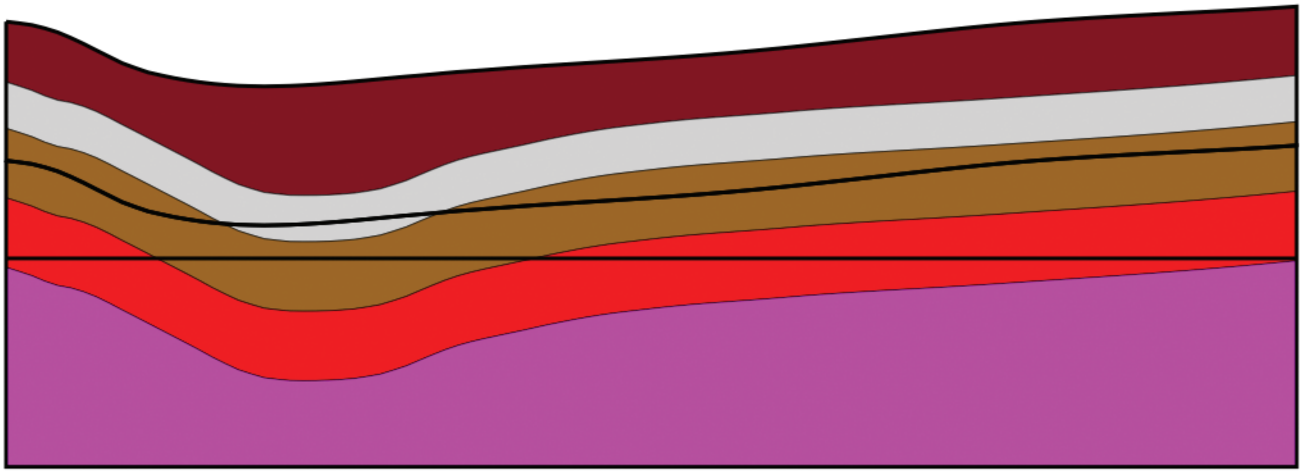
User Guide for HUFPrint, A Tabulation and Visualization Utility for the Hydrogeologic-Unit Flow (HUF) Package of MODFLOW

Chapter 27 of
Book 6. Modeling Techniques, Section A. Ground Water



Techniques and Methods 6-A27

U.S. Department of the Interior
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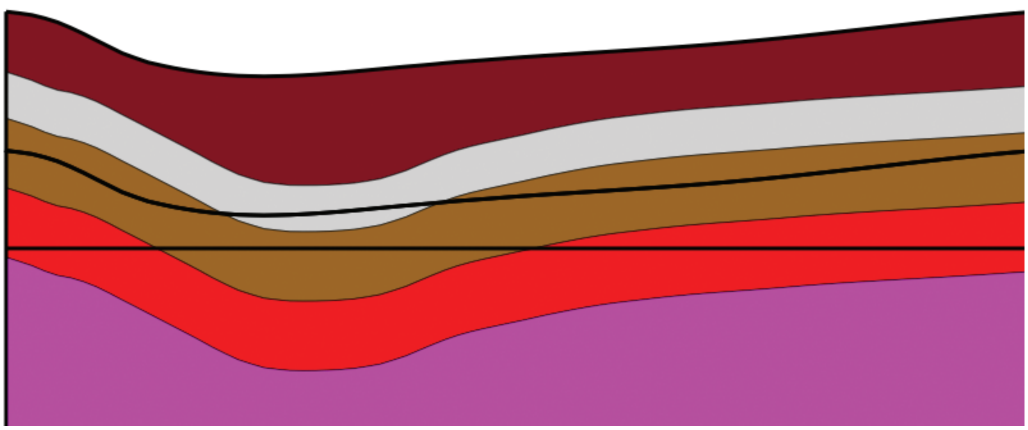
By Edward R. Banta and Alden M. Provost



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Preface

This report documents HUFPrint, a computer program that extracts and displays information about model structure from the input data for a model using the Hydrogeologic-Unit Flow (HUF) Package of MODFLOW, the U.S. Geological Survey's three-dimensional ground-water flow model. The documentation presented herein describes the program, the input requirements, and the output.

The performance of this program has been tested in a variety of applications. Future applications, however, might reveal errors that were not detected in the test simulations. Users are requested to notify the U.S. Geological Survey of any errors found in this document or the computer program. Updates might occasionally be made to this document and to the program. Users can download the software and check for updates on the Internet at http://water.usgs.gov/software/HUFPrint/.

Abbreviations

Abbreviation	Meaning
CC	Hydraulic conductance in the column direction (along columns) between adjacent model cells
CR	Hydraulic conductance in the row direction (along rows) between adjacent model cells
CV	Hydraulic conductance in the vertical direction between adjacent model cells
HANI	Horizontal anisotropy; the ratio of hydraulic conductivity in the column direction to hydraulic conductivity in the row direction
HGU	Hydrogeologic unit
HGUVANI	A HUF-Package input variable that indicates whether vertical hydraulic conductivity is to be input directly or calculated from horizontal hydraulic conductivity and vertical anisotropy
HK	Hydraulic conductivity in the row direction
HKCC	Hydraulic conductivity in the column direction
HUF	Hydrogeologic Unit Flow (Package)
KDEP	Hydraulic-conductivity depth dependence (Anderman and Hill, 2003)
LVDA	Layer variable-direction horizontal anisotropy (Anderman and others, 2002)
SS	Specific storage
SY	Specific yield
VANI	Vertical anisotropy; the ratio of horizontal hydraulic conductivity in the row direction to vertical hydraulic conductivity
VK	Vertical hydraulic conductivity

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)

User Guide for HUFPrint, A Tabulation and Visualization Utility for the Hydrogeologic-Unit Flow (HUF) Package of MODFLOW

By Edward R. Banta and Alden M. Provost

Abstract

This report documents HUFPrint, a computer program that extracts and displays information about model structure and hydraulic properties from the input data for a model built using the Hydrogeologic-Unit Flow (HUF) Package of the U.S. Geological Survey's MODFLOW program for modeling ground-water flow. HUFPrint reads the HUF Package and other MODFLOW input files, processes the data by hydrogeologic unit and by model layer, and generates text and graphics files useful for visualizing the data or for further processing. For hydrogeologic units, HUFPrint outputs such hydraulic properties as horizontal hydraulic conductivity along rows, horizontal hydraulic conductivity along columns, horizontal anisotropy, vertical hydraulic conductivity or anisotropy, specific storage, specific yield, and hydraulic-conductivity depth-dependence coefficient. For model layers, HUFPrint outputs such effective hydraulic properties as horizontal hydraulic conductivity along rows, horizontal hydraulic conductivity along columns, horizontal anisotropy, specific storage, primary direction of anisotropy, and vertical conductance. Text files tabulating hydraulic properties by hydrogeologic unit, by model layer, or in a specified vertical section may be generated. Graphics showing two-dimensional cross sections and one-dimensional vertical sections at specified locations also may be generated. HUFPrint reads input files designed for MODFLOW–2000 or MODFLOW–2005.

Introduction

In the Hydrogeologic-Unit Flow (HUF) Package (Anderman and Hill, 2000; 2003; Anderman and others, 2002) of MODFLOW (Harbaugh, 2005; Harbaugh and others, 2000), most hydraulic system properties are assigned on the basis of hydrogeologic units (HGUs); this information is then used to calculate effective model-layer properties. However, the printing capabilities in the HUF Package are limited to printing information for HGUs, and using HUF to print this information requires running MODFLOW. Thus, the HUF package provides no convenient way to extract and display the HGU and effective model-layer properties it computes.

This report describes HUFPrint, a separate program that runs independently of MODFLOW. It reads the HUF Package input file and selected other MODFLOW input files and writes HGU and effective model-layer properties to output files in a variety of forms. Hydraulic properties of HGUs can be written for all units or for specific individual units. Effective hydraulic properties can be written for each layer. All numeric hydraulic-property values and elevations output by HUFPrint are in the user-selected units for model input.

Graphics files showing cross sections can be generated, allowing visualization of the model layers and HGUs superimposed. A one-dimensional representative vertical section at a single cell location through the entire model thickness can be generated to illustrate the HGUs and model layers side by side; an extensive informational file listing hydraulic information at this location also is generated. HUFPrint supports generation of graphics files in the Postscript format (Adobe Systems, Inc., 2008). Postscript files may be viewed with the program "GSview" (Lang, 2007) or another Postscript viewer. If needed, a variety of utility programs are available from other sources for converting Postscript files to other graphics formats. The program "pstoedit" (Glunz, 2007) is one such utility.

All examples and figures in this report are generated from the example data set described in the last section of the report. All numeric units are in the user-selected units for model input.

Obtaining and Installing the Software

HUFPrint and related files may be downloaded from the URL listed in the Preface of this report. The download is a self-extracting archive file that contains an executable file for the Windows operating system, Fortran source-code files, and example input and data.

Executable files for operating systems other than Windows may be generated by compiling and linking the source-code files in the "src" subdirectory using a Fortran–90 compiler that supports the operating system of interest. Once extracted or compiled, the executable file may be invoked as described in the following sections.

Acknowledgments

Thanks are extended to Evan Anderman, formerly of Calibra Consulting LLC, and Mike LeFrancois of Norwest Applied Hydrology, who did much of the original programming for HUFPrint. Reviews by Jan Uhlik, Claudia Faunt, and Suzanne Paschke resulted in substantial improvements to the functionality of the program and to the readability of the report.

Program Execution and Input Instructions

Users are encouraged to invoke HUFPrint from the operating-system command prompt at first, to gain familiarity with the input requirements and to aid in identifying input errors. HUFPrint also may be invoked from a user-written command script, batch file, or other program. Two arguments are required; a third argument, shown in brackets, is optional. The command-line syntax is:

```
HUFPRINT NAME-FILE COMMAND-FILE [LIST-FILE]
```

where:

NAME-FILE is the name of a MODFLOW Name file for the model of interest; COMMAND-FILE is the name of a text file containing HUFPrint commands used to specify the desired output; and LIST-FILE is the name of a HUFPrint listing file, to which output generated by HUFPrint as it processes MODFLOW input files is to be written. If LIST-FILE is omitted, the default name for the HUFPrint listing file is “hufprint-list.txt”.

The first file listed in the Name file must be identified with file type “List” or “Global”; this file is not opened or modified, but its unit number is used for the HUFPrint listing file. All input files listed in the MODFLOW Name file are opened for read-only access. Data are read from the HUF, Discretization, Basic, and if listed, Multiplier and Zone files. Definitions and values for HUF-Package parameters are read from the HUF file. However, for a MODFLOW–2000 model, if a Sensitivity Process (SEN) input file is listed in the Name file, and if the SEN file provides values for parameters defined in HUF input, the parameter values in the SEN file override the corresponding parameter values in the HUF file. Similarly, for a MODFLOW–2005 model, if a Parameter Value (PVAL) file is listed in the Name file, and if the PVAL file provides values for parameters defined in HUF input, the parameter values in the PVAL file override the corresponding parameter values in the HUF file. To ensure that output generated by HUFPrint is consistent with a particular MODFLOW model, it is expected that the Name file and all input files listed therein are those used to make an actual MODFLOW run.

The HUFPrint command file is used to specify the desired output of HUFPrint. The format of the command file is both free and non-case sensitive. However, the specific options for each command must lie on the same line as the command to which they refer. Blank lines are ignored. Each line of a command file is processed to see if it contains a command or a comment. Comments and blank lines are allowed throughout the command file. Any line beginning with a “#” symbol is interpreted as a comment. Comment lines read from the command file and diagnostic information, if appropriate, are written to a file named by appending “.hco” to the file name given as COMMAND-FILE. In the event of unexpected results, comment lines can be inserted into the command file to aid in identifying command lines that may require modification. Input read from MODFLOW input files is echoed to the HUFPrint listing file; this file also can be informative in the event of unexpected results.

Commands

HUFPrint recognizes five commands (OUTFILE, PRINT_HGU, PRINT_LAY, PRINT_XSECTION, and PRINT_VSECTION), which are documented in this section. All commands are optional.

OUTFILE command

OUTFILE is a command that allows the user to define a string to be used as the first part of the name of each file generated by HUFPrint (except the HUFPrint listing and “.hco” files). The syntax of the OUTFILE command is:

```
OUTFILE BASENAME
```

where:

BASENAME defines a base filename for the generated output files.

Names of specific output files vary by output-file type, as documented in the following sections. The output files can be written either in the current working directory or in another directory provided as part of BASENAME. To produce files in a directory other than the current working directory, the directory should be specified as part of BASENAME, using a forward slash (“/”) to separate directory names, and the directory must exist prior to executing HUFPrint; when HUFPrint is run under the Windows operating system, either a forward slash (“/”) or a backslash (“\”) may be used as a directory separator and to separate the final directory name from the string to be used in forming the file names. If the OUTFILE command is not used, the output files will be written in the current working directory by default, and output files will be named as described in the following sections. OUTFILE affects the locations and names of all subsequent output files until the next OUTFILE command is entered.

Examples

```
OUTFILE TEST
```

All output files will start with the string “TEST” and will be written in the current working directory.

```
OUTFILE PRINT/TEST
```

A directory named “PRINT” must be located in the current working directory in which HUFPrint is executed. Subsequent output files will be created in this directory and will start with the string “TEST”.

PRINT_HGU command

The PRINT_HGU command generates one or more text files in which values of a hydraulic-property array for an HGU are tabulated. The syntax of the PRINT_HGU command is:

```
PRINT_HGU UNIT_NAME PRINT_CODE PRINT_FLAGS
```

where:

`UNIT_NAME` refers to the name of an HGU defined in the HUF Package input file. HUFPrint will create individual output files containing hydraulic-property array values for the specified UNIT_NAME. If UNIT_NAME is specified as “ALL”, a file will be generated for each of the HGUs defined in the HUF Package input file for each specified print flag.

`PRINT_CODE` is one of a set of integer print-code values that can be used to specify the output format in the generated output file. Refer to table 1 for a complete listing of the available print codes and corresponding formats.

`PRINT_FLAGS` is either “ALL” or a list of one or more of the following print flags: “HK”, “HANI”, “HKCC”, “VK”, “SS”, “SY”, and “KDEP”. PRINT_FLAGS determines the hydraulic-property arrays to be printed. The print flag will be incorporated in the output file name. Specifying “ALL” is equivalent to listing all seven print flags. For a complete description of the available flags and hydraulic properties, refer to table 2 and the “Print flags” section. If the user specifies the VK print flag and if HUF Package input (variable HGUVANI) specifies that vertical anisotropy is used in place of vertical hydraulic conductivity, the name of the output file will include “VANI” rather than “VK,” and the file will contain vertical anisotropy values.

Table 1. PRINT_CODE values and output formats for HUFPrint

[See “Print_codes” section of report for explanation of format]

PRINT_CODE	Format
0	10G11.4
1	11G10.3
2	9G13.6
3	15F7.1
4	15F7.2
5	15F7.3
6	15F7.4
7	20F5.0
8	20F5.1
9	20F5.2
10	20F5.3
11	20F5.4
12	10G11.4
13	10F6.0
14	10F6.1
15	10F6.2
16	10F6.3
17	10F6.4
18	10F6.5
19	5G12.5
20	6G11.4
21	7G9.2

Table 2. PRINT_FLAG for commands PRINT_HGU and PRINT_LAY in HUFPrint

PRINT_FLAG	PRINT_HGU	PRINT_LAY
HK	Horizontal hydraulic conductivity of the HGU along rows or, if LVDA is active, hydraulic conductivity along the primary direction of anisotropy	Effective horizontal hydraulic conductivity of the model layer along rows. If LVDA is active, effective hydraulic conductivity along the primary direction of anisotropy
HANI	Horizontal-anisotropy ratio of the HGU	Effective horizontal anisotropy of the model layer, calculated as effective hydraulic conductivity along rows divided by effective hydraulic conductivity along columns, or if LVDA is active, the effective horizontal hydraulic conductivity along the primary direction of anisotropy divided by the effective hydraulic conductivity along the orthogonal direction of anisotropy
HKCC	Horizontal hydraulic conductivity along columns or, if LVDA is active, perpendicular to the primary direction of anisotropy	
VK	Vertical hydraulic conductivity or vertical anisotropy ratio of the HGU, depending on the value of HGUVANI[3] specified in HUF input	Not applicable
SS	Specific storage of the HGU	Effective specific storage of the model layer
SY	Specific yield	Not applicable
KDEP	Hydraulic conductivity depth-dependence coefficient[1]	Not applicable
LVDA	Not applicable	Primary direction of anisotropy[2]
CV	Not applicable	Model calculated branch conductance between a cell and the cell below. CV does not apply to the bottom model layer.

[1]. See Anderman and Hill (2003)

[2]. See Anderman and others (2002)

[3]. HGUVANI is a HUF-Package input variable that indicates whether vertical hydraulic conductivity is to be input directly or calculated from horizontal hydraulic conductivity and vertical anisotropy

Examples

`PRINT_HGU HGU3 16 HK`

This command will generate one output file with the name "BASENAME_HGU3_HK.dat", containing a table of values of horizontal hydraulic conductivity along rows for HGU "HGU3" (fig. 1); the HUF input file must include the definition of an HGU named "HGU3". The hydraulic conductivity values will be written using a print code of 16. BASENAME refers to the base filename specified in the OUTFILE command; however, if no OUTFILE command applies, the file name will be "HGU3_HK.dat".

`PRINT_HGU HGU2 2 HK VK`

This command will produce two files containing hydraulic-property arrays for HGU "HGU2". One file will contain horizontal hydraulic-conductivity (HK) values. If BASENAME is defined in an OUTFILE command, the file will be named BASENAME_HGU2_HK.dat; if not, the file will be named HGU2_HK.dat. A second file will contain vertical hydraulic-conductivity values. If BASENAME is defined, this file will be named "BASENAME_HGU2_VK.dat"; if not, the file will be named "HGU2_VK.dat". Both files will be written using a print code of 2.

`PRINT_HGU ALL 3 ALL`

This command will generate a file for each hydraulic-property array defined for each of the HGUs. All files will be written using a print code of 3.

PRINT_LAY command

The PRINT_LAY command generates one or more text files in which effective hydraulic-property values for a model layer are tabulated. The syntax for the PRINT_LAY command is:

`PRINT_LAY MODEL_LAYER PRINT_CODE PRINT_FLAGS`

where:

`MODEL_LAYER` is the model layer of interest. Only one layer can be specified in each PRINT_LAY command. However, more than one PRINT_LAY command can be used in the command file, allowing many layers to have hydraulic information written to files in a single invocation of HUFPrint.

`PRINT_CODE` is one of a set of integer print-code values that can be used to specify the output format in the generated output file. Refer to table 1 for a complete listing of the available print codes and corresponding formats.

`PRINT_FLAGS` is either "ALL" or a list of one or more of the following print flags: "HK",

```
                  HYDRAULIC CONDUCTIVITY ALONG ROWS FOR HYDROGEOLOGIC UNIT HGU3

             1        2        3        4        5        6        7        8        9       10
            11       12       13       14       15       16       17       18       19       20
            21       22       23       24       25       26       27       28       29       30
            31       32       33       34       35       36       37       38       39       40
            41       42       43       44       45       46       47       48       49       50
            51       52       53       54       55       56       57       58
 ....................................................................................................
 1       4.991    4.865    4.747    4.636    4.533    4.435    4.343    4.257    4.175    4.098
         4.024    3.955    3.889    3.826    3.766    3.709    3.655    3.603    3.553    3.506
         3.460    3.416    3.374    3.334    3.295    3.258    3.222    3.187    3.154    3.121
         3.090    3.060    3.031    3.002    2.975    2.948    2.923    2.897    2.873    2.849
         2.826    2.804    2.782    2.760    2.739    2.719    2.699    2.679    2.660    2.641
         2.622    2.604    2.586    2.569    2.551    2.534    2.518    2.501
 2       4.992    4.865    4.747    4.637    4.533    4.436    4.344    4.257    4.175    4.098
         4.025    3.955    3.889    3.826    3.767    3.709    3.655    3.603    3.553    3.506
         3.460    3.416    3.374    3.334    3.295    3.258    3.222    3.187    3.154    3.121
         3.090    3.060    3.031    3.003    2.975    2.948    2.923    2.898    2.873    2.849
         2.826    2.804    2.782    2.760    2.739    2.719    2.699    2.679    2.660    2.641
         2.622    2.604    2.586    2.569    2.552    2.535    2.518    2.501
```

Figure 1. Excerpt from file TEST_HGU3_HK.dat. Hydraulic-conductivity values for the first two rows of HGU3 are shown. The integers in the heading (1–58) indicate the model column numbers, and integers at the left side (1–2), indicate model row numbers.

"HANI", "HKCC", "SS", "LVDA", and "CV". PRINT_FLAGS determines the hydraulic-property arrays to be printed. The print flag will be incorporated in the output file name. Specifying "ALL" is equivalent to listing all six print flags. For a complete description of the available flags and hydraulic properties, refer to table 2.

Examples

`PRINT_LAY 1 16 HK`

This command will generate one output file named "BASENAME_L001_HK.dat", which will contain a tabulation of effective horizontal hydraulic conductivity along rows for layer 1 using print code 16 for the output (fig. 2). BASENAME refers to the string specified in an OUTFILE command. However, if an OUTFILE command does not apply, the name of the file generated by PRINT_LAY will be "L001_HK.dat". The string "L001" identifies the model layer number.

`PRINT_LAY 2 2 ALL`

This command will generate one file for each effective hydraulic-property array for model layer 2, using print code 2.

PRINT_XSECTION command

The PRINT_XSECTION command creates a graphical representation of a cross section between two defined model-cell centers in Postscript format. The syntax of the PRINT_XSECTION command is:

`PRINT_XSECTION IROW ICOL FROW FCOL NUMSEG RVEXAG`

where:

`IROW` and `ICOL` are integers identifying the initial cell's row and column location. The left side of the cross-section graphic will represent the center of this cell through the entire model thickness.

`FROW` and `FCOL` are integers identifying the final cell's row and column location. The right side of the cross-section graphic will represent the center of this cell through the entire model thickness.

`NUMSEG` is an integer number of line segments to be used to draw the cross section between the two chosen cell locations. This value can be used to make the final visualization coarse (using a relatively small value for

```
             HYDRAULIC CONDUCTIVITY ALONG ROWS FOR LAYER   1

         1       2       3       4       5       6       7       8       9      10
        11      12      13      14      15      16      17      18      19      20
        21      22      23      24      25      26      27      28      29      30
        31      32      33      34      35      36      37      38      39      40
        41      42      43      44      45      46      47      48      49      50
        51      52      53      54      55      56      57      58
...................................................................................
1    0.000   0.000   0.000   0.000  27.795  27.294  27.113  27.225  27.610  28.224
    29.006  29.889  30.800  31.670  32.380  32.105   0.000   0.000   0.000   0.000
     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
2    0.000   0.000   0.000  28.506  27.646  27.424  27.902  28.760  29.776  30.788
    31.823  32.687  32.985  32.547  31.664  31.798  32.341  33.214   0.000   0.000
     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
     0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
```

Figure 2. Excerpt from TEST_L001_HK.dat. Effective hydraulic-conductivity values for the first two rows of layer 1 are shown. Zeroes are written where the IBOUND array contains zeroes, indicating inactive cells. The integers in the heading (1-58) indicate the model column numbers, and integers at the left side (1–2), indicate model row numbers.

NUMSEG) or fine (using a relatively large value). Hydrogeologic-unit and model-layer top and bottom elevations are interpolated between cell centers as needed at each segment endpoint. The interpolation methodology uses the basis-function approach documented for interpolation of simulated heads for hydraulic-head observations in MODFLOW–2000 (Hill and others, 2000).

`RVEXAG` is a real number that defines the vertical exaggeration of the cross section. If the graphic representation at the specified vertical exaggeration would exceed the allowable space on a page, the vertical exaggeration is changed to allow the representation to fit on the page, and the user is notified of the change by a message written to the screen.

Note: when choosing a cross-section location, ensure that the line of section avoids areas where the IBOUND array (Harbaugh and others, 2000) is zero, which designates inactive cells. PRINT_XSECTION does not draw HGUs or model layers where interpolation with inactive cells would be required. If an inactive cell is encountered in a cross section, a warning message is written to the screen.

The output file will be named "BASENAME_XSEC_IROW_ICOL_FROW_FCOL.ps", where IROW, ICOL, FROW, and FCOL are replaced by their integer values. BASENAME refers to the base filename specified in the OUTFILE command. However, if no OUTFILE command applies, the file name will be "XSEC_IROW_ICOL_FROW_FCOL.ps".

Example

```
PRINT_XSECTION 11 1 29 57 20 10.0
```

This command will generate one Postscript formatted output file representing a cross section from row and column location (11, 1) to (29, 57) with 20 line segments and a vertical exaggeration of 10 (fig. 3).

PRINT_VSECTION command

The PRINT_VSECTION command creates two output files. The first file is a Postscript-formatted file containing a graphical representation of a one-dimensional vertical section at a single horizontal cell location for the entire model thickness, showing the model layers and HGUs side by side (fig. 4). The second file is a text file listing all available hydraulic

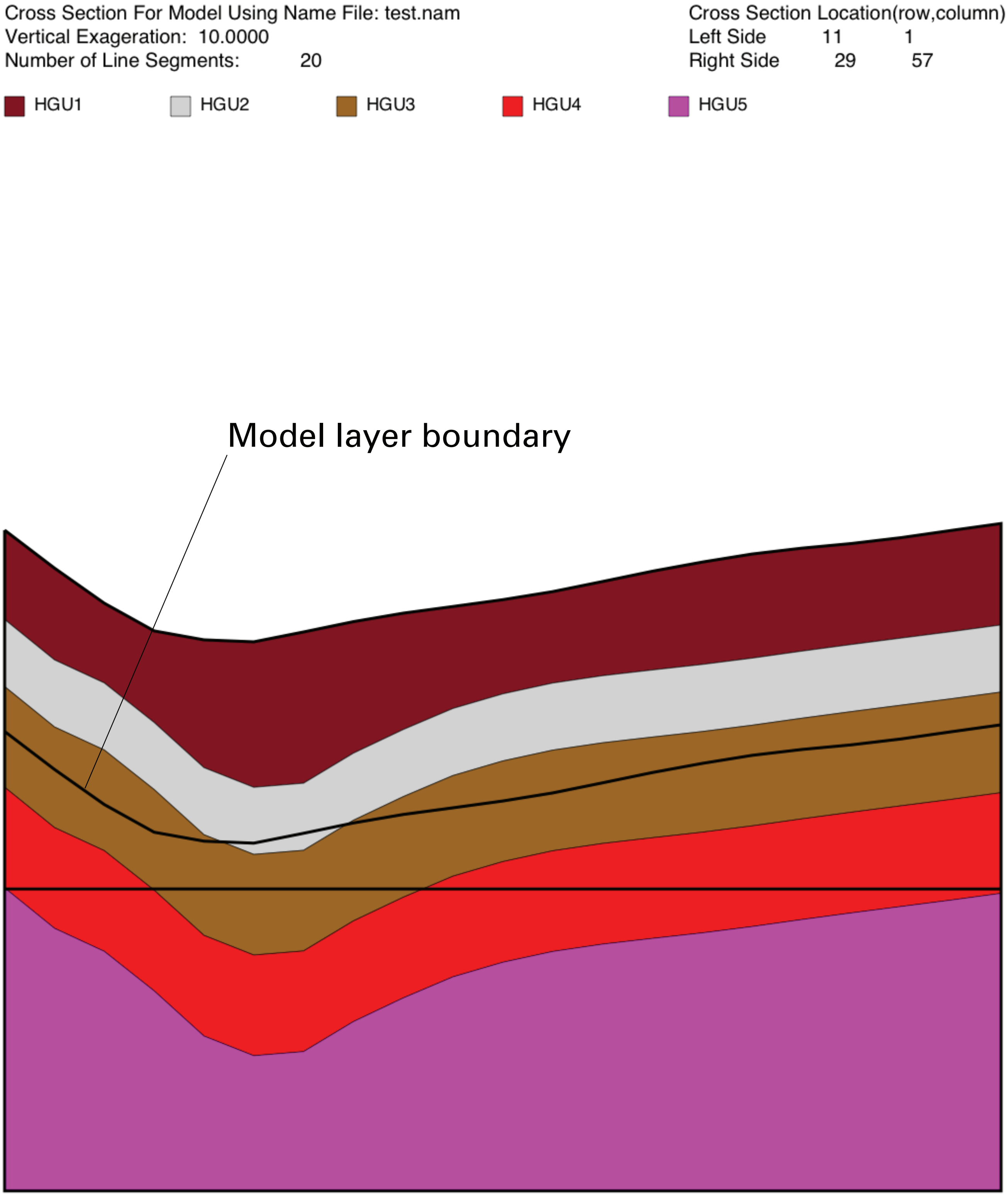

Figure 3. Cross-section example graphic. HGUs are represented as filled polygons delimited by fine lines. Model layers are identified only by their boundaries, which are symbolized by heavier lines; layer numbers increase from top (layer 1) to bottom (layer 3).

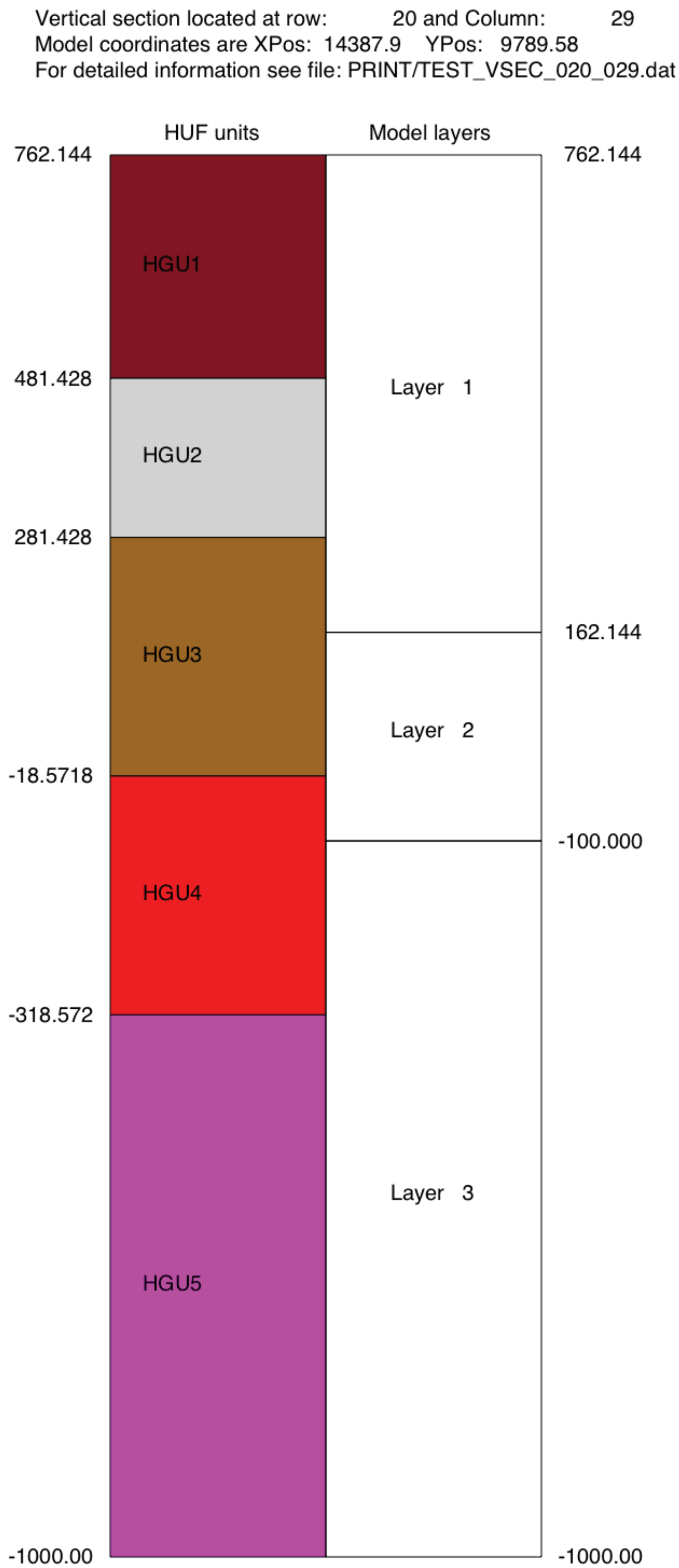

Figure 4. Vertical-section example graphic. Model coordinates XPos and YPos, expressed in the model length unit, are measured from the grid origin (the upper left corner of the cell in row 1, column 1); XPos is measured parallel to model rows, and YPos is measured parallel to model columns. Elevations, shown on the left and right sides of the vertical section, also are expressed in the model length unit.

```
PRINT/TEST_VSEC_020_029.dat
NAME file for this simulation: test.nam
Parameter Information at     Location: Row       20  Col    29
This model has  5 HGU Units, and  3 model layers.

HUF Information
---------------



Unit: HGU1        Unit number:      1
----------------------------------------------------------------------------------
Top           762.14366
Thickness     280.71550
Bottom        481.42816

Parameter    Type     Value         Mult. Array   Mult. Value    Zone Array  Zone #
HK1          HK      40.000000      MULT1         1.5840255      ALL


Unit: HGU2        Unit number:      2
----------------------------------------------------------------------------------
Top           481.42816
Thickness     200.00000
Bottom        281.42816

Parameter    Type     Value         Mult. Array   Mult. Value    Zone Array  Zone #
HK2          HK      10.000000      MULT1         1.5840255      ALL

...

LAYER Information
------------------

Layer   1
----------------------------------------------------------------------------------
Top           762.14366
Thickness     600.00000
Bottom        162.14366
Start head    1000.0000

  HK                 HANI                LVDA
 0.59252764E-01      1.0000000           0.36E+02

     Backward              Forward
CR:  21273.772             21175.751
CC:  21458.125             21435.687
CV:                        2793.6020
```

Figure 5. Excerpts from vertical-section example data output file. CR, Hydraulic conductance between specified cell and adjacent cell in the row direction; CC, Hydraulic conductance between specified cell and adjacent cell in the column direction; CV, Hydraulic conductance between specified cell and adjacent cell in the vertical direction. Other abbreviations correspond to print flags (table 2).

information for both the model layers and HGUs for the same location. For each HGU, the file lists top and bottom elevation and unit thickness. In addition the file lists the following hydraulic information for each HGU: the parameter name, type, value, multiplier array, multiplier value, zone array name, and zone number. For each model layer, the output file tabulates top elevation, thickness, bottom elevation, starting head, horizontal hydraulic conductivity, horizontal anisotropy, layer variable direction anisotropy (if any), specific storage (if a transient solution), and row, column, and vertical conductances to the adjacent model cells. The syntax of the PRINT_VSECTION command is:

```
PRINT_VSECTION ROW COL
```

where:

`ROW` and `COL` are integers defining the row and column indices, respectively, of the cell location where the vertical section is to be generated.

The Postscript output file will be named “BASENAME_VSEC_ROW_COL.ps”, where ROW and COL are replaced by their integer values and BASENAME is a string defined by an applicable OUTFILE command. The text/data output file will be named “BASENAME_VSEC_ROW_COL.dat”. If no OUTFILE command applies, the file names will not include “BASENAME_”.

Example

```
PRINT_VSECTION 20 29
```

This PRINT_VSECTION command will generate two output files. One file will be a Postscript formatted file named “BASENAME_VSEC_020_029.ps” representing a vertical section at row and column location (20, 29) (fig. 4). The other file will be a data file named “BASENAME_VSEC_020_029.dat” containing the hydraulic properties at the same row, column location through the entire thickness of the model (fig. 5).

Print codes

Valid values for PRINT_CODE and corresponding output formats are listed in table 1. The output formats are Fortran specifications of the form NXw.d, where N is the number of data values per line and Xw.d is an edit descriptor. Two forms for the edit descriptor are supported: Fw.d and Gw.d. For the Fw.d edit descriptor, w is field width reserved for each data value and d is the number of digits to the right of the decimal point; data values are written without exponents. For the Gw.d edit descriptor, w is field width, four characters of which are reserved for an exponent, and d is the maximum number of digits to be used to represent the fractional part of the value; the presence or absence of an exponent depends on the magnitude of the data value.

Print flags

The hydraulic property for which values are tabulated in each output file generated by the PRINT_HGU and PRINT_LAY commands is controlled by PRINT_FLAG specifications. Valid print flags and their meanings for the two commands are listed in table 2. Several of the print flags apply to only one of the two commands.

The VK print flag is not supported by the PRINT_LAY command because the vertical conductance (CV) terms computed by the HUF Package generally cannot be converted to equivalent layer-averaged vertical hydraulic-conductivity or vertical anisotropy values. The CV terms define the branch conductances between vertically adjacent cells. In the HUF Package, calculation of CV between two vertically adjacent cells uses VK properties of the HGUs in the lower half of a given cell and the upper half of the underlying cell. When a cell (1) has adjacent cells above and below and (2) overlaps multiple HGUs, the HGU-based VK values used to compute the CV term between that cell and the overlying cell generally will differ from the HGU-based VK values used to compute the CV term between that cell and the underlying cell. An effective VK could be calculated for the cell’s contribution to CV for the connection with the overlying cell, and an effective VK could be calculated for the cell’s contribution to CV for the connection with the underlying cell. However, these two effective VK values generally will differ even though they apply to the same cell. This dilemma prevents calculation of a single effective VK for any cell that overlaps HGUs having differing VK values. It also means that HUFPrint cannot be used to generate equivalent input for the Layer-Property Flow (LPF) Package of MODFLOW, because the LPF Package uses VK values defined for cells to compute the CV terms. However, the CV arrays output by HUFPrint could be used in combination with cell dimensions to generate Vcont (vertical hydraulic conductivity divided by thickness between cell centers) arrays for the Block-Centered Flow (BCF) Package (Harbaugh and others, 2000), because Vcont applies to the vertical connection between cells rather than the cells themselves.

The SY print flag is not applicable to the PRINT_LAY command because the specific yield in effect in a given cell at any given time step in the simulation is that defined for the HGU in which the calculated head for that cell lies.

The KDEP print flag is not applicable to the PRINT_LAY command because an effective depth-dependence coefficient for a cell in general cannot be computed where the cell contains multiple HGUs.

The LVDA print flag is not applicable to the PRINT_HGU command because the LVDA capability (Anderman and others, 2002) allows definition of variable-direction anisotropy only by model layer.

The CV print flag is not applicable to the PRINT_HGU command because vertical conductance is calculated only between vertically adjacent cells. Unlike the properties corresponding to the other print flags, vertical conductance is not an intrinsic material property. Its value depends in part on the horizontal and vertical dimensions of the two cells that contribute to each value in the array.

Example Command File and Command Line Execution

An example command file for HUFPrint is shown in figure 6. An example of invoking HUFPrint at an MS–DOS command prompt is shown in figure 7. Roffey (2005) provides a good introduction to the use of the MS–DOS command prompt under the Windows operating system.

Example HUFPrint output

An example MODFLOW data set was prepared to demonstrate the use of HUFPrint. In the example data set, the model domain was discretized into 39 rows, 58 columns, and 3 model layers. Five HGUs were defined; from top to bottom the units were named HGU1 through HGU5. An arbitrarily variable surface ranging from about 632 to about 1,021 ft was defined for use as the top of HGU1 and of model layer 1. The bottom of model layer 1 was defined to give layer 1 a uniform thickness of 600 ft, and model layers 2 and 3 were given uniform bottom elevations of –100 ft and –1,000 ft, respectively. The top of unit HGU2 was assigned to another arbitrarily variable surface, ranging from about 165 to about 715 ft. The top of unit HGU3 was defined to give unit HGU2 a uniform thickness of 200 ft. The tops of units HGU4 and HGU5 and were defined to give each of the units HGU3 and HGU4 a uniform thickness of 300 ft. The thickness of unit HGU 5 was defined such that the bottom of unit HGU5 conformed to the bottom of model layer 3 at –1,000 ft.

The screen output that would result from running HUFPrint command file "test_commands.txt" (fig. 6) with the example model is shown in figure 8. Ten files would be generated (fig. 9).

```
# Hufprint example command file test_commands.txt
OUTFILE Print/test
PRINT_HGU HGU3 16 HK
PRINT_HGU HGU4 4 ALL
PRINT_LAY 1 16 HK
PRINT_VSECTION 20 29
PRINT_XSECTION 11 1 29 57 20 10.0
```

Figure 6. Example command file for HUFPrint. An introductory "#" sign designates a comment in the first line; subsequent lines are HUFPrint commands explained in the text.

```
C:>hufprint test.nam test_commands.txt
```

Figure 7. Command-line execution of HUFPrint at the MS–DOS command prompt.

```
HUFPrint ver. 1.0.0 7/28/2008

 Using NAME file: test.nam
 Using COMMAND file: test_commands.txt
   1 file of hydraulic data for hydrogeologic units created
   5 files of hydraulic data for hydrogeologic units created
   1 file of hydraulic data for model layers created
   1 vertical section in postscript format created
   1 file of hydraulic data for vertical section created
   1 cross section in postscript format created

 HUFPrint output written to file: hufprint-list.txt
 Normal termination of HUFPrint
```

Figure 8. Screen output of HUFPrint for the example described in the text.

```
TEST_HGU3_HK.dat
TEST_HGU4_HANI.dat
TEST_HGU4_HK.dat
TEST_HGU4_HKCC.dat
TEST_HGU4_KDEP.dat
TEST_HGU4_VANI.dat
TEST_L001_HK.dat
TEST_VSEC_020_029.ps
TEST_VSEC_020_029.dat
TEST_XSEC_011_001_029_057.ps
```

Figure 9. Files generated by the HUFPrint example described in the text.

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