```
C     C E R E S   W H E A T   N I T R O G E N   M O D E L
C
C      MARCH 1986
C
C
C     CERES WHEAT MODEL
C     DEVELOPED BY RITCHIE,NIX.FISCHER,SPEIRTZ,MEYER,GALLAGHER
C     DYKE,KIRBY OTTER AND OTHERS
C
C     NITROGEN ROUTINES DEVELOPED BY GODWIN,JONES, ET AL
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'COMIBS.BLK'
      INCLUDE 'PREDOB.BLK'
      LOGICAL IECHON
      CHARACTER*1 IECHC,IEHVC,IFIN
      NSENS = 0
      NREP = 0
      NOUT0 = 40
      NOUT1 = 41
      NOUT2 = 42
      NOUT3 = 43
      NOUT4 = 44
      KOUTWA = 7
      KOUTGR = 7
      KOUTNU=7
      OPEN (UNIT = NOUT0,FILE = 'SIM.DIR',STATUS='NEW')
100   FORMAT(' C E R E S   W H E A T   M O D E L ',/.
     1 '  VERSION 1.00 INCORPORATING STANDARDIZED I/O',//)
      WRITE(*,100)
      PAUSE ' <CR> TO CONTINUE'
C
C     SIMULATION LOOP
C
200   NREP=NREP+1
      IRET=0
      CALL IPEXP
300   WRITE (*.400)
400   FORMAT(30(/),2X,'RUN-TIME OPTIONS? ',
     1       //2X.'0)   RUN SIMULATION.'.
     2        /2X,'1)   SELECT SIMULATION OUTPUT FREQUENCY.',
     3        /2X.'2)   MODIFY SELECTED MODEL VARIABLES INTERACTIVELY.',
     4       //2X,'<=== CHOICE? [ DEFAULT = 0 ]')
      READ (*.500) NSENS
500   FORMAT(I2)
      IF (NSENS .LT. 0 .OR. NSENS .GT. 2) GO TO 300
      IF (NSENS .EQ. 0 .OR. NSENS .EQ. 2) GO TO 600
      IF (NSENS .EQ. 1) CALL IPFREQ
      GO TO 300
600   CONTINUE
      WRITE (*.700)
700   FORMAT(T21.'<=== ENTER UP TO HERE RUN IDENTIFIER, ',
     1'<CR> FOR NONE.')
      READ (*.800) TITLER
800   FORMAT(A20)
      CALL IPTRT
      CALL IPWTH
      CALL IPSWIN
900   IFIRST=1
      WRITE(*,1000)
1000  FORMAT(' DO YOU WANT INPUT DATA ECHOED TO SCREEN (Y/N)?')
      READ(*.1200)IECHC
      IF(IECHC.EQ.'Y'.OR.IECHC.EQ.'Y')IECHON=.TRUE.
```

```
      SWDF1=1.0
      SWDF2=1.0
      SWDF3=2.0
      ICSDUR=0
      JHEAD=0
      KHEAD=0
      NDEF1=1.0
      NDEF2=1.0
      NDEF3=1.0
      NDEF4=1.0
      IF (ISWNIT.EQ.0) GO TO 200
      TANC=0.0
      RANC=0.0
      TOPSN=0.0
      ROOTN=0.0
      GNP=0.0
      TNUP=0.0
      NHDUP=0
200   IF(ISWSWB.EQ.0)KOUTWA=0
      CALL OPSEAS
      JDATEX=367
      CUMDTT=0.
      SUMDTT=0.
      DTT=0.
      CRAIN=0.
      PRECIP=0.
      RETURN
      END
C
C     ********** SUBROUTINE TO READ AND INITIALIZE SOIL INFORMATION ****
C
      SUBROUTINE SOILRI
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'NTRC2.BLK'
      INCLUDE 'NMOVE.BLK'
      INCLUDE 'COMIBS.BLK'
C
      IF(U.EQ.0.)U=6.0
      SWR=(SW(1)-LL(1))/(DUL(1)-LL(1))
      IF (SWR.LT.0.) SWR=0.
      IF (SWR.GE..9) GO TO 100
      SUMES2=25-27.8*SWR
      SUMES1=U
      T=(SUMES2/3.5)**2
      GO TO 200
100   SUMES2=0.
      SUMES1=100-SWR*100
      T=0.
200   CONTINUE
      XX=0.
      TSW=0.
      TDUL=0.
      TLL=0.
      TSAT=0.
      CUMDEP=0.
      IDRSW=0
      DO 300 L=1,NLAYR
           ESW(L)=DUL(L)-LL(L)
           CUMDEP=CUMDEP+DLAYR(L)
           TLL=TLL+LL(L)*DLAYR(L)
           IF(SW(L).GT.DUL(L))IDRSW=1
           WX=1.016*(1.-EXP(-4.16*CUMDEP/DEPMAX))
```

```
          WRN(I)=EXP(-3.0*DEPTH/DEPMAX)
          WSUM=WSUM+WRN(I)
          NOUT(I)=0.0
          NUP(I)=0.0
200   CONTINUE
      DO 300 I=1,NLAYR
          FACTOR=WRN(I)/WSUM
          FOM(I)=ROOT*FACTOR
          FON(I)=RNKG*FACTOR
300   CONTINUE
      DEPTH=0.0
      IOUT=1
      DO 400 I=1,NLAYR
          HOLD=DEPTH
          DEPTH=DEPTH+DLAYR(I)
          IF(SDEP.LE.DEPTH)THEN
              FR=(SDEP-HOLD)/SDEP
              IF (I.EQ.1)FR=1
              IOUT=2
          ELSE
              FR=DLAYR(I)/SDEP
          ENDIF
          ADD=STRAW*FR
          FOM(I)=FOM(I)+ADD
          FON(I)=FON(I)+ADD*0.40/SCN
          GO TO (400,500), IOUT
400   CONTINUE
500   TIFOM=0.0
      TIFON=0.0
      DO 600 I=1,NLAYR
          HUM(I)=OC(I)*1.E03*BD(I)*DLAYR(I)/0.4
          TIFOM=TIFOM+FOM(I)
          TIFON=TIFON+FON(I)
600   CONTINUE
      DMINR=8.3E-05
      IF(DMOD.NE.0.) DMINR=DMINR*DMOD
      DO 700 L=1,NLAYR
          FAC(L)=1.0/(BD(L)*1.E-01*DLAYR(L))
          SNO3(L)=NO3(L)/FAC(L)
          SNH4(L)=NH4(L)/FAC(L)
          NHUM(L)=OC(L)*DLAYR(L)*BD(L)*1.E02-(SNO3(L)+SNH4(L))
          FPOOL(L,1)=FOM(L)*0.20
          FPOOL(L,2)=FOM(L)*0.70
          FPOOL(L,3)=FOM(L)*0.10
700   CONTINUE
      OBTMX=TAV+AMP/2.0
      OBTMN=TAV-AMP/2.0
      OBSOL=450
      HDAY=200.
      IF (LAT.LT.0.)HDAY=20.
      CUMDEP=0.
      TBD=0.
      DO 800 L=1,NLAYR
          Z(L)=CUMDEP+DLAYR(L)*5.0
          CUMDEP=CUMDEP+DLAYR(L)*10.0
800   TBD=TBD+BD(L)
      ABD=TBD/FLOAT(NLAYR)
      F=ABD/(ABD+686.*EXP(-5.63*ABD))
      DP=1000.+2500.*F
      WW=.356-.144*ABD
      B=ALOG(500./DP)
      TMN=(OBTMX+OBTMN)*0.5
      TAV=TMN
      ALBEDO=SALB
      TMA(1)=(1-ALBEDO)*(TMN+(OBTMX-TMN)*SQRT(OBSOL/800.))
      ATOT=5.0*TMA(1)
```

```
          WRITE (NOUT1.1500) JDAY(J).AIRR(J)
          IF(IECHON)WRITE (*.1500) JDAY(J),AIRR(J)
600   CONTINUE
      DL1=0.0
      ANO3=0.0
      ANH4=0.0
      TDUL=0.0
      TSAT=0.0
      TSW=0.0
      TPESW=0.0
      IF(IECHON)THEN
          WRITE (*    .700) PEDON
          WRITE (*.1300) SALB,U,SWCON,CN2
          WRITE (*,1600)
      ENDIF
      WRITE (NOUT1,700) PEDON
700   FORMAT(/6X,'SOIL PROFILE DATA [ PEDON: ',A12,' ]')
      WRITE (NOUT1,1300) SALB,U,SWCON,CN2
      WRITE (NOUT1,1600)
      DO 800L = 1, NLAYR
          DL2=DL1+DLAYR(L)
          ANO3=ANO3+SNO3(L)
          ANH4=ANH4+SNH4(L)
          TDUL=TDUL+DUL(L)*DLAYR(L)
          TPESW=TPESW+(DUL(L)-LL(L))*DLAYR(L)
          TSW=TSW+SW(L)*DLAYR(L)
          TSAT=TSAT+SAT(L)*DLAYR(L)
          WRITE (NOUT1,1700) DL1,DL2,LL(L),DUL(L),SAT(L),ESW(L),SW(L),
     1WR(L),NO3(L),NH4(L)
          IF(IECHON)WRITE (*.1700) DL1,DL2,LL(L),DUL(L),SAT(L)
     1 ,ESW(L),SW(L),WR(L),NO3(L),NH4(L)
          DL1=DL2
800   CONTINUE
      WRITE (NOUT1.1800) DEPMAX,TLL,TDUL,TSAT,TPESW,TSW,ANO3,ANH4
      IF(IECHON)WRITE (*,1800) DEPMAX,TLL,TDUL,TSAT,TPESW,TSW,
     1 ANO3,ANH4
      IF(ISWNIT.NE.0)THEN
          WRITE (NOUT1.1900)
          IF(IECHON)WRITE (*,1900)
          DO 900J = 1. NFERT
              IF (AFERT(J) .EQ. 0.)THEN
                  M = 6
              ELSE
                  M = IFTYPE(J)
                  IF (M .EQ. 0) M = 1
              ENDIF
              WRITE (NOUT1.2000) JFDAY(J).AFERT(J).DFERT(J),FTYPE(M)
              IF(IECHON)WRITE (*,2000) JFDAY(J),AFERT(J),
     1 DFERT(J).FTYPE(M)
900       CONTINUE
      ELSE
          WRITE(NOUT1.2100)
          IF(IECHON)WRITE(*,2100)
      ENDIF
C*** SET GENETIC COEFFICIENTS TO APPROPRIATE UNITS
      IF(P1V.EQ.1)P1V=0.033
      IF(P1V.EQ.2)P1V=0.018
      IF(P1V.EQ.3)P1V=0.003
      IF(P1D.NE.0)P1D=P1D*0.002
      IF(P5.NE.0.)P5=430+P5*20
      IF(G2.NE.0)G2=5+G2*5
      IF(G3.NE.0)G3=0.65+G3*0.35
      IF(G4.NE.0.)G4=-0.005+G4*0.35
      IF(G6.EQ.0.0)G6=1.0
      G1=1.0
      G5=1.0
```

```
      INCLUDE 'COMIBS.BLK'
C
      IF (KHEAD.EQ.1) GO TO 100
      IF (KOUTGR.NE.0) WRITE (NOUT2,400)
      KHEAD=1
      GO TO 200
100   DAGR=FLOAT(IOUTGR)
      ASWDF1=ASWDF1/DAGR
      ASWDF2=ASWDF2/DAGR
      CALL CALDAT
      WRITE (NOUT2,500) JDATE,SUMDTT,BIOMAS,TPSM,LAI,RTWT,
     1  STMWT,GRNWT,LFWT,RTDEP,PTF,RLV(1),
     2  RLV(3),RLV(5)
200   ASWDF1=0.
      ASWDF2=0.
      IOUTGR=0
      RETURN
C
300   FORMAT (1H1,//,2X,A36,2X,A16,/)
400   FORMAT (1H ,'JUL   CDTT    BIO',2X,'TPSM',3X,'LAI',3X,'ROOT  STEM'
     1 ,1X,'GRAIN',3X,'LEAF  RTD  PTF  L1  L3  L5',/)
500   FORMAT (1X,I3,3F6.0,F6.2,F7.3,F6.3,F6.3,F7.3,F5.0,F5.2,1X,3F4.1)
      END
C
      SUBROUTINE NWRITE
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'NTRC2.BLK'
      INCLUDE 'PREDOB.BLK'
C
      APTNUP=TOPSN*10*PLANTS
      IF (KOUTNU .EQ. 0) RETURN
      IF (ISTAGE .GT. 6) RETURN
      IOUTNU=IOUTNU+1
      ATANC=ATANC+TANC
      ANFAC=ANFAC+NDEF2
      IF (IOUTNU .EQ. KOUTNU) CALL OUTNU
      RETURN
      END
C
C
C***********SOIL AND PLANT N OUPUT ROUTINE*****************
C
      SUBROUTINE OUTNU
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'NTRC2.BLK'
      INCLUDE 'PREDOB.BLK'
      INCLUDE 'COMIBS.BLK'
C
      IF (NHDUP .EQ. 1) GO TO 100
      IF (KOUTNU .NE. 0) THEN
          WRITE (NOUT4,400)(L,L=1,5),(L,L=1,3)
      ENDIF
      NHDUP=1
      GO TO 300
100   DAUP=FLOAT(IOUTNU)
      ATANC=(ATANC/DAUP)*100.0
      ANFAC=ANFAC/DAUP
      AGRN=GRAINN*PLANTS*10.0
200   CALL CALDAT
      WRITE (NOUT4,600)JDATE,ATANC,ANFAC,APTNUP,AGRN,
     1 (NO3(L),L=1,5),(NH4(L),L=1,3)
```

```
      ND=31
300   IF (ND.GE.JDATE) GO TO 400
      MO=MO+1
      ND=ND+IDIM(MO)
      GO TO 300
400   ND=JDATE-ND+IDIM(MO)
      JDATEX=JDATE
      RETURN
C
C
500   FORMAT (/12X,'THE PROGRAM STARTED ON JULIAN DATE',2X,I3,/)
      END
C
C
C*********************************************************************
      SUBROUTINE OPHARV
C*********************************************************************
C      SUBROUTINE WRITES PREDICTED AND OBSERVED OUTPUT TO
C      SUMMARY OUT1 FILE
C
      INCLUDE 'NNC4.BLK'
      INCLUDE 'PREDOB.BLK'
C
      PBIOMS=BIOMAS*10.0
      IF(IHVON)THEN
          WRITE(*,100)
          WRITE(*,200)JANTH,IANTJD,JPHMA,MATJD,YIELD,XYIELD,PGRNWT,XGRW
     1T ,GPSM,XGPSM,CGPE,XGPE,CLAI,XLAI,PBIOMS,XBIOM,STOVER,XSTRAW,PGNP,
     2 GRPCTN,TOTNUP,XTOTNP,APTNUP,XAPTNP,GNUP,XGNUP
      ENDIF
      WRITE(NOUT1,100)
      WRITE(NOUT1,200)JANTH,IANTJD,JPHMA,MATJD,YIELD,XYIELD,PGRNWT,
     1 XGRWT,GPSM,XGPSM,CGPE,XGPE,CLAI,XLAI,PBIOMS,XBIOM,STOVER,
     2 XSTRAW,PGNP,GRPCTN,TOTNUP,XTOTNP,APTNUP,XAPTNP,GNUP,XGNUP
100   FORMAT(1X,/,25X,'PREDICTED',5X,'OBSERVED')
200   FORMAT( 1X, 'ANTHESIS DATE           ',5X,I3,10X,I3,/,
     1          1X, 'MATURITY DATE           ',5X,I3,10X,I3,/,
     2          1X, 'GRAIN YIELD (KG/HA)     ',1X,F7.0,6X,F7.0,/,
     3          1X, 'KERNEL WEIGHT (MG)      ',1X,F7.1,6X,F7.1,/,
     4          1X, 'GRAINS PER SQ METRE     ',1X,F7.0,6X,F7.0,/,
     5          1X, 'GRAINS PER EAR          ',1X,F7.2,6X,F7.2,/,
     6          1X, 'MAX. LAI                ',2X,F6.2,7X,F6.2,/,
     7          1X, 'BIOMASS (KG/HA)         ',1X,F7.0,6X,F7.0,/,
     8          1X, 'STRAW  (KG/HA)          ',1X,F7.0,6X,F7.0,/,
     9          1X, 'GRAIN N%                ',2X,F6.2,7X,F6.2,/,
     1          1X, 'TOT N UPTAKE (KG N/HA)  ',1X,F7.1,6X,F7.1,/,
     2          1X, 'STRAW N UPTAKE          ',1X,F7.1,6X,F7.1,/,
     3          1X, 'GRAIN N UPTAKE          ',1X,F7.1,6X,F7.1,/)
      RETURN
      END
C
C     ***  COLD SUBROUTINE  ***
C
      SUBROUTINE COLD
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC4.BLK'
      INCLUDE 'COMIBS.BLK'
C
      IF (VF.EQ.1.) GO TO 200
      VD=0.
      IF (TEMPMX.LE.0.) GO TO 200
      IF (TEMPMN.GT.15.) GO TO 100
      VD1=1.4-0.0778*TEMPCR
      VD2=0.5+13.44/(TEMPMX-TEMPMN+3.)**2*TEMPCR
```

```
C
      SUBROUTINE PHASEI
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
      INCLUDE 'NTRC1.BLK'
C
      IF (ISTAGE.GT.5) GO TO 100
      CNSD1=0.0
      CNSD2=0.0
      CSD1=0.
      CSD2=0.
      ICSDUR=0
100   GO TO(200,300,400,500,600,700,800,900,1000),ISTAGE
200   ISTAGE=2
      SUMDTT=0.
      P2=PHINT*3.
      IF(TILN*PLANTS.GT.1000)TILN=1000./PLANTS
      RETURN
300   ISTAGE=3
      P3=PHINT*2.
      SUMDTT=SUMDTT-P2
      GROLF=0.
      GPLA=PLA-SENLA
      RETURN
400   ISTAGE=4
      P4=200.
      SUMDTT=SUMDTT-P3
      SWMIN=STMWT
      GPLA=PLA-SENLA
      RETURN
500   ISTAGE=5
      TBASE=1.
      VANC=TANC
      VMNC=TMNC
      SUMDTT=SUMDTT-P4
      GPLA=PLA-SENLA
      GRNWT=0.0035*GPP
      RETURN
600   ISTAGE=6
      LAI=0.0
      RETURN
700   ISTAGE=7
      CUMDTT=0.
      CRAIN=0.
      CES=0.
      CEP=0.
      CET=0.
      DTT=0.
      RETURN
800   ISTAGE=8
      RTDEP=SDEPTH
      RETURN
900   ISTAGE=9
      CET=0.
      P9=40.+10.2*SDEPTH
      CES=0.
      CEP=0.
      CUMDTT=0.
      CRAIN=0.
      SUMDTT=0.
      VF=0.
      CUMVD=0.
      TBASE=2.
```

```
      APTNUP=TOPSN*10*PLANTS
      TEMPCN=TEMPMN
      TEMPCX=TEMPMX
      TOTNUP=APTNUP
      XS=SNOW
      IF (XS.GT.15.) XS=15.
      IF (TEMPMN.LT.0.) TEMPCN=2.+TEMPMN*(0.4+0.0018*(XS-15.)**2)
      IF (TEMPMX.LT.0.) TEMPCX=2.+TEMPMX*(0.4+0.0018*(XS-15.)**2)
      TEMPCR=(TEMPCX+TEMPCN)/2.
C     ********* CALCULATES THERMAL TIME ****************************
      DTT=TEMPCR-TBASE
      IF (TEMPCX.GE.TBASE) GOTO 100
      DTT=0.
      GOTO 400
100   IF (TEMPCN.GT.TBASE) GOTO 200
      TCOR=(TEMPCX-TBASE)/(TEMPCX-TEMPCN)
      DTT=(TEMPCX-TBASE)/2.*TCOR
200   IF (TEMPCX.LE.26.) GOTO 400
      TCOR=(TEMPCX-26.)/(TEMPCX-TEMPCN)
      DTT=13.*(1.+TCOR)+TEMPCN/2.*(1.-TCOR)
      IF(TEMPCN.LE.26.) GOTO 300
      DTT=26.
300   IF ( TEMPCX.LT.34.) GOTO 400
      TCOR=(TEMPCX-34.)/(TEMPCX-TEMPCN)
      DTT=(60.-TEMPCX)*TCOR+26.*(1.-TCOR)
      IF (TEMPCN.GE.26.) GOTO 400
      TCOR=(26.-TEMPCN)/(TEMPCX-TEMPCN)
      DTT=DTT*(1.-TCOR)+(TEMPCN+26.)/2.*TCOR
400   SUMDTT=SUMDTT+DTT
500   GO TO (1500,1800,2000,2200,2700,3600,600,900,1300), ISTAGE
C     ********************DETERMINE SOWING DATE**********************
600   CALL CALDAT
      WRITE (NOUT1,4000)
      WRITE(*,4000)
      WRITE (NOUT1,3900) JDATE,CUMDTT
      WRITE(*,3900)JDATE,CUMDTT
      NDAS=0.
      CALL PHASEI
      IF (ISWSWB.EQ.0) RETURN
      CUMDEP=0.
      DO 700 L=1,NLAYR
          CUMDEP=CUMDEP+DLAYR(L)
          IF (SDEPTH.LT.CUMDEP) GO TO 800
700   CONTINUE
800   LO=L
      RETURN
C     **************DETERMINE GERMINATION DATE**********************
900   IF (ISWSWB.EQ.0) GO TO 1100
      IF (SW(LO).GT.LL(LO)) GO TO 1100
      SWSD=(SW(LO)-LL(LO))*0.65+(SW(LO+1)-LL(LO+1))*0.35
      NDAS=NDAS+1
      IF (NDAS.LT.90) GO TO 1000
      ISTAGE=5
      PLANTS=0
      GPP=1.
      GRNWT=0.
      WRITE(NOUT1,4200) JDATE
      WRITE(*,4200)
      RETURN
1000  IF (SWSD.LT.0.02) RETURN
1100  CALL CALDAT
      WRITE (NOUT1,1200) JDATE,CUMDTT,CET,CRAIN,PESW
      WRITE (*,1200) JDATE,CUMDTT,CET,CRAIN,PESW
1200  FORMAT(1X,I3,F6.0,' GERMINATION',39X,F4.0,2X,F4.0,2X,F4.0)
      CALL PHASEI
      RETURN
```

```
2400  FORMAT(' ANTHESIS WAS AT',I5)
      GPP=STMWT*G2
      GPSM=GPP*PLANTS
      IF(GPSM.LT.100)THEN
          WRITE(NOUT1,2500)
          WRITE(*,2500)
          PLANTS=0.
          GPP=1.
          ISTAGE=6
2500      FORMAT(' CROP FAILURE GROWTH PROGRAM TERMINATED')
      ENDIF
      CALL CALDAT
      WRITE (NOUT1,2600)JDATE,CUMDTT,GPSM,BIOMAS,LAI,APTNUP,XANC,CET,
     1 CRAIN,PESW
      WRITE (*,2600)JDATE,CUMDTT,GPSM,BIOMAS,LAI,APTNUP,XANC,CET,CRAIN
     1 ,PESW
2600  FORMAT(1X,I3,F6.0,' BEG GR FILL,GPSM=',F7.0,F6.0,1X,F5.2,1X,F5.1,
     1 2X,F4.2,3(2X,F4.0))
      GO TO 3100
C     ******************DETERMINE PHYSIOLOGICAL MATURITY***************
2700  XSTAGE=SUMDTT/P5+5.0
      NDAS=NDAS+1
      IF (PLANTS.GT.0.) GO TO 2800
      GRNWT=0.
      GO TO 2900
2800  IF (SUMDTT.LT.P5) GO TO 3300
2900  YIELD=GRNWT*10.*PLANTS
      SKERWT=GRNWT/GPP
      IF (SKERWT.LT.0.020) GPSM=YIELD*5.
      IF (SKERWT.LT.0.020) SKERWT=0.020
      YIELDB=YIELD/67.
      STOVER=BIOMAS*10.-YIELD
      PGNP=(GRAINN/GRNWT)*100.0
      JPHMA=JDATE
      CGPE=GPSM/TPSM
      GNUP=GRAINN*PLANTS*10.
      TOTNUP=GNUP+APTNUP
      CALL CALDAT
      WRITE (NOUT1,3000)JDATE,CUMDTT,SKERWT,BIOMAS,LAI,
     1 APTNUP,XANC,CET,CRAIN,PESW
      WRITE (*,3000)JDATE,CUMDTT,SKERWT,BIOMAS,LAI,
     1 APTNUP,XANC,CET,CRAIN,PESW
3000  FORMAT(1X,I3,F6.0,' MATURITY GRN WT= ',F7.4,F6.0,1X,F5.2,1X,F5.1,
     1 2X,F4.2,3(2X,F4.0))
3100  IF(ISWSWB.EQ.0)GO TO 3200
      SI1(ISTAGE)=CSD1/ICSDUR
      SI2(ISTAGE)=CSD2/ICSDUR
      SI3(ISTAGE)=CNSD1/ICSDUR
      SI4(ISTAGE)=CNSD2/ICSDUR
      XANC=TANC*100.0
      PGRNWT=SKERWT*1000.0
3200  PLANTS=XPLANT
      IF (ISTAGE.EQ.5) GO TO 3400
      CALL PHASEI
3300  RETURN
3400  WRITE (NOUT1,4100) YIELD,YIELDB,GPSM
      WRITE(*,4100)YIELD,YIELDB,GPSM
      CALL OPHARV
      WRITE (NOUT1,3700)
      WRITE(*,3700)
      DO 3500 I=1,5
          WRITE (NOUT1,3800) I,SI1(I),SI2(I),SI3(I),SI4(I)
          WRITE (*,3800) I,SI1(I),SI2(I),SI3(I),SI4(I)
3500  CONTINUE
3600  CALL PHASEI
      IRET=1
```

```
      FLUX(1)=PINF*0.1
      IDRSW=1
700   IF (IDRSW.EQ.0) GO TO 1300
      IDRSW=0
      DO 1100 L=1,NLAYR
          IF (FLUX(L).EQ.0.) GO TO 800
          HOLDW=(SAT(L)-SW(L))*DLAYR(L)
          IF (FLUX(L).LE.HOLDW) GO TO 800
          DRAIN=SWCON*(SAT(L)-DUL(L))*DLAYR(L)
          SW(L)=SAT(L)-DRAIN/DLAYR(L)
          FLUX(L)=FLUX(L)-HOLDW+DRAIN
          IDRSW=1
          GO TO 1000
800       SW(L)=SW(L)+FLUX(L)/DLAYR(L)
          IF (SW(L).LT.DUL(L)+0.003) GO TO 900
          DRAIN=(SW(L)-DUL(L))*SWCON*DLAYR(L)
          SW(L)=SW(L)-DRAIN/DLAYR(L)
          FLUX(L)=DRAIN
          IDRSW=1
          GO TO 1000
900       FLUX(L)=0.
1000      IF (L.LT.NLAYR) FLUX(L+1)=FLUX(L)
1100  CONTINUE
      IF (L.GE.NLAYR) L=NLAYR
      DRAIN=FLUX(L)*10.0
      IF (ISWNIT.NE.0.AND.IDRSW.EQ.1) CALL NFLUX(1)
      DO 1200 L=1,NLAYR
          FLUX(L)=0.0
1200  CONTINUE
C     *******************POTENTIAL EVAPORATION ROUTINE******************
1300  TD=0.60*TEMPMX+0.40*TEMPMN
      ALBEDO=SALB
      IF (ISTAGE.GT.6) GO TO 1400
      IF (ISTAGE.LT.5.) ALBEDO=0.23-(0.23-SALB)*EXP(-0.75*LAI)
      IF (ISTAGE.GE.5) ALBEDO=0.23+(LAI-4)**2/160.
1400  IF (SNOW.GT.0.5) ALBEDO=0.6
      EEQ=SOLRAD*(2.04E-4-1.83E-4*ALBEDO)*(TD+29.)
      EO=EEQ*1.1
      IF (TEMPMX.GT.24.) EO=EEQ*((TEMPMX-24.)*0.05+1.1)
      IF (TEMPMX.LT.5.0) EO=EEQ*0.01*EXP(0.18*(TEMPMX+20.))
      EOS=EO*(1.-0.43*LAI)
      IF (LAI.GT.1.) EOS=EO/1.1*EXP(-0.4*LAI)
C     **********************SOIL AND PLANT EVAPORATION ROUTINE**********
      IF (SUMES1.GE.U.AND.WINF.GE.SUMES2) GO TO 1500
      IF (SUMES1.GE.U.AND.WINF.LT.SUMES2) GO TO 1600
      IF (WINF.GE.SUMES1) GO TO 1900
      SUMES1=SUMES1-WINF
      GO TO 2000
1500  IF (WINF.LT.SUMES2) GO TO 1600
      WINF=WINF-SUMES2
      SUMES1=U-WINF
      T=0.
      IF (WINF.GT.U) GO TO 1900
      GO TO 2000
1600  T=T+1.
      ES=3.5*T**0.5-SUMES2
      IF (WINF.GT.0.) GO TO 1700
      IF (ES.GT.EOS) ES=EOS
      GO TO 1800
1700  ESX=0.8*WINF
      IF (ESX.LE.ES) ESX=ES+WINF
      IF (ESX.GT.EOS) ESX=EOS
      ES=ESX
1800  CONTINUE
      SUMES2=SUMES2+ES-WINF
      T=(SUMES2/3.5)**2
```

```
          IF (SWDF.LT.0.) SWDF=0.
          IF(ISWNIT.NE.0)THEN
               TOTN=NO3(L)+NH4(L)
               RNFAC=1.0-(1.17*EXP(-0.15*TOTN))
               IF(RNFAC.LT.0.01)RNFAC=0.01
          ENDIF
          RLDF(L)=AMIN1(SWDF,RNFAC)*WR(L)*DLAYR(L)
          IF (CUMDEP.LT.RTDEP) GO TO 3000
          RTDEP=RTDEP+DTT*0.22*AMIN1((SWDF1*2.0),SWDF)*95.0/PHINT
          IF (RTDEP.GT.DEPMAX) RTDEP=DEPMAX
          RLDF(L)=RLDF(L)*(1.-(CUMDEP-RTDEP)/DLAYR(L))
          TRLDF=TRLDF+RLDF(L)
          GO TO 3100
3000  TRLDF=TRLDF+RLDF(L)
3100  IF (TRLDF.LT.RLNEW*0.00001) GO TO 3400
      RNLF=RLNEW/TRLDF
      CUMDEP=0.
      DO 3300 L=1,L1
          CUMDEP=CUMDEP+DLAYR(L)
          RLV(L)=RLV(L)+RLDF(L)*RNLF/DLAYR(L)-0.01*RLV(L)
          IF(CUMDEP.LT.115)GO TO 3200
          RLVF=0.377-0.0015*CUMDEP
          IF(RLV(L).GT.RLVF)RLV(L)=RLVF
3200      IF(RLV(L).LT.0.)RLV(L)=0.
3300  CONTINUE
C     ********** CALCULATE WATER UPTAKE AND SOIL DEFICIT FACTORS *******
3400  IF (EP.EQ.0.) GO TO 3800
      EP1=EP*0.1
      TRWU=0.
      DO 3500 L=1,NLAYR
          IF (RLV(L).EQ.0.0) GO TO 3600
          RWU(L)=2.67E-3*EXP(62.*(SW(L)-LL(L)))/(6.68-ALOG(RLV(L)))
          IF (RWU(L).GT.RWUMX) RWU(L)=RWUMX
          IF (SW(L).LE.LL(L)) RWU(L)=0.
          RWU(L)=RWU(L)*DLAYR(L)*RLV(L)*(0.18+0.00272*(RLV(L)-18.)**2)
          IF(CUMPH.LT.4.AND.LAI.LT.1)RWU(L)=RWU(L)*(3.-2.*LAI)
          TRWU=TRWU+RWU(L)
3500  CONTINUE
3600  WUF=1.
      IF (EP1.LE.TRWU) WUF=EP1/TRWU
      TSW=0.
      DO 3700 L=1,NLAYR
          RWU(L)=RWU(L)*WUF
          SW(L)=SW(L)-RWU(L)/DLAYR(L)
          TSW=TSW+SW(L)*DLAYR(L)
3700  CONTINUE
      PESW=TSW-TLL
      SWDF2=1.
      IF (TRWU/EP1.LT.1.5) SWDF2=0.67*TRWU/EP1
      SWDF1=1.
      IF (EP1.LT.TRWU) GO TO 3800
      SWDF1=TRWU/EP1
      EP=TRWU*10.
3800  ET=ES+EP
      CEP=CEP+EP
      CET=CET+ET
      CSD1=CSD1+1.0-SWDF1
      CSD2=CSD2+1.0-SWDF2
      RETURN
      END
C
C     ********** SUBROUTINE TO CALCULATE PHENOLOGICAL STAGE ***********
C
C     ***************************** GROWTH SUBROUTINE ****************
C
      SUBROUTINE GROSUB
```

```
      GO TO 1500
800   PTF=0.70+0.1*AMIN1(SWDF1,NDEF2)
      GRORT=(1.-PTF)*CARBO
      GROSTM=(.15+0.12*SUMDTT/PHINT)*CARBO*PTF
      GROLF=CARBO-GRORT-GROSTM
      PLA=PLA+GROLF*115.
      IF (CUMPH.GT.4.) PLALR=(PLSC(LN-4)-PLSC(LN-5))*TI
      IF (SENLA/PLA.GT.0.4) PLALR=0.
      TILSW=TILSW+G4*0.0889*DTT*AMIN1(NDEF2,SWDF1)*SUMDTT/PHINT**2
      RTSW=(STMWT+GROSTM)/TILSW/TILN
      TNOLD=TILN
      TILN=TILN*DTT*0.005*(RTSW-1.)+TILN
      IF (TILN.LT.1.) TILN=1.
      IF ((TNOLD-TILN).GT.0.) DTN=(TNOLD-TILN)*PLANTS
      SENTIL=SENTIL+DTN
      GO TO 1500
900   PTF=0.75+0.1*AMIN1(SWDF1,NDEF2)
      GRORT=(1.-PTF)*CARBO
      GROSTM=CARBO*PTF
      PLALR=0.0003*DTT*GPLA
      TILSW=TILSW+G4*DTT*0.25/PHINT*AMIN1(SWDF1,NDEF2)
      RTSW=(STMWT+GROSTM)/TILSW/TILN
      TILN=TILN*DTT*0.005*(RTSW-1.)+TILN
      IF (TILN.LT.1.) TILN=1.
      GO TO 1500
1000  PTF=0.80+0.1*AMIN1(SWDF1,NDEF2)
      GRORT=CARBO*(1.-PTF)
      GROSTM=CARBO*PTF
      PLALR=0.0006*DTT*GPLA
      GO TO 1500
1100  PTF=SWMIN/STMWT*0.35+0.65
      IF (PTF.GT.1.) PTF=1.
      CARBO=CARBO*(1.-(1.2-0.8*SWMIN/STMWT)
     1 *(SUMDTT+100.0)/(P5+100.0))
      GRORT=CARBO*(1.-PTF)
      PLALR=GPLA*2.*SUMDTT*DTT/(P5*P5)
      IF (TEMPM.GT.10.) RGFILL=0.65+(0.0787-0.00328*
     1 (TEMPMX-TEMPMN))*(TEMPM-10.0)**0.8
      IF (TEMPM.LE.10.) RGFILL=0.065*TEMPM
      IF (RGFILL.GT.1.) RGFILL=1.
      GROGRN=RGFILL*GPP*G3*0.001
      IF(ISWNIT.EQ.0)GO TO 1300
      RGNFIL=4.829666-3.2488*DTT+0.2503*(TEMPMX-TEMPMN)+4.3067*TEMPM
      IF(TEMPM.LE.10)RGNFIL=0.483*TEMPM
      NSINK=RGNFIL*GPP*G6*1.E-6
      NSINK=NSINK*NDEF2
      IF (NSINK.EQ.0.0) GO TO 1200
      RMNC=0.75*RCNP
      VANC=TOPSN/TOPWT
      NPOOL1=TOPWT*(VANC-VMNC)
      NPOOL2=RTWT*(RANC-RMNC)
      IF(NPOOL2.LT.0.0)NPOOL2=0.0
      IF(NPOOL1.LT.0.0)NPOOL1=0.0
      NPOOL=NPOOL1+NPOOL2
      NSDR=NPOOL/NSINK
      IF(NSDR.LT.1.0)THEN
           NSINK=NSINK*NSDR
      ENDIF
      IF (NSINK.GT.NPOOL1)THEN
           VANC=VMNC
           TOPSN=TOPWT*VANC
           NPOOL2=NPOOL2-(NSINK-NPOOL1)
           NPOOL1=0.0
           ROOTN=RTWT*RMNC+NPOOL2
           RANC=ROOTN/RTWT
      ELSE
```

```
            NPOOL1=NPOOL1-NSINK
            TOPSN=NPOOL1+VMNC*TOPWT
            VANC=TOPSN/TOPWT
      ENDIF
1200  GRAINN=GRAINN+NSINK
1300  GROSTM=CARBO*PTF-GROGRN
      IF(STMWT.GE.SWMIN)GO TO 1400
      IF(CARBO*PTF.LT.GROGRN) GROGRN=CARBO*PTF
      GROSTM=0.
1400  GRNWT=GRNWT+GROGRN
1500  PLSC(LN)=PLA
      IF (SWDF1.GT..8) GO TO 1700
      W1=2.0-SWDF1/0.8
      SN1=2.0-NDEF4/0.8
      CF=PLALR*0.25*AMIN1(W1,SN1)
      PLALR=CF*4.
      DO 1600 I=1,LN
         PLSC(I)=PLSC(I)-CF
1600  CONTINUE
1700  SENLA=SENLA+PLALR
      IF(PLA-SENLA.GT..035*TILN) GOTO 1800
      SENLA=PLA-TILN*0.035
      IF (ISTAGE.GT.1) GOTO 1800
      IF (SEEDRV.GT.0.) GOTO 1800
      SEEDRV=LFWT*0.05+RTWT*0.05
      IF(SEEDRV.GT.0.05) SEEDRV=0.05
      LFWT=LFWT-SEEDRV*0.5
      RTWT=RTWT-SEEDRV*0.5
1800  LAI=(PLA-SENLA)*PLANTS*0.0001
      IF(LAI.LT.0.0001) LAI=0.0001
      EXLFW=LFWT
      LFWT=LFWT+GROLF-LFWT*0.000267*DTT*(1.-SENLA/PLA)
      DLFWT=(EXLFW-LFWT)*PLANTS
      IF (DLFWT.GT.0.) SENLF=SENLF+DLFWT
      STMWT=STMWT+GROSTM-STMWT*0.000267*DTT
      RTWT=RTWT+0.6*GRORT-0.005*RTWT
      BIOMAS=(LFWT+STMWT+GRNWT)*PLANTS
      TPSM=TILN*PLANTS
      PSW=PLA*0.1
1900  IF (ISWNIT.EQ.0) GO TO 2000
      PGRORT=PCARB*(60-XSTAGE*8)/100
      PDWI=PCARB-PGRORT
      DDM=CARBO*PTE
      IF(PTF.GT.0.9)DDM=CARBO*0.9
      TOPWT=LFWT+STMWT+SEEDRV
      CALL NUPTAK
2000  RETURN
      END
C
C
C*****************DRAINAGE AND LEACHING ROUTINE*******************
C
      SUBROUTINE NFLUX(IFLAG)
C
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'NTRC2.BLK'
      INCLUDE 'NMOVE.BLK'
C
      IF(IFLAG.EQ.2)GO TO 400
      DO 100 L=1,NLAYR
         NOUT(L)=0.0
100   CONTINUE
      OUTN=0.0
      DO 300 L=1,NLAYR
         SNO3(L)=SNO3(L)+OUTN
```

```
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
      INCLUDE 'NTRC1.BLK'
C
      REAL NSINK,NPOOL1,NPOOL2,NPOOL,NSDR
      IF(PLANTS.EQ.0)RETURN
      IF(HI.GT.1.8)RETURN
      IF (ISWNIT.NE.0) CALL NFACTO
      PAR=0.02092*SOLRAD
      PCARB=7.5*PAR**0.6/PLANTS*(1.-EXP(-0.85*LAI))
      PRFT=1.-0.0025*((0.25*TEMPMN+0.75*TEMPMX)-18.)**2
      IF(TEMPMN.LT.-3.)PRFT=0.
      IF (PRFT.LT.0.) PRFT=0.
      CARBO=PCARB*AMIN1(SWDF1,NDEF1)*PRFT
      IF(CARBO.LE.0)CARBO=0.0001
      TEMPM=(TEMPMX+TEMPMN)/2.
      IF(ISTAGE.GT.2)GO TO 100
      TI=DTT/PHINT
      CUMPH=CUMPH+TI
      LN=CUMPH+2.
      CLG=7.5
      EGFT=1.2-0.0042*(TEMPM-17.)**2
      IF (EGFT.GT.1.) EGFT=1.
      IF(EGFT.LT.0.) EGFT=0.
      IF (DTT.GT.0.) GOTO 100
      PTF=0.5
      RETURN
100   GO TO (200,300,900,1000,1100,2000),ISTAGE
200   AWR=150.-.075*TDU
300   PLAGMS=CLG*(CUMPH**.5)*AMIN1(SWDF2,EGFT,NDEF2)*TI
      PLAG=PLAGMS*(0.3+0.7*TILN)
      IF(TPSM.GT.900.) PLAG=PLAGMS*900./PLANTS
      GROLF=PLAG/AWR
      GRORT=CARBO-GROLF
      TNOLD=TILN
      IF (GRORT.GT.0.35*CARBO) GOTO 500
      GRORT=CARBO*0.35
      IF (SEEDRV.EQ.0.)GOTO 400
      SEEDRV=SEEDRV+CARBO-GROLF-GRORT
      IF (SEEDRV.GE.0.) GOTO 500
      SEEDRV=0.
400   GROLF=CARBO*0.65
      PLAG=GROLF*AWR
500   IF(CUMPH.LT.2.5)GO TO 600
      TC1=-2.5+CUMPH
      IF(TPSM.EQ.3000)THEN
          TC2=0.0
      ELSE
          TC2=2.50E-7*(3000-TPSM)**3
      ENDIF
      W1=1.4*SWDF2-0.4
      SN1=1.4*NDEF3-0.4
      TILN=TILN+TI*AMIN1(W1,SN1)*AMIN1(TC1,TC2)
600   IF(TILN.LT.1.) TILN=1.
      IF (JSTAGE.GT.21) GOTO 700
      IF((TNOLD-TILN).LT.0) JSTAGE=21
700   DTN=(TNOLD-TILN)*PLANTS
      IF (DTN.GT.0.) SENTIL=SENTIL+DTN
      PLA=PLA+PLAG
      PLALR=0.
      IF (CUMPH.GT.4.) PLALR=(PLSC(LN-4)-PLSC(LN-5))*TI
      IF (SENLA/PLA.GT.0.4) PLALR=0.
      PTF=GROLF/CARBO
```

```
      GO TO 2200
1900  SUMES1=0.
2000  SUMES1=SUMES1+EOS
      IF (SUMES1.GT.U) GO TO 2100
      ES=EOS
      GO TO 2200
2100  ES=EOS-0.4*(SUMES1-U)
      SUMES2=0.6*(SUMES1-U)
      T=(SUMES2/3.5)**2
2200  SW(1)=SW(1)-ES*.1/DLAYR(1)
      IF(SW(1).GE.LL(1)*SWEF)GO TO 2300
      ES1=(LL(1)*SWEF-SW(1))*DLAYR(1)*10.
      SW(1)=LL(1)*SWEF
      ES=ES-ES1
2300  NIND=NLAYR-1
      DO 2400 L=1,NLAYR
         FLOW(L)=0.0
         SWX(L)=SW(L)
2400  CONTINUE
      IST=1
      IF (DLAYR(1).EQ.5.0) IST=2
      DO 2500 L=IST,NIND
         MU=L+1
         THET1=SW(L)-LL(L)
         IF (THET1.LT.0.) THET1=0.
         THET2=SW(MU)-LL(MU)
         DBAR=0.88*EXP(35.4*(THET1+THET2)*0.5)
         IF (DBAR.GT.100.) DBAR=100.
         FLOW(L)=DBAR*(THET2-THET1)/(DLAYR(L)+DLAYR(MU))*0.5
         WAT1=DUL(1)-SW(1)
         IF(FLOW(1).GT.WAT1)FLOW(1)=WAT1
         IF(WAT1.LT.0.0)FLOW(1)=0.0
         SWX(L)=SWX(L)+FLOW(L)/DLAYR(L)
         SWX(MU)=SWX(MU)-FLOW(L)/DLAYR(MU)
2500  CONTINUE
      IF (ISWNIT.NE.0) CALL NFLUX(2)
      DO 2600 L=1,MU
         SW(L)=SWX(L)
2600  CONTINUE
      CES=CES+ES
      EP=0.
      IF (ISTAGE.GE.6) GO TO 2700
      IF (LAI.LE.3.0) EP=EO*(1.-EXP(-LAI))
      IF (LAI.GT.3.0) EP=EO
      IF (EP+ES.GT.EO) EP=EO-ES
      GO TO 2900
2700  ET=ES
      CET=CET+ET
      TSW=0.
      DO 2800 L=1,NLAYR
         TSW=TSW+SW(L)*DLAYR(L)
2800  CONTINUE
      PESW=TSW-TLL
      RETURN
C        ***************ROOT GROWTH AND DEPTH ROUTINE*****************
2900  IF (GRORT.EQ.0.) GO TO 3400
      RLNEW=GRORT*PLANTS*1.05
      TRLDF=0.
      CUMDEP=0.
      RNFAC=1.0
      DO 3000 L=1,NLAYR
         L1=L
         CUMDEP=CUMDEP+DLAYR(L)
         SWDF=1.
         IF (SW(L)-LL(L).LT.0.25*ESW(L)) SWDF=4.*(SW(L)-LL(L))/
     1   ESW(L)
```

```
      RETURN
C
3700  FORMAT (/,1X,'GROWTH STAGE',6X,'CSD1',6X,'CSD2',5X,'CNSD1',5X,
     1  'CNSD2')
3800  FORMAT (1X,I12,4F10.2)
3900  FORMAT(1X,I3,F6.0,' SOWING')
4000  FORMAT (' JD  CDTT PHENOLOGICAL STAGE        BIOM    LAI NUPTK  '
     1 ,' N%     CET  RAIN  PESW')
4100  FORMAT (/,1X,'YIELD (KG/HA) =',F7.0,5X,'(BU/ACRE)=',F6.1,5X,
     1  'FINAL GPSM= ',F7.0)
4200  FORMAT (1X,'SEED DID NOT GERMINATE BY JDATE =',I4)
      END
C
C
C     ********** WATER BALANCE SUBROUTINE ******************************
C
      SUBROUTINE WATBAL
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'NTRC2.BLK'
      INCLUDE 'NMOVE.BLK'
C
      DIMENSION RLDF(10)
      ICSDUR=ICSDUR+1
      PRECIP=0.
      IOFF=0
      IF (IIRR.NE.2) GO TO 200
      DO 100 J=1,NIRR
           IF (JDATE.NE.JDAY(J)) GO TO 100
           PRECIP=AIRR(J)
           IOFF=1
 100  CONTINUE
 200  TPRECP=PRECIP+RAIN
      IF (TEMPMX.GT.1..AND.SNOW.EQ.0.) GO TO 400
      IF (TEMPMX.GT.1.) GO TO 300
      SNOW=SNOW+RAIN
      RAIN=0.
      GO TO 400
 300  SNOMLT=TEMPMX+RAIN*0.4
      IF (SNOMLT.GT.SNOW) SNOMLT=SNOW
      SNOW=SNOW-SNOMLT
      RAIN=SNOMLT+RAIN
 400  PRECIP=PRECIP+RAIN
      DRAIN=0.
      PINF=0.
      RUNOFF=0.
      WINF=0.
      IF (PRECIP.EQ.0.) GO TO 700
C     **CALCULATE RUNOFF BY WILLIAMS -SCS CURVE NO. TECHNIQUE********
      SUM=0.
      DO 500 L=1,NLAYR
           SUM=SUM+WF(L)*(SW(L)-LL(L))/ESW(L)
 500  CONTINUE
      R2=SMX*(1.-SUM)
      IF (R2.LE.2.54) R2=2.54
      PB=PRECIP-0.2*R2
      IF (PB.LE.0.) GO TO 600
      RUNOFF=PB*PB/(PRECIP+.8*R2)
      IF(IOFF.EQ.1)RUNOFF=0.
 600  PINF=PRECIP-RUNOFF
C     **CALCULATE DRAINAGE AND SOIL WATER REDISTRIBUTION*************
      WINF=PINF
```

```
C       ******************DETERMINE SEEDLING EMERGENCE DATE**************
1300  XSTAGE=SUMDTT/P9
      NDAS=NDAS+1
      RTDEP=RTDEP+0.1*DTT
      CALL COLD
      IF (SUMDTT.LT.P9) RETURN
      CALL CALDAT
      WRITE (*,1400)JDATE,CUMDTT,CET,CRAIN,PESW
      WRITE (NOUT1,1400)JDATE,CUMDTT,CET,CRAIN,PESW
1400  FORMAT(1X,I3,F6.0,' EMERGENCE',41X,F4.0,2(2X,F4.0))
      CALL PHASEI
      RETURN
C     ******************DETERMINE DURATION OF VEGETATIVE PHASE**********
1500  CALL COLD
      NDAS=NDAS+1
      IF (VF.LT.0.3) GO TO 1600
      DEC=0.4093*SIN(0.0172*(JDATE-82.2))
      DLV=((-S1*SIN(DEC)-0.1047)/(C1*COS(DEC)))
      IF(DLV.LT.-0.87)DLV=-0.87
      HRLT=7.639*ACOS(DLV)
      DF=1.-P1D*(20.-HRLT)**2
1600  TDU=TDU+DTT*AMIN1(VF,DF)
      XSTAGE=TDU/400.0+1.0
      IF (TDU.LE.400.*(PHINT/95.)) GO TO 3300
      CALL CALDAT
      WRITE (NOUT1,1700) JDATE,CUMDTT,CUMVD,BIOMAS,LAI,APTNUP,XANC,CET
     1,CRAIN,PESW
      WRITE (*,1700) JDATE,CUMDTT,CUMVD,BIOMAS,LAI,APTNUP,XANC,CET,
     1 CRAIN,PESW
1700  FORMAT(1X,I3,F6.0,' T SPKLT VE DAYS=',F8.0,F6.0,1X,F5.2,1X,F5.1,
     1 2X,F4.2,3(2X,F4.0))
      GO TO 3100
C     ****************END VEGETATIVE AND BEGIN EAR GROWTH**************
1800  XSTAGE=SUMDTT/P2+2
      NDAS=NDAS+1
      IF (SUMDTT.LT.P2) GO TO 3300
      CALL CALDAT
      CLAI=LAI
      WRITE (NOUT1,1900) JDATE,CUMDTT,BIOMAS,LAI,APTNUP,XANC,CET,CRAIN
     1,PESW
      WRITE (*,1900) JDATE,CUMDTT,BIOMAS,LAI,APTNUP,XANC,CET,CRAIN
     1,PESW
1900  FORMAT(1X,I3,F6.0,' END VEG BEGIN EAR GROWTH',F6.0,1X,F5.2,1X,
     1 F5.1,2X,F4.2,3(2X,F4.0))
      GO TO 3100
C     **********DETERMINE END OF PRE-ANTHESIS EAR GROWTH***************
2000  XSTAGE=SUMDTT/P3+3.0
      NDAS=NDAS+1
      IF (SUMDTT.LT.P3) GO TO 3300
      CALL CALDAT
      WRITE (NOUT1,2100)JDATE,CUMDTT,TPSM,BIOMAS,LAI,APTNUP,XANC,CET,
     1 CRAIN,PESW
      WRITE (*,2100)JDATE,CUMDTT,TPSM,BIOMAS,LAI,APTNUP,XANC,CET,CRAIN
     1 ,PESW
2100  FORMAT(1X,I3,F6.0,' END EAR GR. EARS=',F7.0,F6.0,1X,F5.2,1X,
     1 F5.1,2X,F4.2,3(2X,F4.0))
      GO TO 3100
C     ********DETERMINE BEGINNING OF GRAIN FILL*************************
2200  NDAS=NDAS+1
      IF(SUMDTT.GT.80)GO TO 2300
      JANTH=JDATE
2300  XSTAGE=SUMDTT/P4+4.0
      IF (SUMDTT.LT.P4) GO TO 3300
C****        ANTHESIS IS 80 DEG DAYS INTO THIS PHASE
      WRITE(NOUT1,2400)JANTH
      WRITE(*,2400)JANTH
```

```
      RETURN
1000  ISTAGE=1
      SUMDTT=SUMDTT-P9
      DTT=SUMDTT
      TDU=0.0
      DF=0.01
      LAI=PLANTS*4.E-6
      PLA=.04
      LFWT=0.00034
      SEEDRV=0.012
      STMWT=0.
      GROSTM=0.
      GRNWT=0.
      SENLA=0.
      GRORT=0.
      TOPWT=SEEDRV*0.5
      RTWT=SEEDRV*0.5
      BIOMAS=0.
      CUMPH=0.
      TILSW=0.01
      TILN=1.
      TBASE=0.
      TPSM=PLANTS
      CSD1=0.
      CSD2=0.
      CNSD1=0.0
      CNSD2=0.0
      CUMDEP=0.
      PLSC(1)=0.
      IF(ISWSWB.EQ.0)GO TO 1600
      DO 1100 L=1,NLAYR
           CUMDEP=CUMDEP+DLAYR(L)
           RLV(L)=0.0024*PLANTS/DLAYR(L)
           IF (CUMDEP.GT.RTDEP) GO TO 1200
1100  CONTINUE
1200  RLV(L)=RLV(L)*(1.-(CUMDEP-RTDEP)/DLAYR(L))
      L1=L+1
      IF (L1.GE.NLAYR) GO TO 1400
      DO 1300 L=L1,NLAYR
           RLV(L)=0.
1300  CONTINUE
1400  DO 1500 L=1,NLAYR
           RWU(L)=0.
1500  CONTINUE
      IF (ISWNIT.EQ.0) GO TO 1600
      RANC=0.045
      TANC=0.045
      GRAINN=0.0
      ROOTN=RANC*RTWT
      TOPSN=TOPWT*TANC
1600  RETURN
      END
C
C
      SUBROUTINE PHENOL (IRET)
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'PREDOB.BLK'
      INCLUDE 'COMIBS.BLK'
      DIMENSION SI3(6), SI4(6)
      IRET=0
      XANC=TANC*100.0
```

```
      VD=AMIN1 (1.,VD1.VD2)
      IF(VD.LT.0.) VD=0.
      CUMVD=CUMVD+VD
100   IF (CUMVD.LT.10.AND.TEMPMX.GT.30.) CUMVD=CUMVD-.5*(TEMPMX-30.)
      IF (CUMVD.LT.0.) CUMVD=0.
      IF (ISTAGE.EQ.9) RETURN
      VF=1.-P1V*(50.-CUMVD)
      IF (VF.LE.0.) VF=0.
      IF (VF.GT.1.) VF=1.0
200   IF (ISTAGE.GT.7.) RETURN
      IF (TEMPMN.GT.TBASE-3..AND.HI.EQ.0.) RETURN
      HTI=G5
      IF(HI.GE.HTI)GO TO 300
      IF(TEMPCR.LT.TBASE-1.)GO TO 500
      IF(TEMPCR.GT.TBASE+8.)GO TO 400
      HI=HI+0.1-(TEMPCR-(TBASE+3.5))**2/506.
      IF(HI.LT.HTI)GO TO 400
300   IF(TEMPCR.GT.TBASE+0.)GO TO 400
      HI=HI+0.083
      IF(HI.GT.HTI*2.)HI=HTI*2.
400   IF(TEMPMX.LT.TBASE+10.)GO TO 500
      HI=HI+0.2-0.02*TEMPMX
      IF(HI.GT.HTI)HI=HI+0.2-0.02*TEMPMX
      IF(HI.LT.0.)HI=0.
500   IF (TEMPMN.GT.-6.) RETURN
C     ****************** CALCULATES LEAF SENESCENCE***********
      CK=(0.020*HI-0.10)*(TEMPMN*.85+TEMPMX*.15+10.+.25*SNOW)
      IF (CK.LT.0) CK=0
      IF (CK.GT..96) CK=0.96
      SENLA=SENLA+CK*(PLA-SENLA)
      DO 600 I=1.LN
          PLSC(I)=PLSC(I)*(1.-CK)
600   CONTINUE
      IF(PLA-SENLA.GT.TILN*.5) GO TO 700
      SENLA=PLA-TILN*0.5
      IF (SEEDRV.GT.0.) GOTO 700
      SEEDRV=LFWT*.05+RTWT*.05
      IF(SEEDRV.GT.0.05)SEEDRV=0.05
      LFWT=LFWT-SEEDRV*0.5
      RTWT=RTWT-SEEDRV*0.5
C          ****************** CALCULATES TILLER AND PLANT DEATH*
700   TEMKIL=TBASE-6.-6.*HI
      IF(TEMKIL.LT.TEMPCR)RETURN
      IF(TILN.GE.1.)TILN=TILN*(0.9-0.02*(TEMPCR-TEMKIL)**2)
      IF(TILN.GE.1.)GO TO 800
      PLANTS=PLANTS*(0.95-0.02*(TEMPCR-TEMKIL)**2)
      TILN=1.
      IF(PLANTS.LT.5.)GO TO 1000
800   WRITE(NOUT1.900)JDATE.TEMKIL.TEMPCR.HI.TILN.PLANTS
      WRITE(*,900)JDATE,TEMKIL.TEMPCR.HI.TILN.PLANTS
900   FORMAT(' CROP WAS DAMAGED BY COLD TEMPERATURE ON DAY',I5,5X,
     1 'TEMKIL='.F5.1.5X,'TEMPCR=',F5.1,5X,'HI=',F5.2,5X,'TILN=',
     2 F5.2,5X,'PLANTS=',F4.0)
      RETURN
1000  WRITE(7,1100)JDATE.TEMKIL,TEMPCR,HI
      WRITE(*,1100)JDATE.TEMKIL.TEMPCR.HI
1100  FORMAT(' AT LEAST 95% OF CROP KILLED BY COLD TEMP ON DAY',I5,5X,
     1 'TEMKIL=',F5.1,5X,'TEMPCR=',F5.1,5X,'HI=',F5.2)
      PLANTS=0.
      GRNWT=0.
      GPP=1.
      ISTAGE=5
      RETURN
      END
C
C     ********** PHASE INITIALIZATION SUBROUTINE **********************
```

```
300   ATANC=0.0
      IOUTNU=0
      ANFAC = 0.0
      RETURN
C
400   FORMAT (/,' JUL',2X,'TOPS',2X,'NFAC',1X,'TOT N',1X,'GRAIN',
     1 5(3X,'NO3'),3(3X,'NH4'),/,1X,'DAY',3X,'N %',8X,'UPTK',
     2 2X,'UPTK',8I6)
500   FORMAT (/,A,2X,A/)
600   FORMAT (I4,E6.2,E6.2,2E6.1,8E6.1)
      END
C
C
C
C     ***************************** WRITE SUBROUTINE *****************
C
      SUBROUTINE WRITE
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
C
      CUMDTT=CUMDTT+DTT
      CRAIN=CRAIN+PRECIP
      IF (KOUTWA.EQ.0) GO TO 100
      IOUTWA=IOUTWA+1
      AES=AES+ES
      AEP=AEP+EP
      AET=AET+ET
      AEO=AEO+EO
      ASOLR=ASOLR+SOLRAD
      ATEMX=ATEMX+TEMPMX
      ATEMN=ATEMN+TEMPMN
      ARUNOF=ARUNOF+RUNOFF
      ADRAIN=ADRAIN+DRAIN
      APRECP=APRECP+TPRECP
      IF (IOUTWA.EQ.KOUTWA) CALL OUTWA
100   IF (KOUTGR.EQ.0) RETURN
      IF (ISTAGE.GT.6) RETURN
      IOUTGR=IOUTGR+1
      ASWDF1=ASWDF1+SWDF1
      ASWDF2=ASWDF2+SWDF2
      IF (IOUTGR.EQ.KOUTGR) CALL OUTGR
      RETURN
      END
C
C
C     ********** SUBROUTINE TO CONVERT JULIAN DAY TO CALENDAR DATE *****
C
      SUBROUTINE CALDAT
C
      INCLUDE 'NNC1.BLK'
C
      IF (JDATE.GE.JDATEX) GO TO 200
      DO 100 I=1,12
          IDIM(I)=31
100   CONTINUE
      IDIM(4)=30
      IDIM(6)=30
      IDIM(9)=30
      IDIM(11)=30
      IDIM(2)=28
      IF (MOD(IYR,4).EQ.0) IDIM(2)=29
      IF (JDATEX.EQ.367) WRITE (NOUT1,500) JDATE
200   MO=1
```

```
      G6=1.0
      RETURN
1000  FORMAT (1H1.A.2X.A//)
1100  FORMAT (/1X.5X.'LATITUDE =',F6.1,' , SOWING DEPTH = '.F4.0,
     1 ' CM . PLANT POPULATION = '.F4.0.'PLANTS PER SQ METER')
1200  FORMAT (/1X.5X.'GENETIC SPECIFIC CONSTANTS',3X.'P1V =',F5.3,2X,
     1 'P1D =',F6.4.2X,'P5=',F5.0,2X,'G2 =',F6.2,2X,
     2 'G3 ='.F5.2,2X,'G4 =',F5.2,/)
1300  FORMAT (1X,5X.'SOIL ALBEDO= ',F4.2,2X,'U=',F5.1,2X,'SWCON=',F6.2,
     1 '     RUNOFF CURVE NO.=',F6.1)
1400  FORMAT (/6X.'JULIAN DAY     IRRIGATION(MM)')
1500  FORMAT (8X,I5,7X.F5.0)
1600  FORMAT (//.2X,'DEPTH-CM',5X,'LO LIM',1X,'UP LIM',1X,'SAT SW',
     1 1X.'EXT SW'.2X.'IN SW',5X,'WR',4X.'NO3'.4X.'NH4'/)
1700  FORMAT (1X,F5.0,'-',F5.0,F9.3,1X,4(1X,F6.3).1X.F6.3.2F7.1)
1800  FORMAT(/.4X,'0.-',F5.0,F9.1.1X,4(1X.F6.1),F14.0.F7.0)
1900  FORMAT (/,' FERTILIZER INPUTS',/,' JULIAN DAY',5X,'KG/HA',5X,
     1 'DEPTH'.'    SOURCE',/)
2000  FORMAT (I10,2F10.2.3X.A40)
2100  FORMAT (/,' NITROGEN NON-LIMITING',/)
      END
C     ********** OUTPUT SUBROUTINE FOR WATER BALANCE*******************
C
      SUBROUTINE OUTWA
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
      INCLUDE 'COMIBS.BLK'
C
      DIMENSION AVEARG(10)
      EQUIVALENCE (AVEARG(1).AES)
      IF (JHEAD.EQ.1) GO TO 100
      IF (KOUTWA.NE.0) WRITE (NOUT3,600)
      JHEAD=1
      GO TO 300
100   DAWA=FLOAT(IOUTWA)
      DO 200 I=1.7
         AVEARG(I)=AVEARG(I)/DAWA
200   CONTINUE
      CALL CALDAT
      WRITE (NOUT3,700) JDATE,(AVEARG(I),I=2,7),AVEARG(10),
     1 SW(1),SW(2),SW(3),SW(4),SW(5),PESW
300   DO 400 I=1.10
         AVEARG(I)=0.
400   CONTINUE
      IOUTWA=0
      RETURN
C
500   FORMAT (1H1,///,2X,A36,2X,A16,/)
600   FORMAT (1H ,/,1X.'JUL',1X,10('-').' AVERAGE ',9('-'),1X,
     1 'PERIOD   SW CONTENT W/DEPTH  TOTAL'./,
     2 ' DAY  EP   ET   EO  SR   MAX  MIN  PREC',
     3 '     SW1  SW2  SW3  SW4  SW5   PESW',/)
700   FORMAT (I4,F4.1,2F5.1,F5.0,2F5.1,1X,F6.2,1X,5(F5.2),2X,F5.1)
      END
C
C     ****************OUTPUT SUBROUTINE FOR GROWTH*********************
C
      SUBROUTINE OUTGR
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
```

```
      DO 900 I=2,5
900   TMA(I)=TMA(1)
1000  CONTINUE
      CALL SOLT
C********** INITIALIZE NITRIFICATION ROUTINE
      DO 1100 L=1,NLAYR
           CNI(L)=0.1
           WFY(L)=(SW(L)-LL(L))/DUL(L)
           IF (SW(L).GT.DUL(L)) WFY(L)=1.0-((SW(L)-DUL(L))
     1                  /(SAT(L)-DUL(L)))
           IF (WFY(L).LT.0.0) WFY(L)=0.0
           TFY(L)=0.0009766*ST(L)*ST(L)
           IF (ST(L).LT.5.0) TFY(L)=0.0
           PHN(L)=1.0
           IF(PH(L).LT.6.0)PHN(L)=(PH(L)-4.5)/1.5
           IF(PH(L).GT.8.0)PHN(L)=9.0-PH(L)
1100  CONTINUE
      RETURN
      END
C
C
C*************************************************************************
      SUBROUTINE ECHO(IECHON)
C*************************************************************************
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'NTRC2.BLK'
C
      INCLUDE 'COMIBS.BLK'
      LOGICAL IECHON
      CHARACTER*40 FTYPE(6)
C
      DATA FTYPE/'UREA','AMMONIUM NITRATE',
     1'ANHYDROUS AMMONIA OR AMMONIUM SULPHATE',
     2'CALCIUM AMMONIUM NITRATE','M NITRATE',' '/
C
C
      WRITE (NOUT1,400) INSTE,SITEE,EXPTNO,YEAR,NTRT
      WRITE (NOUT1,200) TITLEE,TITLET
      WRITE (NOUT1,100) TITLEW
      WRITE (NOUT1,300) TAXON
      WRITE (NOUT1,500)VARTY
100   FORMAT (1X,'WEATHER :',A40)
200   FORMAT (1X,'EXP.    :',A40,
     1        /1X,'TRT.    :',A40)
300   FORMAT (1X,'SOIL    :',A60)
400   FORMAT (1X,'INST_ID :',A2,2X,'SITE_ID: ',A2,2X,'EXPT_NO: ',
     1A2,2X,'YEAR : 19',I2,2X,'TRT_NO: ',I2)
500   FORMAT(1X,'VARIETY  :',A16)
      WRITE (NOUT1,1100) LAT,SDEPTH,PLANTS
      WRITE (NOUT1,1200) P1V,P1D,P5,G2,G3,G4
      WRITE (NOUT1,1400)
      IF(IECHON)THEN
           WRITE (*    ,400) INSTE,SITEE,EXPTNO,YEAR,NTRT
           WRITE (*    ,200) TITLEE,TITLET
           WRITE (*    ,100) TITLEW
           WRITE (*    ,300) TAXON
           WRITE (*,500)VARTY
           WRITE (*,1100) LAT,SDEPTH,PLANTS
           WRITE (*,1200) P1V,P1D,P5,G2,G3,G4
           WRITE (*,1400)
      ENDIF
      DO 600J = 1, NIRR
```

```
          WF(L)=WX-XX
          XX=WX
          RWU(L)=0.0
          FLUX(L)=0.0
          IF (L.LE.5) FLOW(L)=0.0
300   CONTINUE
      RTDEP=DEPMAX
      IF (NSENS .EQ. 2) THEN
          WRITE(*,400)
400       FORMAT(' INPUT A VALUE TO ESTIMATE HOW 'FULL' THE PROFILE IS
     1AT' ,'THE BEGINNING OF THE RUN.',/,
     2 ' A VALUE OF 1.0 IDICATES FULL TO THE DUL.',/,
     3 ' VALUE CHOSEN IS :    ',$)
          READ (*,*)SOILN
          CUMDEP=0.
          DO 500 L = 1,NLAYR
               SW(L)=DUL(L)
               IF (SOILN .LE. 1) THEN
                    SW(L)=LL(L)+(DUL(L)-LL(L))*SOILN
                    CUMDEP=CUMDEP+DLAYR(L)
                    IF (CUMDEP .GT. 110) THEN
                         DLL=0.008*(CUMDEP-110.)*(DUL(L)-LL(L))+LL(L)
                         IF(SW(L).LT.DLL)SW(L)=DLL
                    ENDIF
               ENDIF
500       CONTINUE
      ENDIF
      CN1=-16.91+1.348*CN2-0.01379*CN2**2+0.0001172*CN2**3
      SMX=254.*(100./CN1-1.)
      SWEF=0.9-0.00038*(DLAYR(1)-30.)**2
      CET=0.
      CES=0.
      CEP=0.
      CRAIN=0.
      RWUMX=0.03
      RETURN
      END
C
C
C******************SOIL NITROGEN INITIALIZATION SUBROUTINE***********
C
      SUBROUTINE SOILNI
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'NTRC2.BLK'
      INCLUDE 'NMOVE.BLK'
      INCLUDE 'COMIBS.BLK'
      DIMENSION WRN(10)
C*****SUBROUTINE INITIALIZES SOIL NITROGEN PARAMETERS
      IF(DMOD.EQ.0.)DMOD=1.
      CTNUP=0.0
      DO 100 I=1,NLAYR
           IF (BD(I).EQ.0.) BD(I)=1.2
           IF (PH(I).EQ.0.0) PH(I)=7.0
100   CONTINUE
C*****CALCULATE N CONTRIBUTIONS
      RCN=40
      SNKG=STRAW*0.40/SCN
      RNKG=ROOT*0.40/RCN
C******DISTRIBUTE ROOT MASS
      WSUM=0.0
      DEPTH=0.0
      DO 200 I=1,NLAYR
           DEPTH=DEPTH+DLAYR(I)
```

```
      WRITE(*,1100)
1100  FORMAT(' DO YOU WANT POST HARVEST COMPARISON WITH OBSERVED DATA'
     1 ,/,'  DISPLAYED ON THE SCREEN (Y/N) ? ')
      READ(*,1200)IEHVC
1200  FORMAT(A)
      IF(IEHVC.EQ.'Y'.OR.IEHVC.EQ.'Y')IHVON=.TRUE.
      CALL PROGRI
      IFIRST=2
      IF (ISWSWB.NE.0) CALL SOILRI
      IF (ISWNIT.NE.0) CALL SOILNI
      CALL ECHO(IECHON)
1300  READ (11,1700,END=1400) IYR,JDATE,SOLRAD,TEMPMX,TEMPMN
     1,RAIN
      SOLRAD=SOLRAD*23.9
      IF (JDATEX.EQ.367) CALL CALDAT
      IF (ISWNIT.NE.0) CALL NTRANS
      IF (ISWSWB.NE.0) CALL WATBAL
      IF (JDATE.EQ.ISOW.OR.ISTAGE.NE.7) CALL PHENOL (IRET)
      IF(IRET.EQ.1)GO TO 1500
      IF (ISTAGE.LT.6) CALL GROSUB
      IF (ISWNIT.NE.0) CALL NWRITE
      CALL WRITE
      GO TO 1300
1400  WRITE (NOUT1,1800)
      WRITE(*,1800)
1500  WRITE(*,1600)
1600  FORMAT(' SIMULATION COMPLETE FOR THIS TREATMENT',/,
     1 ' DO YOU WANT TO SIMULATE THE NEXT TREATMENT Y/N?')
      READ(*,'(A)')IFIN
      IF(IFIN.EQ.'Y'.OR.IFIN.EQ.'Y')THEN
          CLOSE(11)
          GO TO 200
      ELSE
          STOP
      ENDIF
1700  FORMAT (5X,I2,1X,I3,1X,F5.2,2(1X,F5.1),1X,F5.1,1X,F6.2)
1800  FORMAT (6X,'END OF WEATHER DATA')
      END
C
C     ****************************** PROGRAM INITIALIZATION
C
      SUBROUTINE PROGRI
C
      INCLUDE 'NNC1.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NNC4.BLK'
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'COMIBS.BLK'
      INCLUDE 'PREDOB.BLK'
      IF (ISWNIT.EQ.1) THEN
          MINCK=0
      ENDIF
      WRITE (*,100)
100   FORMAT (25(/),15X,'SIMULATION HAS BEGUN....PLEASE WAIT.'/
     1  10X, 'DON''T TOUCH THE TERMINAL UNTIL IT PROMPTS YOU.')
      S1=SIN(LAT*0.01745)
      C1=COS(LAT*0.01745)
      XPLANT=PLANTS
      ISTAGE=7
      TBASE=2.
      LAI=0.
      SENTIL=0.
      SENLF=0.
      HI=0.
      SNOW=0.
```

```
          NO3(L)=SNO3(L)*FAC(L)
          IF (NO3(L).GT.1.0) GO TO 200
          OUTN=0.0
          GO TO 300
200       NOUT(L)=SNO3(L)*FLUX(L)/(SW(L)*DLAYR(L)+FLUX(L))
          SMIN=1.0/FAC(L)
          IF(SNO3(L)-NOUT(L).LT.SMIN)NOUT(L)=SNO3(L)-SMIN
          OUTN=NOUT(L)
          SNO3(L)=SNO3(L)-OUTN
          NO3(L)=SNO3(L)*FAC(L)
300    CONTINUE
       RETURN
400    CONTINUE
       DO 500 L=1,NLAYR
          NUP(L)=0.0
500    CONTINUE
       OUTN=0.0
       DO 600 J=1,MU
          K=MU+1-J
          SNO3(K)=SNO3(K)+OUTN
          IF(FLOW(K).LT.0.)GO TO 600
          NUP(K)=SNO3(K)*FLOW(K)/(SW(K)*DLAYR(K)+FLOW(K))*0.5
          OUTN=NUP(K)
          IF(K.EQ.1)GO TO 600
          SNO3(K)=SNO3(K)-OUTN
600    CONTINUE
       OUTN=0.0
       DO 700 J=1,MU
          SNO3(J)=SNO3(J)-OUTN
          IF(FLOW(J).GT.0.)GO TO 700
          NUP(J)=SNO3(J)*FLOW(J)/(SW(J)*DLAYR(J)+FLOW(J))*0.5
          OUTN=NUP(J)
          SNO3(J)=SNO3(J)+OUTN
700    CONTINUE
       RETURN
       END
C
C
C*********************NITROGEN DEFICIENCY FACTOR ROUTINE************
C
       SUBROUTINE NFACTO
C
       INCLUDE 'NNC1.BLK'
       INCLUDE 'NNC2.BLK'
       INCLUDE 'NTRC1.BLK'
C
       REAL NFAC
C***** CONVERT XSTAGE TO ZADOKS GROWTH STAGE
       IF(XSTAGE.LE.2.0)ZSTAGE=XSTAGE
       IF(XSTAGE.GT.2..AND.XSTAGE.LE.3.0)ZSTAGE=2.0+2.0*(XSTAGE-2.0)
       IF(XSTAGE.GT.3..AND.XSTAGE.LE.4.)ZSTAGE=4.0+1.7*(XSTAGE-3.0)
       IF(XSTAGE.GT.4..AND.XSTAGE.LE.4.4)ZSTAGE=5.7+0.8*(XSTAGE-4.0)
       IF(XSTAGE.GT.4.4.AND.XSTAGE.LE.6.)ZSTAGE=6.02+1.8625*(XSTAGE-4.4)
       YSTAGE=XSTAGE
       ZS2=ZSTAGE*ZSTAGE
       ZS3=ZS2*ZSTAGE
       ZS4=ZS3*ZSTAGE
       IF(P1V.EQ.0.033)THEN
          TCNP=-5.0112400-6.350677*ZSTAGE+14.95784*SQRT(ZSTAGE)
      1 +0.2238197*ZS2
       ELSE
          TCNP=7.4531813-1.7907829*ZSTAGE+0.6092849*SQRT(ZSTAGE)
      1 +0.0933967*ZS2
       ENDIF
       IF(ZSTAGE.GT.6.0)TCNP=TCNP-(ZSTAGE-6.0)*0.140
       TCNP=TCNP/100.0
```

```
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'NTRC2.BLK'
      INCLUDE 'NMOVE.BLK'
C
      REAL NUF,NDEM
      DIMENSION RNO3U(10), RNH4U(10)
      TNUP=0.0
      TANC=TOPSN/TOPWT
      RANC=ROOTN/RTWT
      TRNLOS=0.0
      TRLV=0.0
      DO 100 L=1,NLAYR
           TRLV=TRLV+RLV(L)
           NO3(L)=SNO3(L)*FAC(L)
           NH4(L)=SNH4(L)*FAC(L)
100   CONTINUE
      DNG=PDWI*TCNP
      IF(XSTAGE.LE.1.2)DNG=0.0
      IF (PDWI.EQ.0.) PDWI=1.
      TNDEM=TOPWT*(TCNP-TANC)+DNG
      RNDEM=RTWT*(RCNP-RANC)+PGRORT*RCNP
      NDEM=TNDEM+RNDEM
      ANDEM=NDEM*PLANTS*10.0
      DROOTN=0.0
      DTOPSN=0.0
      TRNU=0.0
      NUF=0.0
      TNUP=0.0
      IF (ANDEM.LE.0.0) GO TO 400
      DO 200 L=1,NLAYR
           IF (RLV(L).EQ.0.0) GO TO 300
           L1=L
           FNH4=1.0-EXP(-0.025*NH4(L))
           FNO3=1.0-EXP(-0.0275*NO3(L))
           IF (FNO3.LT.0.03) FNO3=0.0
           IF (FNH4.LT.0.03) FNH4=0.0
           SMDFR=(SW(L)-LL(L))/ESW(L)
           IF(SMDFR.LT.0.0)SMDFR=0.0
           IF(SW(L).GT.DUL(L))SMDFR=1.0-(SW(L)-DUL(L))/(SAT(L)-DUL(L))
           RFAC=RLV(L)*SMDFR*SMDFR*DLAYR(L)*100
           IF(XSTAGE.GT.5.0)RFAC=RFAC*(6.0-XSTAGE)
           RNO3U(L)=RFAC*FNO3*0.006
           UP1=SNO3(L)-RNO3U(L)
           SMIN=1.0/FAC(L)
           IF (UP1.LT.SMIN) UP1=SMIN
           RNO3U(L)=SNO3(L)-UP1
           RNH4U(L)=RFAC*FNH4*0.006
           TRNU=TRNU+RNO3U(L)+RNH4U(L)
200   CONTINUE
300   IF (ANDEM.GT.TRNU) ANDEM=TRNU
      IF (TRNU.EQ.0.0) GO TO 600
      NUF=ANDEM/TRNU
      TRNU=TRNU*NUF
400   TRNS=0.0
      DO 500 L=1,L1
           UNO3=RNO3U(L)*NUF
           UNH4=RNH4U(L)*NUF
           SNO3(L)=SNO3(L)-UNO3
           PNUP=UNO3+UNH4
           IF(TANC.GT.TCNP)RNLOSS=RANC*RTWT*0.05*PLANTS*RLV(L)/TRLV
           SNH4(L)=SNH4(L)-UNH4
           TRNLOS=TRNLOS+RNLOSS
           FON(L)=FON(L)+RNLOSS
           TNUP=TNUP+PNUP
           TRNS=TRNS+SNO3(L)+SNH4(L)
500   CONTINUE
```

```
          NH4(L)=SNH4(L)*FAC(L)
          TF=(ST(L)-5.0)/30.0
          IF(ST(L) .LT. 5.0)TF=0.0
          TOTN=SNO3(L)+SNH4(L)-2.0/FAC(L)
          IF (TOTN .LT. 0.0) TOTN=0.0
          CNR=(0.4*FOM(L))/(FON(L)+TOTN)
          CNRF=EXP(-0.693*(CNR-25)/25.0)
          IF (CNRF .GT. 1.0) CNRF=1.0
          FOM(L)=0.0
          GRCOM=0.0
          GRNOM=0.0
          DO 800 JP=1.3
               FOM(L)=FOM(L)+FPOOL(L.JP)
               G1=TF*MF*CNRF*RDECR(JP)
               X=FPOOL(L.JP)/FOM(L)
               GRNOM=GRNOM+G1*X*FON(L)
               GRCOM=GRCOM+G1*X*FOM(L)
800       CONTINUE
          RHMIN=NHUM(L)*DMINR*TF*MF*DMOD
          HUM(L)=HUM(L)-RHMIN*10.0+0.2*GRNOM/0.04
          NHUM(L)=NHUM(L)-RHMIN+0.2*GRNOM
          RNAC=AMIN1(TOTN.GRCOM*(0.02-FON(L)/FOM(L)))
          IF(RNAC .LT. 0.)RNAC=0.
          FOM(L)=FOM(L)-GRCOM
          FON(L)=FON(L)+RNAC-GRNOM
          NNOM=0.8*GRNOM+RHMIN-RNAC
          SNH4(L)=SNH4(L)+NNOM
          IF (SNH4(L) .GT. 1.0) GO TO 900
          DEF=1.0-SNH4(L)
          SNO3(L)=SNO3(L)-DEF
          SNH4(L)=1.0
C***********NITRIFICATION SECTION
900       SANC=1.0-EXP(-0.01363*SNH4(L))
          ELNC=AMIN1(TF.WFD.SANC)
          RP2=CNI(L)*EXP(2.302*ELNC)
          IF (RP2 .LT. 0.05) RP2=0.05
          IF (RP2 .GT. 1.0) RP2=1.0
          CNI(L)=RP2
          A=AMIN1(RP2.WFD.TF.PHN(L))
          B=(A*40.0*NH4(L)/(NH4(L)+90.0))*SNH4(L)
          RNTRF=AMIN1(B,SNH4(L)-2.0)
          IF(RNTRF .LT. 0.0)RNTRF=0.0
          SNH4(L)=SNH4(L)-RNTRF
          SNO3(L)=SNO3(L)+RNTRF
          SARNC=1.0-EXP(-0.1363*SNH4(L))
          XW=AMAX1(WFD.WFY(L))
          XT=AMAX1(TF.TFY(L))
          CNI(L)=CNI(L)*AMIN1(XW.XT.SARNC)
          IF (CNI(L) .LE. 0.05) CNI(L)=0.05
          WFY(L)=WFD
          TFY(L)=TF
          TMINH=TMINH+RHMIN
C
C*********DENITRIFICATION SECTION
          DNRATE=0.0
          IF(NO3(L) .LT. 1.0)GO TO 1000
          FW=0.0
          IF (SW(L) .LE. DUL(L)) GO TO 1000
          IF(ST(L) .LT. 5.0)GO TO 1000
          SOILC=0.58*HUM(L)
          CW=(SOILC*FAC(L))*0.0031+24.5+0.4*FPOOL(L,1)
          FW=1.0-(SAT(L)-SW(L))/(SAT(L)-DUL(L))
          FT=0.1*EXP(0.046*ST(L))
          DNRATE=6.0*1.E-05*CW*NO3(L)*BD(L)*FW*FT*DLAYR(L)
          SMIN=1.0/FAC(L)
          SNO3(L)=SNO3(L)-DNRATE
```

```
      IF (NREP .EQ. 1) GO TO 1400
      ENDFILE(NOUT1)
      ENDFILE(NOUT2)
      ENDFILE(NOUT3)
      ENDFILE(NOUT4)
1400  OPEN (UNIT = NOUT1,FILE = OUT1,STATUS = 'NEW')
      OPEN (UNIT = NOUT2,FILE = OUT2,STATUS = 'NEW')
      OPEN (UNIT = NOUT3,FILE = OUT3,STATUS = 'NEW')
      OPEN (UNIT = NOUT4,FILE = OUT4,STATUS = 'NEW')
      WRITE (NOUT0,1500) TITLEE,OUT1,OUT2,OUT3,OUT4,FILEB
1500  FORMAT(1X,A40,5(1X,A12))
1600  CONTINUE
C
      NLTRT = NTRT
      OPEN (18, FILE = FILE8,STATUS = 'OLD')
      WRITE (*,1700) TITLEE
1700  FORMAT (30(/),T2,'TRT',T47,'INST.',T54,'SITE',T60,'EXPT.',
     1/,T2,'NO.',T7,A40,T48,'ID',T55,'ID',T61,'NO'.
     2          T66,'YEAR',/,T2,'---',T7,40('-'),T47,'----',
     3          T54,'----',T60,'----',T66,'----')
1800  READ  (18,1900, END = 2100) TRTNO,TITLET
      WRITE (*,2000) TRTNO,TITLET,INSTE,SITEE,EXPTNO,YEAR
1900  FORMAT (9X,I2,1X,A40,/)
2000  FORMAT ( T2,I2,')',T7,A40,T48,A2,T55,A2,T61,A2,T66,'19',I2)
      GO TO 1800
2100  REWIND 18
      IF (NTRT .GT. TRTNO) NTRT = 1
C
2200  WRITE (*,2300) NTRT
2300  FORMAT(/,1X,I2,']',2X,'<=== CURRENT TREATMENT SELECTION.',
     1/6X,'<--- NEW SELECTION?' )
      READ (*,2400,ERR = 2200) N
2400  FORMAT(I2)
      IF (N .LT. 0 .OR. N .GT. TRTNO) GO TO  2200
      IF (N .NE. 0) NTRT = N
2500  READ (18,2600,END = 2800) TRTNO,TITLET,ISOILT,KVARTY
2600  FORMAT (9X,I2,1X,A40,2(1X,I4))
      READ (18,2700,END = 2800) ISIM,ISOW,PLANTS,ROWSPC,SDEPTH,IIRR,
     1      ISWNIT,EFFIRR,DSOIL,THETAC,PHINT,IPHN
2700  FORMAT (I4,1X,I3,1X,F6.2,1X,F6.3,1X,F5.2,2(1X,I2),1X,F6.2,1X,
     1F5.2,1X,F6.1,1X,F6.2,1X,I2)
      ISWSWB=1
      IF(IIRR.EQ.4)ISWSWB=0
      IF (TRTNO .NE. NTRT) GO TO 2500
      GO TO 3100
2800  IF (TRTNO .EQ. NTRT) GO TO 3100
      WRITE (*,2900) NTRT,FILE8
2900  FORMAT(1X,'ERROR! TREATMENT NO. ',I2,' MISSING IN FILE ',A12,'.',
     11X,'<CTRL-BREAK> AND FIX THE PROBLEM FIRST.')
      READ (*,3000) ANS
3000  FORMAT(1A1)
3100  CLOSE (18)
C
C     NEW SECTION TO MODIFY VALUES FOR ISOW, PLANTS, AND ISWNIT
C
      IF (NSENS .EQ. 2) THEN
          WRITE (*,'(//,A,I3/)')' CURRENT SOWING DATE IS ',ISOW
          WRITE (*,'(A,$)')' MODIFY SOWING DATE ? (Y,N) : '
          READ (*,'(A1)') ANS
          IF (ANS .EQ. 'Y' .OR. ANS .EQ. 'Y') THEN
              WRITE (*,'(A,$)')'  ENTER NEW VALUE    (I3)  : '
              READ (*,'(I3)')ISOW
          ENDIF
          WRITE (*,'(/A,F6.2)')' CURRENT PLANT POPULATION IS ',PLANTS
          WRITE (*,'(A,$)')    ' MODIFY PLANTS ?       (Y,N) : '
          READ (*,'(A1)')ANS
```

```
      SUBROUTINE IPVAR
C
      INCLUDE 'COMIBS.BLK'
      INCLUDE 'NNC2.BLK'
      INCLUDE 'NNC1.BLK'
C
C***  VARIETY SELECTION.
      NVARS = 0
      IF (NSENS .EQ. 2) THEN
          WRITE (*,100)
100       FORMAT (30(/),23X,'============================',/
     1                  23X,' VARIETIES IN THE DATA BASE ',/
     2                  23X,'============================',/)
      ENDIF
      OPEN (19,FILE = FILE9,STATUS = 'OLD' )
200   READ (19,300,END = 600) IVAR,VARTY,P1V,P1D,P5,G2,G3,G4
300   FORMAT(I4,A16,F8.6,F8.6,F7.1,F8.5,2(F7.5))
      IF (NSENS .EQ. 0 .AND. IVAR .EQ. KVARTY) GO TO 1300
      IF (NSENS .NE. 0) THEN
          NVARS = NVARS + 1
          IF (NVARS .EQ. 1)WRITE (*,400)
          IF (NVARS .GT. 14) THEN
              WRITE (*,'(/,A,$)')'  PRESS <ENTER> TO CONTINUE LISTING.
     1'
              READ (*,'(A1)')ANS
              WRITE (*,'(7(/))')
              NVARS = 1
              WRITE (*,400)
          ENDIF
          WRITE (*,500) IVAR,VARTY
      ENDIF
400   FORMAT(/,23X,'   NO.     VARIETY NAME    ',
     1         /,23X,'  ----   ----------------   ')
500   FORMAT(25X,I4,3X,A16)
      GO TO 200
600   IF (NSENS .EQ. 0) THEN
          WRITE (*,700) KVARTY,FILE9
700       FORMAT(/,' ERROR! VARTY NO ',I3,' NOT FOUND IN FILE :',A12,
     1       /T8, '<CTRL BREAK> TO STOP EXECUTION AND FIX THE FILE.')
          READ (*,*) ANS
          GO TO 1300
      ENDIF
      REWIND 19
C
800   WRITE (*,900) KVARTY
900   FORMAT(/1X,I4,']',1X,'<======== VARIETY SELECTED. ',/5X,
     1  '<-------- NEW SELECTION? ')
      READ (*,1000,ERR = 800) N
1000  FORMAT(I4)
      IF (N .LT. 0 .OR. N .GT. IVAR) GO TO 800
      IF (N .NE. 0) KVARTY = N
1100  READ (19,300,END = 1200) IVAR,VARTY,P1V,P1D,P5,G2,G3,G4
      IF (IVAR .NE. KVARTY) GO TO 1100
      GO TO 1300
1200  CONTINUE
      WRITE (*,700) KVARTY,FILE9
      READ (*,*) ANS
1300  CLOSE (19)
      RETURN
      END
C
      SUBROUTINE IPSOIL
C
C***  SOIL SELECTION.
C
      INCLUDE 'COMIBS.BLK'
```

```
      SUBROUTINE IPSWIN
      INCLUDE 'NNC3.BLK'
      INCLUDE 'NTRC2.BLK'
      INCLUDE 'COMIBS.BLK'
C
      INTEGER TRTNO
      IF (DSFILE .GT. 0) RETURN
      OPEN (15,FILE = FILE5,STATUS = 'OLD')
100   READ (15,200,END = 700,ERR = 500) TRTNO
200   FORMAT(I2)
      I = 0
300   I = I + 1
      READ (15,400,END = 700,ERR = 500) DLAYR(I),SW(I),NH4(I),
     1 NO3(I),PH(I)
400   FORMAT(F6.0,1X,F6.3,3(1X,F4.1))
      IF(SW(I).EQ.0.)SW(I)=SWINIT(I)
      IF (DLAYR(I) .GE. 0) GO TO 300
      IF (TRTNO .NE. NTRT) GO TO 100
      GO TO 900
500   WRITE (*,600) FILE5
600   FORMAT(/10X,'ERORR! FORMAT DATA MISMATCH IN FILE: '.A12./10X,
     1      'ENTER <CTRL-BREAK> TO STOP EXECUTION AND FIX THE FILE.')
      READ (*,*) ANS
      GO TO 900
700   WRITE (*,800) FILE5
800   FORMAT(/10X,'ERROR! ENDOF DATA IN FILE: '.A12./10X,
     1      'ENTER <CTRL-BREAK> TO STOP EXECUTION AND FIX THE FILE.')
      READ (*,*) ANS
900   CLOSE (15)
C
1000  RETURN
      END
C
C
C
      SUBROUTINE IPTRT
C
C
      INCLUDE 'PREDOB.BLK'
      INCLUDE 'NNC3.BLK'
      INCLUDE 'COMIBS.BLK'
      INCLUDE 'NNC1.BLK'
      INTEGER TRTNO
      NIRR = 0
      IF (IIRR .NE. 2 ) GO TO 1400
      OPEN (16,FILE = FILE6,STATUS = 'OLD')
100   READ (16,*,END = 600,ERR = 800) TRTNO
      IF (TRTNO .EQ. NTRT) GO TO 300
200   READ (16,*,END = 600,ERR = 800) ITEMP
      IF (ITEMP .GT. 0) GO TO 200
      GO TO 100
300   NIRR = 0
400   NIRR = NIRR + 1
      READ (16,*,END = 600,ERR = 800) ITEMP,AMT
      IF (ITEMP .LE. 0) GO TO 500
C
C     CONVERT AMT FROM MM TO CM
C
      JDAY(NIRR) = ITEMP
      AIRR(NIRR) = AMT
      GO TO 400
500   NIRR = NIRR - 1
      GO TO 1000
600   WRITE (*,700) NTRT,FILE6
700   FORMAT(/10X.'DATA ON TREATMENT NO. '.I3.' MISSING IN '.
     1A12,' . <CNTRL> <BREAK>, FIX THE FILE AND RE-RUN THE SIMULATION.')
```

```
2000  CLOSE (8)
C
      CALL IPSOIL
      CALL IPVAR
      CALL IPNIT
      CALL IDWTH
C      CALL OPECHO
      RETURN
      END
C
C
C
      SUBROUTINE IPWTH
C
      INCLUDE 'COMIBS.BLK'
      INCLUDE 'NNC1.BLK'
C
C     READ NEW WEATHER RECORD, IF APPROPRIATE
C
C     LEAVE TIS LINE OUT UNTIL WE FIGURE OUT HOW NWFILE IS SET
C      IF (NREP .GT. 1 .AND. NWFILE .EQ. 0) GO TO 1000
      OPEN (11,FILE = FILE1,STATUS = 'OLD')
      READ (11,100) LAT,XLONG,PAREAC,PARDAT
100   FORMAT(4X,2(1X,F6.2),2(1X,F5.2))
      READ (11,200)  IPY,INITDA
200   FORMAT(5X,I2,1X,I3,1X,F5.2,2(1X,F5.1),F5.1,1X,F6.2)
      CLOSE (11)
      IF (ISOW .GE. INITDA .AND. ISIM .GE. INITDA) GO TO 400
      WRITE (*,300)
300   FORMAT(/10X,
     1'  PLANTING AND/OR SIMULATION DATE SPECIFIED IS BEFORE THE',/10X,
     2'FIRST AVAILABLE WEATHER DAY. <CTRL-BREAK> AND FIX THE FILE.')
      READ (*,*) ANS
400   IF (ISOW .GE. ISIM) GO TO 600
      WRITE (*,500)
500   FORMAT(/10X,'WATER BALANCE MUST BEGIN ON OR BEFORE THE PLANTING',
     1' DATE.',/10X,'<CTRL-BREAK> AND FIX THE CROP MANAGEMENT FILE.')
      READ (*,*) ANS
600   OPEN (11,FILE = FILE1,STATUS = 'OLD')
      READ (11,100) LAT,XLONG,PAREAC,PARDAT
700   CONTINUE
800   CONTINUE
900   CONTINUE
C
C      IF (NREP .GT. 1 .AND. IWATER .EQ. ISIM .AND. NWFILE .EQ. 0) GO TO
C     +     1300
C      MAXWTH = IP
C      IF(MAXWTH.GT.365) MAXWTH=365
C      ISIM   = IWATER
C 1300 CONTINUE
      RETURN
      END
      SUBROUTINE IPFREQ
      INCLUDE 'NTRC1.BLK'
      INCLUDE 'NNC1.BLK'
      WRITE (*,100)
100   FORMAT(30(/))
200   CONTINUE
      WRITE (*,300) KOUTWA
300   FORMAT(1X,I2,' DAYS  ','<=== OUTPUT FREQUENCY FOR WATER BALANCE ',
     1'COMPONENTS.', /10X,'<--- NEW VALUE?')
      READ (*,400,ERR = 500) IOUTWA
400   FORMAT(I2)
      IF (IOUTWA  .LT. 0 .OR. IOUTWA .GT. 100) GO TO 500
      IF (IOUTWA  .GT. 0) KOUTWA = IOUTWA
      GO TO 900
```

```
C       -------------------------------------------------------------
C       FILE7 SECTION
C       -------------------------------------------------------------
      TRTNO = 0
      OPEN (33,FILE = FILE7,STATUS='OLD')
      DO 700 K = 1,10000
400       READ (33,1100,END=900,ERR=800) TRTNO,INSTE,SITEE,YR,EXPTNO
          IF (TRTNO .EQ. NTRT) THEN
              IF (NSENS .EQ. 2) WRITE (*,1500) TRTNO
              DO 500 J = 1,10000
                  READ (33,1200,END=900,ERR=800) JFDAY(J),AFERT(J),
     1                             DFERT(J),IFTYPE(J)
                  IF (JFDAY(J) .LT. 0) GO TO 900
                  IF (NSENS .EQ. 2) THEN
                      WRITE(*,1600)
                      WRITE(*,1700) JFDAY(J),AFERT(J),DFERT(J),IFTYP
     1E(J)
                      WRITE(*,'(/A$)')
     1              ' DO YOU WANT TO MODIFY THESE DATA ? (Y,N) : '
                      READ  (*,1400)ANS
                      IF (ANS .EQ. 'Y' .OR. ANS .EQ. 'Y') THEN
                          WRITE (*,'(/A$)')'   MODIFY DAY    ? (Y,N
     1) : '
                          READ (*,1400)ANS
                          IF (ANS .EQ. 'Y' .OR. ANS .EQ. 'Y') THEN
                              WRITE (*,'(A$)')'   ENTER NEW DAY
     1        : '
                              READ (*,*) JFDAY(J)
                          ENDIF
                          WRITE (*,'(A$)')'   MODIFY AMOUNT ? (Y,N)
     1 : '
                          READ (*,1400)ANS
                          IF (ANS .EQ. 'Y' .OR. ANS .EQ. 'Y') THEN
                              WRITE (*,'(A$)')'   ENTER NEW AMOUNT
     1        : '
                              READ (*,*) AFERT(J)
                          ENDIF
                          WRITE (*,'(A$)')'   MODIFY DEPTH  ? (Y,N)
     1 : '
                          READ (*,1400)ANS
                          IF (ANS .EQ. 'Y' .OR. ANS .EQ. 'Y') THEN
                              WRITE (*,'(A$)')'   ENTER NEW DEPTH
     1        : '
                              READ (*,*) DFERT(J)
                          ENDIF
                          WRITE (*,'(A$)')'   MODIFY TYPE   ? (Y,N)
     1 : '
                          READ (*,1400)ANS
                          IF (ANS .EQ. 'Y' .OR. ANS .EQ. 'Y') THEN
                              WRITE (*,'(A$)')'   ENTER NEW TYPE
     1        : '
                              READ (*,*) IFTYPE(J)
                          ENDIF
                      ENDIF
                  ENDIF
500           CONTINUE
          ELSE
              DO 600 M = 1,10000
                  READ (33,1200,END=900,ERR=800) MDAY
                  IF (MDAY .LT. 0) GO TO 400
600           CONTINUE
          ENDIF
700   CONTINUE
800   IERROR = 1
      TRTNO  = -99
900   IF (TRTNO .NE. NTRT) THEN
```

```
          WRITE (NOUT4,300) TITLEW
          WRITE (NOUT4,500) TAXON
          WRITE (NOUT4,700) VARTY
      ENDIF
200   FORMAT(/1X,'RUN ',I2,' ',A20)
300   FORMAT (1X,'WEATHER :',A40)
400   FORMAT (1X,'EXP.    :',A40,
     1       /1X,'TRT.    :',A40)
500   FORMAT (1X,'SOIL    :',A60)
600   FORMAT (1X,'INST ID :',A2,2X,'SITE_ID: ',A2,2X,'EXPT_NO: ',
     1A2,2X,'YEAR : 19',I2,2X,'TRT NO: ',I2)
700   FORMAT (1X,'VARIETY :  ',A16)
C
      GO TO (800,1000,1200,1400),IIRR
800   IF(KOUTGR.GT.0)WRITE (NOUT2,900)
      IF(KOUTWA.GT.0)WRITE (NOUT3,900)
      IF(KOUTNU.GT.0)WRITE (NOUT4,900)
900   FORMAT (1X,'IRRIG.  :NEVER IRRIGATED, RAINFED.')
      GO TO 1600
1000  IF(KOUTGR.GT.0)WRITE (NOUT2,1100)
      IF(KOUTWA.GT.0)WRITE (NOUT3,1100)
      IF(KOUTNU.GT.0)WRITE (NOUT4,1100)
1100  FORMAT(1X,'IRRIG.  :ACCORDING TO THE FIELD SCHEDULE.')
      GO TO 1600
1200  IF(KOUTGR.GT.0)WRITE (NOUT2,1300) DSOIL,THETAC
      IF(KOUTWA.GT.0)WRITE (NOUT3,1300) DSOIL,THETAC
      IF(KOUTNU.GT.0)WRITE (NOUT4,1300) DSOIL,THETAC
1300  FORMAT(1X,'IRRIG.  :IRRIGATED TO F.C. IF AVAILABLE WATER IN ',
     1'TOP ',F4.2,'M DROPS BELOW ',F4.1,' %.',/,
     2' THIS FUNCTION DISABLED')
      GO TO 1600
1400  IF(KOUTGR.GT.0)WRITE (NOUT2,1500)
      IF(KOUTWA.GT.0)WRITE (NOUT3,1500)
      IF(KOUTNU.GT.0)WRITE (NOUT4,1500)
1500  FORMAT(1X,'IRRIG.  :ASSUMED NO WATER STRESS.')
1600  IF (IIRR .NE. 3) GO TO 1800
      IF(KOUTGR.GT.0)WRITE (NOUT2,1700) AMTMIN
      IF(KOUTWA.GT.0)WRITE (NOUT3,1700) AMTMIN
      IF(KOUTNU.GT.0)WRITE (NOUT4,1700) AMTMIN
1700  FORMAT(10X,'NOTE: NOT IRRIGATED IF DEMAND IS LESS',
     1' THAN ',F5.2,'MM')
1800  RETURN
      END
```

```
<------------------------------------------------------------------>

      NNC2.BLK

<------------------------------------------------------------------>
C
C NON-NITROGEN COMMON BLOCK 2
C
      COMMON /COLDC/ SNOW,TEMPCR.TDU.VE.CUMVD.HI
      COMMON /GENET/ P1V,P1D.P2.P3.P4,P5,g1,g2,g3,g4,g5,g6
      COMMON /PHENL/ P9,CUMDTT.TBASE.SUMDTT,DF,S1,C1,ISTAGE,
     1  jstage,dtt,idur,cumph,SSTT,CSTT

<------------------------------------------------------------------>

         NNC3.BLK

<------------------------------------------------------------------>
C
C Non-Nitrogen Common Block 3
C
      Real L1
      Common /Soili/ Salb.Swcon.Cn2.Dlayr(10),Dul(10),L1(10),Sw(10),
     1 Sat(10).Depmax,Tdul.Nlayr,Smx.Wf(10),Wr(10).Rwu(10).Swef
     2 ,Swinit(10)
      Common /Irrig/ Nirr,Jday(366).Airr(366)
      Common /Water/ Sumes1.Sumes2.T,T11,Pesw,Tsw,Cumdep,Esw(10).
     1    Csd1,Csd2,Si1(6),Si2(6),Icsdur,Es,Ep.Et.Eo.Ces,Cep,Cet,
     1    Rlv(10).Precip,Crain,Drain,Idrsw,Rtdep,Swdf1,Swdf2,
     1    Swdf3,Trwu,Rwumx

<------------------------------------------------------------------>

        NNC4.BLK

<------------------------------------------------------------------>
C
C NON-NITROGEN COMMON BLOCK 4
C
      COMMON /CLIMT/ TEMPMN.TEMPMX.RAIN.SOLRAD
      COMMON /WRITS/ AES.AEP,AET.AEO.ASOLR,ATEMX.ATEMN.ARUNOF,
     1  ADRAIN,APRECP,ASWDF1,ASWDF2,IOUTGR,IOUTWA,JHEAD,KHEAD,
     2  TPRECP.RUNOFF
      REAL LAI,LFWT
      COMMON /GROTH/ GPSM.GPP.GRORT.PTF.LAI.biomas.pla,gpla,ln,senla,
     1  LFWT.PSW,TILSW.SEEDRV,REGM.SLW.TILN,widsl,xplant,plsc(25),
     1  RTWT,STMWT,GRNWT,swmin,tpsm,egmx.grolf,grostm,senlf,sentil

<------------------------------------------------------------------>

     NNC5.BLK

<------------------------------------------------------------------>
C
C NON-NITROGEN COMMON BLOCK 5
C
```

**************DIRECTORY OF TERMS FOR WHEAT NITROGEN MODEL JULY 1986*************

ADDM	
ADRAIN	
AEO	
AEP	These terms beginning with A followed by a variable name
AES	described elsewhere are averages used in the output routines.
AET	They represent averages of that variable over a period of
APRECP	days defined by default as 7 days but may be interactively
ARUNOF	altered via the variable KOUTWA for variables whose output
ASOLR	is printed in the water balance section and similarly by
ASWDF1	KOUTGR for variables whose output is printed in the growth
ASWDF2	section and by KOUTNU for variables whose output is printed
ATEMN	in the N output section.
ATEMX	
APESW	
AVEARG	
ATANC	
ATEMN	
ATEMX	
ANFAC	
A	- Zero to unity factor for relative nitrification rate (unitless)
ABD	- Average soil bulk density (g/cm**3)
ADD	- Temporary variable used in the calculation of crop residue distribution (kg/ha)
AFERT(J)	- Amount of nitrogen added as fertilizer on JFDAY(J) (kg N/ha)
AIRR(J)	- Amount of irrigation added on JDAY(J) (mm)
ALBEDO	- Integrated crop and soil albedo - unitless
ALX	- Current Julian date as a radian fraction of 1 year for soil temperature caculations
AMP	- Annual amplitude in annual average temperature
ANDEM	- Crop N demand (kg N/ha)
ANH4	- Total extractable ammonium N in soil profile (kg N/ha)
ANO3	- Total extractable nitrate N in soil profile (kg N/ha)
APTNUP	- Vegetative N uptake (kg N/ha)
ATOT	- Accumulator used to calculate moving average soil surface temperatures
AVEARG(10)	- Array used to store variables for soil water output calculations
AW	- Available water used in soil temperature calculations (cm)
AWR	- Assimilate area to weight ratio (square cm/g)
B	- Interim variable used in the Gamma function to predict soil temperature
BD	- Bulk density of soil (g/cm**3)
BDATE	- Character variable indicating the beginning date of weather contained within a weather file
BIOMAS	- The accumulated dry weight biomass of above ground plant material following seedling emergence - g/sq.meter

C1	- Cosine of the latitude - radians
CARBO	- The daily biomass production - g/plant
CEP	- Cumulative transpiration after germination - mm
CES	- Cumulative evaporation after germination - mm
CET	- Cumulative evapotranspiration after germination - mm
CF	- Temporary variable used in leaf area reduction calculations
CGPE	- Predicted number of grains per ear
CK	- Variable which determines the fraction of green leaf area which is reduced by cold temperature
CLAI	- Predicted crop leaf area index at anthesis
CN1	- Intermediate quantity used to calculate daily runoff
CN2	- Curve number input used to calculate daily runoff
CNI(L)	- Capacity for nitrification index in layer L. This is a zero to unity number indicating the relative capability for nitrification to proceed.
CNR	- C:N ratio calculated as (kg C in FOM)/(kg N in FOM + kg mineral N)
CNRF	- Zero to unity C:N ratio factor for decomposition rate
CNSD1	- Accumulates nitrogen deficit factor (NFAC) in each stage and is printed at the end of each stage as a daily average
CNSD2	- Accumulates nitrogen deficit factor (NDEF2) in each stage and is printed at the end of each stage as a daily average
CRAIN	- Cumulative precipitation after germination - mm
CSD1	- Accumulates soil water deficit factor 1 (SWDF1) in each stage and is printed at the end of each stage as a daily average
CSD2	- Accumulates soil water deficit factor 2 (SWDF2) in each stage and is printed at the end of each stage as a daily average
CSTT	- Accumulates thermal time from beginning of Stage 2, for use in calculating normal leaf senescence - degree C days
CTNUP	- Cumulative tops N uptake (kg N/ha)
CUMDEP	- Cumulative depth of the soil profile - cm
CUMDTT	- Cumulative daily thermal time after germination - degree C days
CUMPH	- Accumulated phyllochron intervals and equivalent leaf number on primary tiller - unitless
CUMVD	- Cumulative vernalization days
CW	- Water soluble carbon content of soil (ppm)
DAGR	- Floating variable for the integer IOUTGR
DAUP	- Floating variable for the integer IOUTNU
DAWA	- Floating variable for the integer IOUTWA
DBAR	- Average soil water diffusivity used to calculate upward water flow in top layers
DD	- Soil temperature damping depth (mm)
DEC	- Declination of the sun - radians
DEF	- Interim variable used to ensure soil nitrogen pools remain positive
DEPMAX	- Maximum soil depth where soil water content changes - mm
DEPTH	- Depth to the bottom of a layer from the surface (cm)
DF	- Day length factor-effect of day length on thermal development units - unitless

DFERT(J)	- Depth of incorporation of fertilizer application on Julian date (JFD)
DL1	- Upper depth of a soil layer - cm
DL2	- Lower depth of a soil layer - cm
DLAYR(L)	- Depth increment of soil layer L - cm
DLFWT	- Change in leaf weight (g/m**2)
DLL	- Intermediate variable used in soil water initialization
DLV	- Temporary variable used in the determination of day length
DMINR	- Humic fraction decay rate (1/days)
DMOD	- Zero to unity dimensionless factor used to decrease to rate of mineralization in soils with chemically protected organic matter
DNG	- N demand of potential new growth of tops (g N/plant)
DNRATE	- Denitrification rate (kg N/ha/day)
DP	- Maximum damping depth for the soil layer (mm)
DRAIN	- Drainage rate - cm/day
DROOTN	- Daily change in plant root nitrogen content (g N/plant)
DT	- Difference between moving average soil surface temperature and long-term daily average ambient temperature
DTN	- Change in tiller number
DTOPSN	- Daily change in plant tops nitrogen content (g N/plant)
DTT	- Daily thermal time - degree C days
DUL(L)	- Drained upper limit soil water for soil layer L - volume fraction
EDATE	- Character variable indicating the ending date of weather contained within a weather file
EEQ	- Equilibrium evaporation used to calculate potential evapotranspiration - mm/day
EGFT	- Zero to unity index describing the effect of temperature on leaf extension growth
EGMX	- Maximum extension growth of a leaf (cm/day)
ELNC	- Environmental limit on nitrification capacity (zero to unity unitless factor)
EO	- Potential evapotranspiration - mm/day
EOS	- Potential soil evaporation - mm/day
EP	- Actual plant evaporation (transpiration) - mm/day
EP1	- Actual transpiration - cm/day
ES	- Actual soil evaporation - mm/day
ES1	- Actual soil evaporation - cm/day
ESW(L)	- Extractable soil water content for soil Layer L (the difference between DUL and LL - volume fraction)
ESX	- Temporary soil evaporation variable - mm/day
ET	- Actual soil and plant evaporation - mm/day
EXLFW	- Temporary holding variable for LFWT
EXPTNO	- Experiment number (used in DSSAT I/O)
F	- Interim variable used to calculate soil temperature
FAC(L)	- Conversion factor for PPM N to kg N/ha for Layer L
FACTOR	- Relative weighting to distribute crop root residues at the beginning of a simulation

FILE0	- Character variable with file name for crop specific coefficients (not used by CERES WHEAT)
FILE1	- Character variable with file name for daily weather data
FILE2	- Character variable with file name for soil profile properties
FILE3	- Character variable with file name for unused at present time
FILE4	- Character variable with file name for soil nitrogen dynamics properties
FILE5	- Character variable with file name for soil profile initial conditions\
FILE6	- Character variable with file name for irrigation management data
FILE7	- Character variable with file name for nitrogen fertilizer management data
FILE8	- Character variable with file name for crop management data
FILE9	- Character variable with file name for genetic coefficients
FILEA	- Character variable with file name for measured summary data
FILEB	- Character variable with file name for measured seasonal data for graphics
FLOW(L)	- Volume of water moving from Layer L due to unsaturated flow (CM) positive indicates upward movement and negative value indicates downward movement
FLUX(L)	- Water moving downward from Layer L with drainage (cm)
FNH4	- Unitless soil ammonium supply index
FNO3	- Unitless soil nitrate supply index
FOM(L)	- Fresh organic matter (residue) in Layer L (kg/ha)
FON(L)	- N in fresh organic matter in Layer L (kg N/ha)
FPOOL(L,J)	- Fresh organic matter in layer L kg/O.M./ha. If J=1 pool is comprised of carbohydrates, if J=2 pool is comprised of cellulose, and if J=3 pool is comprised of lignin
FR	- Unitless value used to distribute crop residue
FT	- Temperature factor affecting denitrification rate
FTYPE(M)	- Fertilizer type code
FW	- Unitless soil moisture factor affecting denitrification rate
G1	- Genetic specific constant related to rate of vegetative expansion growth during Stage 1
G2	- Genetic specific constant related to the number of grains produced
G3	- Genetic coefficient for determining grain fill rate - mg/day
G4	- Genetic specific constant for determination of tiller number. It is the weight of a single typical tiller stem (excluding leaves) and ear, at the time the stem and ear stop elongating - g
G5	- Genetic specific constant related to winter hardiness - unitless
GNP	- N concentration in daily increment of grain growth (g N/g dry matter)
GNUP	- Grain N content kg N/ha
GPLA	- Green plant leaf area (sq.cm/plant)
GPP	- Number of grains per plant
GPSM	- Grains per square metre
GRAINN	- Grain N content (g N/plant)
GRCOM	- Gross release of carbon from organic matter decomposition (kg C/ha)
GRNOM	- Gross release of N from organic matter decomposition (kg N/ha/day)
GRNWT	- Weight of grains - g
GROGRN	- Daily growth of the grain - g
GROLF	- Daily leaf growth - g
GRORT	- Daily root growth - g

GROSTM	- Daily stem growth - g
GRPCTN	- Observed grain N% at maturity
HDAY	- Day of the year of the hottest day (200 <- northern hemisphere, 20 <- southern hemisphere)
HI	- Hardiness index to calculate cold hardening - unitless Varies from 0 (no hardening) to 2 (maximum hardening)
HOLD	- Temporary variable in calculations for distribution of organic matter
HOLDW	- The amount of water a soil layer will hold above its present level, used to calculate downward flow - cm
HRLT	- Daylength including civil twilight - hrs
HTI	- Temporary variable used to compare HI with G5
HUM(L)	- Stable humic fraction material in Layer L (kg/ha)
IANTJD	- Observed Julian date of anthesis
ICSDUR	- Accumulates days of each growth stage for calculating mean soil water deficit factor CSD1 and CSD2
IDIM(I)	- Days in month I
IDRSW	- An integer containing information about downward flowing soil water, = 0 no downward flow, = 1 downward flow
IDUMSL	- Number of layers in soils file (used in DSSAT I/O but not model calculations)
IDUR	- Duration for growth of current leaf
IECHON	- Logical variable to indicate whether inputs are to be echoed to the screen
IFLAG	- Switch variable used to direct control to either the leaching component or the upward flux component of subrouting NFLUX
IFTYPE	- Code number for fertilizer type
IHVON	- Logical variable to indicate that post-harvest comparisons of predicted and observed data are to be displayed on the screen
IIRR	- Switch variable to indicate type of irrigation (maybe none)
INSTE	- Institute ID code (DSSAT I/O)
IOFF	- Switch variable to disable runoff during irrigation
IOUT	- Switch variable used in the distribution of organic matter
IOUTGR	- Number of days since growth conditions were last written
IOUTNU	- Number of days sine N output was last written
IOUTWA	- Number of days since water conditiong were last written
IRET	- Variable to specify an alternate return from subroutine PHENOL when growth stage 6 is reached
ISOW	- Julian date of sowing
IST	- Variable to determine number of layers considered in unsaturated flow
ISTAGE	- Phenological stage = 1 Emergence to terminal spikelet = 2 Terminal spikelet to end of vegetative growth = 3 End of vegetative growth to end of pre-anthesis ear growth = 4 Pre-anthesis ear growth to beginning of grain fill (anthesis occurs during this phase) = 5 Beginning of grain fill to physiological maturity = 6 Physiological maturity to fallow (harvest) = 7 Fallow to sowing

	= 8 Sowing to germination
	= 9 Germination to emergence
ISWNIT	- A switch parameter specified as input that determines whether nitrogen calculators are performed
ISWSWB	- A switch parameter specified as input that determines whether the model calculates the soil water balance parts of the model
IVARTY	- Number assigned to a variety in the variety file
IYR	- Last two digits of year
JANTH	- Predicted Julian date of anthesis
JDATE	- Julian date
JDATEX	- A switch used for establishing days/month and printing the starting date
JDAY(I)	- Julian date of Ith irrigation
JFDAY(J)	- Julian date of fertilizer application J
JHEAD	- Used to write table heading for water use table
JPHMA	- Predicted Julian date of maturity
JSTAGE	- Integer representaative of Zadoks' growth stage
K	- Reverse loop variable for upflux calculations and day indicator in moving average soil surface temperature calculations
KHEAD	- Used to write table heading for growth table
KOUTGR	- Frequency in days for printing growth output
KOUTNU	- Frequency in days for printing nitrogen output
KOUTWA	- Frequency in days for printing water use output
KSOIL	- The number assigned to a soil in the soils file
KVARTY	- The number assigned to a crop variety in the variety file
L0	- Layer in the soil identified with the sowing depth
L1	- The number of soil layers to the bottom of the root zone
LAI	- Leaf area index
LAT	- Latitude - degrees (use negative for southern hemisphere)
LFWT	- Leaf weight of all leaves on a plant - g
LL(L)	- Lower limit soil water content for soil Layer L - volume fraction
LN	- Leaf number of the primary tiller
MATJD	- Observed Julian date of maturity
MF	- Zero to unity moisture factor for residue decomposition rate
MO	- Number of month of year
MU	- Loop variable to indicate layer below the current layer
ND	- Day of the month
NDAS	- Number of days after sowing
NDEF1	- Zero to unity N deficiency factor for photosynthetic rate
NDEF2	- Zero to unity N deficiency factor for expansion growth
NDEF3	- Zero to unity N deficiency factor for tiller number
NDEF4	- Zero to unity N deficiency factor for grain N determination
NDEM	- Plant nitrogen demand (g/plant)
NFAC	- Zero to unity factor based on actual and critical N concentrations
NFERT	- Number of fertilizer applications made
NFEXP	- Variable to indicate whether or not to open a new experiment file (DSSAT I/O)
NH4(L)	- Soil ammonium (PPM) in Layer L
NHDUP	- Used to write table headings for plant N output

NHUM(I) - N associated with the stable humic fraction in Layer I (kg N/ha)
NIND - Variable to indicate second from bottom layer
NIRR - Number of irrigations
NLAYR - Number of layers in soil
NNOM - Net N released from all organic sources in a layer (kg N/ha)
NO3(L) - Soil nitrate (ppm) in Layer L
NOUT(L) - Nitrate N leaching from layer (kg N/ha)
NOUT1 - Logical unit number for output to file OUT1
NOUT2 - Logical unit number for output to file OUT2
NOUT3 - Logical unit number for output to file OUT3
NOUT4 - Logical unit number for output to file OUT4
NOUTO - Logical unit number for output to file OUTO (not used by CERES WHEAT)
NPOOL - Total plant N available for translocation to grain (g/plant)
NPOOL1 - Tops N available for translocation to grain (g/plant)
NPOOL2 - Root N available for translocation to grain (g/plant)
NSDR - Plant N supply/demand ratio used to modify grain N content
NSENS - Switch variable to indicate whether changes to management variables are to be interactively made or not (DSSAT I/O)
NSFILE - Variable to indicate whether or not to open a new soils file (DSSAT I/O)
NSINK - Demand for N associated with grain filling (g/plant/day)
NSOIL - Number assigned to the soil to be used from the soils file, it should correspond to KSOIL in the soil file
NUF - Plant N supply/demand ratio used to modify uptake
NUP(L) - Nitrate N moving from Layer L with unsaturated flow (kg N/ha)
NWFILE - Variable to indicate whether or not to open a new weather file (DSSAT I/O)
OBSOL - Long-term annual average solar radiation (Langleys)
OBTMN - Long-term annual average minimum temperature - degrees C
OBTMX - Long-term annual average maximum temperature - degrees C
OC(L) - Organic carbon in Layer L (%)
OUT1 - Character variable with file name for output record of crop model inputs
Simulated biomass and water balance
components at selected phenological
stages.
Harvest summary (simulated and observed).
OUT2 - Character variable with file name for simulated crop variables vs time
OUT3 - Character variable with file name for weather variables and simulated soil water balance vs time
OUT4 - Character variable with file name for simulated soil nitrogen variables vs time
OUTN - Nitrate N leaching from a layer (kg N/ha)
P1D - Genetic specific coefficient that determines sensitivity to day length
P1V - Genetic specific coefficient that determines sensitivity to vernalization
P2 - Thermal time between terminal spikelet and end of vegetative growth, equal to 3 phyllochron intervals - degree C days
P3 - Thermal time from terminal spikelet to end of pre-anthesis ear elongation growth, equal to 2 phyllochron intervals - degree C days

P4	- Thermal time between end of pre-anthesis ear growth and beginning of grain fill - degree C days
P5	- Thermal time between beginning of grain fill and maturity - degree C days
P9	- Thermal time from germination to seedling emergence - degree C days
PAR	- Daily photosynthetically active radiation, calculated as half the solar radiation - MJ/square metre
PB	- Intermediate quantity for calculating daily runoff - cm
PBIOMS	- Predicted crop biomass at maturity (kg/ha)
PCARB	- Daily amount of carbon fixed - g
PDWI	- Potential increment of new shoot growth (g/plant)
PEDON	- Soil Pedon number (used in DSSAT I/O but not model calculations)
PESW	- Potentially extractable soil water in the profile equal to total soil water in the profile equal to total soil water (TSW) minus total water at the lower limit (TLL) - cm
PGNP	- Predicted grain N% at maturity
PGRNWT	- Predicted weight of individual grains (mg)
PGRORT	- Potential increment of new root growth (g/plant)
PH(L)	- Soil pH in layer L
PHINT	- The phyllochron interval-the interval in thermal time between successive leaf and tiller appearances - degree days
PHN(L)	- Zero to unity factor describing the effect of soil pH or nitrification rate on layer L
PINF	- The precipitation that infiltrates into the soil - cm/day
PLA	- Plant leaf area - sq. cm
PLAG	- The rate of expansion of leaf area on one plant - sq.cm/day
PLAGMS	- Plant leaf area growth rate on the main stem (sq.cm/day)
PLALR	- Plant leaf area loss rate (sq.cm/plant/day)
PLANTS	- Number of plants per square meter
PLAS	- The rate of senescence of leaf area on one plant - sq.cm/day
PLSC(LN)	- Cumulative leaf area at the time when each main stem leaf reaches full size. LN is the leaf number on the main stem.
PNUP	- Plant N uptake from layer (kg N/ha)
PRECIP	- Temporary variable used for rain
PRFT	- Photosynthetic reduction factor for low and high temperatures
PSW	- 1) Stage 1 specific leaf weight - mg/sq.cm 2) Stages 2-5 average tiller stem plus ear weight divided by the potential stem plus ear weight, in both cases for printing purposes
PTF	- Fraction of photosynthesis partitioned to above ground plant parts
R2	- Intermediate quantity used to calculate daily runoff
RAIN	- Precipitation - mm/day
RANC	- Root actual nitrogen concentration (g N/g root dry weight)
RCN	- C:N ratio of root residue of previous crop
RCNP	- Root critical nitrogen concentration (g N/g root dry weight)
RDECR(J)	- The maximum rate constant for decay of residue components (1/days)
REGM	- Mean relative extension growth (REG) during each phyllochron interval
RFAC	- Interim variable describing the effects of root length density on potential N uptake from a layer

RGFILL	- Rate of grain fill - mg/day
RGNFIL	_ Rate of daily grain N accumulation - micrograms/grain/day
RHMIN	- N mineralized from humus in a layer (kg N/ha)
RLDF(L)	- A root length density factor for soil layer L used to calculate new root growth distribution - unitless
RLNEW	- New root length to be added to the total root system length - cm. root per sq. cm. ground
RLV(L)	- Root length per unit soil volume for soil Layer L - cm/cm**3
RLVF	- Factor to constrain root growth at depth (unitless)
RMNC	- Root minimum nitrogen concentration (g N/g root dry weight)
RNAC	- Immobilization rate of N associated with the decay of residues (kg N/ha/day)
RNDEM	- Plant root demand for nitrogen (g/plant)
RNFAC(L)	- Zero to unity factor describing mineral N availability effect on root growth in Layer L
RNH4U(L)	- Potential ammonium uptake from Layer L (kg N/ha)
RNKG	- Amount of N added to soil profile as root residue kg N/ha
RNLOSS	- Loss of N from the plant via root exudation in one layer (g. N/plant)
RNLF	- Intermediate factor used to calculate distribution of new root growth in the soil - unitless value between 0 and 1
RNO3U(L)	- Potential nitrate uptake from Layer L (kg N/ha)
RNTRF	- Amount of ammonium nitrified in a layer (kg N/ha/day)
ROOT	- Mass of root residue of previous crop (kg/ha)
ROOTN	- Plant root N content (g N/plant)
RP2	- Temporary variable used in nitrification calculations
RTDEP	- Depth of rooting - cm
RTSW	- Weight of an average stem plus ear relative to a potential stem plus ear
RTWT	- Root weight - g/sq.metre
RUNOFF	- Daily runoff - cm
RWU(L)	- Root water uptake from soil Layer L - cm
RWUMX	- Maximum daily root water uptake per unit root length - cm**3/cm root
S1	- Sine of latitude
SALB	- Bare soil albedo - unitless
SANC	- Supply of ammonium effect on nitrification capacity
SARNC	- Supply of ammonium effect on the reduction of nitrification capacity (zero to unity, unitless)
SAT(L)	- Field saturated soil water content in Layer L - cm volume fraction
SCN	- C:N ratio of surface residue of previous crop
SDEP	- Depth of incorporation of residue (CM)
SDEPTH	- Depth of seeding in soil - cm
SEEDRV	- Reserve carbohydrates in seed for use by plant in seedling stage - g
SENLA	- Area of leaf that senesces from a tiller on a given day - sq.cm
SENTIL	- Number of senescenced tillers (tillers/m2)
SI1(I)	- Accumulates SWDF1 for growth stage I
SI2(I)	- Accumulates SWDF2 for growth stage I
SI3(I)	- Accumulates NFAC for growth stage I
SI4(I)	- Accumulates NDEF2 for growth stage I

SITEE - Codes for site ID (used in DSSAT I/O but not model calculations)
SITES - Codes for site ID (used in DSSAT I/O but not model calculations)
SITEW - Codes for site ID (used in DSSAT I/O but not model calculations)
SKERWT - Weight of a single kernel - g
SLW - Specific leaf weight - g/sq.cm
SMDFR - Soil moisture deficit factor affecting N uptake
SMIN - Interim variable to prevent soil N pools from becoming less than 1 ppm
SMLT - Amount of snow melt - mm
SMX - Intermediate quantity used to calculate daily runoff
SN1 - Temporary variable to describe N stress effect on tiller reduction
SNH4(L) - Soil ammonium in Layer L (kg N/ha)
SNKG - Amount of N added to soil profile as fresh residue kg N/ha
SNO3(L) - Soil nitrate in Layer L (kg N/ha)
SNOW - Precipitation in the form of snow - mm
SNOWMLT - Daily rate of snow melting (mm)
SOILC - Soil carbon content (kg C/ha)
SOILN - Variable used to modify initial soil water status
SOLRAD - Solar radiation - LY/day
SSTT - Sum of daily thermal time (DTT) from beginning of stage 2 until end of stage 5 - degree C days
ST(L) - Soil temperature in Layer L (degrees C)
STMWT - Stem weight of an average tiller after terminal spikelet - g
STOVER - Predicted straw biomass at maturity (kg/ha)
STRAW - Mass of surface residue of previous crop (kg/ha)
SUM - Intermediate quantity used to calculate runoff
SUMDTT - The sum of daily thermal time (DTT) for various phenological stages - degree days
SUMES1 - Accumulative soil evaporation in stage 1 - mm
SUMES2 - Accumulative soil evaporation in stage 2 - mm
SW(L) - Actual soil water content in Layer L - volume fraction
SWCON - Constant for calculating drainage rate
SWDF - Soil water deficit factor for Layer L used to calculate root growth and water uptake - unitless value between 0 and 1
SWDF1 - Soil water deficit factor used to calculate the reduction in the less sensitive process of photosynthesis and transpiration - unitless value between 0 and 1
SWDF2 - Soil water deficit factor used to calculate the reduction in more sensitive process of leaf growth and tiller formation - unitless value between 0 and 1
SWDF3 - Soil water deficit factor affecting tillering when the top soil layer is dry
SWDFR - Soil water deficit factor for root growth on distribution
SWEF - Soil water èvaporation fraction. The fraction of the lower limit water content that determines the lowest possible value the top soil layer water content can become by soil evaporation. The value depends on the depth of the first layer.
SWINIT(L) - Default initial water content for each soil layer - cm/cm

SWMIN	- Minimum stem weight of a plant after anthesis, used to calculate amount of reserves that can be used to fill grain - g
SWR	- Unitless value used to calculate initial value of SUMES2
SWSD	- An approximation of the soil water content above the lower limit at the seeding depth used to determine whether the seed can germinate (volume fraction)
SWX(L)	- Temporary array for soil water in layers (volume fraction)
SY	- Interim variable used in soil temperature calculation
T	- Time after 2nd stage soil evaporation is reached-days
TANC	- Tops actual N concentration (g N/g dry weight)
TAV	- Annual average ambient temperature (degrees C)
TAXON	- Soil classification name (used in DSSAT I/O but not model calculations)
TBASE	- Base temperature where development rate is zero calculate winter dormancy - degrees
TBD	- Accumulator used to calculate average bulk density
TC1	- Tiller competition factor 1
TC2	- Tiller competition factor 2
TCNP	- Tops critical N concentration (g N/g dry weight)
TCOR	- A correction used to calculate thermal time when the minimum temperature falls below the base temperature degree C day
TD	- Weighted temperature used to calculate potential evaporation - degrees
TDU	- Thermal development units - degree days
TDUL	- Total soil water held in the soil at the drained upper limit - cm
TEMKIL	- Loss of tillers due to cold temperature
TEMPCN	- Minimum daily temperature estimate for plant crown - degrees C
TEMPCR	- Mean daily temperature estimate for plant crown - degrees C
TEMPCX	- Maximum daily temperature estimate for plant crown - degrees C
TEMPM	- Mean temperature - degrees C
TEMPMN	- Minimum temperature - degrees C
TEMPMX	- Maximum temperature - degrees C
TF	- Temperature factor for nitrification on mineralization
TFY(L)	- Yesterday's temperature factor for nitrification in Layer L
THET1	- The soil water content above the lower limit (LL) for the upper layer of soil for water flow from a lower layer-volume fraction
THET2	- The soil water content above the lower, limit (LL) for the lower layer of soil for water flow into an upper layer-volume fraction
TI	- Fraction of a phyllochron interval which occurred as a fraction of today's daily thermal time
TIFOM	- Total initial fresh organic matter (kg/ha
TIFON	- Total initial fresh organic matter (kg N/ha)
TILN	- Number of tillers per plant
TILSW	- Potential weight of a single tiller stem plus ear, used to calculate final tiller numbers - g/tiller
TITLEE	- Experiment title (DSSAT I/O)
TITLER	- Experiment title (DSSAT I/O)
TITLES	- Experiment title (DSSAT I/O)
TITLET	- Treatment title (DSSAT I/O)

TITLEW	- Weather station title (DSSAT I/O)
TLL	- Total soil water in the soil profile at the lower limit - cm
TMA(K)	- 5 Day moving average soil surface temperature for day K
TMINH	- Total N released by mineralization of stable humic fraction in the profile on 1 day (kg N/ha)
TMN	- Mean temperature (degrees C)
TMNC	- Plant tops minimum nitrogen concentration (g N/g dry weight)
TNDEM	- Plant tops demand for nitrogen (g N/plant)
TNOLD	- Previous day's tiller number
TNUP	- Total plant N uptake from the profile (kg N/ha)
TNUP	- Total N uptake from the profile on 1 day (kg N/ha)
TOPSN	- N contained in plant tops excluding grain (g N/plant)
TOPWT	- Weight of plant tops excluding grain (g)
TOTN	- Total mineral N in a laery (kg N/ha)
TOTNUP	- Predicted total shoot N uptake at maturity (kg N/ha)
TPESW	- Total potential extractable soil water in the soil profile - cm
TPRECP	- Total precipitation - mm
TPSM	- Tillers per square meter
TRLDF	- An intermediate calculation used to calculate distribution of new root growth in soil
TRLV	- Total root length density variable
TRNLOS	- Total plant N lost by root exudation (g N/plant)
TRNU	- Total potential root nitrogen uptake from the soil (kg N/ha)
TRWU	- Total potential daily root water uptake from the soil-plant system - cm
TSAT	- Total soil water in profile at filed saturation - cm
TST(L)	- Soil temperature accumulator for calculation of period mean soil temperature
TSW	- Total soil water in the profile - cm
U	- Upper limit of stage 1 soil evaporation - mm
UNH4	- Plant uptake of ammonium from a layer (kg N/ha)
UNO3	- Plant uptake of nitrate from a layer (kg N/ha)
UP1	- Interim variable used to prevent soil N pools from becoming less than 1 ppm
VANC	- Plant vegetative actual N concentration (g N/plant)
VARTY	- Variety name
VD	- Vernalization for a day - unitless value between 0 and 1
VD1	- Intermediate calculation used to calculate VD
VD2	- Intermediate calculation used to calculate VD
VF	- Vernalization factor - effect of vernalization on thermal development units (TDU) - unitless
VMNC	- Plant vegetative minimum N concentration (g N/g dry weight)
W1	- Temporary variable to describe moisture stress effect on tiller reduction
WAT1	- Temporary variable used in upward flow calculations
WC	- Moisture content affect on soil temperature
WF(L)	- Weighting factor for soil depth L to determining
WFD	- Today's water factor for nitrification
WFY(L)	- Yesterday's water factor for nitrification in layer L

WINF	- Amount of water infiltrating into the soil as used in the soil evaporation routine - mm runoff amount - unitless
WR(L)	- Weighting factor for soil depth L to determine new root growth distribution - unitless
WRN(L)	- Temporary variable used to calculate distribution of residues in the soil
WSUM	- Variable used to calculate distribution of organic residues
WUF	- An intermediate factor used to calculate root water uptake - unitless
WW	- Soil porosity
WX	- Intermediate value used to calculate runoff
XANC	- Tops actual N concentration (%)
XAPTNP	- Observed total straw N uptake at maturity (kg N/ha)
XBIOM	- Observed biomass at maturity (kg/ha)
XGNUP	- Observed grain N uptake (kg grain N/ha)
XGPE	- Observed number of grains per ear
XGPSM	- Observed number of grain per square metre
XGRNWT	- Observed weight of individual grains (mg)
XI	- Non-integer Julian date
XL	- Temporary variables used to determine soil
XL2	- Moisture effect on mineralization rate
XLAI	- Observe maximum leaf area index
XPLANT	- Temporary variable to transfer the value of the numbers of plants/sq.metre
XS	- Represents snow (=<15mm) in equation to modify DTT
XSTAGE	- Non-integer growth stage indicator ranging from zero to six
XSTRAW	- Observe biomass of straw at harvest (kg/ha)
XT	- Temperature effect on nitrification capacity
XTOTNP	- Observe total shoot N uptake at maturity (kg N/ha)
XW	- Moisture effect on nitrification capacity
XX	- Intermediate value used to calculate runoff
XYIELD	- Observed grain yield kg/ha
YEAR	- Year number (last two digits)
YIELD	- Yield - kg/ha
YIELDB	- Yield - bushels/acre
Z(L)	- Depth to midpoint of soil layer L (mm)
ZD	- Variable used in the calculation of soil temperature
ZS2	- Square of Zadoks' growth stage used in critical concentration calculations
ZSTAGE	- Zadoks' growth stage

APPENDIX 3

IBSNAT Technical Report 5

Reproduced with permission:

IBSNAT Project
University of Hawaii
2500 Dole Street, Krauss Hall 118
Honolulu, Hawaii 96822

Decision Support System for Agrotechnology Transfer (DSSAT)

Documentation for IBSNAT Crop Model
Input and Output Files, Version 1.0

IBSNAT Technical Report 5
1986

TABLE OF CONTENTS

RATIONALE AND PURPOSE

A major goal of the International Benchmark Sites for Agrotechnology Transfer (IBSNAT) Project is to develop improved capabilites for transferring agricultural production technology from sites of origin to new locations. To reach this goal, IBSNAT is developing a systems approach which uses crop simulation models adapted to evaluate the potential of various soil and crop management alternatives. In order for this approach to be successful, crop models must first be validated by comparing model predictions with observations from field experiments. Crop model validation requires: (1) an experiment at a site, (2) data describing the soil profile and initial conditions at the site, (3) management practices and weather data collected during the experiment, and (4) measurements of actual crop development, growth, and yield for each treatment in the experiment. In some cases, the experiment could be a farmer's field and thus consist of only one treatment. Usually, however, a collection of experiments is needed for validation under different weather and management conditions. After the experiment is conducted, the soil, weather, and management data are entered into computer files, the files are converted to a format required by crop model inputs, and the same experiment is simulated. Crop model predictions can then be compared with actual experimental observations, and any differences between observed and simulated results can be analyzed.

The IBSNAT Project has accepted responsibility for developing several major food crop models. Three models (maize, wheat, and soybean) have been adapted to IBSNAT standards and are available for validation by collaborators at their sites. Additional models for rice, *Phaseolus* beans, potatoes, and peanuts are currently being developed at different locations, and models for sorghum, cassava, and aroids may soon be started. All of these crop models require similar inputs of soil, weather, and management data, and all predict similar outputs of soil responses, crop growth, and yield data.

OVERVIEW OF THE INPUT AND OUTPUT FILE STRUCTURES

The standard input and output files were developed after careful study of the three existing models being adapted for IBSNAT use: CERES-Maize (Jones and Kiniry 1986), CERES-Wheat, and SOYGRO V5.0 (Wilkerson *et al.* 1985). Each of these models uses daily weather data, the same soil water balance model (Ritchie 1985), and similarly detailed descriptions of crop phenological development, growth, and yield (Jones and Kiniry 1986; Wilkerson *et al.* 1985). However, inputs and outputs were initially different and changes were required in each model as it was adapted for use in the DSSAT. The modified crop model versions are: IBSNAT/CERES-Maize V1.0, IBSNAT/CERES-Wheat V1.0, and IBSNAT/SOYGRO V5.3.

The input and output files for IBSNAT crop models in the DSSAT are organized into four types. The files are arranged so that all treatments of an experiment can be simulated for direct comparison with field data collected and entered into the MDS, and so that sensitivity analysis can be performed on various management options. User-friendly interfaces for the crop models allow users to select an experiment and then select any or all treatments from the experiment for simulation. Thus, experiments reported in the MDS can easily be simulated for comparison with observed data. Users may also elect to modify treatment conditions to evaluate "what-if" questions. For example, different weather, soil, cultivar, planting date, irrigation management, row spacing, and nitrogen fertilizer management can be changed interactively. Simulated results can then be plotted from any of the runs for comparison with real experimental treatments or for evaluation of hypothetical treatments.

The first type of file has information which identifies experimental data (EXP.DIR) and weather data (WTH.DIR). A second group of files provides input data for crop genetic coefficients, weather, soil, and management information for all of the treatments of an experiment (FILE1, FILE2,..., FILE0). The third type of file contains field-measured data extracted from the MDS for comparison with simulated results for all experimental treatments (FILEA, FILEB). The tion of the beginning of the weather record. FILE1 contains the weather data, stored in files either by year or by a date which starts in one year and continues into the following year. One weather file can be used by several experiments as well as by all treatments in a particular experiment. If an experiment has multiple locations with different weather stations at each location, the EXP.DIR file must contain a 3-line entry for each location.

Data for all input files can be retrieved from the MDS in the IBSNAT DSSAT, but these data can also be created manually during model development. In some instances, input data for a specific variable may not be available. For all input files, a "-9" will be placed in that variable field to indicate the missing value.

Output Files

Four standard output files are associated with an experiment. There may be slight differences in output files OUT1 and OUT2 among crops. However, these differences are minimal and are used primarily because of differences in the measurement variables. Examples presented later in this report will show the explicit differences that exist between each of these files among crop models. The third output file, OUT3, is the same for all crop models. The fourth output file, OUT4, is also the same for all crop models which have a nitrogen balance for the soil. All current and new IBSNAT models should conform as closely as possible to these output formats and file names. These output files are set up so that all simulation results from a session are concantenated in the respective file types. When users wish to save simulated results, they must change the names of these outputs to permanent files. Each time a new session is started, OUT1-OUT4 are re-initialized and any previous results will be lost. Additional outputs, other than the ones described in Table 1, could be included as separate files when a model is being developed, or even applied to studies requiring special outputs.

Table 2. Description of codes used in input file-naming convention. An example is given for the file named UFGA8101.SB6.

Characters	*Reference*	*Example*	*Description*
1-2	Institute ID	UF†	University of Florida
3-4	Site ID	GA	Gainesville
5-6	Year experiment planted	81	1981
7-8	Experiment no.	01	Experiment 1
9	Must be "."	.	--------------
10-11	Crop code	SB††	Soybean
12	File number	6	Description Management Data

†Users should refer to the *IBSNAT Technical Report 1, Second Edition, Revised 1986* for their institute codes.

††The following crop codes are used for IBSNAT crops: WH=Wheat; MZ=Maize; SG=Sorghum; ML=Millet; RI=Rice; PT=Potatoes; CS=Cassava, AR=Aroids; SB=Soybeans; PN=Peanuts; BN=Dry Beans.

DISCUSSION

The development of standards, although necessary, is not without drawbacks. To a large extent, the definition of standard model inputs and outputs imposes certain restrictions on model structures and thus on the capability of a model to predict responses to certain factors. This effect is not the intent of the standards presented in this document. Indeed, it is anticipated that future models or changes in existing models will require additional inputs that are not now included in the defined files. This section discusses a few potential directions model developments may take. For example, there are no files that specify phosphorus fertilizer management because the existing models do not respond to phosphorus. Work currently in progress on a phosphorus model will eventually become part of the crop models. At that time, FILE7, the fertilizer management file which currently only contains nitrogen fertilizer data, would need changing. Dates and amounts of phosphorus fertilizer could be appended to FILE7 without affecting the standard data for nitrogen fertilizer in the same file, or in any of the other files. Since other changes may occur in future models, all revised versions of the input and output data files will be made and distributed periodically by IBSNAT. It is important, therefore, that collaborators who are developing new components for models should add new inputs to the files so that existing data are unchanged.

When adding new input requirements to the models, it is important that model developers document the sources of the input values. In particular, IBSNAT model developers should be aware that the existing soil profile data and the minimum data set (MDS) impose limitations on the estimation of inputs. Whenever possible, therefore, inputs should be derived or estimated from these basic data sources to allow model application for all sites where such data are available. If this is not possible, IBSNAT should be informed so that consideration can be given to changing the MDS or soil profile data requirements. However, suggestions for changes in the basic site data are not encouraged because of the difficulty and time required in effecting such changes. In

STRUCTURES FOR MODEL DIRECTORY FILES

EXP.DIR: Experiment File Directory

Description

The experiment file directory was developed to allow great flexibility in retrieving data needed to simulate various experiments from different locations and different years. This file contains the names of all input and output data files associated with a particular experiment for a crop. For each experiment in the file, three lines of information are required, and there must be a blank space before each field, except before the first field on each line, to ensure readability of this file. On the first line, the experiment identifier (8 characters) specifies the institute code, site code, year of experiment, and experiment number. After skipping one space, the next 40 characters briefly describe the experiment. The next two 12-character fields on line one identify the weather file name associated with this experiment (FILE1) and the name of the soil profile file (FILE2). On the second line of the experiment directory file, there are six 12-character fields which identify the names of files FILE4 through FILE9 for this experiment. On the third line, two 12-character fields identify the names of the validation files FILEA and FILEB, and four 7-character fields identify output files OUT1 through OUT4. If more than one experiment is to be simulated, three lines, equivalent in content to the first three described above, are appended to the EXP.DIR file for each experiment.

Two examples of EXP.DIR are shown on the following page, one for a 1978 soybean experiment in Gainesville, Florida and one for a 1983 maize experiment in Waipio, Hawaii. An EXP.DIR is needed for each crop model in the DSSAT, and the crop code identifier is appended to the front of this file name for each crop. For example, the soybean experiment directory is named SBEXP.DIR, whereas the maize experiment directory is named MZEXP.DIR.

WTH.DIR: Weather File Directory

Description

This file has a list of all weather data file names along with information on location, and beginning and ending month of weather data in the file. Weather file names include institute and site code identifiers, beginning month of weather, number of months of weather records, and the year in which the data starts. For example, UFGA0112.W78 is the name of the weather data file for University of Florida (UF), at the Gainesville site (GA), beginning with January data (01), and containing 12 months of data (12) for 1978 (78). Weather data in a file can start in one year and go into a second year. For example, IBWA1106.W83 has data starting in November, 1983, and continuing for 6 months through April, 1984. This WTH.DIR file should contain the file names of all weather data that a user would need to simulate actual or hypothetical experiments. An example of this file is given below with reference to eight weather data sets. In the DSSAT, this file is independent of crop type.

Data Formats

Variable Name	FORTRAN Format	Description
WTHID	A4	Weather station ID.
WTHDES	1X,A40	Weather station description.
BEGDATE	A8	Beginning date in weather file.
ENDDATE	1X,A8	Ending date in weather file.
FILE1	1X,A12	Weather file name.

Example of the Weather Directory File, WTH.DIR

```
|-- column numbers
|-----------------------------------------------------------------------
|===>     11111111112222222222333333333344444444445555555555666666666677777
123456789012345678901234567890123456789012345678901234567890123456789012345
---------------------------------------------------------------------------
IBWA WAIPIO, IBSNAT PROJECT 1983                  11/22/83 04/25/84 IBWA1106.W83
UFGA GAINESVILLE, FLORIDA 1978                    01/01/78 12/31/78 UFGA0112.W78
UFGA GAINESVILLE, FLORIDA 1979                    01/01/79 12/31/79 UFGA0112.W79
UFGA GAINESVILLE, FLORIDA 1980                    01/01/80 12/31/80 UFGA0112.W80
UFGA GAINESVILLE, FLORIDA 1981                    01/01/81 12/31/81 UFGA0112.W81
UFGA GAINESVILLE, FLORIDA 1982                    01/01/82 12/31/82 UFGA0112.W82
UFQU QUINCY,      FLORIDA 1979                    01/01/79 12/31/79 UFQU0112.W79
UFCA CASTANA,     IOWA    1979                    01/01/79 12/31/79 UFCA0112.W79
```

ta Formats

Variable Name	FORTRAN Format	Description
'ormat for line 1		
IDUMSL	1X, I2	Number asssigned to a soil type.
PEDON	1X, A12	SCS pedon number.
;TAXON	1X, A60	Soil classification.
'ormat for line 2		
SALB	F6.2	Bare soil albedo, no units.
U	1X, F5.2	Upper limit of stage 1 soil evaporation, mm.
SWCON	1X, F6.2	Soil water drainage constant, fraction drained per day.
CN2	1X, F6.2	SCS curve number used to calculate daily runoff.
TAV	1X, F5.1	Annual average ambient temperature, °C.
AMP	1X, F5.1	Annual amplitude in mean monthly temperature, °C.
DMOD	1X, F3.1	Zero-to-unity factor which reduces the rate constant for mineralization of the humus pool for soils which are poor mineralizers due to chemical or physical protection of the organic matter (default = 1).
SWCON1[a,b]	1X, E9.2	Coefficient in the steady state solution to the radial flow, root uptake equation, cm^3/cm root-day (default = 0.00267).
SWCON2[a,b]	1X, F6.1	Coefficient in the steady-state solution to the radial flow, root uptake equation, cm^3/cm root-day (default = 58).
SWCON3[a,b]	1X, F5.2	Coefficient in the steady-state solution to the radial flow, root uptake equation, cm^3/cm root-day (default = 6.68).
RWUMX[b]	1X,F5.2	Maximum daily root water uptake per unit root length, cm^3/cm root-day (default = 0.03).
PHFAC3[b]	1X,F4.2	Variable to reduce apparent photosynthesis attributed to soil fertility (for grain legume models, default = 1.00).

Example

This example has weather data from an IBSNAT experiment in Waipio, Hawaii and it does not include PAR data; that is, there are no data in variable field 9 and PARDAT on line 1 is 0.00.

```
|-- column numbers
|----------------------------------
|===>     1111111111222222222233333
1234567890123456789012345678901234
----------------------------------
IBWA  21.00 158.00 12.07  0.00
IBWA 83 326 15.48  28.0  18.0  0.0
IBWA 83 327 15.48  30.0  17.0  0.0
IBWA 83 328 15.48  31.0  17.5  0.0
IBWA 83 329 15.48  30.0  17.5  0.0
IBWA 83 330 15.48  30.0  16.0  0.0
IBWA 83 331 15.48  30.0  18.5  0.0
IBWA 83 332 13.35  30.0  18.0  0.0
IBWA 83 333 13.35  30.0  17.0  0.0
IBWA 83 334 13.35  30.0  17.0  0.0
IBWA 83 335 14.44  31.0  18.0  0.0
IBWA 83 336 14.44  31.5  17.5  0.0
IBWA 83 337 14.44  30.0  17.0  0.0
IBWA 83 338 14.44  30.0  18.0  0.0
IBWA 83 339 17.24  30.0  18.0  0.0
IBWA 83 340 17.24  29.5  18.0  0.0
IBWA 83 341 14.56  30.5  17.5  0.0
```

STRUCTURES FOR MODEL INPUT DATA FILES

FILE1: Daily Weather Data

Description

Daily weather data must be available in FILE1 for all days of the growing season (minimum requirement), beginning with day of planting and ending at crop maturity. Ideally, the file should contain weather data collected both before planting and after crop maturity. Then, the simulation could start before planting so that soil processes would be simulated. Initial conditions for the soil should coincide with the first day of simulation. Additional weather data also allows users to select alternate planting dates or longer duration crop varieties for model sensitivity analysis. On the first line of this file, the institute and weather station site code identifiers are listed, followed by latitude, longitude, a conversion coefficient (PARFAC) to convert total radiation to photosynthetically active radiation (PAR), and an indicator as to whether PAR is available in the data file (PARDAT). Some crop models such as IBSNAT/SOYGRO V5.3 require PAR data and the PARFAC is used when PAR data are not in the weather file (PARDAT=0.00). It should be noted that PAR data are not part of the MDS, so PARFAC will normally be used to estimate PAR from total radiation data. However, when PAR data are included in the weather file, columns 37-42 are reserved for those data, and the indicator PARDAT is set to 1.0. On all subsequent lines in the file, eight variables are recorded, and columns 37-42 are reserved for PAR data when it is available. The variables and format for each line of data for FILE1 are provided on the next page.

'ata Formats

Variable Name	FORTRAN Format	Description
'ormat for line 1		
EXPID	A8	Experiment identifier.
EXPDES	1X,A40	Experiment description.
FILE1	1X,A12	Daily weather data file name.
FILE2	1X,A12	Soil profile file name.
ormat for line 2		
FILE4	A12	Soil nitrogen dynamics properties file name.
FILE5	1X,A12	Soil profile initial conditions file name.
FILE6	1X,A12	Irrigation management data file name.
FILE7	1X,A12	Nitrogen fertilizer management data file name.
FILE8	1X,A12	Crop management data file name.
FILE9	1X,A12	Genetic coefficients file name.
'ormat for line 3		
FILEA	A12	Measured summary data file name.
FILEB	1X,A12	Measured seasonal data file name.
OUT1	1X,A7	File name for output file 1.
OUT2	1X,A7	File name for output file 2.
OUT3	1X,A7	File name for output file 3.
OUT4	1X,A7	File name for output file 4.

:xample of SBEXP.DIR

```
-- column numbers
--------------------------------------------------------------------------------
===>        111111111122222222223333333333444444444455555555556666666666777777777
23456789012345678901234567890123456789012345678901234567890123456789012345678901234567
--------------------------------------------------------------------------------
GA7801 BRAGG SOYBEANS, IRR & NON-IRRIGATED        UFGA0112.W78 SPROFILE.SB2
GA7801.SB4 UFGA7801.SB5 UFGA7801.SB6 UFGA7801.SB7 UFGA7801.SB8 GENETICS.SB9
GA7801.SBA UFGA7801.SBB OUT1.SB OUT2.SB OUT3.SB OUT4.SB
```

xample of MZEXP.DIR

```
-- column numbers
--------------------------------------------------------------------------------
===>        111111111122222222223333333333444444444455555555556666666666777777777
23456789012345678901234567890123456789012345678901234567890123456789012345678901234567
--------------------------------------------------------------------------------
3WA8401 WAPIO,HAWAII IBSNAT EXPERIMENT              IBWA1010.W83 SPROFILE.MZ2
3WA8401.MZ4 IBWA8401.MZ5 IBWA8401.MZ6 IBWA8401.MZ7 IBWA8401.MZ8 GENETICS.MZ9
3WA8401.MZA IBWA8401.MZB OUT1.MZ OUT2.MZ OUT3.MZ OUT4.MZ
```

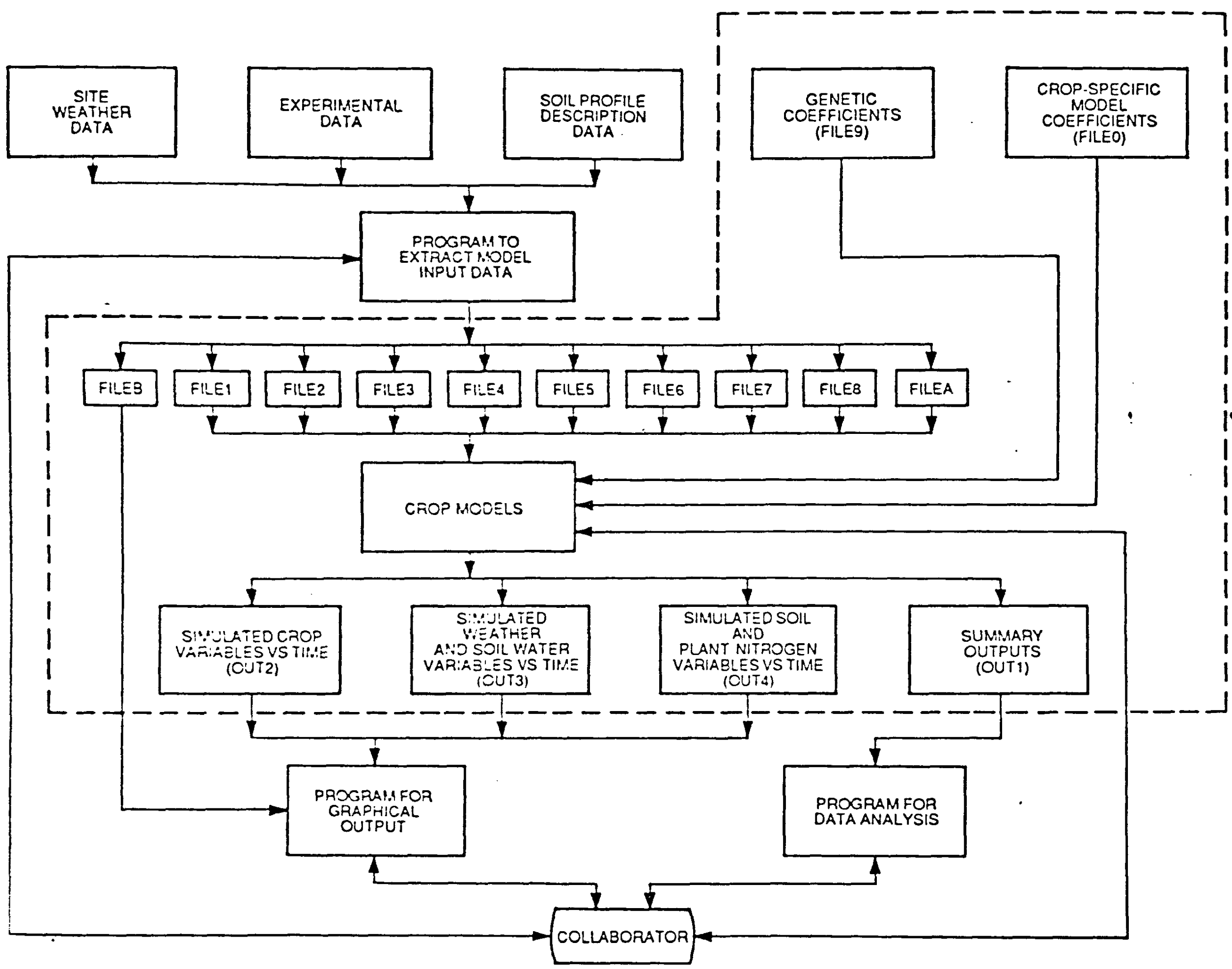
dition, model developers should supply procedures for estimating model inputs from these basic :a sources.

Model input data that is neither site-specific nor time-dependent should be included in a ›p-specific data file as indicated in Figure 1. At this time, IBSNAT does not intend to ndardize such files. They will be supplied to users along with the models. However, model velopers should carefully document such files so that users can modify the data for local ibration, if necessary. Model developers should also supply and document the genetic efficient data file for each crop model. The source of the coefficients and methods for imating coefficients for additional varieties should be detailed.

In addition to the four standard output files, modelers and users may wish to add additional :puts. An additional file (or files) should be used so that files OUT1 through OUT4 remain ed and can link directly into standard application programs. Future changes may also be needed standard outputs for various applications, and suggestions are highly encouraged.

IBSNAT can not anticipate when a future revision will be issued, but when it occurs, SNAT will send revisions to those who have received the original versions. Suggestions from rs for improvements are highly encouraged and will be carefully considered in future revisions.

Brief descriptions of each of the input and output files, their variable descriptions, and amples of each input and output file are presented in the next sections.



'igure 1. Schematic of the linkage between crop models and the collaborator experiment, ·eather, and soil data; and the programs for providing graphical outputs and data analysis results ɔ collaborators. The dashed line encompasses the standard data files and crop model. Crop ıodelers must adhere to formats defined in this documentation to ensure that their models can link ıto the IBSNAT DSSAT.

Table 1. Description of standard input and output files for the IBSNAT crop models.

File Variable Names	*Description*
Directory files	
EXP.DIR	Directory of files for each experiment.
WTH.DIR	Directory of available weather data.
Input files	
FILE1	Daily weather data.
FILE2	Soil profile properties.
FILE3	Unused at present time.
FILE4	Soil nitrogen dynamics properties.
FILE5	Soil profile initial conditions.
FILE6	Irrigation management data.
FILE7	Nitrogen fertilizer management data.
FILE8	Crop management data.
FILE9 (by crop)	Genetic coefficients.
FILE0 (by crop)	Crop-specific coefficients.
Validation files with measured data	
FILEA (by crop)	Measured summary data.
FILEB (by crop)	Measured seasonal data for graphics.
Output files	
OUT1 (by crop)	Output record of crop model inputs. Simulated biomass and water balance components at selected phenological stages. Harvest summary (simulated and observed).
OUT2 (by crop)	Simulated crop variables *vs* time.
OUT3	Weather variables and simulated soil water balance *vs* time.
OUT4	Simulated soil nitrogen variables *vs* time.

fourth file type contains output results for all experimental and hypothetical treatments that were simulated during one session (OUT1, OUT2, OUT3, OUT4). Outputs include summary results as well as seasonal values for crop, soil water, and soil nitrogen variables.

Various types of input and output files used by IBSNAT crop models in the DSSAT and the file variable names which will be used by all crop models are shown in Table 1. To readily identify files, a descriptive file naming convention has been adopted. This enables the file type, crop, institute, site, and year of planting to be quickly ascertained. The convention is based upon a series of two character identifiers as depicted in Table 2 for an example file, UFGA8101.SB6. The EXP.DIR file is a directory file used to specify these file names for a given experiment. When individual models are integrated into the DSSAT, the descriptive naming convention will be used to enable all future analyses.

To help simplify the integration of new models into the IBSNAT DSSAT, models should have an input and an output module containing subroutines that read and write the various input and output files. A schematic of the DSSAT now under development (Figure 1) shows the linkages between the data bases for weather, soil, and site experiments (MDS), the input files required for execution of IBSNAT crop models, and the standard crop model output files for subsequent graphical display and analysis.

Input Files

Files FILE4 through FILE8 contain input data for all treatments of an experiment. In contrast, FILE2 contains data for all soil types and FILE9 contains genetic coefficients for all cultivars of the crop. Since FILE2 contains soil profile data for many soils, a standard name of SPROFILE.SB2 is used with soybean data sets, and similarly, SPROFILE.WH2, with wheat data sets, etc. Similarly, GENETICS.SB9 is FILE9 for soybeans and contains genetic coefficients for many cultivars. For each treatment of the experiment, the soil and cultivar are specified in the treatment management file (FILE8). Because weather data files could conveniently be used by any of the models, slightly different naming conventions are used to enable identifica-

In the past, little effort has been made to standardize inputs and outputs for crop models, and hus each has evolved with unique data structures. Since collaborators may use crop models to ompare the productivity of severals crops at various sites, input data structures must be tandardized. Standardized inputs will enable all current IBSNAT crop models to use the same ite data to simulate growth and yield responses of each crop for a particular site, and will enable rop modelers to develop application programs for their models which have the ability to access he same data. In addition, standardized model outputs will help collaborators interpret results rom different models and will make analysis or graphical presentation easier. Then, routine nalysis procedures could be systematically applied to all the crop models in technology transfer tudies.

IBSNAT is developing an integrated computer system that provides collaborators with access o crop models for validation under local conditions. This facilitates the use of crop models to valuate the suitability of crop production technology at specific sites. This integrated system is ne IBSNAT Decision Support System for Agrotechnology Transfer (DSSAT). The DSSAT onsists of several components: (1) crop models; (2) soil and weather data; (3) collaborators' xperimental data; and (4) application programs to enter and retrieve data, link the models with site nd experimental data files, and analyze the observed and simulated data for specific objectives. he minimum data set (MDS) described in *IBSNAT Technical Report 1, Second Edition, Revised 986* contains standardized site and experimental data formats for use by collaborators around the orld. A data base management system (DBMS) stores these data and provides easy-to-use rocedures for entering site and experimental data and retrieving data for subsequent analyses and rop model simulation.

Standardized input and ouput data formats for different crop models give collaborators the bility to use any of the crop models after fundamental site data are obtained. The purpose of this eport is to document these input and output files and formats. Scientists who are developing odels or model applications for IBSNAT must adopt these file structures and data formats.

PREFACE

This report's conception and development arose from the recognition by several IBSNAT collaborators of the need to standardize and document crop model input and output file structures and data formats for those scientists who are developing crop models or model applications for IBSNAT. It was through their efforts that this document was written.

IBSNAT wishes to thank principal contributors, Clement P.Y. Chan, *Data Manager,* IBSNAT Project, Department of Agronomy and Soil Science, University of Hawaii; James W. Jones, *Professor of Agricultural Engineering,* Agricultural Engineering Department, University of Florida; Douglas C. Godwin, *Agronomist-Systems Modeler*, Agro-Economic Division, International Fertilizer Development Center, Muscle Shoals, Alabama; and Shrikant S. Jagtap, *Post-doctoral Research Scientist,* Agricultural Engineering Department, University of Florida.

IBSNAT also gratefully acknowledges the technical assistance and support of the following scientists in the preparation of this document; Kenneth J. Boote, Foster B. Cady, J. Barry Dent, C. Allan Jones, Kyle M. Kittleson, Joe T. Ritchie, Upendra Singh.

IBSNAT, the International Benchmark Sites Network for Agrotechnology Transfer, is a group consisting of the contractor (the University of Hawaii) and several collaborators. Together they have created a prototype network of national, regional, and international agricultural research centers for the purpose of developing, validating, and using a scientific method for the effective transfer of agrotechnology among and within countries in the tropics and subtropics.

IBSNAT is a program of the U.S. Agency for International Development implemented by the University of Hawaii, under Contract No. AID/DAN-4054-C-00-2071-00.

Data Formats (continued)

Variable Name	FORTRAN Format	Description
Format for line 3 through n		
DLAYR (L)	F6.0	Thickness of soil layer L, cm.
LL (L)	1X, F6.3	Lower limit of plant-extractable soil water for soil layer L, cm^3/cm^3.
DUL (L)	1X, F6.3	Drained upper limit soil water content for soil layer L, cm^3/cm^3.
SAT (L)	1X, F6.3	Saturated water content for soil layer L, cm^3/cm^3.
SW (L)	1X, F6.3	Default soil water content for soil layer L, cm^3/cm^3.
WR (L)	1X, F6.3	Weighting factor for soil depth L to determine new root growth distribution, no units.
BD (L)	1X, F5.2	Moist bulk density of soil in soil layer L, g/cm^3.
OC (L)	1X, F5.2	Organic carbon concentration in soil layer L, %.
NH4 (L)	1X, F4.1	Default soil ammonium in soil layer L, mg elemental N/kg soil.
NO3 (L)	1X, F4.1	Default soil nitrate in soil layer L, mg elemental N/kg soil.
PH (L)	1X, F4.1	Default pH of soil in soil layer L in a 1:1 soil: water slurry.

[a] The equation for radial flow described by Ritchie (1985) follows:
Uptake = SWCON1 * EXP (SWCON2 (SW(L) - LL(L))) (SWCON3 - ALOG (RLV(L))).
[RLV(L) = root length density for soil layer L (cm root/cm^3 soil).]

[b] These variables are not required by the IBSNAT/CERES-Maize V1.0 and -Wheat V1.0 models. Thus, default or blank values are read but not utilized by these models.

FILE5: Soil Profile Initial Conditions

Description

FILE5 contains initial conditions for soil profile water and nitrogen dynamics submodels. These initial conditions specify the values of water content, ammonium, nitrate, and pH in each vertical layer at the start of the first day of the simulation. Thus, the simulation must be started on the day for which the initial conditions are specified, even if the planting date is later. Soil profile initial conditions must be specified for a date before planting, or at the latest, on the date of planting which is input in FILE8. The thickness of each layer and the number of layers in this file must correspond exactly with those in FILE2. The first line of data in FILE5 consists of treatment number and an experiment code identifier. Then, there will be one line of data for each soil layer and a "-1" on the line immediately following the data for the last soil layer. This file will have data for each treatment of an experiment at a site, with the treatment being identified on the top line of each consecutive set.

Data Formats

Variable Name	FORTRAN Format	Description
Format for line 1		
TRTNO	I2	Treatment number
INSTS	1X, A2	Code for institute ID.
SITES	A2	Code for site ID.
YEAR	A2	Year number, last two digits.
EXPTNO	I2	Experiment number.
Format for all other lines		
DLAYR (L)	F6.0	Depth of layer L, cm.
SW (L)	1X, F6.3	Soil water content of soil layer L, cm^3/cm^3.
NH4 (L)	1X, F4.1	Soil ammonium in soil layer L, mg elemental N/kg soil.
NO3 (L)	1X, F4.1	Soil nitrate in soil layer L, mg elemental N/kg soil.
PH (L)	1X, F4.1	pH of soil in soil layer L in a 1:1 soil:water slurry.

FILE6: Irrigation Management Data

Description

For each treatment in an experiment at a site, the Julian dates and depths of irrigation are contained in FILE6. The first line of data for each treatment in the file must contain the treatment number and the experiment code identifier. Then, one line of data is required for each irrigation event. After all irrigation events have been entered for a treatment, a "-1" is entered in each field to signal the end of data for the treatment. Data for the second treatment and subsequent treatments are stacked below that of the first treatment, and data for all treatments are thus contained in this file.

Data Formats

Variable Name	FORTRAN Format	Description
Format for line 1		
TRTNO	I2	Treatment number.
INSTE	1X, A2	Code for institute ID.
SITEE	A2	Code for site ID.
YEAR	A2	Year number, last two digits.
EXPTNO	I2	Experiment number.
Format for all other lines		
JDLAPL (J)	I4	Julian day of year of irrigation event J .
AMT (J)	1X, F4.0	Amount of irrigation added on JDLAPL (J), mm.

FILE7: Fertilizer Management Data

Description

This file is organized similarly to FILE6. For each fertilizer application, one line of data with the four variables listed below must be supplied to FILE7. Since fertilizer applications may vary among treatments, data for each treatment will be stacked on top of each other in this file, each set having the treatment number and experiment code identifier on its top line of data. Following the last entry for each treatment, a "-1" in each field will be used to signal the end of that treatment's data.

Data Formats

Variable Name	FORTRAN Format	Description
Format for line 1 of each treatment		
TRTNO	A2	Treatment number.
INSTE	1X, A2	Code for institute ID.
SITEE	A2	Code for site ID.
YEAR	A2	Year number, last two digits.
EXPTNO	I2	Experiment number.
Format for all fertilizer application events		
JFDAY (J)	I4	Julian day of year of nitrogen fertilizer application J.
AFERT (J)	1X, F5.1	Amount of fertilizer nitrogen added on JFDAY (J), kg N/ha.
DFERT (J)	1X, F5.1	Depth of incorporation of fertilizer application on Julian day (JFDAY), cm.
IFTYPE (J)	1X, I2	Code number for type of fertilizer as specified in Appendix 4, *IBSNAT Technical Report 1, 2d ed.*

Example

```
|-- column numbers
|-------------------
|===)      111111111
1234567890123456789
-------------------
01 IBWA8201
 333  17.0  15.0  5
   6  17.0  15.0  5
  41  17.0  15.0  5
  -1
```

Data Formats (continued)

Variable Name	FORTRAN Format	Description
Format for line 2 of each treatment in this file		
ISIM	I4	Julian date simulation begins.
ISOW	1X, I3	Sowing date, Julian day of the year.
PLANTS	1X, F6.2	Plant population, plants/m^2.
ROWSPC	1X, F6.3	Row spacing, m.
SDEPTH	1X, F5.2	Sowing depth, cm.
IIRR	1X, I2	Switch describing irrigation (default = 1). 1: no irrigation applied 2: irrigation applied using field schedule 3: automatically irrigated at threshold soil water 4: assume no water stress, water balance not used
ISWNIT	1X, I2	Switch to indicate if nitrogen routines are used (default = 0). 0: nitrogen subroutines are not used, assumes adequate nitrogen 1: nitrogen subroutines are used
EFFIRR	1X, F6.2	Irrigation system efficiency, fraction.
DSOIL	1X, F5.2	Irrigation management depth, m.
THETAC	1X, F6.1	Available water triggering irrigation, %.
PHINT	1X, F6.2	Phyllochron interval (day degree). Default = 95 (CERES models).
IPHN	1X, I2	Indicates phenology model is to be used (default = 0), or that phenology stages are input (default = 1). Used in grain legume models only.

Example

```
|-- column numbers
|------------------------------------------------------------------
|===>      1111111111222222222233333333334444444444555555555566666
1234567890123456789012345678901234567890123456789012345678901234
------------------------------------------------------------------
IBWA8401   1 Pioneer X304C 0 kg N/ha                       1   42
 326 334    5.79  0.500  5.00  2  1   0.75  0.50    40.0  95.00  1
```

STRUCTURES FOR MODEL VALIDATION FILES

FILEA: Measured Crop Summary Data
(May vary by crop)

Description

For each treatment of each experiment, crop experimental data may differ. FILEA contains crop measured field data for each treatment averaged over all replications. The measured field data are needed for the standard outputs which list simulated and measured data side-by-side. FILEA may vary slightly among the different crops. For that reason, we have listed FILEA formats for maize, wheat, and soybean. Note that the files are very similar, and modelers are asked to conform to these formats as closely as possible to facilitate model linkage into the DSSAT once it is available.

Data Formats (continued)

Variable Name	FORTRAN Format	Description
Wheat		
INSTE	A2	Code for institute ID.
SITEE	A2	Code for site ID.
YEAR	A2	Year number, last two digits.
EXPTNO	I2	Experiment number.
TRTNO	1X, I2	Treatment number.
XYIELD	1X, F7.0	Actual field-measured grain yield dry weight basis, kg/ha.
XGRWT	1X, F7.4	Field-measured kernel dry weight, g/kernel.
XGPSM	1X, F6.0	Field-measured grain number, grains/m^2.
XGPE	1X, F4.0	Field-measured grain number, grains/ear.
XLAI	1X, F5.2	Field-measured leaf area index at anthesis, m^2/m^2.
XBIOM	1X, F6.0	Field-measured, aboveground dry biomass at maturity, kg/ha.
XSTRAW	1X, F6.0	Measured straw and chaff dry weight at maturity kg/ha.
ISLKJD	1X, I3	Field-measured anthesis date, Julain day of year.
MATJD	1X, I3	Field-measured physiological maturity date, Julian day of year.
Start line 2		
GRPCTN	F6.2	Measured nitrogen concentration in grain at maturity, %.
XTOTNP	1X, F5.1	Measured crop nitrogen content at maturity, kg/ha.
XAPTNP	1X, F5.1	Measured stover nitrogen content at maturity, kg/ha.
XGNUP	1X, F5.1	Measured grain nitrogen content at maturity, kg/ha.

(Continued on next page)

FILEB: Observed Data for Graphics

Description

FILEB allows observed data to be plotted with simulated results for each treatment simulated. Data for all treatments of an experiment are stored in one file. The first line is used as the header line to identify the treatment. On the second line, the first variable identifies the number of state variables for which there are matching field data, and the rest of the variables on this line are pointers which indicate the state variable number for each column of data. Starting with the third line, there is one line of data for each observation date recorded in the MDS. Replication data for each treatment can be included by using a different line of data for each replication. A "-1" on the line immediately following a data line indicates the end of data for a specific treatment. These files may vary slightly among crops. For example, V-stage in soybeans replaces leaf number in maize, but these variables are similar in concept. In the DSSAT, this file will be created automatically for each experiment by retrieving the data from the MDS and creating a FILEB for each experiment.

Data Formats

Variable Name	FORTRAN Format	Description
Maize/Wheat		
[Header]	*	ID codes for institute, site, experiment number, year, and treatment.
Start line 2		
NOVAR	*	Number of state variables for which there are matching field data.
NV(I), I=1, NOVAR	*	Pointer which indicates state variable number for each column of data.
Start line 3		
JULDATE	*	Julian date.
NV(1)	*	Leaf number.
NV(2)	*	Leaf area index, m^2/m^2.
NV(3)	*	Root weight, kg/ha.
NV(4)	*	Stem weight, kg/ha.
NV(5)	*	Grain dry weight, kg/ha.
NV(6)	*	Leaf dry weight, kg/ha.
NV(7)	*	Biomass, kg/ha.
NV(8)	*	Shoot N uptake, kg N/ha.

* Format uses one or more spaces to separate one variable from the next.

(Continued on next page)

STANDARD MODEL OUTPUT FILES: OUT1, OUT2, OUT3, OUT4

Four files have been defined for standard output. Modelers may wish to use additional outputs in other files, but they must adhere to the variables and formats in these files so simulated and observed results can be linked to the graphics and analysis programs which are now being developed in the DSSAT. These files, OUT1, OUT2, OUT3, and OUT4 are for summary output, simulated crop variables *vs* time, simulated weather and soil water variables *vs* time, and simulated soil and plant nitrogen variables *vs* time. Files OUT1 and OUT2 may vary slightly among crops because of the variable names and genetic coefficients. Sample output files for the IBSNAT/CERES-Maize V1.0 and IBSNAT/SOYGRO V5.3 models are given on the following pages. Source codes for IBSNAT/CERES-Maize V1.0, IBSNAT/CERES-Wheat V1.0, and IBSNAT/SOYGRO V5.3 or other existing IBSNAT models can be obtained from IBSNAT for adaptation to new models.

NOTE: All footnoted items on pages 44-51 require the formats specified in each footnote so that those data can be read in by the graphic programs.

Sample OUT2 for SOYGRO V5.3

```
RUN[4] [5] 1
INST[5]_ID :UF   SITE_ID: GA   EXPT_NO: 01   YEAR : 1981[6] TRT_NO: 1[7]
EXP.      :COBB, IRRIGATED, WITH VEG & REPRO STRESS
TRT.      :IRRIGATED
WEATHER   :GAINESVILLE, FLORIDA 1981
SOIL      :Hyperthermic, coated Typic Quartzipsamments
VARIETY   :COBB                 MG-  8
IRRIG.    :ACCORDING TO THE FIELD SCHEDULE.
```

JUL DAY[8]	VST-AGE	LAI	PODS NO	STEM WT	SEED WT	LEAF WT	CANO-PY	ROOT LENGTH VOLUME L1	L2	L3	L4	L5	WATER STRESS
[9]													
183	0.	.00	0.	0.	0.	0.	0.	.1	.1	.0	.0	.0	1.00[10]
190	1.	.11	0.	9.	0.	34.	43.	.1	.1	.0	.0	.0	1.00
197	3.	.38	0.	40.	0.	116.	156.	.2	.3	.0	.0	.0	1.00
204	5.	.88	0.	171.	0.	245.	416.	.2	.5	.1	.0	.0	1.00
211	7.	1.42	0.	421.	0.	413.	834.	.3	.8	.2	.1	.0	1.00
218	9.	2.33	0.	793.	0.	658.	1450.	.6	1.1	.2	.1	.0	1.00
225	11.	3.48	0.	1283.	0.	969.	2252.	1.1	1.6	.3	.2	.0	1.00
232	12.	4.57	0.	1805.	0.	1261.	3066.	1.5	2.0	.4	.3	.1	1.00
239	14.	5.46	0.	2337.	0.	1507.	3843.	1.8	2.3	.5	.3	.1	1.00
246	16.	5.50	273.	2875.	0.	1720.	4608.	2.1	2.5	.6	.4	.1	1.00
253	16.	5.44	1101.	3161.	0.	1828.	5403.	2.2	2.6	.6	.4	.1	1.00
260	16.	5.43	1458.	3213.	183.	1848.	6205.	2.1	2.5	.6	.4	.1	1.00
267	16.	5.36	1136.	3197.	787.	1824.	6841.	2.1	2.5	.6	.4	.1	1.00
274	16.	4.87	1136.	3145.	1562.	1684.	7396.	2.0	2.4	.6	.4	.1	1.00
281	16.	4.42	1136.	3120.	2330.	1561.	7983.	1.9	2.4	.6	.4	.1	1.00
288	16.	3.98	1136.	3014.	2981.	1406.	8339.	1.9	2.4	.6	.4	.1	1.00
295	16.	3.61	1136.	2928.	3476.	1276.	8660.	1.9	2.4	.6	.4	.1	1.00
302	16.	.72	1136.	2364.	3579.	254.	7210.	1.9	2.3	.5	.4	.1	1.00
309	16.	.15	1136.	2128.	3582.	53.	6771.	1.9	2.3	.5	.4	.1	1.00

4 Column 2-4.
5 Column 2-5.
6 Column 50-51.
7 Column 62-63.
8 Column 2-4. This heading must be repeated for each new treatment.
9 Blank line.
10 Format uses one or more spaces to separate one variable from the next.

Sample OUT1 for CERES-Maize V1.0

```
RUN NO.  1 OUTPUT SUMMARY
                                            WATER BALANCE COMPONENTS

INST_ID :IB  SITE_ID: WA  EXPT_NO: 01  YEAR : 1984  TRT_NO:  4
EXP.     :WAPIO,HAWAII IBSNAT EXPERIMENT
TRT.     :Pioneer H610 0 kg N/ha
WEATHER :Waipio
SOIL     :Tropeptic Eutrustox
VARIETY  :H610

     LATITUDE =  21.0 , SOWING DEPTH =    5. CM , PLANT POPULATION =    6. PLANTS PER SQ METER

     GENETIC SPECIFIC CONSTANTS   P1 =370.00  P2 = .52  P5=860.00  G2 =650.00  G3 = 7.500

     JULIAN DAY     IRRIGATION(MM)
         337            43.
         339            22.
         341            18.
         350             8.
         355            11.
         357             6.
         364             6.
           6             6.
           9             6.
          13             5.
          19             5.
          20             5.
          26            19.
          41             9.
          43             9.
          55            15.
          59            10.
          69            17.
          73            13.
          75            14.
          78            15.
          82            12.
          84            18.
          88            12.

     SOIL PROFILE DATA [ PEDON: Waipio Pedon ]
     SOIL ALBEDO=  .14  U=  5.0  SWCON=   .60   RUNOFF CURVE NO.=  60.0
```

DEPTH-CM	LO LIM	UP LIM	SAT SW	EXT SW	IN SW	WR	NO3*	NH4*
0.- 10.	.220	.350	.550	.130	.324	1.000	4.3	3.6
10.- 30.	.240	.350	.550	.110	.328	.800	2.0	1.9
30.- 50.	.250	.370	.480	.120	.346	.400	1.0	1.4
50.- 70.	.260	.380	.460	.120	.356	.200	1.0	1.4
70.- 90.	.250	.380	.460	.130	.354	.050	.7	.6
90.- 110.	.260	.400	.480	.140	.372	.020	.6	.5
T 0.- 109.	27.4	41.1	54.1	13.7	38.4		16.	17.

* NOTE: Units are in kg N / ha.

(Continued on next page)

Sample OUT2 for CERES-Maize V1.0

```
RUN[4] 1 trt 4
INST[5]_ID :IB   SITE_ID: WA   EXPT_NO: 01   YEAR : 1984[6] TRT_NO: 4[7]
EXP.      :WAPIO,HAWAII IBSNAT EXPERIMENT
TRT.      :H610 0 kg N/ha
WEATHER   :Waipio
SOIL      :Tropeptic Eutrustox
VARIETY   :  H610
IRRIG.    :ACCORDING TO THE FIELD SCHEDULE.
```

JUL DAY[8]	CDTT	BIO	LN	LAI	ROOT	STEM	GRAIN	LEAF	RTD	PTF	L1	L3	L5 [9]
353	212.	7.	7	.15	25.	12.	0.	57.	66.	.73	.2	.0	.0 [10]
360	320.	11.	9	.24	32.	12.	0.	101.	89.	.78	.3	.0	.0
2	442.	17.	12	.33	43.	12.	0.	158.	109.	.80	.3	.0	.0
9	77.	27.	14	.50	46.	14.	0.	259.	109.	.85	.4	.0	.0
16	165.	37.	16	.62	51.	28.	0.	341.	109.	.88	.4	.0	.0
23	265.	52.	18	.75	57.	75.	0.	445.	109.	.90	.4	.1	.0
30	367.	68.	20	.84	64.	150.	0.	534.	109.	.91	.4	.1	.0
37	442.	86.	22	.93	71.	258.	0.	600.	109.	.92	.5	.1	.0
44	547.	114.	24	1.01	84.	456.	0.	682.	109.	.93	.6	.1	.0
51	88.	148.	24	1.01	105.	478.	0.	603.	109.	.93	.7	.1	.0
58	184.	197.	24	.99	153.	600.	55.	509.	109.	.93	.8	.2	.0
65	275.	232.	24	.98	390.	600.	403.	505.	109.	.86	2.2	.4	.1
72	381.	266.	24	.94	662.	600.	756.	502.	109.	.80	3.8	.8	.1
79	488.	302.	24	.88	815.	600.	1114.	499.	109.	.79	5.0	1.1	.1
86	599.	338.	24	.77	961.	600.	1478.	495.	109.	.78	5.0	1.2	.2
93	709.	374.	24	.63	1032.	600.	1845.	491.	109.	.78	5.0	1.4	.2
100	820.	402.	24	.46	1024.	565.	2159.	489.	109.	.80	4.9	1.4	.2

4,5,6,7,8,9,10 Same as footnotes marked for SOYGRO V5.3, OUT2, page 45.

Sample OUT4 for CERES-Maize V1.0

```
RUN   1 trt 4
INST_ID :IB   SITE_ID: WA   EXPT_NO: 01   YEAR : 1984   TRT_NO:   4
EXP.     :WAPIO,HAWAII IBSNAT EXPERIMENT
TRT.     :Pioneer H610 0 kg N/ha
WEATHER :Waipio
SOIL     :Tropeptic Eutrustox
VARIETY :   H610
IRRIG.   :ACCORDING TO THE FIELD SCHEDULE.
```

JUL DAY	TOPS N %	NFAC	TOT N UPTK	GRAIN UPTK	LEACH	MINLN	DENIT	NO3 1	NO3 2	NO3 3	NH4 1	NH4 2
353	3.29	.52	2.0	.0	1.0	2.0	.0	1.8	2.5	3.3	2.0	.8
360	2.82	.35	3.1	.0	8.6	2.3	.2	1.0	1.8	3.4	1.9	.9
2	2.60	.32	4.2	.0	1.2	2.9	.1	1.0	1.7	3.7	2.0	1.0
9	2.21	.28	5.5	.0	.7	2.8	.0	1.2	1.7	4.0	2.0	1.0
16	1.98	.24	7.2	.0	.4	2.8	.0	1.0	1.8	4.2	2.0	1.0
23	1.79	.24	8.5	.0	.4	2.8	.0	1.2	1.7	4.4	2.0	1.0
30	1.57	.21	10.5	.0	.4	2.7	.0	1.0	1.8	4.7	1.9	1.0
37	1.56	.27	13.2	.0	1.0	2.9	.0	1.0	1.4	4.7	1.8	1.0
44	1.42	.27	15.6	.0	.6	3.0	.0	1.0	1.4	4.7	1.9	1.0
51	1.59	.40	18.0	.0	.0	3.0	.0	1.0	1.4	4.8	1.8	1.0
58	1.74	.58	19.1	1.0	.0	2.7	.0	1.0	1.4	4.8	1.9	1.0
65	1.50	1.00	15.8	6.9	.1	3.3	.0	1.0	1.0	4.6	1.2	1.1
72	1.32	.95	13.7	12.9	.0	3.7	.0	1.0	1.0	3.9	1.2	1.0
79	1.17	.82	12.4	19.0	.0	3.6	.0	1.0	1.0	3.3	1.2	1.0
86	1.05	.76	10.9	25.2	.0	3.5	.0	1.0	1.0	2.7	1.1	1.0
93	.94	.67	9.8	31.4	.0	3.5	.0	1.0	1.0	2.1	1.1	1.0
100	.80	.46	8.0	36.7	.0	2.8	.0	1.0	1.0	1.8	1.2	1.0

Appendix 4. Listing of N-Model Testing Data Base

Obs	Loc.	Yr	CV	Irr	N	Grain Yield		Biomass		N Uptake		Grain N Uptake		Grain Protein		Anthesis N Uptake	
						O	P	O	P	O	P	O	P	O	P	O	P
1	GARD	81	NEWT	P	0	4,064	4,058	9,230	10,634	72.9	100.0	61.3	66.2	8.6	9.3	58.6	96.2
2	GARD	81	NEWT	P	56	5,329	4,281	11,475	11,285	122.1	110.3	98.2	74.4	10.5	9.9	97.3	105.7
3	GARD	81	NEWT	P	140	5,126	4,377	11,014	11,743	127.8	122.1	104.3	83.7	11.6	10.9	92.5	113.2
4	GARD	81	NEWT	J	0	3,949	5,860	8,911	15,056	63.3	149.2	51.3	102.8	7.4	10.0	62.4	140.4
5	GARD	81	NEWT	J	56	5,080	5,887	11,772	15,304	104.3	155.9	83.8	108.4	9.4	10.5	84.8	146.0
6	GARD	81	NEWT	J	140	5,082	6,100	11,916	15,556	127.5	160.0	103.4	111.3	11.6	10.4	116.3	149.9
7	GARD	81	NEWT	F	0	4,624	4,501	10,338	11,951	91.2	132.8	75.4	92.4	9.3	11.7	72.8	96.2
8	GARD	81	NEWT	F	56	5,018	4,652	11,084	12,511	116.5	145.4	91.6	101.2	10.4	12.4	87.3	105.7
9	GARD	81	NEWT	F	140	4,948	4,795	11,127	13,014	119.6	155.4	96.4	108.5	11.1	12.9	15.3	113.2
10	GARD	81	NEWT	A	0	4,175	5,861	9,386	15,116	76.1	152.7	63.0	105.9	8.6	10.3	76.6	140.4
11	GARD	81	NEWT	A	56	5,211	6,067	12,187	15,469	115.0	165.4	92.3	116.0	10.1	10.9	98.1	146.0
12	GARD	81	NEWT	A	140	4,988	6,100	11,916	15,959	129.9	184.9	101.5	131.6	11.6	12.3	109.9	149.9
13	GARD	81	NEWT	P	28	4,585	4,135	10,005	10,570	90.7	99.7	74.0	66.7	9.2	9.2	0.0	0.0
14	GARD	81	NEWT	P	84	5,185	4,376	11,216	11,239	123.8	112.1	99.2	76.8	10.9	10.0	0.0	0.0
15	GARD	81	NEWT	P	112	5,400	4,417	12,416	11,386	138.9	115.4	111.8	79.0	11.8	10.2	0.0	0.0
16	GARD	81	NEWT	J	28	5,119	5,839	11,501	14,829	97.7	149.4	80.8	104.5	9.0	10.2	0.0	0.0
17	GARD	81	NEWT	J	84	5,185	5,848	12,897	14,994	125.7	152.4	95.5	106.7	10.5	10.4	0.0	0.0
18	GARD	81	NEWT	J	112	5,440	5,861	13,118	15,075	135.9	153.4	110.7	106.9	11.6	10.4	0.0	0.0
19	GARD	81	NEWT	F	28	4,756	4,471	10,427	11,718	103.4	135.4	84.3	95.7	10.1	12.2	0.0	0.0
20	GARD	81	NEWT	F	84	5,188	4,728	11,412	12,440	124.5	147.7	100.1	104.5	11.0	12.6	0.0	0.0
21	GARD	81	NEWT	F	112	5,948	4,764	13,079	12,567	148.4	150.1	117.9	106.1	11.3	12.7	0.0	0.0
22	GARD	81	NEWT	A	28	5,079	5,840	11,904	14,897	100.0	153.6	82.9	107.6	9.3	10.5	0.0	0.0
23	GARD	81	NEWT	A	84	5,109	6,028	12,187	15,271	122.6	169.1	96.8	120.6	10.8	11.4	0.0	0.0
24	GARD	81	NEWT	A	112	5,353	6,042	13,043	15,452	137.7	176.0	108.9	125.1	11.6	11.8	0.0	0.0
25	ASHL	81	NEWT	D	0	2,317	2,852	5,994	6,635	59.2	62.6	44.3	43.0	10.9	8.6	50.9	51.5
26	ASHL	81	NEWT	D	60	3,330	3,542	10,178	8,751	103.2	93.6	63.7	66.5	10.9	10.7	101.0	73.8
27	ASHL	81	NEWT	D	180	4,521	3,947	12,649	9,882	166.6	119.7	99.9	85.9	12.6	12.4	175.0	85.1
28	ASHL	81	NEWT	I	0	1,438	1,770	3,926	4,619	37.7	37.2	26.7	22.4	10.6	7.2	45.5	35.5
29	ASHL	81	NEWT	I	60	3,025	3,105	9,424	7,901	87.8	68.4	56.8	43.6	10.7	8.0	81.5	65.0
30	ASHL	81	NEWT	I	180	4,695	4,694	13,064	11,946	166.5	120.6	95.5	83.2	11.6	10.1	147.6	111.5
31	HUTC	79	CENT	D	0	1,828	2,456	6,347	6,853	66.6	68.4	38.5	48.3	12.0	11.2	58.9	66.1
32	HUTC	79	CENT	D	28	2,224	2,860	8,918	8,311	97.1	84.2	50.7	59.7	13.0	11.9	86.7	81.5
33	HUTC	79	CENT	D	56	2,325	3,069	7,483	9,470	79.6	99.2	52.2	71.1	12.8	13.2	84.1	96.8
34	HUTC	79	CENT	D	84	2,164	3,169	8,375	10,055	98.3	108.1	50.5	78.4	13.3	14.1	112.8	105.3
35	HUTC	79	CENT	D	112	2,365	3,131	9,202	10,020	107.5	109.4	59.3	79.6	14.3	14.5	123.2	106.9
36	HUTC	79	CENT	D	140	2,372	3,121	9,540	10,004	119.7	109.9	58.7	79.9	14.1	14.6	100.4	106.9
37	GARD	80	NEWT	P	0	3,517	3,058	9,376	9,149	80.1	82.7	67.3	52.6	10.9	9.8	0.0	81.1
38	GARD	80	NEWT	P	28	4,060	3,479	11,225	10,305	107.7	99.1	86.9	65.3	12.2	10.7	115.1	97.2
39	GARD	80	NEWT	P	56	3,396	3,592	8,864	10,746	92.4	109.0	79.2	73.1	13.3	11.6	117.1	106.2
40	GARD	80	NEWT	P	84	3,999	3,611	11,223	10,838	119.3	111.9	94.7	76.0	13.5	12.0	134.0	108.2
41	GARD	80	NEWT	P	112	3,786	3,622	10,289	10,885	117.1	113.8	93.7	77.5	14.1	12.2	133.8	109.5
42	GARD	80	NEWT	P	140	3,417	3,631	9,205	10,915	105.4	115.3	86.9	79.0	14.5	12.4	114.8	110.0
43	GARD	80	NEWT	J	0	3,839	4,277	10,592	11,369	83.6	96.9	70.0	63.0	10.4	8.4	130.7	92.9
44	GARD	80	NEWT	J	28	4,140	5,038	11,451	13,456	95.3	117.8	78.4	77.8	10.8	8.8	123.9	113.8
45	GARD	80	NEWT	J	56	4,415	5,698	12,727	15,300	103.2	140.1	89.1	94.0	11.5	9.4	147.9	136.9

(Continued)

Appendix 4. Listing of N-Model Testing Data Base (Continued)

Obs	Loc.	Yr	CV	Irr	N	Grain Yield		Biomass		N Uptake		Grain N Uptake		Grain Protein		Anthesis N Uptake	
						O	P	O	P	O	P	O	P	O	P	O	P
91	TELH	79	SONA	D	0	4,710	4,562	11,850	10,233	0.0	85.4	0.0	58.4	0.0	7.3	0.0	84.0
92	TELH	79	SONA	D	60	4,000	5,824	10,180	13,678	0.0	127.2	0.0	92.0	0.0	9.0	0.0	124.6
93	TELH	79	SONA	I	0	3,760	4,692	9,340	10,576	0.0	85.8	0.0	57.6	0.0	7.0	0.0	84.0
94	TELH	79	SONA	I	60	4,960	6,289	12,120	14,182	0.0	127.8	0.0	91.6	0.0	8.3	0.0	124.6
95	TELH	79	NOVI	D	0	3,590	2,358	10,790	7,893	0.0	81.0	0.0	53.8	0.0	13.0	0.0	80.6
96	TELH	79	NOVI	D	60	3,670	3,137	11,760	11,471	0.0	124.8	0.0	85.3	0.0	15.5	0.0	124.4
97	TELH	79	NOVI	I	0	4,070	2,545	11,050	9,430	0.0	81.7	0.0	47.8	0.0	10.7	0.0	80.6
98	TELH	79	NOVI	I	60	4,440	3,653	12,170	13,441	0.0	125.3	0.0	76.9	0.0	12.0	0.0	124.4
99	KAFR	80	MEXI	D	0	3,220	4,258	10,700	11,451	89.5	107.0	56.5	71.7	10.0	9.6	45.3	104.8
100	KAFR	80	MEXI	D	60	3,940	5,223	11,701	14,887	112.9	150.5	73.3	103.5	10.6	11.3	86.7	147.6
101	KAFR	80	SONA	D	0	3,940	5,282	7,905	12,109	63.4	107.1	58.8	77.8	8.5	8.4	75.3	104.4
102	KAFR	80	SONA	D	60	4,840	5,762	11,335	14,686	104.9	141.8	88.3	104.1	10.4	10.3	93.1	137.8
103	KAFR	80	NOVI	D	0	3,840	3,269	9,600	10,584	83.7	105.9	67.4	70.0	10.0	12.2	70.7	103.3
104	KAFR	80	NOVI	D	60	4,360	4,058	10,847	14,320	104.3	150.8	83.4	101.8	10.9	14.3	98.7	148.5
105	TELH	80	MEXI	2	120	5,040	5,079	12,642	14,734	118.9	141.0	92.8	89.1	10.5	10.0	0.0	0.0
106	TELH	80	MEXI	D	120	4,030	5,079	11,060	14,712	112.6	139.9	78.5	88.2	11.1	9.9	0.0	0.0
107	TELH	80	MEXI	D	120	3,420	4,115	9,790	13,267	98.3	137.0	68.4	90.2	11.4	12.5	0.0	0.0
108	TELH	80	MEXI	D	30	1,920	2,410	4,950	7,494	41.9	67.4	31.0	39.3	9.2	9.3	0.0	0.0
109	TELH	80	SONA	2	120	4,930	5,828	12,900	13,790	127.1	141.1	97.7	105.3	11.3	10.3	0.0	0.0
110	TELH	80	SONA	1	120	4,080	5,828	10,124	13,780	101.1	140.3	81.6	104.3	11.4	10.2	0.0	0.0
111	TELH	80	SONA	D	120	3,470	5,451	9,582	13,498	90.6	133.3	68.2	98.5	11.2	10.3	0.0	0.0
112	TELH	80	SONA	D	30	1,920	3,468	4,800	8,248	39.7	68.8	31.7	46.2	9.4	7.6	0.0	0.0
113	TELH	80	NOVI	2	120	4,540	3,984	10,344	14,300	95.1	141.1	78.1	89.5	9.8	12.8	0.0	0.0
114	TELH	80	NOVI	1	120	4,280	3,991	9,909	14,281	94.4	139.9	77.3	88.2	10.3	12.6	0.0	0.0
115	TELH	80	NOVI	D	120	3,150	3,351	8,600	12,537	85.9	137.3	62.4	90.5	11.3	15.4	0.0	0.0
116	TELH	80	NOVI	D	30	1,540	2,046	3,968	7,323	33.4	67.8	25.9	40.9	9.6	11.4	0.0	0.0
117	MDRS	71	HYSL	I	0	7,520	5,119	16,460	12,946	179.6	122.1	143.8	89.8	10.9	10.0	166.5	117.2
118	MDRS	71	HYSL	I	90	8,120	5,796	18,230	15,002	198.6	164.4	156.7	126.1	11.0	12.4	212.6	147.2
119	MDRS	71	HYSL	I	180	7,280	6,237	17,430	15,373	237.6	190.9	178.8	147.7	14.0	13.5	0.0	147.2
120	MDRS	71	HYSL	I	180	7,360	6,318	16,640	15,582	218.0	190.3	169.2	148.5	13.1	13.4	225.6	150.0
121	MDRS	71	HYSL	I	270	6,990	6,390	16,750	15,737	258.6	201.9	182.7	156.9	14.9	14.0	247.7	151.2
122	MDRS	71	NUGA	I	0	6,570	5,754	15,870	13,056	152.4	123.0	118.7	94.9	10.3	9.4	139.7	119.8
123	MDRS	71	NUGA	I	90	7,750	6,192	18,180	14,517	208.4	154.4	150.9	120.6	11.1	11.1	189.9	134.3
124	MDRS	71	NUGA	I	180	7,650	6,933	18,180	15,157	259.6	183.2	178.5	148.4	13.3	12.2	0.0	134.3
125	MDRS	71	NUGA	I	180	6,910	6,537	15,380	14,989	207.8	180.1	154.0	144.5	12.7	12.6	224.3	137.0
126	MDRS	71	NUGA	I	270	6,340	6,992	15,380	15,222	240.8	190.8	155.7	155.8	14.0	12.7	247.7	140.2
127	BOZE	71	NEWA	I	0	1,100	1,461	2,060	3,132	27.5	29.1	25.5	21.5	13.2	8.4	0.0	0.0
128	BOZE	71	NEWA	I	50	2,310	3,492	4,540	8,215	48.3	74.8	40.9	52.7	10.1	8.6	0.0	0.0
129	BOZE	71	NEWA	I	100	3,890	3,928	7,170	9,333	90.0	93.5	77.8	68.9	11.4	10.0	0.0	0.0
130	BOZE	71	NEWA	I	150	4,850	4,202	8,830	9,534	118.0	105.0	105.5	79.6	12.4	10.8	0.0	0.0
131	BOZE	71	NEWA	I	100	3,530	4,059	6,730	9,327	90.3	94.1	76.2	69.8	12.3	9.8	0.0	0.0
132	BOZE	71	NEWA	I	100	3,550	4,058	6,690	9,382	95.2	97.3	74.7	72.6	12.0	10.2	0.0	0.0
133	BOZE	71	NEWA	I	100	2,960	3,993	5,800	8,920	87.5	93.0	69.1	69.4	13.3	9.9	0.0	0.0
134	BOZE	71	NEWA	I	100	2,990	3,993	5,930	8,963	92.5	95.6	77.6	72.2	14.8	10.3	0.0	0.0
135	BOZE	71	NEWA	I	125	4,160	4,201	7,860	9,618	105.9	111.0	84.7	84.8	11.6	11.5	0.0	0.0

(Continued)

Appendix 4. Listing of N-Model Testing Data Base (Continued)

Obs	Loc.	Yr	CV	Irr	N	Grain Yield		Biomass		N Uptake		Grain N Uptake		Grain Protein		Anthesis N Uptake	
						O	P	O	P	O	P	O	P	O	P	O	P
181	WAIT	58	BENC	D	67	2,688	3,422	0	14,994	67.2	176.7	49.0	96.1	10.4	16.0	0.0	170.9
182	WAIT	58	BENC	D	134	2,352	3,504	0	16,699	118.7	191.0	59.8	99.6	14.5	16.2	0.0	189.1
183	WONG	66	GAME	D	0	670	842	2,016	1,688	14.6	15.4	0.0	12.0	0.0	8.1	0.0	0.0
184	WONG	66	GAME	D	61	1,337	2,068	4,256	4,428	31.3	46.7	0.0	37.0	0.0	10.2	0.0	0.0
185	WAGG	62	HERO	D	0	2,866	2,278	10,416	10,971	154.5	138.2	95.5	84.7	19.0	21.2	222.9	138.6
186	WAGG	62	HERO	D	56	2,240	2,264	9,744	11,280	155.7	145.1	60.5	89.0	15.4	22.4	227.4	144.9
187	WAGG	62	HERO	D	112	2,128	2,276	9,632	11,313	150.1	147.9	57.9	89.8	15.5	22.5	198.2	147.9
188	WAGG	62	HERO	D	168	2,016	2,276	9,408	11,314	151.2	148.9	70.7	89.8	20.0	22.5	212.8	148.8
189	WAGG	62	HERO	I	0	2,800	2,798	10,864	12,280	154.5	143.3	94.3	88.4	19.2	18.0	222.9	137.4
190	WAGG	62	HERO	I	56	2,576	2,874	10,528	12,611	155.7	144.4	85.0	90.3	18.8	17.9	227.4	144.5
191	WAGG	62	HERO	I	112	2,352	2,879	10,080	12,628	150.1	147.9	78.4	93.4	19.0	18.5	198.2	147.1
192	WAGG	62	HERO	I	168	2,240	2,883	10,080	12,637	151.1	148.9	78.6	94.1	20.0	18.6	212.8	148.9
193	WAGG	62	HERO	D	45	2,866	2,235	10,416	11,144	154.5	142.7	95.5	87.4	19.0	22.3	222.9	142.6
194	WAGG	62	HERO	D	101	2,240	2,271	9,744	11,305	155.7	148.6	60.5	89.6	15.4	22.5	227.4	149.1
195	WAGG	62	HERO	D	157	2,128	2,266	9,632	11,290	150.1	149.2	57.9	89.4	15.5	22.5	198.2	149.6
196	WAGG	62	HERO	D	213	2,016	2,266	9,408	11,293	151.2	149.6	70.7	89.4	20.0	22.5	212.8	149.6
197	WAGG	62	HERO	I	45	2,800	2,841	10,864	12,464	154.5	142.6	94.3	89.2	19.2	17.9	222.9	142.4
198	WAGG	62	HERO	I	101	2,576	2,879	10,528	12,641	155.7	148.6	85.0	93.9	18.8	18.6	227.4	148.3
199	WAGG	62	HERO	I	157	2,352	2,870	10,080	12,619	150.1	149.2	78.4	94.7	19.0	18.8	198.2	149.8
200	WAGG	62	HERO	I	213	2,240	2,869	10,080	12,612	151.1	149.6	78.6	94.6	20.0	18.8	212.8	149.6
201	LANC	67	GAME	D	0	329	181	0	361	8.3	2.9	0.0	2.0	0.0	6.2	0.0	0.0
202	LANC	67	GAME	D	77	531	1,217	0	2,779	16.2	20.1	0.0	12.0	0.0	5.6	0.0	0.0
203	LANC	67	GAME	D	77	766	1,225	0	2,795	25.2	20.2	0.0	12.0	0.0	5.6	0.0	0.0
204	LANC	67	GAME	D	77	1,082	1,359	0	3,075	27.4	22.5	0.0	13.6	0.0	5.7	0.0	0.0
205	LANC	67	GAME	D	77	1,344	1,657	0	3,365	30.8	24.6	0.0	16.6	0.0	5.7	0.0	0.0
206	ROTH	75	HUNT	D	0	3,400	3,986	5,650	8,232	49.0	64.0	47.1	45.5	7.9	6.5	26.7	60.7
207	ROTH	75	HUNT	D	30	4,000	4,921	7,550	10,800	57.0	87.3	51.9	62.2	7.4	7.2	44.3	84.5
208	ROTH	75	HUNT	D	60	5,400	5,812	10,000	13,095	83.0	109.8	76.7	78.5	8.1	7.7	68.3	107.1
209	ROTH	75	HUNT	D	90	6,400	6,323	12,430	14,904	107.0	130.2	96.6	93.2	8.6	8.4	83.2	127.6
210	ROTH	75	HUNT	D	120	6,600	6,565	13,250	16,440	123.0	150.3	110.0	108.3	9.5	9.4	113.3	146.8
211	ROTH	75	HUNT	D	150	7,000	6,689	14,250	16,716	153.0	159.6	136.3	117.4	11.1	10.0	158.5	155.2
212	ROTH	75	HUNT	D	180	6,600	6,689	13,000	16,725	149.0	160.1	134.3	117.4	11.6	10.0	164.9	155.2
213	ROTH	75	HUNT	D	210	7,000	6,691	14,060	16,739	197.0	160.8	158.4	118.6	12.9	10.1	176.1	155.2
214	ROTH	75	CAPP	D	0	3,600	3,464	7,300	8,301	62.0	64.7	59.4	37.7	9.4	6.2	39.4	61.6
215	ROTH	75	CAPP	D	30	4,200	4,526	8,950	10,954	69.0	88.4	64.1	52.4	8.7	6.6	47.4	85.3
216	ROTH	75	CAPP	D	60	4,800	5,379	10,000	13,075	72.0	108.8	67.4	65.1	8.0	6.9	70.6	105.8
217	ROTH	75	CAPP	D	90	5,800	6,187	12,700	15,087	98.0	130.0	87.5	80.3	8.6	7.4	81.4	126.7
218	ROTH	75	CAPP	D	120	6,100	6,712	13,000	16,776	111.0	149.8	98.5	94.2	9.2	8.0	112.6	147.5
219	ROTH	75	CAPP	D	150	6,800	7,118	15,050	18,000	153.0	168.2	126.5	109.9	10.6	8.8	135.6	166.5
220	ROTH	75	CAPP	D	180	6,200	7,123	14,300	18,019	150.0	170.9	121.8	112.5	11.2	9.0	154.9	168.9
221	ROTH	75	CAPP	D	210	6,500	7,134	14,500	18,032	172.0	171.6	138.0	112.6	12.1	9.0	182.9	168.9
222	ROTH	75	FUND	D	0	3,100	3,377	5,500	7,986	52.0	63.6	50.0	40.3	9.2	6.8	31.9	60.4
223	ROTH	75	FUND	D	30	4,600	4,413	8,800	10,576	71.0	87.3	67.0	55.7	8.3	7.2	48.0	84.5
224	ROTH	75	FUND	D	60	5,600	5,392	10,800	12,878	88.0	109.7	80.6	71.9	8.2	7.6	66.2	107.1
225	ROTH	75	FUND	D	90	5,900	6,061	11,300	14,761	88.0	130.4	77.6	87.2	7.5	8.2	87.3	127.6

(Continued)

APPENDIX 5

FORTRAN Program (METBR) to Read Daily Rainfall Data and Calculate Conditional Probabilities, Parameters of the Gamma Distribution and Statistics on Observed Rainfall

```
      PROGRAM METBR
      DIMENSION RAIN(120,366),XRAIN(366)
C       COMMON/A1/XRAIN(366),NYR(100),IEND
      CHARACTER*17 DEV
      CHARACTER*10 FNAM1,FNAM2,FNAM3,FNAM4
C       FNAM1=RAINFALL FILE
C       FNAM2=COEFFICIENT FILE
C       FNAM3=CHECK FILE
C       FNAM4=STATISTICS FILE
      OPEN(UNIT=25,FILE='TTEST.DAT',STATUS='OLD')
      OPEN(UNIT=1,FILE='RAN.NAM',STATUS='OLD')
      DO 700 I=1,50
           READ(1,100)DEV,FNAM1,FNAM2,FNAM3,FNAM4
100        FORMAT(A,1X,A,1X,A,1X,A,1X,A)
200        FORMAT(A,1X,A,1X,A,/,1X,A,1X,A)
           TYPE 200,DEV,FNAM1,FNAM2,FNAM3,FNAM4
           OPEN(UNIT=21,FILE=FNAM1,STATUS='OLD')
           OPEN(UNIT=6,FILE=FNAM2,STATUS='NEW')
           OPEN(UNIT=12,FILE=FNAM3,STATUS='NEW')
           OPEN(UNIT=20,FILE=FNAM4,STATUS='NEW')
           IEND=0
           DO 400 M=1,120
                CALL RDRAIN(XRAIN,KY,IEND)
                DO 300 JD=1,366
                     RAIN(M,JD)=XRAIN(JD)/10.0
300             CONTINUE
                IF(IEND.EQ.1)GO TO 500
400        CONTINUE
500        TYPE 600,M
600        FORMAT(' M=',I6)
           CALL WSTATS(M,RAIN)
C        CALL PPRAIN(RAIN,M)
           CALL PCRAIN(RAIN,M)
700   CONTINUE
      STOP
      END
C    THIS ROUTINE READS DAILY RAINFALL FILES IN THE FORMAT
C    WK.RAIN RECORDS AND PUTS ONE YEAR'S DATA INTO A VECTOR
C    IT IS SET FOR USE AS A SUBROUTINE.
      SUBROUTINE RDRAIN(RAIN,KY,IEND)
      DIMENSION RAIN(366),IRA(8),NYR(120),XRAIN(120,366)
C        COMMON/A1/RAIN,NYR,IEND
      KY = 0
      LY = 1
      NDAYS = 365
      NB = 0
      JD = 0
      KY = KY + 1
      READ(21,*,END=2000) NW,NYR(KY)
      IF(MOD(NYR(KY),4))200,100,200
C       IF(1900.EQ.NYR(KY))GO TO 101
100   LY = 0
      NDAYS = 366
200   NB = NB + 1
      NDAY = 7
300   READ(21,*,END=1400) NW,(IRA(J),J = 1,NDAY)
      IF(NB.GT.NW) GO TO 1200
400   IF(NB.LT.NW) GO TO 800
      IF(NW.EQ.9.AND.LY.EQ.0) GO TO 700
      IF(NW.EQ.30) GO TO 700
500   DO 600 I=1,NDAY
           JD = JD + 1
600   RAIN(JD) = FLOAT(IRA(I))
      NDAY = 7
      NB = NB + 1
      IF(NB.LE.52) GO TO 300
```

```
      END
      BLOCK DATA
      COMMON /BK15/NC(13),IYR,NT,IDA,MO,ND
      DATA NC/0,31,60,91,121,152,182,213,244,274,305,335,366/
      DATA NT/1/
      END
      SUBROUTINE PPRAIN(XRAIN,NYR)
      DIMENSION XRAIN(120,365)
      DIMENSION NWD(12),NDD(12),NDW(12),NWW(12)
      DIMENSION SUM(12),SUM2(12),SUM3(12)
      DIMENSION SL(12),PWW(12),PWD(12),RBAR(12),XL(12)
      DIMENSION SD(12),SKEW(12),ALPHA(12),BETA(12)
      DIMENSION NW(12),IC(12),SUML(12)
      DIMENSION RLBAR(12),AL2(12),BE2(12),DATE(12)
      DIMENSION PPPW(12),ND(12)
      CHARACTER *36 A(2)
      DATA DATE /'JAN.','FEB.','MAR.','APR.','MAY ','JUNE',
     1          'JULY','AUG.','SEP.','OCT.','NOV.','DEC.'/
      DATA A(1) /'                                    '/
      DATA A(2) /'NOT ENOUGH DATA TO DEFINE PARAMETERS'/
      DO 100 I=1,12
           ND(I)=0
           PPPW(I)=0.
           NWD(I)=0
           NWW(I)=0
           NDD(I)=0
           NDW(I)=0
           NW(I)=0
           SL(I)=0.
           SUML(I)=0.
           SUM(I)=0.
           SUM2(I)=0.
           PWW(I)=0.
           PWD(I)=0.
           XL(I)=0.
           ALPHA(I)=0.
           BETA(I)=0.
           RBAR(I)=0.
           SD(I)=0.
           SKEW(I)=0.
100   SUM3(I)=0.
      INUMB=0
      XYR=NYR
      RIM1=0.
      DO 1100 J=1,NYR
           DO 1000 K=1,365
                INUMB=INUMB+1
                IF(K .GE. 001 .AND. K .LE. 031) MO=1
                IF(K .GE. 032 .AND. K .LE. 059) MO=2
                IF(K .GE. 060 .AND. K .LE. 090) MO=3
                IF(K .GE. 091 .AND. K .LE. 120) MO=4
                IF(K .GE. 121 .AND. K .LE. 151) MO=5
                IF(K .GE. 152 .AND. K .LE. 181) MO=6
                IF(K .GE. 182 .AND. K .LE. 212) MO=7
                IF(K .GE. 213 .AND. K .LE. 243) MO=8
                IF(K .GE. 244 .AND. K .LE. 273) MO=9
                IF(K .GE. 274 .AND. K .LE. 304) MO=10
                IF(K .GE. 305 .AND. K .LE. 334) MO=11
                IF(K .GE. 335 .AND. K .LE. 365) MO=12
                RAIN=XRAIN(J,K)
                IF(RAIN .GT. 20.) RAIN=0.0
                IF(RAIN .GT. 0.00) NW(MO)=NW(MO)+1
                ND(MO)=ND(MO)+1
                IF(RAIN)600,600,200
200             IF(RIM1)300,300,400
300             NWD(MO)=NWD(MO)+1
```

```
     2 AM1(3,3,13),AA(20),XCOV1(3,3,13),XCOV(3,3,13),VAR(3,3,13),
     3SA1(3,3,13),SB1(3,3,13),VAR1(3,3,13)
      NNN=NYRS*365
C*****COMPUTE LAG-ZERO CORRELATION MATRIX
      DO 100 I = 1,3
           DO 100 J = 1,3
                DO 100 K = 1,13
                     NN(I,J,K)=0
                     NM(I,J,K)=0
                     SA(I,J,K)=0.
                     SB(I,J,K)=0.
                     XN(I,J,K)=0.
                     XN1(I,J,K) = 0.
                     SS(I,J,K) = 0.
                     SS1(I,J,K) = 0.
100   CONTINUE
      DO 200 IYR = 1,NYRS
           DO 200 K = 1,13
                DO 200 KDAY = 1,28
                     DO 200 I = 1,3
                          DO 200 J = 1,3
                               KK=(IYR-1)*365+(K-1)*28+KDAY
                               IF(XR(I,KK) .GT. 998. .OR. XR(J,KK) .GT.
     1998.)GO TO 200
                               NN(I,J,K)=NN(I,J,K)+1
                               SA(I,J,K)=SA(I,J,K)+XR(I,KK)
                               SB(I,J,K)=SB(I,J,K)+XR(I,KK)*XR(I,KK)
                               SS(I,J,K)=SS(I,J,K)+XR(I,KK)*XR(J,KK)
200   CONTINUE
      DO 300 K = 1,13
           DO 300 I = 1,3
                DO 300 J = 1,3
                     XN(I,J,K)=NN(I,J,K)
                     XN(J,I,K) = NN(I,J,K)
                     IF(XN(I,J,K) .LE. 1.)  VAR(I,J,K)=0.
                     IF(XN(I,J,K) .LE. 1.)  XCOV(I,J,K)=0.
                     IF(XN(I,J,K) .LE. 1.)  GO TO 300
                     VAR(I,J,K)=(SB(I,J,K)-((SA(I,J,K)*SA(I,J,K))/XN(I,J
     1,K)))/(XN(I,J,K)-1.)
                     XCOV(I,J,K)=(SS(I,J,K)-((SA(I,J,K)*SA(J,I,K))/XN(I,
     1J,K)))/(XN(I,J, K)-1.)
300   CONTINUE
      DO 400 K = 1,13
           DO 400 I = 1,3
                DO 400 J = 1,3
                     AAB=SQRT(VAR(I,J,K)*VAR(J,I,K))
                     IF(AAB .EQ. 0.) AMO(I,J,K)=0.
                     IF(AAB .EQ. 0.) GO TO 400
                     AMO(I,J,K)=XCOV(I,J,K)/AAB
400   CONTINUE
C*****AMO(I,J) IS LAG-ZERO CORRELATION MATRIX
C*****COMPUTE THE LAG-ONE CORRELATION MATRIX
      DO 500 I = 1,3
           DO 500 J = 1,3
                DO 500 K = 1,13
                     SA(I,J,K) = 0.
                     SA1(I,J,K) = 0.
                     SB(I,J,K) = 0.
                     SB1(I,J,K) = 0.
                     SS(I,J,K) = 0.
500   CONTINUE
      DO 600 IYR = 1,NYRS
           DO 600 K = 1,13
                DO 600 KDAY = 1,28
                     KK=(IYR-1)*365+(K-1)*28+KDAY
                     KP1 = KK + 1
```

```
      DO 200 I=1.N
           SUM2=SUM2+((Y(I)  -STAT1)**2)
200   CONTINUE
      STAT2=SUM2/XN
      STAT5=(XN/(XN-1.))*STAT2
      RETURN
      END
      SUBROUTINE GAMMA(Y,NP,N,ALPHA,BETA,J)
      DIMENSION Y(2000)
      DIMENSION N(26),ALPHA(26),BETA(26)
      XN=N(J)
      CALL BDS(YBAR.VAR,Y,N,J)
      A1=YBAR*YBAR/VAR
      SUM=0.
      M=N(J)
      DO 100 I=1.M
           IF(Y(I) .LE. 0.0) Y(I)=0.001
           SUM=SUM+ALOG(Y(I))
100   CONTINUE
      AX=ALOG(YBAR)-SUM/XN
200   DELTA=0.04475*(0.26**A1)
      A=((1.+SQRT(1.+1.3333*AX))/(4.*AX))-DELTA
      DIFF=ABS(A-A1)
      IF(DIFF .LE. 0.001) GO TO 300
      A1=A
      GO TO 200
300   B=YBAR/A
      ALPHA(J)=A
      BETA(J)=B
      RETURN
      END
      SUBROUTINE WSTATS(NYRS,RAIN)
      DIMENSION RAIN(120.366)
     1 ,TOTRF(12),TOTMX(12),TOTMN(12).TOTRD(12)
     2 ,XBRF(12).XBTX(12).XBTN(12),XBTR(12).TOTMF(120,12),TOTWD(120,12)
     3  ,DATE(12),TOTREV(120,12),XBWD(12),XBREV(12).XBRD(12),NC(13)
     4 ,TOTRW(120.12).XBRW(12)
     5 ,XBAR(12),SD(12),VAR(12)
     6. XBAR2(12),SD2(12).CV(12).CV2(12)
      DATA DATE /'JAN.','FEB.','MAR.','APR.','MAY ','JUNE',
     1          'JULY','AUG.','SEP.','OCT.','NOV.','DEC.'/
      DATA NC/0,31.60,91,121,152,182,213,244,274,305,335,366/
      DATA NT/1/
      DO 0 I=1.12
      DO 100 JYR=1.120
           TOTRW(JYR,I)=0.0
           TOTMF(JYR,I)=0.0
100   TOTWD(JYR.I)=0.0
      TOTRF(I)=0.0
6  CONTINUE
      DO 400 JYR=1.NYRS
           DO 300 IMO=1.12
                IST=NC(IMO)+1
                IEND=NC(IMO+1)
                IF(IEND.EQ.366)IEND=365
                IWET=0
                DO 200 ID=IST.IEND
                     TOTRF(IMO)=TOTRF(IMO)+RAIN(JYR.ID)
                     IF(RAIN(JYR.ID).GT.0.0)THEN
                          TOTWD(JYR,IMO)=TOTWD(JYR,IMO)+1
                          TOTMF(JYR,IMO)=TOTMF(JYR.IMO)+RAIN(JYR,ID
     1)
                          IF(IWET.EQ.0)THEN
                               TOTRW(JYR,IMO)=TOTRW(JYR,IMO)+1
                               IWET=1
                          ELSE
```

```
      XYRS=FLOAT(NYRS)
      WRITE(20,100)STRING
100   FORMAT(' PARAMETER    ',A)
      WRITE(20,200)
200   FORMAT(///,5X,'MONTH',8X,'MEAN',8X,'S.D.',8X,'C.V.',11X,'W'
     1 ,11X,'WT')
      DO 400 I=1,12
         SSQ=VAR(I)*VAR(I)
         W=SSQ/XYRS
         WT=W*T5
         WRITE(20,300)DATE(I),XBAR(I),VAR(I),SD(I),W,WT
300      FORMAT(6X,A4,3F12.2,2F12.5)
400   CONTINUE
      RETURN
      END
      SUBROUTINE STATS(NYRS,W,RAIN,ID,XM,XM1,SD,SD1,CX,CX1,W2)
      DIMENSION W(120,366),RAIN(120,366),XM(12),SD(12),SD1(12)
      DIMENSION CX(12),CX1(12),XM1(12),DATE(12),NC(13)
      DIMENSION W2(120,12)
      DATA NC/0,31,60,91,121,152,182,213,244,274,305,335,366/
      DO 600 I = 1,12
         IST=NC(I)+1
         IEND=NC(I+1)
         IF(IEND.EQ.366)IEND=365
         XN = 0.
         XN1 = 0.
         SUM = 0.
         SUM1 = 0.
         SS = 0.
         SS1 = 0.
         DO 300 JD=IST,IEND
            DO 300 JY = 1,NYRS
               IF(ID .EQ. 2) GO TO 100
               IF(RAIN(JY,JD))100,100,200
100            CONTINUE
               XN = XN + 1.
               SUM = SUM+W(JY,JD)
               SS = SS + (W(JY,JD)*W(JY,JD))
               GO TO 300
200            CONTINUE
               XN1 = XN1 + 1.
               SUM1 = SUM1 + W(JY,JD)
               SS1=SS1+(W(JY,JD)*W(JY,JD))
300      CONTINUE
         IF(XN .LE. 2.) XM(I) = 0.
         IF(XN .LE. 2.) SD(I) = 0.
         IF(XN .LE. 2.) CX(I) = 0.
         IF(XN .LE. 2.) GO TO 400
         XM(I) = SUM / XN
         SD(I) = SQRT((SS-SUM*SUM/XN)/(XN-1.))
         IF(XM(I) .LT. 0.001) XM(I) = 0.001
         CX(I) = SD(I) / XM(I)
400      CONTINUE
         IF(ID .EQ. 2) GO TO 600
         IF(XN1 .LE. 2.) XM1(I)=0.
         IF(XN1 .LE. 2.) SD1(I) = 0.
         IF(XN1 .LE. 2.) CX1(I) = 0.
         IF(XN1 .LE. 2.) GO TO 500
         XM1(I) = SUM1 / XN1
         SD1(I)=SQRT((SS1-SUM1*SUM1/XN1)/(XN1-1.))
         IF(XM1(I) .LT. 0.001) XM1(I) = 0.001
         CX1(I)=SD1(I)/XM1(I)
500      CONTINUE
600   CONTINUE
      RETURN
      ENTRY RSTATS(NYRS,W,RAIN,ID,XM,XM1,SD,SD1,CX,CX1,W2)
```

```
              IF(K .GE. 182 .AND. K .LE. 212) MO = 7
              IF(K .GE. 213 .AND. K .LE. 243) MO = 8
              IF(K .GE. 244 .AND. K .LE. 273) MO = 9
              IF(K .GE. 274 .AND. K .LE. 304) MO = 10
              IF(K .GE. 305 .AND. K .LE. 334) MO = 11
              IF(K .GE. 335 .AND. K .LE. 365) MO = 12
              RAIN=XRAIN(J,K)
              IF(RAIN .GT. 0.00) NW(MO)=NW(MO)+1
              ND(MO)=ND(MO)+1
              IF(RAIN) 600,600,200
200           IF(RIM1)300,300,400
300           NWD(MO)=NWD(MO)+1
              GO TO 500
400           NWW(MO)=NWW(MO)+1
500           CONTINUE
              SUML(MO)=SUML(MO)+ALOG(RAIN)
              SUM(MO)=SUM(MO)+RAIN
              SUM2(MO)=SUM2(MO) + RAIN * RAIN
              SUM3(MO)=SUM3(MO)+RAIN*RAIN*RAIN
              SL(MO) = SL(MO)+ALOG(RAIN)
              GO TO 900
600           IF(RIM1) 700,700,800
700           NDD(MO)=NDD(MO)+1
              GO TO 900
800           NDW(MO)=NDW(MO)+1
900           RIM1 = RAIN
1000       CONTINUE
1100  CONTINUE
      DO 1200 I = 1,12
           XXND=ND(I)
           YYNW=NW(I)
           PPPW(I) = YYNW/XXND
           III=1
           IF(NW(I) .LT. 3) III=2
           IC(I) = III
           IF(NW(I) .LT. 3) GO TO 1200
           XNWW=NWW(I)
           XNWD=NWD(I)
           XXNW=NWW(I)+NDW(I)
           XND=NDD(I)+NWD(I)
           XNW=NW(I)
           PWW(I)=XNWW/XXNW
           PWD(I)=XNWD/XND
           RBAR(I)=SUM(I)/XNW
           RLBAR(I)=SUML(I)/XNW
           Y=ALOG(RBAR(I))-RLBAR(I)
           ANUM=8.898919+9.05995*Y+0.9775373*Y*Y
           ADOM=Y*(17.79728+11.968477*Y+Y*Y)
           ALPHA2=ANUM/ADOM
           IF(ALPHA2 .GE. 1.0) ALPHA2=0.998
           BETA2=RBAR(I)/ALPHA2
           ALPHA(I)=ALPHA2
           BETA(I)=BETA2
1200  CONTINUE
      WRITE(6,1300)
      WRITE(12,1300)
1300  FORMAT(///,8X,'--MARKOV CHAIN--                    -GAMMA DIST-',/,
     1 1X,' MONTH  P(W/W)    P(W/D)                 ALPHA   BETA',/)
      DO 1500 I = 1,12
           WRITE(12,1400)DATE(I),PWW(I),PWD(I),ALPHA(I),BETA(I),A(IC(I))
           WRITE(6,1400)DATE(I),PWW(I),PWD(I),ALPHA(I),BETA(I),A(IC(I))
1400       FORMAT(1X,A4,F8.3,F10.3,11X,F11.3,F7.3,5X,A36)
1500  CONTINUE
      DO 1600 J=1,12
           YDATA(1,J)=PWW(J)
           YDATA(2,J)=PWD(J)
```

APPENDIX 6

Calculated Rainfall Generation Parameters for Locations in the Australian Wheat Belt

Calculated Rainfall Generation Parameters for Locations in the Australian Wheat Belt

		January	February	March	April	May	June	July	August	September	October	November	December
Barraba	p(w/w)	0.445	0.440	0.431	0.386	0.447	0.437	0.406	0.411	0.384	0.409	0.413	0.443
	p(w/d)	0.180	0.160	0.119	0.112	0.114	0.160	0.151	0.150	0.143	0.181	0.183	0.172
	alpha	0.801	0.723	0.758	0.731	0.744	0.731	0.737	0.767	0.842	0.797	0.796	0.866
	beta	14.246	16.513	14.022	12.117	11.439	9.650	9.261	8.556	8.880	11.090	12.956	11.706
Bathurst	p(w/w)	0.382	0.397	0.417	0.433	0.460	0.495	0.483	0.458	0.412	0.442	0.417	0.385
	p(w/d)	0.165	0.159	0.140	0.138	0.161	0.207	0.208	0.213	0.224	0.202	0.176	0.168
	alpha	0.817	0.838	0.818	0.808	0.825	0.865	0.893	0.874	0.938	0.865	0.896	0.809
	beta	12.356	11.885	10.745	9.018	7.562	6.214	5.593	5.966	6.035	8.339	9.039	10.961
Bendigo	p(w/w)	0.399	0.425	0.411	0.499	0.580	0.640	0.637	0.650	0.563	0.531	0.457	0.429
	p(w/d)	0.119	0.100	0.126	0.161	0.218	0.271	0.305	0.301	0.281	0.242	0.177	0.146
	alpha	0.622	0.626	0.646	0.713	0.735	0.724	0.787	0.821	0.762	0.760	0.751	0.744
	beta	10.683	12.325	10.047	7.623	6.894	6.471	5.100	4.842	6.078	6.725	6.842	7.021
Biloela	p(w/w)	0.522	0.540	0.453	0.410	0.445	0.466	0.416	0.341	0.368	0.436	0.419	0.464
	p(w/d)	0.220	0.204	0.160	0.106	0.099	0.097	0.093	0.093	0.084	0.142	0.191	0.208
	alpha	0.691	0.594	0.624	0.586	0.574	0.613	0.569	0.691	0.662	0.721	0.762	0.681
	beta	15.830	21.353	14.929	14.562	16.632	12.868	11.567	8.226	9.509	11.492	14.090	16.179
Clare	p(w/w)	0.380	0.435	0.413	0.551	0.633	0.650	0.657	0.645	0.584	0.520	0.462	0.402
	p(w/d)	0.100	0.090	0.112	0.168	0.228	0.294	0.327	0.310	0.296	0.242	0.167	0.124
	alpha	0.666	0.653	0.722	0.783	0.824	0.911	0.939	0.949	0.872	0.817	0.788	0.740
	beta	8.888	9.961	7.229	7.857	7.614	6.313	5.750	5.695	6.668	6.710	6.446	7.265
Cobar	p(w/w)	0.377	0.422	0.392	0.358	0.423	0.413	0.399	0.390	0.323	0.360	0.361	0.376
	p(w/d)	0.081	0.101	0.081	0.082	0.102	0.137	0.123	0.128	0.113	0.117	0.102	0.099
	alpha	0.719	0.752	0.713	0.722	0.809	0.795	0.885	0.859	0.872	0.855	0.723	0.820
	beta	12.338	10.343	11.176	10.627	7.178	6.909	4.950	6.498	6.234	7.183	9.435	10.401
Condobolin	p(w/w)	0.329	0.376	0.380	0.400	0.402	0.455	0.391	0.385	0.353	0.380	0.351	0.310
	p(w/d)	0.101	0.105	0.101	0.106	0.133	0.173	0.182	0.173	0.155	0.151	0.113	0.117
	alpha	0.755	0.777	0.750	0.761	0.831	0.873	0.841	0.847	0.899	0.799	0.830	0.788
	beta	13.489	12.272	11.845	9.787	8.029	5.852	5.563	6.207	5.709	8.709	9.450	11.180
Coonabarabran	p(w/w)	0.459	0.478	0.460	0.454	0.489	0.514	0.457	0.449	0.420	0.416	0.435	0.444
	p(w/d)	0.154	0.144	0.117	0.110	0.126	0.171	0.169	0.163	0.157	0.171	0.160	0.157
	alpha	0.638	0.647	0.662	0.670	0.678	0.690	0.669	0.733	0.708	0.772	0.810	0.785
	beta	20.143	20.255	17.557	14.672	13.159	10.648	10.538	10.134	10.787	10.488	10.917	11.652
Coonamble	p(w/w)	0.406	0.456	0.450	0.365	0.416	0.440	0.394	0.383	0.356	0.366	0.371	0.361
	p(w/d)	0.117	0.124	0.092	0.088	0.104	0.134	0.126	0.126	0.124	0.133	0.123	0.122
	alpha	0.686	0.705	0.729	0.698	0.762	0.786	0.719	0.808	0.801	0.777	0.795	0.764
	beta	17.647	15.740	13.876	12.783	11.251	8.228	9.000	7.434	8.441	10.176	10.480	11.052
Cowra	p(w/w)	0.395	0.386	0.424	0.404	0.492	0.536	0.516	0.490	0.428	0.403	0.383	0.369
	p(w/d)	0.126	0.124	0.102	0.121	0.141	0.200	0.214	0.228	0.190	0.187	0.151	0.134
	alpha	0.781	0.867	0.804	0.896	0.862	0.869	0.908	0.855	0.884	0.899	0.853	0.814
	beta	14.167	10.524	13.082	9.068	7.904	6.932	5.498	6.137	7.424	8.493	10.137	12.202
Dalby	p(w/w)	0.507	0.493	0.456	0.416	0.433	0.422	0.426	0.363	0.322	0.402	0.410	0.439
	p(w/d)	0.170	0.156	0.138	0.095	0.099	0.124	0.110	0.106	0.127	0.158	0.184	0.201
	alpha	0.757	0.670	0.659	0.641	0.679	0.686	0.689	0.822	0.798	0.811	0.761	0.746
	beta	14.755	16.985	16.885	14.486	11.940	11.690	11.278	8.103	9.720	11.020	14.126	15.796
Dalwallinu	p(w/w)	0.294	0.323	0.345	0.414	0.466	0.585	0.575	0.510	0.426	0.345	0.371	0.202
	p(w/d)	0.063	0.069	0.072	0.109	0.193	0.295	0.294	0.269	0.199	0.139	0.070	0.054
	alpha	0.656	0.639	0.659	0.784	0.815	0.873	0.926	0.912	0.918	0.898	0.806	0.785
	beta	8.518	9.921	10.930	5.706	6.404	6.691	5.117	4.583	3.530	3.665	4.619	5.726

(Continued)

Calculated Rainfall Generation Parameters for Locations in the Australian Wheat Belt (Continued)

		January	February	March	April	May	June	July	August	September	October	November	December
Jondaryan	p(w/w)	0.397	0.417	0.409	0.319	0.366	0.401	0.337	0.310	0.288	0.346	0.319	0.358
	p(w/d)	0.148	0.129	0.119	0.080	0.075	0.104	0.100	0.089	0.103	0.139	0.169	0.171
	alpha	0.983	0.911	0.976	0.893	0.933	0.940	0.980	0.998	0.998	0.998	0.977	0.998
	beta	14.666	14.519	12.270	12.453	11.649	10.169	8.731	8.175	8.548	11.178	12.118	13.635
Kadina	p(w/w)	0.279	0.351	0.287	0.457	0.558	0.548	0.555	0.537	0.469	0.383	0.344	0.339
	p(w/d)	0.081	0.074	0.098	0.155	0.217	0.298	0.318	0.302	0.257	0.213	0.142	0.102
	alpha	0.768	0.691	0.792	0.782	0.889	0.852	0.968	0.937	0.916	0.865	0.847	0.831
	beta	6.407	9.494	6.172	6.632	5.234	5.071	3.860	4.036	4.261	4.855	4.931	5.301
Kerang	p(w/w)	0.316	0.386	0.330	0.379	0.447	0.446	0.452	0.441	0.403	0.378	0.325	0.285
	p(w/d)	0.071	0.076	0.088	0.114	0.158	0.212	0.215	0.221	0.191	0.175	0.128	0.100
	alpha	0.796	0.689	0.711	0.784	0.803	0.864	0.904	0.935	0.843	0.872	0.823	0.829
	beta	9.269	11.401	11.000	7.085	6.497	5.022	4.270	4.386	5.408	6.719	6.953	8.243
Kybybolite	p(w/w)	0.431	0.462	0.465	0.599	0.697	0.698	0.727	0.719	0.667	0.610	0.516	0.489
	p(w/d)	0.115	0.115	0.151	0.224	0.298	0.365	0.430	0.418	0.362	0.271	0.241	0.175
	alpha	0.668	0.630	0.649	0.716	0.779	0.791	0.837	0.899	0.826	0.784	0.766	0.170
	beta	6.556	7.944	6.118	5.404	4.918	4.492	4.435	4.057	4.789	5.106	4.962	5.538
Loxton	p(w/w)	0.300	0.326	0.332	0.357	0.441	0.441	0.431	0.469	0.355	0.341	0.324	0.296
	p(w/d)	0.072	0.082	0.077	0.119	0.173	0.207	0.241	0.241	0.207	0.166	0.131	0.096
	alpha	0.685	0.655	0.689	0.790	0.888	0.822	0.902	0.920	0.813	0.752	0.838	0.832
	beta	8.919	11.438	7.537	4.600	4.186	3.599	3.076	3.090	4.576	6.233	5.029	6.086
Merbein	p(w/w)	0.372	0.378	0.397	0.419	0.507	0.537	0.505	0.461	0.426	0.412	0.384	0.332
	p(w/d)	0.077	0.077	0.087	0.110	0.167	0.208	0.243	0.230	0.177	0.171	0.134	0.096
	alpha	0.724	0.624	0.650	0.717	0.722	0.728	0.820	0.792	0.818	0.709	0.702	0.722
	beta	8.116	11.274	7.851	5.413	4.826	3.902	3.107	3.534	4.212	6.022	6.470	6.460
Miles	p(w/w)	0.514	0.502	0.472	0.372	0.394	0.414	0.403	0.359	0.360	0.364	0.359	0.438
	p(w/d)	0.170	0.155	0.130	0.095	0.094	0.108	0.102	0.097	0.102	0.148	0.174	0.193
	alpha	0.718	0.731	0.706	0.715	0.669	0.698	0.711	0.810	0.810	0.845	0.819	0.739
	beta	16.819	15.327	14.689	12.334	13.446	12.156	11.467	8.600	9.496	10.846	12.481	15.629
Moora	p(w/w)	0.303	0.302	0.306	0.469	0.537	0.669	0.659	0.606	0.528	0.414	0.345	0.241
	p(w/d)	0.055	0.068	0.077	0.124	0.219	0.292	0.337	0.295	0.242	0.187	0.101	0.069
	alpha	0.641	0.560	0.643	0.782	0.825	0.836	0.881	0.941	0.931	0.957	0.867	0.794
	beta	8.034	11.072	9.911	5.819	7.176	8.012	6.748	4.982	3.890	3.344	3.614	4.629
Moree	p(w/w)	0.417	0.428	0.372	0.339	0.422	0.382	0.373	0.345	0.348	0.322	0.318	0.362
	p(w/d)	0.142	0.140	0.106	0.087	0.090	0.132	0.122	0.111	0.112	0.147	0.144	0.144
	alpha	0.845	0.720	0.724	0.815	0.789	0.742	0.806	0.856	0.860	0.854	0.835	0.833
	beta	13.208	16.804	17.530	11.817	11.862	11.421	9.616	8.510	9.093	10.235	12.283	12.370
Muresk	p(w/w)	0.223	0.308	0.393	0.517	0.600	0.680	0.706	0.661	0.541	0.472	0.322	0.252
	p(w/d)	0.051	0.065	0.069	0.137	0.222	0.370	0.377	0.304	0.247	0.157	0.098	0.055
	alpha	0.598	0.564	0.652	0.665	0.680	0.660	0.668	0.719	0.780	0.779	0.905	0.701
	beta	8.660	11.819	9.098	6.334	8.549	8.555	7.646	5.714	4.081	4.731	3.294	5.384
Nhill	p(w/w)	0.330	0.366	0.359	0.478	0.564	0.584	0.607	0.616	0.551	0.503	0.437	0.366
	p(w/d)	0.095	0.089	0.106	0.157	0.213	0.298	0.318	0.314	0.285	0.226	0.166	0.126
	alpha	0.687	0.655	0.682	0.763	0.846	0.837	0.927	0.944	0.895	0.817	0.772	0.694
	beta	7.901	10.116	7.731	5.645	4.676	4.356	3.417	3.474	4.073	5.126	5.756	7.240
Northam	p(w/w)	0.256	0.306	0.387	0.488	0.590	0.684	0.695	0.634	0.557	0.477	0.391	0.271
	p(w/d)	0.053	0.059	0.072	0.119	0.217	0.305	0.328	0.286	0.242	0.170	0.088	0.060
	alpha	0.633	0.614	0.584	0.704	0.790	0.840	0.848	0.891	0.960	0.840	0.931	0.718
	beta	8.775	10.769	10.665	6.297	6.853	6.942	6.313	5.055	3.309	4.089	3.204	5.266

(Continued)

Calculated Rainfall Generation Parameters for Locations in the Australian Wheat Belt (Continued)

		January	February	March	April	May	June	July	August	September	October	November	December
Walgett	p(w/w)	0.432	0.472	0.444	0.392	0.475	0.416	0.397	0.372	0.356	0.341	0.385	0.376
	p(w/d)	0.115	0.113	0.099	0.078	0.087	0.129	0.113	0.101	0.102	0.120	0.112	0.112
	alpha	0.731	0.751	0.773	0.718	0.766	0.753	0.803	0.778	0.819	0.760	0.795	0.852
	beta	16.691	16.134	12.451	12.190	11.593	9.019	7.326	8.587	8.030	10.534	9.946	9.505
Walpeup	p(w/w)	0.331	0.440	0.416	0.483	0.567	0.567	0.570	0.593	0.482	0.508	0.395	0.300
	p(w/d)	0.093	0.088	0.098	0.142	0.244	0.304	0.340	0.306	0.263	0.206	0.166	0.116
	alpha	0.608	0.603	0.574	0.684	0.701	0.666	0.740	0.771	0.754	0.738	0.750	0.708
	beta	8.544	11.128	10.213	5.769	4.236	3.536	3.275	3.397	4.209	5.704	5.660	7.196
Warialda	p(w/w)	0.401	0.416	0.391	0.312	0.422	0.406	0.392	0.383	0.356	0.379	0.378	0.377
	p(w/d)	0.179	0.159	0.133	0.105	0.110	0.142	0.138	0.136	0.135	0.169	0.171	0.168
	alpha	0.793	0.788	0.700	0.749	0.754	0.766	0.795	0.799	0.810	0.810	0.868	0.858
	beta	15.068	16.539	16.208	14.050	12.654	10.728	9.692	9.264	10.466	11.226	11.712	12.056
Warooka	p(w/w)	0.299	0.333	0.320	0.485	0.581	0.613	0.627	0.617	0.548	0.447	0.379	0.298
	p(w/d)	0.085	0.079	0.110	0.200	0.290	0.359	0.415	0.388	0.314	0.237	0.164	0.113
	alpha	0.630	0.593	0.718	0.759	0.835	0.854	0.976	0.970	0.942	0.851	0.765	0.808
	beta	6.782	10.474	5.097	5.517	4.855	5.132	3.964	3.881	3.849	4.592	4.980	4.792
Warracknabeal	p(w/w)	0.400	0.391	0.438	0.478	0.619	0.632	0.610	0.635	0.656	0.522	0.432	0.208
	p(w/d)	0.072	0.097	0.059	0.187	0.195	0.241	0.257	0.195	0.168	0.150	0.147	0.111
	alpha	0.628	0.748	0.979	0.709	0.759	0.679	0.998	0.998	0.998	0.706	0.605	0.834
	beta	11.293	5.216	3.700	5.342	5.064	4.786	2.387	3.942	3.933	4.692	12.658	3.075
Wellington	p(w/w)	0.388	0.397	0.391	0.392	0.418	0.459	0.427	0.431	0.358	0.374	0.405	0.353
	p(w/d)	0.125	0.120	0.109	0.109	0.133	0.173	0.188	0.188	0.163	0.165	0.136	0.138
	alpha	0.788	0.772	0.783	0.802	0.824	0.822	0.824	0.884	0.880	0.837	0.850	0.868
	beta	14.072	14.321	12.437	11.960	10.321	8.772	7.469	7.259	7.489	9.839	11.345	11.435
West Wyalong	p(w/w)	0.352	0.337	0.352	0.357	0.424	0.454	0.455	0.387	0.339	0.348	0.300	0.311
	p(w/d)	0.101	0.101	0.098	0.113	0.140	0.180	0.194	0.206	0.181	0.166	0.119	0.112
	alpha	0.707	0.765	0.718	0.751	0.817	0.839	0.840	0.920	0.872	0.860	0.775	0.867
	beta	13.469	12.167	13.073	10.878	7.584	6.485	5.320	4.840	5.942	7.902	10.530	10.225
Wongan Hills	p(w/w)	0.262	0.355	0.379	0.444	0.536	0.642	0.613	0.571	0.463	0.385	0.360	0.317
	p(w/d)	0.053	0.059	0.064	0.109	0.191	0.286	0.302	0.279	0.210	0.143	0.098	0.050
	alpha	0.652	0.535	0.610	0.730	0.719	0.840	0.848	0.853	0.905	0.865	0.711	0.740
	beta	8.297	11.828	9.696	5.853	6.842	6.001	5.462	4.530	3.110	3.217	4.444	4.635
Young	p(w/w)	0.301	0.371	0.385	0.433	0.495	0.532	0.537	0.472	0.428	0.421	0.379	0.311
	p(w/d)	0.124	0.120	0.111	0.131	0.166	0.226	0.229	0.245	0.225	0.197	0.146	0.135
	alpha	0.719	0.753	0.720	0.822	0.844	0.893	0.946	0.952	0.911	0.862	0.829	0.853
	beta	14.693	12.753	14.737	10.818	8.429	7.434	6.454	6.279	6.827	9.241	9.833	11.291

<<________________________________MEANS FOR 120 YEARS--------------

MONTH	RAIN	WET DAYS	REV	AV LEN
JAN.	65.843	6.525	9.975	1.598
FEB.	59.862	6.025	9.023	1.638
MAR.	52.068	5.975	7.848	1.626
APR.	43.054	5.867	7.088	1.761
MAY	45.524	7.283	6.233	1.836
JUNE	45.726	8.658	5.204	1.931
JULY	44.496	8.875	5.051	1.873
AUG.	45.289	8.708	5.300	1.799
SEP.	46.869	8.258	5.840	1.703
OCT.	60.181	8.242	7.141	1.728
NOV.	55.482	6.925	7.722	1.670
DEC.	57.684	6.442	8.476	1.552

PARAMETER rain

MONTH	MEAN	S.D.	C.V.	VAR	SKEW
JAN.	65.84	44.73	0.68	2000.70642	1.01228
FEB.	59.86	49.56	0.83	2455.83447	1.12299
MAR.	52.07	45.12	0.87	2036.22351	1.53968
APR.	43.05	31.32	0.73	981.21271	0.90863
MAY	45.52	32.22	0.71	1037.93616	0.93773
JUNE	45.73	32.53	0.71	1058.44446	1.59814
JULY	44.50	28.40	0.64	806.66779	1.08442
AUG.	45.29	28.15	0.62	792.49133	1.06654
SEP.	46.87	26.76	0.57	716.35059	1.18132
OCT.	60.18	35.29	0.59	1245.05933	0.38017
NOV.	55.48	39.02	0.70	1522.75940	1.18338
DEC.	57.68	44.35	0.77	1967.24365	0.94837
YEAR	622.08	177.18	0.28	31393.98242	0.44659

PARAMETER wdpm

MONTH	MEAN	S.D.	C.V.	VAR	SKEW
JAN.	6.53	3.22	0.49	10.38592	0.40929
FEB.	6.03	3.25	0.54	10.56239	0.64794
MAR.	5.97	3.40	0.57	11.57080	0.76043
APR.	5.87	3.37	0.57	11.34342	0.91850
MAY	7.28	3.43	0.47	11.76779	0.41513
JUNE	8.66	3.87	0.45	14.98312	0.61229
JULY	8.88	3.73	0.42	13.89181	0.32269
AUG.	8.71	3.79	0.44	14.39321	0.14878
SEP.	8.26	3.22	0.39	10.37808	0.25505
OCT.	8.24	3.49	0.42	12.15119	0.35084
NOV.	6.93	3.08	0.44	9.46492	0.23903
DEC.	6.44	3.34	0.52	11.15623	0.34667
YEAR	87.78	18.63	0.21	347.22952	0.42043

PARAMETER rrev

MONTH	MEAN	S.D.	C.V.	VAR	SKEW
JAN.	9.98	5.67	0.57	32.09851	1.20495
FEB.	9.02	5.12	0.57	26.21694	0.40727
MAR.	7.85	4.94	0.63	24.35607	1.29018
APR.	7.09	4.25	0.60	18.08726	0.98423
MAY	6.23	3.96	0.63	15.64937	1.72104
JUNE	5.20	2.62	0.50	6.88793	1.05999

Total no. of dry periods/qtr	1	11.83	2.95	0.32	
Av dry spell length		6.65	0.00	1.20	
Total no. of dry periods/qtr	2	12.28	2.84	-0.06	-
Av dry spell length		6.11	0.00	1.98	
Total no. of dry periods/qtr	3	14.80	2.83	-0.22	
Av dry spell length		4.75	0.00	2.05	
Total no. of dry periods/qtr	4	13.26	3.13	-0.13	
Av dry spell length		5.74	0.00	3.30	1

Deciles for JAN.

Decl	Monthly Rainfall	Daily rainfall
1	114.82001	25.28000
2	92.80000	16.30000
3	87.16000	11.70000
4	75.18000	7.90000
5	61.34999	5.30000
6	51.13999	3.60000
7	36.90001	2.50000
8	25.90000	1.50000
9	12.25000	0.80000

Deciles for FEB.

Decl	Monthly Rainfall	Daily rainfall
1	133.59001	24.40000
2	101.52000	17.00000
3	73.57000	11.40000
4	62.30000	8.60000
5	49.70000	5.30000
6	34.39999	3.80000
7	27.47001	2.50000
8	12.58000	1.50000
9	6.12000	0.80000

Deciles for MAR.

Decl	Monthly Rainfall	Daily rainfall
1	114.64001	21.60000
2	77.66000	13.58000
3	63.46000	8.90000
4	50.12000	6.40000
5	41.65000	4.80000
6	33.12000	3.04000
7	25.18000	2.00000
8	15.62000	1.30000
9	4.92000	0.80000

Deciles for APR.

Decl	Monthly Rainfall	Daily rainfall
1	84.18000	19.05000
2	62.08000	12.20000
3	52.97000	8.10000
4	47.62000	5.60000
5	38.70000	3.80000
6	32.84000	2.50000
7	24.06000	1.80000
8	14.34000	1.00000
9	4.60000	0.50000

Deciles for MAY

Decl	Monthly Rainfall	Daily rainfall
1	88.96001	16.30000
2	71.52000	10.00000
3	60.61000	6.60000
4	49.02000	4.60000
5	40.84999	3.00000
6	30.81999	2.30000
7	21.69000	1.50000
8	15.64000	1.00000
9	7.80001	0.50000

Deciles for JUNE

Decl	Monthly Rainfall	Daily rainfall
1	94.84000	13.50000

2	89.38000	14.00000
3	77.75002	9.99000
4	59.37999	6.90000
5	41.95000	5.10000
6	34.76000	3.30000
7	28.22000	2.30000
8	21.64000	1.30000
9	10.07000	0.50000

DEciles for dry period length

Decl	DRy period length
1	13.000
2	9.000
3	6.000
4	5.000
5	4.000
6	3.000
7	2.000
8	1.000
9	1.000

Longest dry spell= 91.0 days
Next longest 57.0
Next longest 57.0
Shortest dry spell= 1.0 days
Next shortest 1.0
Next shortest 1.0

APPENDIX 8

Sample Statistical Comparison of Observed and Generated Rainfall for Bathurst

A N A L Y S I S   F R O M   D A I L Y   R A I N F A L L   T A P E
Station=   BATHURST

DATA FROM FILE BATHUR.rst

No of observed years= 120
No of generated years=   99
PARAMETER =MONTHLY RAINFALL

MONTH	ACT MEAN	GEN MEAN	ACT S2	GEN S2	POOL VAR	T	SIG
JAN.	65.84	61.74	238084.06	146049.34	5.71	0.72	N.S.
FEB.	59.86	58.87	292244.31	146219.09	6.10	0.16	N.S.
MAR.	52.07	56.34	242310.59	109264.50	5.47	-0.78	N.S.
APR.	43.05	40.02	116764.31	80312.88	4.09	0.74	N.S.
MAY	45.52	43.37	123514.41	78522.48	4.14	0.52	N.S.
JUNE	45.73	44.08	125954.89	52301.55	3.89	0.42	N.S.
JULY	44.50	45.76	95993.47	59120.45	3.63	-0.35	N.S.
AUG.	45.29	44.87	94306.47	64176.70	3.67	0.11	N.S.
SEP.	46.87	43.88	85245.72	51993.03	3.41	0.88	N.S.
OCT.	60.18	59.97	148162.06	96989.16	4.56	0.05	N.S.
NOV.	55.48	56.68	181208.38	112011.34	4.99	-0.24	N.S.
DEC.	57.68	57.48	234102.00	105477.00	5.37	0.04	N.S.
YEAR	622.0800	613.0500	0.31E+05	0.10E+05		5.5685	*

Month	Act Var	Gen Var	F	Sig
JAN.	2000.7	1490.3	1.34	*
FEB.	2455.8	1492.0	1.65	*
MAR.	2036.2	1114.9	1.83	*
APR.	981.2	819.5	1.20	*
MAY	1037.9	801.2	1.30	*
JUNE	1058.4	533.7	1.98	*
JULY	806.7	603.3	1.34	*
AUG.	792.5	654.9	1.21	*
SEP.	716.4	530.5	1.35	*
OCT.	1245.1	989.7	1.26	*
NOV.	1522.8	1143.0	1.33	*
DEC.	1967.2	1076.3	1.83	*

Analysis of skewness

Month	Act Rtb	Gen Rtb	Ratio	
JAN.	1.0	0.6	4.15	*
FEB.	1.1	1.1	0.29	n.s.
MAR.	1.5	1.0	3.34	*

1	109.73	99.56	19.30	18.38
2	91.18	82.69	11.90	12.26
3	80.94	71.35	8.10	8.73
4	69.46	63.84	5.80	6.94
5	56.85	55.55	4.10	4.80
6	43.92	50.82	2.50	3.28
7	37.42	43.90	1.80	2.17
8	27.90	36.39	1.20	1.16
9	13.14	19.77	0.50	0.49

Frequency Distributions for rainfall amounts in: NOV.

Decile	Act Mon Rfall	Gen Mon Rfall	Act Day Rfall	Gen Day Rfall
1	101.74	100.13	20.04	19.60
2	89.04	81.69	12.70	13.18
3	76.39	74.31	9.10	9.55
4	61.12	64.64	6.40	7.05
5	43.85	54.68	4.60	5.29
6	35.96	42.45	3.60	3.70
7	27.43	36.50	2.30	2.43
8	20.88	25.61	1.30	1.45
9	15.13	13.90	0.80	0.67

Frequency Distributions for rainfall amounts in: DEC.

Decile	Act Mon Rfall	Gen Mon Rfall	Act Day Rfall	Gen Day Rfall
1	128.91	105.98	24.10	20.56
2	89.38	90.17	14.00	13.20
3	77.75	73.11	9.99	9.80
4	59.38	62.90	6.90	6.50
5	41.95	55.59	5.10	4.56
6	34.76	42.83	3.30	3.26
7	28.22	33.49	2.30	2.08
8	21.64	25.17	1.30	1.28
9	10.07	18.91	0.50	0.53

Deciles for dry periods

Decile	Act Dry Length	Gen DRy Length
1	13.00	12.00
2	9.00	8.00
3	6.00	6.00
4	5.00	5.00
5	4.00	4.00
6	3.00	3.00
7	2.00	2.00
8	1.00	2.00
9	1.00	1.00

LOngest 91.0 56.0 Next 57.0 43.0 Next 57.0 40.0

BATHURST 52.2 52.3 91. 56. 5.8 5.6

APPENDIX 9

Calculated Parameters for Temperature and Solar Radiation Data Generation

Calculated Parameters for Temperature and Solar Radiation Data Generation

Location	TMXD	ATX	CVTX	ACVTX	TXMW	TN	ATN	CVTN	ACVTN	RMD	AR	RMW
Bathurst	20.41	-8.13	0.18	0.04	17.47	6.36	-6.62	-0.62	-2.69	441.30	-198.29	440.85
Bendigo	21.05	-8.42	0.17	-0.02	18.01	8.85	-5.33	0.42	0.19	443.57	-251.17	441.07
Cambooya	24.74	-6.00	0.12	0.03	23.15	9.64	-7.55	0.75	0.88	424.89	-148.86	425.09
Clare	22.67	-8.05	0.18	-0.02	18.27	8.23	-5.23	0.51	0.29	453.44	-245.72	451.30
Cobar	25.63	-9.24	0.16	0.04	22.29	12.64	-7.73	0.34	0.19	497.32	-226.16	496.58
Condobolin	24.73	-9.23	0.15	0.04	21.50	11.20	-7.66	0.41	0.28	465.20	-242.21	463.69
Coonabarabran	24.26	-8.21	0.15	0.04	21.12	8.01	-7.56	1.33	1.84	450.00	-209.62	450.76
Cowra	22.68	-9.11	0.16	0.04	19.48	9.81	-6.55	0.43	0.27	446.98	-233.37	445.57
Dalby	26.46	-6.79	0.12	0.03	24.10	12.23	-7.17	0.37	0.33	477.05	-174.37	477.45
Dalwallinu	26.45	-8.85	0.14	0.01	23.15	12.07	-6.10	0.28	0.10	496.78	-244.77	494.30
Dubbo	24.54	-8.43	0.15	0.04	21.47	10.69	-7.67	0.45	0.37	465.45	-226.89	465.43
Esperance	23.28	-5.98	0.17	-0.03	19.50	10.25	-4.25	0.28	0.08	401.36	-180.18	400.60
Forbes	24.16	-9.08	0.16	0.04	20.81	9.55	-6.92	0.57	0.44	465.50	-234.93	465.13
Geraldton	26.25	-5.95	0.14	-0.03	23.41	13.52	-5.10	0.24	0.08	456.60	-161.73	454.81
Gilgandra	24.58	-7.93	0.14	0.03	21.76	10.22	-7.50	0.55	0.55	465.83	-227.73	463.88
Goondiwindi	27.13	-7.87	0.12	0.04	24.41	13.05	-7.60	0.32	0.26	479.84	-186.12	480.63
Griffith	23.76	-8.46	0.17	0.03	20.50	9.37	-6.72	0.56	0.41	450.14	-241.59	446.60
Hamilton	19.94	-7.45	0.20	-0.04	16.42	7.00	-3.28	0.52	0.18	400.38	-227.17	396.97
Horsham	22.28	-8.28	0.18	-0.02	19.01	8.54	-4.94	0.45	0.19	429.14	-237.92	425.18
Kadina	23.74	-7.42	0.17	-0.03	19.98	10.78	-5.03	0.34	0.12	442.47	-237.93	440.09
Kyabram	21.96	-8.69	0.17	-0.02	19.08	8.08	-5.80	0.59	0.43	422.73	-251.73	419.00
Kybybolite	21.57	-7.68	0.19	-0.03	18.10	7.74	-3.60	0.52	0.14	400.03	-223.17	395.37
Loxton	24.11	-7.80	0.18	-0.02	20.80	9.20	-5.41	0.48	0.27	451.23	-243.64	449.52
Manjimup	21.88	-6.42	0.16	-0.02	17.94	9.82	-3.56	0.29	0.07	410.87	-211.10	408.77
Merbein	24.11	-8.28	0.16	0.01	20.71	10.20	-6.01	0.41	0.19	469.61	-250.94	464.59
Merredin	25.48	-8.97	0.15	0.02	22.69	11.37	-6.42	0.35	0.17	460.73	-235.12	458.26
Miles	27.30	-6.89	0.11	0.03	24.91	12.32	-8.15	0.44	0.45	478.05	-173.81	477.83
Moree	26.78	-8.16	0.12	0.04	23.90	12.19	-8.01	0.44	0.38	469.50	-194.37	470.95
Mudgee	23.35	-8.06	0.15	0.03	20.45	8.64	-7.16	0.74	0.79	433.01	-186.42	432.83
Muresk	25.34	-8.86	0.14	0.00	22.78	10.25	-6.10	0.37	0.22	455.48	-246.20	452.30
Nhill	22.50	-8.26	0.19	-0.02	19.08	8.09	-4.76	0.52	0.21	431.27	-248.45	427.29
Nuriootpa	22.08	-7.54	0.20	0.01	17.89	8.68	-4.64	0.48	0.20	436.63	-249.49	434.24
Nyngan	26.20	-9.07	0.14	0.03	23.02	11.85	-7.90	0.37	0.26	488.57	-237.20	488.39

(Continued)

APPENDIX 10

WGEN Program With Procedures to Compute Statistics on Generated Weather Data

```
      PROGRAM METZ
C*********************************************
C
C       PROGRAM READS IN FILES CONTAINING COEFFICIENTS AND THEN
C       GENERATES A STRING OF WEATHER DATA AND ANALYSES IT
C
      DIMENSION TXM(366),TXS(366),TXM1(366),
     1 TXS1(366),TNM(366),TNS(366),RMO(366),RS0(366),RM1(366),RS1(366),
     2 RC(366),RAIN(366),TMAX(366),TMIN(366),RAD(366),C(4),T(4),ACOM(20)
     3,NI(12),SR(12),SSTX(12),SSTN(12),SSRAD(12),SRAIN(12),STMAX(12),
     4STMIN(12),SRAD(12),NII(12),PWW(12),PWD(12),ALPHA(12),BETA(12)
      DIMENSION RAIN2(50,365),TMAX2(50,365),TMIN2(50,365),RAD2(50,365)
      CHARACTER*10 FNAM5,FNAM6,FNAM7,FNAM12
      DATA C/0.,0.,0.,0./
      DATA T/0.,0.,0.,0./
      DATA NI/31,59,90,120,151,181,212,243,273,304,334,365/
      DATA NII/31,60,91,121,152,182,213,244,274,305,335,366/
C*************************************************************
C*                  INPUT #01 - TITLE                        *
C*************************************************************
      OPEN(UNIT=7,STATUS='NEW',FILE='TMP.TMP',DISPOSE='DELETE')
      OPEN(UNIT=25,STATUS='OLD',SHARED,FILE='TTEST.DAT')
      OPEN(UNIT=22,STATUS='OLD',FILE='TAPEZ2.NAM')
      TYPE 100
100   FORMAT(' START=?')
      ACCEPT *,ISTART
      LZ=ISTART-1
      DO 200 L=1,LZ
           READ(22,300)FNAM5
           TYPE 300,FNAM5
200   CONTINUE
      DO 4400 MISTN=ISTART,53
           READ(22,300)FNAM5,FNAM7,FNAM6,FNAM12
300        FORMAT(A,1X,A,1X,A,1X,A)
           OPEN(UNIT=95,STATUS='OLD',FILE=FNAM5)
           OPEN(UNIT=5,STATUS='OLD',FILE=FNAM6)
           OPEN(UNIT=20,STATUS='NEW',FILE=FNAM12)
           OPEN(UNIT=6,STATUS='NEW',FILE=FNAM7)
400        READ(5,500)(ACOM(I),I=1,15)
500        FORMAT(20X,15A4)
           WRITE(6,600)(ACOM(I),I=1,20)
600        FORMAT('1',20A4)
           WRITE(7,600)(ACOM(I),I=1,20)
C*************************************************************
C*                  INPUT # 02                               *
C*  NYRS = YEARS OF DATA TO BE GENERATED                     *
C*  KGEN = GENERATION OPTION CODE                            *
C*       IF KGEN = 1,RAIN, MAX TEMP, MIN TEMP, AND SOLAR     *
C*       RADIATION WILL BE GENERATED                         *
C*       IF KGEN = 2 OBSERVED RAIN WILL BE USED AND MAX TEMP,*
C*       MIN TEMP, SOLAR RADIATION WILL BE GENERATED         *
C*  ALAT = STATION LATITUDE IN DEGREES                       *
C*************************************************************
           READ(5,700)ALAT
700        FORMAT(23X,F10.2)
           NYRS=49
           WRITE(7,800)NYRS,ALAT
800        FORMAT(I10,F10.0)
           KGEN=1
C***** CALCULATE MAXIMUM SOLAR RADIATION FOR EACH DAY
           XLAT = ALAT*6.2832/360.
           DO 1000 I = 1,366
                XI = I
                SD = 0.4102*SIN(0.0172*(XI-80.25))
                CH = -TAN(XLAT)*TAN(SD)
                IF(CH .GT. 1.0) H = 0.
```

```
                TNS(J) = ABS(TNM(J)*(CVTN+ACVTN*DT))
                RMO(J) = RMD+AR * DR
                RSO(J) = ABS(RMO(J)*(CVRD+ACVRD*DR))
                RM1(J) = RMO(J) - D2
                RS1(J) = ABS(RM1(J)*(CVRW+ACVRW*DR))
2000      CONTINUE
          DO 2100 IM=1,12
                SR(IM) = 0.
                SSTX(IM) = 0.
                SSTN(IM) = 0.
                SSRAD(IM) = 0.
2100      CONTINUE
          XYR = NYRS
          SYTX = 0.
          SYTN = 0.
          SYRAD = 0.
          SYR = 0.
          DO 4100 I = 1,NYRS
                IYR = I
                IF(KGEN .EQ. 1) GO TO 2400
C***********************************************************
C*    INPUT # 12 - MEASURED RAINFALL FOR NYRS.             *
C*                  OMIT IF KGEN = 1.                      *
C***********************************************************
                KK = 0
                IJ = 1
2200            READ(5,2300) IYR,MO,IDAY,RAIN(IJ)
2300            FORMAT(4X,3I2,20X,F10.0)
                IF(KK .EQ. 1) GO TO 2500
2400            IDAYS = 365
                IFLG= MOD(IYR,4)
                IF(IFLG .EQ. 0) IDAYS = 366
                KK = 1
                IF(KGEN .EQ. 1) GO TO 2600
2500            IJ = IJ + 1
                IF(IJ .LE. IDAYS) GO TO 2200
2600            CONTINUE
                CALL WGEN(PWW,PWD,ALPHA,BETA,TXM,TXS,TXM1,TXS1,TNM,TNS,R
     1MO,RSO,RM1,RS1,RAIN,TMAX,TMIN,RAD,KGEN,RC,IDAYS,NI,NII)
                DO 2700 IM = 1,12
                     SRAIN(IM) = 0.
                     STMAX(IM) = 0.
                     STMIN(IM) = 0.
                     SRAD(IM) = 0.
2700            CONTINUE
                IM = 1
                YTMAX = 0.
                YTMIN = 0.
                YRAD = 0.
                RYR = 0.
                IDA = 0
                DO 3400 J=1,IDAYS
                     IDA = IDA + 1
                     IF(IDAYS .EQ. 366) GO TO 2900
                     IF(J .GT. NI(IM)) GO TO 2800
                     GO TO 3000
2800                 IM = IM + 1
                     IDA = 1
                     GO TO 3000
2900                 IF(J .GT. NII(IM)) GO TO 2800
3000                 CONTINUE
3100                 FORMAT(3I2,2F6.0,F8.3,4X,F6.0)
                     IF(I .GT. 1) GO TO 3300
                     WRITE(6,3200)IM,IDA,IYR,J,RAIN(J),TMAX(J),TMIN(J),R
     1AD(J)
3200                 FORMAT(2X,4I5,F7.2,3F7.0)
```

```
      DATA IP/0/
      IM = 1
      DO 2700 IDAY=1,IDAYS
          IF(IDAYS .EQ. 366) GO TO 100
          IF(IDAY .GT. NI(IM)) IM = IM + 1
          GO TO 200
100       IF(IDAY .GT. NII(IM)) IM = IM + 1
200       CONTINUE
          IF(KGEN .EQ. 2) GO TO 1500
          CALL RANDN(RN)
          IF(IP-0) 300,300,500
300       IF(RN - PWD(IM  ))600,600,400
400       IP = 0
          RAIN(IDAY) = 0.
          GO TO 1800
500       IF(RN-PWW(IM  ))600,600,400
600       IP = 1
          AA = 1./ALPHA(IM)
          AB = 1./(1.-ALPHA(IM))
          TR1 = EXP(-18.42/AA)
          TR2 = EXP(-18.42/AB)
          SUM = 0.
          SUM2 = 0.
700       CALL RANDN(RN1)
          CALL RANDN(RN2)
          IF(RN1-TR1) 800,800,900
800       S1 = 0.
          GO TO 1000
900       S1 = RN1**AA
1000      IF(RN2-TR2) 1100,1100,1200
1100      S2 = 0.
          GO TO 1300
1200      S2 = RN2**AB
1300      S12 = S1 + S2
          IF(S12-1.) 1400,1400,700
1400      Z = S1/S12
          CALL RANDN(RN3)
          RAIN(IDAY) = -Z*ALOG(RN3)*BETA(IM)
1500      IF(RAIN(IDAY)) 1600,1600,1700
1600      IP = 0
          GO TO 1800
1700      IP = 1
1800      IF(IP-1) 1900,2000,2000
1900      RM=RM0(IDAY)
          RS = RS0(IDAY)
          TXXM = TXM(IDAY)
          TXXS = TXS(IDAY)
          GO TO 2100
2000      RM = RM1(IDAY)
          RS = RS1(IDAY)
          TXXM = TXM1(IDAY)
          TXXS = TXS1(IDAY)
2100      CONTINUE
          DO 2300 K = 1,3
2200          AA = 0.
              CALL RANDN(RN1)
              CALL RANDN(RN2)
              V = SQRT(-2.*ALOG(RN1))*COS(6.283185*RN2)
              IF(ABS(V) .GT. 2.5) GO TO 2200
              E(K) = V
2300      CONTINUE
          DO 2400 I = 1,3
              R(I) = 0.
              RR(I) = 0.
2400      CONTINUE
          DO 2500 I = 1,3
```

```
C TOTWD= TOTAL WET DAYS/MONTH
C TOTMF= MONTHLY RAINFALL
C TOTRW= RUN OF WET DAYS
C TOTMX= TOTAL MAX. TEMP/MONTH
C TOTMN= TOTAL MIN. TEMP/MONTH
C TOTRF= MONTHLY RAINFALL FOR ALL YEARS
C XBRW= AVERAGE LENGTH OF WET SPELL
C XBRF= MONTHLY RAINFALL
C XBWD= WET DAYS/MONTH
C XBREV= AVERAGE RAINFALL/EVENT
C XBTX= MAX. TEMPERATURE
C XBTN= MIN. TEMPERATURE
C XBRD= RADIATION
C TXWD=MAX TEMP WET DAYS
C TXDD = MAX TEMP DRY DAYS
C TNWD=MIN TEMP WET DAYS
C TNDD MIN TEMP DRY DAYS
C SLX= SIGNIFICANCE LEVEL INDICATOR FOR NORMAL DISTRIBUTION
       DIMENSION RAIN(50,365),TMAX(50,365),TMIN(50,365)
     1 ,RADN(50,365),TOTRF(12),TOTMX(12),TOTMN(12),TOTRD(12)
     2 ,XBRF(12),XBTX(12),XBTN(12),XBTR(12),TOTMF(50,12),TOTWD(50,12)
     3  ,DATE(12),TOTREV(50,12),XBWD(12),XBREV(12),XBRD(12),NC(13)
     4 ,TOTRW(50,12),XBRW(12)
     5 ,XBAR(12),SD(12),VAR(12)
     6, XBAR2(12),SD2(12),CV(12),CV2(12),FSKEW(12),FKURT(12)
       DIMENSION TXGE40(50,12),TXGE35(50,12),TXGE30(50,12),
     1 TMLE5(50,12),TMLZ(50,12),SLX(12),TXWD(50,12),TXDD(50,12),
     2 TNWD(50,12),TNDD(50,12),NDX(12)
       DATA DATE /'JAN.','FEB.','MAR.','APR.','MAY ','JUNE',
     1           'JULY','AUG.','SEP.','OCT.','NOV.','DEC.'/
       DATA NC/0,31,60,91,121,152,182,213,244,274,305,335,366/
       DATA NT/1/
       DATA SLX/12*99.999/
       TYPE 100
100    FORMAT(' IN WSTATS')
       DO 300 I=1,12
            NDX(I)=NYRS
            DO 200 JYR=1,50
                 TOTRW(JYR,I)=0.0
                 TOTMF(JYR,I)=0.0
200         TOTWD(JYR,I)=0.0
            TOTRF(I)=0.0
            TOTMX(I)=0.0
            TOTMN(I)=0.0
300    TOTRD(I)=0.0
       DO 600 JYR=1,NYRS
            DO 500 IMO=1,12
                 W1=0
                 W2=0.
                 T1=0
                 T2=0
                 T3=0.
                 T4=0.
                 C1=0.
                 C2=0.
                 C3=0.
                 C4=0.
                 C5=0.
                 IST=NC(IMO)+1
                 IEND=NC(IMO+1)
                 IF(IEND.EQ.366)IEND=365
                 IWET=0
                 DO 400 ID=IST,IEND
                      IF ( TMAX(JYR,ID) .GE. 40. ) C1=C1+1.
                      IF ( TMAX(JYR,ID) .GE. 35. ) C2=C2+1.
                      IF ( TMAX(JYR,ID) .GE. 30. ) C3=C3+1.
```

```
              TOTC=TOTC+TOTWD(JYR.IMO)/TOTRW(JYR,IMO)
700           TOT1=TOT1+TOTWD(JYR.IMO)
              TOT2=TOT2+TOTREV(JYR.IMO)
              TOT3=TOT3+TOTMF(JYR.IMO)
800         CONTINUE
            XBRW(IMO)=TOTC/XYRS
            XBRF(IMO)=TOT3/XYRS
            XBWD(IMO)=TOT1/XYRS
            XBREV(IMO)=TOT2/XYRS
            XBTX(IMO)=TOTMX(IMO)/(XYRS*DMO)
            XBTN(IMO)=TOTMN(IMO)/(XYRS*DMO)
            XBRD(IMO)=TOTRD(IMO)/(XYRS*DMO)
C        TYPE 2901.IMO.DMO.TOTMX(IMO).XBTX(IMO),TOTRD(IMO).XBRD(IMO)
C2901        FORMAT(' IMO DMO TOTMX XBTX TOTRD XBRD',I5,F5.0,4F15.2)
900   CONTINUE
      WRITE(20,1000)NYRS
1000  FORMAT(//,'<<___________________________________MEANS FOR'
     1 ,I5,' YEARS----------------------------------->',//,
     2  5X,'MONTH',6X,'TMAX',6X,'TMIN',6X,'RADN',6X,'RAIN',3X,
     3 'WET DAYS',7X,'REV',4X,'AV LEN')
      DO 1200 I=1.12
            WRITE(20.1100)DATE(I),XBTX(I),XBTN(I),XBRD(I),XBRF(I)
     1 ,XBWD(I).XBREV(I).XBRW(I)
1100        FORMAT(6X,A4,7F10.3)
1200  CONTINUE
      REWIND 25
C****       INPUT CRITICAL T VALUES
1300  READ(25.*)NDF,T5,T1
1400  FORMAT(I,2F)
      IF(NDF-1.EQ.NYRS)GO TO 1500
      GO TO 1300
1500  DO 1600 MT=1,12
1600  SLX(MT)=99.999
      CALL STATS(NYRS.TMIN.RAIN.2.XBAR.XBAR2.SD.SD2.CV.CV2.TOTWD)
      CALL WRITER('TMIN'.XBAR.SD.CV.DATE.NYRS.FSKEW.FKURT.SLX)
      CALL STATS(NYRS.TMAX.RAIN.2.XBAR.XBAR2.SD.SD2.CV.CV2.TOTWD)
      CALL WRITER('TMAX'.XBAR.SD.CV.DATE.NYRS.FSKEW.FKURT.SLX)
      CALL STATS(NYRS.RADN.RAIN.2.XBAR.XBAR2.SD.SD2.CV.CV2.TOTWD)
      CALL WRITER('RADN'.XBAR.SD.CV.DATE.NYRS.FSKEW.FKURT.SLX)
      CALL RSTATS(NYRS.TMIN.RAIN.2.XBAR,XBAR2,SD.SD2,CV,CV2,TXGE40)
      CALL NORMCK(TXGE40.NYRS.12.SLX)
      CALL SPLIT(NYRS,TXGE40.FSKEW.FKURT)
      CALL WRITER('XG40'.XBAR.SD.CV.DATE.NYRS.FSKEW.FKURT.SLX)
      CALL RSTATS(NYRS.TMIN.RAIN.2.XBAR,XBAR2,SD,SD2,CV,CV2,TXGE35)
      CALL NORMCK(TXGE35.NYRS.12.SLX)
      CALL SPLIT(NYRS.TXGE35.FSKEW.FKURT)
      CALL WRITER('XG35'.XBAR.SD.CV.DATE.NYRS.FSKEW.FKURT.SLX)
      CALL RSTATS(NYRS.TMIN.RAIN.2.XBAR,XBAR2.SD,SD2.CV,CV2,TXGE30)
      CALL NORMCK(TXGE30.NYRS.12.SLX)
      CALL SPLIT(NYRS,TXGE30.FSKEW.FKURT)
      CALL WRITER('XG30'.XBAR.SD.CV.DATE.NYRS.FSKEW.FKURT.SLX)
      CALL RSTATS(NYRS.TMIN.RAIN.2,XBAR.XBAR2,SD,SD2,CV,CV2,TMLE5)
      CALL NORMCK(TMLE5.NYRS.12.SLX)
      CALL SPLIT(NYRS.TMLE5.FSKEW.FKURT)
      CALL WRITER('NLE5'.XBAR.SD.CV.DATE.NYRS.FSKEW.FKURT.SLX)
      CALL RSTATS(NYRS.TMIN,RAIN.2.XBAR,XBAR2.SD,SD2,CV,CV2,TMLZ)
      CALL NORMCK(TMLZ.NYRS.12.SLX)
      CALL SPLIT(NYRS.TMLZ.FSKEW.FKURT)
      CALL WRITER('NLZ '.XBAR.SD.CV.DATE.NYRS.FSKEW.FKURT.SLX)
      CALL RSTATS(NYRS.TMIN,RAIN,0,XBAR,XBAR2,SD,SD2,CV,CV2,TOTWD)
      CALL NORMCK(TOTWD.NYRS.12,SLX)
      CALL SPLIT(NYRS.TOTWD.FSKEW.FKURT)
      CALL WRITER('WDPM'.XBAR.SD.CV.DATE.NYRS.FSKEW.FKURT.SLX)
      CALL RSTATS(NYRS.TMIN,RAIN,0.XBAR,XBAR2.SD,SD2,CV,CV2.TOTMF)
      CALL SPLIT(NYRS.TOTMF.FKEW.FKURT)
      CALL NORMCK(TOTMF,NYRS,12.SLX)
```

```
                  IF(ID .EQ. 2) GO TO 100
                  IF(RAIN(JY,JD))100,100,200
100               CONTINUE
                  XN = XN + 1.
                  SUM = SUM+W(JY,JD)
                  SS = SS + (W(JY,JD)*W(JY,JD))
                  GO TO 300
200               CONTINUE
                  XN1 = XN1 + 1.
                  SUM1 = SUM1 + W(JY.JD)
                  SS1=SS1+(W(JY,JD)*W(JY,JD))
300         CONTINUE
            IF(XN .LE. 2.) XM(I) = 0.
            IF(XN .LE. 2.) SD(I) = 0.
            IF(XN .LE. 2.) CX(I) = 0.
            IF(XN .LE. 2.) GO TO 400
            XM(I) = SUM / XN
            SD(I) = SQRT((SS-SUM*SUM/XN)/(XN-1.))
            IF(XM(I) .LT. 0.001) XM(I) = 0.001
            CX(I) = SD(I) / XM(I)
400         CONTINUE
            IF(ID .EQ. 2) GO TO 600
            IF(XN1 .LE. 2.) XM1(I)=0.
            IF(XN1 .LE. 2.) SD1(I) = 0.
            IF(XN1 .LE. 2.) CX1(I) = 0.
            IF(XN1 .LE. 2.) GO TO 500
            XM1(I) = SUM1 / XN1
            SD1(I)=SQRT((SS1-SUM1*SUM1/XN1)/(XN1-1.))
            IF(XM1(I) .LT. 0.001) XM1(I) = 0.001
            CX1(I)=SD1(I)/XM1(I)
500         CONTINUE
600   CONTINUE
      RETURN
      ENTRY RSTATS(NYRS,W,RAIN,ID,XM,XM1,SD,SD1,CX,CX1,W2)
      DO 900 I=1,12
            XN=0.
            SUM=0.
            SS=0.
            DO 700 JY=1,NYRS
                  XN=XN+1
                  SUM=SUM+W2(JY,I)
                  SS=SS+W2(JY,I)*W2(JY,I)
700         CONTINUE
            IF(XN.LE.2)THEN
                  XM(I)=0.0
                  SD(I)=0.0
                  CX(I)=0.0
                  GO TO 800
            ELSE
            ENDIF
            XM(I)=SUM/XN
            SD(I)=SQRT((SS-SUM*SUM/XN)/(XN-1.))
            IF(XM(I).LT.0.001)XM(I)=0.001
            CX(I)=SD(I)/XM(I)
800         CONTINUE
900   CONTINUE
      RETURN
      END
      SUBROUTINE COFRED(ICH,PWW,PWD.ALPHA.BETA,TXMD,ATX,CVTX,ACVTX
     1 ,TXMW,TN,ATN,CVTN,ACVTN,RMD,AR,RMW)
      DIMENSION PWW(12),PWD(12).ALPHA(12),BETA(12)
C       PROGRAM TO READ GENERATOR COEFFS FROM *.GCB FILES FROM
C       METB PROGRAM
C       TO BE USED AS A SUBROUTINE FOR METZ
      READ(ICH,100)X
100   FORMAT(A4)
```

```
       DATA A3/.4254,.2944,.2487,.2148,.187,.163,.1415,.1219,.1036,
      1 .0862,.0697,.0537,.0381,.0227,.0076/
       DATA A4/.3964,.2737,.2386,.2098,.1878,.1691,.1526,.1376,
      1 .1237,.1108,.0986,.087,.0759,.0651,0.0546,0.0444,0.0343,
      2 0.0244,0.0146,0.0049/
       DATA A5/.3751,.2574,.226,.2032,.1847,.1691,.1554,.143,.1317
      1, .1212,.1113,.102,.0932,.0846,.0764,00685,00608,0.0532,0.0459
      2',0.0386,0.0314,0.0244,0.0174,0.0104,0.0035/
       DATA NA/'PROB NORM D'/
C        WRITE (IOC,100)
       IN=N/10
       K=N/2
       GO TO (100,300,500,700,900),IN
100    DO 200 I=1,K
200    A(I)=A1(I)
       GO TO 1100
300    DO 400 I=1,K
400    A(I)=A2(I)
       GO TO 1100
500    DO 600 I=1,K
600    A(I)=A3(I)
       GO TO 1100
700    DO 800 I=1,K
800    A(I)=A4(I)
       GO TO 1100
900    DO 1000 I=1,K
1000   A(I)=A5(I)
1100   CONTINUE
       DO 1200 I=1,N
1200   Y(I)=X(I)
       CALL SORT(Y,N)
       FN=N
       EY=0
       VY=0
       B=0
       DO 1300 I=1,N
            EY=EY+Y(I)
1300   VY=VY+Y(I)*Y(I)
       VY=VY-EY*EY/FN
       DO 1400 I=1,K
1400   B=B+A(I)*(Y(N+1-I)-Y(I))
C        INSERT SOME CODE TO SKIP AROUND IF VY = 0
       IF(VY.EQ.0)THEN
            W=0
            GO TO 1500
       ENDIF
       W=B*B/VY
       SL=0.
       DO 1500 J=1,9
            K=10-J
            IF(K.GT.9)K=9
            IF(W.LT.WT(IN,K))GO TO 1500
            SL=WT(6,K+1)
            GO TO 1800
1500   CONTINUE
       IF(K.EQ.1)SL=WT(6,1)
C40      WRITE(IOC,105)W,SL,N
1600   FORMAT(3X,'THE SHAPIRO-WILK TEST FOR NORMALITY (COMPLETE SAMPLES)'
      1 ,/,5X,' SMALL SIGNIF LEVEL(EG 0.05) IMPLIES REJECT NORMALITY')
1700   FORMAT(1X,'W=',F6.4,5X,'SIGNIF LEVEL=',F5.2,5X,'NO OBS=',I3,/)
1800   RETURN
       END
       SUBROUTINE SORT(A,N)
       DIMENSION A(N)
       NM1=N-1
       DO 200 I=1,NM1
```

```
FSKEW=S3*FN/(FN-1)/(FN-2)
FKURT=FN*(S4*(FN+1)-3*(FN-1)*S2*S2/FN)/(FN-1)/(FN-2)/(FN-3)
FSKEW=FSKEW/SD**3
FKURT=FKURT/SD**4
CV=SD/EX
RETURN
END
```

APPENDIX 11

Cross and Serial Correlation Coefficients for Daily Maximum and Minimum Temperature Calculated From the Observed Data

Cross and Serial Correlation Coefficients for Daily Maximum and Minimum Temperature Calculated From the Observed Data

Station	Cross-Correlation Coefficients for Tmax and Tmin		Lag-One Serial Correlation Coefficients for	
	Lag"Zero	Lag"One	Tmax	Tmin
Bathurst	0.201	0.350	0.574	0.515
Bendigo	0.458	0.513	0.500	0.519
Cambooya	0.151	0.263	0.486	0.468
Clare	0.306	0.425	0.488	0.463
Cobar	0.625	0.680	0.607	0.604
Condobolin	0.437	0.554	0.563	0.529
Coonabarabran	0.170	0.343	0.609	0.548
Cowra	0.504	0.581	0.593	0.568
Dalby	0.334	0.439	0.605	0.570
Dalwallinu	0.569	0.654	0.545	0.571
Dubbo	0.428	0.536	0.588	0.605
Esperance	0.306	0.501	0.335	0.375
Forbes	0.394	0.507	0.580	0.522
Geraldton	0.324	0.505	0.555	0.556
Gilgandra	0.377	0.484	0.555	0.558
Goondiwindi	0.444	0.550	0.604	0.584
Griffith	0.456	0.577	0.551	0.538
Hamilton	0.290	0.433	0.442	0.365
Horsham	0.366	0.494	0.499	0.503
Kadina	0.378	0.550	0.521	0.498
Kyabram	0.408	0.488	0.506	0.492
Kybybolite	0.320	0.474	0.458	0.407
Loxton	0.342	0.531	0.531	0.455
Manjimup	0.400	0.561	0.414	0.463
Merbein	0.522	0.602	0.533	0.497
Merredin	0.541	0.598	0.539	0.496
Miles	0.292	0.436	0.587	0.529
Moree	0.448	0.525	0.618	0.597
Mudgee	0.139	0.275	0.540	0.534
Muresk	0.311	0.472	0.471	0.440
Nhill	0.383	0.517	0.505	0.465
Nuriootpa	0.409	0.525	0.506	0.459
Nyngan	0.412	0.548	0.592	0.572
Orange	0.398	0.498	0.593	0.508
Parkes	0.628	0.655	0.593	0.594
Pittsworth	0.307	0.428	0.379	0.465
Quirindi	0.234	0.369	0.584	0.483
Rutherglen	0.314	0.391	0.534	0.505
Tamworth	0.447	0.537	0.613	0.589
Temora	0.336	0.449	0.564	0.535
Trangie	0.425	0.515	0.596	0.568
Wagga Wagga	0.417	0.529	0.545	0.551
Waite	0.640	0.674	0.512	0.555
Walgett	0.432	0.547	0.602	0.584
Walpeup	0.559	0.607	0.509	0.503
Warooka	0.429	0.550	0.417	0.457
Warwick	0.035	0.185	0.598	0.553
Wellington	0.303	0.419	0.559	0.567
Wongan Hills	0.538	0.610	0.520	0.533
Young	0.286	0.373	0.497	0.457
Mean	0.383	0.497	0.536	0.517
Std. Deviation	0.126	0.103	0.064	0.057