# A new damping capability in the GMG solver

With version 1.17.00 of MODFLOW-2000, a new adaptive damping capability has been added to the Geometric Multigrid (GMG) solver (Wilson and Naff, 2004). The new capability is described in Banta (2006). A new option for reporting maximum head change also is included in the current version of GMG. Input instructions and other information needed to use the new capability are in the following sections.

## *Revisions to input instructions for the GMG Package*

The meaning of the IADAMP variable has been changed to support the new damping option. The new meaning of IADAMP is:

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IADAMP is a flag that controls adaptive damping. The possible values of
     IADAMP and their meanings are as follows:

  If IADAMP = 0, the value assigned to DAMP is used as a constant
     damping parameter.

  If IADAMP = 1, the value of DAMP is used for the first nonlinear
     iteration. The damping parameter is adaptively varied on the basis
     of the head change, using Cooley's method as described in Mehl and
     Hill (2001), for subsequent iterations.

  If IADAMP = 2, the relative reduced residual damping method
     documented in Mehl and Hill (2001) and modified by Banta (2006) is
     used.
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A new integer variable, IUNITMHC, may be entered following DAMP, IADAMP, and IOUTAMG on the second line of input in the GMG file. The meaning of IUNITMHC is:

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IUNITMHC is a flag and a unit number, which controls output of maximum
     head change values:

  If IUNITMHC = 0, maximum head change values are not written to an
     output file.

  If IUNITMHC > 0, maximum head change values are written to unit
     IUNITMHC.  Unit IUNITMHC should be listed in the Name file with
     "DATA" as the file type.

  If IUNITMHC < 0 or is not present, IUNITMHC defaults to 0.
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When IADAMP is specified as 2, three additional floating-point values are read in free format following ISM and ISC on the third line of input in the GMG file. The values are assigned to variables DUP, DLOW, and CHGLIMIT, which are defined as follows:

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DUP is the maximum damping value that should be applied at any
     iteration when the solver is not oscillating; it is dimensionless.
     An appropriate value for DUP will be problem-dependent. For
     moderately nonlinear problems, reasonable values for DUP would be
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in the range 0.5 to 1.0. For a highly nonlinear problem, a reasonable value for DUP could be as small as 0.1. When the solver is oscillating, a damping value as large as 2.0*DUP may be applied.

DLOW is the minimum damping value to be generated by the adaptive-damping procedure; it is dimensionless. An appropriate value for DLOW will be problem-dependent and will be smaller than the value specified for DUP. For a highly nonlinear problem, an appropriate value for DLOW might be as small as 0.001. Note that the value specified for the next variable, CHGLIMIT, could result in application of a damping value smaller than DLOW.

CHGLIMIT is the maximum allowed head change at any cell between outer iterations; it has units of length. The effect of CHGLIMIT is to determine a damping value that, when applied to all elements of the head-change vector, will produce an absolute maximum head change equal to CHGLIMIT.

When IADAMP is specified as 2 and the value specified for DAMP is less than 0.5, the closure criterion for the inner iterations (DRCLOSE) is assigned simply as RCLOSE. When DAMP is between 0.5 and 1.0, inclusive, or when IADAMP is specified as 0 or 1, DRCLOSE is calculated according to equation 20 on p. 9 of Wilson and Naff (2004).

## *Output produced by the maximum head change option*

The maximum head change option (activated when variable IUNITMHC is greater than zero) reports maximum head change between successive solver (outer, or “Picard”) iterations during solution of the ground-water flow equation. The resulting file contains, for each time step, a tabulation of iteration number; maximum head change; layer, row, and column of the cell at which the maximum head change takes place; damping value; and the head at the cell of maximum head change at the previous and current iterations. The output file is a comma-delimited text file, which can be opened by most spreadsheet programs or viewed in a text editor.

The tabulated values of maximum head change can be plotted with iteration to illustrate solver behavior. The values of head at previous and current iterations can be useful in identifying model features that cause oscillation or other problems of solver nonconvergence.

## *References*

Banta, E.R., 2006, Modifications to MODFLOW boundary conditions and an adaptive-damping scheme for Picard iterations for a highly nonlinear regional model, *in* Poeter, Eileen, Hill, Mary, and Zheng, Chunmiao, MODFLOW and More 2006—Managing Ground Water Systems: International Ground Water Modeling Center and Colorado School of Mines, Golden, Colorado, 2006 [Proceedings], p. 596-600.

Mehl, S.W. and Hill, M.C., 2001, MODFLOW-2000, the U.S. Geological Survey modular ground-water model—User guide to the Link-AMG (LMG) Package for solving matrix equations using and algebraic multigrid solver: U.S. Geological Survey Open-File Report 01-177, 33 p.
Wilson, J.D. and Naff, R.L., 2004, MODFLOW-2000, the U.S. Geological Survey modular ground-water model—GMG Linear Equation Solver Package documentation: U.S. Geological Survey Open-File Report 2004–1261, 47 p.