COMPUTATION OF TIME-RELATED CAPTURE ZONES OF WELLS FOR USE WITH THE ERDAS GEOGRAPHIC INFORMATION SYSTEM

by

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I. Introduction

Program CAPZONE computes time-related "capture zones" for pumping wells in aquifers. It is designed to run on the IBM PC/AT and compatible microcomputers and is used in conjunction with program RASTER and the ERDAS graphics system to produce plots of capture zone areas. Although the program is totally interactive, one should not attempt to run program CAPZONE without (at the very least) reading chapters I, III, and appendices A and B of Chapter IV. Chapter II is included merely to define and explain capture zones. Chapter III is designed to be read while running CAPZONE for the first time and serves somewhat as a tutorial. Appendix C may be consulted if more explanation of the interactive error messages is needed. Appendix B contains information concerning legal numerical responses to prompts in the program. Appendix D contains information concerning the structures of input and output files. This section may be skimmed and be consulted as needed. Appendix A consists of sample runs of Program CAPZONE.

II. Capture Zones

A capture zone is the volume through which groundwater (carrying pollutants) flows to reach a pumping well within a given time (called the "travel time"). The capture zone is usually represented on an areal map as a capture area (1). Thus for simplicity the vertical water flow direction is neglected and the capture zone is computed as the area parallel to the surface (ignoring topography) through which the water flows to reach the pumping well within the travel time. In this manual, the term "capture zone" will refer to this area.

The capture zone is bounded by the "capture zone curve" which is the curve of equal travel time for polutant particles in the aquifer. For computational simplicity the capture zone curve is computed assuming a confined aquifer and a uniform regional flow.

The equation of the capture zone curve (eq. (1)) was derived by Bear and Jacobs (2):

$$(1) \quad e(x' - t') = \cos(y') + (x'/y')\sin(y')$$

where:

$$t' = (2\ vo\ B/(nQ))t$$

$$x' = (2\ voB/Q)x$$

$$y' = (2\ voB/Q)y$$

and:

vo = uniform Darcy velocity

n = aquifer porosity

Q = well pumping rate (discharge)

B = aquifer thickness

x and y (lower case) are defined by the axes shown in Figure 1.

The capture zone curve is an elipse-like curve. For each value of x' the the value of y' is solved for by the method of successive approximations (the remaining quantities are held constant for each curve). The relative Cartesian coordinates x and y are computed from x' and y' using the equations on the previous page. These relative cartesian coordinates are then rotated by directional angle of the hydraulic gradient, translated by a distance equal to the well positional coordinates and converted to longitude, latitude pairs.

III. Running and Using Program Capzone

This whole chapter may be followed as you run CAPZONE or you may read the first 3 subsections of section A and then run CAPZONE while following the sample runs in appendix A of Chapter IV. You may refer to the remainder of chapter III as needed. The subsections of section A are organized according to each input response for easier reference.

The examples in this chapter demonstrate the differences in input, display and change, and output for the two "aquifer parameter options" (see following section). The options are discussed in parallel so pay particular attention to which option is presently being discussed.

A. Input Data

The following section is a step by step explanation of the program input. Ideally, it may be followed completely as you execute program CAPZONE for the first time. In all of the examples of questions (prompts) from the program, only the immediate prompt is shown. All legal responses are explained. All possible responses not listed are to be considered illegal and will lead to an error message and re-prompting. All user responses in the examples are written in **boldface.** An input response line may contain 1, 2 or, in a few cases, more responses. **In all cases, you must type the RETURN or ENTER key after you type all of the items in an input line.**

Program CAPZONE is executed by typing CAPZONE (followed by the RETURN or ENTER key) in response to your system prompt (this may be preceeded by a drive and pathname in MS-DOS format). You may do this now if you want to run CAPZONE while you read this chapter.

1. Choice of Aquifer Parameter Option.

After the opening messages are printed, you are first asked to choose whether you want to input a single set of aquifer parameters which will be held fixed throughout the calculation (thus these values will apply to all of the wells) or input a different set of aquifer parameters for each well. The aquifer parmeters are the following:

HYDRAULIC CONDUCTIVITY
THICKNESS
POROSITY
HYDRAULIC GRADIENT (MAGNITUDE AND DIRECTION)

In reference to these two options, the following terminology will be used in this manual from this point on:

variable aquifer parameter option: for each well, a unique and, in general, different set of values for the above aquifer parameters is read in and this unique set is used to compute the capture zone for the well.

fixed aquifer parameter option: a single set of values for the above aquifer parameters is read in and this set will apply to all wells in the calculation of their capture zones.

In a typical run of program CAPZONE the prompt for this choice of options appears as follows (remember, user responses are in boldface):

DO YOU WISH TO ENTER TO ENTER A DIFFERENT SET FOR EACH WELL?
(ENTER Y (y) OR N (n))**Y**

a response of **Y** indicates that the user chooses the variable aquifer parameter option.

a response of **N** indicates that the user has chosen the fixed aquifer parameter option.

Note that one may also enter lowercase letters **y** or **n.** This applies to all responses to yes or no prompts throughout the program. But any response besides **N, n, Y** or **y** is illegal and will result in an error message and reprompting for the response.

In this example, the user has chosen the variable parameter aquifer option.

If one chooses the variable aquifer parameter option the following very general sequence of tasks is performed by the program:

1) read in aquifer parameters, well coordinates, and pumping rate for well 1 along with the parameters that will remain the same throughout the calculation.

2) display the data for the current well and ask for changes.

3) calculate the capture zone curve for the current well. Write the longitude, latitude curve points to, the output file.

4) if there are no more wells, stop. Otherwise do step 5.

5) read in the aquifer parameters, well coordinates, and pumping rates for the next well.

6) go to step 2.

If one chooses the fixed parameter option the sequence is more simple:

1) read in all data except well coordinates and pumping rates.

2) read in coordinates and pumping rates for all wells.

3) display the data for all wells and ask for changes.

4) calculate capture zone curves for all wells. (aquifer parameters for all wells are the same and were read in in step 1.)

5) stop.

2. Input File or Keyboard?

The next immediate input prompt asks whether the input data will be read from an input file or be typed in at the keyboard.

The actual prompt from the program is as follows:

```
DO YOU WISH TO ENTER DATA FROM AN INPUT FILE?
 (ENTER Y (OR y) FOR FILE, N (OR n) FOR KEYBOARD)N
```

legal responses: Y indicates that input is to come from an input file.

N indicates that data is to be typed in from the keyboard.

lower case letters y and n are also legal (with the same meanings as Y and N respectively).

Anything else is illegal.

In this example the user indicated that data is to come from the keyboard.

If you are doing your first calculation with a particular set of data it is better to enter the data from the keyboard in response to the questions (prompts) and, if desired, save the data to a file which may be used as the input file to later calculations. It is always advisable to save the input entered from the keyboard since you may want to make future runs with sets of data which differ only in a few of the data items. Once a data file is saved, it is easy to read in the data from the file and alter the appropriate data for the new calculation.

3. Input Data File Name.

If you had chosen to enter data from an input file, the next prompt will ask you for the name of this file. The actual prompt is shown below:

PLEASE ENTER THE NAME OF THE INPUT FILE: **D:\EXD\EXAMPLE.DAT**

The file name may be up to 30 characters long and will be truncated (cut off at the right end) if it is longer than 30 characters.

for example:

A file named thisisanextremelylongnameforafile will be read as thisisanextremelylongnameforaf.

If the file is not present, an error message will be printed and you will be asked whether you wish to continue. If you respond with N or n the program will terminate and you can check your directory. If you respond with a Y (or a y) you will be asked again whether you want data to be entered from the keyboard or from a file. From there on everything is the same as in subsections 2 and 3.

In the above example, the user requested input from a file on a disk with drive specification "D", in directory EXD with primary filename "EXAMPLE" and extension "DAT". See your system manual for the rules regarding file and pathname construction.

If the requested file is not a CAPZONE input data file, an error message will be appear and the program will terminate.

If the requested file is not compatible with the aquifer parameter option chosen (that is, in this particular run of program CAPZONE the variable aquifer parameter option was chosen and the file contains data for a fixed aquifer parameter calculation or vice-versa), an error message will appear and the program will terminate.

If you have chosen to enter data from a data file this will be all that you need to enter from the keyboard (aside from naming the output file (sec. 10)) unless you decide to change some of your existing data values. The file will be read and the data will be displayed in list form (see section B of this chapter).

4. Longitude and Latitude of the Northwest Corner.

If you have chosen to enter data from the keyboard you will be first asked to enter the longitude and latitude of the northwest corner of the quadrangle containing the wells.

The user prompt from the program is shown below:

```
PLEASE ENTER THE LONGITUDE AND
LATITUDE OF THE NORTHWEST CORNER
OF THE QUADRANGLE CONTAINING THE
WELLS (LONGITUDE, LATITUDE): 96.125, 38.125
```

legal responses: any 2 legal FORTRAN numbers (appendix B) separated by a comma or at least one space.

Character data input (letters or symbols, usually typos) is, of course, illegal in response to this prompt. It will result in appearance of an error message and re-prompting for

input.

Note that there are two data items to be typed in response to this prompt. If you type one in and hit the return key prematurely (before you type the other one) simply type the second one (latitude) in and hit return again. If you invert the order of input (type the latitude value before the longitude value) or type in a legal but incorrect value for one or more of the two data items, you will have an opportunity to correct this mistake later when the input data is displayed and you are prompted for changes.

5. Aquifer Parameter Input.

If you have chosen to enter the data from the keyboard, you will then be asked to enter the aquifer parameters. Their input is dicussed individually below.

If the fixed aquifer parameter option has been chosen, the following message will appear on the screen:

PLEASE ENTER THE FOLLOWING AQUIFER PARAMETERS:

If the variable aquifer parameter option has been chosen, the number of the current well will appear on the line below this message to remind you what well the current set of aquifer parameters is to apply to.

5a1. Hydraulic Conductivity Units.

If you have chosen the fixed aquifer parameter option or if you have chosen the variable aquifer parameter option and this is the first well, you will be asked to choose your units for the hydraulic conductivity. The prompt is shown below:

PLEASE CHOOSE HYDRAULIC CONDUCTIVITY
UNITS

1. METERS/SEC.
2. GAL/DAY/FT**2
3. FT/SEC.

PLEASE ENTER THE APPROPRIATE LIST NUMBER:2

In this example, the user has chosen GAL/DAY/FT**2.

legal responses: any integer (whole number, no decimal points, please) between 1 and 3 inclusive. Anything else is illegal and will result in an error message and re-prompting.

Regardless of which aquifer parameter option has been chosen, the chosen units will apply to the hydraulic conductivity value(s) for the entire run.

If the variable aquifer parameter option has been chosen, the chosen units will apply to the hydraulic conductivities of each and every well in the run. You are not allowed to have different hydraulic conductivity units for each well. You will not even be asked to choose hydraulic conductivity units after the first well.

5a2. Hydraulic Conductivity.

The next data item that you are asked to enter is the hydraulic conuctivity. The actual prompt from the program is shown below:

```
PLEASE ENTER THE HYDRAULIC CONDUCTIVITY IN
 (GAL/DAY/FT**2):672
```

legal responses: any legal FORTRAN number (Appendix B) which is not zero or negative

anything else is illegal and will result in the display of an error message and reprompting

It is important to take heed of the units that you have chosen. A hydraulic conductivity (or any other parameter) value may be completely reasonable in one set of units but totally unreasonable in another set of units.

As stated in subsection 4, you will have the opportunity to examine all parameter values and to make appropriate changes after the data is entered and before the capture zone calculation is done.

5b1. Thickness Units.

The next item of input from the keyboard is the aquifer thickness. Before you enter the thickness for the entire region of interest (in the case of the fixed aquifer parameter option) or the thickness in the region suurounding the first well capture zone (in the case of the variable aquifer parameter option), you will be asked to choose meters or feet for your thickness units. As is the case for all of the aquifer parameters where input options such as unit choice are possible, the choice that you make applies to the entire run and to this set of data (see subsection 5a2.). The prompt with a sample user response is shown below:

```
METERS OR FEET?
(ENTER M(m) FOR METERS F(f) FOR FEET):f
```

In this example, the user has chosen to enter the thickness(es) in feet.

legal responses: M, m, F, or f

5b2. Thickness.

The next item of input, the aquifer thickness, is then entered in the chosen units. The prompt is shown below:

```
PLEASE ENTER THE THICKNESS IN    (FEET):252
```

In the example, the user has entered an aquifer thickness of 252 feet. (Remember, as for all of the aquifer parameters, this thickness will apply to all the wells if the fixed aquifer parameter option is chosen but only to the current well if the variable aquifer parameter option is chosen.)

legal responses: any nonzero or nonegative FORTRAN number. (appendix B.)

See comments regarding legal but incorrect input in section 5a2.

5c. Porosity.

The next input item, the porosity, is entered as a dimensionless fraction. The prompt with (boldface) response is shown below:

```
POROSITY (DIMENSIONLESS): .2
```

In this example the user has entered a porosity of .2 .

legal responses: any positive fraction less than or equal to 1 (i.e., any number greater than zero but less than or equal to 1).

Any value which is not a number or is less than or equal to zero or greater than 1 will cause an error message to appear and you will be re-prompted for input.

5d1. Input Format Choice for Hydraulic Gradient.

The next item of keyboard input is an input format choice for hydraulic gradient. The prompt is shown below:

```
YOU MAY ENTER THE HYDRAULIC GRADIENT IN 1 OF 2 WAYS:

   1. AS A DIMENSIONLESS MAGNITUDE AND AN ANGLE
      OF DIRECTION WITH RESPECT TO DUE NORTH
      (MEASURED CLOCKWISE FROM DUE NORTH)
   2. AS X AND Y COMPONENTS (DIMENSIONLESS) WHERE:
      A POSITIVE X COMPONENT INDICATES EASTWARD
      A POSITIVE Y COMPONENT INDICATES NORTHWARD

PLEASE ENTER THE NUMBER INDICATING YOUR CHOICE:1
```

Hydraulic gradient is a vector quantity. It has both magnitude and direction. In format choice 1, the hydraulic gradient is specified by entering the total hydraulic gradient scalar magnitude followed by an angle specifying its direction. The angle is measured with respect to an axis pointing due north from the midpoint of the quadrangle (see fig.1). In format choice 2, the hydraulic gradient is entered by specifying two perpendicular components. The first, labeled "x" is the component in the east-west direction. It is positive if it is eastward and negative if it is westward. The second, labeled "Y" is the component in the north-south direction. It is positive if northward and negative if southward (see next subsection for more details).

legal responses: the whole numbers 1 or 2 only.
all other responses are illegal

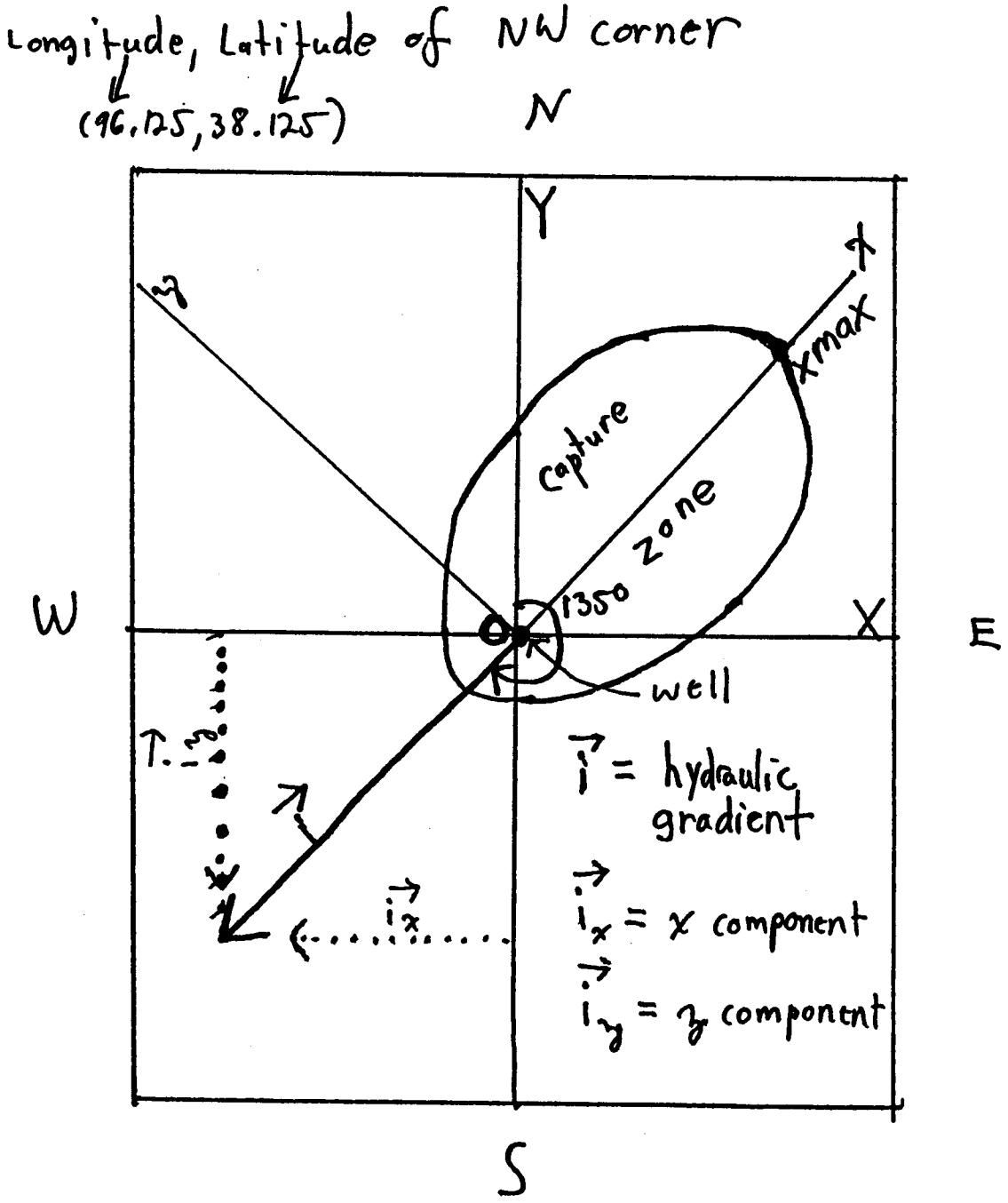

Fig. 1. Well located at center of 7.5 minute quadrangle. Hydraulic gradient vector and capture zone shown.

As is the case for all unit choices, once it is selected, the choice of hydraulic gradient input format may not be changed during the entire calculation (run of CAPZONE). If the input data is subsequently written to a file and this file is read in a later run of CAPZONE, the choice of hydraulic gradient input format is preserved and cannot be changed while the program is running. One must properly alter the input data file to change the input format for hydraulic gradient (see appendix D).

5d2. Hydraulic Gradient.

The next item of keyboard input is the hydraulic gradient vector. If format 1 was chosen (see the prompt example in the previous subsection), the prompt for the total hydraulic gradient and directional angle will be that shown below:

```
PLEASE ENTER THE MAGNITUDE OF THE DIMENSIONLESS
HYDRAULIC GRADIENT FOLLOWED BY THE DIRECTIONAL
ANGLE (IN DEGREES)  (GRADIENT, ANGLE):.003,135
```

legal responses: 2 legal FORTRAN real numbers (Appendix B) separated by a comma or 1 or more spaces.

The hydraulic gradient (first item on the input line) must be nonzero and nonnegative.

As is indicated in the prompt message in the example above, the first item on the input line is the hydraulic gradient, the second is the directional angle measured clockwise from the north (see previous section).

As is the case for any prompt with more than 1 response to a line, if you hit the return key prematurely just type the next data item and hit return after all data items required are entered.

See section 5a2 for comments regarding entering legal but incorrect values for aquifer parameters.

If format 2 is chosen (see previous section) the 2 input prompts will be those shown below:

```
PLEASE ENTER THE DIMENSIONLESS GRADIENT
COMPONENTS:

X DIRECTION (POSITIVE IF EASTWARD) : .002121
Y DIRECTION (POSITIVE IF NORTHWARD) : -.002121
```

legal responses (prompt for x direction): any legal FORTRAN number.

(prompt for y direction): same as above but cannot be zero if x component is zero.

See section 5a2 for comments regarding entering incorrect but legal values for these an any other aquifer parameters.

This concludes the entry of the aquifer parameters. As stated section 1, If the variable aquifer parameter option is chosen, you will have to enter values for each of these parameters for each well. You can enter the unit and format choices only **once** during the input session for the first well.

If the fixed aquifer parameter option is chosen, you enter values, unit choices, and format choices only **once.**

In the example above the user has input a hydraulic gradient with eastward component .002121 and southward compinent of .002121. This results in a hydraulic gradient with a magnitude of .003 and a direction of 135 degrees with respect to due north (same as in the example for format 1).

6. Time of Pumping to the Present.

After the aquifer parameters (for well 1 if variable aquifer parameter option is in effect), unit choices, and format choices have been entered. The next input item that is asked for is the time of pumping to the present or travel time (see section II). The prompt is shown below:

TIME OF PUMPING TO THE PRESENT (YEARS): **10**

In this example the user has chosen to compute capture zones for a time of ten years.

legal responses: Any nonegative FORTRAN real number (Appendix B.).

If the time of pumping to the present (or any other parameter) is such that the maximum travel distance along the x axis in figure 1 (point labeled 0 to point labeled XMAX) is greater than 15 miles, a warning message will appear and you will be asked if you wish to continue (see Appendix C for more details regarding this and all warning and error messages). If you respond Y (or y) the calculation will be performed and capture zones will be produced but they may not be accurate since the parameter data used may not be representative of the aquifer over such a large distance. If you respond N (or n) to this question, the program will terminate.

You will enter the time of pumping to the present only once per run of program CAPZONE regardless of the aquifer parameter option that you have chosen. You cannot have different times for different wells. You may change the time of pumping to the present before the calculation of the first well capture zone begins (see Displaying and Changing Data) as many times as is needed (if you make mistakes, for example).

7. Total Number of Wells.

The next input item is the total number of wells for this run of program CAPZONE. The prompt is shown below:

NUMBER OF WELLS : 2

In this example the user has chosen to calculate capture zones for 2 wells.

legal responses: Any positive FORTRAN integer
(wholenumber---NO DECIMAL POINTS ALLOWED--see Appendix B)
less than or equal to 50.

Warning——— IF YOU HAVE CHOSEN THE VARIABLE AQUIFER PARAMETER OPTION YOU MAY NOT CHANGE THE TOTAL NUMBER OF WELLS ONCE IT IS ENTERED.

If you have chosen the fixed aquifer parameter option you may change the number of wells. If you do, you will have to enter the coordinates and pumping rates for all new wells.

8. Well Coordinate Input.

8a. Well Coordinate Input Units.

The next prompt asks the user to choose between two types of units for the input well coordinates. There are two choices: 1) longitude latitude pairs and, 2) meters with respect to the center of the quadrangle (see Fig. 2). The prompt and user response are shown below:

```
YOU MAY ENTER THE WELL
CO-ORDINATES IN METERS OR IN
LONGITUDE, LATITUDE. ENTER AN
 'L' IF LONGITUDE,LATITUDE
AN 'M' IF IN METERS : L
```

In this example the user has chosen to enter the well coordinates in longitude, latitude pairs. The legal responses are shown below:

legal responses: L, l, M, m

If you type L or l, the well coordinates that you type in must be in longitude and latititude pairs.

If you type M or m, the well coordinates that you type in must be in meters with respect to the center of the quadrangle (i.e., the coordinates of the quadrangle center are 0,0). The east-west coordinate is called "X" (east is positive). The north-south coordinate is called "Y" (north is positive). For more details see the following subsection and Figs. 1 and 2.

As with all unit choices in program CAPZONE you choose your units of well coordinate input only once and this input choice applies to all wells. If you save your input data to a data file this choice is preserved and will apply to all runs of program CAPZONE using this data file. You can not change any units while running program CAPZONE. If you need to change the units of any of your input data (where a unit choice exists) this usually can be accomplished by very simple editing of the input data file (see appendix D).

8b. Well Coordinates.

The next items of input are the coordinates of the wells. If you have chosen the variable aquifer parameter option you will enter the coordinates of one and only one well at this time---the current well (the one for which you have been typing in data up until now--well 1 if you are following the examples.) If you have chosen the fixed aquifer parameter option you must enter the well coordinates of all wells at this point. The legal responses followed by four illustrative examples are shown below. The input units are those chosen by the user:

legal responses: 2 FORTRAN real numbers separated by a comma or at least one space

example 1:

program prompt followed by user input for the case where the user has chosen the variable aquifer parameter option with longitude, latitude as the unit choice:

```
COORDINATES OF WELL   1 (LONGITUDE,LATITUDE): 96.0625, 380625
```

example 2:

the same prompt followed by user input for the variable aquifer parameter case with meters with respect to the quadrangle center as the unit choice:

```
COORDINATES OF WELL   1 (X, Y)              : 0, 0
```

example 3:

same as example 1 but for fixed aquifer parameter option:

```
COORDINATES OF WELL   1 (LONGITUDE, LATITUDE): 96.0625, 38.0625
COORDINATES OF WELL   2 (LONGITUDE, LATITUDE): 96.0313, 38.0313
```

example 4:

same as example 2 but for fixed parameter option:

```
COORDINATES OF WELL   1 (X, Y)          : 0, 0
COORDINATES OF WELL   2 (X, Y)          : 2755, -3475
```

See fig. 2 for diagram of quadrangle of the above examples.

Remember that if the variable aquifer parameter option is in effect you do not enter any of the data for well 2 until well 1 capture zone has been computed.

9. Pumping Rate Input.

9a. Pumping Rate (Discharge) Units.

The next item of input is the choice of pumping rate units. There are three choices. The prompt is shown below:

```
PLEASE CHOOSE PUMPING RATE
UNITS
1.    METERS**3/SEC.
2.    GAL/MIN
3.    FT**3/SEC.

PLEASE ENTER THE APPROPRIATE LIST NUMBER:2
```

In this example the user has chosen to enter the pumping rates in gallons per minute. The legal responses to this prompt are summmarized below:

legal responses: the integers 1, 2 or 3. (whole numbers, NO DECIMAL POINTS!!!)

Once you have chosen the pumping rate units for this run, you may not change them during the run. If you save the data to a file and rerun the program using this data file, the pumping rate units as well as all of the other chosen units will be preserved and can only bechanged by editing the data file and not during a run of CAPZONE (see Appendix D).

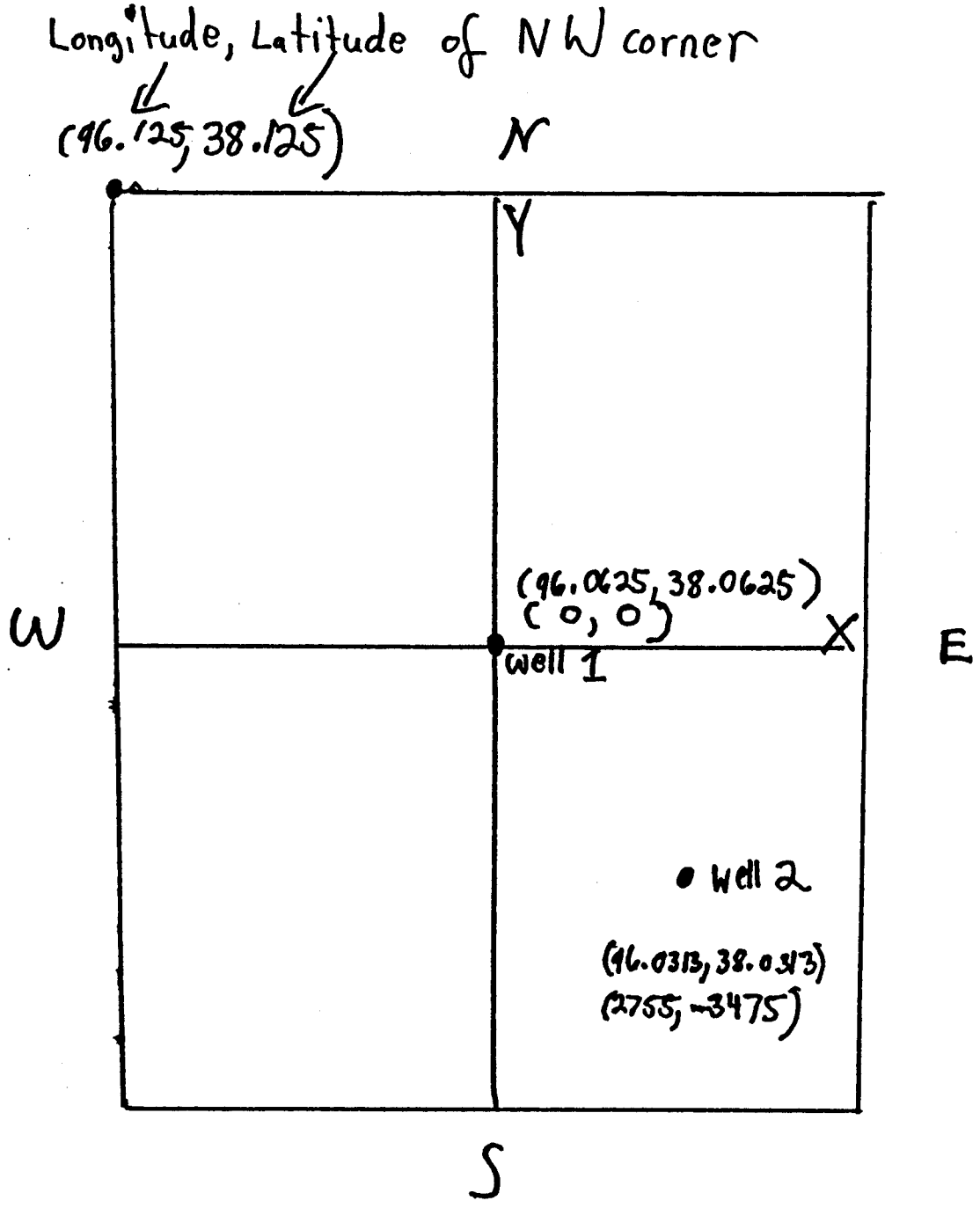

Fig. 2. Wells of examples 1,2,3 and 4 of section 9b. Relationships between coordinates shown.

9b. Pumping Rates (Discharges).

The Rules regarding pump rate input are similar to well coordinate input and are demonstrated by the examples below (after the summary of legal responses):

legal responses: Any nonzero or nonegative FORTRAN real number (Appendix B.).

example 1: This example is for variable aquifer parameter option:

```
PLEASE ENTER THE PUMPING RATE(S)
IN (GAL/MIN)
     WELL  1 : 750
```

example 2: This example is for fixed aquifer paramter option:

```
PLEASE ENTER THE PUMPING RATE(S)
IN (GAL/MIN)
     WELL  1 : 750
     WELL  2 : 100
```

Notice that if the variable aquifer parameter option is in effect, (example 1) only the pumping rate for the current well (in the examples this is still well 1) is read in at this time. The parameters for the second well are asked for and read in upon completion of the capture zone curve for well 1.

If the fixed aquifer parameter option is in effect (example 2), the pump rates for all of the wells (in the examples there are two wells), are read in at this time, one pump rate to a line.

As in the case of the aquifer parameters, you must be sure to check the pump rate list(s) (next section) so that you can change any legal but incorrect values of the pumping rates.

10. Output File Name.

The next prompt is a request for the output file. The actual prompt from the program is shown below:

```
OUTPUT FILE NAME? (UP TO 30 CHARACTERS)
(THIS FILE WILL CONTAIN THE POINTS FOR ALL
CAPTURE ZONE CURVES):EXAMPLE.OUT
```

This prompt will appear regardless of what options you choose. The output file contains the points of all capture zone curves represented as longitude and latitude pairs.

If the requested file already exists, it will be over-written with the capture zone curve points for the current calculation. If the requested file does not exist, it will be created and the output points will be written to it. If you misspell an existing filename, a new file with the results of the calculation will be created with the misspelled name. **Any existing file that is requested in response to this question will be overwritten with the capture zone curve points. Make sure that you do not destroy any valuable files in this way.**

This file is the one containing the capture zone curve points which will be used by program RASTER to create raster graphic data for the capture zones.

This concludes the input for all of the wells if the fixed aquifer parameter option is in effect. This concludes the input for well 1 if the variable aquifer parameter option is in effect.

In the next section the displaying and changing of data values are explained.

B. Displaying and Changing of Data.

1. Displaying and Changing---The Three Lists

CAPZONE allows the user to inspect the input data and gives you the opportunity to change any of their values. This is very useful for the correction of legal but incorrect values entered at the keyboard and for changing a few of the data values while keeping the others the same for different runs.

The input data are presented in the form of data lists all very similar in format. There are three types of data lists. In this manual they will be referred to as:

1) the parameter list

This list contains the following information:

1. LONGITUDE OF NORTHWEST CORNER
2. LATITUDE OF NORTHWEST CORNER
3. HYDRAULIC CONDUCTIVITY
4. THICKNESS
5. POROSITY
6. HYDRAULIC GRADIENT (X COMPONENT OR TOTAL)
7. HYDRAULIC GRADIENT (Y COMPONENT OR ANGLE FROM NORTH)
8. TIME OF PUMPING TO PRESENT
9. (TOTAL) NUMBER OF WELLS

If the fixed aquifer parameter option is chosen, there will be only one parameter list. If the variable aquifer parameter option is chosen, there will be a different parameter list for each well.

2) the well coordinate list

The well coordinate list contains the well coordinates in the chosen units, first coordinate followed by the second one (see examples below). If the fixed aquifer parameter option is in effect, the number of coordinate pairs will be twice the number of wells, therefore the well coordinate list may be split into two or more sub-lists. Each list can have a maximum of 14 items, thus each coordinate list accommodates up to 7 wells. If the variable aquifer parameter option is in effect, there is only one pair of coordinates in the list for each well (that belonging to said well). (again, see examples below).

3) Pumping rate list

The pumping rate list is similar in format to the well coordinate list. The only difference is that there is only one pumping rate per well and there are two coordinates per well. Thus in a fixed aquifer parameter calculation each pumping rate list may accomidate up to 14 wells (again, see below).

A typical display of this aquifer parameter list is shown below for the variable aquifer parameter option. This is only the first parameter list if this option is in effect.

```
****SUMMARY OF INPUT DATA VALUES****
FOR WELL .  1:

1        LONGITUDE OF NORTHWEST CORNER :        96.12500
2         LATITUDE OF NORTHWEST CORNER :        38.12500
3 HYDRAULIC CONDUCTIVITY  (GAL/DAY/FT**2 :     672.00000
4                       THICKNESS (FEET):      252.00000
5                              POROSITY :        0.20000
6           HYDRAULIC GRADIENT (TOTAL) :  0.3000000E-02
7           ANGLE FROM NORTH (DEGREES) :      135.00000
8      TIME OF PUMPING TO PRESENT(YRS.):       10.00000
9                       NUMBER OF WELLS :        2.00000

HOW MANY OF THESE PARAMETERS DO YOU WISH TO CHANGE?
 (ENTER ZERO IF NONE) : 3
```

In this example, the variable aquifer parameter option was chosen, therefore the current well is displayed on the line immediately below the list title. This would be absent if the fixed aquifer parameter option were chosen. Since the variable aquifer parameter option was chosen, there is one aquifer parameter list per well. In the above example the list for well 1 is shown. The aquifer parameter list for well 2, of course, will not be shown until the data for well 2 is entered (after the capture zone curve for well 1 is computed.) If the fixed aquifer parameter option were chosen there would only be one parameter list for the entire run.

The questions you will be asked are the same for both options and, for all practical purposes, for every list. The first is the user prompt displaed at the end of the list above. **Note that the prompt asks for the number of parameters that the user wishes to change——NOT THE LIST NUMBERS OF THE PARAMETERS. These will be asked next.**

Note that in this example from program CAPZONE, the user has chosen to change the values of three parameters. Legal responses to this prompt are enumerated below:

legal responses: Any FORTRAN integer (whole number--NO DECIMAL POINTS!!!) (appendix B) not less than zero and not greater than the number of data items in the list.

An illegal response will result in an error message being displayed, THE LIST BEING DISPLAYED AGAIN, and reprompting for input.

If the response to this prompt is zero the user has indicated that no parameters in this list are to be changed and thus the program will display the next list without asking the following question.

The next question (prompt) from the program asks for the list numbers of the data items that the user wants to change. It will not appear if the user answered zero to the previous question. The list numbers are located in the leftmost column of the list. The user prompt from the program is shown below:

```
NOW ENTER THE NUMBERS(ABOVE LIST) OF EACH ITEM
YOU WANT TO CHANGE (SEPARATED BY COMMAS) : 3,5,4
```

In the example the user has elected to change the hydraulic conductivity, the porosity and the thickness. The set of acceptable responses is enumerated below:

legal responses: Any list of FORTRAN integers (Appendix B) (whole numbers, NO DECIMAL POINTS) which correspond to any of the list numbers in the data list.

****

IF ANY ILLEGAL VALUES ARE ENCOUNTERED IN THE NUMBER LIST THAT IS ENTERED YOU WILL BE RETURNED TO THE DATA LIST AND YOU WILL BE RE-PROMPTED FOR THE NUMBER OF PARAMETERS TO BE CHANGED--NOT THE LIST NUMBERS!!! AFTER YOU RE-ENTER THIS NUMBER YOU WILL BE RE-PROMPTED FOR THE LIST. THIS IS DONE SO THAT YOU WILL RE-READ THE LIST CAREFULLY AND UNDERSTAND WHAT TO ENTER. IF YOU ARE FOLLOWING THE EXAMPLES AS A TUTORIAL, PURPOSELY MAKE MISTAKES IN YOU RESPONSE TO THIS PROMPT A FEW TIMES SO THAT YOU UNDERSTAND THIS CLEARLY.

****

If there is more than one parameter to be changed, any two list numbers must be separated by a comma or at least one space. If the user types the return key prematurely it is only necessary to type the remaining numbers separated by commas and then a carriage return. (the return key is treated as a space if the list is incomplete) If the user enters more numbers in the list than the num of parameters to be changed (previous prompt), the extraneous numbers will be ignored. If the user enters less numbers than are required, the program will not resume until all of the numbers are entered.

Next, the user enters the new values of each of the parameters that are to be changed. One prompt will appear for each parameter that is to be changed. The program prompts for the changes requested in the above examples are shown below:

```
PLEASE ENTER NEW HYDRAULIC CONDUCTIVITY
(GAL/DAY/FT**2) : 555

PLEASE ENTER NEW POROSITY                    :.15

PLEASE ENTER NEW THICKNESS
(FEET) :450
```

In the above examples, the legal user responses are those mentioned in section III for the respective parameters. After the user enters the new value of each of the parameters that are to be changed, CAPZONE asks whether the data list is to be printed again. This prompt is shown on the next page:

```
DO YOU WISH TO SEE THE DATA LIST AGAIN?
(ENTER Y (y) OR N (n) )N
```

The user has chosen not to display the parameter list again. Had the user responded with a y or a Y the parameter list would be displayed, it would reflect the changes made in the parameters and the user would be reprompted for further changes. It is generally a good idea to redisplay the parameter list after any changes are made to the parameters. This gives the user an opportunity to correct any mistakes in the parameter changes.

Next, the well coordinate list is displayed. If the variable aquifer parameter option is chosen, as in the example, there will be one well coordinate list per well. This list will contain only the coordinates of the current well. The display from CAPZONE is shown below:

```
*****SUMMARY OF WELL COORDINATES******

 10   LONGITUDE       COORDINATE OF WELL :   1 : 96.06250
 11   LATITUDE        COORDINATE OF WELL :   1 : 38.06250

HOW MANY OF THESE WELL COORDINATES NEED CHANGING?
 (ENTER ZERO IF NONE ) : 1
```

The rules regarding legal responses to the above prompt are identical to those mentioned concerning the parameter list. Notice that the list numbers on the left continue from where the last list left off.

Next, the desired list number is entered, the new value for the well coordinate is entered and the user elects to re-display the coordinate list. All of these prompts and the rules for their legal responses are essentially identical to the corresponding ones mentioned previously for the parameter list.

```
NOW ENTER THE NUMBERS (ABOVE LIST) OF EACH ITEM
 YOU WANT TO CHANGE (SEPARATED BY COMMAS) : 10
```

```
PLEASE ENTER THE NEW WELL COORDINATE :          96.044

DO YOU WISH TO SEE THE PARAMETER LIST AGAIN?
(ENTER Y (y) OR N (n) )Y

****SUMMARY OF WELL COORDINATES****
(CONTINUED)

 10  LONGITUDE      COORDINATE OF WELL :   1 : 96.04400
 11  LATITUDE       COORDINATE OF WELL :   1 : 38.06250

HOW MANY OF THESE WELL COORDINATES NEED CHANGING?
 (ENTER ZERO IF NONE) : 0
```

Remember, if the fixed aquifer parameter option were chosen, the coordinates for all wells would be shown in one list. If this list were to contain more than 14 well coordinates (7 wells), it would be split into two lists. If it were more than 21 wells long it would be split into three lists, and so on. In the example below, the number of wells is two, therefore the number of well coordinates is four, therefore there is only one well coordinate list.

example of well coordinate list for fixed aquifer parameter calculation with two wells:

```
****SUMMARY OF WELL COORDINATES****

 10  LONGITUDE COORDINATE OF WELL : 1   : 96.06250
 11  LATITUDE  COORDINATE OF WELL : 1   : 38.06250
 12  LONGITUDE COORDINATE OF WELL : 2   : 96.03130
 13  LATITUDE  COORDINATE OF WELL : 2   : 38.03130

HOW MANY OF THE ABOVE WELL COORDINATES NEED CHANGING?
 (ENTER ZERO IF NONE) : 0
```

Finally, the pumping rate list is displayed. The display format, prompts, and rules for legal responses to the prompts are nearly identical to those for the well coordinate list. Thus displaying and changing of pumping rate lists will be demonstrated by examples:

If variable aquifer parameter option was chosen:

```
***SUMMARY OF WELL PUMPING RATES****
(GAL/MIN)

 12 PUMPING RATE FOR WELL:     1:     750.0000

HOW MANY OF THESE PUMPING RATES NEED CHANGING?
 (ENTER ZERO IF NONE ) : 0
```

In the above example the user has elected not to change the pumping rate for well 1. Thus he (she) is not asked if the data list (in this case the pump rate list) should be listed again.

If the fixed aquifer parameter option was chosen:

```
****SUMMARY OF WELL PUMPING RATES****
(GAL/MIN)

  14 PUMPING RATE FOR WELL:     1 :  750.0000
  15 PUMPING RATE FOR WELL:     2 : 1000.0000

HOW MANY OF THESE PUMPING RATES NEED CHANGING?
 (ENTER ZERO IF NONE ) : 2

NOW ENTER THE NUMBERS (ABOVE LIST) OF EACH ITEM
YOU WANT CHANGED (SEPARATED BY COMMAS) : 14,15

PLEASE ENTER NEW PUMPING RATE :              (GAL/MIN) :500

PLEASE ENTER NEW PUMPING RATE :              (GAL/MIN) :700

DO YOU WISH TO SEE THE PUMP RATE LIST AGAIN?
(ENTER Y(y) OR N(n)) :Y

****SUMMARY OF WELL PUMPING RATES****
(GAL/MIN)

 14  PUMPING RATE FOR WELL:     1 : 500.0000
 15  PUMPING RATE FOR WELL:     2 : 700.0000

HOW MANY OF THESE PUMPING RATES NEED CHANGING ?
(ENTER ZERO IF NONE ) : 0
```

2. Saving the Data.

2a. Choice of Saving or Not Saving the Data.

Next, if data has been entered from the keyboard or if any changes to the input data have been made, the user is asked if the data is to be saved (in the case of keyboard input) or rewritten (in the case of data file input where some of the data has been changed). The prompt is shown below:

DO YOU WISH TO SAVE THE DATA? (Y OR N) Y

The legal responses to this prompt are identical to those of all other yes or no responses.

Y (or y)	indicates that data is to be saved or overwritten
N (or n)	indicates that data is not to be saved or overwritten

If the variable aquifer parameter option is in effect and input has been entered from the keyboard the user is asked the above question only once----after all lists for the first well have been displayed and all changes have been made. If he (she) answers Y or y the data for each well will be saved after all lists for that well have been displayed and all changes to the data (if any) have been made. If he (she) answers N or n to the above prompt none of the data for any of the wells will be saved.

If the variable aquifer parameter option is in effect and the input data has been entered from a data file, the user is asked this question for each well after all of the data for the well has been displayed **and at least one change has been made to the data lists for the well.** If the data lists for that well are merely displayed and the user answered a zero to the number of data to be changed for each list, the above question is omitted for that well (If there were no changes to the data for a well, there is no need to update the data for that well on the file). If the user answers Y or y to the above question for a given well, the data for that well on the file is overwritten (updated reflecting the changes to the data list(s) for the well. If the user answers N or n to the above question for a given well, the new data for that well is not saved to the file even though it is used in the calculation of that well's capture zone curve.

If the fixed aquifer parameter option is in effect and data has been entered from the keyboard the user is asked the above question after all of the lists have been displayed and all of the changes have been made (remember, there is only one parameter list, well coordinate list and pumping rate list, the last two of which may be split into smaller sublists, for the entire calculation if this option is in effect) a Y or y answer to the above question will cause all of the input data to be saved to a file. If the user anwers N or n, none of the data will be saved to a file.

If the fixed aquifer parameter option is in effect and input has been entered from a data file, the above question is asked only if at least one change was made to any of the data lists. An answer of Y or y to the question will cause the data file to be updated reflecting the changes made. An answer of N or n to the above question will mean that the file will not be changed even though the changes will be used in the calculation of capture zones (for all wells).

In all cases, if the user answers Y or y to the above question and data was entered from the keyboard, the user will then be asked to enter the name of the file to which the data is to be saved. This is how keyboard input data is saved for future runs.

If the user answers Y or y to the above question and data was entered from a data file, It is thist file (whose name was typed in answer to the input file prompt, subsection 3) that will be updated reflecting all changes to the data.

2b. Name of File Where Data is to be Saved.

If data was entered from the keyboard and a Y or Y was answered to the previous question, the user will be asked for the name of the file where the data (entered from the keyboard) is to be saved. It is this file which may be used as an input file for future runs of CAPZONE. The prompt is shown below:

FILE NAME--? (FULL NAME UP TO 30 CHARS.):**EXSAV.DAT**

In this example, the user has indicated that the data is to be saved to a file named EXSAV.DAT

The rules for legal responses to this question are identical to those for the input filename prompt (subsection 3, section A of this chapter) and the output filename prompt (subsection 10, section A of this chapter).

C. Calculation of Capture Zones and Further Entry of Data.

If the fixed aquifer parameter option has been chosen, CAPZONE will now compute the capture zone curves for all of the wells. These are then written to the output file entered in the response to the prompt of subsection 10 of section A of this chapter.

If the variable aquifer parameter option has been chosen, the capture zone for well 1 will be computed and written to the output file. After this is done CAPZONE will begin to ask you for the aquifer parameter data for well 2 (if there is only 1 well you may use either option). Some of the data items that were entered with the aquifer parameters of well 1 must remain the same for all wells, thus they cannot be reentered or changed after the capture zone curve for well 1 has been computed. These are listed below:

LONGITUDE AND LATITUDE OF NORTHWEST CORNER OF QUAD.
ALL UNIT INPUT AND FORMAT CHOICES
TIME OF PUMPING TO THE PRESENT
TOTAL NUMBER OF WELLS

You will not be asked to enter data for these items again.

If you are running CAPZONE as you read this manual and have been entering the data from the examples using the variable aquifer parameter option, You may now enter your own values for the aquifer parameters of well 2. For the well coordinates and pumping rate for well 2 you may use your own values or use those from the previous examples for the fixed aquifer parameter option. Once you have entered the data for well 2, It will be displayed and you may make changes (except for the data items listed above), then the capture zone for well 2 will be calculated. If you are following the examples, there are no more wells, so the program will terminate.

If you need to see more examples of runs using both options, please see appendix A.

IV. Appendices.

Appendix A. Sample Runs of Capzone.

The following pages contain samples of actual runs of CAPZONE. If you have questions about some of the input items illustrated please consult the appropriate section of chapter III. All user responses are in **boldface.**

1. Using the variable Aquifer Parameter Option.

```
D:\>CAPZONE

                PROGRAM CAPZONE
                VERSION 1.34
                KANSAS GEOLOGICAL SURVEY


              AQUIFER PARAMETERS:

              HYDRAULIC CONDUCTIVITY
              THICKNESS
              POROSITY
              HYDRAULIC GRADIENT (2 PARAMETERS DEFINE IT)

              FOR THESE PARAMETERS YOU MAY ENTER 1 SET OF
              PARAMETERS FOR ALL WELLS OR A DIFFERENT SET
              FOR EACH WELL

DO YOU WISH TO ENTER A DIFFERENT SET FOR EACH WELL?
          (ENTER Y (y) OR N (n) )

              ALL INPUT DATA MAY BE READ FROM AN INPUT FILE
              (IF SUCH A FILE EXISTS) OR IT MAY BE ENTERED
              FROM THE KEYBOARD. IF THIS IS THE FIRST TIME
              THAT YOU HAVE RUN THE PROGRAM, YOU USUALLY ENTER
              THE DATA FROM THE KEYBOARD.  IF THIS IS NOT THE
              FIRST TIME THEN YOU MAKE A CHOICE WHETHER TO ENTER
              FROM AN EXISTING FILE OR FROM THE KEYBOARD.  IN
              EITHER CASE YOU WILL HAVE A CHANCE TO CHANGE ANY
              UNDESIRABLE VALUES OF THE INPUT DATA.

              DO YOU WISH TO ENTER DATA FROM AN INPUT FILE?
               (ENTER Y (OR y) FOR FILE, N (OR n) FOR KEYBOARD):N


               PLEASE ENTER THE LONGITUDE AND
               LATITUDE OF THE NORTHWEST CORNER
               OF THE QUADRANGLE CONTAINING THE
               WELLS (LONGITUDE, LATITUDE): 96.125, 38.125
```

```
    PLEASE ENTER THE FOLLOWING AQUIFER PARAMETERS:

    FOR WELL   1:

         HYDRAULIC CONDUCTIVITY:


              PLEASE CHOOSE HYDRAULIC CONDUCTIVITY
                        UNITS
         1.   METERS/SEC.
         2.   GAL/DAY/FT**2
         3.   FT/SEC.

          PLEASE ENTER THE APPROPRIATE LIST NUMBER:2


         PLEASE ENTER THE HYDRAULIC CONDUCTIVITY IN
          (GAL/DAY/FT**2)  :700

          THICKNESS:
         METERS OR FEET?
          (ENTER M (m) FOR METERS, F (f) FOR FEET):F

          PLEASE ENTER THE THICKNESS IN (FEET)          :252
          POROSITY (DIMENSIONLESS): .15

REGIONAL HYDRAULIC GRADIENT---

     YOU MAY ENTER THE REGIONAL HYDRAULIC GRADIENT IN 1 OF 2 WAYS

        1. AS A DIMENSIONLESS  MAGNITUDE AND AN ANGLE
           OF DIRECTION WITH RESPECT TO DUE NORTH
           (MEASURED CLOCKWISE FROM NORTH)
        2. AS X AND Y COMPONENTS (DIMENSIONLESS) WHERE:
           A POSITIVE X COMPONENT INDICATES EASTWARD
           A POSITIVE Y COMPONENT INDICATES NORTHWARD.

 PLEASE ENTER THE NUMBER INDICATING YOUR CHOICE:1

PLEASE ENTER THE MAGNITUDE OF THE DIMENSIONLESS
HYDRAULIC GRADIENT FOLLOWED BY THE DIRECTIONAL
 ANGLE (IN DEGREES)  (GRADIENT, ANGLE):.003,135
```

```
PLEASE ENTER THE FOLLOWING 2 DATA ITEMS
WHICH WILL REMAIN UNCHANGED THROUGHOUT
THE COMPUTATION:
 TIME OF PUMPING TO PRESENT:(YEARS): 10
 NUMBER OF WELLS : 2


 YOU MAY ENTER THE WELL
 CO-ORDINATES IN METERS OR IN
 LONGITUDE, LATITUDE. ENTER AN
  'L' IF LONGITUDE,LATITUDE,
 AN 'M' IF IN METERS : L


PLEASE ENTER THE FOLLOWING WELL DATA
FOR WELL   1:

      CO-ORDINATES OF WELL   1
        (LONGITUDE, LATITUDE) : 96.06251,38.6265



       PLEASE CHOOSE PUMPING RATE
                UNITS
1.    METERS**3/SEC.
2.    GAL/MIN.
3.    FT**3/SEC.

 PLEASE ENTER THE APPROPRIATE LIST NUMBER:2


PLEASE ENTER THE PUMPING RATE(S):          IN  (GAL/MIN)
      WELL   1 : 500


OUTPUT FILE NAME? (UP TO 30 CHARACTERS)
(THIS FILE WILL CONTAIN THE POINTS FOR ALL
 CAPTURE ZONE CURVES):VAROUT.DAT
```

```
 ****SUMMARY OF INPUT DATA VALUES****
 FOR WELL   1:


 1        LONGITUDE OF NORTHWEST CORNER :              96.12500
 2         LATITUDE OF NORTHWEST CORNER :              38.12500
 3 HYDRAULIC CONDUCTIVITY  (GAL/DAY/FT**2) :          700.00000
 4                    THICKNESS (FEET)   :            252.00000
 5                             POROSITY :              0.15000
 6           HYDRAULIC GRADIENT (TOTAL) :         0.3000000E-02
 7           ANGLE FROM NORTH (DEGREES) :            135.00000
 8      TIME OF PUMPING TO PRESENT(YRS.):             10.00000
 9                      NUMBER OF WELLS :              2.00000

HOW MANY PARAMETERS DO YOU WISH TO CHANGE?
 (ENTER ZERO IF NONE) : 0


****SUMMARY OF WELL COORDINATES****

 10  LONGITUDE      COORDINATE OF WELL :   1 :         96.06251
 11  LATITUDE       COORDINATE OF WELL :   1 :         38.06265

HOW MANY OF THESE WELL COORDINATES NEED CHANGING?
 (ENTER ZERO IF NONE) : 2


NOW ENTER THE NUMBERS(ABOVE LIST) OF EACH ITEM
  YOU WANT TO CHANGE (SEPARATED BY COMMAS) : 10,11

 PLEASE ENTER NEW WELL COORDINATE :                   96.0555


 PLEASE ENTER NEW WELL COORDINATE :                   38.0444



DO YOU WISH TO SEE THE DATA LIST AGAIN?
 (ENTER Y (y) OR N (n) )Y


****SUMMARY OF WELL COORDINATES****

 10  LONGITUDE      COORDINATE OF WELL :   1 :         96.05550
 11  LATITUDE       COORDINATE OF WELL :   1 :         38.04440

HOW MANY OF THESE WELL COORDINATES NEED CHANGING?
 (ENTER ZERO IF NONE) : 0
```

```
****SUMMARY OF WELL PUMPING RATES****
(GAL/MIN)

 12  PUMPING RATE FOR WELL:     1:         500.0000

HOW MANY OF THESE PUMPING RATES NEED CHANGING?
 (ENTER ZERO IF NONE ) : 1


NOW ENTER THE  NUMBERS(ABOVE LIST) OF EACH ITEM
 YOU WANT CHANGED (SEPARATED BY COMMAS) : 12


PLEASE ENTER NEW PUMPING RATE :
 (GAL/MIN)       497.5



DO YOU WISH TO SEE THE PUMP RATE LIST AGAIN?
 (ENTER Y(y) OR N(n)) :Y


****SUMMARY OF WELL PUMPING RATES****
(GAL/MIN)

 12  PUMPING RATE FOR WELL:     1:         497.5000

HOW MANY OF THESE PUMPING RATES NEED CHANGING?
 (ENTER ZERO IF NONE ) : 0


-------PARAMETERS ACCEPTED

 DO YOU WISH TO SAVE THE DATA? (Y OR N) Y

FILE NAME-- ? (FULL NAME UP TO 30 CHARACTERS) VARSAV.DAT

WRITING DATA TO FILE: VARSAV.DAT


 CALCULATING FOR WELL :    1
```

```
PLEASE ENTER THE FOLLOWING AQUIFER PARAMETERS:

FOR WELL   2:

     HYDRAULIC CONDUCTIVITY:


     PLEASE ENTER THE HYDRAULIC CONDUCTIVITY IN
      (GAL/DAY/FT**2)  :856

      PLEASE ENTER THE THICKNESS IN (FEET)        :211
      POROSITY (DIMENSIONLESS): .16

    REGIONAL HYDRAULIC GRADIENT---


    PLEASE ENTER THE MAGNITUDE OF THE DIMENSIONLESS
    HYDRAULIC GRADIENT FOLLOWED BY THE DIRECTIONAL
     ANGLE (IN DEGREES)  (GRADIENT, ANGLE):.0021345,125


    PLEASE ENTER THE FOLLOWING WELL DATA
    FOR WELL   2:

         CO-ORDINATES OF WELL   2
           (LONGITUDE, LATITUDE) : 96.1234,38.1432

    PLEASE ENTER THE PUMPING RATES(S):          IN (GAL/MIN)
          WELL   2 : 775


    ****SUMMARY OF INPUT DATA VALUES****
    FOR WELL   2:


 1        LONGITUDE OF NORTHWEST CORNER :          96.12500
 2         LATITUDE OF NORTHWEST CORNER :          38.12500
 3 HYDRAULIC CONDUCTIVITY  (GAL/DAY/FT**2) :      856.00000
 4                  THICKNESS (FEET)   :          211.00000
 5                          POROSITY :            0.16000
 6           HYDRAULIC GRADIENT (TOTAL) :     0.2134500E-02
 7           ANGLE FROM NORTH (DEGREES) :          125.00000
 8      TIME OF PUMPING TO PRESENT(YRS.):           10.00000
 9                    NUMBER OF WELLS :             2.00000

HOW MANY PARAMETERS DO YOU WISH TO CHANGE?
 (ENTER ZERO IF NONE) : 0
```

```
****SUMMARY OF WELL COORDINATES****

 10 LONGITUDE        COORDINATE OF WELL :   2 :       96.12340
 11 LATITUDE         COORDINATE OF WELL :   2 :       38.14320

HOW MANY OF THESE WELL COORDINATES NEED CHANGING?
 (ENTER ZERO IF NONE) : 1


NOW ENTER THE NUMBERS(ABOVE LIST) OF EACH ITEM
  YOU WANT TO CHANGE (SEPARATED BY COMMAS) : 11

 PLEASE ENTER NEW WELL COORDINATE :                 38.04356



DO YOU WISH TO SEE THE DATA LIST AGAIN?
 (ENTER Y (y) OR N (n) )Y


****SUMMARY OF WELL COORDINATES****

 10  LONGITUDE       COORDINATE OF WELL :   2 :       96.12340
 11  LATITUDE        COORDINATE OF WELL :   2 :       38.04356

HOW MANY OF THESE WELL COORDINATES NEED CHANGING?
 (ENTER ZERO IF NONE) : 0


****SUMMARY OF WELL PUMPING RATES****
(GAL/MIN)

 12  PUMPING RATE FOR WELL:    2:        775.00000

HOW MANY OF THESE PUMPING RATES NEED CHANGING?
 (ENTER ZERO IF NONE ) : 0


--------PARAMETERS ACCEPTED

WRITING TO DATA FILE: VARSV.DAT


 CALCULATING FOR WELL :   2
```

2. Using the Fixed Aquifer Parameter Option.

```
D:\>CAPZONE

            PROGRAM CAPZONE
            VERSION 1.34
            KANSAS GEOLOGICAL SURVEY



          AQUIFER PARAMETERS:

          HYDRAULIC CONDUCTIVITY
          THICKNESS
          POROSITY
          HYDRAULIC GRADIENT (2 PARAMETERS DEFINE IT)

          FOR THESE PARAMETERS YOU MAY ENTER 1 SET OF
          PARAMETERS FOR ALL WELLS OR A DIFFERENT SET
          FOR EACH WELL

DO YOU WISH TO ENTER A DIFFERENT SET FORE EACH WELL?
            (ENTER Y (y) OR n (n) )N

          ALL INPUT DATA MAY BE READ FROM AN INPUT FILE
          (IF SUCH A FILE EXISTS) OR IT MAY BE ENTERED
          FROM THE KEYBOARD.  IF THIS IS NOT THE FIRST TIME
          THAT YOU HAVE RUN THE PROGRAM, YOU USUALLY ENTER
          THE DATA FROM THE KEYBOARD.  IF THIS IS NOT THE
          FIRST TIME THN YOU HAVE A CHOICE WHETHER TO ENTER
          FROM AN EXISTING FILE OR FROM THE KEYBOARD.  IN
          EITHER CASE YOU WILL HAVE A CHANCE TO CHANGE ANY
          UNDESIRABLE VALUES OF THE INPUT DATA.

          DO YOU WISH TO ENTER DATA FROM AN INPUT FILE?
           (ENTER Y (OR y) FOR FILE, N (OR n) FOR KEYBOARD):N


          PLEASE ENTER THE LONGITUDE AND
          LATITUDE OF THE NORTHWEST CORNER
          OF THE QUADRANGLE CONTAINING THE
          WELLS (LONGITUDE, LATITUDE): 96.125,38.125
```

```
PLEASE ENTER THE FOLLOWING AQUIFER PARAMETERS:

     HYDRAULIC CONDUCTIVITY:

           PLEASE CHOOSE HYDRAULIC CONDUCTIVITY
                    UNITS
     1.    METERS/SEC.
     2.    GAL/DAY/FT**2
     3.    FT/SEC.

      PLEASE ENTER THE APPROPRIATE LIST NUMBER:2


     PLEASE ENTER THE HYDRAULIC CONDUCTIVITY IN
      (GAL/DAY/FT**2)  :755

      THICKNESS :
     METERS OR FEET?
      (ENTER M (m) FOR METERS, F (f) FOR FEET):M

      PLEASE ENTER THE THICKNESS IN (METERS)        :66
      POROSITY (DIMENSIONLESS): .16

    REGIONAL HYDRAULIC GRADIENT---

         YOU MAY ENTER THE HYDRAULIC GRADIENT IN 1 OF 2 WAYS

            1. AS A DIMENSIONLESS  MAGNITUDE AND AN ANGLE
               OF DIRECTION WITH RESPECT TO DUE NORTH
               (MEASURED CLOCKWISE FROM NORTH)
            2. AS X AND Y COMPONENTS (DIMENSIONLESS) WHERE:
               A POSITIVE X COMPONENT INDICATES EASTWARD
               A POSITIVE Y COMPONENT INDICATES NORTHWARD

    PLEASE ENTER THE NUMBER INDICATING YOUR CHOICE:2
```

```
PLEASE ENTER THE DIMENSIONLESS HYDRAULIC GRADIENT
COMPONENTS:

 X DIRECTION (POSITIVE IF EASTWARD) : -.0023456
 Y DIRECTION (POSITIVE IF NORTHWARD) : -.0023456


PLEASE ENTER THE FOLLOWING 2 DATA ITEMS
WHICH WILL REMAIN UNCHANGED THROUGHOUT
THE COMPUTATION:
 TIME OF PUMPING TO THE PRESENT:(YEARS): 15
 NUMBER OF WELLS : 3


 YOU MAY ENTER THE WELL
 CO-ORDINATES IN METERS OR IN
 LONGITUDE, LATITUDE.  ENTER AN
  'L' IF LONGITUDE,LATITUDE,
 AN 'M' IF IN METERS : L


  PLEASE ENTER THE FOLLOWING WELL DATA

      CO-ORDINATES OF WELL   1
        (LONGITUDE, LATITUDE) : 96.0625,38.0625


      CO-ORDINATES OF WELL   2
        (LONGITUDE, LATITUDE) : 96.0333,38.0333


      CO-ORDINATES OF WELL   3
        (LONGITUDE, LATITUDE) : 96.11111,38.11111


       PLEASE CHOOSE PUMPING RATE
              UNITS
1.     METERS**3/SEC.
2.     GAL/MIN.
3.     FT**3/SEC.

 PLEASE ENTER THE APPROPRIATE LIST NUMBER:2


PLEASE ENTER THE PUMPING RATE(S):          IN  (GAL/MIN)
     WELL   1 : 500
     WELL   2 : 750
     WELL   3 : 1000
```

****SUMMARY OF INPUT DATA VALUES****

1	LONGITUDE OF NORTHWEST CORNER :	96.12500
2	LATITUDE OF NORTHWEST CORNER :	38.12500
3	HYDRAULIC CONDUCTIVITY (GAL/DAY/FT**2) :	755.00000
4	THICKNESS (METERS) :	66.00000
5	POROSITY :	0.16000
6	HYDRAULIC GRADIENT (X DIR) :	-0.2345600E-02
7	HYDRAULIC GRADIENT (Y DIR) :	-0.2345600E-02
8	TIME OF PUMPING TO PRESENT(YRS.):	15.00000
9	NUMBER OF WELLS :	3.00000

HOW MANY PARAMETERS DO YOU WISH TO CHANGE?
(ENTER ZERO IF NONE) : **0**

****SUMMARY OF WELL COORDINATES****

10	LONGITUDE	COORDINATE OF WELL :	1 :		96.06250
11	LATITUDE	COORDINATE OF WELL :	1 :		38.06250
12	LONGITUDE	COORDINATE OF WELL :	2 :		96.03330
13	LATITUDE	COORDINATE OF WELL :	2 :		38.03330
14	LONGITUDE	COORDINATE OF WELL :	3 :		96.11111
15	LATITUDE	COORDINATE OF WELL :	3 :		38.11111

HOW MANY OF THESE WELL COORDINATES NEED CHANGING?
(ENTER ZERO IF NONE) : **1**

NOW ENTER THE NUMBERS(ABOVE LIST) OF EACH ITEM
YOU WANT TO CHANGE (SEPARATED BY COMMAS) : **14**

PLEASE ENTER NEW WELL COORDINATE : **96.1**

DO YOU WISH TO SEE THE DATA LIST AGAIN?
(ENTER Y (y) OR N (n))**Y**

```
 ****SUMMARY OF WELL COORDINATES****

 10  LONGITUDE       COORDINATE OF WELL :   1 :        96.06250
 11  LATITUDE        COORDINATE OF WELL :   1 :        38.06250
 12  LONGITUDE       COORDINATE OF WELL :   2 :        96.03333
 13  LATITUDE        COORDINATE OF WELL :   2 :        38.03333
 14  LONGITUDE       COORDINATE OF WELL :   3 :        96.10000
 15  LATITUDE        COORDINATE OF WELL :   3 :        38.11111

HOW MANY OF THESE WELL COORDINATES NEED CHANGING?
 (ENTER ZERO IF NONE ) : 0


****SUMMARY OF WELL PUMPING RATES****
(GAL/MIN)

 16  PUMPING RATE FOR WELL:     1:         500.0000
 17  PUMPING RATE FOR WELL:     2:         750.0000
 18  PUMPING RATE FOR WELL:     3:        1000.0000

HOW MANY OF THESE PUMPING RATES NEED CHANGING?
 (ENTER ZERO IF NONE ) : 0


-------PARAMETERS ACCEPTED

 DO YOU WISH TO SAVE THE DATA? (Y OR N) Y

FILE NAME-- ? (FULL NAME UP TO 30 CHARACTERS) FIXSAV.DAT

WRITING TO DATA FILE: FIXSAV.DAT

 CALCULATING FOR WELL : 1
                        2
                        3
```

Appendix B. FORTRAN Numbers.

The numeric keyboard responses in program CAPZONE all require FORTRAN numbers, real or integer.

Examples of legal FORTRAN integers (whole numbers) are:

```
    1
  -21
 2040
+2345
```

Each integer must be composed of digits 0 through 9. No decimal points are allowed. The integer may be preceded by a plus, a minus or one or more leading spaces (implying plus).

Examples of FORTRAN real numbers are the following:

Floating Format (what you will usually use)

```
 1.
 1.0
 0.1
 .1
 1
 2
 2.2345
 .2345
 0.2345
-6743567.1234
```

Exponential Format (scientific Notation--E or e means base 10):

```
1.234E-07    This and below mean same number
1.234E-7
-1.09898e6
.6789e-5
```

The real numbers may be typed in either format, whichever is more convienient. Real numbers may be composed of a + sign, a - sign or one or more leading spaces (implying +) followed by one or more digits (0 through 9) among which there may be included a single decimal point. You may also include the symbol E or e to indicate the base 10 in scientific notation. If you do so, the exponent following the symbol must be a FORTAN integer.

There are a few other possible, legal FORTRAN numeric format possibilities but those demonstrated by the examples above are all that you will need for responses requiring FORTRAN real numbers or integers.

Appendix C. Error and Warning Messages.

1. Error Messages:

1a. For File Input and Output:

******FILE DOES NOT EXIST ----- : <FILENAME>

An attempt was made to access a file (<FILENAME>) which is not in the specified directory. Please check your directorie(s) for the correct spelling and pathname for your file.

******FILE: <FILENAME> NOT A CAPZONE FILE
******THE PROGRAM WILL BE TERMINATED
PLEASE CHECK YOUR DIRECTORY FOR CORRECT FILE

This file (<FILENAME>) is unreadable and therefore cannot be an input data file to program CAPZONE. You should check your directories to make sure which files are CAPZONE input data files and which are not.

******FILE NOT COMPATIBLE WITH CHOSEN OPTION
THIS FILE IS FOR <VARIABLE/FIXED> AQUIFER
PARAMETER OPTION
******THE PROGRAM WILL TERMINATE.
PLEASE CHOOSE ANOTHER FILE,
ANOTHER OPTION, OR ENTER DATA
FROM THE KEYBOARD

In this case the input file is a CAPZONE data file but it contains data for the wrong aquifer parameter option. If you chose the fixed it is for the variable or vice-versa. Check your directory to see which files are input files for the option you chose in the very first prompt. Make sure also that you chose the aquifer parameter option that you had intended to choose. (chap. III, sec.1)

1b. For One-Key Responses (as in Y,N,M,f,etc.):

******ILLEGAL RESPONSE: <RESPONSE>

The one character response that you entered in answer to the prompt was not a legal one for the prompt. Please read the prompt carefully before typing a response.

1c. For General numeric input.

```
*******ENTRY ERROR IN THE ABOVE INPUT LINE :
       INCORRECT DATA TYPE ENTERED FOR ONE OF
       THE <nitems> INPUT DATA ITEMS REQUIRED
       FOR THE LINE

       <correct type> TYPE EXPECTED

       PLEASE REENTER THE LINE AFTER THE PROMPT
```

This error occurs whenever a nonumeric character key is entered in response to a prompt for a numeric data item (e.g., when a "y" is typed accidently in response to a prompt requiring a number). It will also occur when an integer type (no decimal point) numeric value is expected and the user includes a decimal point in the response (e. g. typing 2. instead of 2). <nitems> is the number of input items required in the response. <correct type> is the data type which is expected (integer or real).

1d. For Correct Range (numeric input).

```
******NUMBER OUT OF RANGE
      YOU WILL BE RETURNED TO THE DATA LIST
      PLEASE READ IT CAREFULLY-------
```

This error message appears whenever the user has entered a list number (for a parameter or unit choice in a list) that is not within the range of numbers in the list. It also occurs in response to the prompt concerning the number of parameters to change in a data list (see Chap. IIIB) if the entered number is negative or greater than the total number of items in the list.

```
******HYDRAULIC GRADIENT COMPONENTS
CANNOT BOTH BE ZERO----PLEASE REENTER
```

This is displayed whenever both components of the hydraulic gradient become zero. This may be the result of keyboard input or parameter change. If the user has changed the gradient components in such a way (even though intentional, as in the course of changing the components from (.002,0) to (0,.002), the gradients must be again changed so that at least one component is nonzero.

******ILLEGAL PARAMETER VALUE FOR <data item>: <value>
VALUE CAN'T BE <range> PLEASE REENTER

A value (<value>) has been entered for a parameter, pumping rate, well coordinate, or fixed data item (<data item>) which is out of its legal range (for legal ranges for all data items, consult chapter III). <range> is the illegal range—the range of values that the data item may not assume.

example:

******ILLEGAL PARAMETER VALUE FOR THICKNESS : - 250.000
VALUE CAN'T BE LESS THAN OR EQUAL TO ZERO PLEASE REENTER

******YOU MAY NOT CHANGE THE FOLLOWING
PARAMETERS WHILE THE VARIABLE AQUIFER
PARAMETER OPTION IS IN EFFECT:

1. LONGITUDE OF NW CORNER (AFTER FIRST WELL)
2. LATITUDE OF NW CORNER (AFTER FIRST WELL)
8. TIME OF PUMPING TO THE PRESENT (AFTER FIRST WELL)
9. NUMBER OF WELLS

AT LEAST ONE OF THE ABOVE LIST NUMBERS
WAS ENTERED (<list number>)

This error message occurs whenever the variable aquifer parameter option is in effect and the user tries to change the values of one or more of the first three data items listed above after the capture zone for the first well is computed. It will also occur if the user tries to change the entered number of wells at any time after entry or input from a file (if the variable aquifer parameter option is in effect).

<list number> is one of those above (1,2,8 or 9)

2. Warning Messages.

a. For File Input and Output.

******WARNING---DATA PRESENT FOR ONLY <wells present> WELLS

This may occur at the very end of a CAPZONE run if the user used an input data file created in a previous CAPZONE run that was aborted by the user before the data for all of the wells was entered. The nulber represanting the total number of wells written to the data file is greatar than the number of sets of well data. The program will run correctly for the number of data sets (wells) present, but it will warn the user about the discrepancy and display tha actual number of capture zones computed (<wells present>).

2b. For Calculation of Capture Zone Curves.

******THE SOLUTION DID NOT CONVERGE IN <maxit> ITERATIONS

This warning may occur at the calculation of any point on the capture zone curve. It means that the method of soluthon of the analytical expressions of chapter II is not acceptably accurate at this particular point for this particular set of input data. The y'value produced for this value of x' (fig. 1) will probably be inaccurate. In the present version of CAPZONE, <maxit>, the maximum number of iterations (successive approximations to y) is set at 5000, thus an erroneous or unusual set (e.g. all data typical except pumping rate=.006 gal/min) of input data may require many iterations at a single point, some at which there will be lack of convergence. Thus the execution time may take longer than normal.

If this warning occurs, it is important to type control C to abort the program, rerun the program (if possible) with the same data and check the input lists carefully, correcting any errors (pay particular attention to incorrect units). If the unusual data values were intentional, you have to wait for execution to complete. Since the curve is probably inaccurate at relatively few points, plot the curve(s) to see if they are close to what is expected.

******WARNING---MAXIMUM TRAVEL DISTANCE: <xmeters> (METERS)
<xmiles> (MILES)
TOO LARGE FOR CALCULATION TO BE MEANINGFUL
DO YOU WISH TO CONTINUE THE CALCULATION?
(ENTER Y (y) or N (n)):

The maximum x value (areal distance of groundwater travel, see figs. 1 and 2, chapter 3) exceeds 15 miles. Assuming that the aquifer parameters have a definite, fixed value for this particular well throughout this long distance (<xmeters> and <xmiles>) is totally unreasonable.

CAPZONE then asks if the user wishes to continue the calculation. The response is a yes-no response. If you type Y or y in response to this prompt, the (long) capture zone will be computed. If you type N or n, the program will terminate without computing the curve for this well.

Appendix D. Files and Their Structure.

The following chapter is intended for those users who are familiar with FORTRAN.

1a. Optional Files and Their Structure.

There is only one optional data file. This is the file that contains input data to CAPZONE. It is used as an input file if the user elects to enter data from an input file (chapter III, section 2.) It is used as an output file if the user has entered data from the keyboard and elects to save the data to a file. This file is created and written by CAPZONE this way and is named by the user (Chapter III, section B2b). The structure is shown below. The first column contains the variable names corresponding to the field descriptors in column 2. The variable names are defined below the two columns.

For fixed aquifer parameter option:

variable names	field descriptors	record#
ALLWELLS, MW	1X, L2, I3	1
LO, LA, KLISTNUM	2E30.8, I3	2
TIME	E30.8	3
CCON(1, KLISTNUM	E30.8	4
NWELLS, LON	I3, 1X, L1	5
QLISTNUM	I3	6
CCON(2,QLISTNUM)	E30.8	7
BCON, FT	E30.8, L2	8
PERMI, BI, NE	3E25.8	9
MAG	L2	10
DHX, DHY OR DH, ANG	2E30.8	11
XC(JJ), YC(JJ), QI(JJ)	3E25.8	12 through 11+nwells

where nwells is the number of wells.

For variable aquifer parameter option, nwells equals 1 and mw is the number of wells. Records 9 through 12 are repeated mw times.

variable definitions:

ALLWELLS : has value T if fixed aquifer param. option was chosen, F if variable aquifer param. option was chosen

MW : equals 1 for fixed aquifer param. option, equals number of wells for variable aquifer parameter option

LO, LA : longitude and latitude of northwest corner of quadrangle respectively.

KLISTNUM : list number for hydraulic conductivity unit choice

TIME : time of pumping to present in years.

CCON(1, KLISTNUM) : unit conversion factor for hydraulic conductivity from chosen units to meters per second

NWELLS : see file structure above.

LON : has value T if well coordinates are in longitude, latitude pairs. Has value F if they are in meters with respect to quadrangle center.

QLISTNUM : list number for the pump rate unit choice.

CCON(2, QLISTNUM): conversion factor for pumping rate from chosen units to meters**3/sec.

BCON : conversion factor for thickness from chosen units to meters.

FT : has value T if thickness is in feet, F if in meters.

PERMI : input value of hydraulic conductivity.

BI : input value of thickness.

NE : porosity.

MAG : has value T if hydraulic gradient is to be read as a magnitude followed by an angle, a value of F if it is to be read as x component followed by y component.

DHX, DHY : x and y components of hydraulic gradient.

DH, ANG : magnitude of hydraulic gradient followed by the directional angle measured from due north.

XC, YC : arrays containing the well coordinates (x, y in meters or longitude, latitude)

JJ : counter through wells

1b. Required Files and Their Structure.

There is only one required file. The output file named by the user in chapter III, section A10. This file is written in ERDAS .DIG format (see ERDAS User's Guide, Appendix B., pp.B10-B14). It contains a graphics header followed by each set of curve points. (Each set of curve points is preceded by an element header.) The graphics and element headers must be modified for each plot (see ERDAS User's Guide, Appendix B., pp.B10-B14 for further information concerning modification and structure of .DIG files).

If the maximum value of x' (see chapter II) is less than 10, the number of data points on the curve is 200, if it is greater than or equal to 10 but less than 25, the number of data points on a capture zone curve is 500. If the maximum x' for the curve is greater than 25, the number of data points is 1000.

REFERENCES

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2. Bear, J. and Martin Jacobs. 1965. On the Movement of Water Bodies Injected Into Aquifers. Journal of Hydrology. v. 3, p.37-57