IOWA STATE UNIVERSITY

Using a Physically Based, Coupled Surface Water/Groundwater Model to Assess the Hydrologic Impacts of Tile Drainage In Iowa

Midwest Groundwater Conference
October 1 – October 2, 2012

Alexander Morrison[1]; William W. Simpkins[1]; Kristie J. Franz[1], Alan D. Wanamaker[1], Özlem Acar[1], Matthew Helmers[2], Richard M. Cruse[3]
[1]Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA; [2]Agricultural & Biosystems Engineering, Iowa State University, Ames, IA; [3]Department of Agronomy, Iowa State University, Ames, IA

Introduction

Recent large-scale flood events in Iowa have demonstrated a need to understand how drainage alteration, specifically through tile drainage and ditches related to intensive agriculture, affects peak flow events and streamflow hydrology. We are investigating these relationships in the South Fork watershed, a 78000-ha watershed in north-central Iowa that was recently included as an Upper Mississippi River Basin LTAR site. Approximately 80% of the watershed is tile drained. It was chosen in part for its long data record – more than 15 years of streamflow and tile data – and groundwater monitoring wells. The physically based, coupled surface water/groundwater model, HydroGeoSphere, will be used to simulate the hydrology of the watershed. The goal of the study is to observe and simulate the contributions of tile drainage to streamflow under varying flow conditions, including peak flow. Hydrograph separation using isotopes of water will be also used for model calibration.

Methodology

Samples from the watershed are collected in cooperation with the National Laboratory for Agriculture and the Environment (NLAE). Surface and tile water are collected weekly and precipitation samples (wet and dry) are collected usually the day following the event (Fig. 1). Groundwater samples are collected and water levels are measured monthly in monitoring wells at 11 sampling locations.

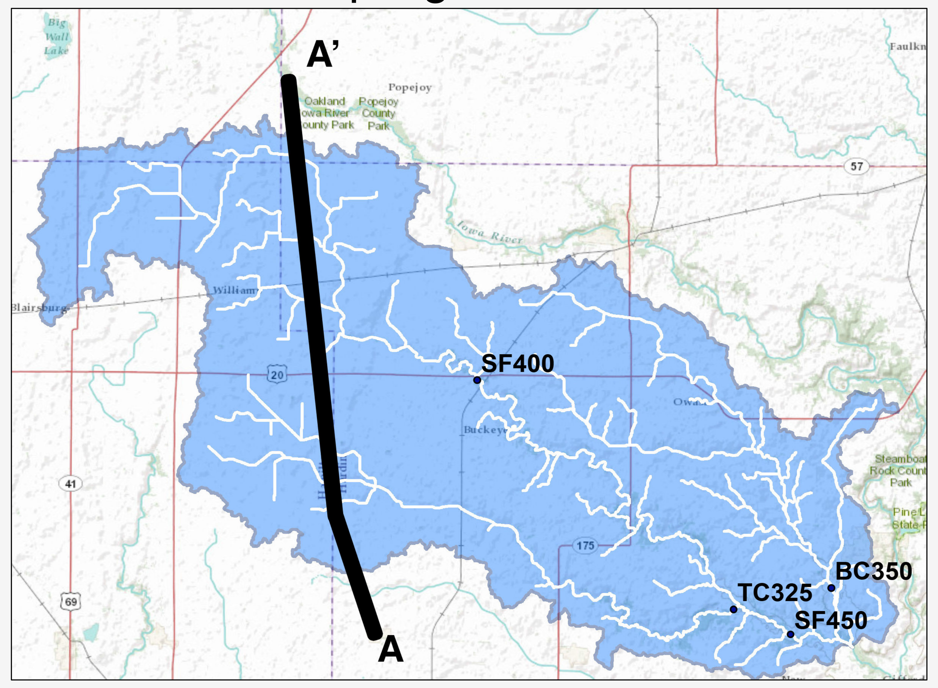


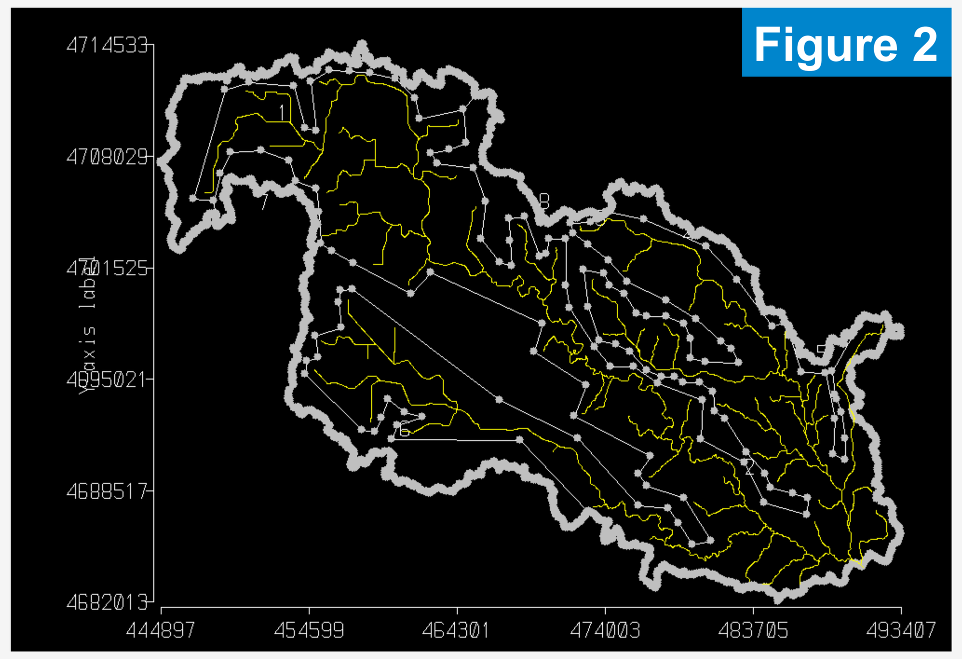
Figure 1. SF400, BC350, TC323, and SF450 are surface water sites. TC241 and TC242 (located immediately downstream of TC240) are tile sample sites. Precipitation samples are collected from a precipitation collector at site TC240P, in addition to water collected from a rain gauge at SF400.

Water samples are analyzed for $\delta^{18}O$ and $\delta^{2}H$ using a Picarro L1102-i Isotopic Liquid Water Analyzer in the Stable Isotope Laboratory in the Department of Geological and Atmospheric Sciences at Iowa State University. The results will be used both as model inputs (as an additional calibration tool) and to determine input of baseflow, tile flow, and precipitation to streamflow. Additional calibration data are available. Water quality data are collected by the NLAE using Isco autosamplers. Streamflow has been recorded for the past 15 years at some sites (SF450, Fig. 1). Additionally, a water-table map for the watershed is available for use in calibration (Fig. 8). Subsurface geology is being constructed in GMS from borings and strip logs available through the Iowa Geological Survey's GeoSAM website.

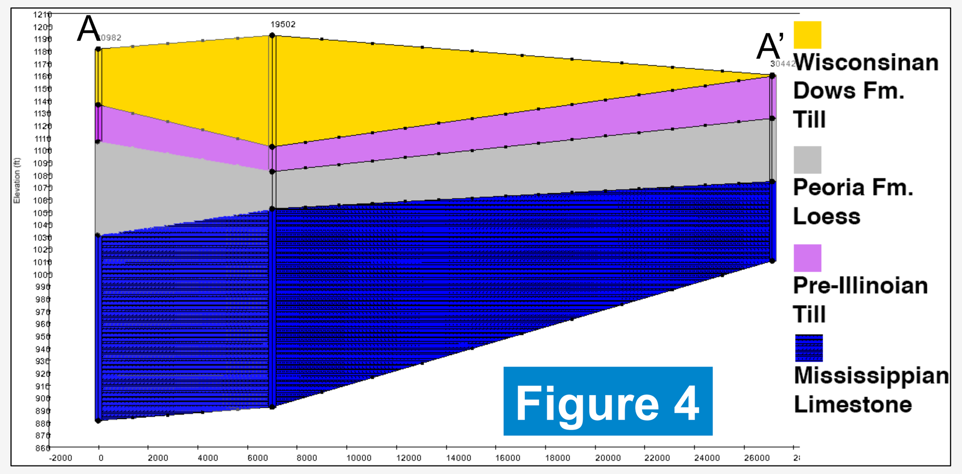
Results

Model

The watershed boundary and stream systems have been imported into GridBuilder, the mesh-generation software for the HydroGeoSphere model (Fig. 2). Three-meter resolution LiDAR (Fig. 3) will also be imported, in addition to a simplified subsurface geology (Fig. 4) created in GMS.



The geology (Fig . 4 , line of section A–A' in Fig. 1) is divided into four main units: the Wisconsinan Dows Formation (till), Peoria Formation (loess), Pre-Illinoian (till), and Mississippian bedrock (limestone). Well logs and borings will be used to construct a 3-D subsurface model in GMS for import into GridBuilder.



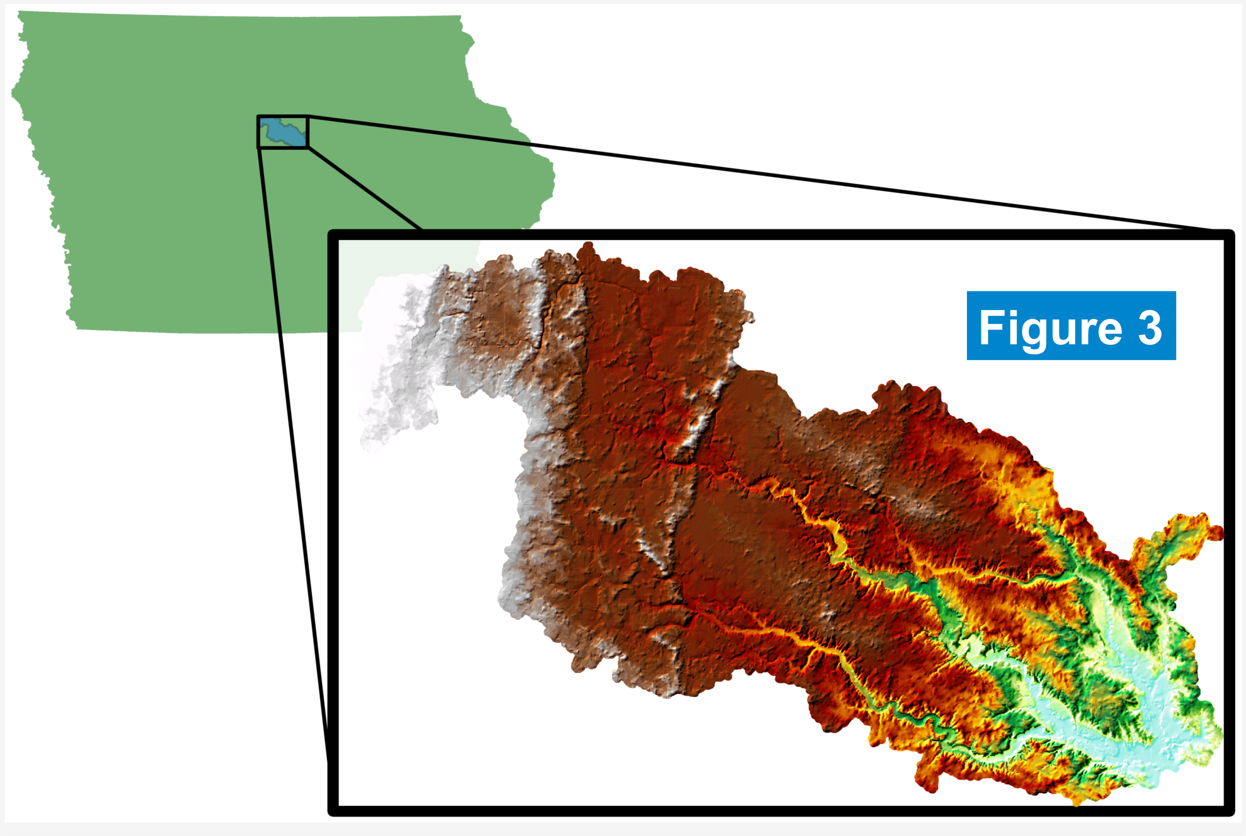


Figure 3 (above): LiDAR elevation hillshade of the South Fork watershed.

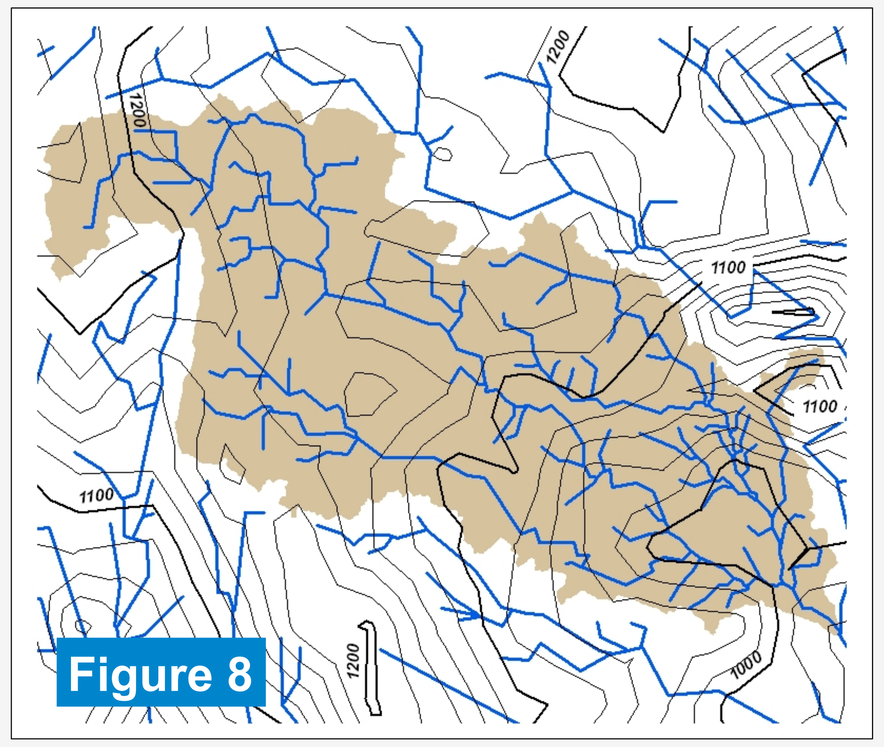


Figure 8 (left): Water-table map of the watershed. Hydraulic head values from wells will be used as targets during model calibration.

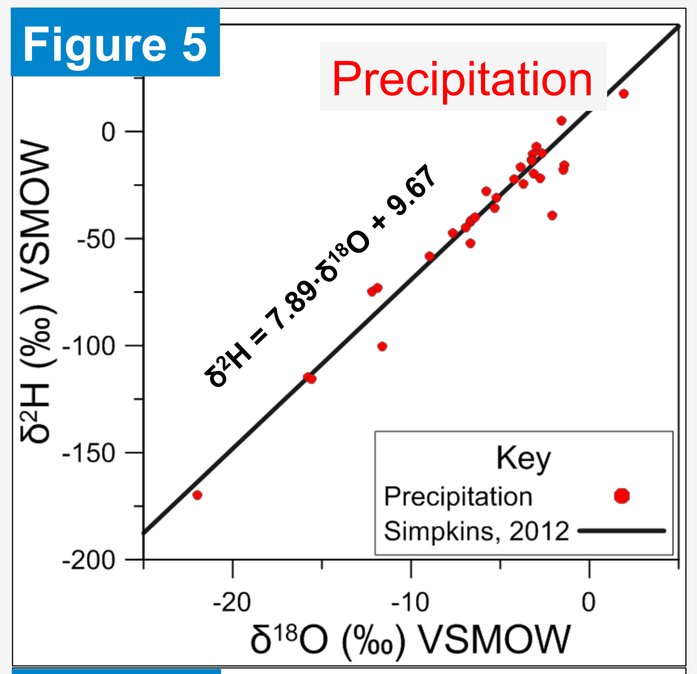
Stable Isotopes of Water

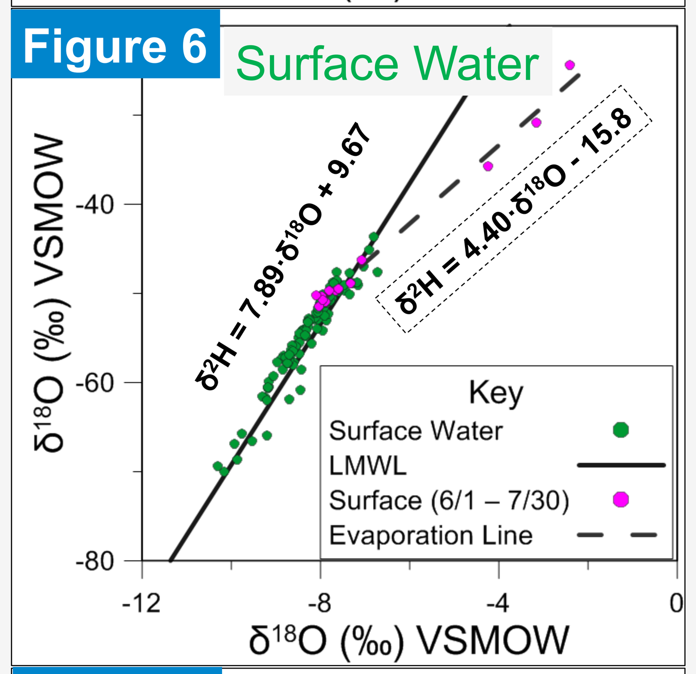
Isotope data have been collected and analyzed for about one year. Precipitation data closely matches the local meteoric water line (LMWL) produced for Ames, IA, about 45 miles to the southwest (Fig. 5). Climate has been unique during the study period; the 2012 drought reached 'extreme' stage by late summer. Evaporation is seen in surface water samples from June and July, 2012; values trend away from the LMWL along a slope of 4.5 (Fig. 6).

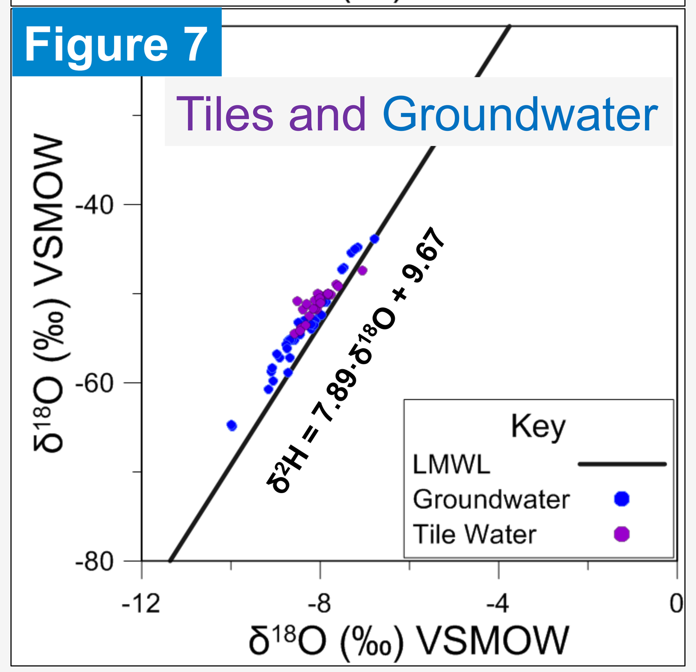
Although the lack of precipitation and recharge this year may have affected isotopes values, separation among the isotopic values of tile water, surface water, precipitation, and groundwater is evident. The large spread of isotopic values in groundwater stands in contrast to the tightly clustered isotope values for tile water (Fig. 7). This contrast is useful for hydrograph separation, where unique isotopic signatures and input sources with little variance are needed. Tile water's small variance could be helpful in distinguishing it from groundwater and precipitation (runoff) during peak-flow events (Table 1).

Table 1

$\delta^{18}O$ (‰)	Surface Water	Groundwater	Tile Water	Precipitation
Max	-2.40	-6.79	-7.05	1.95
Min	-10.31	-10.20	-13.91	-21.96
Average	-8.12	-8.45	-8.62	-6.22
Std. Dev.	1.05	0.76	1.01	5.08







Future Work

Construction of the HydroGeoSphere watershed model and sample collection will continue into 2013. Samples collected to date (November 2011 to September 2012) were collected under extreme drought conditions, representing only one end of the climate continuum. A peak flow event will be needed so that the model can be calibrated under a range of conditions prior to moving into predictive mode. Thus, we join the rest of the Midwest in hoping for a wetter 2013.

Acknowledgements

Funding was provided to PI's Simpkins, Franz, Helmers and Cruse by the Iowa Department of Economic Development. Additional funding was granted to M.S. student Alex Morrison through a Geological Society of America Student Research Grant. We thank the USDA National Laboratory for Agriculture and the Environment for contributing both knowledge and water samples as part of their ongoing research in the watershed.