* estimates and the actual *ET* estimates. It shows the data in the form of 30-minute values, daily totals, and averages. The "month" table (table 4) lists the data collected for a given month, and shows each day's values and monthly totals or averages. Fortran paging commands are used in the formatting to allow each table (with its own header) to start at the top of a new page.

SPECIFICATIONS OF THE STORED DATA ON 3.5-INCH DISKETTES

The original field-data files and processed output files for the study were developed on a Prime computer using a 132 card column format, transferred to microcomputer, and compressed to fit on three 3.5-inch diskettes enclosed in the back pocket of this report. As shown on table 5, a total of 98 files requiring a total of 15.25 megabytes of uncompressed disk space were compressed into five archive files requiring about 4 megabytes of disk space. The file compression was performed using LHarc, Version 1.13c (copyright by Haruyasu Yoshizaki). Included on one of the diskettes is the file compression program LHARC.EXE which can be used to uncompress individual files or all the files in a given archive file after the compressed files are moved to a hard disk drive with sufficient space for the uncompressed files. Also included is the file LHARC.MAN, which contains an explanation manual on how to execute LHarc using an execution command line consisting of a single command, optional switches, and path to where the uncompressed file or files are to reside. The uncompressed files are identical to the original files prior to compression, and are in the American International Standard Code for Information Interchange (ASCII) format. An explanation of the 98 file names and their grouping into library files follows in the next paragraphs.

The field-data files are arranged in 24 monthly data files: 12 for Ash Meadows and 12 for Corn Creek Springs. These files are compressed into the DATA.LZH archive file. A list of these field-data files and their record length is in table 6. These files are labeled with the following naming convention: *AABBBCC.DDD*, where *AA* refers to the location of the monitoring site, *BBB* refers to the month during which data were collected, *CC* refers to the calendar year during which data were collected, and *DDD* refers to the type of file. For example, AMOCT86.DAT contains field data from Ash Meadows during October of 1986. At the top of each field-data file are two card-image records identifying the file.

The processed output files for both the Ash Meadows and Corn Creek Springs sites consist of three output table formats for each month. The processed output files are compressed into the three archive files MIN.LZH, DAY.LZH, and MO.LZH to correspond to the different formats. A listing of these three sets of 24 monthly output files is in table 7. These files are labeled with the following naming convention: *AABBCC.DDD*, where *AA* refers to the location of the monitoring site, *BB* refers to the calendar year during which data were collected, *CC* refers to the month during which data were collected, and *DDD* refers to type of file. For example, CC8610.MIN, CC8610.DAY, and CC8610.MO are the three files that contain the "30-minute", "day", and "month" tables of processed micrometeorological data collected at Corn Creek Springs in 1986 on the tenth month. Two card-image records at the top of each processed file identify the file. These card-image records were entered in the file with the first card-column blank so as not to interfere with the Fortran paging commands if sent to a line printer.

The two program files were compressed into the PGM.LZH archive file. The program file FLD21X.PGM contains the CSI 21X micrologger field-data program shown in appendix A. The program file ETPGM.F77 contains the Fortran program shown in appendix B.

TABLE 5.--*Compressed files on 3.5-inch diskettes*

Name of Compressed files	Number of records and type	Size of uncompressed files (megabytes)
DATA.LZH	24 field-data files	5.58
MIN.LZH	24 "30-minute" files	4.35
DAY.LZH	24 "day" files	5.09
MO.LZH	24 "month" files	.16
PGM.LZH	2 program files	.07
TOTAL	98	15.25

Data were compressed and aggregated using LHarc (copyright by Haruyasu Yoshizaki), a free software program widely used on MS-DOS systems.

TABLE 6.--*Index of field data files on diskettes*

Field site	File name	Record length (number of 80-column card images per file)
Ash Meadows:		
1	AMOCT86.DAT	1,311
2	AMNOV86.DAT	1,386
3	AMDEC86.DAT	1,420
4	AMJAN87.DAT	1,406
5	AMFEB87.DAT	1,312
6	AMMAR87.DAT	2,680
7	AMAPR87.DAT	4,035
8	AMMAY87.DAT	4,025
9	AMJUN87.DAT	4,260
10	AMJUL87.DAT	2,960
11	AMAUG87.DAT	4,600
12	AMSEP87.DAT	4,037
Corn Creek Springs:		
13	CCOCT86.DAT	1,040
14	CCNOV86.DAT	1,366
15	CCDEC86.DAT	1,428
16	CCJAN87.DAT	1,490
17	CCFEB87.DAT	1,340
18	CCMAR87.DAT	2,790
19	CCAPR87.DAT	4,530
20	CCMAY87.DAT	4,116
21	CCJUN87.DAT	4,110
22	CCJUL87.DAT	3,071
23	CCAUG87.DAT	3,876
24	CCSEP87.DAT	5,058

TABLE 7.--*Index of processed data files on diskettes*

Field site	"30-minute" table	"Day" table	"Month" table
<u>Ash Meadows:</u>			
1	AM8610.MIN	AM8610.DAY	AM8610.MO
2	AM8611.MIN	AM8611.DAY	AM8611.MO
3	AM8612.MIN	AM8612.DAY	AM8612.MO
4	AM8701.MIN	AM8701.DAY	AM8701.MO
5	AM8702.MIN	AM8702.DAY	AM8702.MO
6	AM8703.MIN	AM8703.DAY	AM8703.MO
7	AM8704.MIN	AM8704.DAY	AM8704.MO
8	AM8705.MIN	AM8705.DAY	AM8705.MO
9	AM8706.MIN	AM8706.DAY	AM8706.MO
10	AM8707.MIN	AM8707.DAY	AM8707.MO
11	AM8708.MIN	AM8708.DAY	AM8708.MO
12	AM8709.MIN	AM8709.DAY	AM8709.MO
<u>Corn Creek Springs:</u>			
13	CC8610.MIN	CC8610.DAY	CC8610.MO
14	CC8611.MIN	CC8611.DAY	CC8611.MO
15	CC8612.MIN	CC8612.DAY	CC8612.MO
16	CC8701.MIN	CC8701.DAY	CC8701.MO
17	CC8702.MIN	CC8702.DAY	CC8702.MO
18	CC8703.MIN	CC8703.DAY	CC8703.MO
19	CC8704.MIN	CC8704.DAY	CC8704.MO
20	CC8705.MIN	CC8705.DAY	CC8705.MO
21	CC8706.MIN	CC8706.DAY	CC8706.MO
22	CC8707.MIN	CC8707.DAY	CC8707.MO
23	CC8708.MIN	CC8708.DAY	CC8708.MO
24	CC8709.MIN	CC8709.DAY	CC8709.MO

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APPENDIX A.--Field programs used to control micrologger data collection

Program 1. (Eddy-Correlation Program)

```
     *1    (table 1)
     .1    (execution interval-- i.e. 600 samples/minute)
    P92    (set time interval flag for processing)
      0
      5    (process every 5 minutes-- i.e. every 3000 samples)
     10
    P 1    (read wind, temp, and water vapor in millivolts)
      3
     15
      6
     13
      1
      0
    P37    (wind in volts or meters per second)
     13
   .001
     13
    P37    (temp in volts or degrees Celsius)
     14
   .004
     14
    P37    (water vapor in volts for conversion to grams per cubic meter)
     15
   .001
     15
    P62    (obtain means - M(W), M(T), M(V)
      3        and covariances - COV(W,T), COV(W,V) )
      3
      0
      0
      2
      0
   3000
     13
     16
    P37    (OPTIONAL- calculate SHF for field reading)
     19
 (factor)
     21
    P38    (OPTIONAL- divide COV(W,T) by M(V) )
     20
     18
     22
    P37    (OPTIONAL- calculate LHF for field reading)
     22
 (factor)
     22
    P77    (output time as day,hour-minute)
    110
    P70    (output sampled: M(W), M(T), M(V) )
      3
     16
    P78    (use high resolution)
      1
    P70    (output sampled: COV(W,T), COV(W,V) )
      2
     19
```

Output of program 1: Eight columns of information.

01	02	03	04	05	06	07	08
Table ID (No.)	Julian Day (No.)	Time (Hr-Min)	Mean Wind (M(W))	Mean Temp (M(T))	Mean Vapor (M(V))	Covar. for SHF (COV(W,T)	Covar. for LHF (COV(W,V)

Program 2: (Penman Program)

```
   *2    (table 2)
   60    (execution interval-- i.e. 1 sample per minute)
  P01    (read solar radiation, convert to watts per square meter)
    1
    2
    1
    1
(Mult.)
    0
  P01    (read soil-heat flux, convert to watts per square meter)
    1
    2
    2
    2
(Mult.)
    0
  P11    (read temperature, in degrees Celsius)
    1
    3
    1
    3
    1
    0
  P12    (read relative humidity, in percent)
    1
    4
    1
    3
    4
    1
    0
  P03    (read wind speed, convert to meters per second)
    1
    1
    1
    5
(.0127)
    0
  P04    (read wind direction, convert to degrees of north)
    1
   11
    5
    3
    0
    5
    6
(Mult.)
    0
```

```
          P03   (read rain pulse, in milliliters)
            1
            2
            2
            7
            1
            0
          P01   (read net radiation, convert to watts per square meter)
            1
            5
           10
            8
      (Mult.)
            0
          P10   (read battery voltage)
            9
          P92   (set time interval flag for processing)
            0
           30   (process every 30 minutes--i.e. 30 samples per 30 minutes)
           10
          P77   (output time as day,hour-minute)
          110
          P71   (output averages: solar, soil, temp, RH, WS, WD)
            6
            1
          P72   (output totalized: rain)
            1
            7
          P71   (output averages: net radiation)
            1
            8
          P70   (output sampled: battery voltage)
            1
            9
          P73   (output maximum: temp)
            1
           00
            3
          P74   (output minimum: temp)
            1
           00
            3
```

Output of program 2: Fourteen columns of information over two rows.

01	02	03	04	05	06	07	08
Table ID	Julian Day	Time	Solar Rad.	Soil Heat	Temp.	Relative Humidity	Wind Speed

09	10	11	12	13	14
Wind Dir.	Rain	Net Rad.	Battery Voltage	Max. Temp.	Min. Temp.

END

APPENDIX B.--Fortran IV program used to process the field data

```
C     PROGRAM FOR COMPUTING EVAPOTRANSPIRATION - MICHAEL J. JOHNSON

C      CALCULATIONS:  ESTIMATES ACTUAL ET BY EDDY-CORRELATION METHOD USING
C                         DIRECT LATENT-HEAT FLUX MEASUREMENTS.  (ALHF)

C                     ESTIMATES ACTUAL ET BY EDDY-CORRELATION METHOD USING
C                         RESIDUAL LATENT-HEAT FLUX CALCULATED FROM THE
C                         SENSIBLE-HEAT FLUX AND THE ENERGY BUDGET.  (LHFR)

C                     POTENTIAL ET USING PENMAN-COMBINATION EQUATION. (LHFPC)
C                         USES STATE VARIABLES TO CALCULATE ET
C                         CONSIDERING THE FACTORS OF BOTH ENERGY SUPPLY
C                         AND THE TURBULENT (AERODYNAMIC) TRANSPORT OF
C                         WATER AWAY FROM THE EVAPORATING SURFACE.

C                     ESTIMATES POTENTIAL ET BY ESTIMATING RESISTANCE TO
C                         VAPOR TRANSPORT (VTR) AND HEAT TRANSPORT (SHTR)
C                         TO OBTAIN THE 'APPARENT PSYCHROMETER CONSTANT' (APC)
C                         WHICH CAN THEN BE USED IN THE PENMAN-MONTEITH EQUATION.

C                     ESTIMATES MAXIMUM WATER VAPOR FLUX BY USING FICK'S LAW
C                         AND ABOVE CALCULATED VAPOR TRANSPORT RESISTANCE.
C                         (ASSUMES SATURATED WATER VAPOR DENSITY AT
C                         EVAPORATION SURFACE RATHER THAN USING THE ACTUAL
C                         VAPOR DENSITY AT THE EVAPORATION SURFACE IN COMPUTING
C                         THE DIFFERENCE IN THE VAPOR DENSITY WITH THE SURROUNDING
C                         AIR.)   (MWVFF)

C      INPUT:  30 MINUTE PENMAN WEATHER DATA (30 SAMPLES)
C               5 MINUTE EDDY-CORRELATION DATA (3,000 SAMPLES)
C
C      OUTPUT: 30 MIN DATA VALUES           (FORMATED)    - ON WRITE 7
C              30 MIN AND DAILY ET VALUES   (FORMATED)    - ON WRITE 8
C              DAILY AND MONTHLY ET VALUES  (FORMATED)    - ON WRITE 9
C
C
C      USE:    AS INPUT TO SUMMARY PROGRAMS DISPLAYING DAILY AND MONTHLY ET.
C
C************************************************************************
C
      REAL ZMVAP,COVWT,COVWV
      DIMENSION ZMVAP(6),COVWT(6),COVWV(6)
      REAL NRAD,MWIND,MTEMP,MVAP,LHV,LWRAD,LHFPC,LHFR,LHFPM,LHFF
      INTEGER TAB,JDAY,TIME,TABLE,JJDAY,YR,MO,DAY,NCOUNT,ECOUNT,XCOUNT
      INTEGER FLAG,YFLAG,YCOUNT
      DOUBLE PRECISION DD1,DD2,DD3

      READ(5,'(I3)') JJDAY
      READ(5,'(I2)') YR
      READ(5,'(I2)') MO
      READ(5,'(I2)') DAY
      READ(5,'(F15.2)') ALT
      READ(5,'(F15.2)') Z
      READ(5,'(F15.2)') H
      READ(5,'(F15.2)') PC
      READ(5,'(F15.0)') SWITCH
      READ(5,'(F15.4)') X1
      READ(5,'(F15.4)') X2
      READ(5,'(F15.2)') SURFR
```

```
C SET HEADERS & WRITE FIELD VARIABLES FOR WRITE 7 ***
      WRITE(7,9) JJDAY,YR,MO,DAY,ALT,Z,H,PC,SWITCH,X1,X2,SURFR
C
C------------------------------------------------------------------------
C THE FOLLOWING VARIABLES MUST BE CHANGED/VERIFIED BEFORE EACH RUN!
C
C STARTING TIME OF DATA RUN: JULIAN DAY, YEAR, MONTH, DAY
C     JJDAY= 091
C     YR= 87
C     MO= 04
C     DAY=01
C ALTITUDE AT ET STATION, IN FEET: CORN CREEK(CC)= 2990 ; ASH MEADOWS(AM)= 2165
C#    ALT= 2165.
C INSTRUMENT HEIGHT,IN METERS: CC= 2.5 Meters ; AM= 2.0 Meters
C#    Z= 2.0
C CROP CANOPY HEIGHT, IN METERS: CC= 0.8 Meters ; AM=0.3 Meters
C#    H= 0.3
C PERCENTAGE GROUND COVERAGE: CC= 25% ; AM= 100%
C#    PC= 100.
C THE CALIBRATION FACTOR EQUATION, XK, IN BODY OF PROGRAM MUST BE CHANGED
C  BY THROWING A 'SWITCH' >10. OR <10. RESPECTFULLY IF:
C  1) A KRYPTON HYGROMETER IS USED IN PLACE OF A LYMAN-ALPHA HYGROMETER.
C     THE XK IS CALCULATED USING PATH LENGTH AND ABSORPTION COEFFICIENT.
C     FOR S/N #1019   PATH LENGTH=0.912 centimeter          (JUNE,1986)
C                     ABSORP COEF=0.163 cubic meter per gram/centimeter
C                                                           (JUNE,1986)
C#    X1= 0.912
C#    X2= 0.163
C  2) A LYMAN-ALPHA HYGROMETER IS USED IN PLACE OF A KRYPTON HYGROMETER.
C     THE XK IS CALCULATED USING  CALIBRATION VALUES,'A' AND 'B'.
C     FOR S/N #1012     A=-0.0741  B=0.0006   (APRIL,1987)
C     FOR S/N #1013     A=-0.1821  B=0.0033   (APRIL,1987)
C#    X1=-0.0741
C#    X2= 0.0033
C SURFACE REFLECTION (ALBEDO):    CC= .28 ;   AM= .15
C#    SURFR= .15

C------------------------------------------------------------------------
C THE FOLLOWING VARIABLES DO NOT CHANGE:
C
C VON KARMAN'S CONSTANT,DIMENSIONLESS: 0.4
      VON= 0.4
C DEGREES KELVIN
      TK=273.16
C STEPHAN BOLTZMAN CONSTANT:  5.67 E-8  watts per square meter/TK**4
      SBC= 5.67E-08


C THE FOLLOWING PARAMETERS MAY CHANGE:

C SPECIFIC HEAT OF AIR AT 20 DEGREES TC, joules per gram per degree Celsius
      CP=1.005
C     AT OTHER TEMP/HUMID  CP=1.005(1-.84(SPECIFIC HUMIDITY))

C LATENT HEAT OF VAPORIZATION @ 20 DEGREES TC, joules/gram
      LHV=2450.
C     AT OTHER TEMP  LHV=2,500-2.4+.002

C------------------------------------------------------------------------
```

```
C USING THE ABOVE ASSUMPTIONS LET'S CALCULATE:
C ---THE SENSIBLE HEAT TRANSPORT RESISTANCE,SHTR,---
C BY CALCULATING:
C
C --EFFECTIVE CROP CANOPY HEIGHT, IN METERS
      H=H*PC/100.
C --ROUGHNESS PARAMETER FOR MOMENTUM, ZM
C     ASSUME ZM=0.13*H  (CAMPBELL,1977)
      ZM= 0.13*H
C --ROUGHNESS PARAMETER FOR HEAT, ZH
C     ASSUME ZH=ZV=0.2*ZM   (NOTE: ZV= ROUGHNESS PARAM. FOR WATER VAPOR)
      ZH=0.2*ZM
C --ZERO PLANE DISPLACEMENT, D
C     COULD USE: D=0.64*H  FOR DENSE VEGETATION (CAMPBELL,1977); OR
C     LOG D= 0.9793 LOG H -0.1536  FOR VARIED VEGATATION (STANHILL,1969)
      DLG = 0.9793*ALOG10(H)-0.1536
      D = 10.0**DLG
C --THE SENSIBLE HEAT TRANSPORT RESISTANCE IS A FUNCTION OF MEAN WIND SPEED.
C     THUS, SHTR=FUNCTION(WS) = COEFFICIENT*(1/WS)
C     SO LET'S JUST CALCULATE THE COEFFICIENT OF THE FUNCTION AT THIS TIME.
C --SENSIBLE HEAT TRANSPORT RESISTANCE COEFFICIENT, SHTRC
      DD1=(Z-D+ZH)/ZH
      DD2=(Z-D+ZM)/ZM
      SHTRC=(DLOG(DD1)*DLOG(DD2))/VON**2
C THE ABOVE CALCULATIONS SHOULD GIVE THE  SHTR=(SHTRC)/(MEAN WIND SPEED)
C               EXAMPLE          FOR CC:  SHTR= 172.72/(MEAN WIND SPEED)
C               EXAMPLE          FOR AM:  SHTR= 130.64/(MEAN WIND SPEED)
C

C-----------------------------------------------------------------------
C COUNTER TO BE USED TO TERMINATE PROGRAM. WHEN LAST FILE READ PROGRAM
C     STILL NEEDS TO WRITE TO 8 BEFORE ENDING.
      LLL= 1

C END OF DAY FLAG SET TO ZERO AND EDDY DAY SET TO ZERO
      FLAG  = 0
      YFLAG = 0

C DAILY ACCUMULATORS SET TO ZERO FOR WRITE 8
      NCOUNT= 0
      ECOUNT= 0
      CT    = 0.0
      CWS   = 0.0
      CRH   = 0.0
      CR    = 0.0
      CDV   = 0.0
      CSRAD = 0.0
      CNRAD = 0.0
      CSOIL = 0.0
      CASHF = 0.0
      CALHF = 0.0
      CEBC  = 0.0
      CPC   = 0.0
      CET   = 0.0
      CETPC = 0.0
      CETR  = 0.0
      PCET  = 0.0
      PCPC  = 0.0
      PCETR = 0.0
```

```
C AVERAGE DAILY VALUES SET TO ZERO FOR WRITE 8
      ACT   = 0.0
      ACWS  = 0.0
      ACRH  = 0.0
      ACDV  = 0.0
      ACSRAD= 0.0
      ACNRAD= 0.0
      ACSOIL= 0.0
      ACASHF= 0.0
      ACALHF= 0.0
      ACEBC = 0.0
      ACPC  = 0.0
      ACET  = 0.0
      ACETPC= 0.0
      ACETR = 0.0
      APCET = 0.0
      APCPC = 0.0
      APCETR= 0.0

C DAILY ACCUMULATORS SET TO ZERO FOR WRITE 9
      XCOUNT= 0
      YCOUNT= 0
      A1    = 0.0
      A2    = 0.0
      A3    = 0.0
      A4    = 0.0
      A5    = 0.0
      T1    = 0.0
      T2    = 0.0
      T3    = 0.0
      T4    = 0.0
      T5    = 0.0
      T6    = 0.0
      T7    = 0.0
      T8    = 0.0
      T9    = 0.0
      T10   = 0.0
      T11   = 0.0

      AA1   = 0.0
      AA2   = 0.0
      AA3   = 0.0
      AA4   = 0.0
      AT2   = 0.0
      AT3   = 0.0
      AT4   = 0.0
      AT5   = 0.0
      AT6   = 0.0
      AA5   = 0.0
      AT7   = 0.0
      AT10  = 0.0
      AT11  = 0.0

C OUTPUT VALUES SET TO ZERO PRIOR TO EACH RUN:

      WD    = 0.0
      DENA  = 0.0
      WVP   = 0.0
      DENSWV= 0.0
      DENAWV= 0.0
```

```
      SHTR   = 0.0
      VTR    = 0.0
      TPC    = 0.0
      APC    = 0.0
      S      = 0.0
      FU     = 0.0
      MWVFF  = 0.0
      ENERGY= 0.0
      TURBUL= 0.0
      LHFR   = 0.0
      TEMP   = 0.0
      WS     = 0.0
      RH     = 0.0
      RAIN   = 0.0
      DENAWV= 0.0
      SRAD   = 0.0
      NRAD   = 0.0
      SOIL   = 0.0
      ASHF   = 0.0
      ALHF   = 0.0
      EBC    = 0.0
      LHFPC  = 0.0
      EAF    = 0.0
      EFPC   = 0.0
      EFR    = 0.0


C-----------------------------------------------------------------------
C-----------------------------------------------------------------------

C SET HEADERS AT TOP OF PAGE FOR WRITE 7 ***
      WRITE(7,13)

C SET HEADERS AT TOP OF PAGE FOR WRITE 8 ***
      WRITE(8,18)

C SET HEADERS AT TOP OF PAGE FOR WRITE 9 ***
      WRITE(9,25)

C-READ INPUT DATA LINE.
  100 READ (6,10,END=1000) TAB,JDAY,TIME,SRAD,SOIL,TEMP,RH,WS


C CHECK IF NEW DAY HAS STARTED.  IF IT HAS, ACCUMULATE LAST DAY'S INFO.
C     THE CHECK NEEDED IF PENMAN ONLY DATA COLLECTED:
      IF (JJDAY.NE.JDAY.AND.TIME.GE.30) GO TO 211
C     THE CHECK NEEDED IF EDDY AND PENMAN DATA COLLECTED:
      IF (FLAG.EQ.1) GO TO 211
C IF STILL SAME DAY
      GO TO 202


C CALCULATE AVERAGE DAILY VALUES FOR WRITE 8 (& WRITE 9 IF ANY EDDY DATA)
  211 ACT=CT/NCOUNT
      ACWS=CWS/NCOUNT
      ACRH=CRH/NCOUNT
      ACDV=CDV/NCOUNT
      ACSRAD=CSRAD/NCOUNT
      ACNRAD=CNRAD/NCOUNT
      ACSOIL=CSOIL/NCOUNT
      ACPC=CPC/NCOUNT
```

```
      ACETPC=CETPC/NCOUNT
      APCPC=PCPC/NCOUNT
      IF(ECOUNT.EQ.0) GO TO 212
      ACASHF=CASHF/ECOUNT
      ACALHF=CALHF/ECOUNT
      ACEBC=CEBC/ECOUNT
      ACET=CET/ECOUNT
      ACETR=CETR/ECOUNT
      APCET=PCET/ECOUNT
      APCETR=PCETR/ECOUNT

  212 CONTINUE

C END OF DAY.
C PRINT OUT TOTALS, AVERAGES, AND NUMBER OF OBSERVATIONS - WRITE 8 ***
      WRITE(8,21) CR,CET,CETPC,CETR
      WRITE(8,22) ACT,ACWS,ACRH,ACDV,ACSRAD,ACNRAD,ACSOIL,ACASHF,ACALHF,
     *            ACEBC,ACPC,ACET,ACETPC,ACETR
      WRITE(8,23) NCOUNT,ECOUNT
      WRITE(8,31) PCET,PCPC,PCETR,APCET,APCPC,APCETR

C SEND PENMAN DAILY VALUES TO FILE       - WRITE 9  ***
      WRITE(9,26) YR,MO,DAY,ACT,ACWS,ACRH,CR,ACDV,ACSRAD,ACNRAD,ACSOIL,
     *ACASHF,ACALHF,ACEBC,ACPC,CET,CETPC,NCOUNT,ECOUNT

C ACCUMULATE DAILY VALUES OF INTEREST FOR MONTHLY VALUES FOR WRITE 9
      A1=A1+ACT
      A2=A2+ACWS
      A3=A3+ACRH
      T1=T1+CR
      A4=A4+ACDV
      T2=T2+ACSRAD
      T3=T3+ACNRAD
      T4=T4+ACSOIL
      T5=T5+ACASHF
      T6=T6+ACALHF
      A5=A5+ACEBC
      T7=T7+ACPC
      T8=T8+CET
      T9=T9+CETPC

C ACCUMULATE ONLY POSITIVE ET IN millimeters
      T10=T10+PCET
      T11=T11+PCPC

C SET COUNTER FOR ANOTHER DAY FOR WRITE 9
      XCOUNT=XCOUNT+1
      YCOUNT=YCOUNT+YFLAG
      YFLAG = 0

C IF WE HAVE RUN OUT OF INPUT FILES IT IS TIME TO QUIT
      IF (LLL.GT.1) GO TO 1001

C IF WE HAVE MORE FILES, THE DAY HAS ENDED, SO SET DAILY ACCUMULATORS
C     TO ZERO FOR WRITE 8
      FLAG  = 0
      NCOUNT= 0
      ECOUNT= 0
      CT    = 0.0
      CWS   = 0.0
```

```
      CRH   = 0.0
      CR    = 0.0
      CDV   = 0.0
      CSRAD = 0.0
      CNRAD = 0.0
      CSOIL = 0.0
      CASHF = 0.0
      CALHF = 0.0
      CEBC  = 0.0
      CPC   = 0.0
      CET   = 0.0
      CETPC = 0.0
      CETR  = 0.0
      PCET  = 0.0
      PCPC  = 0.0
      PCETR = 0.0

C AVERAGE DAILY VALUES SET TO ZERO FOR WRITE 8
      ACT   = 0.0
      ACWS  = 0.0
      ACRH  = 0.0
      ACDV  = 0.0
      ACSRAD= 0.0
      ACNRAD= 0.0
      ACSOIL= 0.0
      ACASHF= 0.0
      ACALHF= 0.0
      ACEBC = 0.0
      ACPC  = 0.0
      ACET  = 0.0
      ACETPC= 0.0
      ACETR = 0.0
      APCET = 0.0
      APCPC = 0.0
      APCETR= 0.0

C COUNTERS SET FOR NEW DAY FOR WRITE 8
      DAY=DAY+JDAY-JJDAY
      JJDAY=JDAY

C MOVE TO TOP OF PAGE AND SET HEADERS FOR WRITE 7 ***
      WRITE (7,13)
C MOVE TO TOP OF PAGE AND SET HEADERS FOR WRITE 8 ***
      WRITE (8,18)

  202 CONTINUE

C-----------------------------------------------------------------------------
C IDENTIFY IF PENMAN OR EDDY DATA.
      IF (TAB.EQ.1) GO TO 101
      GO TO 444
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------

C-----THIS IS PENMAN DATA
  444 TABLE=2
      READ (6,11) WD,RAIN,NRAD,BAT,TMAX,TMIN

      GO TO 555
C ----------------------------------------------------------------------------
  555 CONTINUE
```

```
C SET NULL ZONE ON WIND DIRECTION TO 999. OR  ZERO
      IF (WD.LE.0.0) WD=00.0

C IS RELATIVE HUMIDITY PROBE WORKING? IF NOT, SKIP PENMAN CALCULATION
      IF(RH.LE.0.0) GO TO 578

C MAKE 30 MINUTE PENMAN CALCULATIONS ( POTENTIAL ET)

C SLOPE OF SATURATION VAPOR DENSITY FUNCTION
      S= 0.337569 + 0.02067*TEMP + 0.000427*TEMP**2 + 0.000011*TEMP**3

C AIR DENSITY    A FUNCTION OF ALTITUDE AND TEMPERATURE
      DENA=(1292.)*(EXP(-(ALT/27000)))*(TK/(TK+TEMP))

C WATER VAPOR PRESSURE
      DD3=TK+TEMP
      WVP=DEXP(52.57633-(6790.4985/DD3)-5.02808*(DLOG(DD3)))

C SATURATED WATER VAPOR DENSITY OF AIR
      DENSWV=WVP/(0.000462*(TK+TEMP))

C ACTUAL WATER VAPOR DENSITY OF AIR
      DENAWV=DENSWV*RH/100.

C SPECIFIC HUMIDITY
      Q=DENAWV/(DENA+DENAWV)

C SPECIFIC HEAT OF AIR
      CP=1.005 * (1.0 - 0.85 * Q)

C LATENT HEAT OF VAPORIZATION, LAMBDA
      LHV=2502. - (2.40 * TEMP)

C THERMODYNAMIC PSYCHROMETER CONSTANT,  (AIR DENSITY * SPECIFIC HEAT OF
C     AIR / LATENT HEAT OF VAPORIZATION)
      TPC=DENA*CP/LHV

C THE WIND FUNCTION, FU, IS THE PRODUCT OF LATENT HEAT OF VAPORIZATION,LHV,
C     TIMES ONE OVER THE SENSIBLE HEAT TRANSPORT RESISTANCE, RH OR SHTR.
C     SINCE SHTR=SHTRC/WS,  THEREFORE FU=LHV/SHTR=LHV*WS/SHTRC .
      FU=LHV*WS/SHTRC
C
C SENSIBLE HEAT TRANSPORT RESISTANCE, Rh or SHTR.
C     (USED FOR PRINT OUT ONLY. - WITH NO WIND IT GIVES A MAX Rh=SHTRC*1000)
C     SINCE SHTR=(SHTRC)/(MEAN WIND SPEED) ,  WE MUST AVOID ZERO DIVIDE
C     ON COMPUTER!
      IWS=WS*1000.0
      IF(IWS.LE.1) WS=0.001
      SHTR=(SHTRC)/(WS)

C IF NET RADIOMETER NOT IN USE, MUST ESTIMATE NET RADIATION.
C    NET RADIATION IS ONE MINUS SURFACE REFLECTANCE TIMES THE DOWNWARD
C    SHORT WAVE SOLAR RADIATION ALL ADDED TO THE NET LONGWAVE RADIATION.
      IF(NRAD .GT. 0.00) GO TO 577

C    ESTIMATE THE NET LONGWAVE RADIATION,LWRAD.
C     THE NET LWRAD IS DIFFERENCE BETWEEN OUTGOING IR TERRESTRIAL RADIATION
C     AND THE DOWNCOMING COUNTER-RADIATION FROM THE ATMOSPHERE.
```

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C         NET LWRAD= SUM OF EARTH AND AIR EMISSIVITY TIMES BLACKBODY RADIATION
C                  = (-Ee + Ea) * (SBC * TEMPkelvin **4)
C         Ee IS ASSUMED TO BE 0.97 OF BLACKBODY
C         Ea can be:  0.72+0.005*TEMPcentigrade     (IDSO-JACKSON,1969)
C                     0.58*DENAWV**0.14286          (BRUTSART,1975)
C                    (SBC*TEMPkelvin**4)*(a-b(WVP)**0.5) (BRUNT,1932)
      LWRAD=((0.58*DENAWV**0.14286)-0.97)*SBC*(TK+TEMP)**4

C     ESTIMATE THE NET RADIATION
      NRAD=(1.0-SURFR)*SRAD + LWRAD
  577 CONTINUE

C LATENT HEAT FLUX - USING: PENMAN COMBINATION EQUATION  (SHTR=VTR)

C     CALCULATE THE ENERGY SUPPLY TERM
      ENERGY=(S/(TPC+S))*(NRAD-SOIL)

C     CALCULATE THE TURBULENT TRANSPORT TERM
      TURBUL=(TPC/(TPC+S))*FU*(DENSWV-DENAWV)

C     PUT BOTH TERMS TOGETHER
      LHFPC=ENERGY+TURBUL

  578 CONTINUE

C DID WE COME FROM EDDY DATA FILE? IF SO, GO BACK.
      IF (TABLE.EQ.1) GO TO 102

C CONVERT watts per square meter TO millimeters per 30 minutes
      EFPC=(LHFPC/LHV)*1.8

C SEND PENMAN 30 minute CALCULATIONS TO FILE  - WRITE 7 ***
      WRITE(7,14) YR,MO,DAY,TIME,TMAX,TMIN,WD,DENA,WVP,DENSWV,DENAWV,
     *            SHTR,TPC,S,FU,ENERGY,TURBUL

C SEND PENMAN 30 minute DATA TO PRINTOUT FILE - WRITE 8 ***
      WRITE (8,19) JDAY,YR,MO,DAY,TIME,TEMP,WS,RH,RAIN,DENAWV,SRAD,NRAD,
     *             SOIL,LHFPC,EFPC

C ACCUMULATE 30 minute VALUES TO MAKE DAILY SUMS FOR WRITE 8 TOTALS
      CT    = CT+TEMP
      CWS   = CWS+WS
      CRH   = CRH+RH
      CR    = CR+RAIN
      CDV   = CDV+DENAWV
      CSRAD = CSRAD+SRAD
      CNRAD = CNRAD+NRAD
      CSOIL = CSOIL+SOIL
      CPC   = CPC+LHFPC
      CETPC = CETPC+EFPC

C ACCUMULATE ONLY POSITIVE ET (millimeters)
      IF(EFPC.GE.0.0) PCPC=PCPC+EFPC

C SET COUNTER FOR ANOTHER 30 minute PENMAN DATA VALUE IN DAY - FOR WRITE 8
      NCOUNT=NCOUNT+1

      GO TO 100
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C
```

```
C-----THIS IS EDDY DATA
  101 TABLE=1
      ZMVAP(1)=TEMP
      COVWT(1)=RH
      COVWV(1)=WS

C READ IN ADDITIONAL EDDY DATA VALUES FOR THE 30 minutes
      DO 111 I=2,6
      READ (6,12) ZMVAP(I),COVWT(I),COVWV(I)
  111 CONTINUE

C READ IN PENMAN DATA FOR SAME 30 MINUTES
      READ (6,10) TAB,JDAY,TIME,SRAD,SOIL,TEMP,RH,WS
      READ (6,11) WD,RAIN,NRAD,BAT,TMAX,TMIN

C CHECK IF NEW DAY HAS STARTED.  IF IT HAS, CONTINUE BUT SET FLAG.
      IF (JJDAY.NE.JDAY) FLAG=1

C GO CALCULATE PENMAN DATA & RETURN
      GO TO 555
  102 CONTINUE

C NOW LETS DETERMINE THE SHF and LHF FOR EACH 5 minutesN
C     THEN TAKE THE AVERAGE FOR THE 30 minutes
      TSHF=0.0
      TLHF=0.0

C NEED TO FIRST DETERMINE IF LYMAN-ALPHA OR KRYPTON HYGROMETER USED
      IF (SWITCH.GE.10.0) GO TO 103

C     LYMAN-ALPHA CONVERSION FACTOR
      XK= 1.0/(X1+2.0*X2*DENAWV)
      GO TO 104
  103 CONTINUE

C     KRYPTON HYGROMETER CONVERSION FACTOR
      XK=1.0/(X1*X2)

  104 CONTINUE
      DO 105 I=1,6
      XSHF=COVWT(I)*DENA*CP
C          WARNING-- ZMVAP(I) COULD BE ZERO -- I.E. IF EDDY EQUIPMENT NOT
C          FUNCTIONING PROPERLY.  WE MUST AVIOD A ZERO DIVIDE ON COMPUTER!
           IZMVAP=ZMVAP(I)*1000.
           IF( IZMVAP .EQ. 0 )  ZMVAP(I)=0.001
      XLHF=COVWV(I)*LHV*XK/ZMVAP(I)
      TSHF=TSHF+XSHF
      TLHF=TLHF+XLHF

  105 CONTINUE
      ASHF=TSHF/6.0
      ALHF=TLHF/6.0

C NOW LETS DETERMINE THE RESIDUAL LATENT-HEAT FLUX, LHFR, FROM THE
C     SENSIBLE-HEAT FLUX AND THE ENERGY BUDGET.

      LHFR=NRAD-SOIL-ASHF

C NOW LETS DETERMINE THE ENERGY-BUDGET CLOSURE  (IN PERCENT)
C     LATENT + SENSIBLE DIVIDED BY NET RADIATION LESS SOIL TIMES 100.
```

```
      EBC= (ALHF+ASHF)/(NRAD-SOIL)*100

C LATENT HEAT FLUX - USING: PENMAN-MONTIETH EQUATION  (SHTR<>VTR)
C     FIRST WE NEED TO DETERMINE THE APPARENT PSYCHROMETER CONSTANT.
C     LET'S USE THE MEASURED LATENT-HEAT FLUX VALUE AND PLACE IT IN THE
C     PEN-MON EQUATION AND SOLVE FOR THE APPARENT PSYCHROMETER CONSTANT
C     WHICH IS THEN EQUATED TO THE THERMODYNAMIC PSYCHROMETER CONSTANT
C     TO SOLVE FOR THE VAPOR TRANSPORT RESISTANCE, RV or VTR.
C     KNOWING 'VTR' ONE CAN NOW SOLVE THE PENMAN-MONTEITH EQUATION FOR
C     ESTIMATED ACTUAL ET FROM WEATHER DATA.

C CHECK LATENT-HEAT FLUX TO SEE IF A NON ZERO VALUE IS PRESENT - IF NOT,
C     SKIP CALCULATION
      IALHF=ALHF*100000.
      IF(IALHF.EQ.0) GO TO 106

C GET APPARENT PSYCHROMETER CONSTANT
      IF (IWS.LE.1) WS=0.0
      APC=((S*(NRAD-SOIL)+(DENA*CP)*(WS/SHTRC)*(DENSWV-DENAWV))/ALHF)-S
      IF (APC.LE.0.0) APC=0.0

C GET VAPOR TRANSPORT RESISTANCE
      VTR=APC*SHTR/TPC
      IF (VTR.LE.0.0) VTR=0.0

C CALCULATE LATENT HEAT FLUX - USING: PENMAN-MONTIETH EQUATION
C     AS EACH VAPOR TRANSPORT RESISTANCE (VTR) WAS DERIVED FROM FIELD
C     MEASURED LATENT HEAT FLUX (ALHF), THE CALCULATED 'LHFPM' SHOULD EXACTLY
C     EQUAL THE 'ALHF' FOR THIS SAME TIME INTERVAL - WHICH IT DOES!
C     -----------------------------------------------------------------------
C     WHAT IS IMPORTANT HERE IS THAT WE NOW HAVE AN ESTIMATE OF WHAT THE VAPOR
C     TRANSPORT RESISTANCE, RV or VTR, IS WHEN EDDY CORRELATION EQUIPMENT IS
C     IN THE FIELD.  THESE 'VTR' VALUES CAN NOW BE USED ALONG WITH THE HEAT
C     TRANSPORT RESISTANCE, SHTR=f(windspeed)=SHTRC/WS,  AND WITH THE
C     THERMODYNAMIC PSYCHROMETER CONSTANT, TPC, TO OBTAIN THE APPARENT
C     PSYCHROMETER CONSTANT, APC,  WHEN JUST THE PENMAN EQUIPMENT IS IN THE
C     FIELD.  THUS GIVING, MAYBE, A BETTER ESTIMATE OF ACTUAL ET THROUGH USE
C     OF THE PEN-MON EQUATION INSTEAD OF USING JUST THE PENMAN EQUATION.
C     THE PENMAN-MONTIETH EQUATION IS:
C           LHFPM=(S*(NRAD-SOIL)+(DENA*CP/SHTR)*(DENSWV-DENAWV))/(APC+S)
C     IN THIS PROGRAM WE ONLY CALCULATE THE 'VTR' AND 'APC' THAT CAN BE USED
C      AND PRINT THEM OUT.
C     --------------------------------------------------------------------------

  106 CONTINUE

C MAXIMUM WATER VAPOR FLUX (MWVFF)- USING: FICK'S EQUATION.
C     FIRST USE FICK'S EQU. TO OBTAIN THE VAPOR FLUX DENSITY (E) IN g/m**2/sec
C     THEN MULTIPLY BY LATENT HEAT OF VAPORIZATION TO GET W/m**2
C
C     (E IS THE DIFFERENCE BETWEEN VAPOR DENSITY AT THE EVAPORATING SURFACE
C      AND THE SURROUNDING AIR DIVIDED BY THE VAPOR TRANSPORT RESISTANCE.
C      HOWEVER, FOR THE VAPOR DENSITY AT THE EVAPORATING SURFACE WE WILL
C      USE THE SATURATED WATER VAPOR DENSITY - GIVING US A MAXIMUM POTENTIAL
C      LATENT HEAT FLUX AS IF THE HIGHEST CONCENTRATION OF WATER VAPOR WERE
C      PRESENT AT THE EVAPORATION SURFACE.)

      IF (VTR.LE.0.0) GO TO 107
      E=(DENSWV-DENAWV)/VTR
      MWVFF=E*LHV
      GO TO 108
  107 LHFF=0.0
  108 CONTINUE
```

```
C CONVERT WATTS PER SQUARE METER - TO - MILLIMETERS PER 30 MINUTES
      EAF =(ALHF /LHV)*1.8
      EFR =(LHFR /LHV)*1.8
      EFPC=(LHFPC/LHV)*1.8
      EFPM=(LHFPM/LHV)*1.8
      EFF =(MWVFF/LHV)*1.8

C SEND EDDY CORRELATION DATA TO FILE - WRITE 7 ***
      WRITE(7,15) YR,MO,DAY,TIME,TMAX,TMIN,WD,DENA,WVP,DENSWV,DENAWV,
     *            SHTR,VTR,TPC,APC,S,FU,MWVFF,ENERGY,TURBUL,LHFR

C SEND EDDY 30 MINUTE DATA TO PRINTOUT FILE - WRITE 8 ***
      WRITE (8,20) JDAY,YR,MO,DAY,TIME,TEMP,WS,RH,RAIN,DENAWV,SRAD,NRAD,
     *             SOIL,ASHF,ALHF,EBC,LHFPC,EAF,EFPC,EFR

C SET COUNTER FOR NUMBER OF 30 MINUTE EDDY'S IN DAY FOR WRITE 8
      ECOUNT=ECOUNT+1

C SET COUNTER FOR ANOTHER 30 MINUTE PENMAN DATA VALUE IN DAY FOR WRITE 8
      NCOUNT=NCOUNT+1

C SET FLAG THAT WE HAVE AN EDDY READING FOR DAY
      YFLAG = 1

C ACCUMULATE 30 MINUTE VALUES TO GET DAILY 30-MINUTE SUMS FOR WRITE 8 TOT/AVE
      CT    = CT+TEMP
      CWS   = CWS+WS
      CRH   = CRH+RH
      CR    = CR+RAIN
      CDV   = CDV+DENAWV
      CSRAD = CSRAD+SRAD
      CNRAD = CNRAD+NRAD
      CSOIL = CSOIL+SOIL
      CASHF = CASHF+ASHF
      CALHF = CALHF+ALHF
      CEBC  = CEBC+EBC
      CPC   = CPC+LHFPC
      CET   = CET+EAF
      CETPC = CETPC+EFPC
      CETR  = CETR+EFR

C ACCUMULATE ONLY POSITIVE ET (millimeter)
      IF(EAF.GE.0.0)   PCET=PCET+EAF
      IF(EFPC.GE.0.0) PCPC=PCPC+EFPC
      IF(EFR.GE.0.0) PCETR=PCETR+EFR

      GO TO 100
C---------------------------------------------------------------------------
C---------------------------------------------------------------------------
 1000 CONTINUE
      LLL=555
      GO TO 211
 1001 CONTINUE

C END OF MONTH FOR WRITE 9

C IF THERE IS NO EDDY DATA, MUST AVOID A ZERO DIVIDE ON COMPUTER!
      NY=YCOUNT
      IF(NY.EQ.0) NY = 1

C AVERAGE SOME OF THE ACCUMULATED VALUES FOR WRITE 9
      AA1=A1/XCOUNT
      AA2=A2/XCOUNT
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```
      AA3=A3/XCOUNT
      AA4=A4/XCOUNT
      AT2=T2/XCOUNT
      AT3=T3/XCOUNT
      AT4=T4/XCOUNT
      AT5=T5/NY
      AT6=T6/NY
      AA5=A5/NY
      AT7=T7/XCOUNT
      AT8=T8/NY
      AT9=T9/XCOUNT
      AT10=T10/NY
      AT11=T11/XCOUNT

C WRITE OUT MONTHLY TOTALS, AVERAGES, AND NO. OF OBSERVATIONS -FOR WRITE 9 ***
      WRITE(9,27) T1,T8,T9
      WRITE(9,28) AA1,AA2,AA3,AA4,AT2,AT3,AT4,AT5,AT6,AA5,AT7,AT8,AT9
      WRITE(9,29) XCOUNT,YCOUNT
      WRITE(9,30) T10,T11,AT10,AT11

C-----------------------------------------------------------------------
C FORMAT STATEMENTS

C OUTPUT TO WRITE 7 'FIELD.VAR' INPUT FILE
    9 FORMAT(1H1/1X,130('-')/T3,'JULIAN',T11,'YEAR',T16,'MONTH',T24,
     *'DAY',T31,'ALTITUDE',T41,'INSTR HT',T50,'CANOPY HT',T61,
     *'GD COVER',T73,'SWITCH',T85,'HYGROM',T95,'HYGROM',T105,
     *'ALBETO'/T34,'(FT)',T46,'(M)',T56,'(M)',T66,'(%)',T84,'CAL CON',
     *T94,'CAL CON',T103,'(DESMAL)'/1X,130('-')/2X,4(I6),2X,5(F10.1),
     *2X,3(F10.4)/1X,130('=')//)

C EXPLANATION OF DATA SYMBOLS USED IN FORTRAN PROGRAM AND OUTPUT FILES
C    8 FORMAT(1X,'OUTPUT FORMAT SYMBOL EXPLANATION'/
C      *T20,'TABLE  - TABLE NUMBER; 1 IS EDDY & 2 IS PENMAN'/
C      *T20,'YR     - YEAR'/
C      *T20,'MO     - MONTH'/
C      *T20,'DAY    - DAY'/
C      *T20,'JDAY   - JULIAN DAY'/
C      *T20,'JU     - JULIAN DAY'/
C      *T20,'TIME   - MILITARY '/
C      *T20,'TEMP   - AVERAGE --  oC'/
C      *T20,'TMAX   - MAXIMUM --  oC'/
C      *T20,'TMIN   - MINIMUM --  oC'/
C      *T20,'WS     - WIND SPEED --  m/s'/
C      *T20,'WD     - WIND DIRECTION --  IN DEGREES OF NORTH'/
C      *T20,'RAIN   - AMOUNT --  ml'/
C      *T20,'RH     - RELATIVE HUMIDITY --  %'/
C      *T20,'###    - data break'/
C      *T20,'DENA   - DENSITY OF AIR --  g/m2'/
C      *T20,'WVP    - WATER VAPOR PRESSURE --  g/m2'/
C      *T20,'DENSWV - DEN. SATURATED WATER VAPOR --  g/m2'/
C      *T20,'DENAWV - DEN. ACTUAL WATER VAPOR --  g/m2'/
C      *T20,'Q      - SPECIFIC HUMIDITY --  DESMAL'//
C      *T20,'CP     - SPECIFIC HEAT OF AIR --  KJ/Kg/oC'/
C      *T20,'LHV    - LATENT HEAT OF VAPORIZATION --  J/g'/
C      *T20,'TPC    - THERMO. PSYCHROMETER CONSTANT --  g/m3/oC'/
C      *T20,'SHTR   - SENSIBLE HEAT TRANSPORT RESIS. --  sec/m '/
C      *T20,'SCHRC  - SHTR * WS = SEN. HEAT TRAN. RESIS. COEFF.'/
C      *T20,'VTR    - VAPOR TRANSPORT RESIS. --  sec/m'/
C      *T20,'APC    - APPARENT PSYCHROMETER CONSTANT --  g/m3/oC'/
C      *T20,'S      - SLOPE FUNCTION --  g/m2/oC'/
C      *T20,'FU     - WIND FUNCTION --  Jm/g/sec'//
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C      *T20,'SRAD   - SOLAR RADIATION --  watts/m2'/
C      *T20,'NRAD   - NET RADIATION --  watts/m2'/
C      *T20,'SOIL   - SOIL HEAT FLUX --  watts/m2'/
C      *T20,'ASHF   - ACTUAL SENSIBLE HEAT FLUX --  watts/m2'/
C      *T20,'ALHF   - ACTUAL LATENT HEAT FLUX --  watts/m2'/
C      *T20,'EBC    - ENERGY BALANCE COEF. --  %'/
C      *T20,'#      - data break '/
C      *T20,'LHFR   - LHF RESIDUAL --  watts/m2'/
C      *T20,'LHFPC  - LHF PEN COMBINATION --  watts/m2'/
C      *T20,'LHFPM  - LHF PEN MONTIETH --  watts/m2'/
C      *T20,'LHFF   - LHF FICK'S EQUATION -- watts/m2'/
C      *T20,'#      - data break'/
C      *T20,'EAF    - EVAP ACTUAL (MEASURED) --  mm/30min'/
C      *T20,'EFR    - EVAP RESIDUAL --  mm/30min'/
C      *T20,'EFPC   - EVAP PEN COMBINATION --  mm/30min'/
C      *T20,'EFPM   - EVAP PEN MONTIETH --  mm/30min'/
C      *T20,'EFF    - EVAP FICK --  mm/30min'/
C      *1x,130('-')//)

C READ IN DATA CARDS
   10 FORMAT(4x,I1,9X,I3,6X,I4,3X,5(2X,F8.2))
   11 FORMAT(2X,6(F8.2,2X))
   12 FORMAT(50X,3(2X,F8.2))

C OUTPUT TO WRITE-7  TOP OF PAGE HEADER
   13 FORMAT(1H1///1X,131('-')/T2,'YR',T5,'MO',T8,'DAY',T11,'TIME',
     *T16,'TMAX',T21,'TMIN',T28,'WD',T33,'DENA',T40,'WVP',T44,'DENSWV',
     *T51,'DENAWV',T60,'SHTR',T71,'VTR',T79,'TPC',T87,'APC',T93,'S',
     *T99,'FU',T104,'MWVFF',T111,'ENERGY',T119,'TURBUL',T129,'LHFR'
     */T16,'(oC)',T21,'(oC)',T27,'(o)',T31,'(g/m3)',T38,'(kPa)',T44,
     *'(g/m3)',T51,'(g/m3)',T60,'(s/m)',T70,'(s/m)',T77,'(  g/m3/oC  )',
     *T95,'(Jm/g/s)',T104,'(W/m2)',T111,'(W/m2)',T119,'(W/m2)',T127,
     *'(W/m2)'/1X,131('-')/)

C OUTPUT TO WRITE-7  PENMAN DATA
   14 FORMAT(T2,I2,T5,I2,T8,I2,T11,I4,T16,F4.1,T21,F4.1,T26,F4.0,T31,
     *F6.1,T38,F5.2,T44,F6.2,T51,F6.2,T58,F7.0,T76,F6.4,
     *T91,F4.2,T96,F6.2,T110,F7.1,T118,F7.1)

C OUTPUT TO WRITE-7  EDDY DATA
   15 FORMAT(T2,I2,T5,I2,T8,I2,T11,I4,T16,F4.1,T21,F4.1,T26,F4.0,T31,
     *F6.1,T38,F5.2,T44,F6.2,T51,F6.2,T58,F7.0,T66,F9.0,T76,F6.4,T83,
     *F7.2,T91,F4.2,T96,F6.2,T102,F7.1,T110,F7.1,T118,F7.1,T126,F7.1)


C OUTPUT TO WRITE-8  TOP PAGE HEADER
   18 FORMAT(1H1//1X,130('-')/T3,'JU',T6,'YR',T9,'MO',T12,'DAY',T16,
     *'TIME',T21,'TEMP',T28,'WIND',T33,'REL-HUM',T42,'RAIN',T47,
     *'VAP-DEN',T55,'SOL-RAD',T63,'NET-RAD',T71,'SOIL-HEAT',T83,
     *'SHF',T91,'LHF',T99,'EBC',T105,'LHF-P',T114,'ET',T120,'ET-P',T127,
     *'ET-R'/T21,'(oC)',T27,'(m/s)',T36,'(%)',T42,'(mm)',T48,'(g/m3)',
     *T56,'(W/m2)',T65,'(W/m2)',T73,'(W/m2)',T81,'(W/m2)',T89,'(W/m2)',
     *T99,'(%)',T105,'(W/m2)',T113,'(mm)',T120,'(mm)',T127,'(mm)'/1X,
     *130('-')/)

C OUTPUT TO WRITE-8  PENMAN DATA
   19 FORMAT(T2,I3,T6,I2,T9,I2,T12,I2,T15,I4,T21,F4.1,T27,F5.2,T34,F5.1,
     *T41,F5.1,T48,F6.3,T56,F6.1,T64,F6.1,T72,F6.1,T104,F6.1,T118,F6.2)

C OUTPUT TO WRITE-8  EDDY DATA
   20 FORMAT(T2,I3,T6,I2,T9,I2,T12,I2,T15,I4,T21,F4.1,T27,F5.2,T34,F5.1,
     *T41,F5.1,T48,F6.3,T56,F6.1,T64,F6.1,T72,F6.1,T80,F6.1,T88,F6.1,
     *T96,F6.1,T104,F6.1,T111,F6.2,T118,F6.2,T125,F6.2)
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C OUTPUT TO WRITE-8  DAILY TOTALS
   21 FORMAT(1X,130('-')/T3,'TOTAL',T40,F6.1,T111,F6.2,T118,F6.2,
     *T125,F6.2)

C OUTPUT TO WRITE-8  DAILY AVERAGES
   22 FORMAT(1X,130('-')/T3,'AVERAGE',T21,F4.1,T27,F5.2,T34,F5.1,
     *T48,F6.3,T56,F6.1,T64,F6.1,T72,F6.1,T80,F6.1,T88,F6.1,T96,
     *F6.1,T104,F6.1,T111,F6.2,T118,F6.2,T125,F6.2)

C OUTPUT TO WRITE-8  DATA COUNT
   23 FORMAT(1X,130('-')/T3,'NO. OF OBSERVATIONS FOR DAY',5X,
     *'PENMAN DATA:',I5,5X,'EDDY DATA:',I5)

C OUTPUT TO WRITE-8 POSITIVE ET (only)
   31 FORMAT(1X/1X,T3,'DAILY TOTAL OF ALL POSITIVE VALUES (only):',
     *T111,F6.2,T118,F6.2,T125,F6.2/T3,
     *'30 MINUTE AVERAGE OF POS. VALUES (only):',
     *T111,F6.2,T118,F6.2,T125,F6.2)

C OUTPUT TO WRITE-9  TOP OF PAGE HEADER
   25 FORMAT(1H1//1X,130('-')/T10,'AVERAGE',T18,'AVERAGE',T26,'AVERAGE',
     *T34,'TOTAL',T41,'AVERAGE',T49,'AVERAGE',T58,'AVERAGE',T67,
     *'AVERAGE',T76,'AVERAGE',T85,'AVERAGE',T94,'AVERAGE',T102,
     *'AVERAGE',T112,'TOTAL',T120,'TOTAL',T127,'COUNT'/T2,'YR',
     *T5,'MO',T8,'DAY',T13,'TEMP',T20,'WIND',
     *T26,'REL-HUM',T35,'RAIN',T41,'VAP-DEN',T49,'SOL-RAD',T58,
     *'NET-RAD',T67,'SOIL-HEAT',T80,'SHF',T89,'LHF',T97,'EBC',T104,
     *'LHF-P',T115,'ET',T121,'ET-P',T127,'PEN/'/T13,'(oC)',
     *T19,'(m/s)',T28,'(%)',T35,
     *'(mm)',T41,'(g/m3)',T50,'(W/m2)',T59,'(W/m2)',T68,'(W/m2)',T77,
     *'(W/m2)',T86,'(W/m2)',T97,'(%)',T103,'(W/m2)',T113,'(mm)',T121,
     *'(mm)',T128,'EDDY'/1X,130('-')/)

C OUTPUT TO WRITE-9  DAILY VALUES
   26 FORMAT(T2,I2,T5,I2,T9,I2,T13,F4.1,T19,F5.2,T26,F5.1,T33,F6.1,
     *T41,F6.3,T49,F7.1,T58,F7.1,T67,F7.1,T76,F7.1,T85,F7.1,T94,F6.1,
     *T102,F7.1,T111,F6.2,T119,F6.2,T127,I2,T129,'/',T130,I2)

C OUTPUT TO WRITE-9  MONTHLY TOTAL VALUES
   27 FORMAT(1X,130('-')/T3,'TOTAL',T32,F7.1,T110,F7.2,T118,F7.2/)

C OUTPUT TO WRITE-9  MONTHLY AVERAGE VALUES
   28 FORMAT(1X,130('-')/T3,'AVERAGE',T13,F4.1,T19,F5.2,T26,F5.1,
     *T41,F6.3,T49,F7.1,T58,F7.1,T67,F7.1,T76,F7.1,T85,F7.1,T94,F6.1,
     *T102,F7.1,T110,F7.2,T118,F7.2/)

C OUTPUT TO WRITE-9  DATA COUNT
   29 FORMAT(1X,130('-')/T3,'NO. OF OBSERVATIONS IN MONTHLY AVERAGE',
     *5X,'PENMAN DATA:',I5,5X,'EDDY DATA:',I5)

C OUTPUT TO WRITE-9  POSITIVE ET ONLY
   30 FORMAT(1X/1X,T3,'TOTAL OF ALL DAILY POSITIVE VALUES (only):',
     *T110,F7.2,T118,F7.2/T3,'AVERAGE DAILY POSITIVE VALUES (only):',
     *T110,F7.2,T118,F7.2)
C-----------------------------------------------------------------------

      END
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