DUE TODAY

Assignment #4 Finite Differencing by spreadsheet: Create a simplified 2D steady finite difference spreadsheet model of your problem, explain what it does.

Your submission should include:
Title
Objective
Problem Description
Spreadsheet setup Description
Simplification of System in order to use the spreadsheet model
Explanation of spreadsheet calculations
Explanation of Results (if appropriate comparison to analytical solution)

Submit the write-up as hard copy and include it in your zip file with the spreadsheet label the zip file: ASSGN4_LASTNAME.ZIP

Grading considers degree of difficulty as well as correctness

Overview of MODFLOW

MODFLOW needs many ASCII text files describing grid, properties, boundary conditions, initial conditions, time steps, stresses, solution and output options.

A graphical user interface (GUI) provides a nice image of model features where you can manipulate model inputs graphically. When you are ready, the GUI creates the text files and executes MODFLOW. You never need to see the text files or know the commands that are necessary to run MODFLOW ... until something goes wrong!

If you do not have the ability to look in, and understand the content of these files or control these commands, you will not be a valuable modeler. Inevitably something does not work correctly in the GUI. Or, you want to do something unique with your project that the GUI developer hadn't planned on. If you do not understand the file structure and commands, you cannot move forward. You are paralyzed, and your project is in jeopardy. I have seen this happen to many people.

In short, you may dislike the tedium of working with text files, but please be patient and persevere because the effort will be worth it in the future. You will be a hero on modeling projects due to this knowledge and skill.

AND we will explore GUIs a bit later in the course

Reading for MODFLOW modelers

Read the MOFLOW documents in order
MODFLOW 1988 1996 2000 2005
links are on the class web page

Read for the essence of how the codes perform
Do not try to read detailed descriptions of input or source code
go back for those details at the specific time you need them in the future

Note the conceptual model features of MODFLOW discussed in the 1988
are very important and are NOT repeated in later documents

Further Reading for MODFLOW modelers

There are many additional simulation packages
And
Many data processing tools
to learn about

KEEP UP-TO-DATE on

New Developments

And

MODFLOW Software updates

USGS Software Web Site
http://water.usgs.gov/nrp/gwsoftware/

BOOKMARK THAT PAGE!

Let's open a new browser session there now,
http://water.usgs.gov/nrp/gwsoftware/
This is where you can get the freeware to install in your own computer

ONLINE MODFLOW MANUAL

USGS Online Guide to MODFLOW-2000/2005

http://water.usgs.gov/nrp/gwsoftware/modflow2000/MFDOC/guide.html

BOOKMARK THAT PAGE!

Let's open a new browser session there now

Note you can download this to your computer and use it off line, but it will not be updated unless you download and replace it

MODFLOW 2000/2005 PROCESS:

MODFLOW-2000/2005 include:
GLO Global Process that controls overall program flow
GWF Ground-water Flow Process
OBS Observation Process

MODFLOW-2000 also includes:
SEN Sensitivity Process (slated for MF2005)
PES Parameter Estimation Process (being discontinued as MF2005 will depend on UCODE)

Plans are to expand the available tools

SUMMARY OF MODFLOW CAPABILITIES:

Single Phase, Saturated Flow
Constant Density
Porous Media (Darcy's Law applies)
1, 2, Or 3 Dimensional (2D areal or cross-section OR Quasi-3D)
Steady State or Transient Flow
Heterogeneous, Anisotropic (aligned with grid), Layered Units
Block Centered Finite Difference with variable grid spacing
Units can be Confined or Convertible
Boundary conditions include: Dirichlet, Neuman, Cauchy, and Phreatic Surface
Stresses such as Wells, Recharge, Evapotranspiration, Rivers, Drains etc
Springs, Thin Barriers to Horizontal Flow, Re-wetting
Many Solver options
Monitoring of simulated values comparable to field observations

Sensitivity of simulated values to changes in some parameter values is available in MF2000 and will be added to MF2005
Estimation of some types of parameters is available in MF2000
Parameter estimation has been discontinued in MF2005 and will instead be accomplished by UCODE

BASIC INPUT ITEMS INCLUDE

Grid
Time stepping
Hydraulic parameters
Boundary Conditions
Stresses
Solution parameters

BASIC OUTPUT ITEMS:

Hydraulic Heads
Drawdown
Flow rates
Mass Balance
Optional info at specified times
Iteration information

Underscore files describing various model inputs/outputs
Binary files containing output in compressed form

Modular Flow Modeling Input

MODFLOW needs an ASCII text file that lists the modules that are to be used to simulate a ground water flow system.

This is the NAME file

MODFLOW needs an ASCII text file for each module. Our focus in this class will be on the commonly used modules. Once you are prepared to use these packages, picking up a new package and using it is easy.

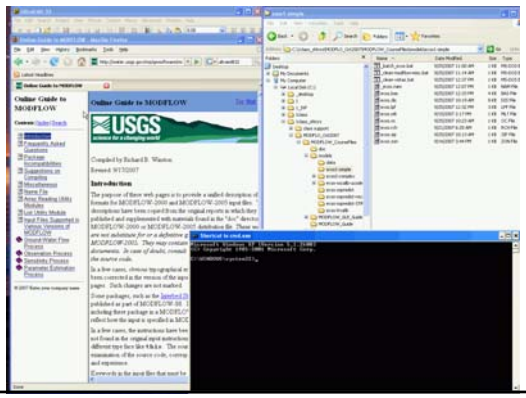
Examples of Common modules for the Ground Water Flow Process of MODFLOW

dis – discretization – describes the grid and time stepping
bas6 – basic - describes the active cells and initial conditions
lpf – layer property flow - describes the properties of the porous media
rch – recharge - describes the rate of water infiltration to the ground water
wel – well– describes flow rates at point locations
ghb – general head boundary - describes head dependent flux boundaries
drn – drain - describes drain/spring location, elevation and bed properties
riv – river - describes river location, stage and bed properties
str – stream - describes stream location, stage/flow and bed properties
pcg/sip – solvers for the matrix equations
oc – output control – describes what to print
mult – multiplication arrays - describes how properties are distributed in space
zone – zone arrays – describes how properties are distributed in space

LET'S BUILD A MODEL FOR THIS SYSTEM TOGETHER

Get your screen ready to build MODFLOW files

Text editor (~~ULTRA EDIT~~ PROGRAMMERS NOTEPAD)
Command Window (left click start and choose *Run* then type cmd, click OK)
Online Manual in a browser (this should already be open)
Windows Explorer (right click STARTand choose *Explore*)
create and position it to a folder where you will store your model work
choose to show details
Under Tools>FolderOptions
unclick Hide extensions for known file types
Let a little of each protrude to facilitate you work



Build simple MODFLOW files

For the simple case we will need a **Name file** with list

Output file

dis
bas6
lpf
mult
zone
rch
riv
sip
oc

Input files

data(binary) for calculated cell by cell flows
data(binary) for calculated heads

Output files

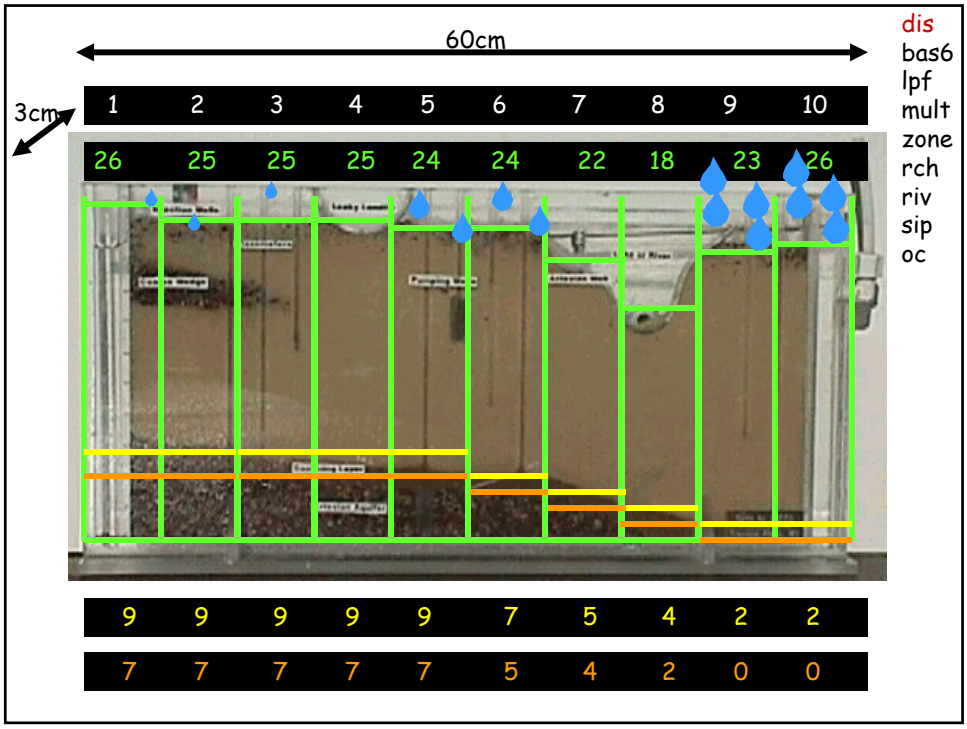
Find directions for the name file in the On-line Guide

DIS discretization package

dis
bas6
lpf
mult
zone
rch
riv
sip
oc

Build dis (MF2000 and later) package:
find instructions in the manual or on-line guide
Work in centimeters and seconds
Start with a steady state simulation

How will you grid this?
Perhaps 1 row 10 col 3 layers?
RATHER use 3 rows
so we can explore MODFLOW input in all dimensions
Perhaps 2 active layers and a quasi3D-confining layer?



Try to run MODFLOW from a command window

Start > Run > cmd OK

If the folder with your files is on a different drive than the default then type its drive letter: e.g. Z:

TYPE cd space THEN folder name OR drag folder name from Windows Explorer

then type:

C:\wrdapp\MF2005.1_8\bin\mf2005.exe your namefile *.nam

* Indicates your chosen root file name

What new files are created? Look inside them.

What is wrong?

NEXT Create a batch file to run MODFLOW *.bat

Contains path to MODFLOW executable & name file name

C:\wrdapp\MF2005.1_8\bin\mf2005.exe *.nam

Try running via double click

Try dragging your batch file into a cmd window & hit return

Add a pause to the batch file and try the double click

BAS6 basic package

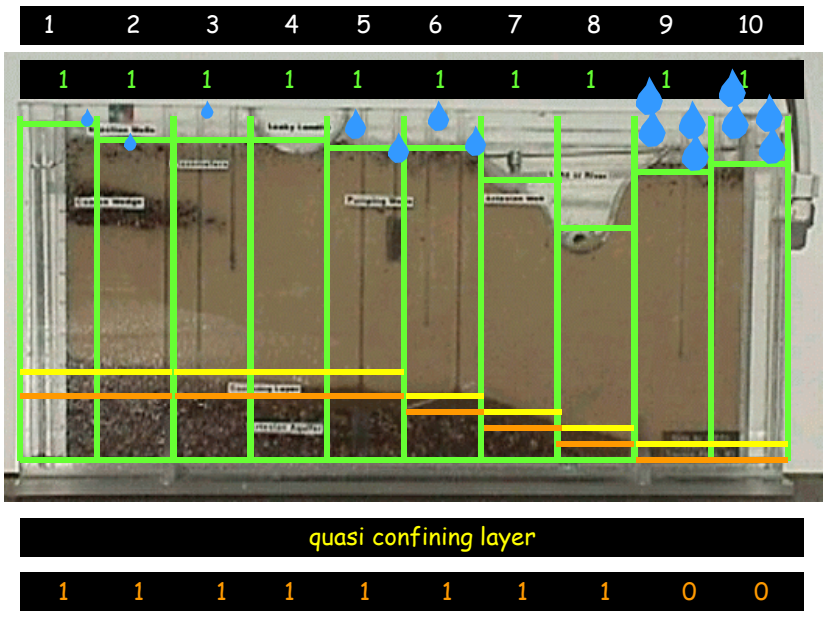
dis
bas6
lpf
mult
zone
rch
riv
sip
oc

Build bas package: find instructions in the manual or on-line guide

What is input via the basic package?
Which cells are active? Constant heads? Inactive?
What will you use for starting heads?

Try to run MODFLOW double click *.bat

dis
bas6
lpf
mult
zone
rch
riv
sip
oc



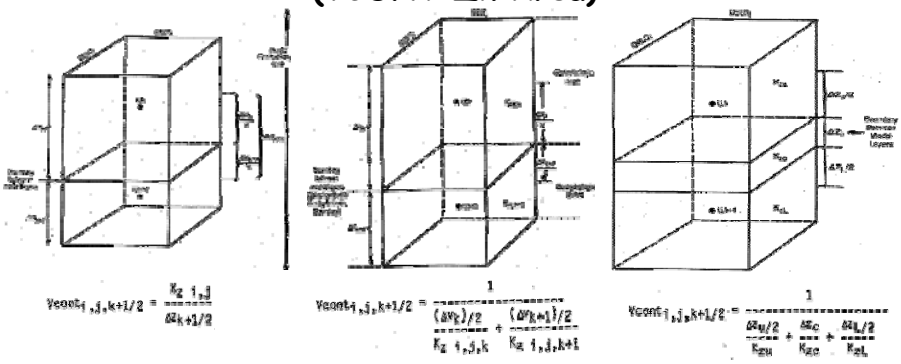
LPF layer property flow package

dis
bas6
lpf
mult
zone
rch
riv
sip
oc

Build lpf (2000 & later) package: find instructions in the manual or on-line guide

What is input using the lpf pcakage?
What aquifer types and charcateristics will we use?
What properties will we use?
What are mult and zones files? Do we need them?

What's a VCONT (earlier MF versions)? Kz/thickness
How does MODFLOW calculate Q between layers? (VCONT Δh Area)



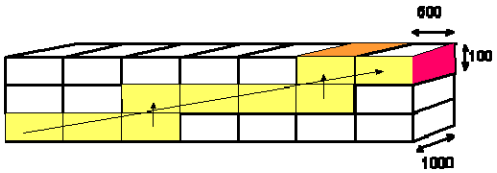
$$Vcont_{i,j,k+1/2} = \frac{K_{z\ i,j,k}}{\Delta z_{k+1/2}}$$

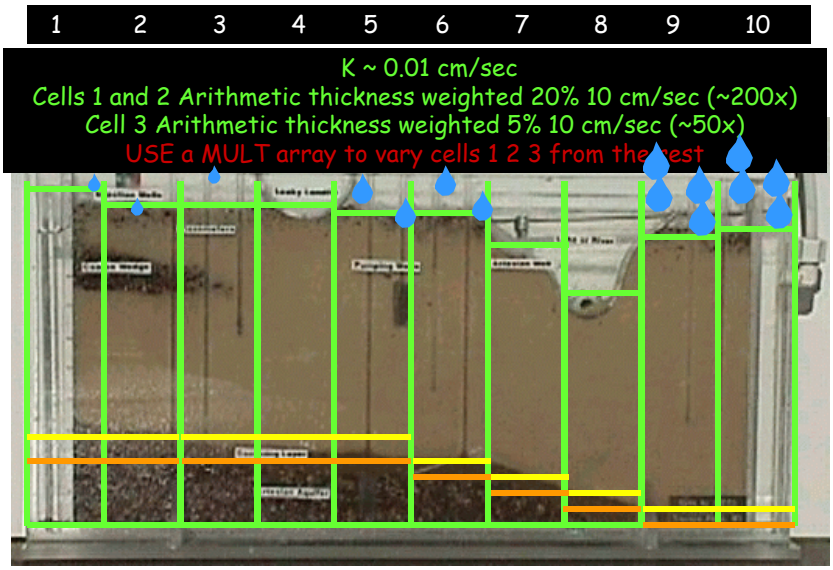
$$Vcont_{i,j,k+1/2} = \frac{1}{\frac{(\Delta z_k)/2}{K_{z\ i,j,k}} + \frac{(\Delta z_{k+1})/2}{K_{z\ i,j,k+1}}}$$

$$Vcont_{i,j,k+1/2} = \frac{1}{\frac{\Delta z_U/2}{K_{zU}} + \frac{\Delta z_C}{K_{zC}} + \frac{\Delta z_L/2}{K_{zL}}}$$

or

$$Vcont_{i,j,k+1/2} = \frac{K_{zc}}{\Delta z_c}$$





dis
bas6
lpf
mult
zone
rch
riv
sip
oc

Try to run MODFLOW with the lpf package double click *.bat

RCH recharge package

dis
bas6
lpf
mult
zone
rch
riv
sip
oc

Build rch package: find instructions in the manual or on-line guide

What is the recharge for this system?
What are the options related to recharge input?
What rate will we use?

Try to run MODFLOW double click *.bat

dis
bas6
lpf
mult
zone
rch
riv
sip
oc

RIV river package

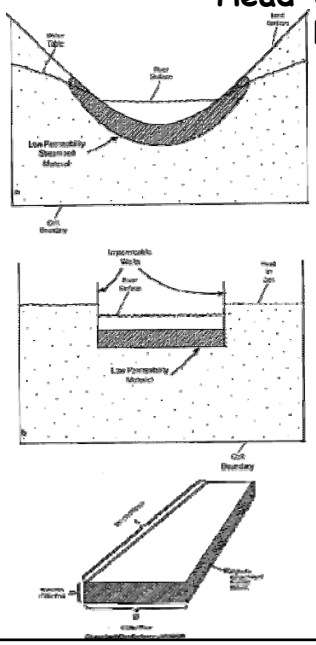
dis
bas6
lpf
mult
zone
rch
riv
sip
oc

Build riv package: find instructions in the manual or on-line guide

What is the river conductance for this system?
What are the options related to river input?
What values will we use?

Try to run MODFLOW double click *.bat

Better define Boundary Conditions
Head-dependent Flux Packages
RIVER riv package



MODFLOW requires that the user input Conductance, which is all of Darcy's Law except the head difference for Head Dependent Flux boundaries.

Q = KA dh/dl

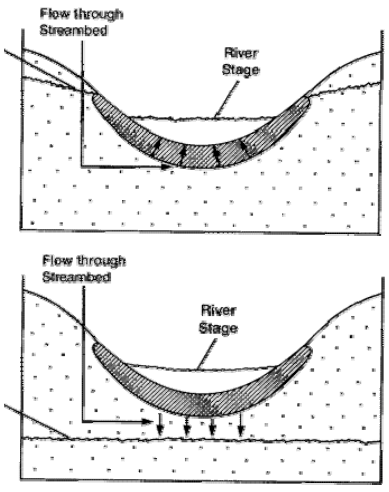
Conductance = KA/thickness

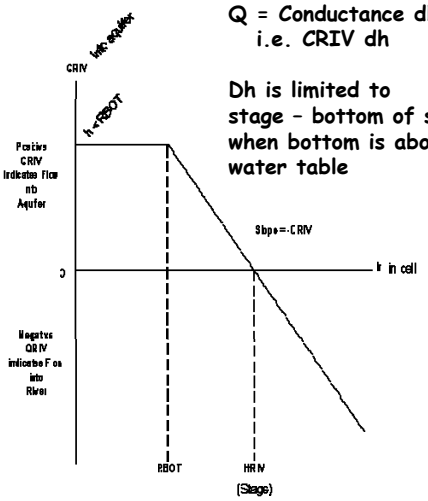
then MODFLOW calculates the flow as:
Q = Conductance dh

Conductance of the river bed is calculated as:
Kv * Area(the plan view area,L*W) / thickness

Condfact omits the K and MODFLOW calculates conductance from that
Condfact = Area/thickness

Better define Boundary Conditions
Head-dependent Flux Packages
RIVER riv package





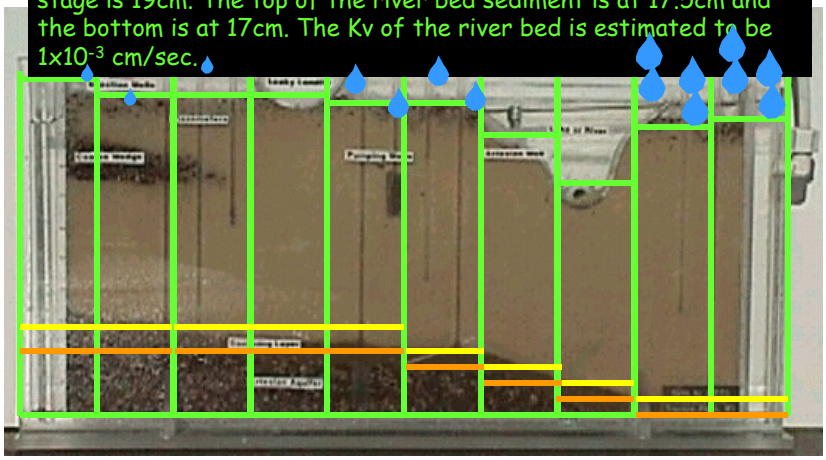
Q = Conductance dh
i.e. CRIV dh

Dh is limited to stage – bottom of sediment when bottom is above the water table

1 2 3 4 5 6 7 8 9 10

dis
bas6
lpf
mult
zone
rch
riv
sip
oc

River is in layer one column 8 rows 1, 2, 3. It is 5cm wide and the stage is 19cm. The top of the river bed sediment is at 17.5cm and the bottom is at 17cm. The Kv of the river bed is estimated to be $1x10^{-3}$ cm/sec.

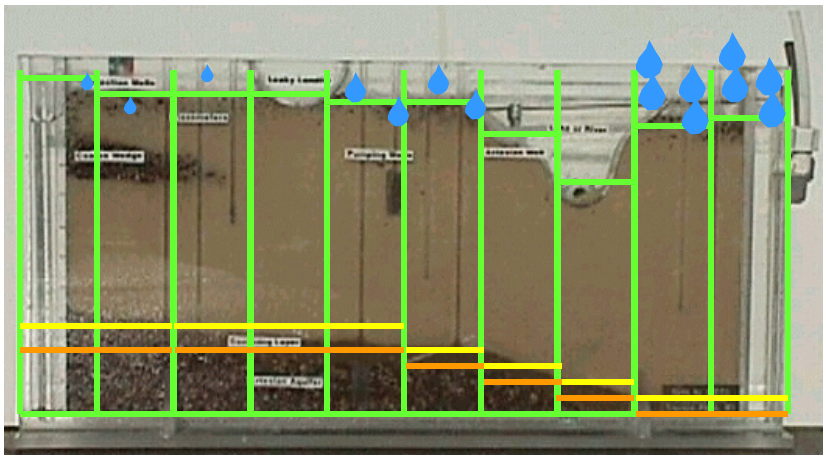


1 2 3 4 5 6 7 8 9 10

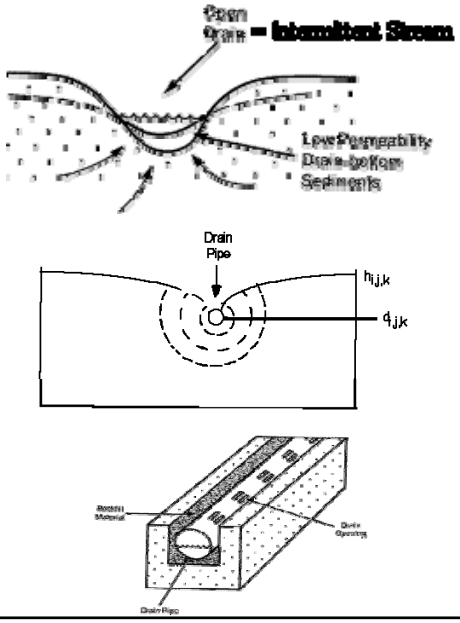
dis
bas6
lpf
mult
zone
rch
riv
sip
oc

HOW COULD WE REPRESENT THE RIVER WITH A DRAIN INSTEAD?

River is in layer one column 8 rows 1, 2, 3. It is 5cm wide and the stage is 19cm. The top of the river bed sediment is at 17.5cm and the bottom is at 17cm. The Kv of the river bed is estimated to be $1x10^{-3}$ cm/sec.



Head-dependent Flux Packages
DRAIN drn package



MODFLOW requires that the user input Conductance, which is all of Darcy's Law except the head difference for Head Dependent Flux boundaries.

Q = KA dh/dl

Conductance = KA/thickness

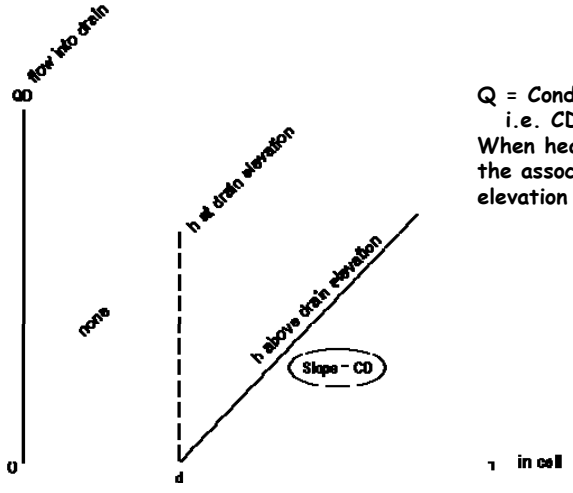
then MODFLOW calculates the flow as:
Q = Conductance dh

Conductance of the drain is calculated as:
$K_{\text{of material over which gradient is calculated}}$ * Area/thickness

Area may be the cylindrical area midway between where the heads used for the gradient are located* length of the drain

Condfact omits the K and MODFLOW calculates conductance from that
Condfact = Area/thickness

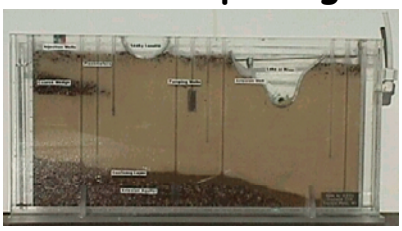
Head-dependent Flux Packages
DRAIN drn package
Only allows outflow



Q = Conductance dh
i.e. CD dh
When head is above the associated elevation

SIP a solver package

dis
bas6
lpf
mult
zone
rch
riv
sip
oc



Build sip package: find instructions in the manual or on-line guide

What are the solver options?

Try 50 iterations with a tolerance=1.0
If the mass balance is poor decrease tol and if necessary increase # iterations

Try to run MODFLOW double click *.bat

Try running this model with different tolerance in sip
What is different? Why?

OC output control package

dis
bas6
lpf
mult
zone
rch
riv
sip
oc

Build oc package: find instructions in the manual or on-line guide

What are the output options?

Try to run MODFLOW double click *.bat

Return to your model file directory
Execute your MODFLOW batch file
What new files were created?
(check date and time to know what is new)
Were they specified in the name file?
Drag them into the text editor

Read through contents for: Echo, Solution Progress, Results
VERY IMPORTANT: USE YOUR HYDROLOGIC COMMON SENSE
Have expectations for the model results, question all aspects of the situation when calculations do not match expectations
Fix Problems

Confused about what might have gone wrong?
1Look for clues in command window after executing MODFLOW
2 View end of output files for messages or at least an indication of the point at which things went wrong

When you run the model, you should expect that there will be errors and be pleasantly surprised if there are not. When you see an error:

1) look closely at the error message, try to understand it, use any clue that may be provided (paths, directories, file names, numbers) to explore it
2) check the directory to see what files were created and view their contents, look at the dates and times on files to determine what was created recently
3) delete outputs and try it again and look at the new outputs
4) as Winston Churchill once said, "never, never, give up". If you do not find the error, keep thinking and experimenting to decipher the situation. Utilize "show me" skills, like printing the flows at constant heads.

DUE NEXT WEEK

to get credit for Assgn#5 (which is not due until Feb 23)

Submit MODFLOW files covered today (Feb 2) but for your project and your grid

If it does all you expect tell me that. If you are having problems, tell me specifically how you know you are having a problem and I will offer suggestions.