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Zonebudget Version 3

Zonebudget (Harbaugh, 1990) is a program that reads budget data produced by a MODFLOW ground-water model (Harbaugh and McDonald, 1996; Harbaugh and others, 2000; Harbaugh, 2005) and produces water budgets for subregions of the modeled area. Version 3 of Zonebudget, which is described here, fundamentally works as previous versions of the code. Changes to the code made for version 3 provide optional output formats and increase the number of zones that can be specified. Input data for the original code should still work with version 3 of the code. The new program also can read both single and double precision budget files. The data precision is automatically detected. Users of Zonebudget are encouraged to read the original documentation for the code provided in Harbaugh (1990), in addition to this supplemental information for version 3.

New Zone Limits

The original program limited the number of zones to 25, and these had to be specified in the range from 1 through 25. The new version allows up to 999 zones in the range of 1-999. Further, composite zones were limited to a maximum of 25 zones, with each composite zone containing up to 10 numeric zones. Now 100 composite zones are allowed, and each can contain up to 50 numeric zones. The numeric zones incorporated in a composite zone can be specified in free format rather than the previous fixed format, but existing files having fixed format should still be read properly. Further, composite zones can now be named by the user rather than having a default name assigned.

New Output Formats

The output file in the original program is a text file that has one page of output for each zone. This original output file still can be obtained in the new program, and two additional forms of a comma-delimited text file also can be obtained. Comma-delimited text files can be easily imported into typical spreadsheet programs, which allow users to make additional calculations beyond those made by Zonebudget. The user can specify any combination of the 3 output forms.

Interactive Input for Zonebudget

Interactive input to Zonebudget is the same as for the original version except for the part that prompts for the output file. The user is prompted for an output (listing) file, cell-by-cell budget file, title, and zone file. If no zone file is specified, zones can be defined interactively. The final prompts ask the user to identify the time steps at which the budgets should be computed.

The prompt for the output file is “Enter a LISTING FILE for results or a base name and file types:”. If a single file is specified, as is done for the previous versions of Zonebudget, the result will be output that is the same as for the previous versions. This file will contain budgets for each numbered zone and each composite zone formatted for printing. Instead of entering the single output file, a base name followed by up to three file types can be entered. The three allowed file types are ZBLST, CSV, and CSV2. ZBLST indicates the original file format. CSV and CSV2 are the two comma-delimited file formats. These files are named with “.zblst”, “.csv”, and “.2.csv”, respectively, appended to the base name. The zone information and title are written to the ZBLST file. If no ZBLST file is specified, then the title and zone information is written to a file with “.log” appended to the base name. For example, if the response to the output-file prompt is “TEST ZBLST CSV”, then files TEST.zblst and TEST.csv will be created.

Comma-Delimited Text Files

The CSV file is similar in structure to the original output file. For each time for which a budget is requested there is one line for each input term and each output term along with totals. The zones are displayed in columns, so one table displays all zones. This makes it easy to compare any budget term for all the different zones.

The CSV2 file displays the complete budget for one zone and one time in a single line. Each column has a separate inflow or outflow budget term. The rows can be sorted by time within the spreadsheet program, which makes it possible to easily see how each term changes with time.

See the Examples Section for more information about the comma-delimited files.

Input Instructions for the Zone File

The zone file contains records that define a zone value for each model cell and, optionally, composite zones. All input except for the IZONE array uses free format. The format for the IZONE array is specified as part of the input data.

`Item 1 - grid dimensions: NLAY NROW NCOL`

NLAY is the number of model layers, NROW is the number of model rows, and NCOL is the number of model columns. These are checked for consistency with the grid dimensions included in the budget file.

`Item 2 - Zone array: IZONE(NCOL,NROW,NCOL)`

This array is read one model layer at a time, starting with layer 1. The user can choose from three input forms for each layer.

`Form 1:` **`CONSTANT`** `ICONST`

The word "CONSTANT" is a keyword that signifies that the entire layer should have the same value, which is specified in the ICONST field.

`Form 2:` **`EXTERNAL`** `FMTIN IPRN`

The keyword "EXTERNAL" indicates that the zone values for the layer are read from a separate file whose name is specified on the following line. The values are read one row at a time, starting with row 1, using the Fortran format specified in field FMTIN. FMTIN must begin with "(" and end with ")" as required by Fortran. If the value in parentheses is blank, free format is used. IPRN specifies whether or not the zone values read are printed in the output file. If IPRN is greater than or equal to 0, the zone values will be printed. If IPRN is less than 0, zone values will not be printed.

`Form 3:` **`INTERNAL`** `FMTIN IPRN`

"INTERNAL" indicates that the zone values for the layer are read from the Zone file immediately following Item 2. The values are read one row at a time, starting with row 1, using the Fortran format specified in field FMTIN. FMTIN must begin with "(" and end with ")" as required by Fortran. If the value in parentheses is blank, free format is used. IPRN specifies whether or not the zone values read are printed in the output file. If IPRN is greater than or equal to 0, the zone values will be printed. If IPRN is less than 0, zone values will not be printed.

`Item 3 - [NAMCOMP] ICOMP(50)`

Up to 100 composite zones can be defined, with each composite zone consisting of up to 50 numeric zones. Each composite zone is specified on a single line. A composite zone need not include 50 numeric zones; simply terminate the line after specifying the desired zones. Specify as many lines as required for the desired number of composite zones. NAMCOMP is the name for the composite zone, which is optional as indicated by "[ ]". The name must start with a non-numeric character and can consist of up to 10 characters. If NAMCOMP is not included, a name is automatically generated.

Examples

Table 1 shows the prompts and 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. This output is identical to the output from the original Zonebudget. 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 prompts 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 5 shows file SAMPLE.csv, which would be created if the response to the prompt for a listing file ("Enter a LISTING FILE for results or a base name and file types:") is "SAMPLE CSV". This file can be imported into many spreadsheet programs. The same information is contained in the CSV2 file, but an example is not shown because the lines of this file are very wide. Each line of the CSV2 file for the sample simulation used in this documentation is 443 characters wide and there are 26 fields (spreadsheet columns) (Table 6). There would be additional fields for simulations with more than four zones.

Table 1. Example interactive session using ZONEBUDGET

```
  ZONEBUDGET version 3.00
  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 a LISTING FILE for results or a base name and file types:
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 zones.
   1   2   3   4

  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
ALLZONES 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
 Single precision budget file

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 ALLZONES  :   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 ALLZONES   at Time Step  1 of Stress Period  1
    -------------------------------------------------------------------------------

    Composite Zone ALLZONES   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 3.00
  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 a LISTING FILE for results or a base name and file types:
SAMPLE2.LST

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

   3 layers        15 rows        15 columns
  Single precision budget file

  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 zones.
   1   2   3   4

  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 5. Example CSV output file from ZONEBUDGET program

```
Time Step,  1,Stress Period,  1,Sim. Time, 8.640000E+04,ZONEBUDGET test,
               ,  ZONE   1      ,  ZONE   2      ,  ZONE   3      ,  ZONE   4      ,
               ,    IN          ,    IN          ,    IN          ,    IN          ,
   CONSTANT HEAD,    0.000000E+00,    0.000000E+00,    0.000000E+00,    0.000000E+00,
           WELLS,    0.000000E+00,    0.000000E+00,    0.000000E+00,    0.000000E+00,
          DRAINS,    0.000000E+00,    0.000000E+00,    0.000000E+00,    0.000000E+00,
        RECHARGE,    1.575000E+02,    0.000000E+00,    0.000000E+00,    0.000000E+00,
   FROM ZONE   1,    0.000000E+00,    3.008996E+01,    0.000000E+00,    4.257742E+01,
   FROM ZONE   2,    7.589696E+00,    0.000000E+00,    1.569367E+01,    2.648276E+00,
   FROM ZONE   3,    0.000000E+00,    5.843753E+00,    0.000000E+00,    4.849793E+00,
   FROM ZONE   4,    0.000000E+00,    0.000000E+00,    0.000000E+00,    0.000000E+00,
Total IN        ,    1.650897E+02,    3.593372E+01,    1.569367E+01,    5.007549E+01,
               ,   OUT          ,   OUT          ,   OUT          ,   OUT          ,
   CONSTANT HEAD,    0.000000E+00,    0.000000E+00,    0.000000E+00,    5.007549E+01,
           WELLS,    6.000000E+01,    1.000000E+01,    5.000000E+00,    0.000000E+00,
          DRAINS,    3.241992E+01,    0.000000E+00,    0.000000E+00,    0.000000E+00,
        RECHARGE,    0.000000E+00,    0.000000E+00,    0.000000E+00,    0.000000E+00,
     TO ZONE   1,    0.000000E+00,    7.589696E+00,    0.000000E+00,    0.000000E+00,
     TO ZONE   2,    3.008996E+01,    0.000000E+00,    5.843753E+00,    0.000000E+00,
     TO ZONE   3,    0.000000E+00,    1.569367E+01,    0.000000E+00,    0.000000E+00,
     TO ZONE   4,    4.257742E+01,    2.648276E+00,    4.849793E+00,    0.000000E+00,
Total OUT       ,    1.650873E+02,    3.593164E+01,    1.569355E+01,    5.007549E+01,
 IN-OUT         ,    2.392577E-03,    2.078565E-03,    1.205467E-04,    0.000000E+00,
Percent Error   ,    1.449269E-03,    5.784609E-03,    7.681260E-04,    0.000000E+00,
,
```

Table 6. Fields in the CSV2 output file for the sample simulation.

TOTIM	Total simulation time in model time units
PERIOD	Stress period number
STEP	Time step number
ZONE	Zone number
CONSTANT HEAD	Inflow from constant-head cells
WELLS	Inflow from wells
DRAINS	Inflow from drains
RECHARGE	Inflow from recharge
From Other Zones	Total inflow across all boundaries with all other zones
Total IN	Total inflow
CONSTANT HEAD	Outflow to constant-head cells
WELLS	Outflow to wells
DRAINS	Outflow to drains
RECHARGE	Outflow to recharge
To Other Zones	Total outflow across all boundaries with all other zones
Total Out	Total outflow
IN-OUT	Total in minus total out
Percent Error	Percent error
FROM ZONE 1	Inflow from Zone 1
FROM ZONE 2	Inflow from Zone 2
FROM ZONE 3	Inflow from Zone 3
FROM ZONE 4	Inflow from Zone 4
TO ZONE 1	Outflow to Zone 1
TO ZONE 2	Outflow to Zone 2
TO ZONE 3	Outflow to Zone 3
TO ZONE 4	Outflow to Zone 4

References

Harbaugh, A.W., 1990, A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional ground-water flow model: U.S. Geological Survey Open-File Report 90-392, 46 p.

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, variously p.

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.

Harbaugh, A.W., and McDonald, M.G., 1996, User's documentation for MODFLOW-96, an update to the U.S. Geological Survey modular finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 96-485, 56 p.