A Computer Program for Calculating Subregional Water Budgets Using Results from the U.S. Geological Survey Modular Three-dimensional Finite-difference Ground-water Flow Model

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ABSTRACT

The computer program ZONEBUDGET, which is written in FORTRAN, calculates subregional water budgets using results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. ZONEBUDGET uses cell-by-cell flow data saved by the model in order to calculate the budgets. Subregions of the modeled region are designated by zone numbers. The user assigns a zone number for each cell in the model. Composite zones can also be defined as combinations of the numeric zones. The report documents the design and use of the program.

INTRODUCTION

ZONEBUDGET is a FORTRAN program that calculates subregional water budgets using results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground-Water Flow Model (McDonald and Harbaugh, 1988), which is commonly referred to as MODFLOW. Hydrologists commonly calculate water budgets in order to help gain an understanding of a ground-water flow system. Computer programs that simulate ground-water flow typically produce water budgets for the modeled region, but often it is useful to have a water budget for a particular subregion of the modeled region. ZONEBUDGET calculates budgets by tabulating the budget data that MODFLOW produces using the cell-by-cell flow option. The user simply specifies the subregions for which budgets will be calculated. The purpose of this report is to document the design of ZONEBUDGET and how to use it.

FUNCTIONAL DESIGN OF THE PROGRAM

A subregion of a model for which ZONEBUDGET calculates a water budget is termed a zone, and a zone is indicated by a zone number. Zone numbers can range from 0 through 25. (The maximum zone number can be increased by changing the program parameter NZDIM). It is not necessary to use all 25 zones, but a zone number must be assigned to each cell in the model grid. In addition, composite zones can be defined as combinations of zones. Each composite zone is designated by an alphabetic letter. Composite zones provide a convenient way to have one cell be included in more than one zone without having to run ZONEBUDGET multiple times with multiple zone definitions. Although 0 is a valid zone number, a budget is not calculated for Zone 0. Thus, the user can exclude cells from budget calculations by assigning them to Zone 0.

Zones are defined either by reading a file, called the zone file, which contains one zone value for each cell, or by interactively entering a sequence of block definitions. A block is a rectangular prism of cells defined by a range of layers, rows, and columns. The cells that are enclosed by the layer, row, and column ranges comprise the block. For example, a block might be defined by layers 3-4, rows 7-20, and columns 2-26. A single zone value is assigned to all the cells in a block. If blocks overlap, the last zone definition overrides any previous definitions. Blocks are useful for making quick zone assignments "on the fly." Accordingly, the definition of zones by blocks is implemented through interactive user input. The user must choose whether to use a zone file or specify zone blocks interactively. The combination of both methods is not allowed.

Composite zones are defined in the zone file. A composite zone is specified by listing up to 10 numeric zones that make up the composite zone. Composite zones can only be specified if zone values are read from a zone file.

ZONEBUDGET makes use of the cell-by-cell flow data that MODFLOW saves on disk. This cell-by-cell data defines the flow into each model cell from each possible source or sink. Outflows are indicated as negative inflows (McDonald and Harbaugh, 1988, p. 3-20). Possible sources and sinks are

stresses, which include recharge, rivers, wells, drains, general-
head boundary, and evapotranspiration;
storage;
constant-head; and
flow between adjacent cells.

Stresses, storage, and constant-head flows represent flow into or out of the simulated flow system, and are straightforward components of the calculated water budget. Flow between adjacent cells is an internal flow that is not directly a part of the water budget for a subregion; however, flow between adjacent cells along a subregion's boundary is used to calculate flows in and out of the subregion. Ground-water flow between subregions must be included in subregional budgets in order to account for all flow. Flow across a subregion's boundary is separately accumulated for each adjacent subregion. That is, if there are 25 zones, Zone 1 may be adjacent to Zones 2-24; and if so, ZONEBUDGET will produce a separate accounting of boundary flow from Zone 1 to each of the other 24 zones.

Each source of water that is listed in the budget is referred to as a budget term. Thus, the budget for each zone will generally contain several stress budget terms, a storage term, a constant-head term, and a number of terms for flow to other zones.

MODFLOW calculates both a volumetric flow rate budget and a cumulative volume
budget over time. ZONEBUDGET calculates only a budget of volumetric flow rates. ZONEBUDGET does not calculate a cumulative budget because this would require cell-by-cell flow terms to be saved on disk each time step. Saving cell-by-cell budget terms for all time steps in a large, transient simulation would require considerable disk space.

If ZONEBUDGET is used to calculate a budget for the entire modeled area, values for each budget term should match the MODFLOW budget except in situations where there are multiple stresses of the same kind in the same cell. For example, MODFLOW allows more than one well to be specified for the same cell. The resulting well flow that is written in the cell-by-cell disk file for a cell having two wells is the sum of the flow into the cell from both wells. If one well is pumping (negative) and one is recharging (positive), the net inflow (either positive or negative) will be saved in the cell-by-cell disk file. Accordingly, ZONEBUDGET will tabulate the net amount for the cell as either an inflow or an outflow. The MODFLOW program will tabulate the well flow differently; MODFLOW will add the pumped amount to outflow and the recharged amount to inflow. Thus, the inflow and outflow amounts will differ between MODFLOW and ZONEBUDGET in this situation. The same can occur with river, drain, and general-head boundary stresses if two stresses of the same type, but opposite flow directions, occur in the same cell. Regardless of these differences in the way inflows and outflows are totaled when the same stress occurs twice in the same cell, the total inflow will equal the total outflow in any budget produced by MODFLOW or ZONEBUDGET if the model simulation executed properly.

When calculating the constant-head budget term, ZONEBUDGET does not directly use cell-by-cell values for constant-head flow as saved by MODFLOW. This is because the values for constant-head flow that are saved by MODFLOW are combinations of flow into the model through the 6 sides of each constant-head cell. Some of the flows may be inflows and some outflows, but only the single net value is saved for each constant-head cell. In order to separately accumulate the inflows and outflows to each constant-head cell, ZONEBUDGET uses the "flow between adjacent cells" budget term to calculate the constant-head flow. The constant-head budget term saved by MODFLOW is still needed by ZONEBUDGET in order to identify constant-head cells; a non-zero, constant-head flow indicates that a cell is constant-head.

ZONEBUDGET implements Zone 0, for which no budget is calculated, as a way to prevent a budget from being calculated in areas for which no budget is desired. Although one might think that it is necessary to assign Zone 0 to no-flow cells, this is not necessary because MODFLOW specifies 0 stresses and flows for any no-flow cells, whether initially no-flow or set to no-flow as a result of dewatering. That is, if no-flow cells are included in a non-zero zone, the no-flow cells will have no impact on the budget.

Computer precision could be a cause of small discrepancies between the budgets produced by ZONEBUDGET and MODFLOW. ZONEBUDGET accumulates budget totals using double precision, and MODFLOW uses single precision. Because of the use of double precision, ZONEBUDGET's output should generally be more accurate than MODFLOW's; however, differences in output are not likely to be significant except for some very large models.

STRUCTURE OF THE PROGRAM

The program consists of 7 parts -- a main program and 6 subroutines. The MAIN program controls overall program flow. It includes an input section and a budget generation section. Four file units, 10-13, are used; and these are defined at the beginning of the MAIN program. A PARAMETER statement specifies maximum array sizes; these values can be increased if needed. Comment statements define the parameters.

Three subroutines deal with data input. Subroutine IZREAD reads budget zones from the zone file, one value for each cell in the model grid. The values are read a layer at a time. The data for each layer are preceded by a control record that is similar to the one used by MODFLOW (McDonald and Harbaugh, 1988, p. 14-4). Subroutine INCOMP is a straightforward subroutine that reads composite zones from the zone file. Subroutine BLOCK defines budget zones interactively by block.

Subroutine ACCM tabulates budget term data a term at a time. Budget terms are treated in three different ways -- constant head, flow between adjacent cells, and everything else. Constant-head terms are used to set flags that will later be used to calculate constant-head flow from flow between adjacent cells. Flow between adjacent cells is used to calculate constant-head flow and flow across subregional boundaries. All other terms are directly accumulated for all cells within each subregion.

Printing is done by two subroutines. Subroutine SUBPR prints the budgets for each zone at each time step for which budget data are found. The inflow and outflow for each budget term are passed to SUBPR, and SUBPR calculates total flows and percent error. Subroutine COMPPR prints the budgets for each composite zone much like SUBPR does. Although a single subroutine could be written to accomplish the combined function of COMPPR and SUBPR, they were kept separate to avoid introducing more complexities.

INSTRUCTIONS FOR USING THE PROGRAM

Cell-by-cell flow terms from a model run must be saved prior to executing ZONEBUDGET. Each stress package and the Block-Centered Flow (BCF) Package determine whether their respective cell-by-cell terms are saved. The BCF Package generates budget terms for constant-head, storage, and flow between adjacent cells. The stress packages and the BCF Package allow a file unit for saving the terms to be specified, which is the second field of the first input record. For example, in the River Package, the cell-by-cell input unit is data item IRIVCB (McDonald and Harbaugh, 1988, p. 6-14). All cell-by-cell terms should be saved, and all terms should be saved in the same file. That is, the same cell-by-cell output unit must be specified for all MODFLOW packages that produce cell-by-cell output. If some terms are not saved, the budget will be incomplete, and a large percent discrepancy will appear in the program output.

The Output Control option of MODFLOW controls the frequency of cell-by-cell output. Record Type 2 of this option controls the saving of cell-by-cell data. No data will be saved unless the value of ICBCFL is specified to be non zero. Record Type 2 is read for each time step, so the user can specify precisely when cell-by-cell budget data are to be saved.

ZONEBUDGET will print budgets for all zones at all the times for which MODFLOW has saved flow terms. Remember that the input to individual stress packages and the BCF Package as well as the input to the Output Control option must be properly specified when using MODFLOW in order for cell-by-cell data to be properly saved for use by ZONEBUDGET.

After cell-by-cell zones have been saved, ZONEBUDGET can be executed; however, the user must also prepare a zone file if it is desired to read a zone value for each model cell from a file or if composite zones are desired. The instructions for preparing a zone file are contained in a following section (see “Input Instructions for the Zone File”).

When ZONEBUDGET is executed, the user will be prompted for information. The program will also display information showing its progress. The following is a list of the prompts and a description of how to respond.

Prompt 1:

"Enter the name of a LISTING FILE for results:"

This is the name of the file to which the budgets for all the zones will be written. ZONEBUDGET accomodates file names that are up to 80 characters long; however, file names must follow the rules of the particular computer being used. If an existing file is named, it will be overwritten. The records written to this file are 80 columns wide or less. The file will contain standard FORTRAN carriage control characters in column 1 of each record. The carriage control character for most records is a space, which indicates single spacing. A 0 at the start of a record indicates that a line should be skipped before printing this record, and a 1 indicates that a new page should be started. Most computers have a way to print such files so that the carriage control characters are acted upon. These characters will be seen if the file is viewed on a display through a text editor or a file listing utility. Although these characters may be a bit distracting, the user should be able to examine such files without much difficulty.

Prompt 2:

"Enter the name of the file containing CELL-BY-CELL BUDGET TERMS:"

The specified file must contain the cell-by-cell budget data from a model simulation.

Prompt 3:

"Enter a TITLE to be printed in the listing:"

The title will be displayed at the top of each subregional budget that is printed. The title can contain up to 80 characters.

Prompt 4:

"Enter the name of your ZONE INPUT FILE (CR for interactive):"

If you want to read zone data from a zone file, enter the name of the file here. If a non-existent file is named, the prompt will be reissued. If a blank line is entered, prompts to enter zones interactively by blocks will be displayed. The block prompts ask for a range of layers, rows, and columns to be given a specified zone value. Before block input is started, all cells in the grid are assigned to Zone 0. Any number of blocks can be entered. A range of layers from 0 through 0 ends block input. Format is free format, meaning that the prompted values may be placed anywhere on a line with a comma or one or more blanks separating adjacent values. A blank cannot be used for a 0.

Prompt 5:

"Choose the option for specifying when budgets are calculated:
A = ALL times stored in the budget file.
P = For each time stored in the budget file, PROMPT user.
L = Enter a LIST of times."

The budget term file may contain data for any number of model time steps. This prompt allows the user to specify for which of these time steps the subregional budgets will be calculated. These responses may be in uppercase or lowercase. Most frequently, the "A" option will be selected in order to cause budgets to be calculated for all times for which budget data have been stored in the budget file. If "P" is selected, a prompt will be issued whenever the time changes in the budget file. The prompt asks if budgets for this time should be calculated. The user must respond with a "Y" or "N" to indicate yes or no. If "L" is selected, the user is prompted to enter up to 10 time steps for which the subregional budgets will be calculated. As in MODFLOW, time steps are identified by a combination of a stress period number and a time step number within the stress period. Up to 10 times may be entered using free format. If the budget file does not contain a specified time, then obviously the budgets cannot be calculated.

In order to demonstrate ZONEBUDGET, the sample problem from the MODFLOW documentation (McDonald and Harbaugh, 1988, Appendix D) was used. Some minor changes to the input data were required in order to save cell-by-cell budget terms. First, input to the Basic Package was modified so that the 12th element of IUNIT was 22, which activated Output Control and specified that its input would be read on unit 22. A new Output Control input file was then created:

```
    0    0    0    0 IHEDFM,IDDNFM,IHEDUN,IDDNUN
    0    1    1    1 INCODE,IHDDFL,IBUDFL,ICBCFL
    1    1    0    0 Hdpr,Ddpr,Hdsv,Ddsv
```

The fourth value of the second record, the value of ICBCFL, is the crucial value. The non-zero value indicates that budget terms should be saved for the first time step, which is the only time step in this steady-state simulation.

Finally, the input data from the Block-Centered Flow and stress-term Packages were changed to indicate that cell-by-cell data should be saved on unit 30:

In the BCF Package input file, IBCFCB was set to 30.
In the WEL Package input file, IWELCB was set to 30.
In the DRN Package input file, IDRNCB was set to 30.
In the RCH Package input file, IRCHCB was set to 30.

When the program was run, unit 30 was connected to file “SAMPLE.BUD,” and cell-by-cell output was written to this file. Unit 22 was connected to the file containing the Output Control input data.

Table 1 shows the displayed output and the user responses for an example execution of ZONEBUDGET. The zone file, SAMPLE.ZON, is shown in Table 2. The result, SAMPLE.LST, is shown in Table 3. As can be seen in Table 3, there is no storage budget term. ZONEBUDGET does not include a storage budget term for steady-state simulations because MODFLOW does not save cell-by-cell flow data for storage in a steady-state simulation. The overall budget produced by MODFLOW always includes a storage budget term even though this value will be 0 in a steady-state simulation.

Table 4 shows the display output and the user responses for a similar example execution of ZONEBUDGET. In this example, the same zone definitions are used, but zones are specified interactively using blocks rather than using a zone file. Four blocks are required to reproduce the zones defined in file SAMPLE.ZON. Also, composite zones are not included because composite zones cannot be specified interactively. The output is not shown here because it is similar to Table 3.

```
                    Table 1.
  Example Interactive Session Using ZONEBUDGET

  ZONEBUDGET version 1.00
  Program to compute a flow budget for subregions of a model using
  cell-by-cell flow data from the USGS Modular Ground-Water Flow Model.

  Enter the name of a LISTING FILE for results:
SAMPLE.LST

  Enter the name of the file containing CELL-BY-CELL BUDGET TERMS:
SAMPLE.BUD

   3 layers        15 rows        15 columns

  Enter a TITLE to be printed in the listing:
ZONEBUDGET test

  Enter the name of your ZONE INPUT FILE (CR for interactive):
SAMPLE.ZON

             4 is your highest zone.

  Choose the option for specifying when budgets are calculated:
  A = ALL times stored in the budget file.
  P = For each time stored in the budget file, PROMPT user.
  L = Enter a LIST of times.
A

 Computing the budget for time step  1 in stress period  1
**** STOP
```

Table 2.
Zone File Used in the Example Interactive Session

```
3 15 15
INTERNAL            (15I2)
 4 1 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 1
 4 1 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 1
 4 1 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 1
 4 1 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 1
 4 1 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 1
 4 1 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 1
 4 1 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 1
 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1
INTERNAL            (15I2)
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
 4 2 2 2 2 2 2 2 2 2 2 2 2 2 2
CONSTANT           3
   1   2   3   4
```

Table 3.
Example Output from ZONEBUDGET Program

```
ZONEBUDGET version 1.00
Program to compute a flow budget for subregions of a model using
cell-by-cell flow data from the USGS Modular Ground-Water Flow Model.

 The cell-by-cell budget file is:
SAMPLE.BUD

  3 layers        15 rows        15 columns

ZONEBUDGET test

 The zone file is:
SAMPLE.ZON

Zone Array for layer  1 will be read from the Zone File
Zone Array for layer  1 will be read using format: (15I2)
-----------------------------------------------------------------------

      1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
-----------------------------------------------------------------------
  1   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

  2   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

  3   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

  4   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

  5   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

  6   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

  7   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

  8   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

  9   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

 10   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

 11   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

 12   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

 13   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

 14   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1

 15   4  1  1  1  1  1  1  1  1  1  1  1  1  1  1
```

```
Zone Array for layer  2 will be read from the Zone File
Zone Array for layer  2 will be read using format: (15I2)
----------------------------------------------------------------------

      1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
----------------------------------------------------------------------
  1   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

  2   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

  3   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

  4   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

  5   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

  6   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

  7   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

  8   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

  9   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

 10   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

 11   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

 12   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

 13   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

 14   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

 15   4  2  2  2  2  2  2  2  2  2  2  2  2  2  2

            Zone Array =  3 for layer  3

  1 Composite Zones:
Composite Zone A:   1   2   3   4
```

```
ZONEBUDGET test

    Flow Budget for Zone  1 at Time Step  1 of Stress Period  1
    -----------------------------------------------------------

                      Budget Term     Flow (L**3/T)
                      -----------------------------

            IN:
            ---
                    CONSTANT HEAD =   0.00000
                            WELLS =   0.00000
                           DRAINS =   0.00000
                         RECHARGE =    157.50
                    Zone  2 to  1 =    7.5897
                    Zone  4 to  1 =   0.00000

                         Total IN =    165.09

            OUT:
            ----
                    CONSTANT HEAD =   0.00000
                            WELLS =    60.000
                           DRAINS =    32.420
                         RECHARGE =   0.00000
                    Zone  1 to  2 =    30.090
                    Zone  1 to  4 =    42.577

                        Total OUT =    165.09

                         IN - OUT =   0.23831E-02

              Percent Discrepancy =                0.00
```

```
ZONEBUDGET test

    Flow Budget for Zone  2 at Time Step  1 of Stress Period  1
    -----------------------------------------------------------

                      Budget Term     Flow (L**3/T)
                      -----------------------------

            IN:
            ---
                    CONSTANT HEAD =   0.00000
                            WELLS =   0.00000
                           DRAINS =   0.00000
                         RECHARGE =   0.00000
                    Zone  1 to  2 =    30.090
                    Zone  3 to  2 =    5.8438
                    Zone  4 to  2 =   0.00000

                         Total IN =    35.934

            OUT:
            ----
                    CONSTANT HEAD =   0.00000
                            WELLS =    10.000
                           DRAINS =   0.00000
                         RECHARGE =   0.00000
                    Zone  2 to  1 =    7.5897
                    Zone  2 to  3 =    15.694
                    Zone  2 to  4 =    2.6483

                        Total OUT =    35.932

                         IN - OUT =   0.20795E-02

              Percent Discrepancy =               0.01
```

```
ZONEBUDGET test

    Flow Budget for Zone  3 at Time Step  1 of Stress Period  1
    -----------------------------------------------------------

                      Budget Term     Flow (L**3/T)
                      -----------------------------

            IN:
            ---
                    CONSTANT HEAD =   0.00000
                            WELLS =   0.00000
                           DRAINS =   0.00000
                         RECHARGE =   0.00000
                    Zone  2 to  3 =    15.694
                    Zone  4 to  3 =   0.00000

                         Total IN =    15.694

            OUT:
            ----
                    CONSTANT HEAD =   0.00000
                            WELLS =    5.0000
                           DRAINS =   0.00000
                         RECHARGE =   0.00000
                    Zone  3 to  2 =    5.8438
                    Zone  3 to  4 =    4.8498

                        Total OUT =    15.694

                         IN - OUT =   0.11836E-03

              Percent Discrepancy =                 0.00
```

```
ZONEBUDGET test

    Flow Budget for Zone  4 at Time Step  1 of Stress Period  1
    ------------------------------------------------------------

                      Budget Term     Flow (L**3/T)
                      -----------------------------

            IN:
            ---
                    CONSTANT HEAD =   0.00000
                            WELLS =   0.00000
                           DRAINS =   0.00000
                         RECHARGE =   0.00000
                    Zone  1 to  4 =    42.577
                    Zone  2 to  4 =    2.6483
                    Zone  3 to  4 =    4.8498

                         Total IN =    50.075

            OUT:
            ----
                    CONSTANT HEAD =    50.075
                            WELLS =   0.00000
                           DRAINS =   0.00000
                         RECHARGE =   0.00000
                    Zone  4 to  1 =   0.00000
                    Zone  4 to  2 =   0.00000
                    Zone  4 to  3 =   0.00000

                        Total OUT =    50.075

                         IN - OUT =   0.00000

              Percent Discrepancy =                0.00
```

```
ZONEBUDGET test

    Flow Budget for Composite Zone A at Time Step  1 of Stress Period  1
    ---------------------------------------------------------------------

    Zone A consists of the following numeric zones:
       1   2   3   4

                      Budget Term     Flow (L**3/T)
                      -----------------------------

            IN:
            ---
                    CONSTANT HEAD =   0.00000
                            WELLS =   0.00000
                           DRAINS =   0.00000
                         RECHARGE =    157.50

                         Total IN =    157.50

            OUT:
            ----
                    CONSTANT HEAD =    50.075
                            WELLS =    75.000
                           DRAINS =    32.420
                         RECHARGE =   0.00000

                        Total OUT =    157.50

                         IN - OUT =   0.45809E-02

              Percent Discrepancy =                0.00
```

Table 4.
Example Interactive Session
in Which Zones Are Defined Interactively Using Blocks

```
  ZONEBUDGET version 1.00
  Program to compute a flow budget for subregions of a model using
  cell-by-cell flow data from the USGS Modular Ground-Water Flow Model.

  Enter the name of a LISTING FILE for results:
SAMPLE2.LST

  Enter the name of the file containing CELL-BY-CELL BUDGET TERMS:
SAMPLE.BUD

   3 layers        15 rows        15 columns

  Enter a TITLE to be printed in the listing:
ZONEBUDGET test in which zones are defined interactively.

  Enter the name of your ZONE INPUT FILE (CR for interactive):


  Enter the start layer, stop layer (0,0 means done):
1,1
  Enter the start row, stop row:
1,15
  Enter the start column, stop column:
1,15
  Enter the zone for this block:
1

  Enter the start layer, stop layer (0,0 means done):
2,2
  Enter the start row, stop row:
1,15
  Enter the start column, stop column:
1,15
  Enter the zone for this block:
2

  Enter the start layer, stop layer (0,0 means done):
3,3
  Enter the start row, stop row:
1,15
  Enter the start column, stop column:
1,15
  Enter the zone for this block:
3

  Enter the start layer, stop layer (0,0 means done):
1,2
  Enter the start row, stop row:
1,15
  Enter the start column, stop column:
```

```
1,1
  Enter the zone for this block:
4

  Enter the start layer, stop layer (0,0 means done):
0,0

             4 is your highest zone.

  Choose the option for specifying when budgets are calculated:
  A = ALL times stored in the budget file.
  P = For each time stored in the budget file, PROMPT user.
  L = Enter a LIST of times.
A

 Computing the budget for time step  1 in stress period  1
**** STOP
```

Input Instructions for the Zone File

The zone file contains records that define a zone value for each model cell and, optionally, composite zones. Five record types may be included in the file as defined below. Depending on the contents of some records, other records may not be used. All record types are never used simultaneously.

Each record type contains one or more input values. Fixed format and free format are used. For fixed format, the data values must be in a specific range of columns called a field. Numeric values should be right justified in the field; character values should be left justified. A blank represents a 0 in a fixed-format numeric field. For free format, there are no absolute field sizes. Values are separated by one or more spaces or by a comma plus optional spaces. Because a space is a delimiter that can separate values, a space cannot be used to indicate 0.

Values to be input are given symbolic item names. Each item name is the name of a program variable or array in ZONEBUDGET. When an item is an array (often called a table or matrix), the dimensions of the array are included as part of the item name. For example, IZONE(NCOL,NROW) is a matrix of values with NROW rows and NCOL columns in each row. For each item, the required format is specified. “Free” indicates free format. “Ix” indicates fixed-format integer values, where x is the width of the field. “nIx” indicates multiple integer fields, where n is the number of fields. “Ax” indicates fixed-format character values, where x is the field width.

Record Type 1

Item: NLAY NROW NCOL
Format: Free Free Free

NLAY is the number of layers in the model grid. NROW is the number of rows, and NCOL is the number of columns.

Record types 2-4 define zone values for one layer of the model grid. Record types 2-4 must be repeated for each layer in the model grid. Layers are input in order starting with layer 1.

Record Type 2

Item: LOCAT ICONST FMTIN IPRN
Format A10 I10 A20 I10

LOCAT indicates the source or location of the zone data for the layer.

A LOCAT value of "CONSTANT" indicates that all cells in the layer have the same zone value, which is the value of item ICONST. In this case, there will be no Record Types 3 and 4.

A LOCAT value of "INTERNAL" indicates that the zone data for the layer are contained within the zone file. In this case, there will be no Record Type 3, so Record Type 4 follows Record Type 2.

A LOCAT value of "EXTERNAL" indicates that the zone data for the layer are contained in a file other than the zone file. The name of this file is contained in Record Type 3.

ICONST is the zone value that is assigned to each cell in the layer if LOCAT has the value "CONSTANT." If LOCAT is other than "CONSTANT", then ICONST is not used. The zone value must be greater than or equal to 0 and less than or equal to 25. (This maximum value can be changed by changing program parameter NZDIM.)

FMTIN is the FORTRAN format of the data in Record Type 4. If LOCAT has the value "CONSTANT," then FMTIN is not used. FMTIN must be a standard

FORTRAN format specification for reading integer data. The format must include parentheses. An example is “(20I4)”, which indicates that 20 integers will be read from each record, and each integer occupies a field of 4 columns. If the FMTIN value is blank, free format is used.

IPRN is a flag that determines if Record Type 4 values are printed in the listing file. If IPRN is greater than or equal to 0, the values are printed. If IPRN is less than 0, values are not printed. If LOCAT has the value “CONSTANT,” then IPRN is not used.

Record Type 3

Item: NAME
Format A80

NAME is the name of a file that contains zone values for a layer of the model. Include Record Type 3 only if LOCAT has the value “EXTERNAL.”

Record Type 4

Item: IZONE(NCOL,NROW)
Format: Defined by Record Type 2

IZONE contains the zone values for each cell in a layer. It is read only if LOCAT has the value “EXTERNAL” or “INTERNAL.” If “INTERNAL,” then include the data within the zone file. IF “EXTERNAL,” then include the data in the file that is named by the item NAME. The format of the data is defined by FMTIN. Data are read a row at a time starting with row 1. If a row of the data contains more values than one record holds, then additional records will be read using the same format until all values for one row have been read. Each row of data must start on a new record. The zone values must be greater than or equal to 0 and less than or equal to 25. (This maximum value can be changed by changing program parameter NZDIM.)

Record Type 5

Item: ICOMP(10)
Format: 10I4

ICOMP is a list of the numeric zones that comprise a composite zone. There are 10 values in ICOMP, but only the values that precede the first 0 value are actually included in the composite zone. That is, the first 0 value terminates the list, and therefore Zone 0 cannot be included in a composite zone. Include one Record Type 5 for each composite zone. If there are no composite zones, do not include any of these records. There can be a maximum of 25 composite zones.

REFERENCES CITED

McDonald, M. G. and Harbaugh, A. W., 1988, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water Resources Investigations, Book 6, Chapter A1, 14 ch.

APPENDIX

Program Listing

The program listing may be obtained from World-Wide Web site:

http://h2o.usgs.gov/software/