PROGRAM WATBUG

DIMENSION T(481), P(481), PE(481), APE(481), D(481), MON(481), LABEL(18)
1 , DAYS(13), H(481), AE(481), ST(481), DST(481), DEF(481),
2 SUR(481), DY(481)

REAL LAT, INDEX

DATA DAYS/0.0,31.0,28.0,31.0,30.0,31.0,30.0,31.0,31.0,30.0,31.0,
1 30.0,31.0/

******************************************************************

* THIS ALGORITHM WAS DEVELOPED BY C. WILLMOTT AT THE DEPARTMENT
* OF GEOGRAPHY, UNIVERSITY OF DELAWARE IN 1978 IN ORDER TO
* FACILITATE THE CALCULATION OF CLIMATIC WATER BUDGETS. A
* MINIMUM AMOUNT OF DATA (I.E., AIR TEMPERATURE, PRECIPITATION
* AND A FEW INITIAL PARAMETERS) AND NO "LOOK-UP" TABLES ARE
* REQUIRED AS ALL RELATIONSHIPS ARE EXPLICITLY SPECIFIED. THE
* PROGRAM WAS REFINED ON A BURROUGHS' B7700 ALTHOUGH STANDARD
* (ANSI COMPATIBLE) FORTRAN WAS USED. IT SHOULD, THEREFORE, RUN
* WITH FEW OR NO MODIFICATIONS ON MOST MODERATE TO LARGE Sized
* MACHINES. IF PROBLEMS ARE ENCOUNTERED, HOWEVER, USERS ARE
* URGED TO CONTACT THE AUTHOR.

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INITIAL PARAMETERS:

"LABEL" - 72 CHARACTER ALPHANUMERIC PROBLEM TITLE.

"N" - NUMBER OF MONTHS OR DAYS OVER WHICH SOIL MOISTURE
BALANCING IS TO OCCUR. IF N EQUALS ONE BALANCING
DOES NOT OCCUR AND ST(1) MUST BE SPECIFIED.

"NT" - TOTAL NUMBER OF MONTHS OR DAYS OVER WHICH THE WATER BUDGET
IS TO BE CALCULATED.

"KD" - THE DAY OF THE MONTH WHERE THE FIRST CALCULATIONS
ARE TO BEGIN. KD MUST BE LESS THAN OR EQUAL
TO THE NUMBER OF DAYS IN MONTH KM.

"KM" - THE FIRST MONTH OF CALCULATIONS.
KM MUST BE BETWEEN ZERO AND 12.

"KY" - THE FIRST YEAR OF CALCULATIONS. LAST TWO DIGITS ONLY.

"FC" - SOIL WATER HOLDING OR FIELD CAPACITY OF THE TOP (ONLY)
SOIL LAYER IN MM.

"SM" - DETERMINES A RESISTANCE FUNCTION OF SOIL WATER TO REMOVAL
BY EVAPOTRANSPIRATION. BLANK OR ZERO INDICATES THAT THE
AVAILABILITY OF SOIL MOISTURE TO EVAPOTRANSPIRATION WILL
DECLINE LINEARLY WITH THE RATIO OF ACTUAL TO POTENTIAL
MAXIMUM SOIL MOISTURE. ANY OTHER NUMERIC DESIGNATION
WILL RESULT IN AN ALTERNATIVE PROCEDURE WHERE MOISTURE IS
WITHDRAWN AT THE MAXIMUM RATE UNTIL THE ACTUAL/POTENTIAL
RATIO DROPS BELOW 0.7 AT WHICH TIME A LINEAR DECLINE IN
AVAILABILITY IS ASSUMED (SEE MATHER, 1974: 106 - CURVES
C AND G).

"LAT" - THE LATITUDE IN DEGREES.
"DT" - TIME DIFFERENTIAL. BLANK OR ZERO INDICATES MONTHLY CALCULATIONS. ANY OTHER NUMBER CAUSES DAILY CALCULATIONS.
"TUNIT" - DESIGNATES THE UNITS OF AIR TEMPERATURE. 1.0 MEANS THE RAW TEMPERATURE DATA ARE IN DEGREES FAHRENHEIT. 2.0 MEANS DEGREES KELVIN. ANY OTHER NUMERIC DESIGNATION OR A BLANK MEANS DEGREES CELSIUS.
"PUNIT" - UNITS OF PRECIPITATION. 1.0 MEANS THE RAW DATA ARE IN CM. 2.0 MEANS INCHES. 3.0 MEANS HUNDRETHS OF AN INCH. OTHER DESIGNATIONS OR BLANKS MEANS MM.
"ST(1)" - ESTIMATED SOIL MOISTURE CONTENT OF THE TOP SOIL LAYER JUST PRIOR TO THE BEGINNING OF CALCULATIONS. ST(1) ONLY NEEDS TO BE SPECIFIED WHEN BALANCING IS NOT TO BE DONE (SEE NOTE BELOW). ST(1) IS IN MM.
"HEAT" - ESTIMATED HEAT INDEX. IT NEEDS TO BE SPECIFIED ONLY WHEN SOIL MOISTURE BALANCING DOES NOT OCCUR (NOTE: BALANCING SHOULD ONLY BE SPECIFIED FOR PERIODS CONTAINING ONE OR MORE COMPLETE YEARS OF DATA).
"INDEX" - SHOULD BE SET GREATER THAN ZERO WHEN CALCULATIONS FOR A SUBSEQUENT STATION ARE TO FOLLOW THESE. (NOTE: CONTROL PARAMETERS AND DATA MUST BE INCLUDED SEQUENTIALLY IN THE INPUT DATA SET FOR EACH STATION THAT IS TO BE EVALUATED).

READ INITIAL PARAMETERS:
NNN= 0
10 READ(5,1000,END=20,ERR=20) LABEL,N,NT,KD,KM,KY,FC,SM,LAT,DT,
       TUNIT,PUNIT,ST(1),HEAT,INDEX
1       NNN= NNN + 1

ASSUMED PARAMETER VALUES, I.E., WHEN THEY ARE NOT SPECIFIED.
IF (N.EQ.O) N= 1
IF (NT.EQ.O) NT= N
IF (KD.EQ.O.AND.DT.NE.0.O) KD= 1
IF (KD.EQ.O.AND.DT.EQ.0.O) KD= 15
IF (KM.EQ.O) KM= 1

SET THE ARRAY SIZES FOR CALCULATING A SOIL WATER BALANCE.
M= N + 1
CALL THE MAIN SUBPROGRAM WHICH CONTROLS ALL CALCULATIONS.
CALL MAIN(N,NT,M,FC,LAT,KT,DM,DT,HEAT,SM,T,P,PE,APE,D,DAYS,
       H,AE,ST,DST,DEF,SUR,MON,LABEL,TUNIT,PUNIT)

TEST TO SEE IF SUBSEQUENT STATIONS ARE TO BE EVALUATED.
IF (INDEX.GT.0.O) GO TO 10

20 CONTINUE
STOP
1000 FORMAT (18A4,,5I5,9F5.0)
END
C***********************************************************************

II
SUBROUTINE MAIN(N,NT,M,FC,LAT,KD,KM, KY, DT, DY, HEAT, SM, T, P, APE, D, DAYS, H, AE, ST, DST, DEF, SUR, MON, LABEL, TUNIT, PUNIT)

REAL LAT, T(M), P(M), AE(M), APE(M), D(M), DAYS(13), H(M), DY(M), AE(M),
ST(M), DST(M), DEF(M), SUR(M), MON(M), FMT(18), LABEL(18)

DIMENSION OUT(10), SUMM(5), SUMY(5)
INTEGER IND(5)
DATA IND/3,4,8,9,10/

READ THE DATA FORMAT (FMT).
READ(5,1000) FMT

UNIT CORRECTION FACTORS.
C1= 1.0
C2= 1.0
FK= 0.0
IF (TUNIT.EQ.1.0) FK= 32.0
IF (TUNIT.EQ.1.0) C1= 5.0 / 9.0
IF (TUNIT.EQ.2.0) FK= 273.16
IF (PUNIT.EQ.1.0) C2= 10.0
IF (PUNIT.EQ.2.0) C2= 25.4
IF (PUNIT.EQ.3.0) C2= 0.254

READ AIR TEMPERATURE AND PRECIPITATION DATA.
DO 10 I= 1,N
  READ(5,FMT,END=290,ERR=280) T(I),P(I)
  NNN= NNN + 1

UNIT TRANSLATIONS.
T(I)= C1 * (T(I) - FK)
P(I)= C2 * P(I)

CONTINUE

KY= KY + 1900

TEST FOR DAILY, MONTHLY, DAY BY DAY OR MONTH BY MONTH BUDGETING.
IF (DT.NE.O.O.AND.N.EQ.1) GO TO 70
IF (DT.EQ.O.O.AND.N.EQ.1) GO TO 20
IF (DT.NE.O.O) GO TO 60

HERE FOR MONTHLY BALANCING.
CALL DATE(N,M,KD,KM,DY,MON,DT,DAYS)
CALL MATHER(N,M,H,T,HEAT,A,PE,APE,DAYS,LAT,DL,KD,KM,MON,DY)
CALL DIFF(N,M,P,APE,D,DEF)
CALL BAL(N,M,ST,D,FC,SM,SUR,DST,DT,DAYS,KM)
CALL EVAPO(N,M,D,AE,APE,P,DST,DEF)

WRITE MONTHLY INPUT DATA AND RESULTS.

WRITE(6,1010) LABEL
WRITE(6,1020) N,NT,FC,LAT

WRITE(6,1010) LABEL
WRITE(6,1020) N,NT,FC,LAT
C IF (N.EQ.1) GO TO 130
C I= 0
GO TO 40
30 CONTINUE
CALL CONV(SUMY,5,1,5)
WRITE(6,1030) (NINT(SUMY(NK)),NK=1,5)
40 CALL INIT(SUMY,5)
WRITE(6,1040) KY
C KY= KY + 1
WRITE(6,1050)
50 I= I + 1
C C ROUND OFF TO NEAREST WHOLE NUMBER AND GET TOTALS BEFORE WRITING.
C CALL OUTPUT(PE,APE,P,D,ST,DST,AE,DEF,SUR,M,OUT,I)
CALL TOTY(OUT,10,IND,SUMY,5)
CALL CONV(OUT,10,2,10)
OUT(1)= T(I)
IMON= MON(I)
WRITE(6,1060) IMON,OUT(1),(NINT(OUT(NK)),NK=2,10)
IF (I.LT.N.AND.INT(MON(I) + .1) .EQ.12) GO TO 30
IF (I.EQ.N.AND.NT.GT.N) GO TO 130
IF (I.EQ.N) GO TO 290
GO TO 50
C 60 CONTINUE
C*** HERE FOR DAILY BALANCING.
C***
CALL DATE(N,M,KD,KM,DY,MON,DT,DAYS)
CALL MATHER(N,M,H,T,HEAT,A,PE,APE,DAYS,LAT,DL,KD,KM,DT,MON,DY)
CALL DIFF(N,M,P,APE,D,DEF)
CALL BAL(N,M,ST,D,FC,SM,SUR,DST,DT,DAYS,KM)
CALL EVAPO(N,M,D,AE,APE,P,DST,DEF)
WRITE DAILY INPUT DATA AND RESULTS.
C 70 CONTINUE
C WRITE(6,1010) LABEL
WRITE(6,1070) N,NT,FC,LAT
C IF (N.EQ.1) GO TO 190
C I= 0
GO TO 90
80 CONTINUE
CALL CONV(SUMM,5,1,5)
CALL CONV(SUMY,5,1,5)
WRITE(6,1080) (NINT(SUMM(NK)),NK=1,5)
WRITE(6,1030) (NINT(SUMY(NK)),NK=1,5)
90 CALL INIT(SUMY,5)
WRITE(6,1040) KY
KY= KY + 1
GO TO 110
100 CONTINUE
CALL CONV(SUMM,5,1,5)
WRITE(6,1080) (NINT(SUMM(NK)),NK=1,5)
110 CALL INIT(SUMM,5)
WRITE(6,1090) MON(I+1)
WRITE(6,1100)
120 I= I + 1
KD= DY(I)
KM= MON(I)

C ROUND OFF TO NEAREST WHOLE NUMBERS AND GET TOTALS BEFORE WRITING.
C
CALL OUTPUT(PE,APE,P,D,ST,DST,AE,DEF,SUR,M,OUT,I)
CALL TOTM(OUT,10,IND,SUMM,5)
CALL TOTY(OUT,10,IND,SUMY,5)
CALL CONV(OUT,10,2,10)
OUT(1)= T(I)
WRITE(6,1060) KD,OUT(1),(NINT(OUT(NK)),NK=2,10)
IF (I.LT.N.AND.MON(I) .EQ.12.AND.DY(I).EQ.DAYS(KM+1)) GO TO 80
IF (I.LT.N.AND.DY(I) .EQ.DAYS(KM+1)) GO TO 100
IF (I.EQ.N.AND.NT.LE.N) GO TO 290
IF (I.EQ.N) GO TO 190
GO TO 120
***
*** HERE FOR MONTH BY MONTH CALCULATIONS.
***
130 CONTINUE
N1= 0
IF (N.GT.1) N1= 1
C
C GET THE INITIAL SOIL MOISTURE, MONTH AND DAY.
C
IF (N.GT.1) ST(1)= ST(N)
KD= 15
IF (N.GT.1) KM= MON(N) + 1
IF (KM.GE.13) KM= 1
DY(1)= KD
MON(1)= KM
C
C SET INITIAL PARAMETERS.
C
NN= NT - N
IF (N.EQ.1) NN= NT
IF (NNN.EQ.1) NNN= 0
N= 1
LL= 0
M= N + 1
C
C TEST FOR APPROPRIATE LABELS.
C
IF (NNN.EQ.0) GO TO 150
IF (KM.GT.1.AND.N1.EQ.1) GO TO 170
IF (KM.GT.1) GO TO 160
C
140 CONTINUE
C
C WRITE LABELS, YEAR AND LAST YEAR'S TOTALS.
C
CALL CONV(SUMM,5,1,5)
WRITE(6,1030) (NINT(SUMM(NK)),NK=1,5)
150 CALL INIT(SUMY,5)
WRITE(6,1040) KY
KY= KY + 1
160 CONTINUE
WRITE(6,1050)
C READ INPUT DATA AND CALL BUDGET SUBROUTINES.
C
170 LL= LL + 1
IF (NNN.EQ.0) GO TO 180
READ(5,FMT,END=290,ERR=280) T(N),P(N)
T(N)= C1 * (T(N) - FK)
P(N)= C2 * P(N)
180 NNN= NNN + 1
CALL MATHER(N,M,H,T,HEAT,A,PE,APE,DAYS,LAT,DL,KD,KM,DT,MON,DY)
CALL DIFF(N,M,P,APE,D,DEF)
D(N+1)= D(N)
CALL BAL(N,M,ST,D,FC,SM,SUR,DST,DAYS,KM)
ST(N)= ST(N+1)
SUR(N)= SUR(N+1)
DST(N)= DST(N+1)
CALL EVAPO(N,M,D,AE,APE,P,DST,DEF)
C ROUND OFF TO NEAREST WHOLE NUMBER AND GET TOTALS BEFORE WRITING.
C
CALL OUTPUT(PE,APE,P,D,ST,DST,AE,DEF,SUR,M,OUT,N)
CALL TOTY(OUT,10,IND,SUMY,5)
CALL CONV(OUT,10,2,10)
OUT(1)= T(N)
WRITE RESULTS AND GET THE NEXT MONTH.
WRITE(6,1060) KM,OUT(1), (NINT(OUT(NK)),NK=2,10)
CALL DATE(N,M,KD,KM,DY,MON,DT,DAYS)
IF (NN.EQ.LL) GO TO 290
IF (KM.EQ.1) GO TO 140
GO TO 170
C*** HERE FOR DAY BY DAY CALCULATIONS.
C***
190 CONTINUE
N1= 0
IF (N.GT.1) N1= 1
C GET THE INITIAL SOIL MOISTURE, MONTH AND DAY.
C
IF (N.GT.1) ST(1)= ST(N)
IF (N.GT.1) KD= INT(DY(N) + 1.01)
IF (N.GT.1) KM= MON(N)
IF (KD.GT.INT(DAYS(KM+1)+0.1)) GO TO 200
DY(1)= KD
MON(1)= KM
GO TO 210
200 CONTINUE
KM= KM + 1
KD= 1
IF (KM.GE.13) KM= 1
DY(1)= KD
MON(1) = KM
210 CONTINUE
C
C INITAILIZE PARAMETERS.
C
NN = NT - N
IF (N .EQ. 1) NN = NT
IF (NNN .EQ. 1) NNN = 0
N = 1
L = 0
M = N + 1
C
C TEST FOR APPROPRIATE LABELS.
C
IF (NNN .EQ. 0) GO TO 230
IF (KD .NE. 1 .AND. KM .NE. 1) GO TO 260
IF (KD .NE. 1 .AND. KM .NE. 1) GO TO 240

220 CONTINUE
C
C WRITE LABELS, THE YEAR AND MONTH AND LAST YEAR'S OR MONTH'S TOTALS.
C
CALL CONV(SUMM, 5, 1, 5)
CALL CONV(SUMY, 5, 1, 5)
WRITE (6, 1080) (NINT (SUMM(NK)), NK = 1, 5)
WRITE (6, 1030) (NINT (SUMY(NK)), NK = 1, 5)

230 CALL INIT(SUMY, 5)
WRITE (6, 1040) KY
KY = KY + 1
GO TO 250

240 CONTINUE
C
C READ INPUT DATA AND CALL BUDGET SUBROUTINES.
C
L = L + 1
IF (NNN .EQ. 0) GO TO 270
READ (5, FMT, END=290, ERR=280) T(N), P(N)
T(N) = C1 * (T(N) - FK)
P(N) = C2 * P(N)

270 NNN = NNN + 1
C
C ROUND OFF TO NEAREST WHOLE NUMBER AND GET TOTALS BEFORE WRITING.
C
CALL MATHER(N, M, H, T, HEAT, A, PE, APE, DAYS, LAT, DL, KD, KM, DT, MON, DY)
CALL DIFF(N, M, P, APE, D, DEF)
D(N+1) = D(N)
CALL BAL(N, M, ST, D, FC, SM, SUR, DST, DT, DAYS, KM)
ST(N) = ST(N+1)
SUR(N) = SUR(N+1)
DST(N) = DST(N+1)
CALL EVAPO(N, M, D, AE, APE, P, DST, DEF)

CALL OUTPUT(PE, APE, P, D, ST, DST, AE, DEF, SUR, M, OUT, N)
CALL TOTM(OUT, 10, IND, SUMM, 5)
CALL TOTY(OUT, 10, IND, SUMY, 5)
CALL CONV (OUT, 10, 2, 10)
OUT (1) = T(N)
WRITE RESULTS AND GET A NEW DATE.
WRITE (6, 1060) KD, OUT (1), (NINT (OUT (NK)), NK = 2, 10)
CALL DATE (N, M, KD, KM, DY, MON, DT, DAYS)
IF (NN .EQ. L) GO TO 290
IF (KM .EQ. 1 .AND. KD .EQ. 1) GO TO 220
IF (KD .EQ. 1) GO TO 240
GO TO 260
WRITE FINAL MESSAGES AND TOTALS.
NNNN = NNN + 1
WRITE (6, 1110) NNNN
GO TO 300
290 CONTINUE
WRITE (6, 1130)
RETURN
1000 FORMAT (18A4)
1010 FORMAT ('0', 18A4)
1020 FORMAT (///, ' NO. OF MONTHS OVER WHICH BALANCING OCCURS IS ', I5, //)
* TOTAL NO. OF MONTHS EVALUATED IS ', I5, //
* SOIL MOISTURE CAPACITY IS ', F5.1, ' MM ', //
* LATITUDE IS ', F4.1)
1030 FORMAT (///, ' YEARLY TOTALS', 3X, 2I6, 18X, 3I6)
1040 FORMAT (///, ' YEAR IS ', I4)
1050 FORMAT (///, ' MONTH IS ', I2)
1080 FORMAT (///, ' NO. OF DAYS OVER WHICH BALANCING OCCURS IS ', I5, //)
* TOTAL NO. OF DAYS EVALUATED IS ', I5, //
* SOIL MOISTURE CAPACITY IS ', F5.1, ' MM ', //
* LATITUDE IS ', F4.1)
1090 FORMAT (///, ' MONTH IS ', I2)
1100 FORMAT (///, ' DEF SURF', //)
1110 FORMAT (///, ' ERROR ENCOUNTERED IN THE DATA AT RECORD ', I5)
1120 FORMAT (///, ' PROCESSING TERMINATED AFTER RECORD ', I5)
1130 FORMAT ( '1')
END
SUBROUTINE DATE (N, M, KD, KM, DY, MON, DT, DAYS)
REAL DY (M), MON (M), DAYS (13)
GENERATE DAY AND MONTH DESIGNATIONS.
TEST FOR MONTHLY, DAILY, MONTH BY MONTH OR DAY BY DAY
CALCULATIONS.
IF (DT .NE. 0.0 .AND. N .EQ. 1) GO TO 60
IF (DT .EQ. 0.0 .AND. N .EQ. 1) GO TO 50
IF (DT.NE.0.0) GO TO 20

C MONTHLY CALCULATIONS.
KD= 15
KM= KM - 1
IF (KM.LE.0) KM= 0
DO 10 I= 1,N
   KM= KM + 1
   IF (KM.GE.13) KM= 1
   MON(I)= KM
   DY(I)= KD
10 CONTINUE
GO TO 80

C DAILY CALCULATIONS.
20 CONTINUE
K= 1
KD= KD - 1
IF (KD.LE.0) KD= 0
IF (KD.GT.0) K= KD
KM= KM - 1
IF (KM.LE.0) KM= 0
J= 0
30 KM= KM + 1
   IF (KM.GE.13) KM= 1
   IF (KD.GT.INT(DAYS(KM+1)+0.1)) KD= 1
   KMP1D= DAYS(KM+1)
   DO 40 I= K,KMP1D
      J= J + 1
      MON(J)= KM
      DY(J)= I
40 CONTINUE
IF (J.GE.N) GO TO 80
K= 1
GO TO 30

C MONTH BY MONTH CALCULATIONS.
50 CONTINUE
KD= 15
KM= KM + 1
IF (KM.GE.13) KM= 1
DY(N)= KD
MON(N)= KM
GO TO 80

C DAY BY DAY CALCULATIONS.
60 CONTINUE
KD= KD + 1
DY(N)= KD
MON(N)= KM
IF (KD.GT.INT(DAYS(KM+1)+0.1)) GO TO 70
GO TO 80
70 CONTINUE
KM= KM + 1
KD= 1
IF (KM.GE.13) KM= 1
DY(N) = KD
MON(N) = KM
80 CONTINUE
RETURN
END

C******************************************************************************
SUBROUTINE MATHER(N,M,H,T,HEAT,A,PE,APE,DAYS,LAT,DL,KD,KM,DT,MON,

REAL LAT, H(M), T(M), PE(M), APE(M), DAYS(13), MON(M), DY(M)

C CALCULATE POTENTIAL EVAPOTRANSPIRATION.
C WHEN LAT IS GREATER THAN 50 DEGS, THE DAYLENGTH CORRECTION
C REMAINS EQUAL TO THAT FOR 50 DEGS. ALAT IS, THEREFORE,
C USED AS THE ARGUMENT FOR SUBROUTINE DAY.
C
ALAT = LAT
IF (ALAT.GE.50.0) ALAT = 50.0

C CALCULATE THE HEAT INDEX DURING BALANCING ON THE FIRST CALL
OF MATHER. ON THE SECOND CALL, GO DIRECTLY TO "PE" CALCULATIONS.
IF (N.LT.12) GO TO 40
IF (N.LT.365.AND.DT.NE.0.0) GO TO 40
XN = N
HEAT = 0.0
DO 30 I = 1,N
   IF (T(I).LE.0.0) GO TO 10
   H(I) = (T(I) / 5.0) ** 1.514
   GO TO 20
10   H(I) = 0.0
20   CONTINUE
HEAT = HEAT + H(I)
30 CONTINUE

C ADJUST "HEAT" FOR BUDGETS GREATER THAN A YEAR.
HEAT = HEAT * 12.0 / XN
NOTE: "A" IS AN EMPIRICALLY
C DERIVED EXPONENT BASED UPON "HEAT".

40 CONTINUE
A = 6.75 / 10.0 ** 7.0 * HEAT ** 3.0-7.71 / 10.0 ** 5.0 * HEAT ** 1.0+1.79 / 10.0 ** 2.0 * HEAT+0.49

C GET INITIAL MONTHLY PE, I.E. BASED UPON 30 DAYS IN A MONTH AND 12 HOURS IN A DAY.
NOTE: PE(I) AND APE(I) ARE CALCULATED IN MM/MONTH OR DAY.

C DO 70 I = 1,N
   IF (T(I).LE.0.0) GO TO 50
   PE(I) = 16.0 * (10.0 * T(I) / HEAT) ** A
    GO TO 70
50   CONTINUE
C CORRECT FOR TEMPERATURES GREATER THAN 26.5 DEG C.
C SEE THORNTONHAITE (1948) FOR EXPLANATION.
IF (T(I) .GE. 26.5) PE(I) = (-415.8547 + 32.2441 * T(I) - 0.4325 * T(I)**2.0)

C CORRECT PE(I) FOR DAILY CALCULATIONS.

IF (DT.NE.0.0) PE(I) = PE(I) / 30.0
GO TO 60
50 PE(I) = 0.0
60 CONTINUE
KD = DY(I)
KM = MON(I)
ADJUST PE FOR DAYLENGTH AND THE NUMBER OF DAYS IN A MONTH.

CALL DAY(DAYS, ALAT, KD, KM, DT, DECD, DL)
APE(I) = PE(I) * (DAYS(KM + 1) / 30.0) * (DL / 12.0)

70 CONTINUE
RETURN
END

C***********************************************************************

SUBROUTINE DAY(DAYS, LAT, KD, KM, DT, DECD, DL)
REAL DAYS(13)
REAL LAT


X = 0.0
DO 10 I = 1, KM
X = X + DAYS(I)
CONTINUE
SUM = X + KD
DAYL = SUM - 80.0
IF (DAYL.LE.0.0) DAYL = 285.0 + SUM

C CALCULATE THE DECLINATION.
DECD = 23.45 * SIN(DAYL / 365.0 * 6.2832)
DECER = DECD * 0.017453

C CALCULATE THE NUMBER OF HOURS OF DAYLIGHT CORRESPONDING TO DAY KD AND MONTH KM (SEE SELLERS, 1965).

CZ = COS(1.5708 + 0.017453 * (50.0 / 60.0))
ALAT = LAT * 0.017453
XX = COS(DECER) * COS(ALAT)
IF (XX.LE.0.0) GO TO 20
CSH = (CZ - SIN(DECER) * SIN(ALAT)) / XX
H = ACOS(CSH)
DL = 24.0 * H / 3.1416
GO TO 30

C ERROR MESSAGE - DIVIDE BY ZERO OR LESS.

20 WRITE(6,1000)
CONTINUE
RETURN
1000 FORMAT ('0', ' ERROR - DIVIDE BY ZERO OR LESS - LAT. ', //, *
' OR THE DECLINATION IS PROBABLY INCORRECT ')
END

SUBROUTINE DIFF(N,M,P,APE,D,DEF)
REAL P(M),APE(M),D(M),DEF(M)
DO 10 I= 1,N
    D(I)= P(I) - APE(I)
    IF (D(I).LT.0.0) DEF(I)= D(I)
10 CONTINUE
RETURN
END

SUBROUTINE BAL(N,M,ST,D,FC,SM,SUR,DST,DT,DAYS,KM)
REAL ST(M),D(M),SUR(M),DST(M),DAYS(13)
DO 80 I= INIT,NP1
    L=I-1
    IF(IFLAG.EQ.1) L= N
    IF(ST(L).GE.FC)ST(L)=FC
    IF (D(I).GE.O.O) GO TO 50
70 TEST FOR MONTHLY OR DAILY WITHDRAWAL.
    IF (DT.NE.O.O) GO TO 30
    WITHDRAWAL FOR MONTHLY BUDGETS (NOTE: THIS IS DONE ON
    AN APPROXIMATE DAY BY DAY BASIS).
    X1= ST(L)
    DO 20 J= 1,30
        SX= ST(L)
        ST(I)= ST(L) + D(I) * RATIO(SX,FC,SM) / 30.0
20 CONTINUE
15 CONTINUE
80 I= INIT,NP1
    L=I-1
    IF(IFLAG.EQ.1) L= N
    IF(ST(L).GE.FC)ST(L)=FC
    IF (D(I).GE.O.O) GO TO 50
70 TEST FOR MONTHLY OR DAILY WITHDRAWAL.
    IF (DT.NE.O.O) GO TO 30
    WITHDRAWAL FOR MONTHLY BUDGETS (NOTE: THIS IS DONE ON
    AN APPROXIMATE DAY BY DAY BASIS).
    X1= ST(L)
    DO 20 J= 1,30
        SX= ST(L)
        ST(I)= ST(L) + D(I) * RATIO(SX,FC,SM) / 30.0
20 CONTINUE
15 CONTINUE

ST(L) = ST(I)

IF (ST(L) .LE. 0.1) ST(L) = 0.1

20 CONTINUE
ST(L) = X1
GO TO 40

30 CONTINUE

C WITHDRAWAL FOR DAILY BUDGETS.

SX = ST(L)
ST(I) = ST(L) + RATIO(SX, FC, SM) * D(I)

40 CONTINUE
IF (ST(I) .LE. 0.1) ST(I) = 0.1
GO TO 70

50 CONTINUE
ST(I) = ST(L) + D(I)
IF (ST(I) .GE. FC) GO TO 60
SUR(I) = 0.0
GO TO 70

60 SUR(I) = ST(I) - FC
ST(I) = FC

70 CONTINUE
DST(I) = ST(I) - ST(L)
IF (D(I) .LE. 0.0) SUR(I) = 0.0
IF (IFLAG .EQ. 0) GO TO 80
Z = ST(I)
GO TO 10

80 CONTINUE

IF (N .EQ. 1) GO TO 100

K = K + 1

C TESTS FOR BALANCES

IF (K .GT. 50) GO TO 100
XX = ABS(ST(N + 1) - ST(I))
ZZ = ABS(Z - ST(I))
IF (XX .LT. 1.0 .AND. ZZ .LE. 1.0) GO TO 100
IF (XX .LT. 1.0) GO TO 90
ST(I) = ST(N + 1)
GO TO 10

90 CONTINUE

C INITIALIZATION FOR SECONDARY BALANCING

IFLAG = 1
INIT = 1
NP1 = 1
GO TO 15

100 CONTINUE

RETURN
END

C******************************************************************************
SUBROUTINE EVAPO(N, M, D, AE, APE, P, DST, DEF)
REAL D(M), AE(M), APE(M), P(M), DST(M), DEF(M)
C
XIII
CALCULATE ACTUAL EVAPOTRANSPIRATION AND DEFICIT.

DO 10 I = 1, N
   AE(I) = APE(I)
   IF (D(I) .LT. 0.0) AE(I) = P(I) + ABS(DST(I))
   DEF(I) = APE(I) - AE(I)
10 CONTINUE
RETURN
END

C***********************************************************************
SUBROUTINE INIT(SUM, N)
DIMENSION SUM(N)
C
I = 0
10 I = I + 1
SUM(I) = 0.0
IF (I.LT.N) GO TO 10
RETURN
END
C***********************************************************************
SUBROUTINE OUTPUT(PE, APE, P, D, ST, DST, AE, DEF, SUR, M, OUT, L)
DIMENSION PE(M), APE(M), P(M), D(M), ST(M), DST(M), AE(M), DEF(M), SUR(M)
1 OUT(2) = PE(L)
   OUT(3) = APE(L)
   OUT(4) = P(L)
   OUT(5) = D(L)
   OUT(6) = ST(L)
   OUT(7) = DST(L)
   OUT(8) = AE(L)
   OUT(9) = DEF(L)
   OUT(10) = SUR(L)
RETURN
END
C***********************************************************************
SUBROUTINE TOTM(X, N, IND, SUM, NN)
DIMENSION SUM(NN), IND(NN), X(N)
C
I = 0
10 I = I + 1
J = IND(I)
SUM(I) = SUM(I) + X(J)
IF (I.LT.NN) GO TO 10
RETURN
END
C***********************************************************************
SUBROUTINE TOTY(X, N, IND, SUM, NN)
DIMENSION SUM(NN), IND(NN), X(N)
C
I = 0
10 I = I + 1
J = IND(I)
SUM(I) = SUM(I) + X(J)
IF (I.LT.NN) GO TO 10
RETURN
END

XIV
J = IND(I)
SUM(I) = SUM(I) + X(J)
IF (I.LT.NN) GO TO 10
RETURN
END

SUBROUTINE CONV(X,NUM,MIN,MAX)
DIMENSION X(NUM)

I = MIN - 1
10 I = I + 1
IF (X(I).EQ.0.0) GO TO 20
Y = ABS(X(I))
J = X(I) / Y
K = Y + 0.5
X(I) = K * J
IF (I.LT.MAX) GO TO 10
RETURN
END

FUNCTION RATIO(SX,FC,SM)
SELECT A FUNCTION THAT DESCRIBES THE RESISTANCE OF SOIL WATER TO REMOVAL BY EVAPOTRANSPIRATION
IF (SM) 10, 10, 20
10 RATIO = SX / FC
RETURN
20 RATIO = SX / (0.7 * FC)
IF (RATIO.GE.1.0) RATIO = 1.0
RETURN
END
TABLE 2.1: AVERAGE CLIMATIC WATER BUDGET AT HAMBANTOTA

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TABLE 2.2: AVERAGE CLIMATIC WATER BUDGET AT MANNAR

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TABLE 2.3a: AVERAGE CLIMATIC WATER BUDGET AT TISSAMAHARAMA

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TABLE 2.3 b: AVERAGE CLIMATIC WATER BUDGET AT PUTTALAM

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### Appendix - III

#### Table 3.1: Average Linkage (Between Groups)

**Agglomeration Schedule**

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Appendix IV

Table 4.1: Checklist for drought impact assessment

1) **Economic Impacts**

★ Costs and losses to agricultural production
- Annual and perennial crop losses
- Damage to crop quality
- Income loss for farmers due to reduced crop yields
- Reduced productivity of cropland.
- Insect infestation
- Plant disease
- Wildlife damage to crops
- Increased irrigation costs
- Cost of new or supplemental water resource development (wells, dams, pipelines)

★ Costs and losses to livestock production
- Reduced productivity of rangeland
- Reduced milk production
- Forced reduction of foundation stock
- Closure/limitation of public lands to grazing
- High cost/unavailability of water for livestock
- Cost of new or supplemental water resource development (wells, dams, pipelines)
- High cost/unavailability of feed for livestock
- Increased feed transportation costs
- High livestock mortality rates
- Disruption of reproduction cycles (delayed breeding)
- Decreased stock weights
- Increased predation of forest range fire

★ Loss from timber production
- Wild land fires
- Tree diseases
- Insect infestation
- Impaired productivity of forest land
- Direct loss of trees, especially young ones

★ Loss from fishery production
- Damage to fish habitat
- Loss of fish and other aquatic organisms due to decreased flows

★ General economic effects
- Decreased land prices
- Loss to industries directly dependent on agricultural production (e.g., machinery and fertilizer manufacturers, food processors, dairies, etc.)
- Unemployment from drought-related declines in production
- Strain on financial institutions (foreclosures, more credit risk, capital shortfalls)
- Revenue losses to federal, state, and local governments (from reduced tax base)
- Reduction of economic development
- Fewer agricultural producers (due to bankruptcies, new occupations)
- Rural population loss

XXIV
2) **Environmental Impacts**

- **Damage to animal species**
  - Reduction and degradation of fish and wildlife habitat
  - Lack of feed and drinking water
  - Greater mortality due to increased contact with agricultural producers, as animals seek food from farms and producers are less tolerant of the intrusion
  - Disease
  - Increased vulnerability to predation (from species concentrated near water)
  - Migration and concentration (loss of wildlife in some areas and too many wildlife in other areas)
  - Increased stress to endangered species
  - Loss of biodiversity

- **Hydrological effects**
  - Lower water levels in reservoirs, lakes, and ponds
  - Reduced flow from springs
  - Reduced stream flow
  - Loss of wetlands
  - Estuarine impacts (e.g., changes in salinity levels)
  - Increased groundwater depletion, land subsidence, reduced recharge
  - Water quality effects (e.g., salt concentration, increased water temperature, pH, dissolved oxygen, turbidity)

- **Damage to plant communities**
  - Loss of biodiversity
  - Loss of trees from urban landscapes, shelterbelts, wooded conservation areas
  - Increased number and severity of fires
  - Wind erosion of soils, reduced soil quality
  - Air quality effects (e.g., dust, pollutants)
  - Visual and landscape quality (e.g., dust, vegetative cover, etc.)
3) **Social Impact**

★ **Health**
- Mental and physical stress (e.g., anxiety, depression, loss of security, domestic violence)
- Health-related low-flow problems (e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations, reduced fire-fighting capability, etc.)
- Reductions in nutrition (e.g., high-cost food limitations, stress-related dietary deficiencies)
- Loss of human life (e.g., from heat stress, suicides)
- Public safety from forest and range fires
- Increased respiratory ailments
- Increased disease caused by wildlife concentrations

★ **Increased conflicts**
- Water user conflicts
- Political conflicts
- Management conflicts
- Other social conflicts (e.g., scientific, media-based)

★ **Reduced quality of life, changes in lifestyle**
- Increased poverty in general
- Population migrations (rural to urban areas, migrants into the United States)
- Loss of aesthetic values
- Reduction or modification of recreational activities

★ **Disruption of cultural belief systems** (e.g., religious and scientific views of natural hazards)

★ **Re-evaluation of social values** (e.g., priorities, needs, rights)

★ **Public dissatisfaction with government drought response**

★ **Perceptions of inequity in relief, possibly related to socio-economic status, ethnicity, age, gender, seniority**

★ **Loss of cultural sites**

★ **Increased data/information needs, coordination of dissemination activities**

★ **Recognition of institutional restraints on water use**

Source: National Drought Mitigation Center, US, 2002