# FLOW OBSERVATIONS IN MODFLOW-2000

## Flow Observations at Cells Having More Than One Head-Dependent Boundary Feature Represented by the Same Package

MODFLOW allows occurrences of the same head-dependent boundary type in a single finite-difference cell. For example, two canals represented by the Drain Package may cross an area such that they would be represented using the same finite difference cell, as designated by its layer, row, and column. Hence, that layer, row, and column would be listed twice in the Drain Package input file.

To accumulate the information needed to define the simulated equivalent of an observation, the Observation Process (OBS) uses an observation cell list from the applicable OBS input file, which defines an observation cell group, and additional information specified in the corresponding Ground-Water Flow Process input file. The information for each cell is accumulated by matching cells listed in the Observation Process input file with those listed in the Ground-Water Flow Process input file. For the General-Head Boundary, Drain, and River Packages, features match when the cell's layer, row, and column match. As long as the cell occurs only once in each list of cells, no problem occurs. If the list of cells used to define the observation cell group includes a feature at a cell where more than one feature is defined for the stress period in which the observation occurs in the Ground-Water Flow input file for the same package, a procedure is needed to ensure that the correct feature is included in the simulated equivalent. In OBS, the following sequential matching procedure is used.

If a cell is listed once in the observation cell group, the simulated equivalent for the observation includes flow calculated only for the first occurrence of the cell, as listed in the Ground-Water Flow Process input file for the package of concern for the stress period in which the observation occurs. Note that the stress period in which the observation occurs may be the reference stress period for the observation, or a later stress period, depending on the length of the reference stress period and the values of the time-offset multiplier and the variable TOFFSET. The listing order of cells in the Ground-Water Flow Process input file is determined as follows: all non-parameter cells are listed before all parameter-controlled cells for a given stress period, and the order in which parameters are listed in the head-dependent boundary flow input file for each stress period determines the listing order of parameter-controlled cells. Within the list of cells controlled by a parameter, the order is determined by the cell list in the parameter definition specified near the top of the Ground-Water Flow Process input file.

When a cell in an observation cell group is to be associated with the second or later occurrence of the cell in the Ground-Water Flow Process input for a given stress period, the observation cell group needs to include two or more occurrences of the cell, where the number of occurrences corresponds to the sequential occurrence of the feature sought. Occurrences of the cell for which the flow calculated by the Ground-Water Flow Process is not to contribute to the flow observation need to be specified with FACTOR=0.0. For each observation cell group, the program starts at the first cell listed for the stress period in the Ground-Water Flow Process input file and searches for a match for the first cell in the observation cell group. After a match is found, appropriate calculations are done and the search for a match for the next cell in the observation cell group begins, starting at the feature following the feature matching the previous cell in the observation cell group. When the end of the list for the stress period in the Ground-Water Flow

Process input file is reached, the search continues at the beginning of the list. This can be confusing and care is needed to obtain the desired results. Searching and matching continues in this fashion until all cells in the observation cell group are matched. For the next observation cell group, the search starts at the beginning of the list for the stress period in the Ground-Water Flow Process input file.

Understanding this search logic is necessary when determining the order in which cells are listed in an observation cell group to ensure that observation cells are matched as intended with features listed for the Ground-Water Flow Process. When the features simulated by a particular package change from one stress period to the next, the list of cells in an observation cell group may not apply appropriately to both stress periods. In this situation, multiple cell groups may need to be defined to specify flow observations in different stress periods.

As an example, consider a model for an area where a series of springs discharge water from intervals at different elevations in an aquifer. For this model, the Drain Package is used and three drain features are specified in each of three finite-difference cells, for a total of nine features. All features are defined using parameters. One parameter is used to simulate three drain features, in rows 5, 6, and 7 of column 6; the elevations of these drain features are 20, 22, and 24 in this model. A second parameter is used to simulate drain features in the same three cells, each having an elevation of 30. A third parameter is used to simulate drain features in the same three cells; the elevation is 45 at the first two cells and 47 at the third cell. For this model, the Ground-Water Flow Process Drain Package input file, listed with file type DRN in the name file, is as follows:

```
# DRN input file
parameter  3  9          Item 1: npdrn mxl
10 0                     Item 2: mxactd idrncb
drn-low   drn  10.0  3   Item 3: parnam partyp parval nlst
1 5 6 20 1.0             Item 4: lay row col elev condfact
1 6 6 22 1.0             Item 4: lay row col elev condfact
1 7 6 24 1.0             Item 4: lay row col elev condfact
drn-med   drn   1.0  3   Item 3: parnam partyp parval nlst
1 5 6 30 1.0             Item 4: lay row col elev condfact
1 6 6 30 1.0             Item 4: lay row col elev condfact
1 7 6 30 1.0             Item 4: lay row col elev condfact
drn-high  drn  10.0  3   Item 3: parnam partyp parval nlst
1 5 6 45 1.0             Item 4: lay row col elev condfact
1 6 6 45 1.0             Item 4: lay row col elev condfact
1 7 6 47 1.0             Item 4: lay row col elev condfact
0 3                      Item 5: itmp np
drn-low                  Item 7: Pname
drn-med                  Item 7: Pname
drn-high                 Item 7: Pname
```

Observations of flow from the springs are represented such that the drain features in rows 5 and 6 at elevations 20 and 22 are associated with observations named D-low-5 and D-low-6, respectively; all the drain features in row 7 are together associated with an observation named D-7, the drain features in rows 5 and 6 at elevation 30 are together associated with an observation named D-med-56, and the springs in rows 5 and 6 at elevation 45 are associated with an observation named D-high-56. The following DROB file correctly associates the five observations with the nine drain features:

```
# DROB input file
5 15  5  0                Item 1: NQDR NQCDR NQTDR IUDROBSV
1.0                       Item 2: TOMULTDR
1  1                      Item 3: NQOBDR NQCLDR
D-low-5   1 0.0 -276.     Item 4
1 5 6 1.0                 Item 5: LAY ROW COL FACTOR
1 1                       Item 3: NQOBDR NQCLDR
D-low-6   1 0.0 -273.     Item 4
1 6 6 1.0                 Item 5: LAY ROW COL FACTOR
1 3                       Item 3: NQOBDR NQCLDR
D-7       1 0.0 -321.     Item 4
1 7 6 1.0                 Item 5: LAY ROW COL FACTOR
1 7 6 1.0                 Item 5: LAY ROW COL FACTOR
1 7 6 1.0                 Item 5: LAY ROW COL FACTOR
1 4                       Item 3: NQOBDR NQCLDR
D-med-56  1 0.0  -35.     Item 4
1 5 6 0.0                 Item 5: LAY ROW COL FACTOR
1 6 6 0.0                 Item 5: LAY ROW COL FACTOR
1 5 6 1.0                 Item 5: LAY ROW COL FACTOR
1 6 6 1.0                 Item 5: LAY ROW COL FACTOR
1 6                       Item 3: NQOBDR NQCLDR
D-high-56 1 0.0  -50.     Item 4
1 5 6 0.0                 Item 5: LAY ROW COL FACTOR
1 6 6 0.0                 Item 5: LAY ROW COL FACTOR
1 5 6 0.0                 Item 5: LAY ROW COL FACTOR
1 6 6 0.0                 Item 5: LAY ROW COL FACTOR
1 5 6 1.0                 Item 5: LAY ROW COL FACTOR
1 6 6 1.0                 Item 5: LAY ROW COL FACTOR
```

If there are multiple head-dependent boundaries for a package in the same cell, the search for cells conducted by the Observation Process requires special attention when creating the parameters that define the boundaries. In some situations, it will be necessary to (1) include cells in the flow package that have a conductance multiplier set to zero and (2) use time-varying parameters and instances, which are described by Harbaugh and others (2000).

To understand the problem and solution, consider an example using the Drain Package of the Ground-Water Flow Process. In this example, there are three drains defined in a single cell. Each drain has a different parameter defining its conductance, and the drains are active at different times in the course of three stress periods. One drain and its parameter is used in stress periods 1 and 2. The second is used in stress periods 2 and 3. The third is used in stress periods 1 and 3. The input file below correctly defines the drains.

```
PARAMETER 2 6     # Item 1: PARAMETER NPDRN MXL
 3 9              # Item 2: MXACTD IDRNCB
DRN_1 DRN 1.0  1 # Item 3: PARNAM PARTYP Parval NLST
  1 1 1 1.0  1.0 # Item 4b: Layer Row Column Elevation Condfact
DRN_2 DRN 2.0  1 # Item 3: PARNAM PARTYP Parval NLST
  1 1 1 2.0  2.0 # Item 4b: Layer Row Column Elevation Condfact
DRN_3 DRN 3.0  1 # Item 3: PARNAM PARTYP Parval NLST
  1 1 1 3.0  3.0 # Item 4b: Layer Row Column Elevation Condfact
  0 2            # Item 5: ITMP NP Stress period 1
DRN_1            # Item 7: PARNAM
DRN_3            # Item 7: PARNAM
 0 2             # Item 5: ITMP NP Stress period 2
DRN_1            # Item 7: PARNAM
DRN_2            # Item 7: PARNAM
 0 2             # Item 5: ITMP NP Stress period 3
DRN_2            # Item 7: PARNAM
DRN_3            # Item 7: PARNAM
```

If observations are defined using these three drains, it would not be possible to define some perfectly reasonable sets of observations correctly. The drain defined by the second parameter (DRN_2) is the second drain in the cell in stress period 2 but it is the first drain in the cell in stress period 3. That makes it impossible to define an observation for the drain in the second parameter in both the second and third stress period. If what is now the second parameter were listed first, the same problem would arise with one of the other parameters. To solve this problem, insert zero-conductance multiplier drain cells into the parameter definition in the Drain Package input file using instances. The example below illustrates how to do this. For each parameter, two instances are defined. For each parameter, the instance named "inactive" includes Condfact equals zero. That instance is used for the stress periods in which the drain is inactive.

Because each drain is in the same order in all the stress periods, drain observations can be defined correctly with the revised input file.

```
PARAMETER 3 6      # Item 1: PARAMETER NPDRN MXL
 3 9               # Item 2: MXACTD IDRNCB Option
DRN_1 DRN 1.0  1 INSTANCES 2 # Item 3: PARNAM PARTYP Parval NLST NUMINST
 Active            # Item 4a: INSTNAM (Parameter instance for SPs 1 and 2)
  1 1 1 1.0  1.0  # Item 4b: Layer Row Column Elevation Condfact
 Inactive          # Item 4a: INSTNAM (Parameter instance for stress period 3)
  1 1 1 1.0  0.0  # Item 4b: Layer Row Column Elevation Condfact
DRN_2 DRN 2.0  1 INSTANCES 2 # Item 3: PARNAM PARTYP Parval NLST NUMINST
 Inactive          # Item 4a: INSTNAM (Parameter instance for stress period 1)
  1 1 1 2.0  0.0  # Item 4b: Layer Row Column Elevation Condfact
 Active            # Item 4a: INSTNAM (Parameter instance for SPs 2 and 3)
  1 1 1 2.0  2.0  # Item 4b: Layer Row Column Elevation Condfact
DRN_3 DRN 3.0  1 INSTANCES 2 # Item 3: PARNAM PARTYP Parval NLST NUMINST
 Active            # Item 4a: INSTNAM (Parameter instance for SPs 1 and 3)
  1 1 1 3.0  3.0  # Item 4b: Layer Row Column Elevation Condfact
 Inactive          # Item 4a: INSTNAM (Parameter instance for stress period 2)
  1 1 1 3.0  0.0  # Item 4b: Layer Row Column Elevation Condfact
  0 3              # Item 5: ITMP NP Stress period 1
DRN_1 Active       # Item 7: PARNAM Iname
DRN_2 Inactive     # Item 7: PARNAM Iname
DRN_3 Active       # Item 7: PARNAM Iname
 0 3               # Item 5: ITMP NP Stress period 2
DRN_1 Active       # Item 7: PARNAM Iname
DRN_2 Active       # Item 7: PARNAM Iname
DRN_3 Inactive     # Item 7: PARNAM Iname
 0 3               # Item 5: ITMP NP Stress period 3
DRN_1 Inactive     # Item 7: PARNAM Iname
DRN_2 Active       # Item 7: PARNAM Iname
DRN_3 Active       # Item 7: PARNAM Iname
```

## REFERENCE


Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, MODFLOW-2000, the U.S. Geological Survey modular ground-water model—User guide to modularization concepts and the ground-water flow process: U.S. Geological Survey Open-File Report 00-92, 121 p.