FLO-2D

MODFLO-2D

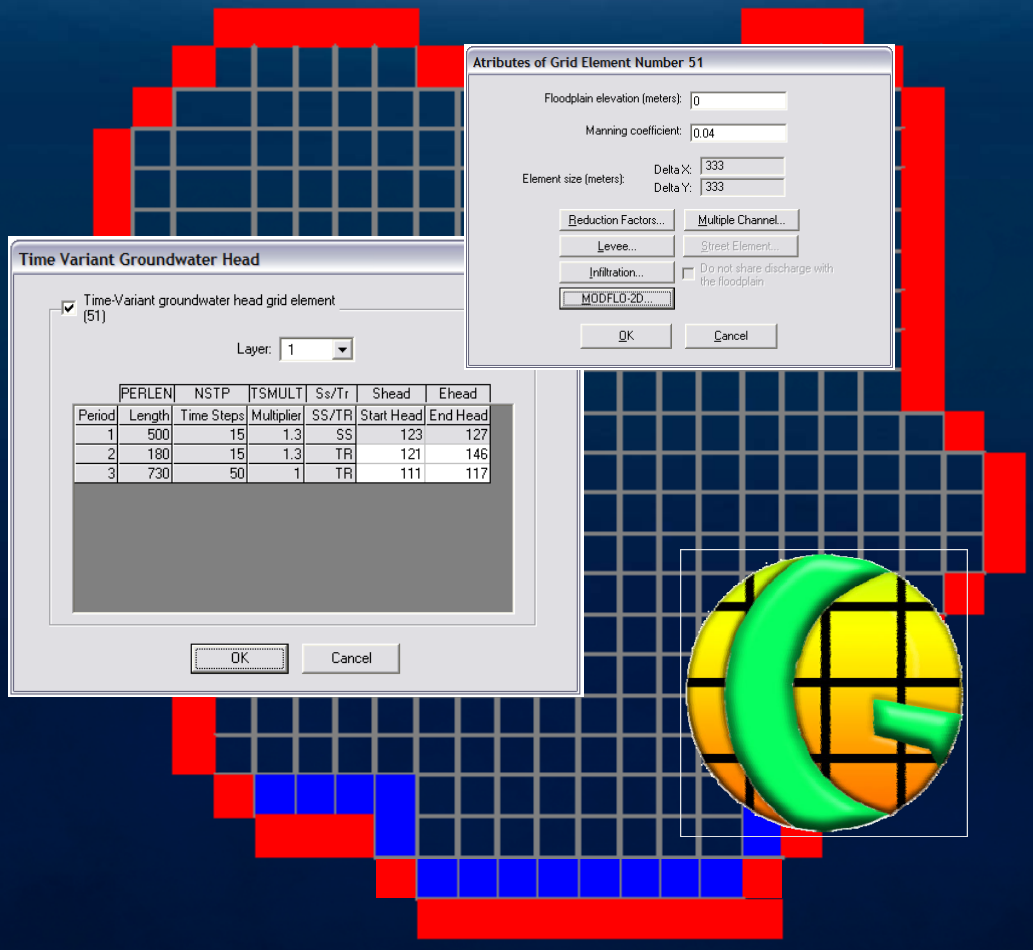


Table of Contents

I. Introduction

The Grid Developer System (GDS) facilitates the creation of data for the integration of the *FLO-2D* and *MODFLOW-2005* models (*MODFLO-2D*). It can develop the FLO-*2D* grid system and graphical edit its attributes and components, plus a subset of the required variables of *MODFLOW-2005* integration.

The *FLO-2D* GDS manual (2011) describes all the functions performed by GDS for the *FLO-2D* model. Many of these functions are used to create the simulation environment of *MODFLO-2D*. Additionally, more functionality has been added to GDS to accomplish the requirements of the integration.

II. MODFLO-2D

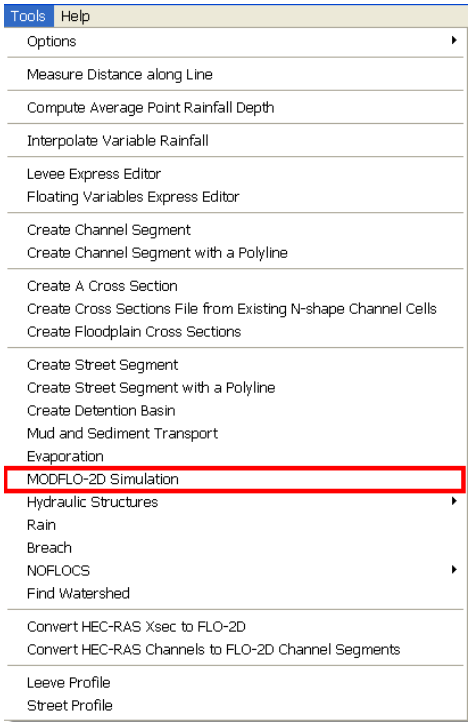
GDS has the following new capabilities related to *FLO-2D* / *MODFLOW* Integration (*MODFLO-2D* integrated model):

- Writes a subset of *MODFLO-2005* data files: Name File, Discretization File, Basic Package File, Time-Variant Specified-Head File, and Block-Centered Flow Package File.
- Allows creation of layers (confined and unconfined), stress periods (steady state and transient), and time-variant groundwater head cells.
- Manages the grid system to incorporate data layers, stress periods, and head cells.
- Allows defining top and bottom elevations of each layer of the groundwater model.
- Editing of *MODFLO-2005* variables for the files listed above.
- Saves and reads *FLO-2D* *.TOP files incorporating *MODFLO-2D* variables.
- Runs FLO-*2D* and *MODFLOW-2005* as integrated models.

2.1 Getting started with GDS *MODFLO-2D*

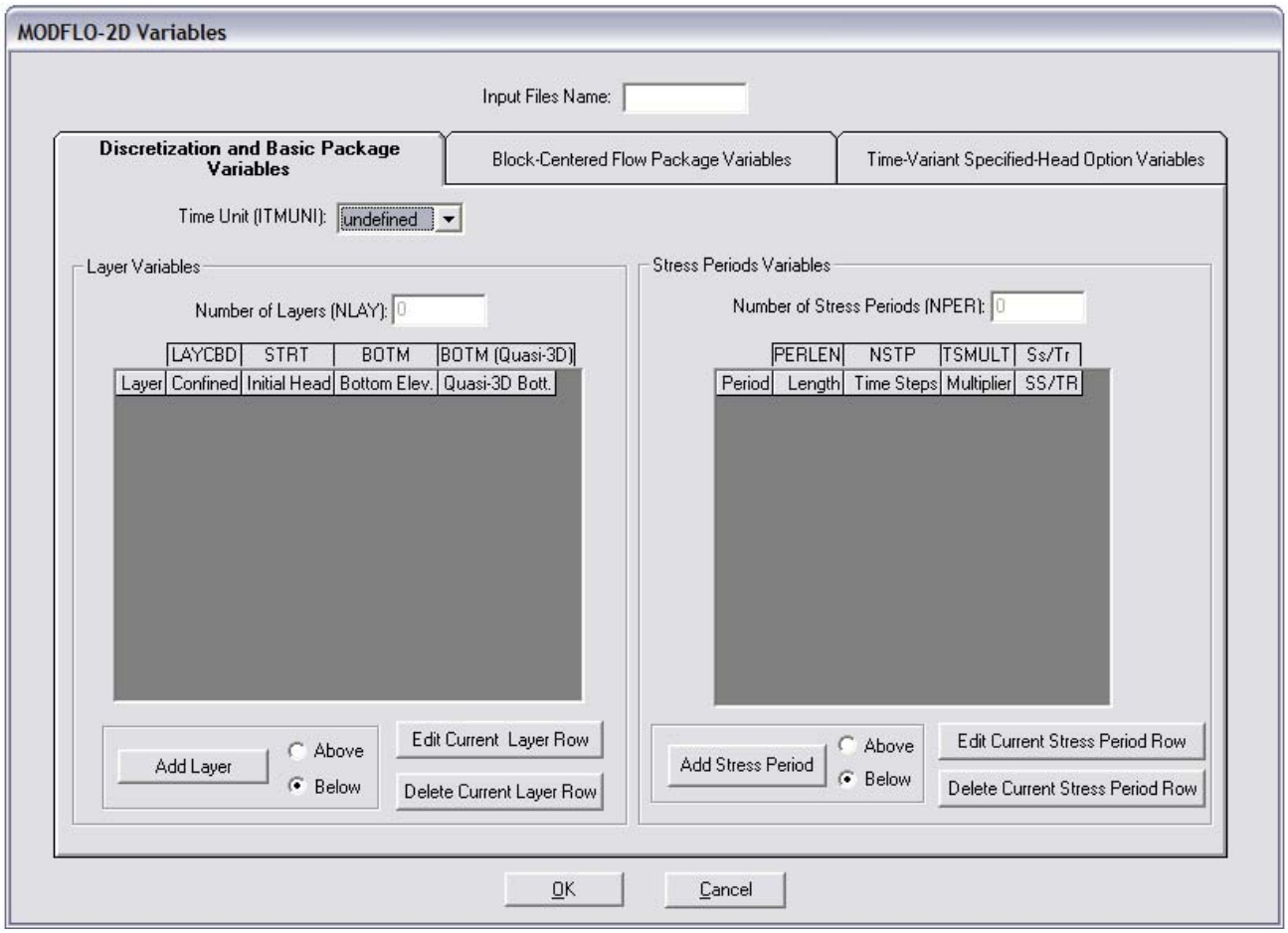
To start editing the *MODFLO-2D* data, it is required to have a GDS grid with boundary and computational area, defined as it is customary in *FLO-2D* (GDS Manual, 2011).

The next step is to define the groundwater layers and stress periods in the *MODFLO-2D* main dialog, using the new menu command *Tools/MODFLO-2D Simulation*:



2.2 *MODFLO-2D* main dialog

The new *MODFLO-2D* tabbed dialog shown in the figure below, allows input data to create *MODFLOW* standard data files.



There are 3 tabs in the dialog:

- ***Discretization and Basic Package Variables*** tab

  These correspond to the variables to be written to the DIS and BA6 *MODFLOW-2005* files.

- ***Block-Centered Flow Package Variables*** tab

  Variables to be written to the BC6 file.

- ***Time-Variant Specified-Head Option Variables*** tab

  Variables required for the CHD file.

a) Discretization and Basic Package Variables

This tab contains the variables used by *MODFLO-2D* saved in the DIS and BA6 files.

Explanation of the variables:

- *Input Files Name:*

  This is the prefix string for all *MODFLOW* files to be included in the Name File *.NAM.

- *Time unit (ITMUNI):*

  This variable indicates the time unit of the model data which must be consistent for all data values that involve time (Harbaugh, 2005). For example, if "years" is the chosen time unit, then the stress-period length, time-step length, transmissivity, and so on, must all be expressed using years for their time units. Note that the program will still run even if "undefined" time units are specified because the fundamental equations used in *MODFLOW* do not require that the time unit be identified. Be sure to use consistent units for all input data even when ITMUNI indicates an undefined time unit. When the time unit is defined, *MODFLOW* uses it to print a table of elapsed simulation time:

  0 - undefined 3 - hours

  1 – seconds 4 - days

  2 – minutes 5 - years

- *Layer Variables frame:*

  This subarea contains data for each layer:

  LAYCBD: confined or unconfined layer.

  LAYCBD—is a flag, with one value for each model layer, that indicates whether or not a layer has a Quasi-3D confining bed below it. 0 indicates no confining bed, and not zero indicates a confining bed. LAYCBD for the bottom layer must be 0 (Harbaugh, 2005).

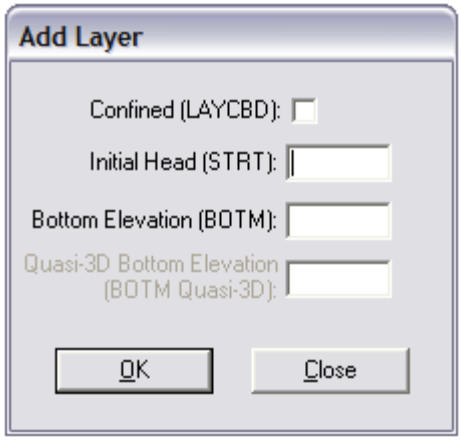
  Initial head (STRT): head at the beginning of the simulation.

  STRT—is initial (starting) head—that is, head at the beginning of the simulation. STRT must be specified for all simulations, including steady-state simulations. One value is read for every model cell. Usually, these values are read layer at a time. When the XSECTION option is specified, however, a single two-dimensional variable for the cross section is read. For simulations in which the first stress period is steady state, the values used for STRT generally do not affect the simulation [exceptions may occur if cells go dry and (or) rewet]. The execution time, however, will be less if STRT includes hydraulic heads that are close to the steady-state solution (Harbaugh, 2005).

  Bottom elevation (BOTM): bottom elevation of an unconfined layer.

  Quasi-3D Bottom elevation (BOTM): bottom elevation of a confined layer.

To add a layer, click the *Add Layer* button. The following dialog box appears:



Write the appropriate data and click *OK*.

To add a layer above or below an already defined layer, select the layer row and click on either the *Above* or *Below* option buttons. Then *Add Layer*

To delete a layer, select the layer row and click the *Delete Current Layer Row*

The variable values of an already defined layer can be changed selecting the row layer and clicking *Edit Current Layer Row*

- *Stress Periods Variables frame:*

  Contains data for each stress period:

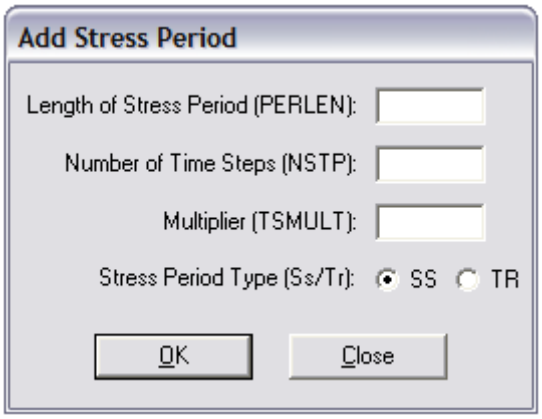
  Length (PERLEN): length of stress period in the selected units (ITMUNI)

  Time Steps (NSTP): number of time steps for each stress period. In this version please use a value of 1 (one time step per stress period).

  Multiplier (TSMULT): multiplier for the length of successive time steps . In this version please use a value of 1.

  Ss/Tr (SS/TR): indicates whether the stress period is steady state or transient.

Click the *Add Stress Period* button. Enter data in this dialog box:



To add a stress period above or below an already defined stress period, select the stress period row and click on either the *Above* or *Below* option buttons then *Add Stress Period*

To delete a stress period, select the stress period row and click *Delete Current Stress Period Row*.

The variable values of an already defined stress period can be changed selecting the stress period row and clicking *Edit Current Stress Period Row*

b) Block-Centered Flow Package Variables

This tab contains variables for the Block-Centered Flow Package (BCF) to be written to the "BC6" file:

Explanation of the variables:

- *Allow wetting capability (IWDFLG):*

  Determines if the wetting capability is active (0: inactive, 1: active).

- *Head factor when cell converts from dry to wet (WETFCT):*

  A factor that is included in the calculation of the head that is initially established at a cell when it is converted from dry to wet (see Harbaugh, 2005, p. 8-26).

- *Iteration interval (IWETIT):*

  Iteration interval for attempting to wet cells. Wetting is attempted every IWETIT iteration. In the *MODFLOW* model this applies to outer iterations and not inner iterations. If IWETIT is 0, the value is changed to 1.

- *Equation to define the initial head at cells that become wet (IHDWET):*

  Equations are: 5-32A or 5-32B in the *MODFLOW* manual.

  If IHDWET = 0, equation 5-32A is used: h = BOT + WETFCT (hn - BOT)

  If IHDWET is not 0, equation 5-32B is used: h = BOT + WETFCT (THRESH)

  See further details in Harbaugh, 2005 p. 5-16.

Table to define the following variables for each stress period:

- *Method of calculating interblock transmissivity (Ltype-Left):*

  0: harmonic mean

  1: arithmetic mean

  2: logarithmic mean

  3: arithmetic mean of saturated thickness and logarithmic mean hydraulic conductivity

- *Layer type (Ltype-Right (LAYCON)):*

  0: confined

  1: unconfined

  2: confined/unconfined. Transmissivity of the layer is constant

  3: confined/unconfined. Transmissivity of the layer varies

- *Horizontal anisotropic factor (TRPY):*

  Ratio of transmissivity or hydraulic conductivity (whichever is being used) along a column to transmissivity or hydraulic conductivity along a row. Set to 1.0 for isotropic conditions.

- *Primary storage coefficient (Sf1):*

  Is the primary storage coefficient. Input only if one or more transient periods are specified in the discretization file (DIS). For LAYCON equal to 1, Sf1 will always be specific yield, whereas for LAYCON equal to 2 or 3, Sf1 will always be confined storage coefficient. For LAYCON equal to 0, Sf1 would normally be confined storage coefficient; however, a LAYCON value of 0 also can be used to simulate water-table conditions where drawdowns everywhere are expected to remain a small fraction of the saturated thickness, and where there is no layer above, or flow from above is negligible. In this case, specific yield values would be entered for Sf1 (Harbaugh, 2005)

- *Transmissivity along rows (Tran):*

  Tran is multiplied by TRPY to obtain transmissivity along columns. Read only for layers where LAYCON is 0 or 2.Read only for layers where LAYCON is 0 or 2.

- *Vertical hydraulic conductivity (Vcon):*

  Vcont—is the vertical hydraulic conductivity divided by the thickness from a layer to the layer below (also called leakance). The value for a cell is the hydraulic conductivity divided by thickness for the material between the node in that cell and the node in the cell below. Because there is not a layer beneath the bottom layer, Vcont cannot be specified for the bottom layer (Harbaugh, 2005).Vcont cannot be specified for the bottom layer.

- *Secondary storage coefficient (Sf2):*

  Sf2 is the secondary storage coefficient. Read only for layers where LAYCON is 2 or 3 and only if there are one or more transient stress periods specified in the Discretization File. The secondary storage coefficient is always specific yield (Harbaugh, 2005). Read only for layers where LAYCON is 2 or 3.

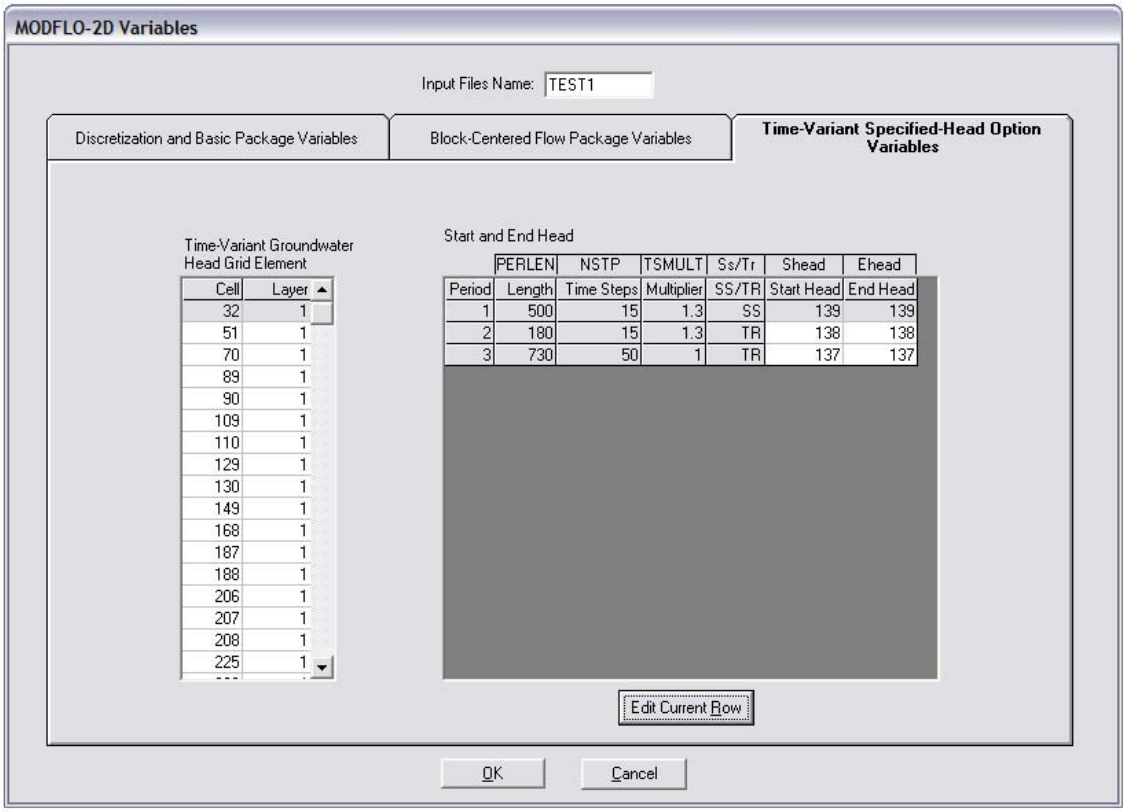
- *Wetting threshold (WETDRY):*

  WETDRY is a combination of the wetting threshold (THRESH) and a flag to indicate which neighboring cells can cause a cell to become wet. If WETDRY < 0, only the cell

below a dry cell can cause the cell to become wet. If WETDRY > 0, the cell below a dry cell and the four horizontally adjacent cells can cause a cell to become wet. If WETDRY is 0, the cell cannot be wetted. The absolute value of WETDRY is the wetting threshold. When the sum of BOT and the absolute value of WETDRY at a dry cell is equaled or exceeded by the head at an adjacent cell, the cell is wetted. Read only if LAYCON is 1 or 3 and IWDFLG is not 0 (Harbaugh, 2005).

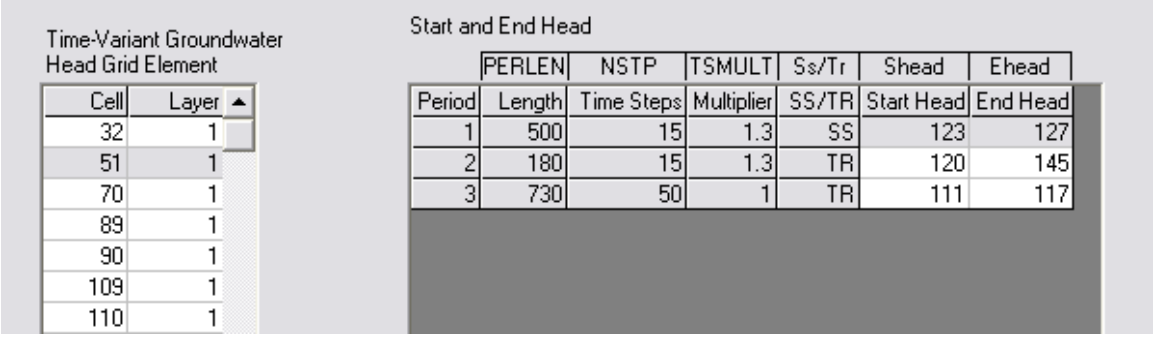
Read only if LAYCON is 1 or 3 and IWDFLG is 0

c) Time-Variant Specified–Head Option Variables

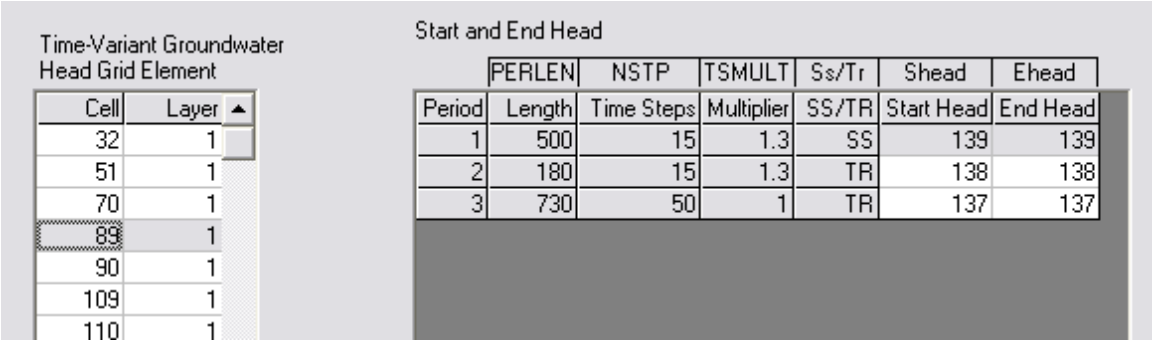


The left table contains the Time-Variant Groundwater Head Grid Elements defined as explained below in section *2.3 Designating constant head cells*.

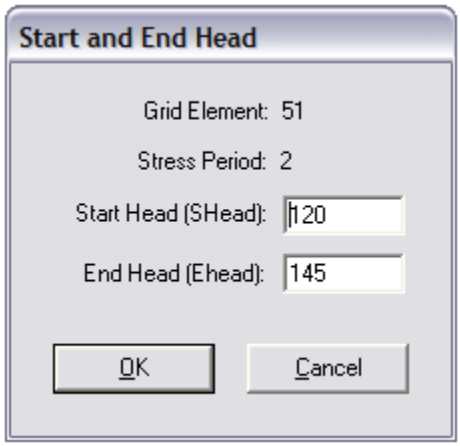
The right table contains, for each constant head cell, the starting and ending head for each stress period defined in the **Discretization and Basic Package Variables** tab. To see the head values of a particular cell, click the row of that cell in the left table. For example, cell 51 has the head values show here:



while cell 89 has this values:



To change the head values of a particular cell for a stress period, click the cell row at the left table, click the desired stress period at the right table, and click the *Edit Current Row* button. The following dialog box is shown:



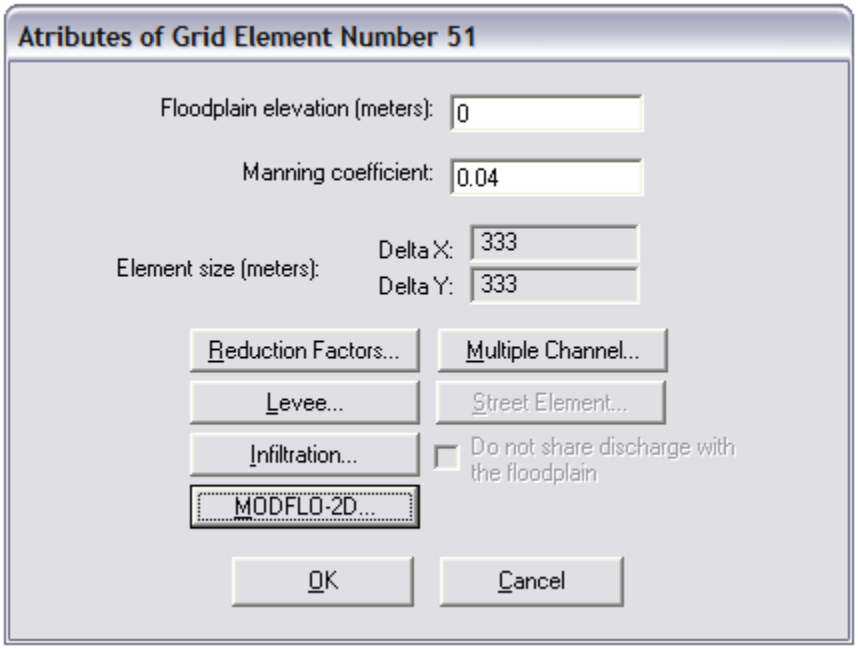
2.3 Designating constant head cells

There are two ways to define Time-Variant groundwater head cells.

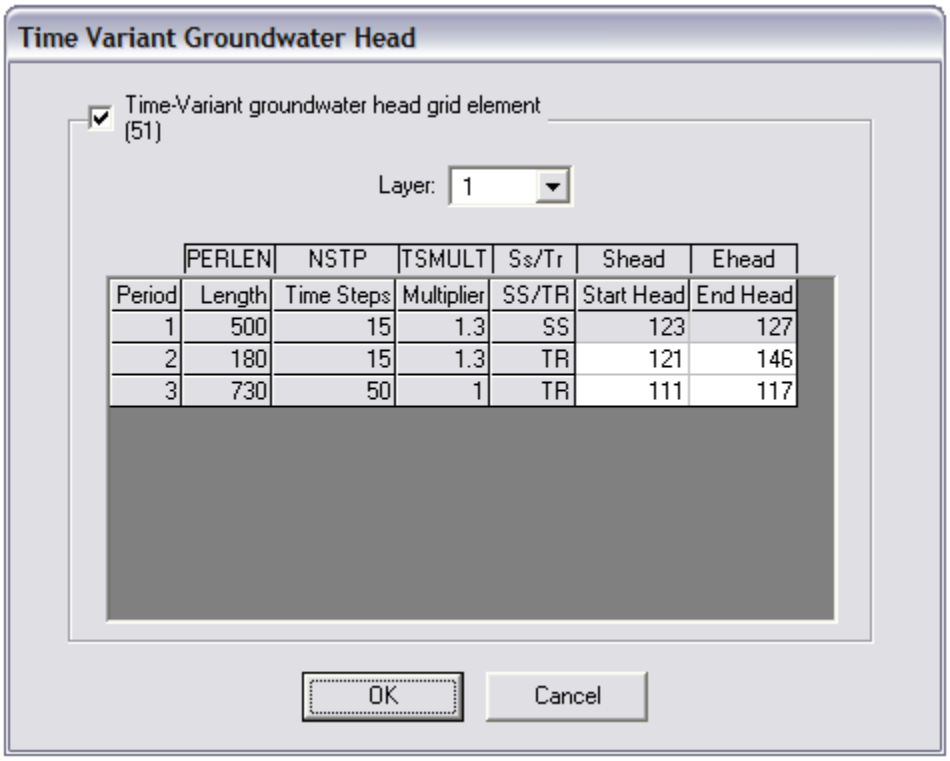
a) By double-clicking a particular cell to expose a dialog box where this operation can be performed.

b) By selecting one or several cells using the *Grid. Select (Grid Elements* menu command).

a) If the user double-clicks a cell, the following dialog is presented:



Clicking the *MODFLO-2D* button allows the selection of this cell as head cell. The following dialog box is shown:

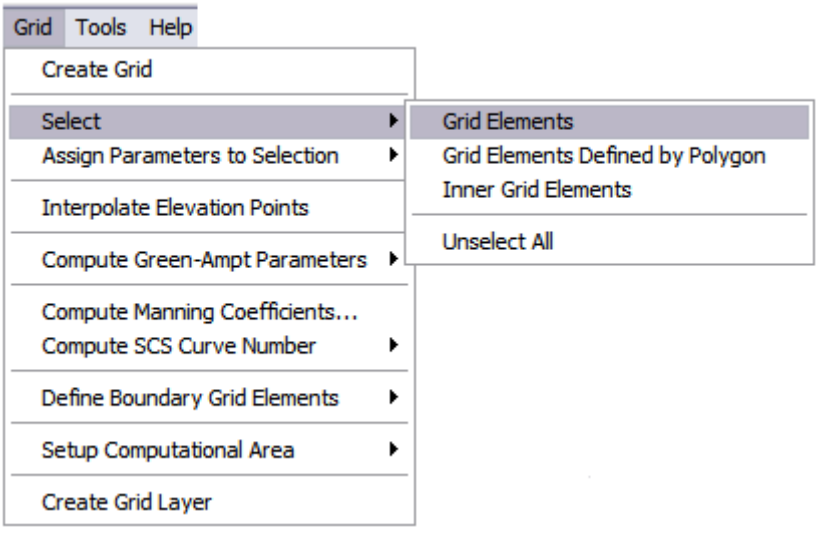


The values for the start and end head for each stress period can be entered in the respective row and column.

The *Time-Variant groundwater head grid element* checkbox permits the definition of a cell as head cell (or to un-define it).

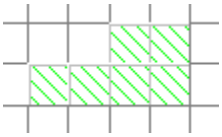
b) Selection of cells.

The menu command *Grid. Select. Grid Elements* allows the designation of one or more head cells.

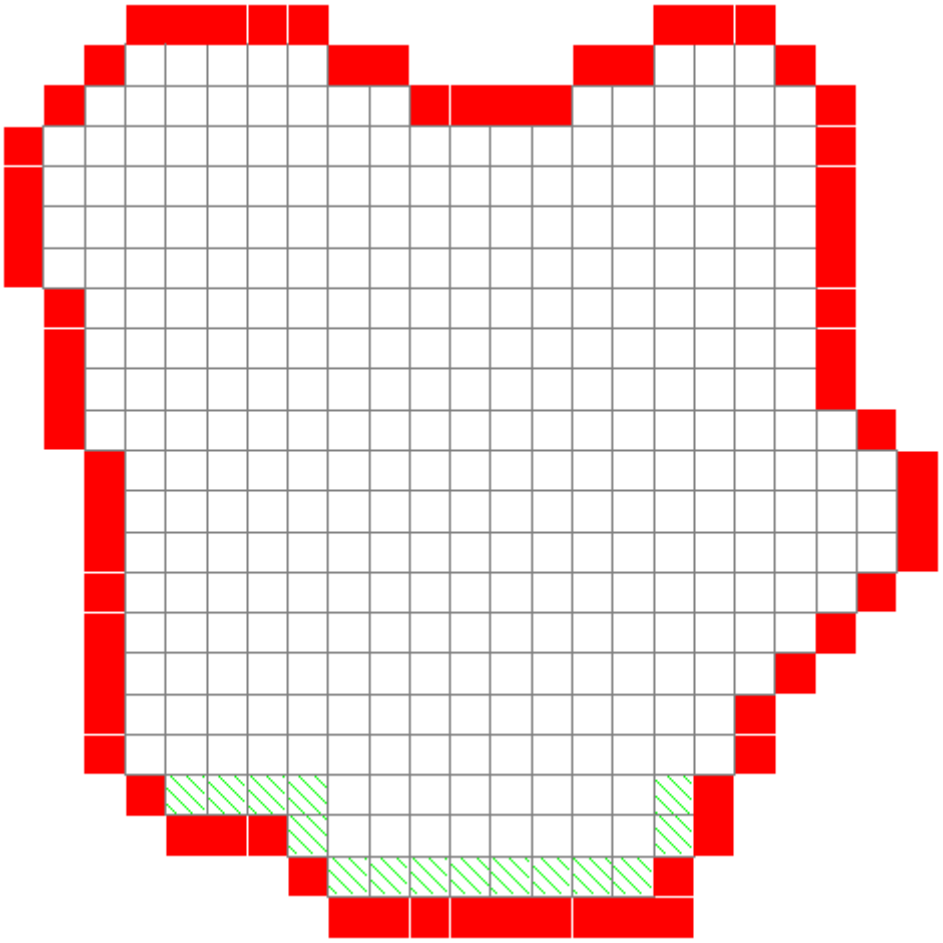


The tool  in the toolbar is also used for the same objective.

When this command is selected, the screen cursor changes to a cross  . The user can now click on the cells he wishes to select. Each selected cell is colored with green hatch:

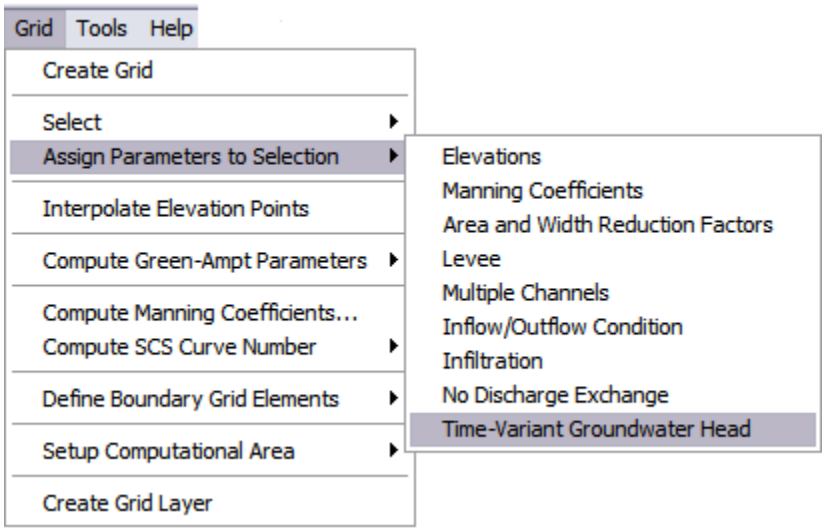


For example:

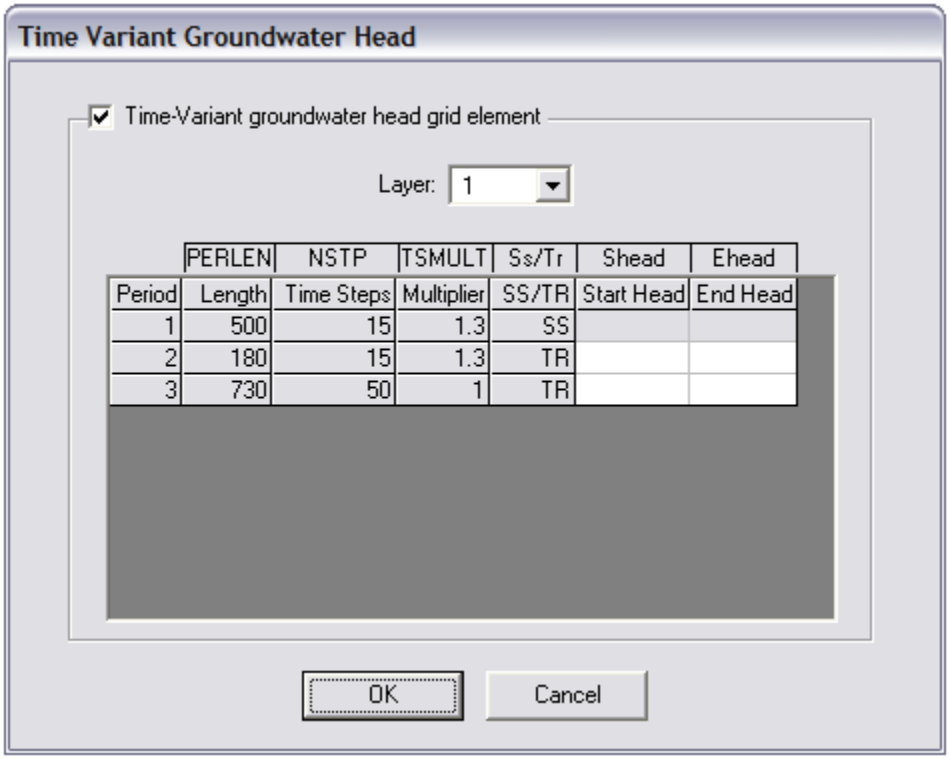


(The menu commands *Grid. Select. Grid Elements Defined by Polygon* and *Grid. Select. Inner Grid Elements* can also be used for this purpose)

Once the cells are selected, use the menu command *Grid. Assign Parameters to Selection. Time-Variant Groundwater Head*:



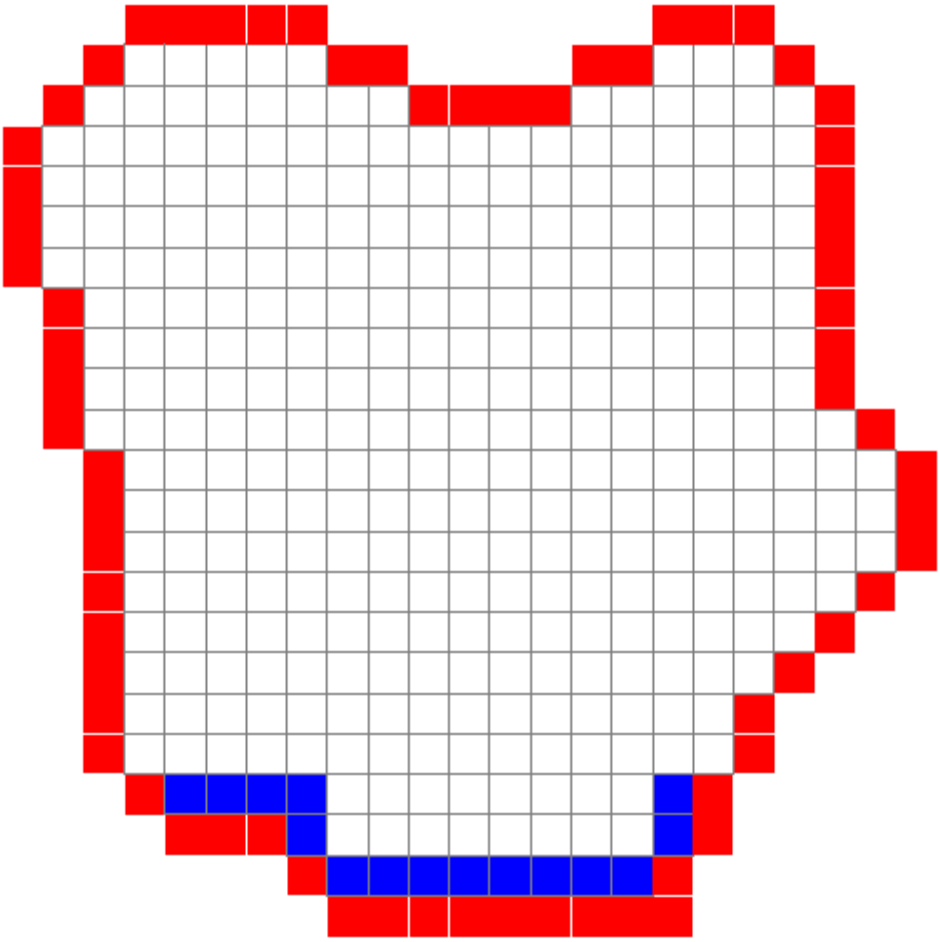
The following box dialog is presented:



There is a row for each stress period. The dropdown list contains the layers previously defined.

The *Time-Variant groundwater head grid element* checkbox permits the definition of a cell as head cell (or to un-define it).

If selected as a groundwater head cell, the cells are blue colored. For the example above:



2.4 Saving and reading *MODFLO-2D* data

A project with *MODFLO-2D* data can be saved as a *.TOP file in order to be able to read it in another session.

For that purpose, use the menu commands *File. Save TOP project….* or *File. Open TOP Project…* to retrieve the data. Or the tool equivalents,  and  , respectively.

2.5 Saving Basic Package files to run the *MODFLO-2D* model

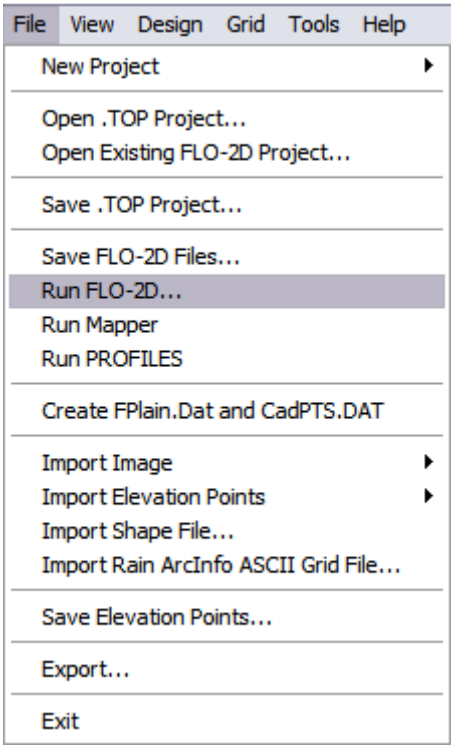
MODFLO-2D uses *MODFLOW-2005* Basic Package files to perform the simulation. The files used by *MODFLO-2D* are:

The Name File:	<prefix name>. nam
The Discretization File:	<prefix name>.dis
The Basic Package File:	<prefix name>.ba6
The Time-Variant Specified-Head Option File:	<prefix name>.chd
The Block-Centered Flow Package File	<prefix name>.bc6

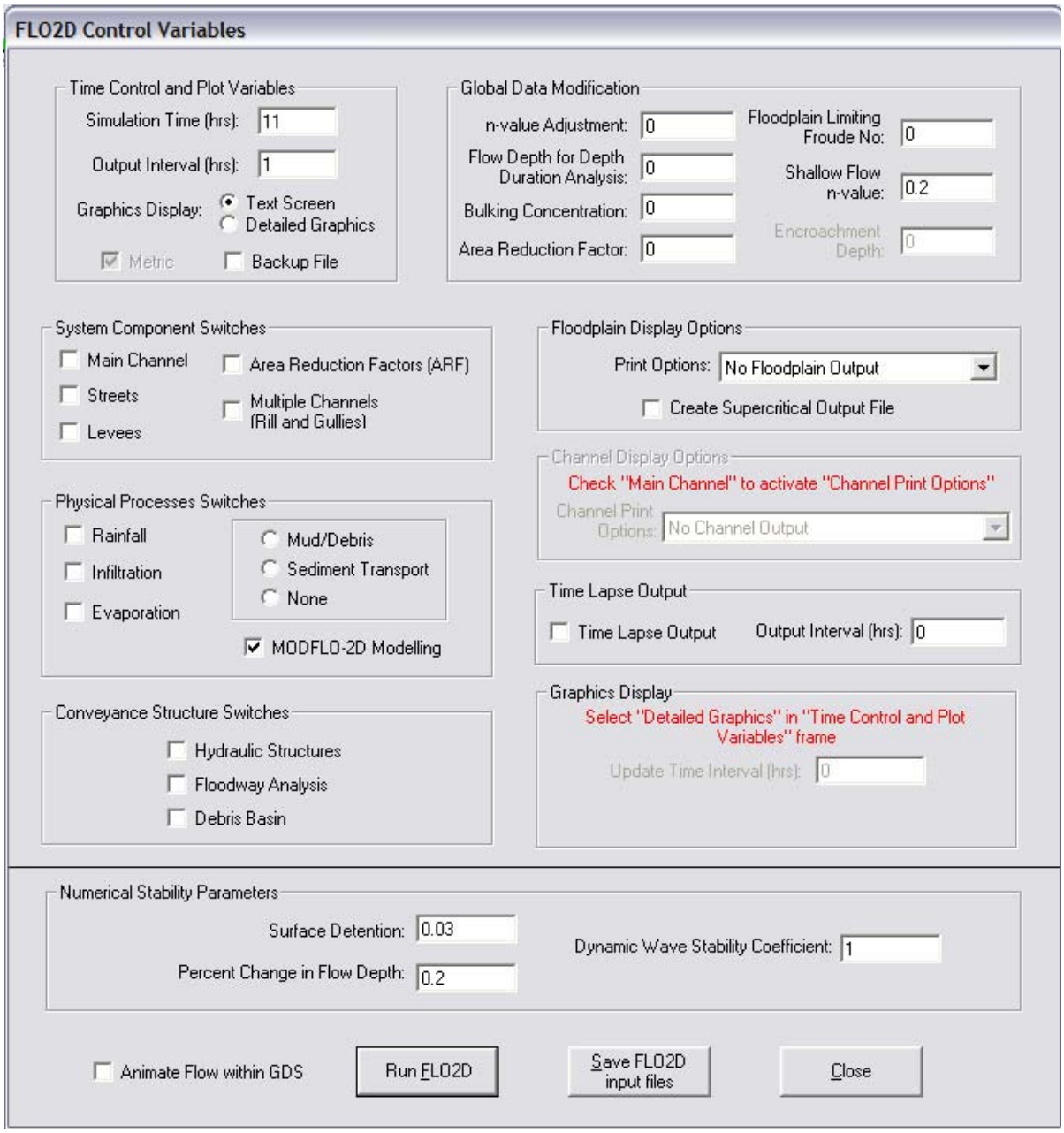
Charter 8 of the *MODFLOW-2005* manual (U.S. Geological Survey Techniques and Methods 6-A16, 2005), describes the contents and format of the files.

2.6 Running *MODFLO-2D* model

MODFLOW-2D modeling is performed using the standard *FLO-2D* running dialog. It is called from GDS using the menu command "*File. Run FLO-2D…*"



The *FLO-2D Control Variables* dialog is presented:



Click the *MODFLO-2D* checkbox in the *Physical Processes Switches* frame, and click the *Run FLO2D* button. The *MODFLO-2D* modeling starts.

If you only want to save the *FLO-2D* and *MODFLO-2D* data, click *Save FLO2D input files*.

REFERENCES

1. *FLO-2D* Data Input Manual. *FLO-2D* Software Inc. 2011

2. GDS Manual. *FLO-2D* Software Inc. 2011

3. Harbaugh, A.W., 2005, *MODFLOW-2005*, The U.S. Geological Survey modular ground-water model—the Ground-Water Flow Process: U.S. Geological Survey Techniques and Methods 6-A16.

4. U.S. Geological Survey Techniques and Methods 6-A16. U.S. Department of Interior. U.S. Geological Survey. 2005