PG. 1-73

- MANY MODELS ARE USED, U.S.G.S. MODFLOW IS ONE POPULAR GENERAL PURPOSE GROUND WATER FLOW MODEL

- A MODULAR THREE-DIMENSIONAL FINITE-DIFFERENCE GROUND-WATER FLOW MODEL

- DESIGNED FOR REGIONAL FLOW MODELING BUT CAN BE USED AT SMALLER SCALES WITH SOME PRECAUTIONS

- MODULAR STRUCTURE THAT GROUPS COMPUTATIONAL AND HYDROLOGIC ABSTRACTIONS INTO LOGICAL GROUPS

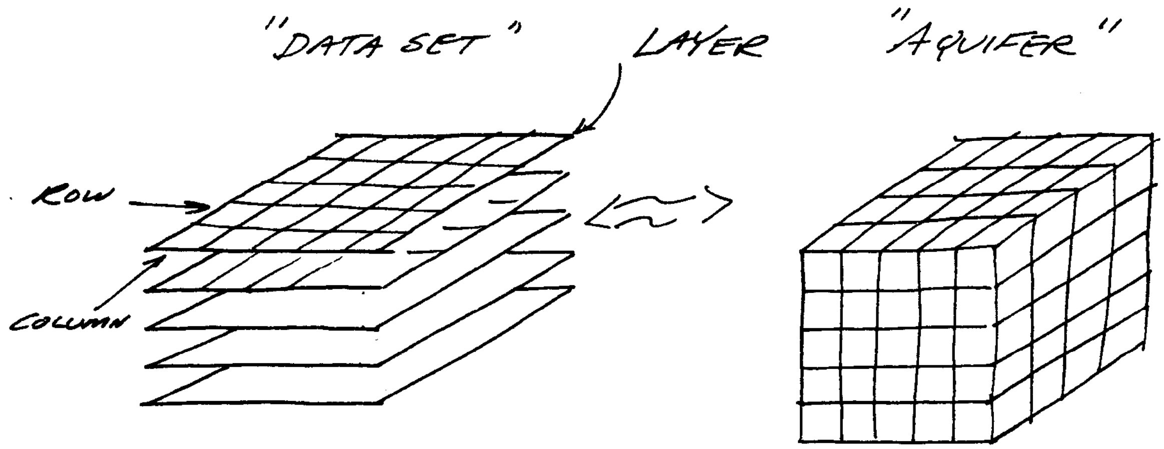
- HYDROLOGIC ABSTRACTIONS
  - RECHARGE
  - RIVER/AQUIFER INTERACTION
  - DRAINS
  - EVAPOTRANSIPIRATION
  - WELLS
  - INTERBED STORAGE AND SUBSIDENCE (SEPARATE MODULE - INCLUDED IN YOUR SOURCE CODE, NOT DOCUMENTED IN STANDARD MODFLOW LITERATURE)

- DATA INPUT FROM SEVERAL FILES DEPENDING ON MODULES USED

- EACH FILE CONTAINS INPUT ITEMS

  ITEMS MAY BE
  - SINGLE RECORD (LINE CONTAINING FIELDS OF DATA)
  - COLLECTION OF RECORDS
  - ARRAY OR COLLECTION OF ARRAYS

- 3-D ARRAYS ARE READ AS A COLLECTION OF 2-D ARRAYS, ONE ASSOCIATED WITH EACH MODEL LAYER



- DATA FILES (DATASETS) CONTAIN DATA REQUIRED FOR
  - -- EACH SIMULATION
  - -- EACH STRESS PERIOD
- A SIMULATION MAY CONSIST OF A SINGLE OR MULTIPLE STRESS PERIODS
- BASIC INPUT FILE WHICH CONTAINS DATA TO SPECIFY WHICH MODULES WILL BE USED AND WHICH FILES THESE MODULES WILL ADDRESS

FINITE DIFFERENCE EQUATION

EQUATION OF MOTION (CARTESIAN CO-ORDINATES)

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)=S_s\frac{\partial h}{\partial t}+q$$

ASSUMPTIONS

-- COORDINATE DIRECTIONS ALIGNED WITH PRINCIPAL DIRECTIONS OF ANISOTROPY.

-- WATER HAS CONSTANT DENSITY

OBJECTIVE

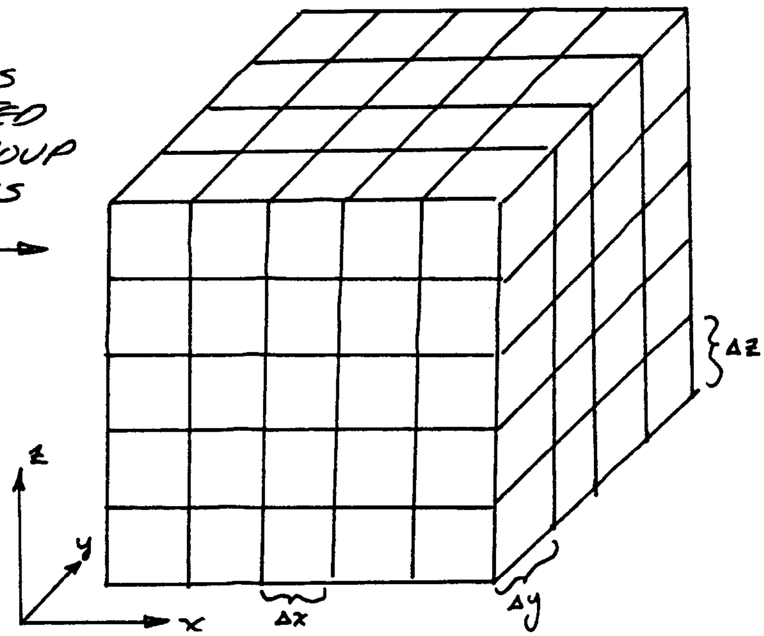
FIND THE FUNCTION $h(x, y, z, t)$ THAT SATISFIES EQUATION OF MOTION AND BOUNDARY CONDITIONS

METHOD

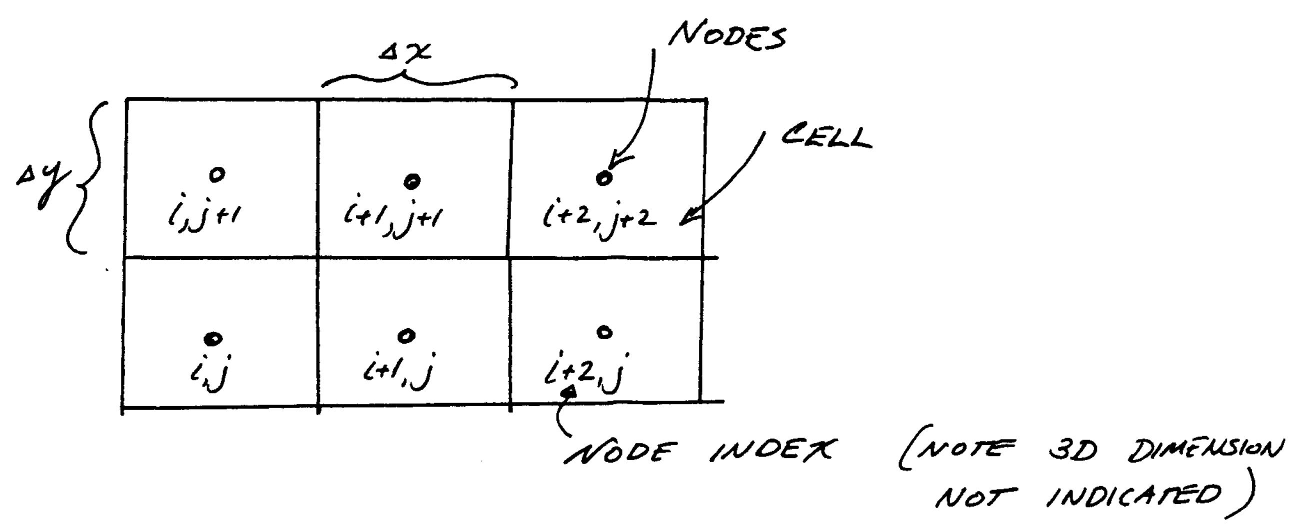
APPLY FINITE DIFFERENCE APPROXIMATION TO EQUATION OF MOTION AND BOUNDARY CONDITIONS THEN SOLVE ALGEBRAIC SYSTEM OF EQUATIONS THAT RESULTS FROM THIS DISCRITIZATION

FINITE DIFFERENCE APPROXIMATIONS

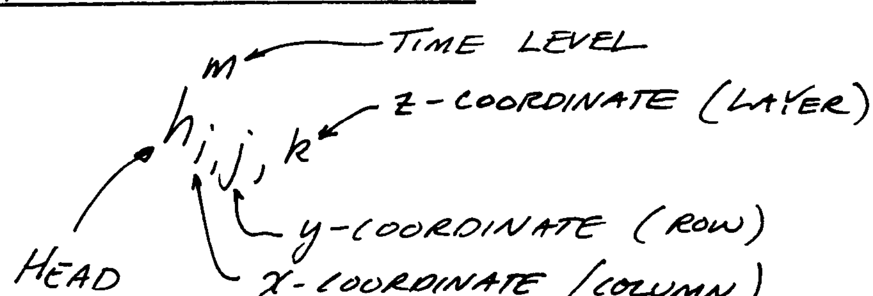
AQUIFER IS REPRESENTED AS A GROUP OF BLOCKS



BLOCK CENTERED FLOW:



VARIABLE LABELING



EQUATION OF MOTION

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right) = S_s\frac{\partial h}{\partial t} + q$$

2ND-ORDER CORRECT FINITE DIFFERENCE(S) IN SPACE

$$\left(K_{xx}\frac{\partial h}{\partial x}\right) \approx \frac{1}{2}\left(K_{xx_{i,j,k}} + K_{xx_{i+1,j,k}}\right)\frac{h^{m}_{i+1,j,k} - h^{m}_{i,j,k}}{\Delta x} \quad \text{(FORWARD)}$$

$$\left(K_{xx}\frac{\partial h}{\partial x}\right) \approx \frac{1}{2}\left(K_{xx_{i-1,j,k}} + K_{xx_{i,j,k}}\right)\frac{h^{m}_{i,j,k} - h^{m}_{i-1,j,k}}{\Delta x} \quad \text{(BACKWARD)}$$

COMBINE FORWARD & BACKWARD TO OBTAIN THE SECOND DERIVATIVES

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right) \approx A_i\, h^{m}_{i+1,j,k} - (A_i + B_i)\, h^{m}_{i,j,k} + B_i\, h^{m}_{i-1,j,k}$$

WHERE

$$A_i = \frac{1}{2}\left(K_{xx_{i+1,j,k}} + K_{xx_{i,j,k}}\right)\frac{1}{\Delta x^2}$$

$$B_i = \frac{1}{2}\left(K_{xx_{i,j,k}} + K_{xx_{i-1,j,k}}\right)\frac{1}{\Delta x^2}$$

1st ORDER CORRECT FINITE DIFFERENCE IN TIME

$$S_s\frac{\partial h}{\partial t} \approx S_{s_{ijk}}\,\frac{h^{m}_{i,j,k} - h^{m-1}_{i,j,k}}{\Delta t} \quad \text{(BACKWARD)}$$

(NOTE: ALL VARIABLES AT TIME LEVEL m ARE UNKNOWN)

THE SPACE APPROXIMATIONS ARE REPEATED IN THREE DIMENSIONS TO OBTAIN A SYSTEM OF ALGEBRAIC DIFFERENCE EQUATIONS:

$$A_i h^m_{i+1,j,k} - (A_i + B_i) h^m_{i,j,k} + B_i h^m_{i-1,j,k} \quad +$$

$$C_i h^m_{i,j+1,k} - (C_i + D_i) h^m_{i,j,k} + D_i h^m_{i,j-1,k} \quad +$$

$$E_i h^m_{i,j,k+1} - (E_i + F_i) h^m_{i,j,k} + F_i h^m_{i,j,k-1}$$

$$=$$

$$\frac{S_{s\,i,j,k}}{\Delta t} \, h^m_{i,j,k} - h^{m-1}_{i,j,k} \quad + \quad \frac{Q^{m-1}}{\Delta x \Delta y \Delta z}$$

WHERE

$$A_i = \frac{1}{2}\left(K_{xx\,i+1,j,k} + K_{xx\,i,j,k}\right)\frac{1}{\Delta x^2}$$

$$B_i = \frac{1}{2}\left(K_{xx\,i,j,k} + K_{xx\,i-1,j,k}\right)\frac{1}{\Delta x^2}$$

$$C_i = \frac{1}{2}\left(K_{yy\,i,j+1,k} + K_{yy\,i,j,k}\right)\frac{1}{\Delta y^2}$$

$$D_i = \frac{1}{2}\left(K_{yy\,i,j,k} + K_{yy\,i,j-1,k}\right)\frac{1}{\Delta y^2}$$

$$E_i = \frac{1}{2}\left(K_{zz\,i,j,k+1} + K_{zz\,i,j,k}\right)\frac{1}{\Delta z^2}$$

$$F_i = \frac{1}{2}\left(K_{zz\,i,j,k} + K_{zz\,i,j,k-1}\right)\frac{1}{\Delta z^2}$$

- ONE EQUATION FOR EACH NODE
- SYSTEM IS ASSEMBLED INTO VECTOR-MATRIX FORM:

$$A h^{m} = B h^{m-1} + Q^{m-1}$$

- SOLUTION IS

$$h^{m} = A^{-1}\left(B h^{m-1} + Q^{m-1}\right)$$

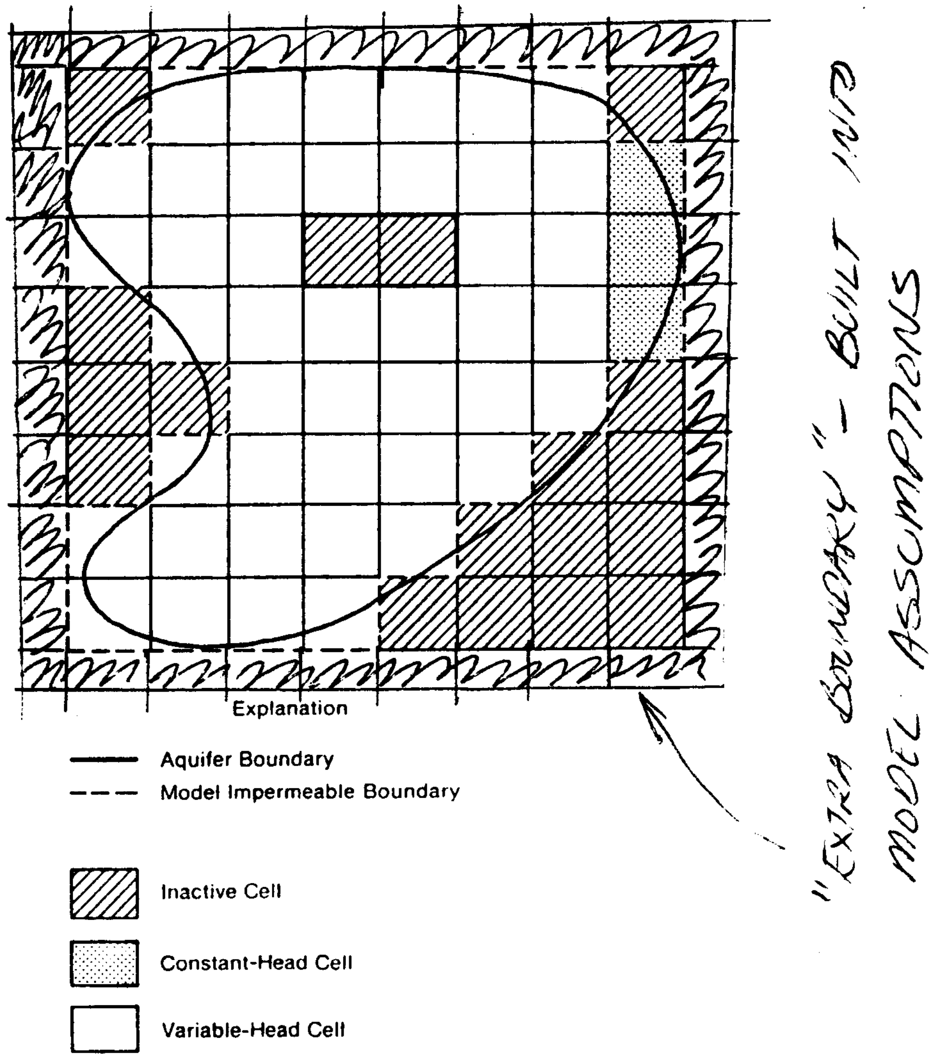
- INVERSION IS PERFORMED NUMERICALLY

- CONSULT ANY NUMERICAL METHODS BOOK TO LEARN MORE ABOUT SOLUTION TECHNIQUES

  AN EXCELLENT REFERENCE IS:

  Lapidus, L, and G.F. Pinder, 1982. Numerical Solution of Partial Differential Equations in Science and Engineering, Wiley, New York

- ALSO READ CH.2 OF MODFLOW CAREFULLY FOR ALTERNATIVE DEVELOPMENT OF FINITE DIFFERENCE EQUATIONS



HORIZONTAL DISCRITIZATION

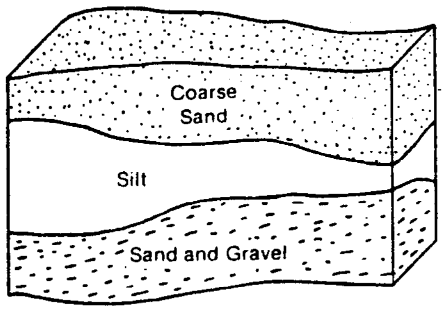
INACTIVE CELLS = NO FLOW CELLS

CONSTANT HEAD CELLS = DIRICHLET BOUNDARY CONDITIONS

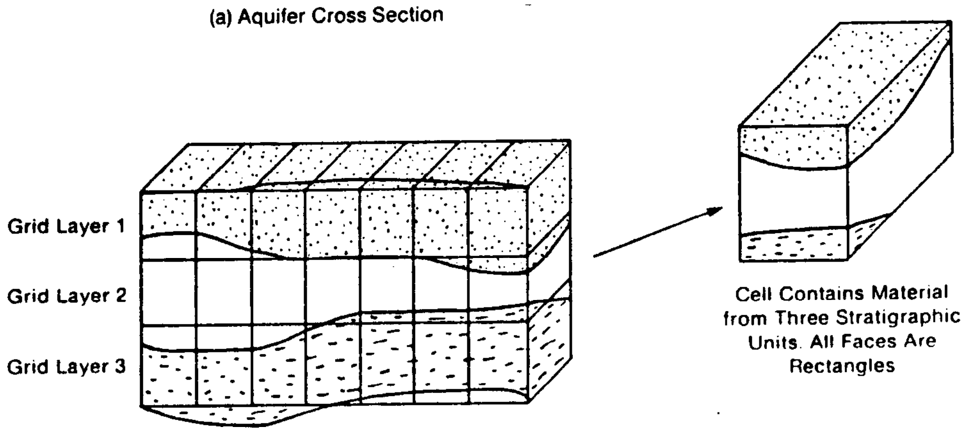
VARIABLE HEAD CELLS = COMPUTATIONAL CELLS

NOTE: THE PROGRAM "AUTOMATICALLY" SURROUNDS AQUIFER WITH NO-FLOW BOUNDARIES

VERTICAL DISCRITIZATION CONVENTIONS



(a) Aquifer Cross Section

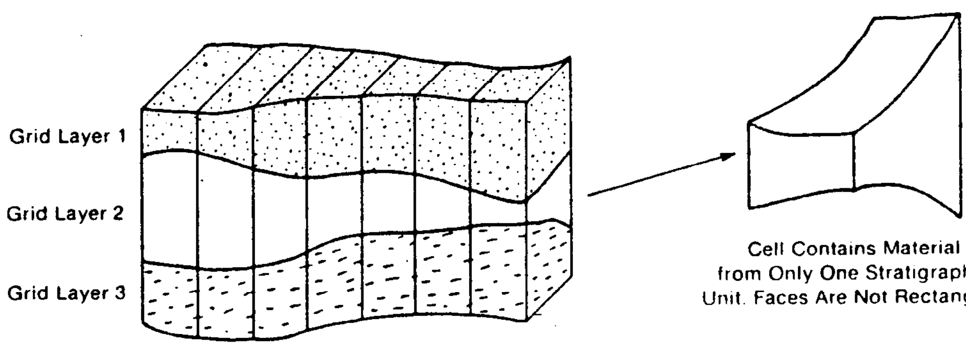


(b) Aquifer Cross Section With Rectilinear Grid Superimposed

Cell Contains Material from Three Stratigraphic Units. All Faces Are Rectangles

← ARBRITARY DIVISION OF FLOW SEGMENTS IN VERTICAL

– NO FORMAL ATTEMPT TO CONFORM TO STRATIGRAPHIC BOUNDARIES



(c) Aquifer Cross Section With Deformed Grid Superimposed

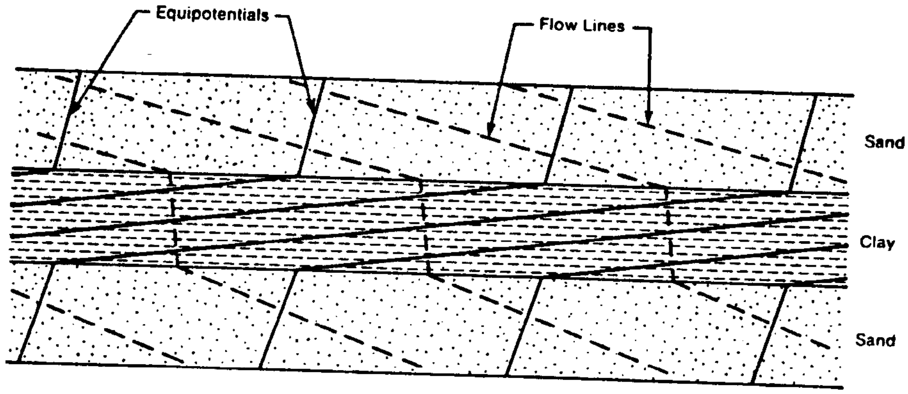
Cell Contains Material from Only One Stratigraphic Unit. Faces Are Not Rectangles

← VARIABLE THICK DIVISION OF FLOW SEGMENTS IN VERTICAL

– FORMAL ATTEMP TO CONFORM TO STRATIGRAPHIC BOUNDARIES

– DEFORMED MESH

IN PRACTICE A COMPROMISE IS USED, DEPENDING ON NATURE OF INVESTIGATION

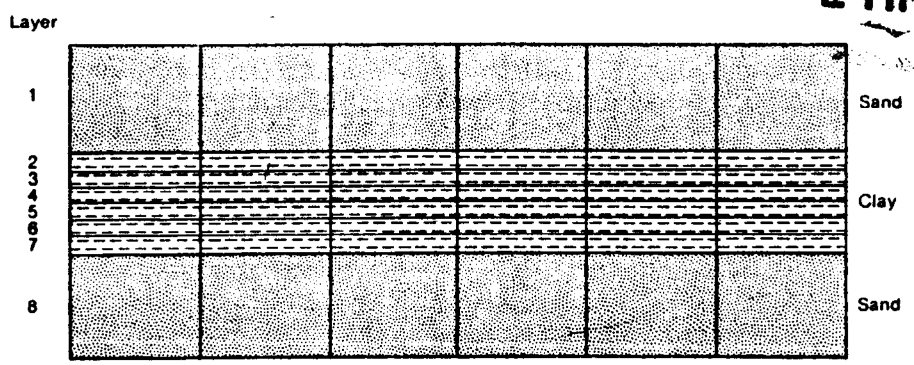


AQUIFER SYSTEM: TWO SAND UNITS SEPARATED BY CLAY UNIT

CONCEPTUAL MODEL: THREE LAYERS, EACH OF UNIFORM THICKNESS

RESULTS: VERTICALLY AVERAGED HORIZONTAL FLOW IN EACH AQUIFER UNIT, WITH VERTICAL LEAKAGE BETWEEN AQUIFER UNITS

COMMENTS: THIS WOULD PROBABLY BE CALLED A QUASI-3D MODEL OR LAYERED SYSTEM MODEL. VERTICAL RESOLUTION IS TOO COARSE TO RELIABLY RESOLVE VERTICAL VELOCITIES; VERTICAL LEAKAGE ESTIMATES WOULD PROBABLY BE RELIABLE. THIS SCHEME WOULD BE USED WHEN PUMPING FROM SANDS IS SUSTAINED BY CLAY STORAGE BUT RELEASE PATTERN NOT [illegible]

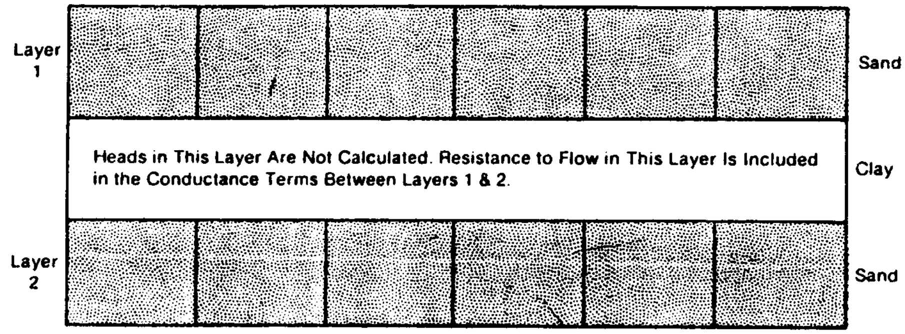


AQUIFER SYSTEM: TWO SAND UNITS SEPARATED BY CLAY UNIT.

CONCEPTUAL MODEL: EIGHT LAYERS, EACH SAND UNIT IS A SINGLE LAYER OF UNIFORM THICKNESS, THE CLAY UNIT IS COMPRISED OF SIX LAYERS OF UNIFORM THICKNESS.

RESULTS: VERTICALLY AVERAGED HORIZONTAL FLOW IN EACH SAND UNIT, WITH 3-D FLOW IN THE CLAY UNIT.

COMMENTS: THIS DISCRITIZATION SCHEME WOULD BE USEFUL WHEN RELEASE PATTERN OF CLAY STORAGE IS IMPORTANT, BUT FLOW PATTERN (IN VERTICAL) IS UNIMPORTANT IN THE SAND UNIT



AQUIFER SYSTEM: TWO SAND UNITS SEPARATED BY A CLAY UNIT.

CONCEPTUAL MODEL: TWO LAYERS EACH OF UNIFORM THICKNESS, EFFECT OF CLAY UNIT IS SIMULATED BY VERTICAL ANISOTROPY - I.E. A CONDUCTANCE TERM THAT ACCOUNTS FOR LOW PERMEABILITY IN VERTICAL LEAKAGE

RESULTS: VERTICALLY AVERAGED HORIZONTAL FLOW IN EACH "SAND" UNIT, VERTICAL LEAKAGE BETWEEN UNITS. THIS SCHEME USED WHEN STORAGE EFFECTS IN CLAY UNITS ARE CONSIDERED INSIGNIFICANT

SUMMARY

--SAME AQUIFER SYSTEM

--CONCEPTUALIZED THREE DIFFERENT WAYS – DEPENDING ON DESIRED INFORMATION

- CLAY STORAGE INSIGNIFICANT
- CLAY STORAGE IMPORTANT, BUT PATTERN OF RELEASE INSIGNIFICANT
- CLAY STORAGE AND RELEASE PATTERN IMPORTANT

COMMENT

PRESENTED DISCRITIZATION SCHEMES FOR CONFINED SYSTEMS. READ DOCUMENTATION FOR DESCRIPTION OF HOW UNCONFINED SYSTEMS ARE CONCEPTUALIZED

MODULES	ACRONYM
BASIC	BAS
BLOCK-CENTERED FLOW	BCF
RIVER	RIV
RECHARGE	RECH
WELL	WELL
DRAIN	DRN
EVAPOTRANSPIRATION	ET
GENERAL-HEAD BOUNDARY	GHB
STRONGLY IMPLICIT PROCEDURE	SIP
SLICE-SUCCESSIVE OVERRELAXATION	SSOR

- ALL SIMULATIONS WILL USE AT LEAST

    BAS
    BCF
    SIP OR SSOR

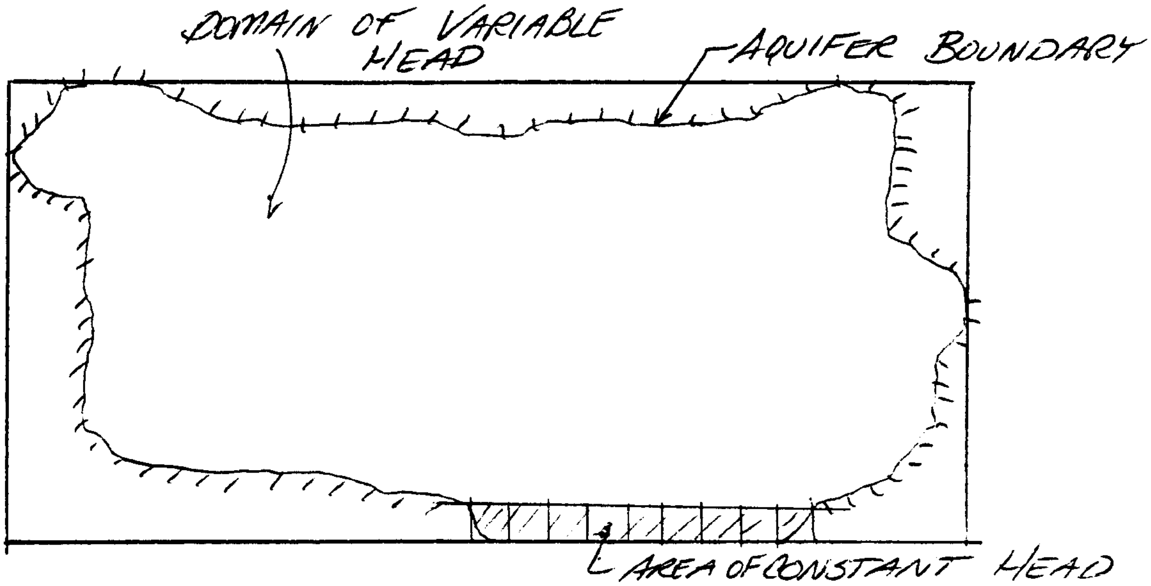
- SIP, SSOR ARE LINEAR EQUATION SOLVERS. THE REMAINING MODULES ARE USED TO "WRITE" THE LINEAR SYSTEM:

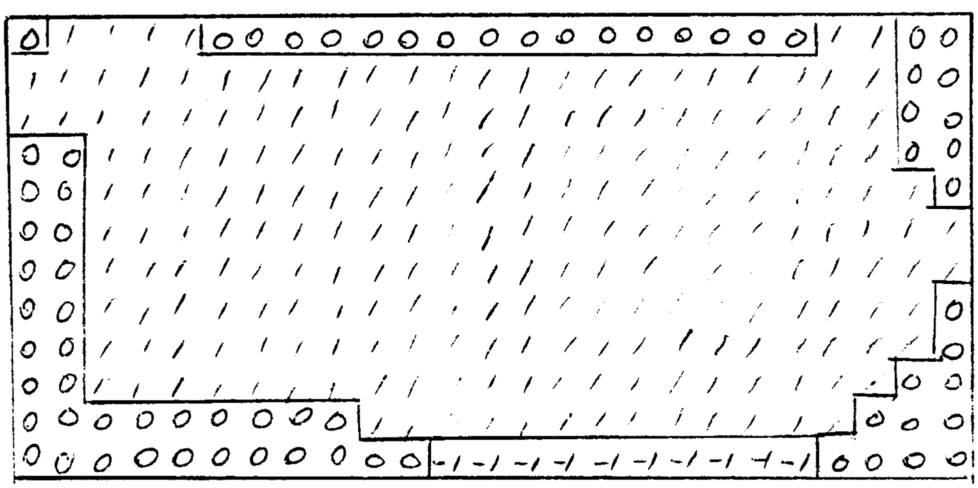
$$A h^{m+1} = B h^{m} + f(Q)$$

- BASIC MODULE READS DATA FROM A FILE NAMED "FOR001".
  - THE FILE CONTAINS DATA ON THE HORIZONTAL AND VERTICAL DISCRITIZATION, TIME DISCRITIZATION, HYDROLOGIC ABSTRACTIONS (OTHER MODULES) AND LOCATION OF DATA FOR THE OTHER PACKAGES

- MAJOR OPTIONS ARE SPECIFIED BY THE IUNIT ARRAY.
  - THIS ARRAY DETERMINES:
    (a) WHETHER OR NOT A PARTICULAR MODEL FEATURE IS TO BE INCLUDED
    (b) THE UNIT NUMBER (FILENAME) OF THE DATASET CORRESPONDING TO THE PARTICULAR FEATURE

- AQUIFER DISCRITIZATION IS SPECIFIED BY A SET OF BOUNDARY ARRAYS CALLED THE IBOUND ARRAY.





IBOUND CODES

- < 0 CONSTANT HEAD
- = 0 NO FLOW
- > 0 VARIABLE HEAD

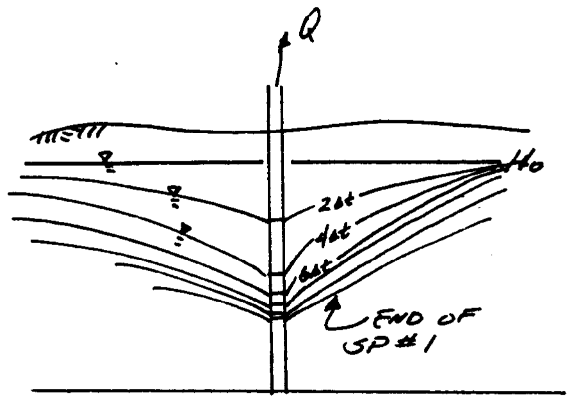
BOUNDARY ARRAY FOR A SINGLE LAYER

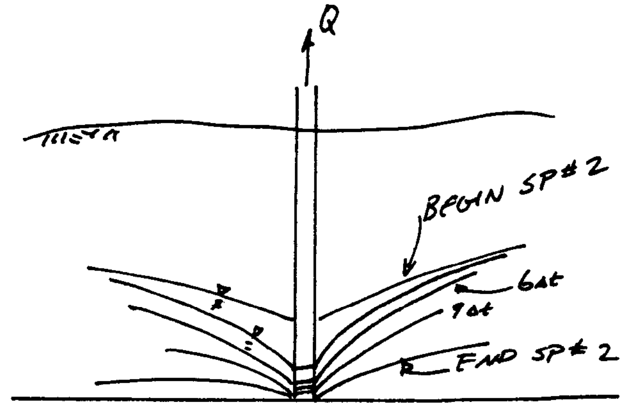
-- INITIAL CONDITIONS FOR EACH LAYER ARE PROVIDED USING A SIMILAR ARRAY STRUCTURE

-- TIME IS DISCRITIZED INTO STRESS PERIODS WHICH ARE MADE UP OF TIME STEPS.

- A STRESS PERIOD IS AN INTERVAL OF TIME WHERE ALL EXTERNAL STRESSES ARE CONSTANT

- A TIME STEP IS SOME INTERVAL OF TIME OVER WHICH A SINGLE COMPUTATIONAL STEP IS EXECUTED





STRESS PERIOD	: 1	STRESS PERIOD	: 2
LENGTH	: 1 YR.	LENGTH	: 1 YR.
# TIME STEPS	: 12	# TIME STEPS	: 6
DISCHARGE	: Q=100 gpm	DISCHARGE	: Q = 1000 gpm

SUMMARY OF BASIC PACKAGE

- AQUIFER MODEL CONCEPTUALIZATION
  (LAYERS, ROWS, COLUMNS)
- TIME DISCRITIZATION
  (STRESS PERIODS, LENGTH E.:
- IUNIT ARRAY
  (IDENTIFY HYDROLOGIC PACKAGES TO INCLUDE)
- IBOUND ARRAY
- INITIAL HEAD ARRAY
- OUTPUT CONTROL (IF DESIRED)

Input for the Basic (BAS) Package except for output control is read from unit 1 as specified in the main program. If necessary, the unit number for BAS input can be changed to meet the requirements of a particular computer. Input for the output control option is read from the unit number specified in IUNIT(12).

Information for the Basic Package must be submitted in the following order:

FOR EACH SIMULATION

BAS1DF

1. Data: HEADNG(32)
   Format: 20A4

2. Data: HEADNG (continued)
   Format: 12A4

3. Data: NLAY NROW NCOL NPER ITMUNI
   Format: I10 I10 I10 I10 I10

4. Data: IUNIT(24)
   Format: 24I3
   (BCF WEL DRN RIV EVT XXX GHB RCH SIP XXX SOR OC)

BAS1AL

5. Data: IAPART ISTRT
   Format: I10 I10

BAS1RP

6. Data: IBOUND(NCOL,NROW)
   Module: U2DINT
   (One array for each layer in the grid)

7. Data: HNOFLO
   Format: F10.0

8. Data: Shead(NCOL,NROW)
   Module: U2DREL
   (One array for each layer in the grid)

NOTE: IBOUND and Shead are treated as three-dimensional arrays in the program. However, the input to each of these arrays is handled as a series of two-dimensional arrays, one for each layer in the grid.

FOR EACH STREDSS PERIOD

BAS1ST

9. Data: PERLEN NSTP TSMULT
Format: F10.0 I10 F10.0

Explanation of Fields Used in
Input Instructions

HEADNG--is the simulation title that is printed on the printout. It may be up to 132 characters long; 80 in the first record and 52 in the second. Both records must be included even if they are blank.

NLAY--is the number of model layers.

NROW--is the number of model rows.

NCOL--is the number of model columns.

NPER--is the number of stress periods in the simulation.

ITMUNI--indicates the time unit of model data. (It is used only for printout of elapsed simulation time. It does not affect model calculations.)

0 - undefined	3 - hours
1 - seconds	4 - days
2 - minutes	5 - years

The unit of time must be consistent for all data values that involve time. For example, if years is the chosen time unit, stress-period length, time-step length, transmissivity, etc., must all be expressed using years for their time units. Likewise, the length unit must also be consistent.

IUNIT--is a 24-element table of input units for use by all major options. Only 10 elements (1-5, 7-9, 11, and 12) are being used. Element 6 has been reserved for a transient leakage package, while element 10 has been reserved for an additional solver, both on the assumption that such packages will be added to the model in the future. Elements 13-24 are reserved for future major options.

IUNIT LOCATION	MAJOR OPTION
1	Block-Centered Flow Package
2	Well Package
3	Drain Package
4	River Package
5	Evapotranspiration Package
6	Reserved for Transient Leakage Package
7	General-Head Boundary Package
8	Recharge Package
9	SIP Package
10	Reserved for additional solver
11	SSOR Package
12	Output Control Option

If IUNIT(n) $\leq$ 0, the corresponding major option is not being used.

If IUNIT(n) > 0, the corresponding major option is being used and data for that option will be read from the unit number contained in IUNIT(n). The unit numbers in IUNIT should be integers from 1 to 99. Although the same number may be used for all or some of the major options, it is recommended that a different number be used for each major option. Printer output is assigned to unit 6 (unless it is changed to meet computer requirements). That unit number should not be used for any other input or output. The user is also permitted to assign unit numbers for output. Those numbers should be different from those assigned to input. The Basic Package reads from unit 1 (unless it is changed to meet computer requirements). It is permissible but unwise to use that unit for other major options.

IAPART--indicates whether array BUFF is separate from array RHS.

If IAPART = 0, the arrays BUFF and RHS occupy the same space. This option conserves space. This option should be used unless some other package explicitly says otherwise.

If IAPART $\neq$ 0, the arrays BUFF and RHS occupy different space. This option is not needed in the program as documented in this publication. It may be needed for packages yet to be written.

ISTRT--indicates whether starting heads are to be saved. If they are saved, they will be stored in array STRT. They must be saved if drawdown is calculated.

If ISTRT = 0, starting heads are not saved.

If ISTRT ≠ 0, starting heads are saved.

IBOUND--is the boundary array.

If IBOUND(I,J,K) < 0, cell I,J,K has a constant head.

If IBOUND(I,J,K) = 0, cell I,J,K is inactive (no-flow).

If IBOUND(I,J,K) > 0, cell I,J,K is variable-head.

HNOFLO--is the value of head to be assigned to all inactive cells (IBOUND = 0) throughout the simulation. Since heads at inactive cells are unused, this does not affect model results but serves to identify inactive cells when head is printed. This value is also used as drawdown at inactive cells if the drawdown option is used. Even if the user does not anticipate having inactive cells, a value for HNOFLO must be submitted.

Shead--is head at the start of the simulation. Regardless of whether starting head is saved, these values must be input to initialize the solution.

PERLEN--is the length of a stress period. It is specified for each stress period.

NSTP--is the number of time steps in a stress period.

TSMULT--is the multiplier for the length of successive time steps. The length of the first time step DELT(1) is related to PERLEN, NSTP and TSMULT by the relation

DELT(1) = PERLEN(1-TSMULT)/(1-TSMULT**NSTP).

BLOCK CENTERED FLOW

-- BCF MODULE READS FORMATION PARAMETERS AND PHYSICAL DOMAIN GEOMETRY TO CONSTRUCT THE FINITE DIFFERENCE FLOW EQUATIONS.

- THE EQUATIONS ARE ASSEMBLED INTO A CONDUCTANCE MESH INSIDE THE PROGRAM

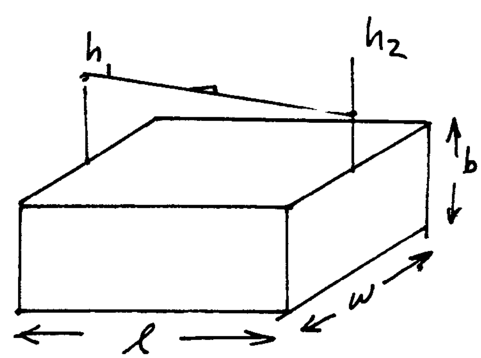
CONDUCTANCE

DARCY'S LAW

$$Q = -KA\,grad(h)$$

$$= -Kbw\frac{h_2 - h_1}{l}$$

$$= Kbw\frac{h_1 - h_2}{l}$$



THE GROUP OF CONSTANTS $\frac{Kbw}{l}$ IS CALLED THE BLOCK CENTERED CONDUCTANCE.

$$C = \frac{Kbw}{l}$$

SO $Q = C(h_1 - h_2) = C\Delta h$

IN TERMS OF TRANSMISSIVITY.

$$C = \frac{Tw}{l}.$$

- THE BLOCK CONDUCTANCES ARE ASSEMBLED INTO A SET OF EQUATIONS THAT CONSTITUTE THE MATHEMATICAL MODEL

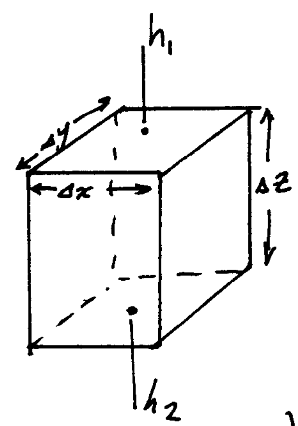
- VERTICAL CONDUCTANCE IS COMPUTED USING IDENTICAL CONCEPTS

DARCY'S LAW

$$Q = -K_v \Delta x \Delta y \frac{h_2 - h_1}{\Delta z}$$

$$= \underbrace{\frac{K_v \Delta x \Delta y}{\Delta z}}_{C_v} \, h_1 - h_2$$

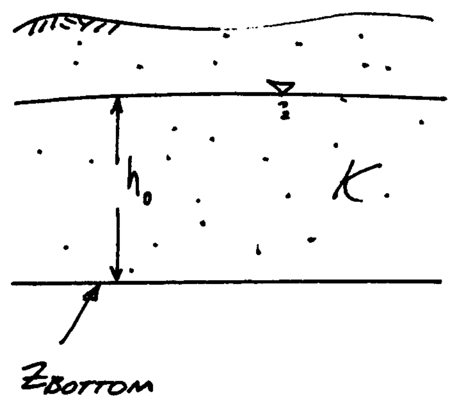
C_v (VERTICAL CONDUCTANCE)



- THE PROGRAM READS A VERTICAL LEAKANCE: $C_v = \frac{K}{\Delta z}$ AND COMPUTES CONDUCTANCE FOR YOU.

NOTE: ONLY PROVIDE $\frac{K_v}{\Delta z}$; NOT ENTIRE CONDUCTANCE VALUE.

WATER TABLE AQUIFERS



PROGRAM MODELS WATER TABLE CONDITIONS BY USING A VARIABLE TRANSMISSIVITY CONCEPT

$$T_{wr} = K(\underbrace{h_0 - z_{BOTTOM}}_{\text{SATURATED THICKNESS}})$$

THIS FORMULATION CHANGES THE LINEAR SYSTEM BECAUSE THE A MATRIX BECOMES TIME DEPENDENT.

$$A(h^m)\cdot h^{m+1} = Bh^m + f(Q^m)$$

SYSTEM IS STILL LINEAR (A TIME-LAG LINEARIZATION IS EMPLOYED) BUT MATRIX ASSEMBLY OCCURS EVERY TIME STEP.

STORAGE

-- BCF USES TWO STORAGE MECHANISMS
- S_y, FOR WATER TABLE AQUIFERS AND
S, FOR CONFINED CONDITIONS

-- PROGRAM WILL DETERMINE APPROPRIATE MECHANISM FOR AQUIFERS WHERE EITHER CONDITION MAY BE PRESENT

<u>BCF SUMMARY</u>

-- FORMULATES FINITE DIFFERENCE MODEL
-- READS
- LAYER TYPE
- $\Delta x, \Delta y$
- ANISOTROPY FACTOR $\left(\frac{T_{COLUMN}}{T_{ROW}} \right)$
- STORAGE COEFFICIENTS
- HYDRAULIC CONDUCTIVITY OR TRANSMISSIVITY
- LAYER POSITION (FOR SATURATED THICKNESS IN WATER TABLE AQUIFERS)
- VERTICAL LEAKANCE

Input for the Block-Centered Flow (BCF) Package is read from the unit specified in IUNIT(1).

FOR EACH SIMULATION

BCF1AL

1. Data: ISS IBCFCB
   Format: I10 I10

2. Data: LAYCON(NLAY) (Maximum of 80 layers)
   Format: 40I2

   (If there are 40 or fewer layers, use one record; otherwise, use two records.)

BCF1RP

3. Data: TRPY(NLAY)
   Module: U1DREL

4. Data: DELR(NCOL)
   Module: U1DREL

5. Data: DELC(NROW)
   Module: U1DREL

A subset of the following two-dimensional arrays are used to describe each layer. The arrays needed for each layer depend on the layer type code (LAYCON) and whether the simulation is transient (ISS = 0) or steady state (ISS ≠ 0). If an array is not needed, it must be omitted. All of the arrays (items 6-12) for layer 1 are read first; then all of the arrays for layer 2, etc.

IF THE SIMULATION IS TRANSIENT

6. Data: sf1(NCOL,NROW)
   Module: U2DREL

IF THE LAYER TYPE CODE (LAYCON) IS ZERO OR TWO

7. Data: Tran(NCOL,NROW)
   Module: U2DREL

IF THE LAYER TYPE CODE (LAYCON) IS ONE OR THREE

8. Data: HY(NCOL,NROW)
   Module: U2DREL

9. Data: BOT(NCOL,NROW)
   Module: U2DREL

IF THIS IS NOT THE BOTTOM LAYER

6

10. Data: Vcont(NCOL,NROW)
    Module: U2DREL

IF THE SIMULATION IS TRANSIENT AND THE LAYER TYPE CODE (LAYCON) IS TWO OR THREE

11. Data: sf2(NCOL,NROW)
    Module: U2DREL

IF THE LAYER TYPE CODE IS TWO OR THREE

12. Data: TOP(NCOL,NROW)
    Module: U2DREL

Explanation of Fields Used in Input Instructions

ISS--is the steady-state flag.

If ISS ≠ 0, the simulation is steady state.

If ISS = 0, the simulation is transient.

IBCFCB--is a flag and a unit number.

If IBCFCB > 0, it is the unit number on which cell-by-cell flow terms will be recorded whenever ICBCFL (see Output Control) is set; the terms which are saved will include cell-by-cell storage terms, cell-by-cell constant head flows, and internal cell-by-cell flows.

If IBCFCB = 0, cell-by-cell flow terms will not be printed or recorded.

If IBCFCB < 0, flow for each constant-head cell will be printed, rather than saved on disk, whenever ICBCFL is set; cell-by-cell storage terms and internal cell-by-cell flows will neither be saved nor printed.

LAYCON--is the layer type table. Each element holds the code for the respective layer. Read one value for each layer. There is a limit of 80 layers. Leave unused elements blank.

0 - confined--Transmissivity and storage coefficient of the layer are constant for the entire simulation.

1 - unconfined--Transmissivity of the layer varies. It is calculated from the saturated thickness and hydraulic conductivity. The storage coefficient is constant; valid only for layer 1.

2 - confined/unconfined--Transmissivity of the layer is constant. The storage coefficient may alternate between confined and unconfined values. Vertical leakage from above is limited if the layer desaturates.

3 - confined/unconfined--Transmissivity of the layer varies. It is calculated from the saturated thickness and hydraulic conductivity. The storage coefficient may alternate between confined and unconfined values. Vertical leakage from above is limited if the aquifer desaturates.

TRPY--is a one-dimensional array containing an anisotropy factor for each layer. It is the ratio of transmissivity or hydraulic conductivity (whichever is being used) along a column to transmissivity or hydraulic conductivity along a row. Read one value per layer. Set to 1.0 for isotropic conditions. NOTE: This is one array with one value for each layer.

DELR--is the cell width along rows. Read one value for each of the NCOL columns.

DELC--is the cell width along columns. Read one value for each of the NROW rows.

sf1--is the primary storage coefficient. Read only for a transient simulation (steady-state flag, ISS, is 0). Note that for Laycon=1, sf1 will always be specific yield, while for Laycon=2 or 3, sf1 will always be confined storage coefficient. For Laycon=0, sf1 would normally be confined storage coefficient; however, layer-type 0 can also be used for simulation of water table conditions where drawdowns are expected to remain everywhere a small fraction of the saturated thickness, and where there is no layer above, or flow from the layer above is negligible; and in this case specific yield values would be entered in sf1.

Tran--is the transmissivity along rows. Tran is multiplied by TRPY to obtain transmissivity along columns. Read only for layers where LAYCON is zero or two.

HY--is the hydraulic conductivity along rows. HY is multiplied by TRPY to obtain the hydraulic conductivity along columns. Read only for layers where LAYCON is one or three.

BOT--is the elevation of the aquifer bottom. Read only for layers where LAYCON is one or three.

Vcont--is the vertical hydraulic conductivity divided by the thickness from a layer to the layer beneath it. Since there is not a layer beneath the bottom layer, Vcont cannot be specified for the bottom layer.

<u>sf2</u>--is the secondary storage coefficient. Read it only for layers where LAYCON is two or three and only if a transient simulation (steady-state flag, ISS, is zero). The secondary storage coefficient is always specific yield.

<u>TOP</u>--is the elevation of the aquifer top. Read only for layers where LAYCON is two or three.

WELLS

- WELL PACKAGE USED TO MODEL FEATURES WHICH WITHDRAW WATER FROM AQUIFER AT A SPECIFIED RATE

- RATE IS INDEPENDENT OF CELL AREA AND HEAD

PACKAGE ADDS A FORCING TERM TO THE ALGEBRAIC EQUATIONS:

$$A h^{m} = B h^{m-1} + Q^{m-1}$$

(Q ← WELLS)

MODULE REQUIRES USER TO SPECIFY

ROW, COLUMN, LAYER, RATE FOR EACH WELL.

FOR WELLS THAT OPERATE IN MULTIPLE LAYERS, DISCHARGE IS DISTRIBUTED (BY USER) IN PROPORTION TO TRANSMISSIVITY (OR HYDRAULIC CONDUCTIVITY)

Well Package Input

Input for the Well (WEL) Package is read from the unit specified in IUNIT(2).

FOR EACH SIMULATION

WEL1AL

1. Data: MXWELL IWELCB
   Format: I10 I10

FOR EACH STRESS PERIOD

WEL1RP

2. Data: ITMP
   Format: I10

3. Data: Layer Row Column Q
   Format: I10 I10 I10 F10.0

   (Input item 3 normally consists of one record for each well. If ITMP is negative or zero, item 3 is not read.)

Explanation of Fields Used in Input Instructions

MXWELL--is the maximum number of wells used at any time.

IWELCB--is a flag and a unit number.

If IWELCB > 0, it is the unit number on which cell-by-cell flow terms will be recorded whenever ICBCFL (see Output Control) is set.

If IWELCB = 0, cell-by-cell flow terms will not be printed or recorded.

If IWELCB < 0, well recharge will be printed whenever ICBCFL is set.

ITMP--is a flag and a counter.

If ITMP < 0, well data from the last stress period will be reused.

If ITMP ≥ 0, ITMP will be the number of wells active during the current stress period.

Layer--is the layer number of the model cell that contains the well.

Row--is the row number of the model cell that contains the well.

Column--is the column number of the model cell that contains the well.

Q--is the volumetric recharge rate. A positive value indicates recharge and a negative value indicates discharge.

Strongly Implicit Procedure Package Input

Input to the Strongly Implicit Procedure (SIP) Package is read from the unit specified in IUNIT(9).

FOR EACH SIMULATION

SIP1AL

1. | | | |
---|---|---|
Data: | MXITER | NPARM |
Format: | I10 | I10 |

SIP1RP

2. | | | | | | |
---|---|---|---|---|---|
Data: | ACCL | HCLOSE | IPCALC | WSEED | IPRSIP |
Format: | F10.0 | F10.0 | I10 | F10.0 | I10 |

Explanation of Fields Used in Input Instructions

MXITER--is the maximum number of times through the iteration loop in one time step in an attempt to solve the system of finite-difference equations. Fifty iterations are generally sufficient.

NPARM--is the number of iteration parameters to be used. Five parameters are generally sufficient.

ACCL--is the acceleration parameter. It must be greater than zero and is generally equal to one. If a zero is entered, it is changed to one.

HCLOSE--is the head change criterion for convergence. When the maximum absolute value of head change from all nodes during an iteration is less than or equal to HCLOSE, iteration stops.

IPCALC--is a flag indicating where the iteration parameter seed will come from.

0 - the seed will be entered by the user.

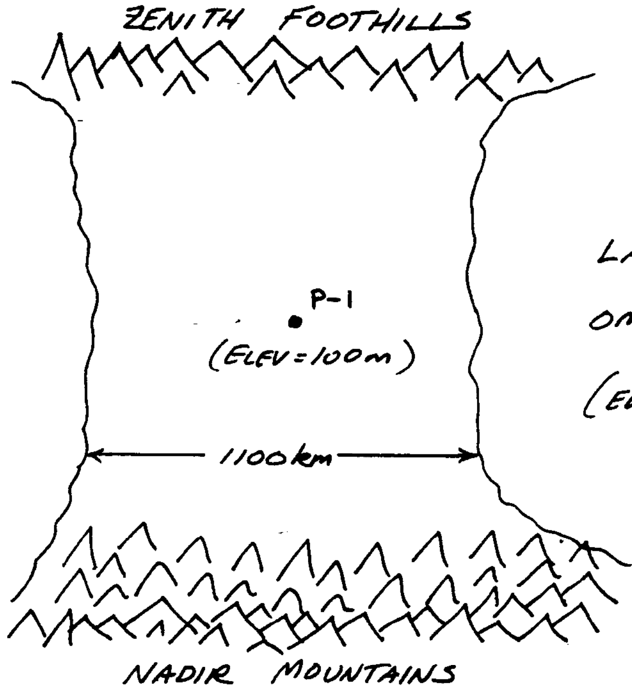
1 - the seed will be calculated at the start of the simulation from problem parameters.

WSEED--is the seed for calculating iteration parameters. It is only specified if IPCALC is equal to zero.

IPRSIP--is the printout interval for SIP. If IPRSIP is equal to zero, it is changed to 999. The maximum head change (positive or negative) is printed for each iteration of a time step whenever the time step is an even multiple of IPRSIP. This printout also occurs at the end of each stress period regardless of the value of IPRSIP.

MODELING EXAMPLE #1

- AN UNCONFINED AQUIFER IN THE HYDROLOGIC SETTING BELOW CONTAINS A SINGLE WELL P-1



- RAINFALL RECORDS INCICATE THAT PRECIPITATION IS APPROXIMATELY 500mm/yr.
- A WATER BUDGET SUGGESTS THAT 50% OF PRECIPITATION ENTERS THE SUBSURFACE AS DEEP PERCOLATION
- AQUIFER IS HOMOGENEOUS & ISOTROPIC WITH $K = 10\,m/day$, $S_y = 0.25$.
- CONSTRUCT A COMPUTER MODEL THAT WILL ALLOW FOR DETERMINATION OF SAFE YIELD OF AQUIFER.
- ASSUME AQUIFER IS 1000m THICK, AND MINIMUM PERMISSIBLE SATURATED THICKNESS IS 250 ft.

- THE OBLEO WATER DEVELOPMENT BOARD WOULD LIKE TO EXPLOIT THE AQUIFER, THEY WOULD LIKE TO KNOW (OVER A 30-YR PLANNING PERIOD)

  (a) WHAT IS THE MAXIMUM, UNIFORM PUMPING RATE AT P-1 THAT CAN BE USED SO THAT THE SATURATED THICKNESS IS NEVER LESS THAN 250m?

  (b) HOW MUCH OF THE PUMPED WATER IS INDUCED RECHARGE FROM THE TWO LAKES?

- IT IS DECIDED TO CONSTRUCT A COMPUTER MODEL TO DETERMINE THE SAFE YIELD (a) OF THE AQUIFER AND THE INDUCED RECHARGE (b).

- MODELING STEPS
  - CONCEPTUAL MODEL
  - MATHEMATICAL MODEL
  - NUMERICAL MODEL
  - DATA SET CODING
  - SOLUTION

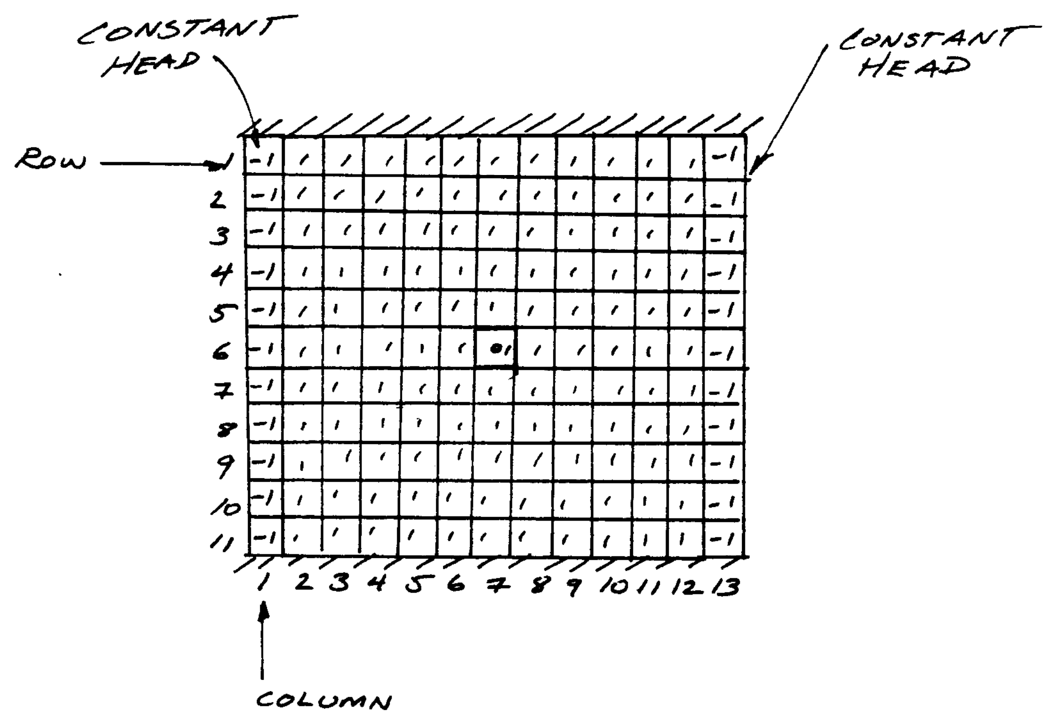
CONCEPTUAL MODEL

THE OBLEO AQUIFER IS CONCEPTUALIZED AS A SINGLE UNCONFINED, HOMOGENEOUS, ISOTROPIC, AQUIFER WITH HYDRAULIC CONDUCTIVITY, $K = 3650 m/yr$, AND SPECIFIC YIELD, $S_y = 0.25$. THE AQUIFER IS RECTANGULAR WITH DIMENSIONS OF 1100 km x 1100 km IN THE HORIZONTAL AND IS 1.0 km THICK. THE ZENITH FOOTHILLS TO THE NORTH ARE CONCEPTUALIZED AS A NO-FLOW BOUNDARY AS ARE THE NADIR MOUNTAINS TO THE SOUTH. LAKE ALPHA TO THE EAST, AND LAKE OMEGA TO THE WEST ARE CONCEPTUALIZED AS CONSTANT HEAD BOUNDARIES. A SINGLE WELL, P-1 IS PLANNED FOR THE OBLEO AQUIFER. P-1 IS LOCATED IN THE GEOGRAPHIC CENTER OF THE AQUIFER, EQUIDISTANT FROM ALL FOUR BOUNDARIES

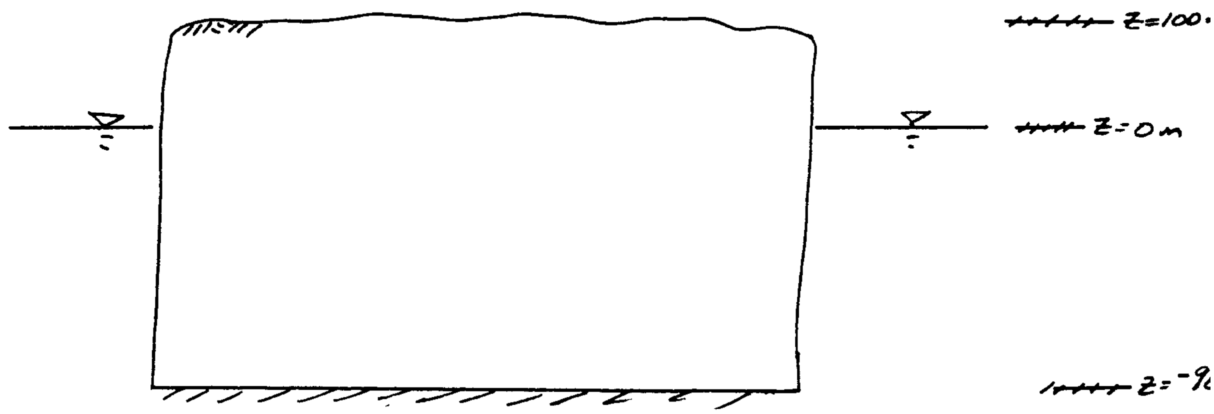
NUMERICAL MODEL

THE OBLEO AQUIFER WILL BE MODELED USING THE DUPUIT ASSUMPTIONS AS A SINGLE AQUIFER LAYER. THE HORIZONTAL RESOLUTION WILL BE 1km x 1km; THE VERTICAL RESOLUTION WILL BE 1km. FLOW IS ASSUMED TO BE ESSENTIALLY HORIZONTAL.

SOLUTIONS TO THE FINITE DIFFERENCE APPROXIMATION OF FLOW WILL BE OBTAINED USING MODFLOW



VERTICAL DATUM & ELEVATIONS



MODFLOW PACKAGES

BASIC + BLOCK CENTERED FLOW (ALWAYS)

RECHARGE + WELLS

SIP OR SSOR

DATA FILES

FOR001 ← BASIC
FOR011 ← BCF

FOR012 ← WELLS

FOR018 ← RECHARGE

FOR019 ← SIP

DATA CODING

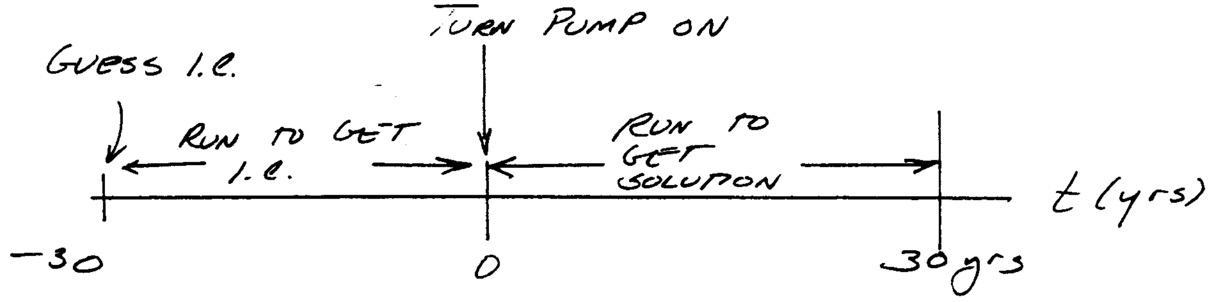
NOTE: MODFLOW ASSUMES ¡¡FORMATTED!! DATA SETS. FAILURE TO PLACE DATA INTO CORRECT FORMAT WILL CAUSE THE PROGRAM TO EITHER

(a) NOT RUN

(b) SOLVE AN ENTIRELY DIFFERENT PROBLEM.

NOTE: SINCE WE DON'T KNOW THE INITIAL CONDITION, WE WILL DO ONE RUN TO GET THE HEAD, THEN A SECOND RUN TO GET THE ANSWER.

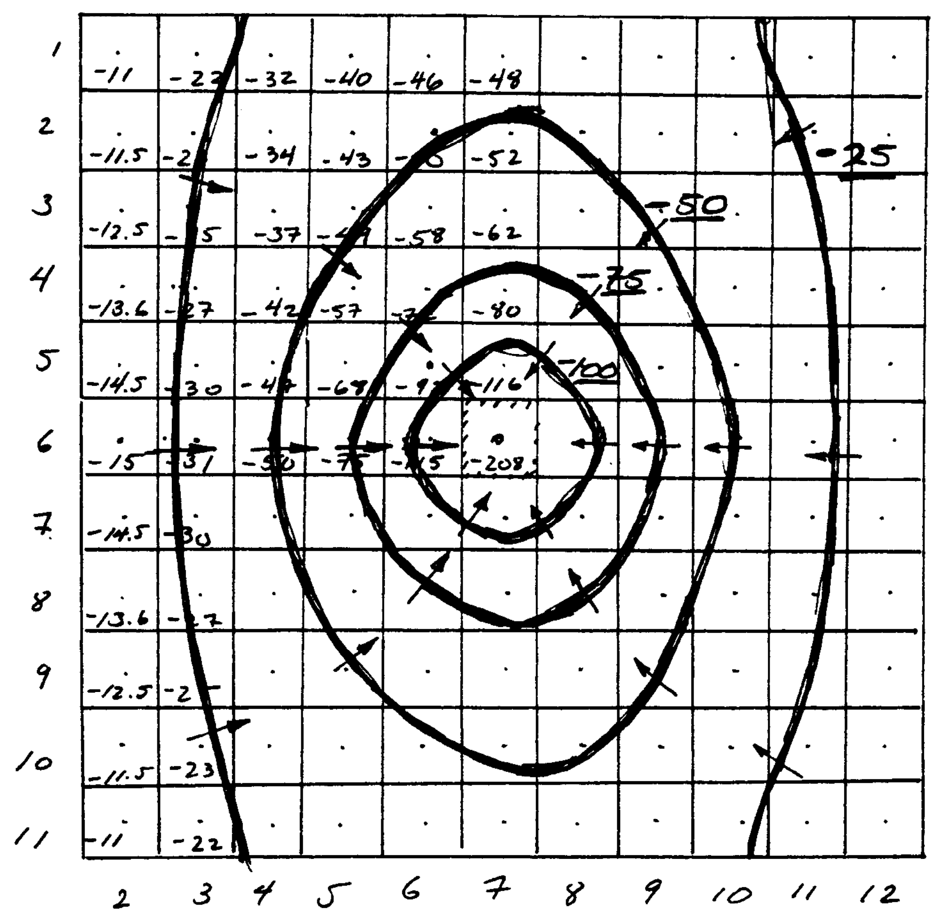
(ACTUALLY ACCOMPLISHED IN A SINGLE RUN BY:)



TO BUILD DATA FILES, USE A TEXT EDITOR ON EXISTING FILES TO MODIFY THEM FOR YOUR PROBLEM

- EXAMPLE INPUT FILES ARE ATTACHED, AS WELL AS OUTPUT

ROUGH CONTOUR MAP (30 yrs - PUMPING)



```
Output from MODFLOW_FOPT                                                                          Tue, Jul 7, 199

                         U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL

CE6361 OBLEO AQUIFER EXAMPLE PROBLEM                                 1 LAYER, 11 ROWS, 13 COLUMNS, UNCONFINED
    1 LAYERS         11 ROWS         13 COLUMNS
   2 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS YEARS

I/O UNITS:
ELEMENT OF IUNIT:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
        I/O UNIT: 11 12  0  0  0  0  0 18 19  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 12/08/83 INPUT READ FROM UNIT  1
ARRAYS RHS AND BUFF WILL SHARE MEMORY.
START HEAD WILL NOT BE SAVED -- DRAWDOWN CANNOT BE CALCULATED
   1172 ELEMENTS IN X ARRAY ARE USED BY BAS
   1172 ELEMENTS OF X ARRAY USED OUT OF  60000

BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 04/24/85 INPUT READ FROM UNIT 11
TRANSIENT  SIMULATION
      LAYER  AQUIFER TYPE
      ------------------
         1         1
    430 ELEMENTS IN X ARRAY ARE USED BY BCF
   1602 ELEMENTS OF X ARRAY USED OUT OF  60000

WEL1 -- WELL PACKAGE, VERSION 1, 04/24/85 INPUT READ FROM 12
MAXIMUM OF     1 WELLS
      4 ELEMENTS IN X ARRAY ARE USED FOR WELLS
   1606 ELEMENTS OF X ARRAY USED OUT OF  60000

RCH1 -- RECHARGE PACKAGE, VERSION 1, 04/24/85 INPUT READ FROM UNIT 18
OPTION 1 -- RECHARGE TO TOP LAYER
    143 ELEMENTS OF X ARRAY USED FOR RECHARGE
   1749 ELEMENTS OF X ARRAY USED OUT OF  60000

SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 04/24/85 INPUT READ FROM UNIT 19
MAXIMUM OF  50 ITERATIONS ALLOWED FOR CLOSURE
  5 ITERATION PARAMETERS
    777 ELEMENTS IN X ARRAY ARE USED BY SIP
   2526 ELEMENTS OF X ARRAY USED OUT OF  60000

CE6361 OBLEO AQUIFER EXAMPLE PROBLEM                                 1 LAYER, 11 ROWS, 13 COLUMNS, UNCONFINED


                         BOUNDARY ARRAY FOR LAYER  1 WILL BE READ ON UNIT  1 USING FORMAT: (20i3)
                    ------------------------------------------------------------------------------

      1  2  3  4  5  6  7  8  9 10 11 12 13
 ...........................................

  1  -1  1  1  1  1  1  1  1  1  1  1  1 -1

  2  -1  1  1  1  1  1  1  1  1  1  1  1 -1

  3  -1  1  1  1  1  1  1  1  1  1  1  1 -1

  4  -1  1  1  1  1  1  1  1  1  1  1  1 -1

  5  -1  1  1  1  1  1  1  1  1  1  1  1 -1

  6   1  1  1  1  1  1  1  1  1  1  1  1 -1

  7  -1  1 [illegible]  1  1  1  1  1  1  1  1  1 -1
```

1/8

2/8

8	-1	1	1	1	1	1	1	1	1	1	1	1	-1
9	-1	1	1	1	1	1	1	1	1	1	1	1	-1
10	-1	1	1	1	1	1	1	1	1	1	1	1	-1
11	-1	1	1	1	1	1	1	1	1	1	1	1	-1

AQUIFER HEAD WILL BE SET TO 100.00 AT ALL NO-FLOW NODES (IBOUND=0).

INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (10f10.0)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DEFAULT OUTPUT CONTROL -- THE FOLLOWING OUTPUT COMES AT THE END OF EACH STRESS PERIOD:
TOTAL VOLUMETRIC BUDGET
HEAD

COLUMN TO ROW ANISOTROPY WILL BE READ ON UNIT 11 USING FORMAT: (10G10.3)

1.0000

DELR WILL BE READ ON UNIT 11 USING FORMAT: (10G10.3)

1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
1000.00	1000.00	1000.00							

DELC WILL BE READ ON UNIT 11 USING FORMAT: (10g10.3)

3/8

1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00 1000.00
1000.00

PRIMARY STORAGE COEF FOR LAYER 1 WILL BE READ ON UNIT 11 USING FORMAT: (10G10.3)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
9	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
10	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
11	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

HYD. COND. ALONG ROWS FOR LAYER 1 WILL BE READ ON UNIT 11 USING FORMAT: (10G10.3)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
2	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
3	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
4	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
5	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
6	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
7	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
8	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
9	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
10	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0
11	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0	3650.0

BOTTOM FOR LAYER 1 WILL BE READ ON UNIT 11 USING FORMAT: (10G10.3)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
2	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
3	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
4	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
5	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
6	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
7	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
8	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
9	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
10	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0
11	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0	-900.0

SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE

MAXIMUM ITERATIONS ALLOWED FOR CLOSURE = 50
ACCELERATION PARAMETER = 1.0000
HEAD CHANGE CRITERION FOR CLOSURE = 0.10000E-06
SIP HEAD CHANGE PRINTOUT INTERVAL = 1

5 ITERATION PARAMETERS CALCULATED FROM SPECIFIED WSEED = 0.00100000 :

0.0000000E+00 0.8221720E+00 0.9683772E+00 0.9943766E+00 0.9990000E+00

STRESS PERIOD NO. 1, LENGTH = 30.00000

NUMBER OF TIME STEPS = 1

MULTIPLIER FOR DELT = 1.000

INITIAL TIME STEP SIZE = 30.00000

1 WELLS

LAYER	ROW	COL	STRESS RATE	WELL NO.
1	6	7	0.00000	1

RECHARGE WILL BE READ ON UNIT 18 USING FORMAT: (10G10.3)

1 2 3 4 5 6 7 8 9 10 11 12 13

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1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
9	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
10	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
11	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

16 ITERATIONS FOR TIME STEP 1 IN STRESS PERIOD 1

MAXIMUM HEAD CHANGE FOR EACH ITERATION:

```
 HEAD CHANGE  LAYER,ROW,COL HEAD CHANGE  LAYER,ROW,COL HEAD CHANGE  LAYER,ROW,COL HEAD CHANGE  LAYER,ROW,COL HEAD CHANGE  LAYER,ROW,COL
-----------------------------------------------------------------------------------------------------------------------------------------
  0.1789     (  1, 11,  7)  0.3522     (  1,  2,  7)  0.5635     (  1, 11,  7)  0.3104     (  1,  1,  8)  0.3423E-01 (  1, 11,  9)
  0.2588E-02 (  1,  5, 11) -0.3325E-02 (  1,  8,  6) -0.2349E-02 (  1, 10,  5) -0.1113E-02 (  1, 11,  7) -0.1702E-03 (  1,  1,  9)
 -0.1604E-04 (  1,  5, 11) -0.2024E-04 (  1,  7, 10) -0.1186E-04 (  1, 11, 10) -0.3640E-05 (  1, 10,  9)  0.5682E-06 (  1,  9, 10)
  0.7556E-07 (  1,  1, 10)
```

HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

ESTIMATE OF PREDEVELOPMENT HEAD!!

	1 / 11	2 / 12	3 / 13	4	5	6	7	8	9	10
1	0.0000	0.4052	0.7351	0.9909	1.173	1.282	1.318	1.282	1.173	0.9909
	0.7351	0.4052	0.0000							
2	0.0000	0.4052	0.7351	0.9909	1.173	1.282	1.318	1.282	1.173	0.9909
	0.7351	0.4052	0.0000							
3	0.0000	0.4052	0.7351	0.9909	1.173	1.282	1.318	1.282	1.173	0.9909
	0.7351	0.4052	0.0000							
4	0.0000	0.4052	0.7351	0.9909	1.173	1.282	1.318	1.282	1.173	0.9909
	0.7351	0.4052	0.0000							
5	0.0000	0.4052	0.7351	0.9909	1.173	1.282	1.318	1.282	1.173	0.9909
	0.7351	0.4052	0.0000							
6	0.0000	0.4052	0.7351	0.9909	1.173	1.282	1.318	1.282	1.173	0.9909
	0.7351	0.4052	0.0000							
7	0.0000	0.4052	0.7351	0.9909	1.173	1.282	1.318	1.282	1.173	0.9909
	0.7351	0.4052	0.0000							
8	0.0000	0.4052	0.7351	0.9909	1.173	1.282	1.318	1.282	1.173	0.9909

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```
      0.7351     0.4052     0.0000

  9   0.0000     0.4052     0.7351     0.9909     1.173     1.282     1.318     1.282     1.173     0.9909
      0.7351     0.4052     0.0000

 10   0.0000     0.4052     0.7351     0.9909     1.173     1.282     1.318     1.282     1.173     0.9909
      0.7351     0.4052     0.0000

 11   0.0000     0.4052     0.7351     0.9909     1.173     1.282     1.318     1.282     1.173     0.9909
      0.7351     0.4052     0.0000
```

```
              VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  1
              ---------------------------------------------------------------------------

     CUMULATIVE VOLUMES      L**3                      RATES FOR THIS TIME STEP      L**3/T
     ------------------                                ------------------------

           IN:                                               IN:
           ---                                               ---
             STORAGE =    0.00000                              STORAGE =   0.00000
       CONSTANT HEAD =    0.00000                        CONSTANT HEAD =   0.00000
               WELLS =    0.00000                                WELLS =   0.00000
    ....™U™U =    0.90750E+09   <-- RECHARGE IN        ....™U™U =   0.30250E+08

            TOTAL IN =    0.90750E+09                         TOTAL IN =   0.30250E+08

          OUT:                                              OUT:
          ----                                              ----
             STORAGE =    0.28850E+08 <-- ΔSTORAGE IN AQUIFER  STORAGE =   0.96166E+06
       CONSTANT HEAD =    0.87865E+09 <-- INDUCED FLUX   CONSTANT HEAD =   0.29288E+08
               WELLS =    0.00000         TO LAKES               WELLS =   0.00000
    ....™U™U =    0.00000                              ....™U™U =   0.00000

           TOTAL OUT =    0.90750E+09                        TOTAL OUT =   0.30250E+08

            IN - OUT =    0.00000                             IN - OUT =   0.00000

 PERCENT DISCREPANCY =              0.00           PERCENT DISCREPANCY =              0.00
```

TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	0.946728E+09	0.157788E+08	262980.	10957.5	30.0000
STRESS PERIOD TIME	0.946728E+09	0.157788E+08	262980.	10957.5	30.0000
TOTAL SIMULATION TIME	0.946728E+09	0.157788E+08	262980.	10957.5	30.0000

```
                    STRESS PERIOD NO.    2, LENGTH =   30.00000
                    ----------------------------------------------

                    NUMBER OF TIME STEPS =     1

                     MULTIPLIER FOR DELT =     1.000

                  INITIAL TIME STEP SIZE =   30.00000

   1 WELLS
```

LAYER	ROW	COL	STRESS RATE	WELL NO.
1	6	7	-0.10000E+10	1

RECHARGE = 0.2500000

50 ITERATIONS FOR TIME STEP 1 IN STRESS PERIOD 2

MAXIMUM HEAD CHANGE FOR EACH ITERATION:

HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL	HEAD CHANGE	LAYER,ROW,COL
-109.7	(1, 6, 7)	-39.14	(1, 6, 7)	-37.70	(1, 6, 7)	-19.82	(1, 6, 7)	-3.177	(1, 6, 7)
-0.5687	(1, 6, 7)	-0.2902	(1, 4, 9)	-0.1254	(1, 1, 10)	-0.7193E-01	(1, 6, 7)	-0.1690E-01	(1, 3, 9)
0.7612E-02	(1, 7, 7)	0.3873E-02	(1, 6, 7)	0.3557E-02	(1, 6, 7)	0.1067E-02	(1, 1, 8)	-0.4330E-03	(1, 10, 9)
0.8723E-04	(1, 7, 6)	0.9885E-04	(1, 7, 6)	0.6186E-04	(1, 9, 6)	0.3285E-04	(1, 6, 7)	0.9420E-05	(1, 6, 7)
0.4929E-05	(1, 6, 7)	0.9489E-06	(1, 8, 10)	0.5456E-06	(1, 9, 8)	0.3227E-06	(1, 11, 5)	-0.3215E-06	(1, 11, 9)
-0.2068E-06	(1, 1, 9)	-0.2353E-06	(1, 11, 9)	-0.1772E-06	(1, 1, 9)	0.1467E-06	(1, 1, 5)	0.2022E-06	(1, 11, 5)
-0.2098E-06	(1, 11, 5)	0.2328E-06	(1, 1, 9)	0.1944E-06	(1, 1, 5)	-0.1748E-06	(1, 1, 5)	0.1780E-06	(1, 11, 9)
-0.2291E-06	(1, 1, 5)	0.2251E-06	(1, 11, 9)	0.1953E-06	(1, 11, 5)	0.2154E-06	(1, 1, 5)	-0.2106E-06	(1, 1, 5)
-0.2296E-06	(1, 11, 5)	-0.2525E-06	(1, 1, 9)	0.1799E-06	(1, 11, 9)	0.2083E-06	(1, 11, 5)	-0.2129E-06	(1, 11, 5)
-0.2118E-06	(1, 1, 9)	-0.2446E-06	(1, 11, 9)	-0.1970E-06	(1, 1, 9)	-0.1466E-06	(1, 11, 5)	0.1991E-06	(1, 11, 5)

****FAILED TO CONVERGE IN TIME STEP 1 OF STRESS PERIOD 2**** ← NOTE WARNING!! INCREASING

HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 2

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.0000	-11.09	-21.91	-31.88	-40.20	-45.89	-47.94	-45.89	-40.20	-31.88	-21.91	-11.09	0.0000
2	0.0000	-11.59	-23.03	-33.80	-43.10	-49.75	-52.28	-49.75	-43.10	-33.80	-23.03	-11.59	0.0000
3	0.0000	-12.50	-25.09	-37.47	-48.95	-58.02	-62.00	-58.02	-48.95	-37.47	-25.09	-12.50	0.0000
4	0.0000	-13.61	-27.71	-42.42	-57.60	-71.84	-80.19	-71.84	-57.60	-42.42	-27.71	-13.61	0.0000
5	0.0000	-14.58	-30.09	-47.40	-67.78	-92.38	-116.5	-92.38	-67.78	-47.40	-30.09	-14.58	0.0000
6	0.0000	-14.98	-31.15	-49.97	-74.72	-115.1	-208.8	-115.1	-74.72	-49.97	-31.15	-14.98	0.0000
7	0.0000	-14.58	-30.09	-47.40	-67.78	-92.38	-116.5	-92.38	-67.78	-47.40	-30.09	-14.58	0.0000
8	0.0000	-13.61	-27.71	-42.42	-57.60	-71.84	-80.19	-71.84	-57.60	-42.42	-27.71	-13.61	0.0000
9	0.0000	-12.50	-25.09	-37.47	-48.95	-58.02	-62.00	-58.02	-48.95	-37.47	-25.09	-12.50	0.0000
10	0.0000	-11.59	-23.03	-33.80	-43.10	-49.75	-52.28	-49.75	-43.10	-33.80	-23.03	-11.59	0.0000
11	0.0000	-11.09	-21.91	-31.88	-40.20	-45.89	-47.94	-45.89	-40.20	-31.88	-21.91	-11.09	0.0000

FIX BY INCREASING ITERATION LIMIT IN FOR019 OR INCREAS[E] CLOSURE TOLERANCE (SAME FILE)

ASSUME THIS IS OK (FOR CLASS) POST-DEVELOPMENT DISTRIBUTION

```
                    VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  2
                    ------------------------------------------------------------------------------

     CUMULATIVE VOLUMES      L**3                            RATES FOR THIS TIME STEP      L**3/T
     ------------------                                      ------------------------

           IN:                                                     IN:
           ---                                                     ---
              STORAGE =   0.13631E+10                                 STORAGE =   0.45438E+08
        CONSTANT HEAD =   0.27729E+11                           CONSTANT HEAD =   0.92431E+09
                WELLS =   0.00000                                       WELLS =   0.00000
    ''''™U™U =   0.18150E+10                               ''''™U™U =   0.30250E+08

             TOTAL IN =   0.30908E+11                                TOTAL IN =   0.10000E+10

          OUT:                                                    OUT:
          ----                                                    ----
              STORAGE =   0.28850E+08                                 STORAGE =   0.00000
        CONSTANT HEAD =   0.87865E+09                           CONSTANT HEAD =   0.00000
                WELLS =   0.30000E+11                                   WELLS =   0.10000E+10
    ''''™U™U =   0.00000                                   ''''™U™U =   0.00000

            TOTAL OUT =   0.30908E+11                               TOTAL OUT =   0.10000E+10

             IN - OUT =    2048.0                                    IN - OUT =   0.00000

  PERCENT DISCREPANCY =                 0.00             PERCENT DISCREPANCY =                 0.00
```

```
      TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD  2
                             SECONDS       MINUTES        HOURS         DAYS          YEARS
                           -------------------------------------------------------------------
     TIME STEP LENGTH      0.946728E+09  0.157788E+08    262980.       10957.5       30.0000
   STRESS PERIOD TIME      0.946728E+09  0.157788E+08    262980.       10957.5       30.0000
 TOTAL SIMULATION TIME     0.189346E+10  0.315576E+08    525960.       21915.0       60.0000
```

STOP

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