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A Simplified and More Efficient Solution for Stream Depletion Analysis in MODFLOW

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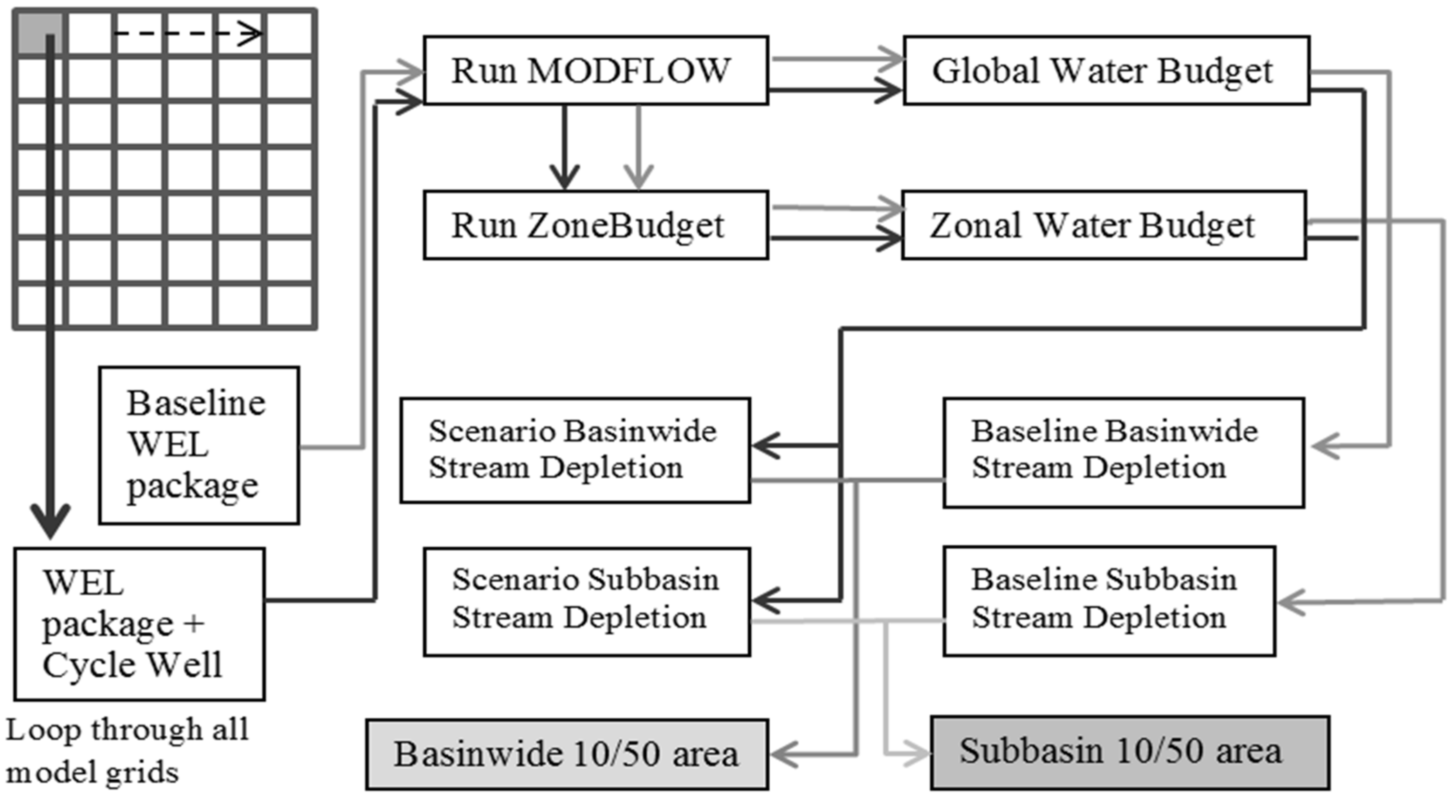
Application of a Groundwater Modeling Tool for Managing Hydrologically Connected Area

- The IWM division of NDNR focuses on the management of hydrologically connected groundwater and surface water supplies.
- Understanding the spatial boundaries of fully appropriated areas (i.e., 10-50 area) is one of the research priorities in the field of IWM in Nebraska.
- This delineation helps water managers in different management roles apply focused management strategies to these areas.

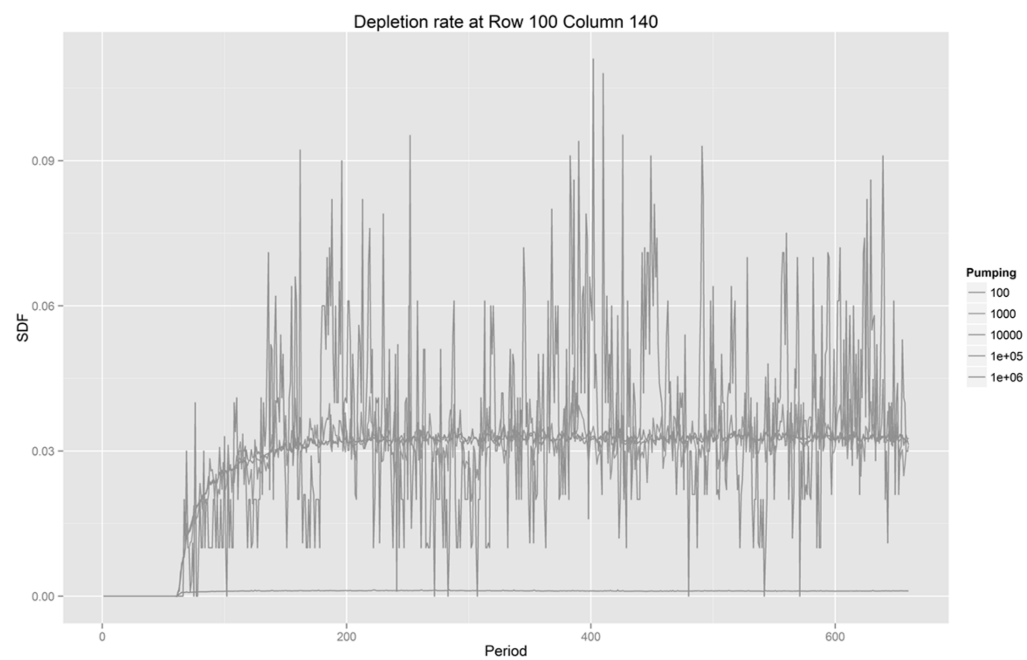
Conventional SDA in MODFLOW



- Build the baseline (calibrated) model
- Add new well and rerun the model
- Calculate the SDF term based on the simulation results
- Repeat the iteration at each grid cell for mapping SDF distribution

Issues With the Conventional Method

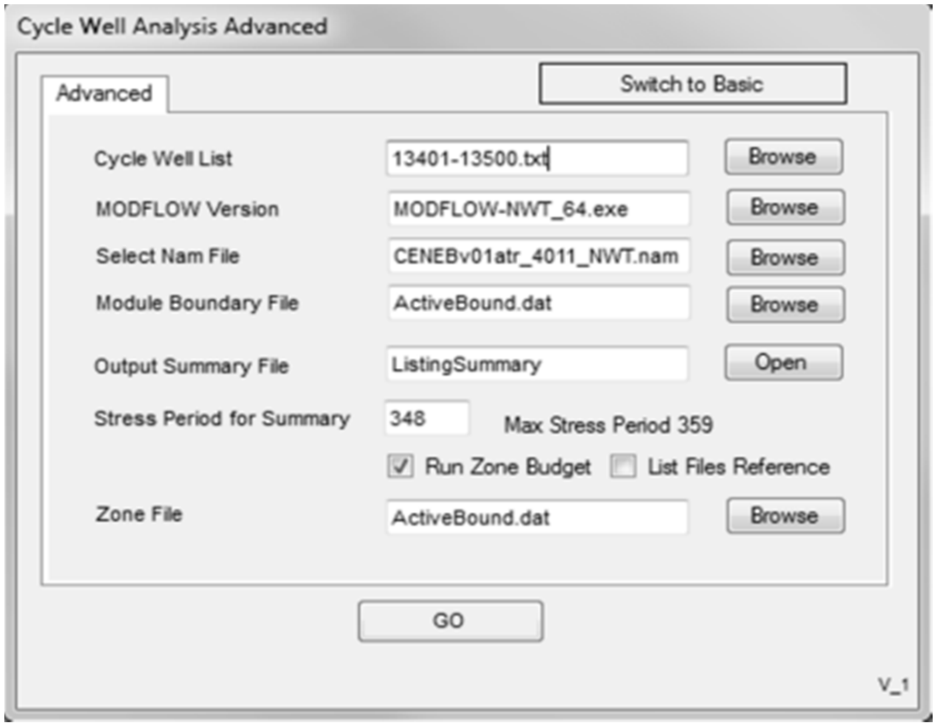
- Labor intensive to set up the analysis
  - Inputs and outputs
  - SDF calculation
- Prolonged running time
  - 200 rows * 200 columns * 1 layer * 5 minutes = 138 days
- Numerical errors
  - Changes vs. Errors



Efforts at NDNR to Improve the SDA Processes

- Cycle Well Analysis (CWA) GUI
  - Automation of input and output processing
- Cycle Well Analysis Spreadsheet (CWAS)
  - More flexible specification of model runs
  - Incorporate automatic pumping definition
- MODFLOW-SDA package (SDA)
  - Linearization of MODFLOW flow equation

Cycle Well Analysis Software GUI



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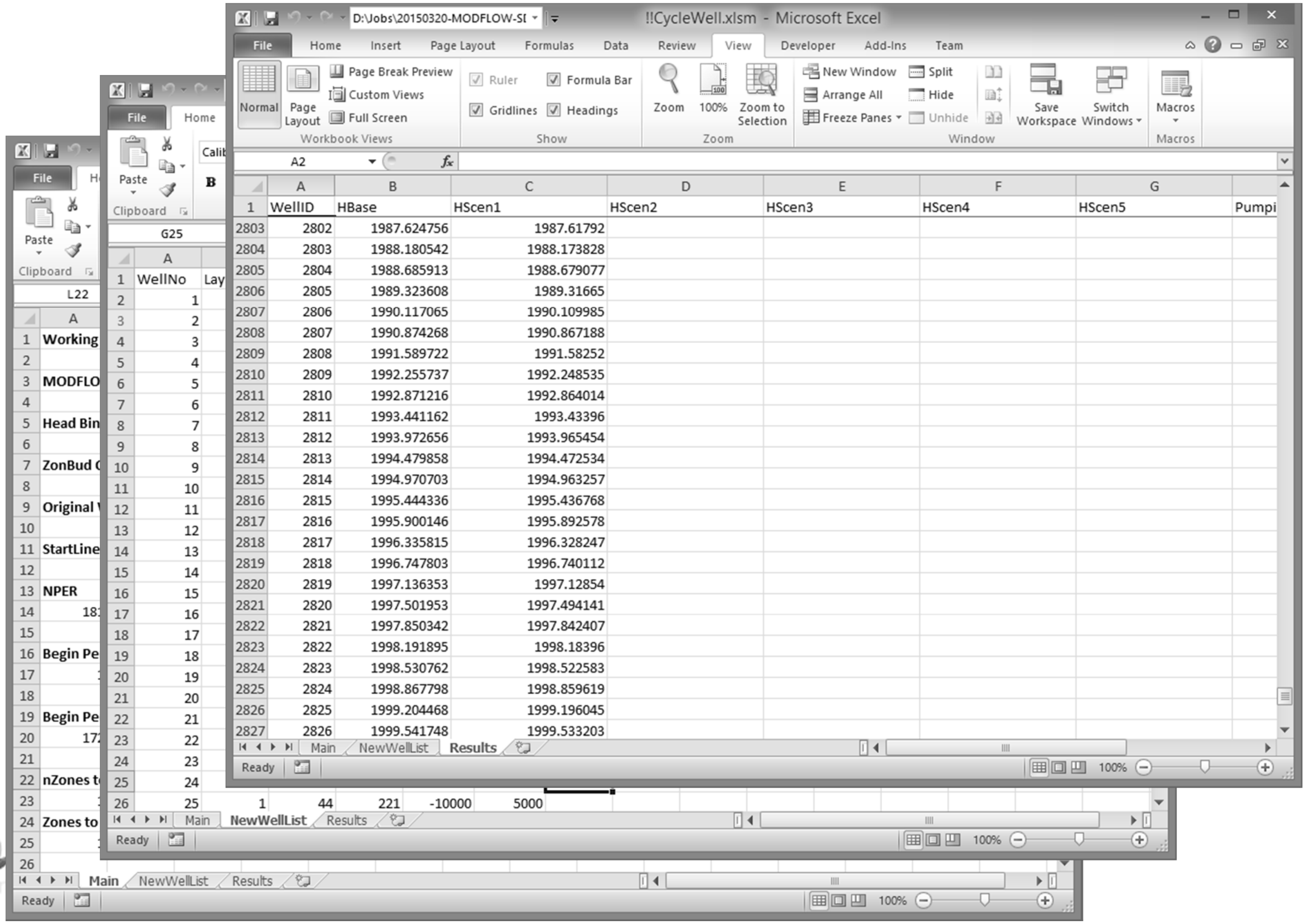
Cycle Well Analysis Spreadsheet



	WellID	HBase	HScen1	HScen2	HScen3	HScen4	HScen5	Pumpi
2803	2802	1987.624756	1987.61792					
2804	2803	1988.180542	1988.173828					
2805	2804	1988.685913	1988.679077					
2806	2805	1989.323608	1989.31665					
2807	2806	1990.117065	1990.109985					
2808	2807	1990.874268	1990.867188					
2809	2808	1991.589722	1991.58252					
2810	2809	1992.255737	1992.248535					
2811	2810	1992.871216	1992.864014					
2812	2811	1993.441162	1993.43396					
2813	2812	1993.972656	1993.965454					
2814	2813	1994.479858	1994.472534					
2815	2814	1994.970703	1994.963257					
2816	2815	1995.444336	1995.436768					
2817	2816	1995.900146	1995.892578					
2818	2817	1996.335815	1996.328247					
2819	2818	1996.747803	1996.740112					
2820	2819	1997.136353	1997.12854					
2821	2820	1997.501953	1997.494141					
2822	2821	1997.850342	1997.842407					
2823	2822	1998.191895	1998.18396					
2824	2823	1998.530762	1998.522583					
2825	2824	1998.867798	1998.859619					
2826	2825	1999.204468	1999.196045					
2827	2826	1999.541748	1999.533203					

Development of a stream depletion analysis (SDA) package for MODFLOW

- Linearization assumptions

Uns
from

Abstract

A solution is obtained for stream flo
streambed penetration of the aquifer and
streambed is clogged and that a linear r
piezometric head across the semipervio
Glover and Balmer, and Hantush. A solu
that this solution might be matched with

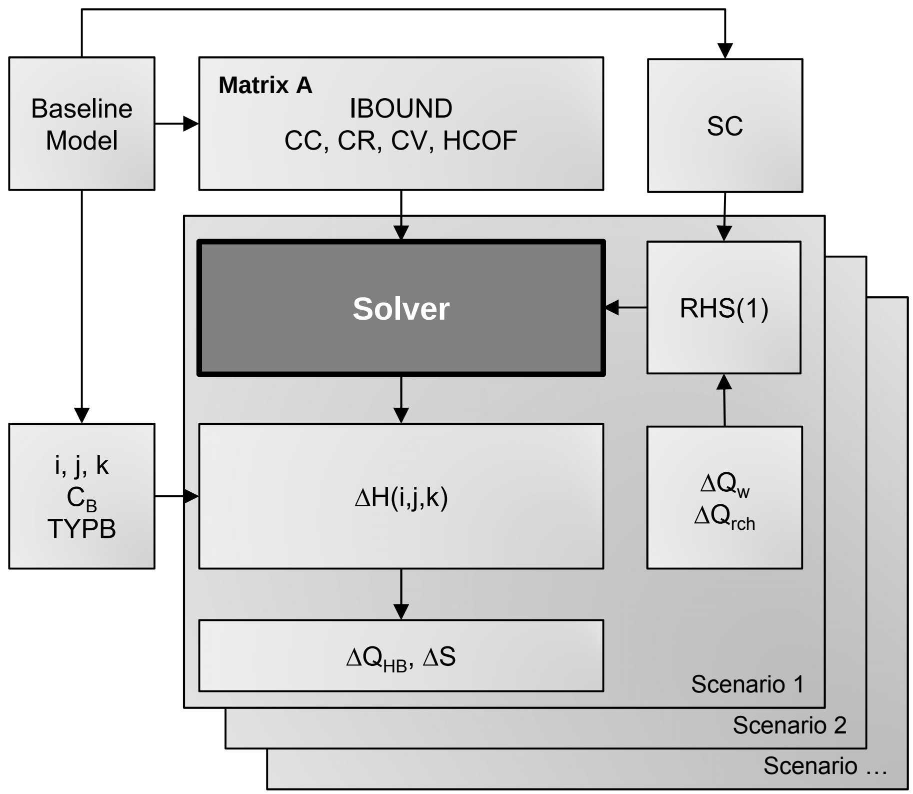
A solution will be obtained herein that considers the effects of streambed clogging and partial stream penetration. A definition sketch for this problem is shown in Figure 3. The calculation of this solution will assume that

- The ratio of vertical to horizontal velocity components is small (the Dupuit approximation)
- The aquifer is of infinite extent and is homogeneous and isotropic in all horizontal directions
- Drawdowns are small enough compared with saturated aquifer thicknesses to allow the governing equations to be linearized
- The streambed cross section has horizontal and vertical dimensions that are small compared to the saturated aquifer thickness, and the stream extends from $y = -\infty$ to $y = \infty$ along $x = 0$
- The well flow rate, Q_w, is constant for $0 < t < \infty$
- Changes in water surface elevation in the river created by pumping are small compared with changes created in the water table elevation on the aquifer side of the semipervious layer
- Seepage flow rates from the river into the aquifer are linearly proportional to the change in piezometric head across the semipervious layer.

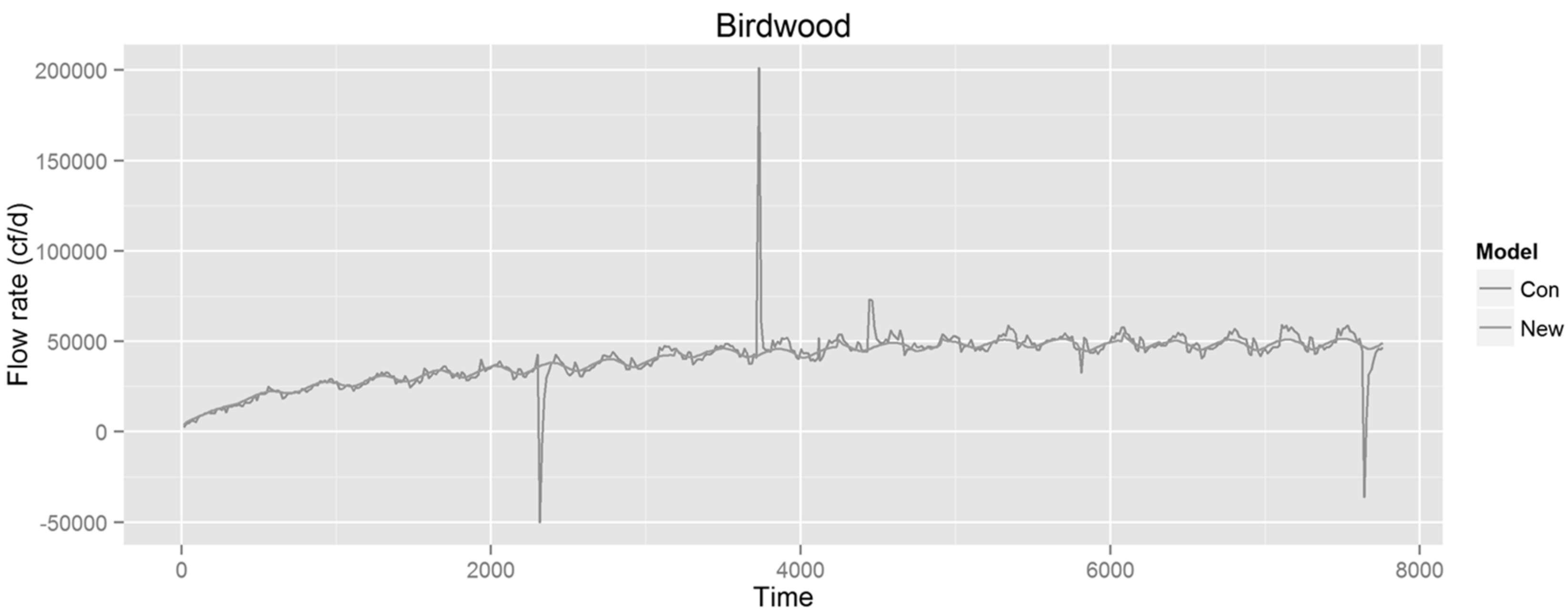
Theory of MODFLOW-SDA

- For baseline model
  - $AH = F$
- For scenario model
  - $A'H' = F'$
- Assuming $A' \approx A$
- Thus
  - $A(H' - H) = (F' - F)$
  - $A\Delta H = \Delta F$

Flowchart of MODFLOW-SDA



Results – COHYST model



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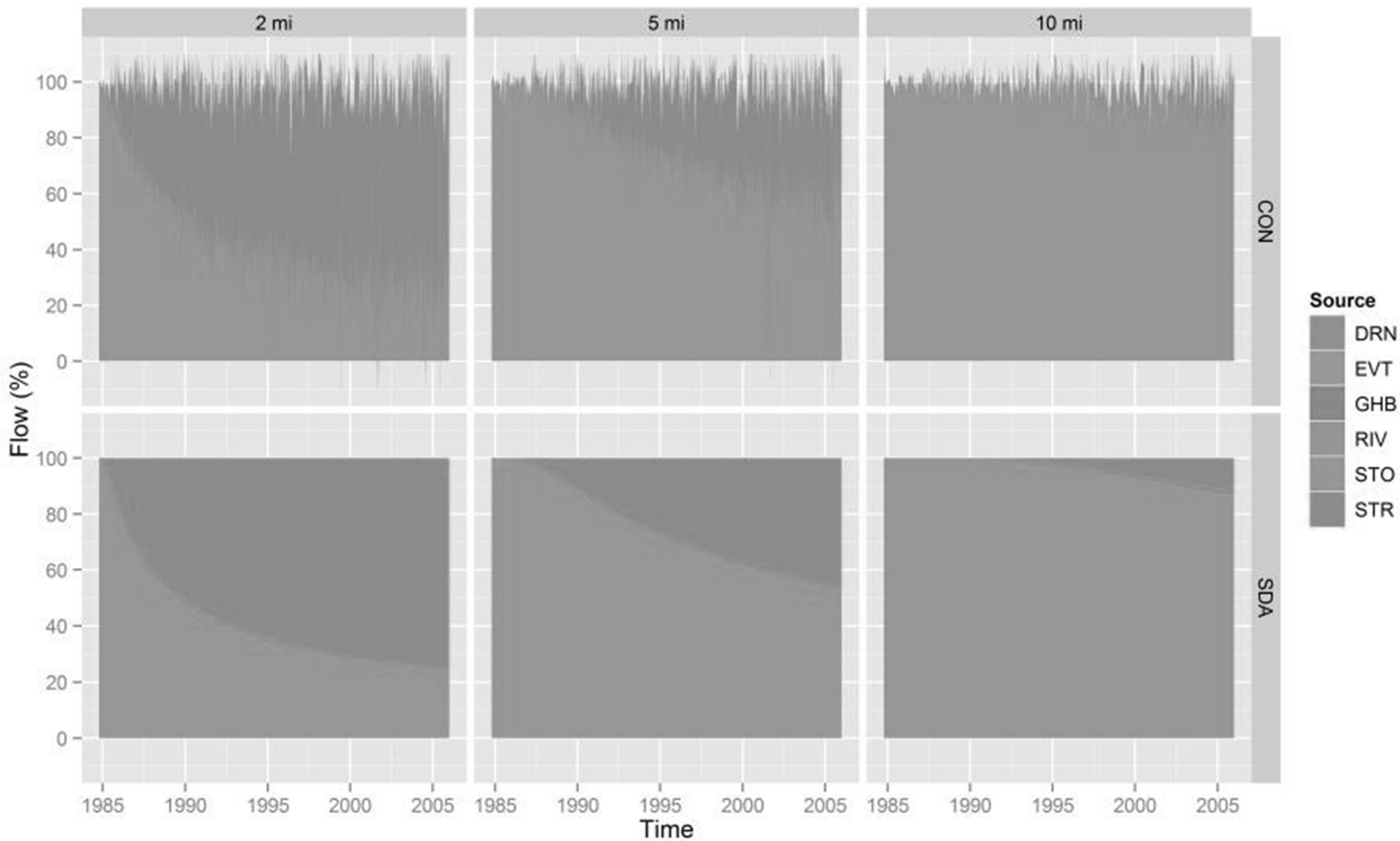
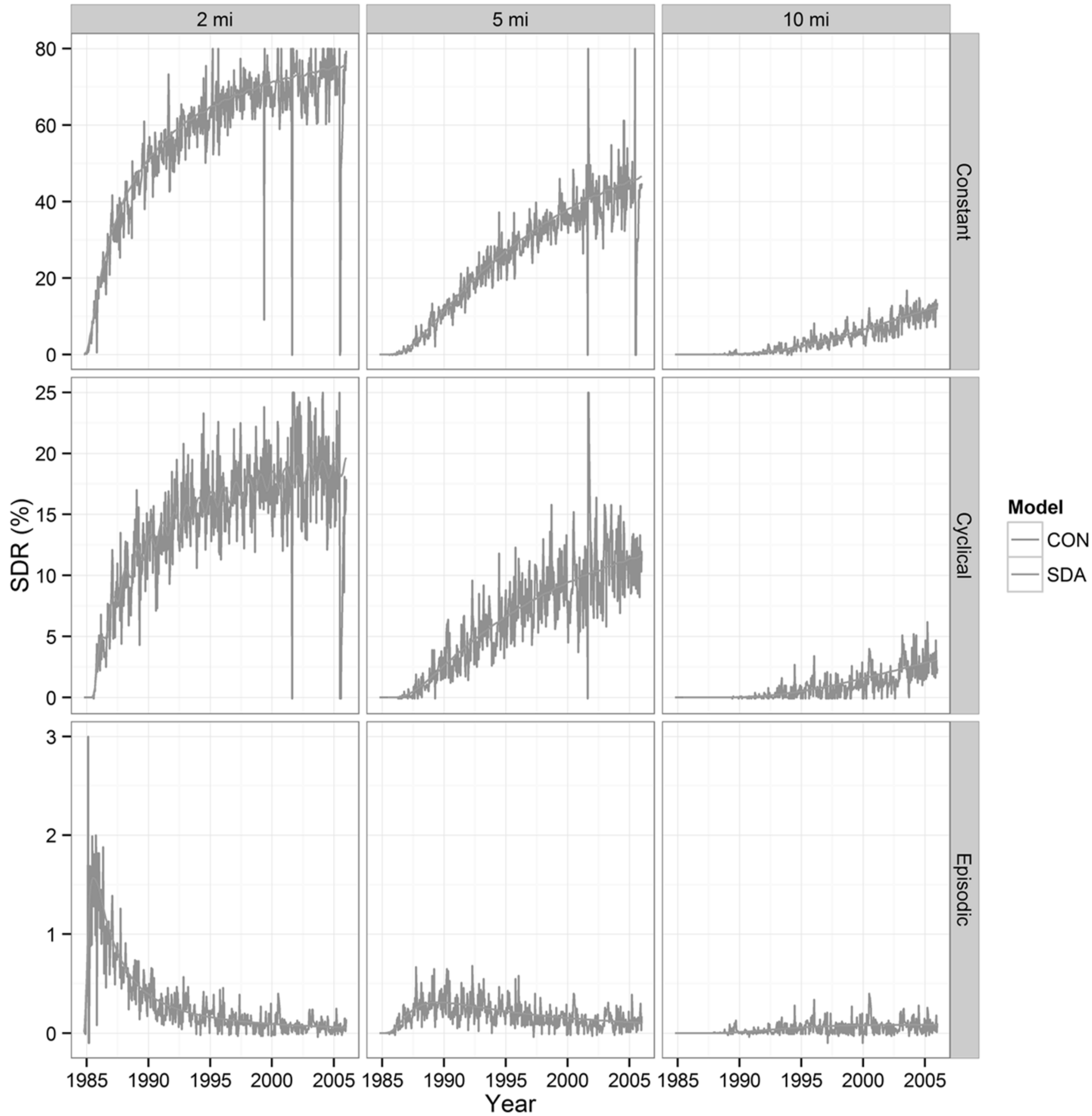
Constant pumping at different distance



Changing pumping pattern at different distance



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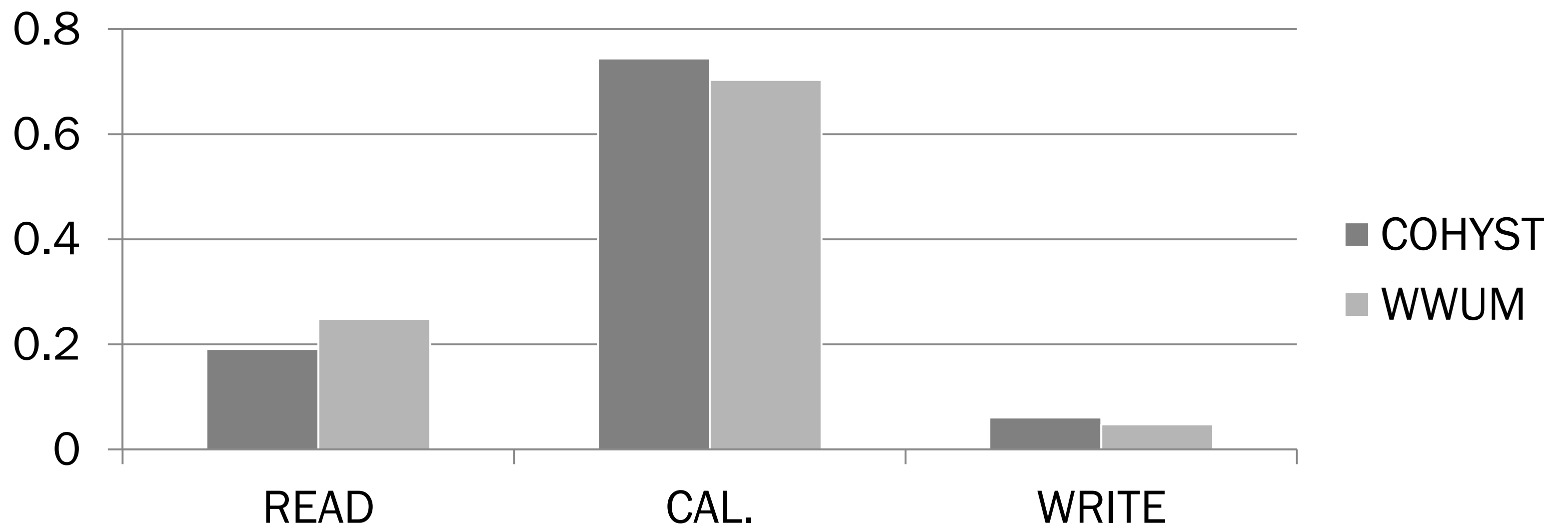
Running time

- Speedup: 20 times faster
  - MODFLOW: 6 minutes
  - MODFLOW-SDA: 20 seconds
- CPU time distribution



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Future development of SDA

- Support other MODFLOW versions
  - OHWM – NWT, FMP, UZF, MNW
- Parallelism
  - JUPITER API
- Integration with GWM

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Software availability

- Software available upon request
- Future updates:
  - michael.ou@nebraska.gov

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