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The distribution of calcium carbonate in soils: A computer simulation using program CALSOIL

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The Distribution of Calcium Carbonate in Soils: A Computer Simulation using Program CALSOIL

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Abstract

CALSOIL is a computer program, written in interpreted BASIC for the IBM-PC, that simulates the development of calcic soil horizons. The program calculates water and carbonate movement in a soil based on information that the user provides. Soil compartments of arbitrary thickness are used to model the changes in carbonate content. The information used to calculate water movement includes water-holding capacities of soil compartments and climatic data. Carbonate movement is modeled as a function of calcite equilibria, which depend on temperature and the partial pressure of carbon dioxide in the soil.

Introduction

The purpose of this report is to provide the basic documentation needed to run the computer program CALSOIL. The algorithms used are only described briefly. CALSOIL is designed to simulate the development of horizons in calcic (desert) soils of the southwestern United States (cf. Machette, 1985). The program can use the measured calcium carbonate distribution in soils to develop or constrain paleoclimatic reconstructions. The program uses elementary concepts regarding the solubility of calcium carbonate and water movement in gravelly soils to simulate the dissolution and movement of carbonate through soils. The program allows the basic variables that control carbonate accumulation to be manipulated by the user. Climate can be modeled as constant, or as changing in a threshold or trend manner. Water available for leaching carbonate can be calculated either according to the methods of Arkley (1963) and McFadden (1982) or by monthly comparisons of precipitation and potential evapotranspiration.

How the Program Works

The program uses arbitrary compartments of variable thickness and a fixed 1.0 cm^2 cross-sectional area to account for the movement of water and carbonate. Each compartment has seven characteristics that affect water and carbonate movement: field capacity, initial water content, permanent wilting point, initial carbonate content, soil pCO_2 (partial pressure of carbon dioxide), soil temperature, and PET (potential evapotranspiration) index. Values for these seven characteristics are specified by the user and placed in a data file. In addition, the user specifies climatic data and an influx rate for carbonate. The program calculates the distribution of carbonate after time intervals and under climate conditions specified by the user.

Climate

CALSOIL incorporates three conceptual models of climate: constant, threshold, and trend (Figure 1). A constant climate is one whose mean annual values of temperature or precipitation do not change with time (Figure 1A). A threshold model of climate is one that experiences a sudden change from one type of climate to another. Mathematically, the threshold model resembles a step function. Trend climate refers to a gradual change in mean climate values with time.

In addition to these climate models, the program allows the user to specify the limits of a random variation to be added to a climate value. The purpose of the random variance is to simulate variations in natural climates. The random variation is computed from the internal computer timer and the BASIC random number generator These variations can be applied to the leaching index, if yearly modeling is used, or temperature and/or precipitation values, if monthly modeling is used. A cartoon illustrating the random number sequence applied to the leaching index is shown on Figure 1D: the mean leaching index was allowed to vary plus or minus one. An actual sequence of 600 iterations generated using the random number generator appears to to be uniformly distributed (Figure 2).

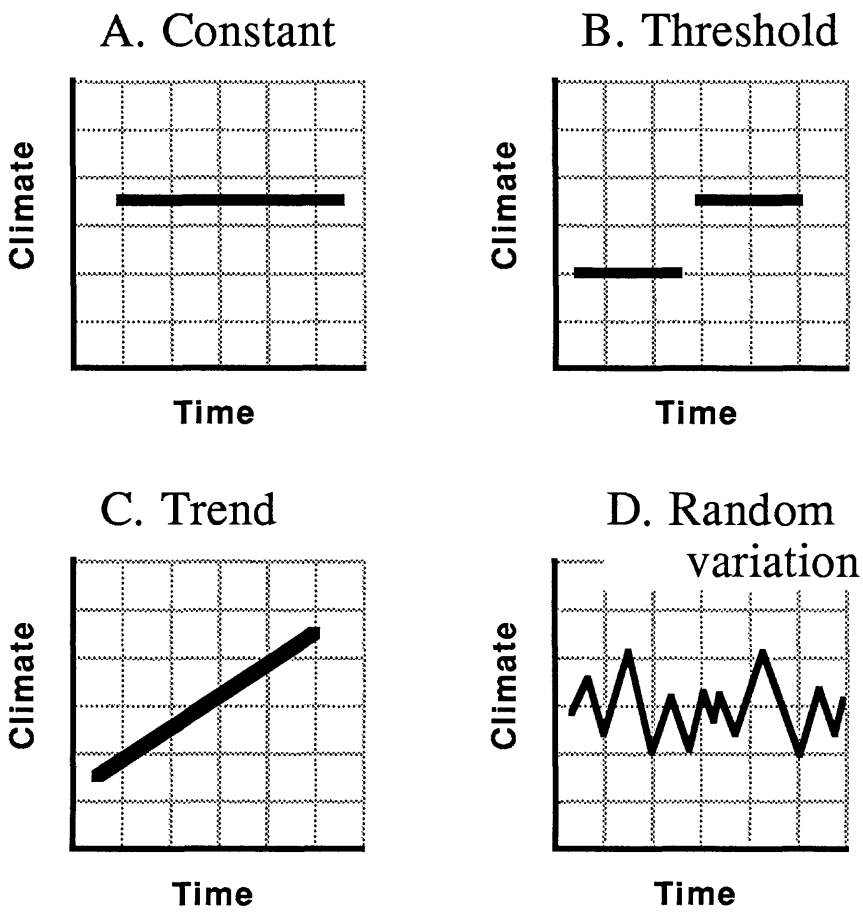

Figure 1. Conceptual models (A-D) of climate used in CALSOIL. See text for discussion.

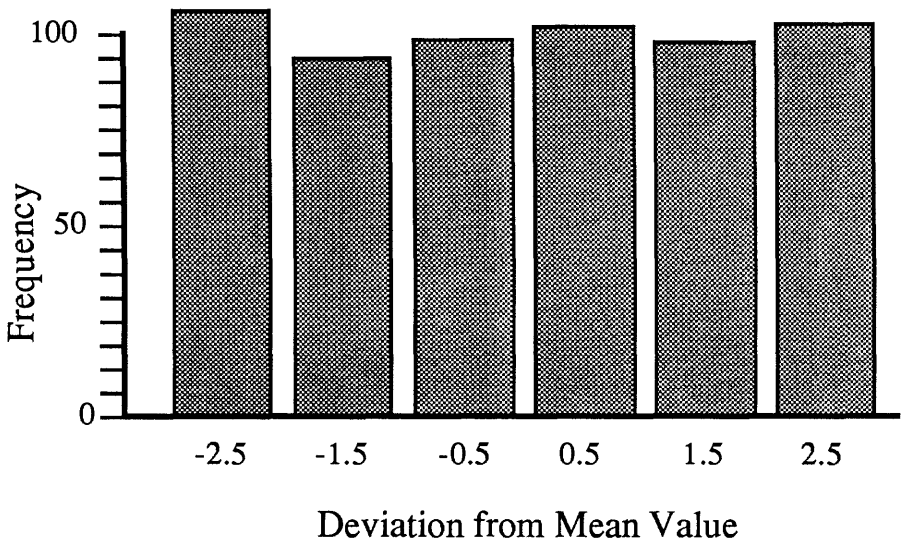

Figure 2. The distribution of the random numbers as produced by the BASIC random number generator. The value was allowed to deviate by three units.

Water Movement

The program accounts for water movement and hence soil moisture conditions in two different ways according to the options selected by the user. The two options are monthly and yearly modeling. An event-based model is under development. The event-based model will use actual daily climatic records as the climate input, rather than mean monthly values. This method will permit an investigator to examine the effect of large storms on carbonate movement.

In yearly modeling, the cumulative annual excess of precipitation over potential evapotranspiration is calculated using records of mean monthly temperature and precipitation. This value, called the *leaching index* (Arkley, 1963), estimates the annual amount of water that is available fo leaching (Figure 3). Water from precipitation can fill the uppermost compartment to its field capacity. If there is more water than the first compartment can hold, it sequentially infiltrates to the next lower compartments until all the water is held (Figure 4). As the water moves from compartment to compartment, it can dissolve calcium carbonate. In yearly modeling, it is assumed that there is no year to year carry over of water, thus each year the soil moisture is initially at the wilting point (cf. McFadden, 1982). This assumption is approximately valid for hot desert climates where

evapotranspiration is much greater than precipitation.

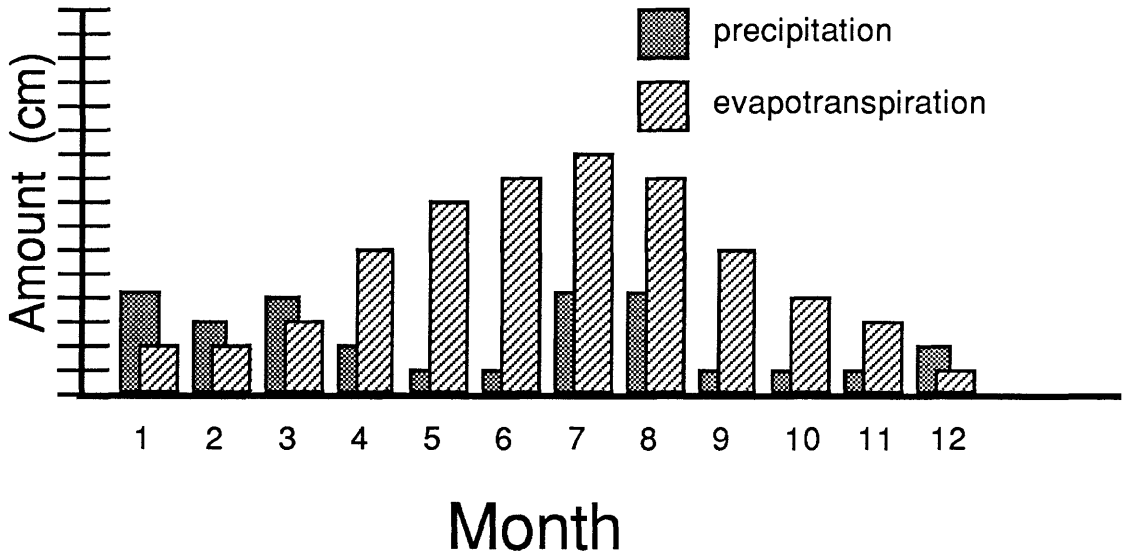

Figure 3. The amount of water available for leaching is the sum of the monthly excess of precipitation over evapotranspiration. The figure illustrates a hypothetical example where an excess occurs only during the months of January, February, March, and December

In monthly modeling, monthly precipitation represents the amount of water entering the uppermost soil compartment. This water can fill the uppermost compartment to its field capacity. Excess water infiltrates to lower compartments. After an infiltration event, the moisture is lost that month by evapotranspiration. Each compartment can lose all the water in excess of its wilting point content. The potential amount of water lost each month is given by the potential evapotranspiration for that month. Monthly potential evapotranspiration may be calculated by either the Thornthwaite (1948) or Papadakis (1965).

The user can specify the compartments from which the water is extracted using the PET index, a concept used by Rodgers (1981). The PET index (Figure 5) is used to determine from which compartments the water is extracted. For example, if the PET index of the uppermost compartment, of a 10 compartment model, is 0.1, then one-tenth of the monthly water loss will come from the uppermost

compartment. If the user wants the uppermost compartment to contribute more to evapotranspiration, then the PET index is increased (eg. from 0.1 to 0.2). The sum of the PET indices for all the compartments must equal unity.

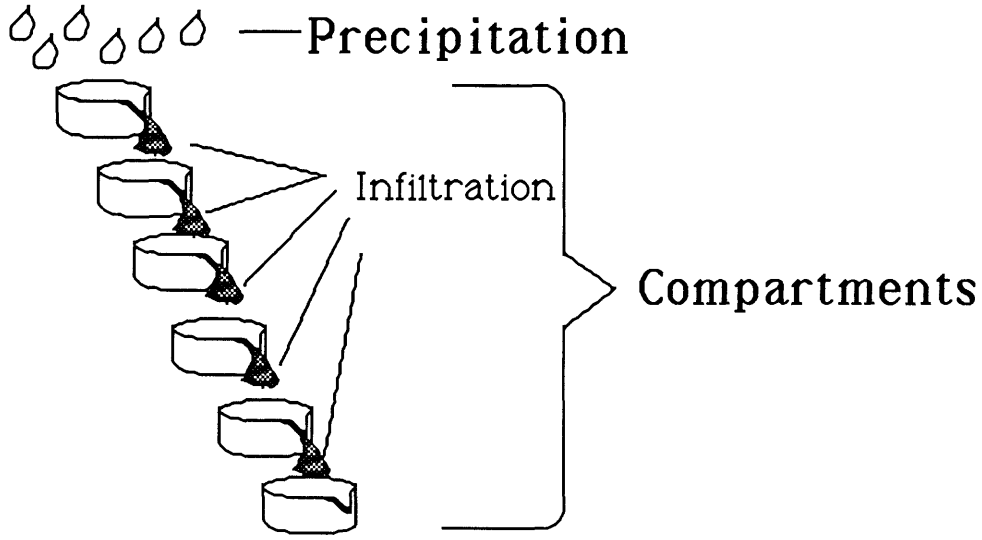

Figure 4. Cartoon showing how the program accounts for water and carbonate movement. Precipitation enters the first compartment and fills it to its field capacity. excess water drains to the next lower compartment. The excess water can dissolve carboante in the first compartment and move it down the soil.

Any excess of soil moisture following evapotranspiration, is carried over to the next month. Thus, in monthly modeling it is possible to have a year-to-year surplus of soil water. Carbonate is dissolved and moved downward every month that has sufficient precipitation to infiltrate below the uppermost compartment.

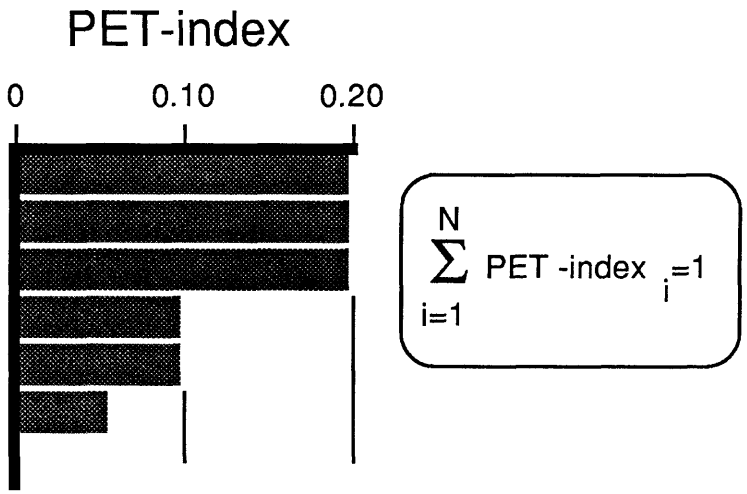

Figure 5. The PET-index is a way to unevenly distribute water loss in a soil. It is based on vegetation, rooting depths, and other physical characteristics that can cause uneven water loss.

Carbonate Movement

The program models carbonate movement in the soil on a compartment basis (cf. Rodgers, 1981, for a discussion of the compartment model). No diffusion occurs across compartment boundaries. Carbonate can cross compartment boundaries only in solution. Sources of calcium carbonate sources include solid calcium carbonate in dust, Ca^{++} in rainwater, or solid carbonate in the soil parent material. Quantities of all three sources, which make up the influx rate, can be specified by the user.

The solubility of calcium carbonate is computed as a function of temperature and pCO_2 (Figure 6). The program uses Ca^{++} molality as given by Drever (1982):

$$m^3Ca^{++} = (pCO_2 K_1 K_{cal} K_{CO_2})/4K_2 \qquad (1)$$

where m is the molality of Ca^{++}, pCO_2 is the partial pressure of carbon dioxide in the soil environment, and K_1, K_2, K_{cal}, K_{CO_2}, are the dissociation constants that describe this carbonate system. Equation (1) assumes that the activities of Ca^{++} and HCO_3^- are both unity, there are no other ions in the solution, and the parent material is chemically inert. These assumptions may be reasonable

when no other salts enter into the soil system. Desert soils commonly do have other salts present, such as gypsum and halite, so that the equation (1) is not generally adequate. While assumptions do not necessarily describe the real soil system, they provide a starting point for more complicated models. The temperature dependences of the dissociation constants are given by:

$-\log(K_1) = 6.53 - 0.0058\ T$ $\quad r^2=0.89$

$-\log(K_2) = 10.59 - 0.0091\ T$ $\quad r^2=0.97$

$-\log(K_{CO_2}) = 1.21 + 0.01\ T$ $\quad r^2=0.82$

$-\log(K_{cal}) = 8.03 + 0.0122\ T$ $\quad r^2=1.00$

where T is the temperature of the system in degrees Centigrade and r^2 is the coefficient of determination. These equations are based on linear regression of the dissociation constants with temperature from data given in Drever (1982).

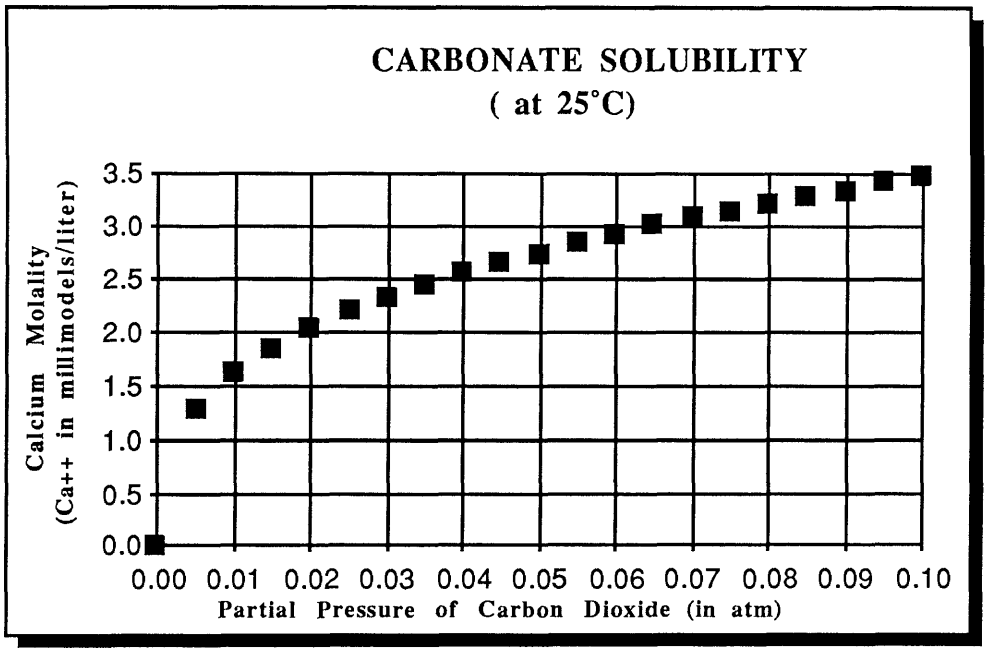

Figure 6. Relation between the partial pressure of carbon dioxide and the molity of Ca^{++} (after Drever, 1982). This relation is used to calculate differences in carbonate solubility.

To modify the procedure by which carbonate solubility is calculated, the user may rewrite subroutine CARBONATE (program lines 22700-23700). The user may want to consider the effects of gypsum, carbonate complexing, or other factors on the solubility of calcium carbonate. The variable array CSOLUBLE holds the solubility of carbonate for each soil compartment.

Setting Up the Program Diskette

This section describes how to set up a diskette for use of the program on an IBM-PC microcomputer. The discussion is intended for those potential users with little familiarity with microcomputers. The program requires an IBM-PC with 256k of RAM, two disk drives (or one drive and a hard disk), IBM-DOS version 2.0 or higher, a spreadsheet program (eg. Supercalc2) or a wordprocessor (eg. Wordstar) , an IBM graphics printer (or Epson FX-80), and can use either a standard IBM monochrome monitor, a color monitor connected to an IBM Color Graphics Adapter, or a monochrome monitor attached to an IBM Enhanced Graphics Adapter set for monochrome display.

Formatting a disk

To start, you will need a copy of the IBM-DOS operating system and an empty diskette. Place the DOS diskette in the A: disk drive, and the empty diskette in the B: disk drive. Turn the computer on. After a minute or so, depending on the amount of memory in your IBM, the computer disk drive will activate and then the system will prompt you for the date. Type the date and press return. Next the system prompts you for the time. Type the time and press return. The system will respond with the A> prompt which indicates that the system is ready to execute commands from the A:drive.

Type **format b:** and then press return. The system asks you to place a new diskette in the B:drive and press any key. Since you have already put a diskette in the B:drive, press a key now. The B:drive will activate during the formatting process. When the format is complete the system asks you if you want to format

another disk. Type N and the system will give you the A> prompt. At this point you need to place a system on the empty diskette.This will allow you to start (or boot) the computer with your new formatted disk. Type **sys B:** and press return. You must press the return key after each command. The system should acknowledge a successful transfer.

Making Directories

For file management purposes, it is helpful to have separate directories for your data and program files. Directories are like file cabinets (Figure 7). The IBM operating system allows you to create directories in order to group similar files. Directories are most useful when using a hard disk, but are also helpful when using floppy diskettes. Create directories by executing the following commands:

copy autoexec.bat b:
mkdir b:\programs
mkdir b:\dos
mkdir b:\supercal

These commands created three directories below the root directory on your work disk. The "programs" directory is for the simulation program and its files. The "dos" directory is for commonly used DOS commands. The "supercal" directory is for a spreadsheet program or data files that will be used as input to CALSOIL. To copy the DOS commands you might find useful execute the following:

cd b:\dos
copy command.com b:
copy format.com b:
copy diskcopy.com b:
copy tree.com b:
copy sys.com b:

These commands change the working directory to "dos" and then copy the dos

commands into your dos directory. The CALSOIL program is written in IBM BASIC (Microsoft BASIC) and requires the BASIC interpreter supplied on the IBM DOS disk. The basic interpretor translates the program into an executable form. Execute the following commands to place the BASIC interpreter in the programs directory:

cd b:\programs
copy basica.com b:

Finally, to place a spreadsheet program in the supercal directory remove the diskette from the A:drive and place the Supercalc2 diskette in the A:drive. Then execute the following commands:

cd b:\supercal
copy *.* b:

These will copy all the Supercal2 files and overlays into the supercal directory. The spreadsheet program Supercalc2 is used for the purpose of illustration only. Most spreadsheets are protected by copywrite law and therefore duplicating the spreadsheet program must be done in accordance with the liscence agreement. If you are using a program that prohibits making backup copies, then omit this step. Any spreadsheet program, that can produce sequential data files (also called a comma separated file) can be used to create data files. Any wordprocessor that can produce ASCII files can also be used. If you use Wordstar, for example, create the file with the "N" command from the no-file menu. If you use Supercalc2, be sure the SDI program is on the Supercalc2 diskette. The SDI program is a utility supplied with Supercalc2 that converts the spreadsheet files into ones that can be read by the CALSOIL. Now remove the Supercalc2 diskette from the A:drive. Remove your work diskette from the B:drive and place it in the A:drive.

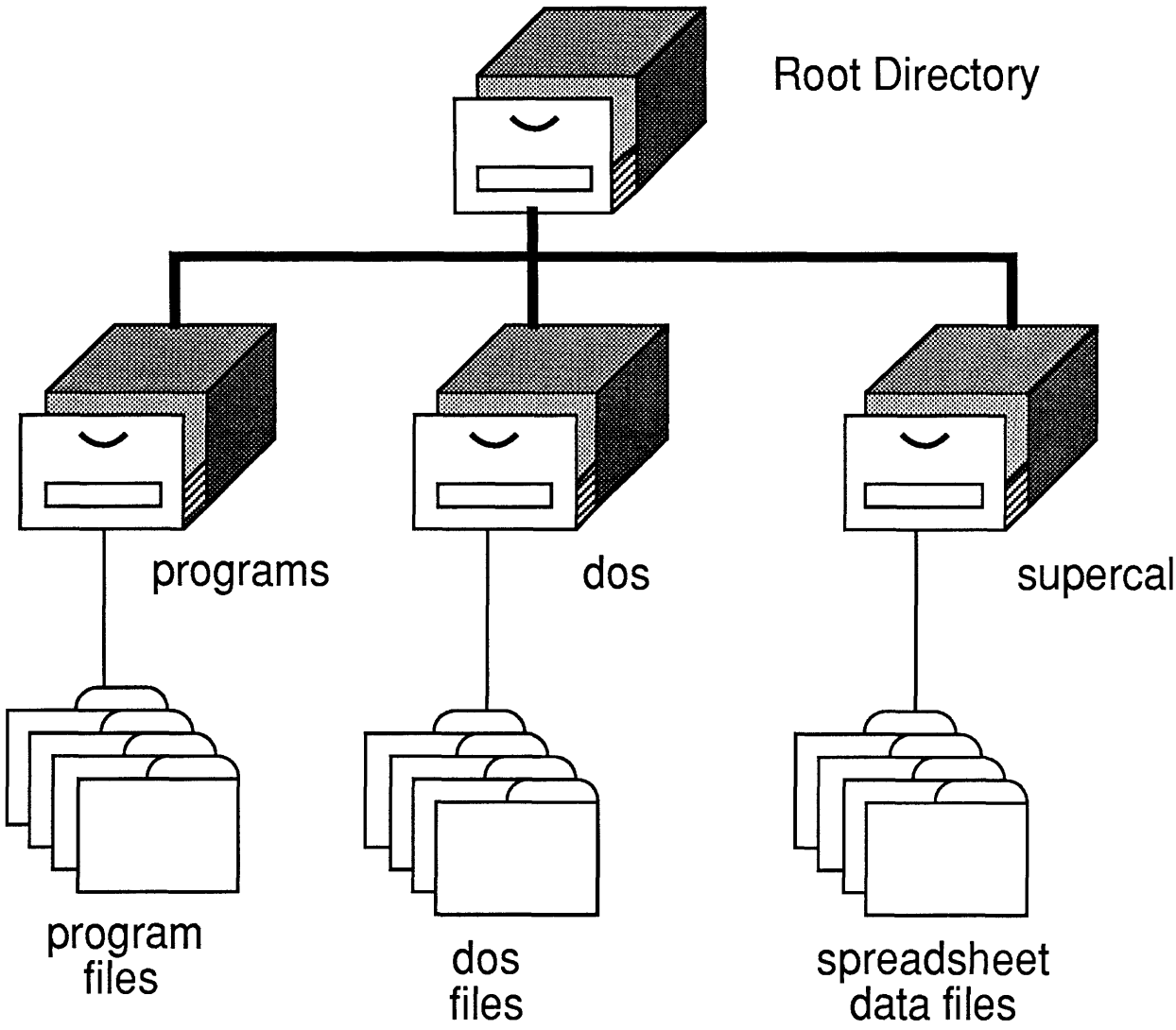

Figure 7. The structure of directories that can be constructed using IBM-DOS. Directories are most useful on a hard disk. After execting the commands given in the text, a structure like the one shown will be made on the program disk.

Getting the Program on Disk

There are two ways to get the CALSOIL on disk. First, you can obtain a copy from the U.S.G.S. or second, you can type the program in yourself from the CALSOIL listing. To copy the program place the copy in the B:drive and execute the following commands:

```
cd \programs
copy b:\programs\program a:
```

This creates a copy of the CALSOIL in the programs directory. Remove the diskette from the B:drive. To type the program in yourself you must first enter the BASIC editor and then type the program. To enter the BASIC editor type:

```
cd \programs
basica
```

The BASIC interpreter will respond with the Ok prompt. Refer to the IBM BASIC manual for information on how to create and save a program file.

Executing the Program

The following steps are needed to run the program:

1- Create the data files
   a) CALSOIL parameter file
   b) compartment data file
   c) climate data file
2- Convert the data files to CALSOIL format.
3- Copy converted files to \programs directory
4- Execute program.

This section will provide an explanation of each step.

Creating Data Files

Supercalc2 can be used to create data files. To create the data files enter the \supercal directory by typing **cd \supercal** and then type **sc2**. This will bring an empty spreadsheet on the screen. The CALSOIL parameter file is created by making the following entries. If you are using a word processor, then each row

refers to a new line and each column letter is simply that value followed by a comma (eg. 20,1,1000,3,10000,.0001,0<return> could be a parameter file entry where 20 is the number of compartments, 1 is the period of the model, and so forth). For an explanation of each variable and its units see the section "Explanation of Variables" below:

row 1: column
A= the number of compartments
B= the period of the model: type 2 for monthly modeling, type 3 for yearly modeling
C= the time between iterations
D= compartment thickness
E= total time of model
F= particulate carbonate flux
G= dissolved carbonate flux

Spreadsheet entries are generally made by entering the data at the spreadsheet input prompt and hitting the return key. Refer to your spreadsheet manual for specific information on manipulating the format of the spreadsheet. When all the entries have been made type **/s,name1,all,** where name1 is a filename that you provide. This saves the parameter file. Next initialize the spreadsheet by typing **/z,y**. Now being entering the compartment data according to the following format:

column
A= field capacity (in cm)
B= intial water content (in cm)
C= wilting point (in cm)
D= calcium carbonate content (grams in compartment)
E= partial pressure of CO_2 (in atm)
F= compartment temperature (°C)
G= PETINDEX (in decimal fraction)

For each compartment enter a row with these data in the appropriate columns.

When done type **/s,name2,a**. This saves the compartment file. Initialize the spreadsheet by typing **/z,y**. Next enter the climate data. For yearly models, those are with period=3 in the parameter file, use the following format:

row 1: column
A= leaching index (in cm)
B= initial leaching index (in cm)
C= final leaching index (in cm)
D= leaching coefficient
E= Model
    type 1 for constant
    type 2 for threshold
    type 3 for trend
F= variance (type 1 if you wish to add a variance)
G= leaching index variance
H= timing of threshold (in years after time zero)

For monthly modeling, those with period=2 in the parameter file, the following format is used:

row 1:
column
A= Model
    type 1 for constant
    type 2 for threshold
    type 3 for trend
B= variance option
    type 1 to enable the variance option
    type 0 to disable the variance option
C= Precipitation variance
D= PET variance
E= timing of threshold (in years after time zero)

row 2:
column
A= PET for month i (where i is the row number minus 1)
B= Preciptitation for month i
C= Initial PET for month i
D= Final PET for month i
E= Initial precipitation for month i
F= Final precipitation for month i
G= Precipitation coefficient
H= PET coefficient
I= Mean temperature for month i

The format for rows 3-13 are the same as for row two. The data placed in rows 3-13 describe months 2-12 (February-December). To save the climate file type **/s,name3,a,** where name3 is a file name that you provide. This completes the task of creating files.

Converting Supercalc2 Files to CALSOIL Files and Copying Them to \Programs Directory:

The "SuperData Interchange" (SDI) program provided by Sorcim, Inc., provides a way to convert Supercalc files to CALSOIL files. To run the conversion, execute the following commands:

cd \supercal
sdi (this calls the SDI program)
a (this option converts to a comma separated ASCII sequential data file)

then follow the SDI program prompts. If your are using a different spreadsheet program, refer to its manual to find out how to convert the spreadsheet into a sequential data file. After you have converted each file, copy the files to the \programs directory. To do this type:

copy *.csv \programs

This command copies SDI converted files as indicated by the .csv file suffix. The system will tell you which files it is copying. If you are going to run the program, then move to the \programs directory by typing **cd \programs**.

Running the Program

To run CALSOIL first change the current directory to \programs by typing **cd \programs**. Then type basica CALSOIL to run the program. The program will ask prompt you for the files you wish to use. These files were previously created as described above. The CALSOIL parameter file must be consistent with the climate file. For example, if you specify yearly modeling in the parameter file, than the climate file must follow the format for yearly modeling. The compartment file may be used for either monthly or yearly modeling. However the number of compartments given in the parameter file must match that number entered in the compartment data file. When the program prompts you for the file names, be sure to include the extension .csv if you are using SDI, unless you have changed the name. It is useful to keep a separate log of the files in which the file attributes are described.

CALSOIL provides print options as well. You can print out a table showing carbonate contents after each iteration. To enable this option, type a **1** after the prompt. Also, you can have the distribution plotted on the printer after each iteration. To enable this option type a **1** after the prompt.

After CALSOIL opens the files, it draws a window on the monitor (Fig. 8). The portion on the right shows the distribution of carbonate in the upper 20 compartments. The year is printed on the upper left. The options you selected are shown (flashing) on the lower right. If an option is not selected it is dimmed rather than flashing.

Upon completion, the computer will beep and wait for any key to be depressed. At this time you could print the screen by holding down the shift key and then depressing the PrtSc key. If a screen print is not needed than just hit any key and BASIC will respond with the "Ok" prompt. To run the program again simply type **run**.

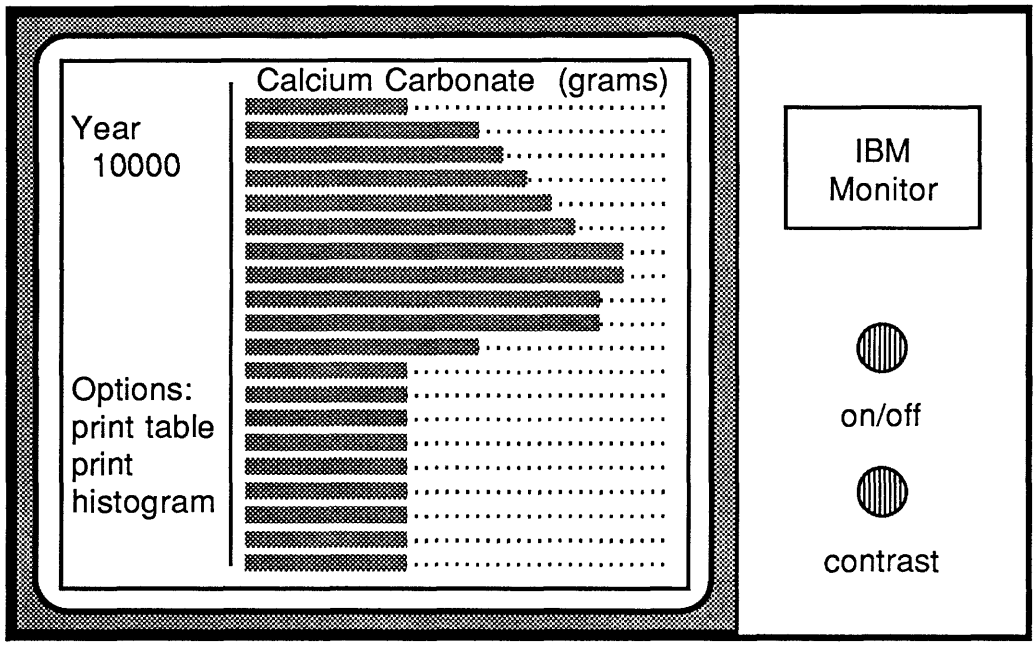

Figure 8. The program draws the carbonate distribution on the screen as shown above. The values are not shown on the screen, only relative amounts because the screen will be rescaled as the distribution changes.

Evapotranspiration Utility Program (EVAP)

The EVAP utility program provides an easy way to calculate many of the climate inputs needed by CALSOIL (Table 2). The program EVAP will convert temperature data or saturation vapor pressure data to potential evapotranspiration. The program can use either the Thornthwaite or Papadakis method. For more information on these methods, please refer to the original work (Thornthwaite and Mather, 1955; Papadakis, 1965).

The temperature to saturation vapor pressure conversion used by the program is given in Lindsley an others (1982, p. 31). To run the EVAP utility, type **cd \programs**. Then type **basica evap**. The program will prompt you for the information it needs and prints out the results. To make a selection, type the first

letter of the desired choice. The program will prompt you for verification. If the selection is correct, respond to the verification request with a "**Y**". To reselect, type "**N**". Be sure the printer is turned on when you run the program.

Explanation of Variables

A description of the variables used by CALSOIL is given below. The variable names used by the program are shown in parentheses and refer to the variable names in the computer program listing.

Parameter File

Number of Compartments (N%): An integer that represent the number of accounting units into which the soil is divided. There should be enough compartments to represent all the soil subhorizons but not more than are needed. Twenty compartments are usually adequate for most applications. There can be no more than 49 compartments. Only the top twenty are displayed on the screen during program execution but all of the compartments are printed.

Period of the Model (PERIOD%): There are three ways the program accounts for water and carbonate movement through the soil. The first way is by a yearly model. The yearly model uses the monthly climate data to calculate a single parameter called the leaching index (LI). The LI represents the amount of water that is available to leach carbonate, yearly. After each year, the soil is assumed to be at the permanent wilting point, thus there is no year-to-year carry over of surplus water. If you elect to use the yearly option, the value of PERIOD% is 3.

Monthly modeling uses a monthly accounting period rather than a yearly one. Using this option, water may be stored in the soil from month to month. The precipitation during any month is allowed to infiltrate into the soil. The potential evapotranspiration for that month is used to determine the amount of water loss during that same month. For monthly modeling, the value of PERIOD% is 2.

For modeling by individual storm event, the user must write his/her own subroutine to calculate the amount of water infiltrating into the soil and water loss during a given month. To use this option, the value of

PERIOD% is 1.

Time Between Iterations (YRSINC%): This integer value, given in years, represents the time interval over which the program calculates the new calcium carbonate distribution. The program uses this value as a multiplier for water movement. Small values for YRSINC% are only needed when the variance option is selected. The smaller the value of YRSINC%, the longer program execution takes.

Compartment Thickness (THICK): The thickness of each compartment (in cm).

Total Time of the Model (YEARS%): The time period (in years) that is being simulated.

Particulate Carbonate Flux (DUST): The rate of input of solid calcium carbonate into the soil. This value is given in grams per square centimeter per year.

Dissolved Carbonate Flux (RAINWATER): The rate of input of carbonate input into the soil system via rainwater. This value is given as concentration in grams of CO_3 per 100 grams of water.

Compartment File

Field Capacity (AWC): Field capacity is the amount of water remaining in a compartment after gravitational water has drained out. This value is given in centimeters of water and applies to the entire compartment.

Initial Water Content (WCOMPT!): This is the amount of water in a compartment, given in cm, at the start of the simulation.

Permanent Wilting Point (WILTPOINT): The amount of water in a compartment, given in cm, when roots can no longer draw water from the soil.

Calcium Carbonate Content (CPRESENT): The amount of calcium carbonate initially present in a compartment. This value can be used to represent the calcium carbonate content of a soil parent material. This value is given in grams.

Partial Pressure of CO_2 (PCO2): The partial pressure of carbon dioxide gas in a compartment, given in atmospheres. This value is used to determine the solubility of calcium carbonate.

Compartment Temperature (STEMP): The mean compartment temperature given in degrees centigrade. The value is used to calculate the solubility of calcium carbonate.

PET Index (PETINDEX): The PET-index determines how water loss by evapotranspiration is distibuted in the soil. PET-index is a decimal fraction that represents that part of the total soil water loss that is given by each compartment. It is only used in monthly models PERIOD%=2. The sum of all PET-indices must be one.

Climate Files

Yearly File

Leaching Index (LEACHINDEX): The annual sum of monthly excess precipitation. Initial Leaching Index (LI(1)): If the trend or threshold models are being utilized, this value is its starting value. Final Leaching Index (LI(2)): If the trend or threshold models are being utilized, this value is the final leaching index value.

Leaching Coefficient (LIFACTOR): If trend climate is utilized, then this coefficient determines a new leaching index for each iteration. To calculate this value use the following formula:

LIFACTOR= [LI(1)-LI(2)]/YEARS%

Model (CLMODEL%): This integer labels the type of climate model to be used (Fig. 1). Use 1 for constant, 2 for threshold, and 3 for trend. A constant climate is one where the mean- leaching index does not change over the duration of the simulation, but may change from iteration to iteration if the variance option is used. A threshold climate is one where the leaching index changes from the initial to final value at a particular iteration. A trend climate is one where the leaching index gradually changes from the initial value to the final value. The gradual change is applied for each iteration and thus the value of YRSINC% affects the manner in which the change occurs. The smaller the value of YRSINC%, the smoother the change from initial to final leaching index.

Variance (CLVARIANCE%): This integer value enables the variance option when it is equal to one. To disable the variance option, use zero.

Leaching Index Variance (LIVARFACTOR): CALSOIL uses the BASIC random number generator to calculate a variance based on the value of LIVARFACTOR. LIVARFACTOR represents the limits of the variation permitted. For example, if you wanted the leaching index to vary by plus or minus 2.00, then you would use a LIVARFACTOR of 2.00. The program would assign a leaching index that could vary randomly within the limits you provide.

Timing of Threshold (YR%): This value (in years) since the beginning of simulation, determines when the leaching index value changes from its initial to final value. This is only used for the threshold model.

Monthly File

PET for each month (PET): Potential evapotranspiration, in centimeters, for each month is calculated by the user. Program EVAP provides an easy way to calculate monthy potential evapotranspiration using either the

Thornthwaite or Papadakis method.

Precipitation (EFFECP): Monthly precipitation in centimeters.

Initial PET by month (PETI): For the threshold climate model these 12 values set the initial potential evapotranspiration values, in centimeters, for each month

Final PET by month (PETF): For the threshold climate model these 12 values set the final potential evapotranspiration values, in centimeters, for each month. These values are used to represent the new climate after the threshold. By using monthly values, the user can control the type of climate change. For example, the user may elect to change only summer potential evapotranspiration.

Initial Precipitation (EFFECPI): This array holds the monthly precipitation values, in centimeters, to be used in a threshold climate model. These values are used until the threshold climate change occurs.

Final Precipitation (EFFECPF): This array holds the monthly precipitation values, in centimeters, that characterize the climate after a threshold climate change.

Precipitation Coefficient (PRFACTOR): This array holds the 12 factors used to recalculate monthly precipitation when using a trend climate. To calculate the PRFACTOR use the following formula:

PRFACTOR(I)= [EFFECPF(I) - EFFECPI(I)]/YEARS%

PET Coefficient (PETFACTOR): This array holds the 12 factors used to recalculate potential evapotranspiration when using a trend climate. Use the following formula:

PETFACTOR(I)= [PETF(I) - PETI(I)]/YEARS%

Mean monthly temperature (TEMP): An array that holds the initial mean-monthly temperatures, in degrees centigrade.

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Table 1

Program Listing of CALSOIL (Version 1.0):

```
1000 '*****************************************************************
1100 'CALSOIL: A program written in Microsoft Basic V3.0 for the        *
1200 '        the IBM-PC and a standard monochrome display.             *
1300 '        July 1985.                                                *
1400 '***************************************** For information about *
1500 '                                          *  this program, please *
1600 '                                        *  contact: L.  Mayer   *
1700 '                                          *    U. S. Geological   *
1800 '                                          *Survey 975, Menlo Park *
1900 '                                          *   California 94025    *
2000 '                                          ************************
2100 '-----------------------------------------------------------------
2200 ' RESERVE SPACE FOR ARRAYS
2300 '      This sections allocates memory to variables and
2400 '      determines the number of compartments that can be
2500 '      processed. This value is now set at 50.
2600 '_____________________________________________________________________
2700 DIM POROSITY(50),DENSITY(50),HIST$(50)
2800 DIM EFFECP(13),PET(13),TEMP(13),CSOLUBLE(50),CAPACITY!(50),AWC(50)
2900 DIM WCOMPT!(50),COR(13)
3000 DIM PETCOMP!(50),PETINDEX(50),INFIL!(50),WILTPOINT(50)
3100 DIM CPRESENT(50),PCO2(50),STEMP(50)
3200 DIM CADDED(50),CREMOVED(50),WATER!(50)
3300 DIM PRFACTOR(13),PETFACTOR(13),EFFECPI(13),PETF(13),EFFECPF(13),PETI(13)
3400 '_____________________________________________________________________
3500 'EXPLANATION OF VARIABLES:
3600 '     EFFECP- holds the monthly precipitation values
3700 '     PET-    hold the computed ETp for each month
3800 '     TEMP-   holds the monthly temperature
3900 '     PRFACTOR-  the trend factor used to recalculate Precipitation
4000 '                  for trend climate models
4100 '     PETFACTOR - the trend factor used to recalulate ETp for
4200 '                  trend climate models
4300 '     EFFECPI- the initial precipitation values before threshold
4400 '     EFFECPF- the final precipitation values after threshold
4500 '     PETI- the initial ETp values before threshold
4600 '     PETF- the final ETp values after threshold
4700 '_____________________________________________________________________
4800 '
4900 '
5000 '
5100 '
5200 '
5300 '-----------------------------------------------------------------
```

```
5400 'MAIN CONTROL SECTION
5500 '-----------------------------------------------------------------
5550 GOSUB 8000
5600 'Open file 1 and get program parameters.  This file
5700 'was previously created using a spreadsheet or some
5800 'other file writing program.
5900 '
6000 OPEN "I",#1,PFILE$:INPUT #1, N%,PERIOD%,YRSINC%,THICK,YEARS%,DUST,RAIN:CLOSE #1
6100 '
6200 'Open file 2 and get compartment parameters.  This file
6300 'was previously created using a spreadsheet or some
6400 'other file writing program.
6500 ' 6600 OPEN "I",#2,COMPFILE$
6700 FOR I%=1 TO N% 6800 INPUT #2,AWC(I%), WCOMPT!(I%),WILTPOINT(I%), CPRESENT(I%),
     PCO2(I%), STEMP(I%),PETINDEX(I%)
6900 NEXT I%
7000 'Open file 3 and get climate parameters.  This file
7100 'was previously created using a spreadsheet or some
7200 'other file writing program.
7300 '
7400 OPEN "I",#3,CLIMFILE$
7500 ON PERIOD% GOSUB 7700,7800,7900
7600 GOTO 10000 7700 BEEP:RETURN
7800 INPUT #3,CLMODEL%,CLVARIANCE%,PVARFACTOR,EVARFACTOR,YR%:FOR X%=1 TO 12:INPUT
     #3,PET(X%),EFFECP(X%),PETI(X%),PETF(X%),EFFECPI(X%),
     EFFECPF(X%),PRFACTOR(X%),PETFACTOR(X%),TEMP(X%):NEXT X%:CLOSE #3:RETURN
7900 INPUT #3,LEACHINDEX,LI(1),LI(2),LIFACTOR,CLMODEL%,CLVARIANCE%, LIVARFACTOR,YR%
     #3:RETURN
8000 CLS 'clear screen and get file names and options
8010 COLOR 9,0:LOCATE 1,25:PRINT"SIMULATION OF CALCIC SOIL DEVELOPMENT";:COLOR 7,0
8020 LOCATE 5,20:PRINT"File name for Program Parameters:";:INPUT PFILE$
8030 LOCATE 8,20:PRINT"File name for Compartment Values:";:INPUT COMPFILE$
8040 LOCATE 11,20:PRINT"File name for Climate Values:";:INPUT CLIMFILE$
8050 LOCATE 14,20:PRINT"Do you want tabular output (1=yes, 0=no):";:INPUT PO
8060 LOCATE 17,20:PRINT"Do you want printed graphs (1=yes, 0=no):";:INPUT POG
8070 RETURN
10000 'This routine handles the routing of the calculations
10100 'INPUT FOR SINGLE STORMS
10200 '
10300 '
10400 '-------------------------------------------------------------
10500 '           CONTROLLER FOR CRUNCHING
10600 '-------------------------------------------------------------
10700 START$=DATE$
10800 ON PERIOD% GOTO 10100,10900,10900
10900 FOR YRS%=YRSINC% TO YEARS% STEP YRSINC%
11000           IF PERIOD%=3 THEN M%=1:GOTO 11200
11100           FOR M%=1 TO 12
11200                    GOTO 19800 'GET CLIMATE
11300                         GOTO 12200 'COMPUTE WATER BALANCE AND CARBONATE
```

```
11400                           GOTO 23800 'OUTPUT TO SCREEN
11500                           'CONTINUE
11600                           IF PERIOD%=3 THEN 11800
11700           NEXT M%
11800 NEXT YRS%
11900 FOR I%=1 TO 10:BEEP:NEXT I%
12000 A$=INKEY$:IF A$="" THEN GOTO 12000 ELSE IF A$="p" THEN GOSUB 16500
12100 END
12200 '-------------------------------------------------------------
12300 '                 MAIN LOOP FOR SOIL WATER AND CARBONATE
12400 '-------------------------------------------------------------
12500 INFIL!(0)=EFFECP(M%)
12600 FOR I%=1 TO N%
12700           IF PERIOD%=3 THEN WCOMPT!(I%)=WILTPOINT(I%)
12800           CAPACITY!(I%)=AWC(I%)-WCOMPT!(I%)
12900           IF PERIOD%<3 THEN PETCOMP!(I%)=(PET(M%)*PETINDEX(I%))
13000           INFIL!(I%)=INFIL!(I%-1)-CAPACITY!(I%):IF INFIL!(I%) <0 THEN INFIL!(I
13100           WATER!(I%)=WATER!(I%)+INFIL!(I%)
13200           WCOMPT!(I%)=WCOMPT!(I%)+INFIL!(I%-1)-INFIL!(I%)
13300           IF WCOMPT!(I%) < WILTPOINT(I%) THEN WCOMPT!(I%)=WILTPOINT(I%)
13400           SUMWAT!=(WCOMPT!(I%)-WILTPOINT(I%))+SUMWAT!
13500           CAPACITY!(I%)=ABS(AWC(I%)-WCOMPT!(I%))
13600 NEXT I%
13700 IF PET(M%)>SUMWAT! THEN AVAILEVAP!=SUMWAT! ELSE AVAILEVAP!=PET(M%)
13800 IF PERIOD%=3 THEN 14700
13900 WHILE (AVAILEVAP!-SUMPETCOMP!)>.01
14000                   FOR I%=1 TO N%
14100                                   IF (WCOMPT!(I%)- PETCOMP!(I%))<=WILTPOINT(I%
     THEN PETCOMP!(I%)=WCOMPT!(I%)-WILTPOINT(I%)
14200                                   WCOMPT!(I%)=WCOMPT!(I%)-
     PETCOMP!(I%):CAPACITY!(I%)=AWC(I%)-WCOMPT!(I%)
14300                                   SUMPETCOMP!=SUMPETCOMP!+PETCOMP!(I%)
14400                   NEXT I%
14500 WEND
14600 SUMWAT!=0:SUMPETCOMP!=0
14700 '-------------------------------------------------------------
14800 '                         CARBONATE ACCOUNTING LOOP
14900 '-------------------------------------------------------------
15000 IF PERIOD%=1 THEN GOTO 15200
15100 IF PERIOD%=2 THEN DUSTFLUX=DUST/12 ELSE DUSTFLUX=DUST
15200 RAINWATER=RAIN*EFFECP(M%)
15300 GOSUB 22700 'CARBONATE SOLUBILITY
15400 CADDED(1)=(DUSTFLUX+RAINWATER)*YRSINC%
15500 CREMOVED(1)=CSOLUBLE(1)*INFIL!(1)*YRSINC%
15600 IF CREMOVED(1) > (CPRESENT(1)+CADDED(1)) THEN CREMOVED(1)=CPRESENT(1)+CADDED(1
15700 CPRESENT(1)=CPRESENT(1)+CADDED(1)-CREMOVED(1)
15800 FOR I%=2 TO N%
15900           CADDED(I%)=CREMOVED(I%-1)
16000           CREMOVED(I%)=CSOLUBLE(I%)*INFIL!(I%)*YRSINC%
16100            IF CREMOVED(I%) > (CPRESENT(I%)+CADDED(I%)) THEN
```

```
     CREMOVED(I%)=CPRESENT(I%)+CADDED(I%)
16200           CPRESENT(I%)=CPRESENT(I%)+CADDED(I%)-CREMOVED(I%)
16300 NEXT I%
16400 GOTO 11400
16500 '-------------------------------------------------------------
16600 '            PRINTED OUTPUT SECTION
16700 '-------------------------------------------------------------
16800 PAGE%=PAGE%+1
16900 LPRINT "DATE= ";START$;TAB(65);"P
AGE #";PAGE%
17000 LPRINT:LPRINT:LPRINT:LPRINT:LPRINT:LPRINT"    ACCOUNTING PERIOD (YEARS) =
     ";YRSINC%:LPRINT
17100 IF PERIOD%=1 THEN LPRINT USING "STORM=##       MONTH=## YEAR=#####
     PRECIPITATION=##.## EVAPOTRANSPIRATION=##.##"; STORM%;M%;YRS%; EFFECP(M%); PET
17200 IF PERIOD%=2 THEN LPRINT USING "MONTH=## YEAR=###### PRECIPITATION=##.##
     TEMPERATURE=###.## ETp=##.##";M%;YRS%;EFFECP(M%);TEMP(M%);PET(M%)
17300 IF PERIOD%=3 THEN LPRINT USING "    YEAR=#####           LEACHING INDEX=###.#
     ";YRS%;EFFECP(M%)
17400 IF PERIOD%=2 THEN LPRINT USING "             TOTAL WATER LOSS BY
     EVAPOTRANSPIRATION= ###.##";AVAILEVAP!
17500 LPRINT:LPRINT:LPRINT:LPRINT:LPRINT:
17600 LPRINT"Comp  Depth   Infil      Water     Total      AWC Carbonate (g)"
17700 LPRINT" #    (cm)    (cm)   Content(cm) Water(cm)    (cm)    (=) (+)      (-)'
17800 LPRINT"====  =====   =====  =========== =========    ==== ==================
17900 FOR I%=1 TO N%
18000 LPRINT USING "###  ###     ##.##     ##.##   #########.#    ##.## #.####  #.#
     #.####";I%;I%*THICK;INFIL!(I%);WCOMPT!(I%);WATER!(I%)*YRSINC%;CAPACITY!(I%
     );CPRESENT(I%);CADDED(I%);CREMOVED(I%)
18100 NEXT I%
18200 LPRINT CHR$(12):LPRINT CHR$(13) 'START A NEW PAGE ON PRINTER
18300 RETURN
18400 '-------------------------------------------------------------
18500 '           ADDS A RANDOM VARIANCE TO CLIMATE
18600 '-------------------------------------------------------------
18700 RANDOMIZE(TIMER/3)
18800 IF PERIOD%=3 THEN 19400
18900 PVAR=(2*PVARFACTOR*RND)-PVARFACTOR
19000 EVAR=(2*EVARFACTOR*RND)-EVARFACTOR
19100 EFFECP(M%)=EFFECP(M%)+PVAR
19200 PET(M%)=PET(M%)+EVAR
19300 GOTO 11300
19400 'FOR YEARLY MODELING
19500 LIVAR=(2*LIVARFACTOR*RND)-LIVARFACTOR
19600 EFFECP(1)=EFFECP(1)+LIVAR
19700 GOTO 11300
19800 '-------------------------------------------------------------
19900 '                  SIMULATE CLIMATES ACCORDING TO SELECTIONS
20000 '-------------------------------------------------------------
20100 IF PERIOD%=3 THEN 21500
20200 'FOR MONTHLY MODELING USING ETp AND EFFECP
```

```
20300 ON CLMODEL% GOTO 20400,20700,21100
20400 'FOR CONSTANT CLIMATE
20500 'USE VALUES CALCULATED IN ETp
20600 IF CLVARIANCE%=1 THEN GOTO 18400 ELSE GOTO 11300
20700 'FOR THRESHOLD CLIMATE
20800 IF YRS%<YR% THEN EFFECP(M%)=EFFECPI(M%):PET(M%)=PETI(M%) 'NO CHANGE IN FIRST
20900 IF YRS%>=YR%  THEN EFFECP(M%)=EFFECPF(M%):PET(M%)=PETF(M%)
21000 IF CLVARIANCE%=1 GOTO 18400 ELSE GOTO 11300
21100 'FOR MONTHLY TREND
21200 EFFECP(M%)=PRFACTOR(M%)+EFFECPI(M%)
21300 PET(M%)=PETFACTOR(M%)+PETI(M%)
21400 IF CLVARIANCE%=1 THEN GOTO 18400 ELSE GOTO 11300
21500 'FOR YEARLY MODELING USING LEACHING INDEX
21600 ON CLMODEL% GOTO 21700,22000,22400
21700 'FOR CONSTANT CLIMATE
21800 EFFECP(1)=LEACHINDEX
21900 IF CLVARIANCE%=1 THEN GOTO 18400 ELSE GOTO 11300
22000 'FOR THRESHOLD CLIMATE
22100 IF YRS%<YR% THEN EFFECP(1)=LI(1)
22200 IF YRS%>=YR% THEN EFFECP(1)=LI(2)
22300 IF CLVARIANCE%=1 THEN GOTO 18400 ELSE GOTO 11300
22400 'FOR TREND CLIMATE
22500 EFFECP(1)=LIFACTOR+LI(1):IF EFFECP(1)<0 THEN EFFECP(1)=0
22600 IF CLVARIANCE%=1 THEN GOTO 18400 ELSE GOTO 11300
22700 '-------------------------------------------------------------
22800 '              SUBROUTINE TO COMPUTE CARBONATE SOLUBILITY
22900 '-------------------------------------------------------------
23000 FOR Z%=1 TO N% 23100 K1=6.53-.0058*STEMP(Z%):K1=10^(-1*K1)
23200 K2=10.59-9.100001E-03*STEMP(Z%):K2=10^(-1*K2)
23300 KCO2=1.21+.0102*STEMP(Z%):KCO2=10^(-1*KCO2)
23400 KCAL=8.03+.0122*STEMP(Z%):KCAL=10^(-1*KCAL)
23500 MCUBED=PCO2(Z%)*K1*KCAL*KCO2/(4*K2):CSOLUBLE(Z%)=MCUBED^(1/3)*.1
23600 NEXT Z% 23700 RETURN
23800 '_____________________________________________________________________
23900 '           DRAW THE CARBONATE DISTRIBUTION
24000 '-------------------------------------------------------------
24100 '
24200 '_____________________________________________________________________
24300 'PLOT DATA: This routine plots the carbonate data derived from the above
24400 '           routines using a simple screen graph method.  The maximum
24500 '           number of horizons is twenty.  Those below the 20th will be
24600 '           tabulated but not plotted on the screen.
24700 '_____________________________________________________________________
24800 '
24900 '
25000 IF YRS%>YRSINC% THEN GOSUB 27200 ELSE GOSUB 25300
25100 IF PO=1 THEN GOSUB 16500
25200 GOTO 11500
25300 'Setup the console for input and take care of basic houskeeping.
25400 NEWPAGE$=CHR$(12)+CHR$(13) 'When newpage$ is lprinted, a new page starts.
```

```
25500 KEY OFF
25600 RESTART$="_................................................."
25700 ARROW$="<-------"
25800 BLANK$="        "
25900 VL$=SPACE$(16):VR$=SPACE$(61)
26000 B$=CHR$(177):L$=CHR$(186):
     UL$=CHR$(201):LL$=CHR$(200):UR$=CHR$(187):LR$=CHR$(188):S$=CHR$(205)
26100 '
26200 '
26300 '
26400 'This segment plots the stuff to the screen and is limited to 20 horizons.
26500 '
26600 PRINT UL$;:FOR C=1 TO 78:PRINT S$;:NEXT:PRINT UR$;
26700 FOR C=1 TO 21:PRINT L$;VL$;L$;VR$;L$;:NEXT
26800 PRINT LL$;:FOR C=1 TO 78:PRINT S$;:NEXT:PRINT LR$;
26900 LOCATE 2,40:COLOR 9,0:PRINT "CALCIUM CARBONATE CONTENT (grams)";: COLOR 10,0
27000 LOCATE 10,78:PRINT"D";:LOCATE 11,78:PRINT "E";:LOCATE 12,78:PRINT "P";:LOCATE
     13,78:PRINT "T";:LOCATE 14,78:PRINT "H";
27100 SCALE=50
27200 COLOR 0,7:LOCATE 3,3:PRINT "Year:";:COLOR 7,0
27300 LOCATE 5,5:PRINT YRS%; 27400 IF PERIOD%=2 THEN LOCATE 7,5:PRINT M%;
27500 COLOR 0,7:LOCATE 13,3:PRINT "Options:";:COLOR 7,0
27600 COLOR 7,0:LOCATE 15,3:PRINT "print table";:LOCATE 17,3:PRINT "print
     histogram";:COLOR 10,0
27700 IF PO=1 THEN COLOR 31:LOCATE 15,3:PRINT "print table";:COLOR 7,0
27800 IF POG=1 THEN COLOR 31: LOCATE 17,3:PRINT "print histogram";:COLOR 7,0
27900 FOR I%=1 TO 20
28000 NBLOCKS=INT(SCALE*CPRESENT(I%))
28100 FOR C=1 TO NBLOCKS:HIST$(I%)=HIST$(I%)+CHR$(177)
28200 NEXT C
28300 LOCATE I%+2,24:PRINT RESTART$;
28400 LOCATE I%+2,25:PRINT HIST$(I%);
28500 HIST$(I%)="" 28600 NEXT I%
28700 IF POG=1 THEN GOSUB 29000 28800 RETURN
28900 GOTO 28900
29000 'This segment plots the stuff to the printer and is not limited.
29010 PAGE%=PAGE%+1
29100 LPRINT "DATE= ";START$;TAB(65);"PAGE #";PAGE%
29110 LPRINT:LPRINT:LPRINT
29115 LPRINT TAB(25);"Calcium Carbonate Content (see table for values)"
29120 LPRINT TAB(24);"|||||||||||||||||||||||||||||||||||||||||||||||||||"
29200 FOR I%=1 TO N%
29300 SCALE=50
29400 NBLOCKS=INT(SCALE*CPRESENT(I%))
29500 FOR C=1 TO NBLOCKS:HIST$(I%)=HIST$(I%)+CHR$(223)
29600 NEXT C
29700 LPRINT TAB(15);I%;"---->";TAB(24);HIST$(I%);
29800 HIST$(I%)=""
29900 NEXT I%
30000 '
```

```
30100 '
30200 LPRINT NEWPAGE$
30300 RETURN
30400 GOTO 11500
```

Table 2

Program Listing of EVAP (Version 1.0):

```
5 KEY OFF
10 '_____________________________________________________________________
20 'Program EVAPOTRANSPIRATION: This utility program calculates potential
30 '                            evapotranspiration using either the method
40 '                            of Thornthwaite or Papadakis.
50 '_____________________________________________________________________
60 'ON ERROR GOTO 1000
70 OPTION BASE 1
80 CLS:COLOR 7,0:PRINT"Be sure to enter Precipitation Record First":FOR I=1 TO 2800
90 '
100 '
110 '
120 'Reserve space for the arrays and define month names.
130 '
140 DIM TMAX(12),TMIN(12),MAXV(12),MINV(12),PET(12),EFFECP(12),
     SATMAX(12),SATMIN(12),TEMP(12),COR(12),MONTHNAME$(12)
150 MONTHNAME$(1)="January":MONTHNAME$(2)="February":MONTHNAME$(3)="March"
160 MONTHNAME$(4)="April":MONTHNAME$(5)="May":MONTHNAME$(6)="June"
170 MONTHNAME$(7)="July":MONTHNAME$(8)="August":MONTHNAME$(9)="September"
180 MONTHNAME$(10)="October":MONTHNAME$(11)="November": MONTHNAME$(12)="December"
190 '
200 '
210 ' This is the Main Menu loop.
220 '
230 CLS:LOCATE 1,1:COLOR 0,7:PRINT "       Main Menu for Evapotranspiration     ";:C
     7,0
240 LOCATE 5,15:PRINT"Options:";
250 LOCATE 7,20:PRINT"Enter Precipitation Data";
260 LOCATE 9,20:PRINT"Thornthwaite Method";
270 LOCATE 11,20:PRINT"Papadakis Method";
280 LOCATE 13,20:PRINT "QUIT";
290 ANS$=INKEY$:IF ANS$="" THEN 290
300 IF ANS$="E" OR ANS$="e" THEN LOCATE 7,50:COLOR 31:PRINT "<------- ";:COLOR 10:L(
     23,25:GOSUB 1630
310 IF ANS$="T" OR ANS$="t" THEN LOCATE 9,50:COLOR 31:PRINT "<------- ";:COLOR 10:L(
     23,25:GOSUB 1630
320 IF ANS$="P" OR ANS$="p" THEN LOCATE 11,50:COLOR 31:PRINT "<------- ";:COLOR 10:1
     23,25:GOSUB 1630
330 IF ANS$="Q" OR ANS$="q" THEN LOCATE 13,50:COLOR 31:PRINT "<------- ";:COLOR 10:1
     23,25:GOSUB 1630
340 GOTO 230
350 '
360 'EVAPOTRANSPIRATION CALCULATIONS FOLLOW
370 '
```

```
380 '_____________________________________________________________________
390 '
400 '
410 '
420 '
430 'Thornthwaite Method: you will need mean monthly
440 '                     temperature and mean monthly precipitation
450 '                     to calculate the amount of water lost by
460 '                     evapotranspiration.
470 '_____________________________________________________________________
480 '
490 CLS
500 LOCATE 1,1:COLOR 0,7:PRINT"  Thornthwaite Option   ":COLOR 7,0
510 HEATINDEX=0:LEACHINDEX=0
520 'initialize variables
530 'set day length correction factors
540 COR(1)=.88:COR(2)=.86:COR(3)=1.03:COR(4)=1.09:COR(5)=1.19:COR(6)=1.2
550 COR(7)=1.22:COR(8)=1.15:COR(9)=1.03:COR(10)=.97: COR(11)=.88:COR(12)=.86
560  '
570 '
580 'input the climate data from the keyboard
590 '
600 FOR M%=1 TO 12
610 LOCATE M%+6,10:PRINT"Temperature=";
620 NEXT M%
630 FOR M%=1 TO 12
640 LOCATE 23,60:COLOR 31:PRINT "            ";:COLOR 10
650 LOCATE 23,60:COLOR 31:PRINT MONTHNAME$(M%);:COLOR 10
660 LOCATE M%+6,25:INPUT TEMP(M%)
670 MONTHINDEX=(TEMP(M%)/5)^1.514
680 HEATINDEX=MONTHINDEX+HEATINDEX
690 NEXT M%
700 LOCATE 23,60:PRINT"  Thank You  "
710 FOR W=1 TO 600:NEXT
720 '
730 'now calculate PET
740 '
750 'set constants
760 A1=6.751E-07:A2=.0000771:A3=.01792
770 A1=6.751E-07:A2=.0000771:A3=.01792:A4=.49239
780 A=A1*HEATINDEX^3-A2*HEATINDEX^2+A3*HEATINDEX+A4
790 FOR M%=1 TO 12
800 PET(M%)=(1.6*(10*TEMP(M%)/HEATINDEX)^A)*COR(M%)
810 IF EFFECP(M%)>PET(M%) THEN LEACHINDEX=LEACHINDEX+EFFECP(M%)-PET(M%)
820 'now calculate PET and Leaching Index
830 NEXT M% 840 CLS:LOCATE 12,35:PRINT"Now Printing Data":LPRINT
850 LPRINT "Thornthwaite Option":LPRINT:LPRINT:LPRINT:LPRINT
860 FOR M%=1 TO 12
870 LPRINT USING "\          \    Precip= ##.##     Temp= ##.##
     PET=###.##";MONTHNAME$(M%);EFFECP(M%);TEMP(M%);PET(M%)
```

```
880 NEXT
890 LPRINT "Leaching Index=";LEACHINDEX
900 LPRINT CHR$(12);CHR$(13)
910 RETURN
920 '
930 '_____________________________________________________________________
940 '
950 'Papadakis Method: you will need mean monthly maximum and minimum
960 '                  saturation vapor pressures (in millibars) to use
970 '                  this method.
980 '_____________________________________________________________________
990 '
1000 '
1010 CLS
1020 LOCATE 1,1:COLOR 0,7:PRINT"    Papadakis Option: Main Menu   ";:COLOR 7,0
1030 LOCATE 5,15:PRINT "Options:";
1040 LOCATE 7,25:PRINT"Use Temperature Data";
1050 LOCATE 9,25:PRINT"Use Vapor Pressures";
1060 ANS$=INKEY$:IF ANS$="" THEN 1060
1070 IF ANS$="T" OR ANS$="t" THEN LOCATE 7,50:COLOR 31:PRINT"<-------- ";:COLOR 10
1080 IF ANS$="V" OR ANS$="v" THEN LOCATE 9,50:COLOR 31:PRINT"<-------- ";:COLOR 10
1090 GOSUB 1770
1100 RETURN
1110 'input the data from the keyboard
1120 '
1130 CLS:LOCATE 1,1:COLOR 0,7:PRINT"   Papadakis Method using Vapor Pressures   ";:C
     7,0
1140 FOR M%=1 TO 12
1150 LOCATE M%+6,10:PRINT"Max Vapor =";:LOCATE M%+6,40:PRINT "Min Vapor =";
1160 NEXT M%
1170 FOR M%=1 TO 12
1180 LOCATE 23,60:COLOR 31:PRINT "            ";:COLOR 10
1190 LOCATE 23,60:COLOR 31:PRINT MONTHNAME$(M%);:COLOR 10
1200 LOCATE M%+6,25:INPUT MAXV(M%):LOCATE M%+6,58:INPUT MINV(M%)
1210 PET(M%)=5.625*(MAXV(M%)-MINV(M%))
1220 NEXT
1230 '
1240 CLS:LOCATE 12,35:PRINT "Now Printing Data"
1250 LPRINT:LPRINT"Papadakis Option using Vapor Pressures":LPRINT:LPRINT:
1260 FOR M%=1 TO 12
1270 LPRINT USING "\          \ Max V=##.##  Min V=##.##    Precip=##
.## PET=###.##";MONTHNAME$(M%);MAXV(M%);MINV(M%);EFFECP(M%);PET(M%)
1280 NEXT
1290 LPRINT CHR$(12);CHR$(13)
1300 '
1310 RETURN
1320 'temperature option of papadakis method
1330 CLS:LOCATE 1,1:COLOR 0,7:PRINT " Papadakis Option using Temperature and Conver
     ";:COLOR 7,0
1340 FOR M%=1 TO 12
```

```
1350 LOCATE M%+6,10:PRINT"Max Temp =";:LOCATE M%+6,40:PRINT"Min Temp =";
1360 NEXT M%
1370 FOR M%=1 TO 12
1380 LOCATE 23,60:COLOR 31:PRINT"              ";:COLOR 10
1390 LOCATE 23,60:COLOR 31:PRINT MONTHNAME$(M%);:COLOR 10
1400 LOCATE M%+6,25:INPUT TMAX(M%):LOCATE M%+6,58:INPUT TMIN(M%)
1410 ' convert from temperatures to vapor pressures
1420 '
1430 MAXV(M%)=33.8639 *((.00738*TMAX(M%)+.8072)^8- .000019* ABS(1.8*TMAX(M%)+48)
     +.001316)
1440 MINV(M%)=33.8639 *((.00738*TMIN(M%)+.8072)^8- .000019*ABS(1.8*TMIN(M%)+48) +.0(
1445 PET(M%)=5.625*(MAXV(M%)-MINV(M%))
1450 '
1460 NEXT
1470 CLS:LOCATE 12,35:PRINT"Now Printing Data"
1480 LPRINT "Papadakis Option using Temperature to Vapor Pressure Conversion"
1490 LPRINT:LPRINT:LPRINT
1500 FOR M%=1 TO 12
1510 LPRINT USING "\          \  Tmax=##.##     Tmin=##.##    Precip=##.##
     PET=###.##";MONTHNAME$(M%);TMAX(M%);TMIN(M%);EFFECP(M%);PET(M%)
1520 NEXT
1530 LPRINT CHR$(12);CHR$(13)
1540 RETURN 1550 END 1560 'ERROR handler
1570 BEEP:CLS:PRINT "   I'm sorry, but you've blundered during data entry"
1580 PRINT "       PLEASE try again"
1590 END
1600 '
1610 '
1620 '
1630 'this routine sends the user to the selected
1640 ' subroutine
1650 LOCATE 23,1:PRINT"Is this the correct selection?";
1660 OK$=INKEY$:IF OK$="" THEN 1660
1670 IF OK$="Y" OR OK$="y" THEN GOTO
1680 ELSE RETURN 1680 OK$=""
1690 IF ANS$="E" OR ANS$="e" THEN GOSUB 1890
1700 IF ANS$="T" OR ANS$="t" THEN GOSUB 430
1710 IF ANS$="p" OR ANS$="P" THEN GOSUB  1010
1720 IF ANS$="q" OR ANS$="Q" THEN CLS:COLOR 7,0:END
1730 RETURN
1740 '
1750 '
1760 '
1770 ' subroutine
1780 LOCATE 23,1:PRINT"Is this the correct selection?";
1790 OK$=INKEY$:IF OK$="" THEN 1790
1800 IF OK$="Y" OR OK$="y" THEN GOTO 1810 ELSE RETURN
1810 OK$=""
1820 IF ANS$="V" OR ANS$="v" THEN GOSUB 1130
1830 IF ANS$="T" OR ANS$="t" THEN GOSUB 1330
```

```
1840 RETURN
1850 '
1860 '
1870 '
1880 '
1890 'get precipitation data
1900 CLS:COLOR 0,7:LOCATE 1,1:PRINT"    Entering Precipitation Data    ";
1910 COLOR 7,0
1920 FOR M%=1 TO 12
1930 LOCATE M%+6,10:PRINT "Precipitation=";
1940 NEXT M%
1950 FOR M%=1 TO 12
1960 LOCATE 23,60:COLOR 31:PRINT "            ";:COLOR 10
1970 LOCATE 23,60:COLOR 31:PRINT MONTHNAME$(M%);:COLOR 10
1980 LOCATE M%+6,25:INPUT EFFECP(M%)
1990 NEXT M%
2000 LOCATE 23,60:PRINT"  Thank You  "
2010 FOR W=1 TO 400:NEXT:RETURN
```