

Simulation of Ground-Water/Surface-Water System in The Rock River Basin, Wisconsin

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LOCATION OF RESEARCH Madison, Wisconsin

DURATION OF PROJECT July 2003 to June 2005

AMOUNTS REQUESTED

<u>First Year</u>	<u>Second Year</u>	<u>Total</u>
\$23,450	\$26,800	\$52,250

TARGETED AGENCY WDNR

DATE OF SUBMITTAL November 2002

Project Title

Simulation of Ground-Water/Surface-Water System in The Rock River Basin, Wisconsin

Project Investigators

James Krohelski and Daniel Feinstein, USGS

Suzanne Wade, Senior Lecturer, University of Wisconsin-Extension

Project Summary

Groundwater concerns, both quantity and quality, have been identified as a significant issue in the Rock River Basin by the Rock River Coalition's Groundwater Issue Team. Issue Teams organized through the RRC are the method being used to implement the DNR's External Partner Team in the Rock River Basin. Efforts to address groundwater issues, particularly groundwater-surface water interactions, have been stymied by lack of information. Currently there are no studies available to explain how the shallow groundwater/surface water hydrologic system works in the Rock River Basins of Wisconsin. To do this, a process-based framework synthesizing what is known about the hydrology (both ground and surface water) is needed. The framework required would describe sources and sinks of water and general directions of groundwater flow and estimates of travel times.

The computer program GFLOW will be used to develop a model of the Rock River Basin. The combined simulation of groundwater and surface water systems and their interaction provides the framework necessary to understand and simulate the hydrologic system. Such information on simulated flows between surface-water features and the groundwater system are critical for understanding the fate and transport of contaminants within the Rock River Basin. The model outputs, in turn, can form the foundation for future studies.

After calibrating the model(s) to existing hydrologic conditions, the model will be used to quantify groundwater movement throughout the basin. Using particle tracking (mathematical particles of water), the groundwater travel paths and travel times will be simulated to illustrate the probable fate and transport

of constituents present in parts of the Basin.

Three meetings a year will be held with municipalities that provide funding or other support for the project. These updates will allow the cities, villages, counties, towns and lake districts with information on how they can utilize the model for land use decision-making once it is completed. Additionally USGS will provide assistance to participating municipalities.

Results of this model will also be used by the Department of Natural Resources on a special project to prioritize Rock River Basin wetlands for restoration, rehabilitation and protection where understanding ground-surface water interaction is critical..

Objectives

1. Improve the overall understanding of the hydrology of the Rock River Basin by testing alternative conceptual models of the system.
2. Highlight areas where more data and what types of data are needed.
3. Evaluate surface/ground-water interactions and baseflow contribution from the Rock River sub-basins
4. Estimate amounts and rates of ground-water flow and travel times
5. Provide information that can be used to characterize contaminant movement in the Basin

Product Deliverables

1. Database of groundwater level measurements and baseflow estimates used to calibrate the model.
2. Groundwater flow model – to quantify the regional hydrologic flow system in the basin to provide a tool to evaluate specific ground-water resource management questions.
3. Study Report – to summarize and document the study methods and findings.
4. Long-term model support – a mechanism for continued use and archiving of the regional ground-water model and associated databases as required by cooperators.

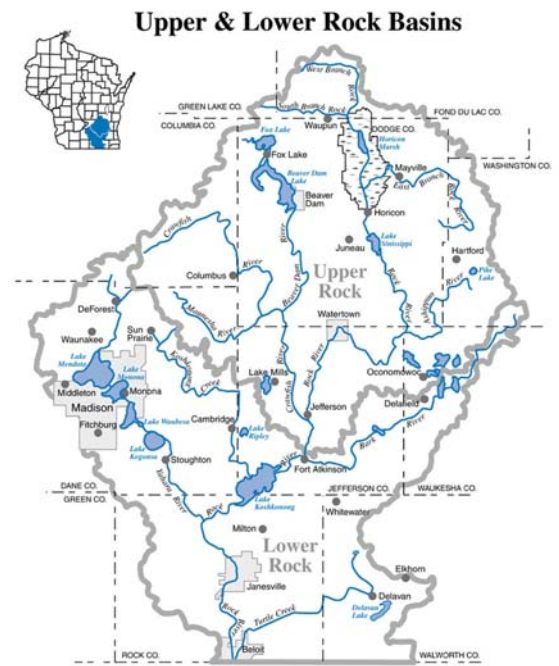
Proposal Narrative

Objectives:

1. Improve the overall understanding of the hydrology of the Rock River Basin by testing alternative conceptual models of the system.
2. Highlight areas where more data and what types of data are needed.
3. Evaluate surface /ground-water interactions and baseflow contribution from the Rock River sub-basins
4. Estimate amounts and rates of ground-water flow and travel times
5. Provide information that can be used to characterize contaminant movement in the Basin

Background:

A number of hydrologic studies (for example: Gaffield and others, 2002; Bradbury and others, 2000; Devaul and others, 1983; Cotter and others, 1969; Krug, 1979; Borman, 1976; Harr and others, 1978; McLeod, 1978; Holt and others, 1970; Borman and Trotta, 1976; Cline, 1965; LeRoux, 1963; Newport, 1962) encompass parts of the Rock River Basin while several large regional hydrologic studies (for example: Young, 1992; Bradbury and others, ongoing hydrologic study of southeastern Wisconsin) encompass all of the Rock River Basin (fig. 1). At least one study (EarthTech, 2000) was developed to explain phosphorous loading from subbasins in the Rock River Basin. None of these studies have attempted to explain how the shallow groundwater/surface water hydrologic system works. To do this, a process-based framework synthesizing what is known about the hydrology (both ground- and surface water) is needed. The framework required would describe sources and sinks of water and general directions of groundwater flow and estimates of travel times. Ideally, this



framework would also highlight areas where more and what types of data are needed to contribute to the understanding of the system. The hydrology of the Rock River Basin is expected to be complex because of the variability across the basin of: surficial deposit type thickness of the surficial deposits the underlying bedrock type), soil permeability and, excess precipitation. The development and calibration of a regional ground-water- flow model integrates the most important factors affecting the ground-water system. Because the groundwater and surface water systems are coupled in this region of the country, the groundwater model must also include many aspects of the surface-water system. The combined simulation of groundwater and surface water systems and their interaction provides the framework necessary to understand and simulate the hydrologic system. A calibrated model is a quantitative characterization of the shallow ground-water flow system. Such information on simulated flows between surface-water features and the groundwater system are critical for understanding the fate and transport of contaminants within the Rock River Basin. The model outputs, in turn, can form the foundation for future studies aimed at evaluating contaminant loading.

Project Plan:

A *stepwise* modeling approach (Haitjema, 1995) is proposed that first uses a simple model to guide data collection then builds on the enhanced data set to incorporate necessary complexity in subsequent versions of the model. This approach is superior to more traditional approaches where all data collection takes place before the modeling is initiated because gaps in our understanding are identified at the beginning of the project. This information can then be used to guide future data collection activities to ensure that the model represents our best understanding.

For regional studies, USGS staff uses two ground-water-flow modeling approaches: finite difference techniques (for example, the computer code MODFLOW), and analytic element techniques (for example, the computer code GFLOW). Examples of studies where these codes have been used by the USGS to evaluate surface-water/ground-water interactions include MODFLOW studies (Krohelski, 1986; Conlon, 1997; Krohelski and others, 2000; Hunt and Steuer 2000; Hunt and others, 2001; Krohelski and others, 2002a; Anderson and others, 2002), GFLOW studies (Hunt and others, 2000a, 2000b; Krohelski and

others, 2002b; Kelson and others, 2002), and joint applications of both techniques (Hunt and Krohelski, 1996; Hunt and others, 1998; Krohelski and others, 2000).

MODFLOW (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996; Harbaugh and others, 2000) is the most widely used ground-water flow model in the world. MODFLOW is a three-dimensional ground-water flow model that has the capability to simulate transient conditions (that is, conditions through time) and a wide variety of hydrogeologic system features. GFLOW (Haitjema, 1995) uses the analytic element method. Although the two codes use the same governing equations, analytic element techniques are different from the finite-difference method in that they do not use a grid. Rather, geologic and hydrologic features in the area of interest are added to the model following their natural geometry. In addition, the aquifer is assumed to be unbounded or infinite; the ground-water flow system is bounded by the geologic and hydrogeologic boundaries (bedrock highs, fully penetrating river and lake systems). In general, the analytic element model is well suited for large regional models and easier to implement than the MODFLOW model. However, the GFLOW model is limited to two-dimensions and can only simulate average conditions (that is, steady state). GFLOW will be the main code used in this study because the regional system is largely two dimensional and seasonal precipitation can be approximated by steady-state conditions. Moreover, conceptual model testing that evaluates the importance of surface-water features as sinks and sources of water are more easily accommodated in GFLOW than in MODFLOW. The effort constructing the GFLOW model will continue to be valuable if a change in model code is required as GFLOW has the capability of extracting MODFLOW input directly out of the analytic element model. Thus, switching from GFLOW to MODFLOW is relatively easy (see Haitjema, 1995; Hunt and others, 1998).

USGS will work with the Rock River Coalition's Groundwater Issue Team and others to interpret data (geologic maps, well construction reports, site-specific field surveys) and to test conceptual models of the shallow ground-water-flow system. An analytic element ground-water-flow model, using the computer program GFLOW (Haitjema, 1995) will be developed to help establish the where and what type of

additional data are needed (for example, estimates of hydraulic conductivity, ground-water- level measurement, streamflow measurement) to increase the understanding of the hydrology of the Rock River Basin.

. After calibrating the model(s) to existing hydrologic conditions, the model will be used to quantify ground-water movement throughout the basin. Using particle tracking (mathematical particles of water), the ground-water travel paths and travel times will be simulated to illustrate the probable fate and transport of constituents present in parts of the Basin.

Methods:

1. Compile existing information regarding the spatial distribution and hydraulic properties of hydrogeologic units, and current and historic water-use data. Sources of information will include existing well construction reports and geologic logs, the regional geologic literature, and publicly available reports on various site-specific studies conducted within the Rock River Basin.
2. Select a base map appropriate for the density of available data. Construct water table map and a map illustrating the locations of the shallow aquifer units and their hydraulic characteristics. We will work with the Rock River Basin Committee and other local officials in the basin to determine an appropriate digital format for these products (for example, GIS format and coordinate system).
3. A database will be constructed so that data are accessible to staff working on the study as well as staff from interested state and local agencies. The database will be constructed and documented so that it can be used after the project is concluded.
4. Synthesize the data collection and mapping efforts to formulate a conceptual model of the regional hydrogeology. Test the conceptual model and define appropriate hydrologic boundaries by developing a simplified regional model (i.e., screening model)
5. A step-wise modeling approach will be used during model development. By conducting a sensitivity analysis of model input a determination will be made as to where additional data are needed.
6. The model will be calibrated by comparing simulated ground-water levels and measured

streamflows.

7. Particle tracking will be performed at various sites to illustrate groundwater flow paths and travel times.
8. A report describing the model development and calibration will be written.

Deliverable Products

1. Database of ground-water- level measurements and baseflow estimates used to calibration the ground-water flow model.
2. Ground-water-flow model – to quantify the regional hydrologic flow system in the basin to provide a tool to evaluate specific ground-water resource management questions.
3. Study Report – to summarize and document the study methods and findings. *Simulation of Ground-Water/Surface-Water Interaction in The Rock River Basin, Wisconsin* will describe the aquifer units, their hydraulic properties, extent, thickness and elevation, and will also summarize baseflow contributions by sub-basin and ground-water travel times. The report will be published as a USGS Water-Resources Investigation Report.
4. Long-term model support – a mechanism for continued use and archiving of the regional ground-water model and associated databases as required by cooperators.

Relevance to Groundwater and Related Problems:

Because this study will improve the understanding of the hydrology of the Rock Basin, it will provide a basis to interpret previously collected water-quality data. The sources and amount of baseflow contribution to the Rock River from its sub-basins will be more accurately known and understood, and water-resource managers will have a tool (ground-water flow model) to assess the affects of hydrologic stress (e.g., development) on water resources. The ground-water- flow model also provides a regional framework for more site-specific studies in the future.

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Training Support/Information Dissemination Plan:

Once completed, USGS will meet with municipal supporters of the model to assist with model use and interpretation. The Rock River Coalition will highlight model development in newsletters, presentations and media releases. The Department of Natural Resources will use the information on a new wetland prioritization project.

Curriculum Vitae of Principal Investigators

The amount of time Jim will spend on the project will depend on the availability of USGS Hydrogeologic Studies Section staff. Current plans are to have Daniel Feinstein develop and calibrate the majority of the groundwater flow model with support from other section staff.

James T. Krohelski
Supervisory Hydrologist
U.S. Geological Survey
8505 Research Way
Middleton, Wisconsin
(608/821-3850)

Jim Krohelski has been extensively involved in ground-water field studies and simulations for the last 20 years. He has cooperatively developed regional ground-water flow models for the Lower Fox River Valley and Dane County. He has, also, developed ground-water flow models to simulate ground water/lake water interactions as part of the Electric Power Research Institutes Acid Rain research program and the USGS cooperative program. He has been active in performing optimization studies for ground-water management studies and in evaluating the effects of mining on surface-water bodies.

Daniel T. Feinstein
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Daniel Feinstein has been involved in ground-water flow modeling, contaminant-transport modeling and aquifer pump test analysis for 15 years. He has devoted much of his career to applying quantitative techniques to the design and implementation of remediation projects in Wisconsin. He has worked extensively in testing new particle-tracking and solute-transport codes. He is also expert in geostatistical techniques and unsaturated flow modeling. He has taught ground-water modeling courses in the United States, Italy and England. He is currently active in evaluating the ground-water model for the proposed Crandon Mine and has recently completed a groundwater flow model of Southeast Wisconsin that was developed cooperatively with the Wisconsin Geological and Natural History Survey and the Southeast Wisconsin Regional Planning Commission.

Suzanne S. Wade
UWEX Rock River Basin Educator
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Suzanne Wade will be spending roughly 5% time on this project, primarily in organization of municipal contacts including general communication and organization of three meetings a year. As the UWEX Rock River Basin Educator, she provides facilitation and educational assistance to the Rock River Coalition's six issue teams and other organizations and agencies in the area of natural resources. She has

extensive background in the organization of complex projects including directing the Elkhart Lake-Glenbeulah K-12 Integrated Environmental Education Project and 'Testing the Water: Linking Students and the Watershed thru Technology'. She was the coordinator for the Rock River Watershed Partnership, dedicated to exploring the possibility of nutrient trading in the basin. She has a Master's Degree from UWEGB in environmental education, advanced work in adult education, and a Bachelors degree, from UWGB with joint majors in ecosystems analysis and biology as well as a teaching certification for grades 7-12 in Biology and Environmental Science,

Current or Pending Support

Current:

The Rock River Basin Groundwater Issue Team is the main organizing body for this project.

Active members include:

Paula Allen: DATCP

Jim Congdon, Ruth Johnson, Dave Johnson and Ron Curtis: DNR

Laurie Lambert: Dane County Land Conservation Department

Dennis Bries: Farm Bureau

Mark Krumenacher: GZA GeoEnvironmental Inc

Rick Wietersen: Rock County Health Department

Ed Morse: Rural Water Association

David Neuendorf and Suzanne Wade: University of Wisconsin-Extension

Municipalities that have pledged \$200 in support of the project as of November 15, 2002 are:

Cities of Waupun, Lake Mills, Fox Lake, Watertown and Horicon

County of Rock

Towns of Fulton and Hartford

Municipalities providing letters of support

Dane County Regional Planning Commission

Town of Emmet

Villages of Wales and Clinton

Pending:

A letter asking for project support was sent to all municipalities: counties, cities, villages, towns and lake districts in the basin. Several are in the process of obtaining support but appropriate board action could not be taken before this grant submissal

This project is intended to be part of the U.S. Geological Survey Federal-State Cooperative Water-Resources Program. Salaries for projects within this program are always derived from a non-Federal funding agency such as the WDNR. These salaries are listed in the following budget. Costs associated with all other items and with overhead are not listed because they will be covered by federal matching money. This matching money is available through the Cooperative program. The cost of this project will be matched 60/40 with federal dollars to cover all costs except salaries.

Municipalities are contributing \$200 towards the cost of this project. These funds will be used for ineligible expenses incurred by the Rock River Coalition or UW-Extension.

Budget STUDY ELEMENT	FY 2003	FY 2004	Total
Salary:			
USGS Hydrogeologic Section Staff	20,000	20,000	40,000
Salary: RRC Grant Coordinator	2,250	2,600	4,850
Supplies/Services			
a) office supplies, phone, duplicating	500	500	1,000
b) accountant fees	400	400	800
Municipal meetings (3/year)	300	300	600
-mailings, room costs, handouts			
Report Printing (300 copies)		3,000	3,000
Total	23,450	26,800	50,250

1FY 2003 is July 1, 2003 to June 30, 2004

2FY 2004 is July 1, 2004 to June 30, 2005