Changes to the UZF1 package for release version 1.7 (September 2009)

A bug was fixed that affected the value of the UZF input variable VKS. The error occurred if the vertical hydraulic conductivity for UZF was specified in the LPF input file by setting the UZF input variable IUZFOPT=2. The UZF variable VKS was calculated incorrectly if the LPF input variable LAYVKA was not set to 0, such that the LPF input variable VKA is the ratio of horizontal to vertical hydraulic conductivity. For all other cases, VKS was calculated correctly.

Another bug was fixed that affected simulation of unsaturated flow in dry lake cells. If UZF and LAK Packages are used in the same simulation, UZF calculates recharge and discharge for dry lake cells. A bug in UZF was not allowing recharge and discharge to be simulated for dry lake cells.

Another bug was fixed that, in some cases, caused water content profiles to be printed incorrectly. This bug did not affect simulation results; rather, it only affected how numbers were printed to separate formatted output files of water-content profiles using the output option variable NUZGAG.

Finally, the options were changed again for printing unsaturated flow budget terms using the MODFLOW utility programs UBUDSV and UBDSV3 (Harbaugh, 2005). If IUZFCB1 or IUZFCB2 are specified as negative values, then infiltration and unsaturated zone ET are printed to unformatted files using UBUDSV or UBDSV3, respectively. If these variables are specified as positive values, then only groundwater budget items calculated by UZF are printed, including recharge, groundwater discharge to land surface, and groundwater ET, and excludes infiltration and unsaturated zone ET.

Changes to the UZF1 package for MODFLOW-2005 version 1.5

A change was made to the UZF Package (Niswonger and others, 2006) to make sure the input variable VKS is non-zero for active cells. If VKS was specified as zero for active cells in the previous version of UZF, the model would stop without a warning or error message. The new release of UZF will print an error message in the main listing file before stopping if zero values are specified for VKS.

Changes were made to UZF to allow simulations that include both the UZF Package and the HUF Package (Anderman and Hill, 2000). UZF presently requires that the unsaturated hydraulic properties be constant for a vertical column of cells between land surface and the water table. However, the HUF Package allows for vertical hydraulic conductivity and specific yield to vary in the vertical direction within a single MODFLOW cell and in time when the water table fluctuates through HUF units. At the beginning of a simulation, UZF will calculate the average of the specific yield values specified for a finite-difference cell within the HUF Package input file for calculating residual water content (UZF variable THTR) and the value of THTR will stay constant during a simulation. Similarly, UZF will calculate the average of the vertical hydraulic conductivity values specified for a finite-difference cell within the HUF Package input file for calculating the unsaturated hydraulic conductivity (UZF variable `VKS`).

An option was added to UZF for applying infiltration directly to the water table. This option might be useful for simulating ground-water discharge to land surface while not routing flow through the unsaturated zone. Water is not routed through the unsaturated zone when the variable `IUZFOPT` is set less than or equal to zero. For this case, unsaturated hydraulic properties should not be specified; however, the variable `VKS` is still required. Additionally, if simulating ET (`IETFLG`>0) without routing unsaturated flow (`IUZFOPT=0`) then the variable `EXTWC` should not be specified; however, the variables `PET` and `EXTDP` are still required when simulating ET (`IETFLG` >0).

The options have been changed for printing unformatted unsaturated-zone infiltration, ground-water recharge, ground-water discharge and ET using the MODFLOW utility programs UBUDSV and UBDSV3 (Harbaugh, 2005). The variable `IUZFCB1` that is used for writing output from UBUDSV now has three options. For `IUZFCB1`<0, budget information is printed; however, only ET from saturated ground water is printed. This option could be used when not routing flow through the unsaturated zone. For `IUZFCB1=0`, unformatted budget information will not be printed. For `IUZFOPT>0`, unformatted budget information is printed, including ET from both the unsaturated and saturated zones. The same three optional values can be specified for `IUZFCB2`, which will result in the same printed information except data will be printed from UBDSV3.

The average height of undulations, D (Figure 1), in the land surface altitude must now be specified within the UZF input file (UZF program variable `SURFDEP`) as the last variable in the first line of the UZF input file. A complete listing of the modified input instructions for the UZF1 Package is presented on pages 213-217 in Markstrom and others (2008). The lists of required and optional variables (in brackets) for the first line in the UZF input file are shown below:

```
NUZTOP IUZFOPT IRUNFLG IETFLG IUZFCB1 IUZFCB2 [NTRAIL2]
[NSETS2] NUZGAG SURFDEP
```

The variables `NTRAIL2` and `NSETS2` only are read when `IUZFOPT` is greater than zero.

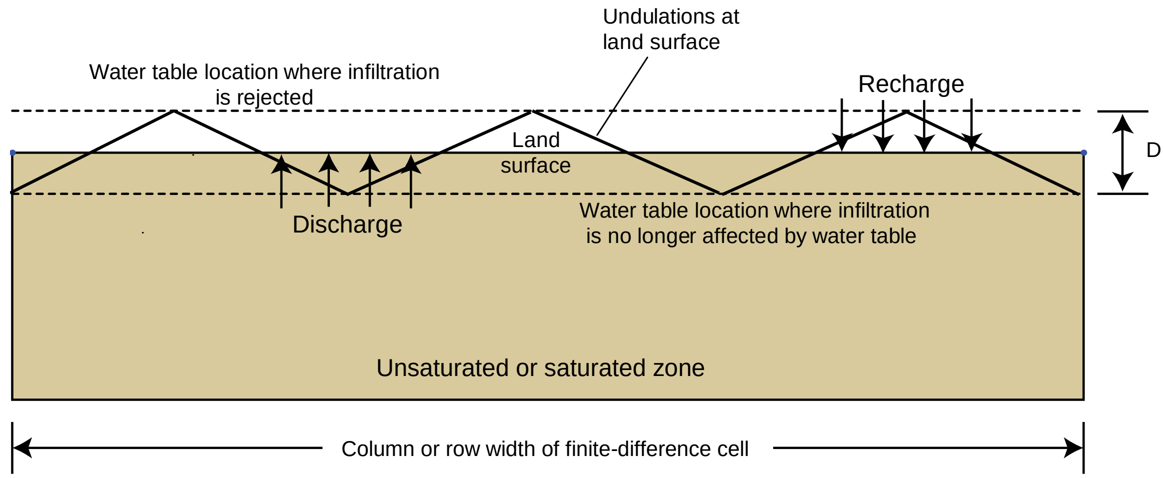

Figure 1. The effect of undulation depth, D, at land surface on ground-water recharge and discharge in relation to the water table in a finite-difference cell.

Changes to the UZF package for release version 1.3; 6-20-07

The calculation was changed for simulating head-dependent recharge and discharge when the ground-water head is near or above land surface. The approach conceptualizes land surface as an undulating surface that represents variations in land surface altitude within the area of a single MODFLOW cell. The average height of undulations, D, in the land surface altitude is set to 1.0 internally within UZF to avoid changing the UZF input requirements; however, D (UZF program variable `SURFDEP`) can be changed within the UZF source code file gwf2uzf1.f. If the source file gwf2uzf1.f is changed then the program must be recompiled. This approach for simulating recharge and discharge reduces the iterations required for convergence and allows a smooth transition between a recharging and discharging condition.

Ground-water recharge

The specified infiltration (i.e. UZF input file variable `FINF`; Niswonger and others, 2006, p. 32) is applied to the saturated zone instead of the unsaturated zone if the ground-water head is above land surface (i.e. Discretization file input variable `TOP`; Harbaugh, p. 8-11) minus one-half the undulation depth, D (fig. 1). The units of the undulation depth are the same as those specified by variable `LENUNI` in the Discretization File. Recharge to the saturated zone decreases as a function of ground-water head, often called rejected recharge, and is calculated according to:

$$
\begin{aligned}
q &= 0 && h^{n-1} > TOP + 0.5D \\
q &= \frac{FINF}{D}\left[h^{n} - (TOP - 0.5D)\right] && TOP - 0.5D \le h^{n-1} \le TOP + 0.5D \\
q &= FINF && TOP - 0.5D > h^{n-1}
\end{aligned}
$$

where

q is the recharge, in length per time;

$FINF$ is the infiltration rate applied to the finite-difference cell, in length per time;

h^n is the ground-water head for time step m and iteration n, in length;

h^{n-1} is the ground-water head for time step m and iteration $n-1$, in length;

D is the undulation depth along land surface within the finite-difference cell, in length; and

TOP is the altitude of land surface, in length.

Ground-water discharge

Ground-water discharge to land surface is computed as:

$$Q = CND\left(h^n - (TOP - 0.5D)\right)$$

$$CND = \frac{K_v A_{fdc}}{0.5 celthk D}\left(h^{n-1} - TOP + 0.5D\right) \qquad TOP - 0.5D < h^{n-1}$$

$$CND = 0 \qquad TOP - 0.5D \geq h^{n-1}$$

where

CND is the conductance across land surface, in length squared per time;

K_v is the vertical hydraulic conductivity of the unsaturated zone, in length per time;

$celthk$ is the thickness of the model cell, in length;

Q is the volumetric-flow rate of water that discharges from ground water to land surface, in length cubed per time.

References

Anderman, E.R., and Hill, M.C., 2000, MODFLOW-2000, the U.S. Geological Survey modular ground-water model—Documentation of the Hydrogeologic-Unit Flow (HUF) Package: U.S. Geological Survey Open-File Report 2000-342, 89 p.

Markstrom, S.L., Niswonger, R.G., Regan, R.S., Prudic, D.E., and Barlow, P.M., 2008, GSFLOW—Coupled ground-water and surface-water flow model based on the integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005): U.S. Geological Survey Techniques and Methods 6-D1, 240 p.

Niswonger, R.G., Prudic, D.E., and Regan, R.S., 2006, Documentation of the Unsaturated-Zone Flow (UZF1) Package for modeling unsaturated flow between the land surface and the water table with MODFLOW-2005: U.S. Geological Survey Techniques and Methods Book 6, Chapter A19, 62 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 paginated.