

Appendix 1: Data Input Instructions for the Unsaturated-Zone Flow (UZF1) Package

MODFLOW Name File

Percolation of water through an unsaturated zone is activated by including a record in the MODFLOW name file using the file type (Ftype) “UZF” to indicate that relevant calculations are to be made in the model and to specify the related input data file. The UZF1 Package is compatible with MODFLOW-2005 (Harbaugh, 2005), but not with earlier versions of MODFLOW. The user can optionally specify unsaturated-zone water budgets and water content profiles for selected model cells by including a record in the MODFLOW name file using the file type (Ftype) “DATA” that specifies the relevant output data file name for each model cell. The row and column cell indices for each selected model cell are included in the UZF output file. Three types of information may be printed to the specified file for each model cell depending on the OUTTYPE option specified. The three OUTTYPE options are: option 1 prints volumes of water entering, leaving, and stored in the unsaturated zone; option 2 prints volumes and rates for water entering, leaving, and stored within the unsaturated zone; and option 3 prints the water content profile between land surface and the water table. Additionally, a time series of infiltration, unsaturated zone evapotranspiration, recharge, and ground-water discharge summed over the model domain may be printed to a specified file.

Unsaturated-Zone Flow Package Input Data

The UZF1 Package input file consists of items numbered from 0 through 16, each consisting of one or more records. These data are used to specify information about the hydraulic properties of the unsaturated zone, the infiltration rate, evapotranspiration, and certain output control options. All input variables are read using free format unless indicated otherwise. In free format, variables are separated by one or more spaces or by a comma and optionally one or more spaces. A blank field cannot be used to set a variable value to zero. Units of length (L) and time (T) are used to define the dimensions of each variable.

The UZF1 Package relies on the specific yield values as specified in the Layer-Property Flow (LPF) Package or the Block-Centered Flow (BCF) Package. Thus, the option for unsaturated flow is only available when either the LPF or BCF Package is used in the simulation. When the option to use vertical hydraulic conductivity in the LPF Package is specified, the layer(s) that contain cells where unsaturated flow will be simulated must be specified as convertible. That is, the variable LAYTYP specified in the LPF Package must not be equal to zero, otherwise the model will print an error and stop execution. The variable VKA in LPF may be specified as the ratio of horizontal to vertical hydraulic conductivity (LAYVKA is not zero) or as the vertical hydraulic conductivity (LAYVKA=0). When using the BCF Package, the right digit of LTYPE (LAYCON) must be greater or equal to one or the model will print an error and stop execution. Neither parameter estimation nor solute transport can be simulated with the UZF1 Package.

For Each Simulation

0. Data: [#Text]

Text A character variable (up to 199 characters) that is printed when the file is read. The “#” character must be in column 1, and, accordingly, the variable starts in column 2. Any characters can be included in Text.

Note 1: Item 0 can be repeated multiple times.

1. Data: NUZTOP IUZFOPT IRUNFLG IETFLG IUZFCB1 IUZFCB2 NTRAIL2 NSETS2 NUZGAG SURFDEP

NUZTOP An integer value used to define which cell in a vertical column that recharge and discharge is simulated.

- 1 Recharge to and discharge from only the top model layer. This option assumes land surface is defined as top of layer 1.
- 2 Recharge to and discharge from the specified layer in variable IUZFBND. This option assumes land surface is defined as top of layer specified in IUZFBND.
- 3 Recharge to and discharge from the highest active cell in each vertical column. Land surface is determined as top of layer specified in IUZFBND. A constant head node intercepts any recharge and prevents deeper percolation.

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IUZFOPT	An integer value equal to 0, 1, or 2. A value of zero indicates that flow will not be routed through the unsaturated zone, rather infiltration will be applied directly to the saturated zone. A value of 1 indicates that the vertical hydraulic conductivity will be specified within the UZF1 Package input file using array VKS. A value of 2 indicates that the vertical hydraulic conductivity will be specified within either the BCF or LPF Package input file.
IRUNFLG	An integer value that specifies whether ground water that discharges to land surface will be routed to stream segments or lakes as specified in the IRUNBND array (IRUNFLG not equal to zero) or if ground-water discharge is removed from the model simulation and accounted for in the ground-water budget as a loss of water (IRUNFLG=0). The Streamflow-Routing (SFR2) and(or) the Lake (LAK3) Packages must be active if IRUNFLG is not zero.
IETFLG	An integer value that specifies whether or not evapotranspiration (ET) will be simulated. ET will not be simulated if IETFLG is zero, otherwise it will be simulated.
IUZFCB1	An integer value used as a flag for writing ground-water recharge, ET, and ground-water discharge to land surface rates to a separate unformatted file using subroutine UBUDSV. If IUZFCB1>0, it is the unit number to which the cell-by-cell rates will be written when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control. If IUZFCB1 ≤ 0, cell-by-cell rates will not be written to a file.
IUZFCB2	An integer value used as a flag for writing ground-water recharge, ET, and ground-water discharge to land surface rates to a separate unformatted file using module UBDSV3. If IUZFCB2>0, it is the unit number to which cell-by-cell rates will be written when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control. If IUZFCB2≤0, cell-by-cell rates will not be written to file.
NTRAIL2	An integer value equal to the number of trailing waves used to define the water-content profile following a decrease in the infiltration rate. The number of trailing waves varies depending on the problem, but a range between 10 and 20 is usually adequate. More trailing waves may decrease mass-balance error and will increase computational requirements and memory usage. This variable is not specified if IUZFOPT is zero or less.
NSETS2	An integer value equal to the number of wave sets used to simulate multiple infiltration periods. The number of wave sets should be set to 20 for most problems involving time varying infiltration. The total number of waves allowed within an unsaturated zone cell is equal to NTRAIL2*NSETS2. An error will occur if the number of waves in a cell exceeds this value. This variable is not specified if IUZFOPT is zero or less.
NUZGAG	An integer value equal to the number of cells (one per vertical column) that will be specified for printing detailed information on the unsaturated zone water budget and water content. A gage also may be used to print the budget summed over all model cells.
SURFDEP	A real value equal to the average undulation depth within a finite-difference cell.

Note 2: The variables NTRAIL2 and NSETS2 are used for dimensioning arrays.

2. Data: [IUZFBND (NCOL, NROW)] -- U2DINT

IUZFBND An array of integer values used to define the aerial extent of the active model in which recharge and discharge will be simulated.

If IRUNFLG > 0: Read item 3

3. Data: [IRUNBND (NCOL, NROW)] -- U2DINT

IRUNBND An array of integer values used to define the stream segments within the Streamflow-Routing (SFR2) Package or lake numbers in the Lake (LAK3) Package that overland runoff from excess infiltration and ground-water discharge to land surface will be added. A positive integer value identifies the stream segment and a negative integer value identifies the lake number.

IF IUZOPT = 1: Read item 4.**4. Data:** [VKS (NCOL, NROW)] -- U2DREL

VKS An array of positive real values used to define the saturated vertical hydraulic conductivity of the unsaturated zone (LT^{-1}).

Note 3: Vertical hydraulic conductivity is optional when either the LPF or BCF Package is used to define vertical hydraulic conductivity of cells (IUZFOPT=2).

5. Data: [EPS (NCOL, NROW)] -- U2DREL

EPS An array of positive real values for each model cell used to define the Brooks-Corey epsilon of the unsaturated zone. Epsilon is used in the relation of water content to hydraulic conductivity (Brooks and Corey, 1966). This variable is not specified if IUZFOPT is zero or less.

6. Data: [THTS (NCOL, NROW)] -- U2DREL

THTS An array of positive real values used to define the saturated water content of the unsaturated zone in units of volume of water to total volume (L^3L^{-3}). This variable is not specified if IUZFOPT is zero or less.

7. Data: [THTI (NCOL, NROW)] -- U2DREL

THTI An array of positive real values used to define the initial water content for each vertical column of cells in units of volume of water at start of simulation to total volume (L^3L^{-3}). THTI should not be specified for steady-state simulations. This variable is not specified if IUZFOPT is zero or less.

If NUZGAG>0: Item 8 is repeated NUZGAG times**8. Data:** {IUZROW} {IUZCOL} IFTUNIT {IUZOPT}

IUZROW An integer value equal to the row number of the cell that unsaturated-zone information will be printed for each time step. The variable is not used when IFTUNIT is negative.

IUZCOL An integer value equal to the column number of the cell that unsaturated-zone information will be printed for each time step. The variable is not used when IFTUNIT is negative.

IFTUNIT An integer value equal to the unit number of the output file. A positive value is for output of individual cells whereas a negative value is for output that is summed over all model cells. The summed output includes applied infiltration, runoff, actual infiltration, ground-water discharge to land surface, ET from the unsaturated zone, ET from ground water, recharge, and change in unsaturated-zone storage.

IUZOPT An integer value that is a flag for the type of expanded listing desired in the output file. The variable is not used when IFTUNIT is negative.

- 1 Prints time, ground-water head, and thickness of unsaturated zone, and cumulative volumes of infiltration, recharge, storage, change in storage and ground-water discharge to land surface.
- 2 Same as option 1 except rates of infiltration, recharge, change in storage, and ground-water discharge also are printed.
- 3 Prints time, ground-water head, thickness of unsaturated zone, followed by a series of depths and water contents in the unsaturated zone. This option cannot be used when IUZFOPT is zero or less.

Note 4: Item 8 must include exactly NUZGAG lines (records) of data. If NUZGAG > 1, it is permissible to repeat the same cell if a summary of volumes and rates and water contents are desired for a given cell. The records within item 8 can be listed in any order.

Note 5: A unique unit number for IFTUNIT must be specified for each line or record in item 8 and each number must match that used in the MODFLOW name file as Ftype "DATA" file types and file names (see Harbaugh, 2005).

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For Each Stress Period

9. Data: NUZF1

NUZF1 An integer value for reusing or reading infiltration rates that can change each stress period. If $NUZF1 \geq 0$, then infiltration rates at land surface are specified. If $NUZF1 < 0$, then infiltration rates from the previous stress period are used.

If $NUZF1 > 0$:

10. Data: [FINF (NCOL, NROW)] - U2DREL

FINF An array of positive real values used to define the infiltration rates (L^1) at land surface for each vertical column of cells.

Note 6: If FINF is specified as being greater than the vertical hydraulic conductivity then FINF is set equal to the vertical unsaturated hydraulic conductivity. Excess water is routed to streams or lakes when IRUNFLG is not zero, and if SFR2 or LAK3 is active.

If $IETFLG > 0$: Read Items 11 through 16

11. Data: NUZF2

NUZF2 An integer value for reusing or reading ET demand rates that can change each stress period. If $NUZF2 \geq 0$, then ET demand rates are specified. If $NUZF2 < 0$, then ET demand rates from the previous stress period are used.

If $NUZF2 > 0$:

12. Data: [PET (NCOL, NROW)] - U2DREL

PET An array of positive real values used to define the ET demand rates (L^1T^1) within the ET extinction depth interval for each vertical column of cells.

13. Data: NUZF3

NUZF3 An integer value for reusing or reading ET extinction depths that can change each stress period. If $NUZF3 \geq 0$, then ET extinction depths are specified. If $NUZF3 < 0$, then depths from the previous stress period are used.

If $NUZF3 > 0$:

14. Data: [EXTDP (NCOL, NROW)] - U2DREL

EXTDP An array of positive real values used to define the ET extinction depths.

Note 7: The quantity of ET removed from a cell is limited by the volume of water stored in the unsaturated zone above the extinction depth. If ground water is within the ET extinction depth, then the rate removed is based on a linear decrease in the maximum rate at land surface and zero at the ET extinction depth. The linear decrease is the same method used in the Evapotranspiration Package (McDonald and Harbaugh, 1988, chap. 10).

15. Data: NUZF4

NUZF4 An integer value for reusing or reading the extinction water content that can change each stress period. If $NUZF4 \geq 0$, then extinction water contents are specified. If $NUZF4 < 0$, then the extinction water contents from the previous stress period are used.

If $NUZF4 > 0$:

16. Data: [EXTWC (NCOL, NROW)] - U2DREL

EXTWC An array of positive real values used to define the extinction water content below which ET cannot be removed from the unsaturated zone. This variable is not specified if IUZFOPT is zero or less.

Note 8: EXTWC must have a value between $(THTS - S_y)$ and THTS, where S_y is the specific yield specified in either the LPF or BCF Package.