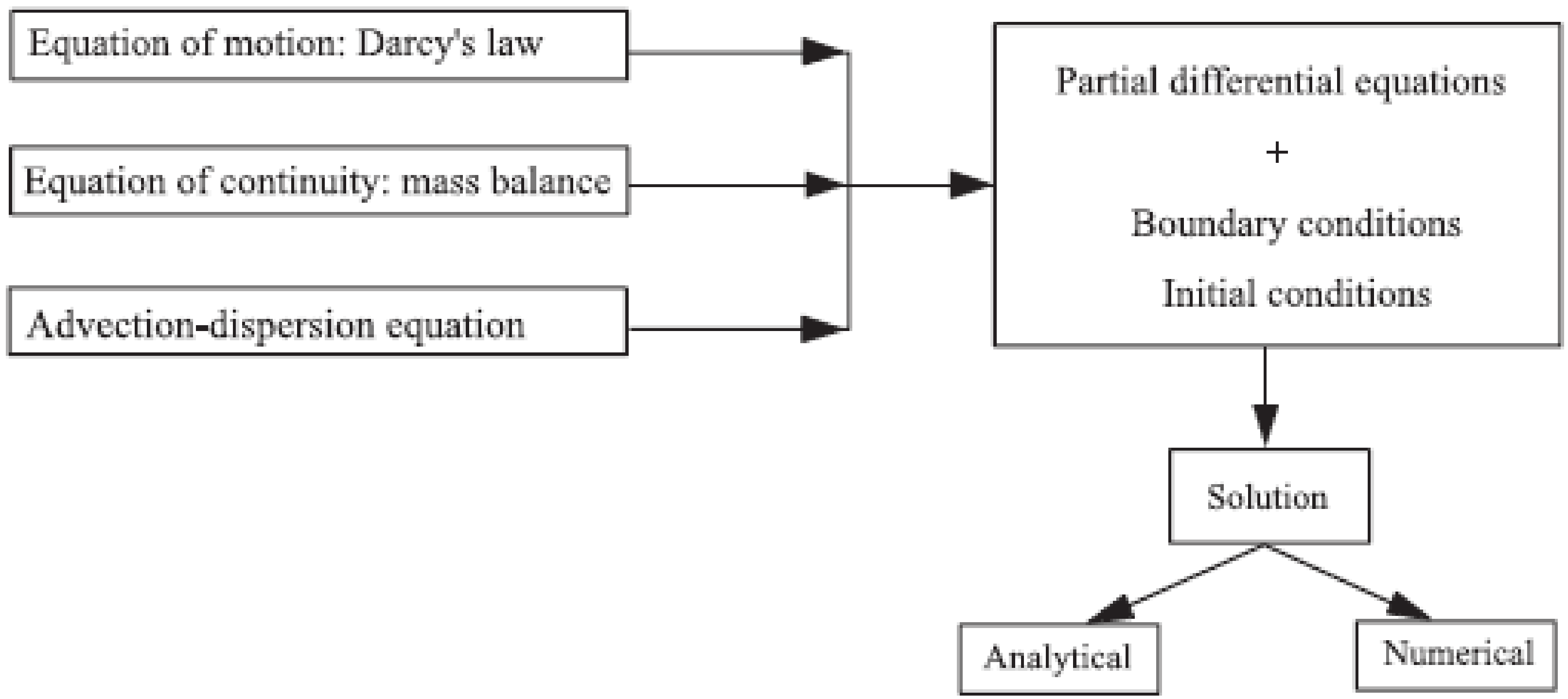
Professional Software for Groundwater Modelling: MODFLOW

Groundwater Engineering| CE60205 Lecture: 22

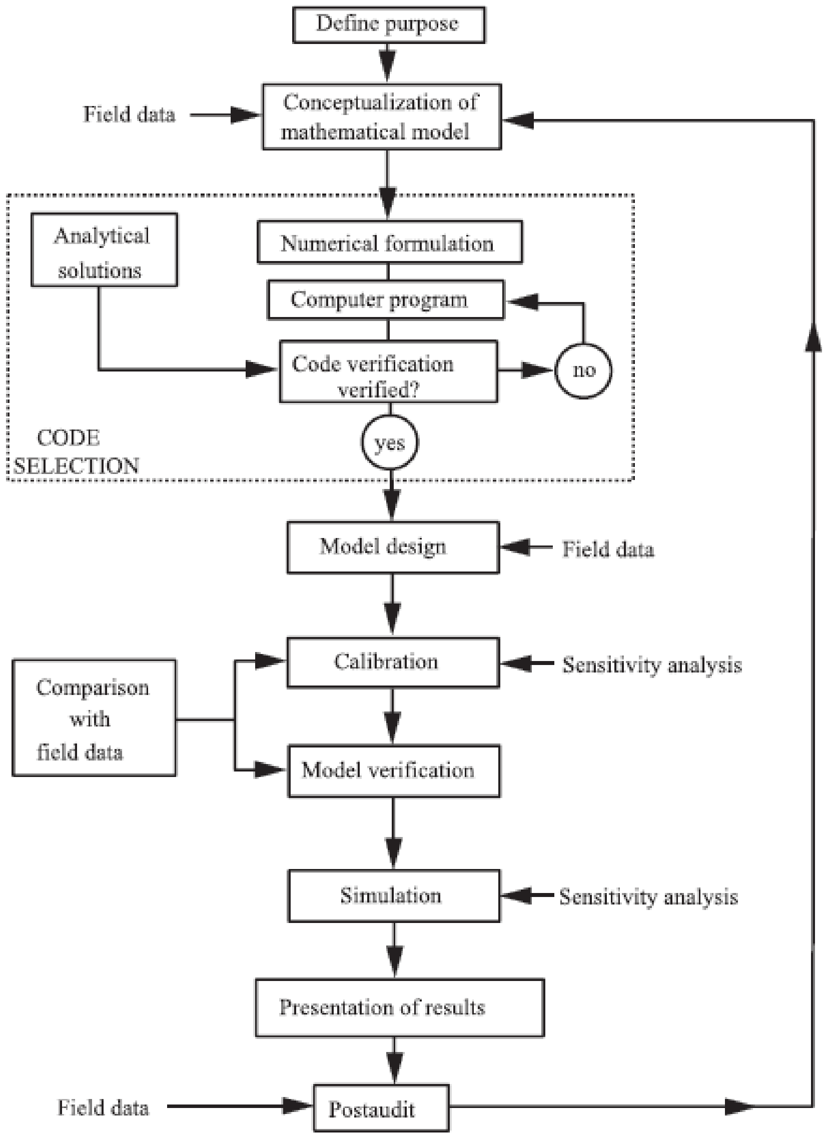
Learning Objective(s)

- To solve groundwater flow and transport using standard model

Groundwater Model



Groundwater Model (Contd.)



Groundwater Model (Contd.)

- A conceptual groundwater flow model is a simplification of a real-world groundwater problem such that (1) it captures the essential features of the real-world problem and (2) it can be described mathematically-Haitjema, 1995

- A conceptual model is an evolving hypothesis identifying the important features, processes and events controlling fluid flow and contaminant transport of consequence at a specific field site in the context of a recognized problem-NRC, 2001

Groundwater Model (Contd.)

- Numerical methods
  - Finite difference (FD)
  - Finite element (FE)
  - Finite volume (FV)
  - SPH
  - Spectral
  - Mesh free

Groundwater Model (Contd.)

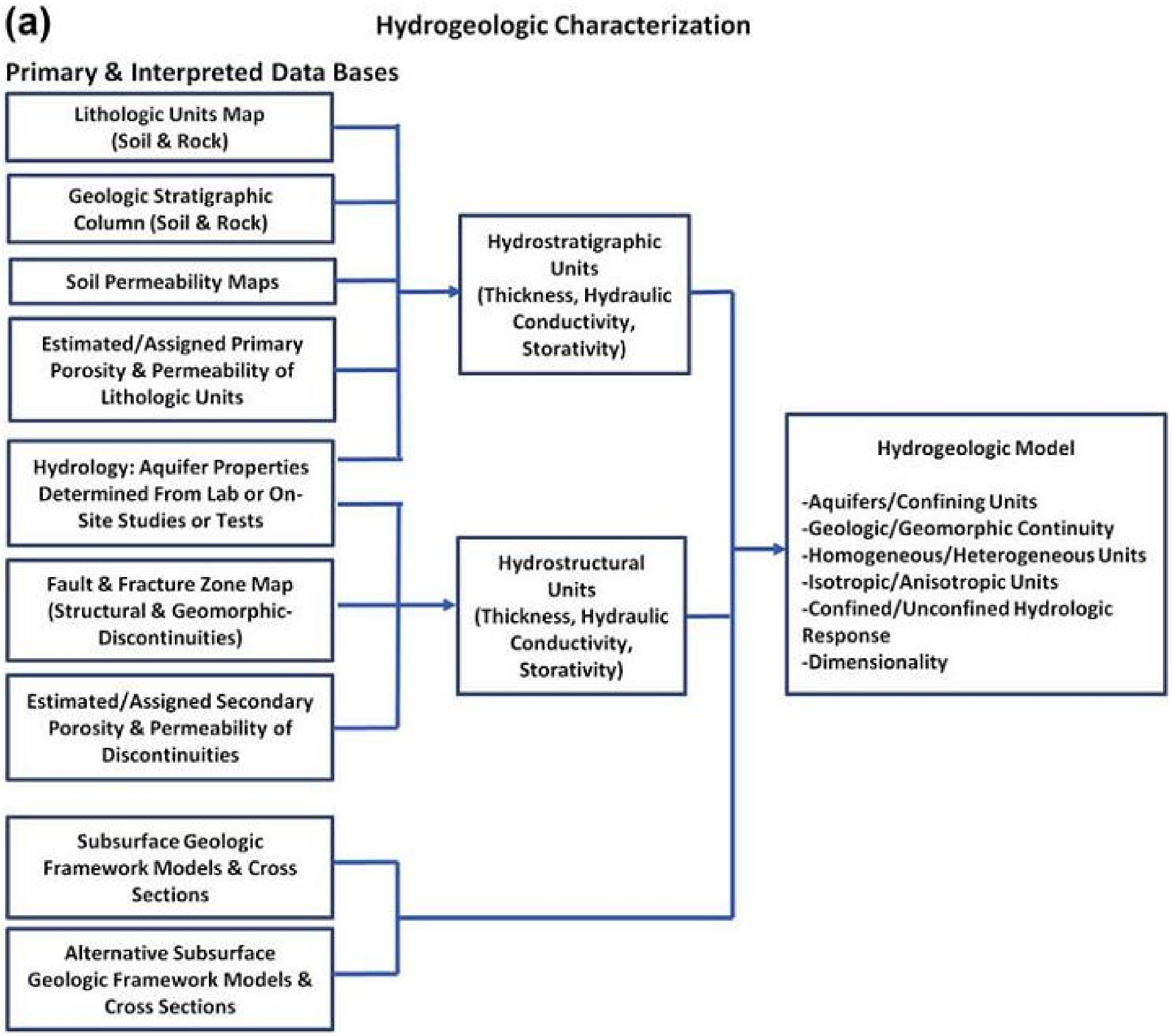


Figure 2.2 Data and analyses leading to (a) hydrogeologic site conceptual model.

Groundwater Model (Contd.)

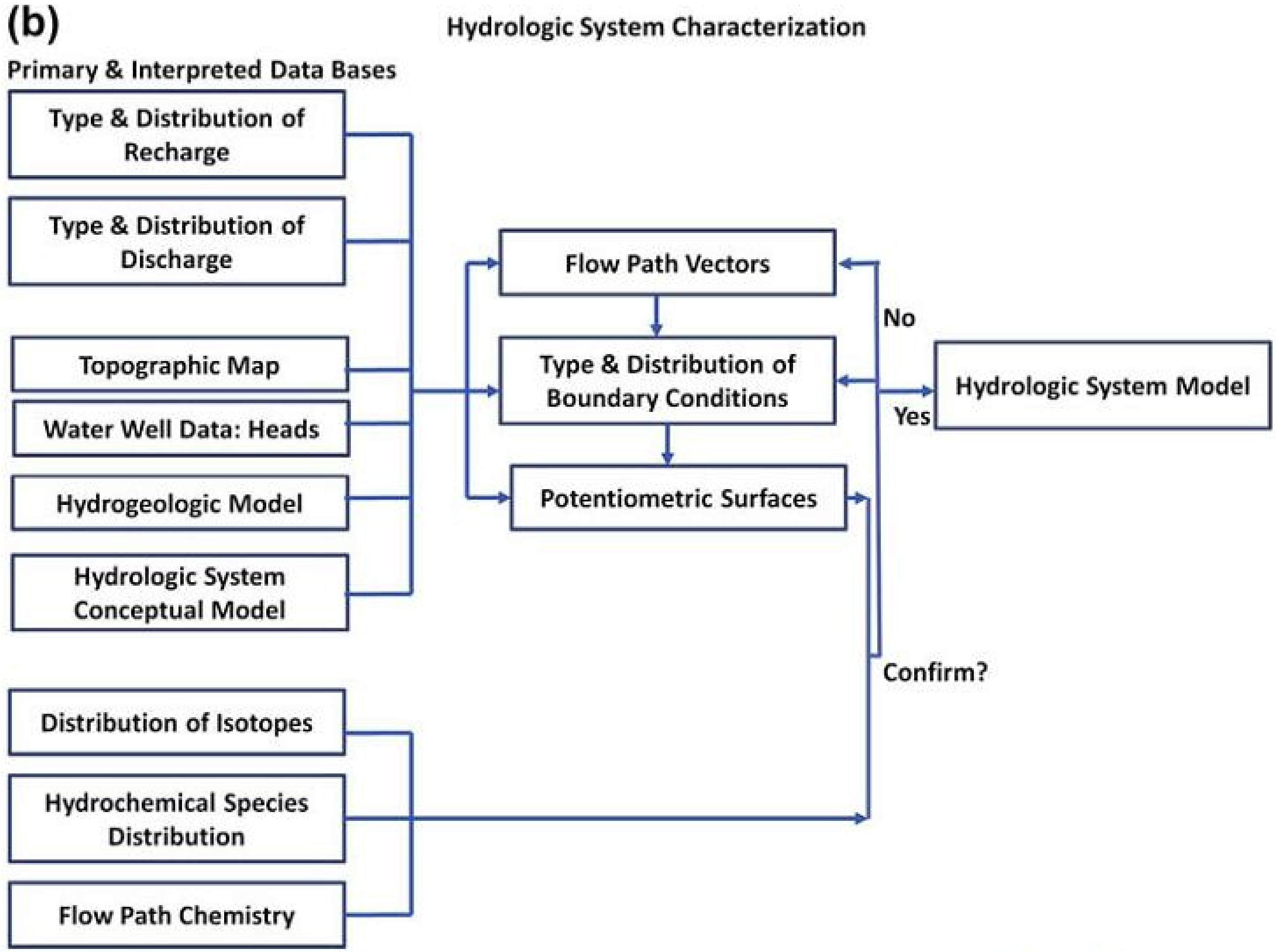


Figure 2.2 Cont'd. (b) hydrologic system conceptual model *(modified from Kolm, 1996)*.

Groundwater Model (Contd.)

- Standard simulation models
- MODFLOW
- FEMWATER
- SEAWAT
- **SUTRA**
- MT3DMS
- RT3D
- MODPATH
- SHARP
- Standard simulation models
- HST3D
- HYDROTHERM
- PHAST
- TOUGH2
- FLOTRAN
- iTOUGH
- BIOPLUME
- HYDRUS

Groundwater Model (Contd.)

- MODFLOW

$$\frac{\partial}{\partial x}\left(K_x\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z\frac{\partial h}{\partial z}\right)=S_s\frac{\partial h}{\partial t}-W^*$$

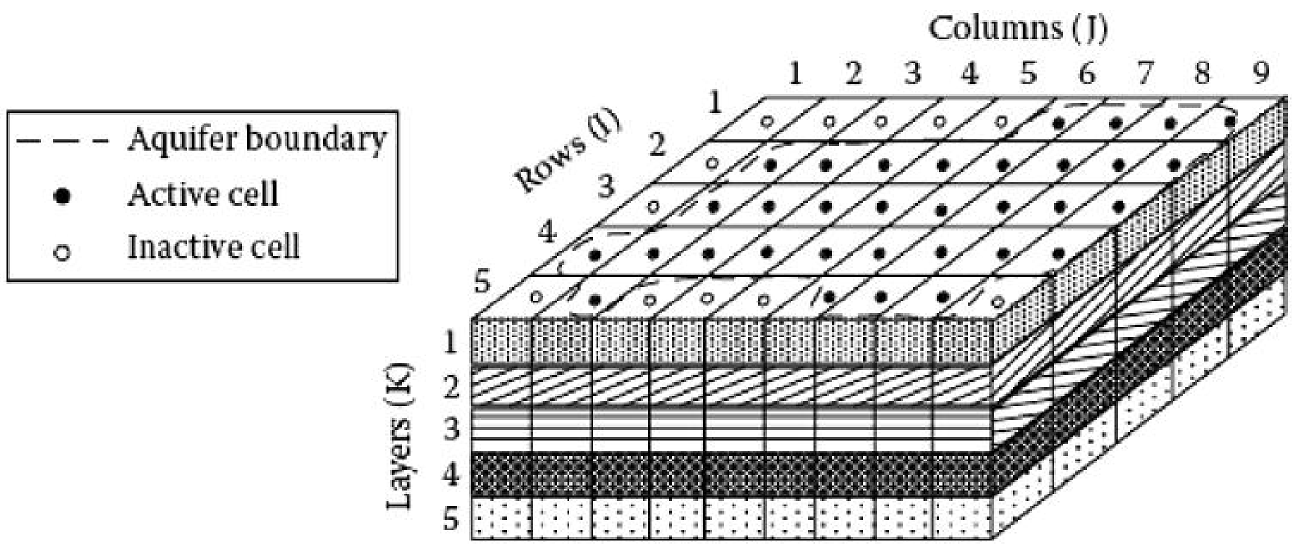


FIGURE 6.1 Illustration of discretization of continuous media into finite-difference cells.

Groundwater Model (Contd.)

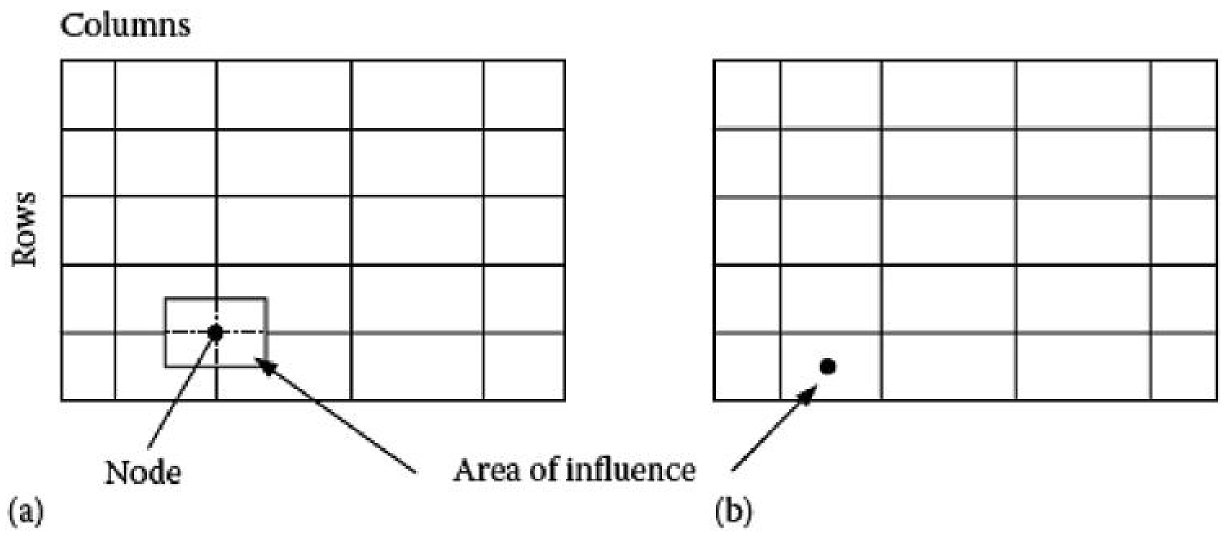


FIGURE 6.2 Illustration of 2D space discretization methods: (a) mesh-centered and (b) block-centered.

Groundwater Model (Contd.)

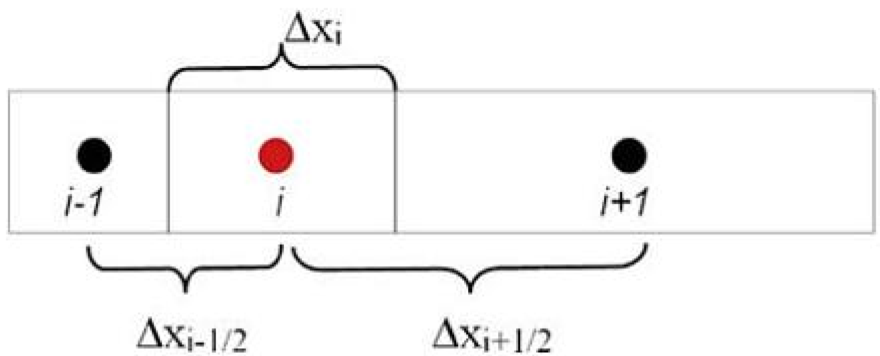


Figure 3.6 FD notation for irregularly spaced nodes in the *x*-direction in a block-centered grid. The grid and notation are shown in one dimension only.

$$\frac{\partial h}{\partial x} = \frac{h_{i+1,j,k} - h_{i-1,j,k}}{2\Delta x} \qquad \frac{\partial h}{\partial t} = \frac{h_{ij}^{n+1} - h_{ij}^{n}}{\Delta t}$$

$$\frac{\partial^2 h}{\partial x^2} = \frac{1}{\Delta x}\left[\frac{h_{i+1,j,k} - h_{i,j,k}}{\Delta x} - \frac{h_{i,j,k} - h_{i-1,j,k}}{\Delta x}\right] = \frac{h_{i-1,j,k} - 2h_{i,j,k} + h_{i+1,j,k}}{(\Delta x)^2}$$

Groundwater Model (Contd.)

$$\frac{\partial}{\partial x}\left(K_x\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z\frac{\partial h}{\partial z}\right)=S_s\frac{\partial h}{\partial t}-W^*$$

$$\frac{1}{(\Delta x)_{i,j,k}}\left[Kx_{(i+1/2,j,k)}\frac{h^{n+1}_{i+1,j,k}-h^{n+1}_{i,j,k}}{(\Delta x)_{i+1/2,j,k}}-Kx_{(i-1/2,j,k)}\frac{h^{n+1}_{i,j,k}-h^{n+1}_{i-1,j,k}}{(\Delta x)_{i-1/2,j,k}}\right]$$

$$+\frac{1}{(\Delta y)_{i,j,k}}\left[Ky_{(i,j+1/2,k)}\frac{h^{n+1}_{i,j+1,k}-h^{n+1}_{i,j,k}}{(\Delta y)_{i,j+1/2,k}}-Ky_{(i,j-1/2,k)}\frac{h^{n+1}_{i,j,k}-h^{n+1}_{i,j-1,k}}{(\Delta y)_{i,j-1/2,k}}\right]$$

$$+\frac{1}{(\Delta z)_{i,j,k}}\left[Kz_{(i,j,k+1/2)}\frac{h^{n+1}_{i,j,k+1}-h^{n+1}_{i,j,k}}{(\Delta z)_{i,j,k+1/2}}-Kz_{(i,j,k-1/2)}\frac{h^{n+1}_{i,j,k}-h^{n+1}_{i,j,k-1}}{(\Delta z)_{i,j,k-1/2}}\right]$$

$$=S_s\frac{h^{n+1}_{i,j,k}-h^{n}_{i,j,k}}{(\Delta t)}-W^*_{(i,j,k)}$$

Groundwater Model (Contd.)

A general expression for conductance, C, between two cells in a rectangular FD grid is:

$$C = \frac{KA}{L}$$

K is the intercell hydraulic conductivity

$Q = C\Delta h$

MODFLOW i = rows and j = columns

$$\begin{aligned}
&\mathrm{CV}_{i,j,k-1/2}h_{i,j,k-1} + \mathrm{CR}_{i-1/2,j,k}h_{i-1,j,k} + \mathrm{CC}_{i,j-1/2,k}h_{i,j-1,k} \\
&+\left(-\mathrm{CV}_{i,j,k-1/2} - \mathrm{CR}_{i-1/2,j,k} - \mathrm{CC}_{i,j-1/2,k} - \mathrm{CV}_{i,j,k+1/2}\right. \\
&\left.-\mathrm{CR}_{i+1/2,j,k} - \mathrm{CC}_{i,j+1/2,k} + \mathrm{HCOF}_{i,j,k}\right)h_{i,j,k} \\
&+\mathrm{CV}_{i,j,k+1/2}h_{i,j,k+1} + \mathrm{CR}_{i+1/2,j,k}h_{i+1,j,k} + \mathrm{CC}_{i,j+1/2,k}h_{i,j+1,k} = \mathrm{RHS}_{i,j,k}
\end{aligned}$$

where CR and CC are horizontal conductances within rows and columns

CV is the vertical conductance between layers.

$$[A]\{h\} = \{f\}$$

Groundwater Model (Contd.)

ModelMuse: A Graphical User Int ×

usgs.gov/software/modelmuse-a-graphical-user-interface-groundwater-models

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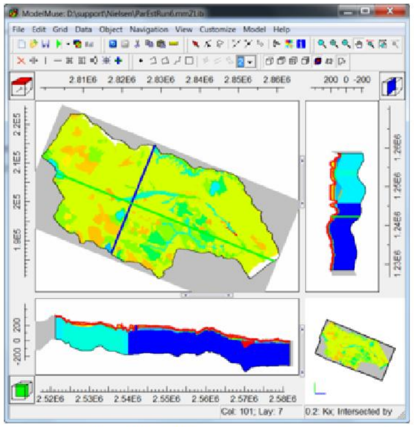
ModelMuse: A Graphical User Interface for Groundwater Models

Release Date: AUGUST 16, 2020

Overview of ModelMuse

ModelMuse is a graphical user interface (GUI) for the U.S. Geological Survey (USGS) models MODFLOW 6, MODFLOW–2005, MODFLOW-LGR, MODFLOW-LGR2, MODFLOW-NWT, MODFLOW-CFP, MODFLOW-OWHM, MODPATH, ZONEBUDGET, PHAST, SUTRA 2.2, SUTRA 3.0, MT3D-USGS, and WellFootprint and the non-USGS model MT3DMS. This software package provides a GUI for creating the flow and transport input file for PHAST and the input files for the other models. In ModelMuse, the spatial data for the model are independent of the grid, and the temporal data are independent of the stress periods. Being able to input these data independently allows the user to redefine the spatial and temporal discretization at will.



Screenshot from ModelMuse showing example model parameters.

Download Current Version of ModelMuse

The current release is ModelMuse v.4.3.0.0.

ModelMuse for Microsoft Windows Operating Systems

Users are encouraged to read the documents that are provided in the 'doc' directory of this software distribution, including the 'Release.chm' file. The recommended method of installing ModelMuse is with the installer. However, if there is difficulty in using the installer, ModelMuse can be installed by unzipping the zip file. The installer associates the extensions .gpt, .gpb and .mmZLib with ModelMuse. If the zip file is used instead of the installer, the user may wish to make those associations manually.

Contacts

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Explore More Science

MODFLOW

SUTRA

Water

Groundwater Model (Contd.)

- MODFLOW in ModelMuse

- Flow using MODFLOW
  - URL: https://www.youtube.com/watch?v=dE5RCUElIu4

- Transport using MODFLOW and MT3DMS
  - URL: https://www.youtube.com/watch?v=IFIMZ9Vy1iM

Thank you