

A PROPOSAL TO EVALUATE THE IMPACTS OF NON-METALLIC MINING AND IRRIGATED AGRICULTURE ON GROUNDWATER RESOURCES IN WESTERN CHIPPEWA CO., WI

Introduction

The quantity of surface and groundwater resources is critical to the ongoing quality of life and economic well-being of residents and businesses in Chippewa County, Wisconsin. Current economic trends are placing more intensive demands on the land and natural resource base of the west-central region of Wisconsin. For example, areas of western Wisconsin are experiencing an increase in the number of acres of cropland that are irrigated.

Coincident with these changes in agricultural practices is a global demand for energy and a related increase in demand for “frac sand” from Wisconsin. When injected into gas production wells, frac sand props open fractures in bedrock formations surrounding the well, increasing well yield. While there are no gas producing wells in Wisconsin, demand for sand is growing because of production wells in other regions of the United States. In response to high demand for this sand, numerous industrial sand mines are being developed to extract high quality sand and sandstone from within the Jordan and Wonewoc Formations. These formations extend throughout upland areas in west-central Wisconsin.

Residents, local officials, and other concerned citizens recognize these changes and are interested in better understanding the potential cumulative impacts of changes in groundwater recharge and groundwater use on water resources in west-central Wisconsin. Potential recharge changes are due to landscape changes associated with mine reclamation while changes groundwater use are tied to the expected expansion of irrigated agriculture, industrial sand mining, and other high-capacity groundwater withdrawal operations. One common question is: How will existing and future changes in water use and recharge impact the availability of groundwater supplies that support surface water features such as streams and rivers?

The study seeks to develop a better understanding of groundwater resources within western Chippewa County. The project scope includes development of a dynamic tool, a groundwater flow model, to evaluate the impacts of changes to groundwater recharge and withdrawal on the hydrologic system. This groundwater study will benefit water resources management efforts in the region by characterizing hydrogeologic conditions and incorporating this characterization into a computer model capable of evaluating a set of scenarios associated with alternative management plans and/or hydrologic conditions (e.g., changes in water use or climatic conditions, such as drought).

Chippewa County Department of Land Conservation and Forest Management (LCFM), the Wisconsin Geological and Natural History Survey (WGNHS), and the U.S. Geological Survey (USGS) have developed the project to build upon existing inventories of land and water resources conducted by state and local agencies. Such inventories provide a technical basis for ongoing natural resource management efforts.

Project results will be of direct benefit to the citizens of Chippewa County, State and local Government, and agricultural and mining interests. The results will provide interested parties with quality scientific information to support informed decision making regarding water resources within western Chippewa County. The project is designed to provide general information that will be transferable to other areas with similar terrain and geology, and support groundwater resource related decision making throughout west-central Wisconsin.

A map of the study area (**Figure 1 – Preliminary Model Area**) illustrates the area of focus for the groundwater flow model. **Appendix A – Summary of Technical Discussions**, contains a detailed explanation of groundwater flow models and the results expected from this model.

Objectives

The objectives of this study are to:

1. **Develop soil water balance and groundwater flow models to evaluate the impacts of current and future water use and topography on the hydrologic system**

Available geologic and hydrologic data will be used to build and calibrate the soil water balance and groundwater flow models. These models will be used to:

- a. Evaluate impacts that current groundwater use associated with frac sand mining and irrigated agriculture have on water resources,
- b. Evaluate how changes in topography (i.e., mine reclamation) and water use (i.e., irrigated agriculture and industrial sand production) affect water resources through two scenario simulations representing peak frac sand production (~2030) and post-mine reclamation (~2050).

2. **Disseminate the study results to project stakeholders and the general public**

Results of the modeling study will be made available to all interested parties through a series of presentations and a final report. This will provide all parties with technical analyses regarding the effects of mining, irrigation and other high-capacity groundwater uses on streamflow and groundwater levels, to support informed decision making by facility operators, local units of government, regulatory agencies, and the general public.

3. **Transfer the study results to similar geologic/hydrologic settings as appropriate**

Results of the groundwater flow modeling will form the basis for a set of insights regarding the response of groundwater resources to stressors (e.g., pumping) in neighboring areas with comparable geologic and hydrologic settings.

Project Outline & Timeframe

The three (3) primary objectives identified above will be met by completing eight tasks. These tasks fall within two (2) project components which will proceed in parallel over the course of the project.

1. **Technical Investigation and Modeling Component:**

1. **Data Collection and Interpretation** – Collect and interpret available surface and subsurface hydrologic and geologic data for the groundwater flow model.
2. **Soil Water Balance (SWB) Modeling** – Build a SWB model to evaluate recharge under current and future conditions (see Task 4 – Scenario Testing).
3. **Groundwater Modeling and Calibration** – Develop a groundwater model, including significant elements of the surface and subsurface hydrologic and geologic conditions, and calibrate to steady state conditions representing the landscape prior to frac sand mining.

4. **Scenario Testing** – Apply the models to evaluate the impacts of changes in groundwater pumping and recharge for two scenarios representing (1) peak sand mine operations (~2030) and (2) post-mine reclamation (~2050), which include the associated configurations or expansions in irrigated lands.
 5. **Transferability** – Apply the models to evaluate generalized system responses to expected groundwater pumping and recharge changes associated with frac sand mining and irrigation operations that are common to west-central Wisconsin.
2. **Public Outreach and Reporting Component:**
1. **Fact sheet** – Prepare a WGNHS fact sheet generally describing Chippewa County’s water resources and the objectives and methods of this groundwater modeling study.
 2. **Public Outreach and Stakeholders Meetings** – Provide public outreach at meetings to educate the public about water resources of Chippewa County and the goals and results of the groundwater modeling study. Presentations will be held annually to update the general public on project progress and solicit feedback from the project stakeholders over the course of the project.
 3. **Interim and final reporting** – Convey results of the data collection and SWB modeling through an interim report. A final report will document the five tasks outlined above in the Technical Investigation and Modeling Component.

These project tasks will be performed over a five (5) year project period extending from August 1, 2012, through August 1, 2017. A timeline and task summary are provided in **Table 1 – Project Workflow and Activities Schedule**.

Project Participation, Management, & Oversight

This project has been developed as a collaborative effort among public agencies, mining and agricultural interests, and non-profit conservation organizations (NCO’s). To complete the project, participating parties have agreed to share information and contribute available resources (e.g., staff, equipment, and money) on a voluntary basis to the Chippewa County LCFM. The project will be managed by and administered through the Chippewa County LCFM.

Brief professional biographies of the four WGNHS and USGS project investigators are included in **Appendix B – Project Investigator Biographies**.

Major components of the project will be conducted under technical service contracts developed between Chippewa County LCFM and the USGS (e.g., groundwater model (MODFLOW) development, calibration and scenario testing), and Chippewa County LCFM and the WGNHS (e.g., hydrogeological data collection, groundwater recharge model development (Soil Water Balance (SWB) model), and public education and outreach). Streamflow monitoring is being conducted by the USGS in western Chippewa County under a separate contract with the Chippewa County LCFM

Project coordination will be provided through use of a Project Stakeholders Group (P.S.G.) composed of major stakeholders, including project sponsors, interested citizens, non-profit conservation organizations (NCOs) and industry representatives. An outline of the P.S.G charge and scope of responsibility is provided in **Appendix C – Project Stakeholders Group Charge**.

Project Financing, Budget, & Fiscal Accountability

A five (5) year project budget has been prepared to itemize the projected costs and anticipated revenues, associated with each project component. The project budget will be administered through the Chippewa County LCFM, and updated annually through the County budget process. The proposed project budget is provided in **Appendix D – Project Budget**.

Project Performance, Tracking, & Accountability

A table of planned activities has been developed and will be used to schedule project tasks and to guide project workflow. This table is provided in the above referenced **Table 1 – Groundwater Study Workflow and Activities Schedule**.

Project performance will be systematically measured using the project schedule and timely completion of product deliverables.

An annual report will be prepared by the Chippewa County LCFM to outline the status of planned activities, present product deliverables, and summarize preliminary findings, experiences, and results that may be of benefit to project participants, other municipalities, and the general public.

Project Tasks, Schedule & Deliverables

Component 1 - Technical Investigation & Modeling

Task 1 – Data Collection & Interpretation

Site specific geologic and hydrogeologic data will be collected to characterize the hydrogeologic system. This data will provide the basis for the technical investigation and subsequent modeling effort. Existing geologic data will be gathered from available records.

Well construction reports (WCRs), stratigraphic logs (i.e., lithologic descriptions of drill cuttings), rock core, and geophysical logs will be used to characterize the geologic and hydrogeologic properties across the model domain. Data from measuring water levels, pumping tests and streamgaging activities also provide insight into the hydrogeologic system, and will be compared to existing resources (e.g., Pleistocene Geology of Chippewa County, Geology of Wisconsin Northwest Sheet, and Geology of Wisconsin West Central Sheet). Top of land surface, top of bedrock, and top of Precambrian surfaces will serve as stratigraphic control to constrain development of distinct hydrostratigraphic units (i.e., model layers).

WCRs, well water levels, pumping test data, high-capacity water-use (i.e., groundwater withdrawal) data within the project area will be provided by Chippewa County LCFM. Chippewa County LCFM will also provide all available data from the frac sand mining companies regarding groundwater withdrawals and water levels from their respective sites.

The WGNHS will conduct on-site geophysical surveys at wells of opportunity to improve understanding of the geologic and hydrogeologic character of lithologic strata. The WGNHS will also evaluate available stratigraphic logs and rock cores within the project area. Additional subsurface data from the frac sand mining sites (e.g., geophysical logs and pumping test results) will be provided by Chippewa County LCFM when available from the frac sand mining companies.

The USGS will continue to measure streamflow under a separate contract with Chippewa County LCFM. Additional one-time measurements of streamflow during baseflow conditions will be made to provide greater spatial understanding of groundwater/surface water interactions across the study area.

Deliverables: Data from borehole geophysical logs will be available shortly after data collection. Provisional streamflow, temperature, and conductivity data, collected during ongoing stream gaging

activities under a separate contract with Chippewa County LCFM, will be available on the USGS web page in near real-time. Collected data and associated interpretations will be presented in person to the Chippewa County LCFM and other project sponsors by the WGNHS and USGS in the form of PowerPoint presentations. Copies of presentations will be made available in PDF format to the Chippewa County LCFM for reference and distribution to other project sponsors, relevant agencies, organizations and individuals. Description of data collection methods and interpretations will be included in the interim and final reports.

Time frame: It is anticipated that this phase will continue into 2014. Collected data and subsequent interpretations will be presented to the project sponsors upon completion of significant milestones. The exact timing and content of these presentations will be agreed upon by the WGNHS, USGS and the Chippewa County LCFM. Examples of significant data collection and interpretation milestones could include but are not limited to collection of all available data sources and interpretation of geologic and hydrogeologic units.

Task 2 – Soil Water Balance Modeling

A Soil Water Balance (SWB) model will be developed by the WGNHS to estimate recharge to the groundwater system. The SWB model incorporates historical climate data in conjunction with topography, soil hydrologic group, soil available water storage, and land-use data to estimate recharge across the model domain. This estimate of recharge is used as input to the groundwater flow model.

A second use of the SWB model is evaluating potential impacts from anticipated changes to land-use in areas of extensive sand mining. The SWB model will be modified to account for future conditions, including surface topography, soil type, and land-use forecast by the proposed reclamation plans at the sand mines. Potential impacts of land reclamation on groundwater recharge and the hydrogeologic system can be examined by comparing SWB results from pre-mining and post-reclamation conditions. The Chippewa County LCFM will provide the WGNHS with topographic, soil type and land-use data for current conditions in the project area (i.e., immediately prior to frac sand mining) as well as for the two future land use scenarios (i.e., 2030 and 2050).

Deliverables: The SWB modeling, including the method and results, will be presented in the interim and final reports. Preliminary results will be made available earlier in the form of PowerPoint presentations made at project meetings and provided in PDF format to the Chippewa County LCFM for reference and distribution.

Time frame: SWB modeling will occur from 2012 through 2014. Preliminary results will be made available at meetings scheduled by the WGNHS, USGS, and Chippewa County LCFM, and will include compilation of the data used in the SWB model and results for current and post-reclamation scenarios.

Task 3 – Groundwater Modeling & Calibration

The USGS will lead development of the groundwater model, employing state-of-the-practice modeling techniques adapted to the hydrogeologic setting in Chippewa County. The groundwater flow model can be thought of as a tool that integrates hydrogeologic data, such as the extent, thickness and permeability of geologic units, groundwater levels, stream locations and flows, well locations and pumping rates, and groundwater recharge. The model is then calibrated, meaning that model parameters are adjusted until model results match a set of targets. Calibration targets include measurements of water level and stream flows. Following calibration, the model is used to simulate system responses to hydrologic stresses. Such stresses include changes in location and rates of groundwater withdrawals or groundwater recharge.

The model will focus on an area (**Figure 1**) that encompasses several permitted and proposed frac sand mining operations. This area is representative of the hydrologic and geologic conditions of potential future mining sites in west-central Wisconsin. The model includes a region beyond the area of focus as a matter of practice in such studies to prevent boundary conditions from incorrectly affecting model results

in the area of interest. The area of focus will contain finer resolution and more focused data collection efforts than the area around it. Data collected both inside and outside of the area of focus will be used in the model and available for subsequent studies, but model results will be limited to the area of focus.

Initial development of the model requires discretization of the study area into a three-dimensional model “grid”. The grid consists of cells which may vary in size, with smaller cells used in the area of focus. The three dimensional model will represent steady-state conditions, meaning that it will simulate long-term average conditions. The model will be calibrated with historical and current streamflow records and groundwater level measurements. As part of the model calibration, a sensitivity analysis will be performed to identify which hydrologic parameters used in the model have the greatest effect on the model results. The results of the sensitivity analysis are useful to understand the most significant controls on the groundwater system.

Deliverables: Model documentation, including construction, calibration, sensitivity analysis, and results will be included in the final report. PowerPoint presentations made at project meetings will contain preliminary results, and these presentations will be made available in PDF format to the Chippewa County LCFM for reference and distribution.

Time frame: Model construction will begin in 2014 and continue through 2015. Model simulations and report writing will be conducted during 2016 and 2017. Updates will be presented to project sponsors at annual meetings, and will describe significant milestones, such as compilation of model inputs, model construction, calibration, and scenario testing.

Task 4 – Scenario Testing

Following calibration of the groundwater flow model, the USGS will use the model to evaluate the groundwater system under specific scenarios of water use and recharge. Comparisons will be made between the calibrated model representing current conditions (prior to frac sand mining) and two scenarios within the model area of focus. Such scenarios will provide quantitative estimates of hydrogeological system response (e.g., hydraulic heads, groundwater flow directions, stream flow) to changes in pumping and recharge. These scenarios will be designed to represent distinct phases of frac sand mining operations and associated configurations or expansions in irrigated lands (i.e., anticipated 2030 and 2050 topography and pumping conditions). Specific scenario conditions (i.e., topography and pumping rates in 2030 and 2050) will be determined during progression of the project with input from the Project Stakeholders Group.

Deliverables: Results of scenario testing will be included in the final report. PowerPoint presentations will be made in person to the Chippewa County LCFM and other project sponsors at interim dates to communicate preliminary results. Copies of these presentations will be made available in PDF format to the Chippewa County LCFM for reference and distribution.

Time frame: It is anticipated that this phase will begin in 2015 and continue into 2016. Preliminary scenario testing, development, and results will be presented to the project sponsors at meetings scheduled by the WGNHS, USGS, and Chippewa County LCFM.

Task 5 – Transferability

Transferability in this context refers to the ability to distill qualitative outcomes from model building, calibration, and scenario testing within the model boundary to areas **outside** the model boundary. These areas could include neighboring counties and other settings with similar geologic and hydrogeologic conditions. This is accomplished by using the conceptual and numerical models developed for Chippewa County’s hydrogeologic system to develop a set of relationships that can be applied outside of the model boundary (**Figure 1**). This will allow interested parties to generally assess expected impacts of pumping and land use change in similar hydrogeologic settings. For example, simulations may be run that incorporate changes in the distance between wells and streams, or the number of wells, to evaluate the

effect of such changes on simulated stream flows and groundwater levels. These heuristic results provide the opportunity to use the findings of this project to draw general conclusions and insights regarding the response of similar hydrologic systems outside of the model area to changes in groundwater pumping expected from operation of sand mines or irrigated agriculture

Deliverables: Results of transferability analyses will be presented in person to the Chippewa County LCFM and other project sponsors by the WGNHS and USGS in the form of PowerPoint presentations. Copies of presentations will be made available in PDF format to the Chippewa County LCFM for reference and distribution to other project sponsors, relevant agencies, organizations and individuals.

Time frame: Work on the transferability of project results will occur during 2015 and 2016). Updates on progress on this task, including definition of variables and the format of the information, will be presented to the project sponsors at presentations scheduled by the WGNHS, USGS, and Chippewa County LCFM.

Component 2 - Public Outreach & Reporting

Task 1 – Fact sheet

The WGNHS will develop a fact sheet that highlights important aspects of Chippewa County's groundwater resources and the objectives of this groundwater modeling project. The fact sheet will serve as point of reference for the general public regarding the potential impacts of frac sand mining and irrigated agriculture on water resources within western Chippewa County. The fact sheet will also inform interested parties about this data collection and groundwater modeling effort. Chippewa County LCFM staff will provide review of the fact sheet prior to completion.

Deliverables: The WGNHS will produce 200 paper copies and a PDF of the fact sheet. The Chippewa County LCFM may produce additional copies and distribute paper and electronic copies to interested parties.

Time frame: The fact sheet will be produced during 2012 and 2013, with a target date of six months following the start of the project.

Task 2 – Public Outreach & Stakeholders Meetings

Informational meetings will be held with the citizens of Chippewa County and project stakeholders in coordination with the WGNHS, USGS, and Chippewa County LCFM over the course of the project to present the scope and preliminary results of this study and allow an opportunity for engagement concerning the County's groundwater resources. Public meetings will be scheduled during the early phase of the project to "roll-out" the study and then annually to provide updates on progress and preliminary results. Emphasis will be placed on explaining groundwater resources, connections between groundwater and surface water resources, and the potential impacts of pumping in Chippewa County. Such educational efforts can inform discussions within the community related to potential impacts of high capacity pumping for frac sand mines irrigation and municipal water withdrawals on groundwater and surface water resources. The completion of project milestones, outlined above for Tasks 1 – 5 of Component 1 (Technical Investigations and Modeling), will represent the bulk of the information presented at these meetings.

Deliverables: Public meetings will be provided in person by the WGNHS and USGS in the form of PowerPoint presentations. Copies of presentations will be made available in PDF format to the Chippewa County LCFM following the meetings for distribution.

Time frame: It is anticipated that the first public meeting will be held within six months of the start of the project (early 2013). The timing and content of these presentations will be agreed upon by the WGNHS, USGS, and Chippewa County LCFM.

Task 3– Interim & Final Reporting

The WGNHS and USGS will document project methods, findings and conclusions in a final report to be published by the WGNHS during 2017. The report will describe the conceptualization of the hydrogeologic flow system, construction and calibration of the groundwater computer model, simulated effects of frac sand mining on groundwater and baseflow in near-by streams, evaluations of hydrologic scenarios in the area of focus, and transferability guidelines for consideration outside the modeling area.

An interim report by WGNHS will described early data collection and SWB simulations.

Deliverables: Paper copies and PDF files of the interim and final reports will be provided to Chippewa County LCFM for distribution to interested parties. The WGNHS and USGS will make presentations of final results at Chippewa County LCFM coordinated meetings during the final phase of the project as discussed above in Task 2 (Public outreach and stakeholders meetings).

Time frame: The interim report will be submitted mid-way through the project by 2015. The final report will be submitted by August 1, 2017.

Relevance and Benefits of USGS involvement

Energy, agricultural, and environmental security are National concerns. Understanding environmental effects of hydraulic fracturing is an important component of understanding its long-term role as a component of National energy security. Similarly, understanding effects of water use for irrigated agriculture is an important component of understanding local, regional, and national water availability. Completion of the proposed work will provide the USGS, its cooperators, and public and private stakeholders with improved understanding of how frac sand mining and irrigated agriculture are expected to affect local and regional water resources. The USGS mission will benefit by keeping current on evaluations of the energy, agriculture, and water nexus; by applying recently added capabilities of MODFLOW to a new situation; and by increasing understanding of surface-water/groundwater interactions and their effect on water availability in a regionally common hydrogeologic setting. Information from this study will help the cooperator and interested public and private stakeholders to evaluate planned land management activities with regard to effects on local water resources. In addition, the public will gain an improved understanding of the source of their water supply.

Figure 1 - Preliminary Model Area

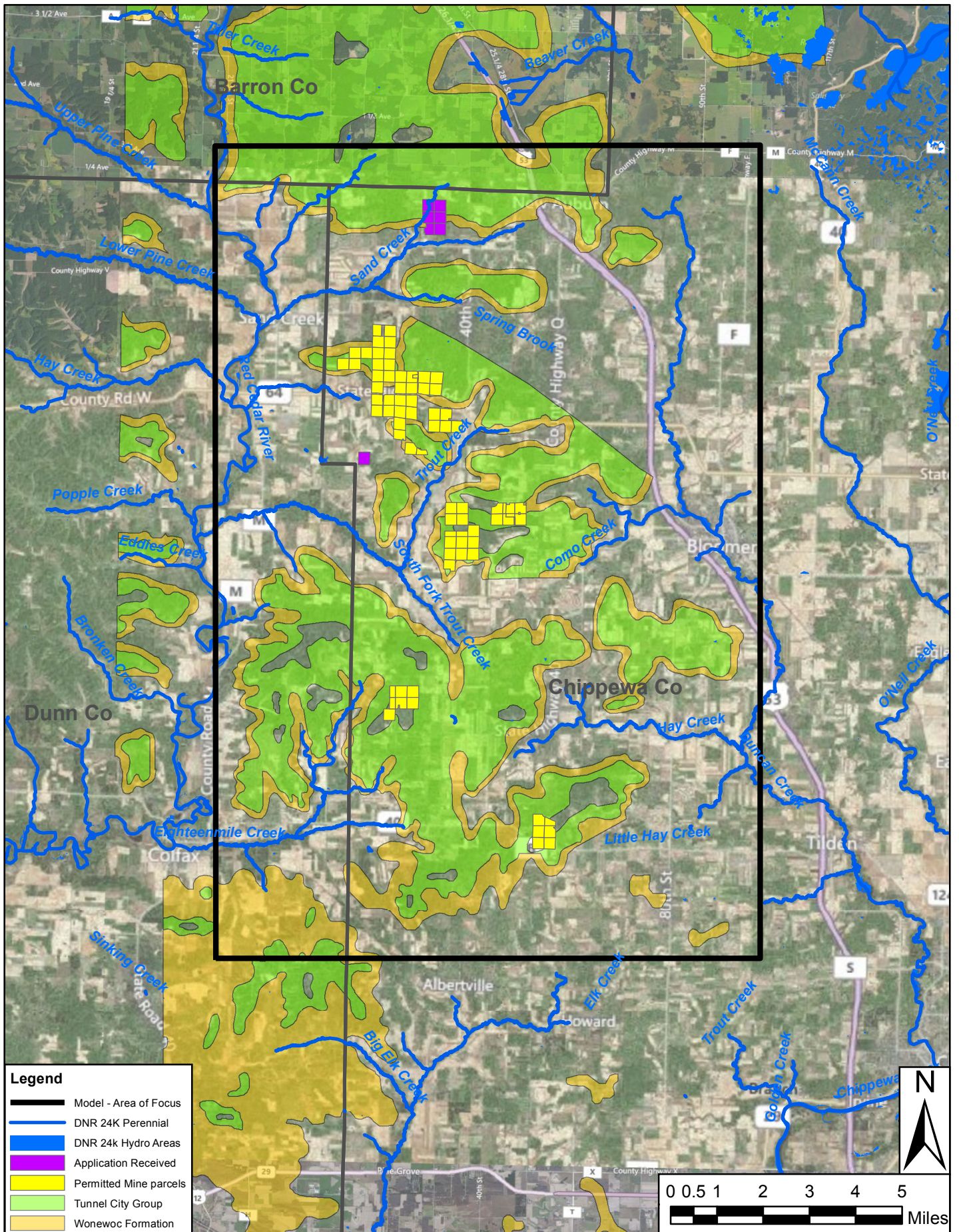


TABLE 1 - Project Workflow and Activities Schedule

Calendar Year	2012				2013				2014				2015				2016				2017			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Data Collection and Interpretation																								
- Collect and compile well & geophysical data			X	X	X	X																		
- Analyze & process				X	X	X	X	X																
- Interpretation (i.e., build model layers)							X	X	X	X														
Soil Water Balance (SWB) Modeling																								
- Collect climate/soils data			X	X	X	X																		
- Collect land use and elevation data			X	X	X	X																		
- Build model						X	X																	
- Review model							X	X																
- Define scenarios							X	X																
- Conduct model runs								X	X															
- Complete/Format results									X	X														
Groundwater Modeling and Calibration																								
- Construct model grid and decide on modeling packages					X	X	X	X																
- Build hydrological model								X	X	X	X	X	X	X										
- Calibrate model											X	X	X	X										
- Compile/Format results													X	X	X	X	X							
Scenario Testing																								
- Define test scenarios										X	X	X	X	X	X	X	X	X						
- Conduct model runs															X	X	X	X						
- Compile/Format results																X	X	X	X					
Transferability																								
- Conduct analysis																	X	X						
- Compile/Format results																			X	X				
Public Outreach																								
WGNHS Fact Sheet																								
- Identify purpose/content (WGNHS)			X	X																				
- Prepare & finalize drafts (WGNHS)				X	X																			
- Print & distribute (WGNHS)					X																			
Public Outreach and Stakeholders Meetings																								
- Identify purpose/content			X	X																				
- Conduct public outreach meetings					X																			
- Conduct stakeholders meetings - Specific times TBD					X		X			X				X				X						
Interim and Final Reporting																								
- Complete annual report (Chippewa Co LCFM)					X				X				X				X							
- Complete interim project report (WGNHS)												X												
- Complete final project report (WGNHS / USGS)																							X	
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
Federal Fiscal Year (USGS)					2013				2014				2015				2016				2017			
State Fiscal Year (WGNHS)			2013				2014				2015			2016			2017							

Note: USGS project work begins in FY2013 following approval of a Joint Funding Agreement

APPENDIX A

Benefits of groundwater studies and flow models

The WGNHS and the USGS have worked cooperatively on many regional-scale groundwater studies that include computerized groundwater flow models. Such projects have included Sauk, La Crosse, Rock, and Dane Counties, and the 7-county Southeast Wisconsin Regional Planning Commission area. These efforts are customized to address the geologic and hydrogeologic setting, the issues and concerns in the area, and the resources available for the project.

For this project focusing on western Chippewa County, the purpose is to provide science-based information about groundwater resources. Such information can be used to help manage these resources to ensure continued availability of high quality drinking water and preservation of local surface-water features. One of the best ways to illustrate and use the groundwater information is to incorporate it into a computerized groundwater flow model. A flow model is a tool that allows us to simulate water levels and the rates and directions of groundwater flow. We use groundwater models to illustrate groundwater flow paths, to determine how a new well could change local groundwater levels, and to simulate groundwater flow to lakes, streams, and springs. Models provide accurate estimates of changes in groundwater levels resulting from changes to the groundwater system, such as additional wells or changes in rainfall. People use groundwater models to assist with numerous types of natural resource, land use, and economic decisions.

The following is a partial list of questions and issues that can be addressed with information from a groundwater flow model:

What goes into the model?

The model incorporates the thickness and extent of geologic formations, such as the layers of sandstone, shale and limestone in the region. Each layer of sand and gravel or rock in the model is assigned some hydrogeologic characteristics, such as the amount and rate at which groundwater flows through the geologic material. The model also includes the locations of wells and pumping rates, and the location and flow in streams and rivers. Another very important input to the model is the amount of rainfall and snowmelt that reach the groundwater system, referred to as “recharge”.

Some of these characteristics, for example, well locations and pumping rates, may change over time. Impacts of changes in pumping rates and locations can be evaluated by using the model to test differing scenarios. For example the model can be run several times with different configurations of pumping wells, pumping rates, or changes in groundwater recharge. This provides insight into effects of pumping, land use, or drought on stream flow or groundwater levels. For this project, we plan to use the model to test scenarios between pre-mine and post-mine conditions, or before or after expansion in irrigated land. The current proposal is limited to a “steady-state” model that cannot reproduce seasonal changes in the hydrologic system. Although a transient model would account for seasonal fluctuations it requires significantly more data for calibration, and in turn, significantly more time and cost for development.

How is the model useful to understand future land use or water management scenarios?

This project includes the use of a Soil Water Balance (SWB) model. This model is independent of the groundwater flow model, and its purpose is to estimate groundwater recharge over the study area. The

SWB model focuses on properties above the water table, and incorporates land-use, soil type, soil water storage and topographic information. The SWB model results are estimates of groundwater recharge that vary over the study area, based on the type of soil (sandy or clayey), the type of vegetation (forest, row crop, pasture or developments) and the daily temperature and amount of rain or snowfall. One set of the SWB model results will simulate current conditions—that is existing land use, soil type, and topography. The model will then be modified to produce a second set of estimates that incorporate changes to land use, soil type and topography at a future time period, following reclamation of area sand mines.

What is MODFLOW and how does it work?

MODFLOW is a widely-used software package used to simulate groundwater flow (below the water table), developed by the U.S. Geological Survey. Information used with MODFLOW to construct a model of a specific area includes geologic layers (i.e. model layers), recharge, well locations, pumping rates, surface water features where applicable, and the groundwater storage and flow properties of the geologic layers.

After the model is built (meaning all the information is put into the computer program), it is calibrated by comparing measurements of streamflow and water levels to calculated or modeled values for baseflow and water levels. The inputs to the model (such as recharge and permeability of the rock layers) are adjusted until the modeled values closely match measurements. Sensitivity analysis is also part of the calibration process, and it allows us to understand how much changing the inputs to the model changes the results. By identifying which model parameters are the most sensitive (i.e., generate the largest changes in model results), we develop a better understanding of the most important controls on the groundwater system. Ultimately, this informs us about the model's ability to correctly simulate the actual hydrologic system and identify strengths and limitations of the groundwater model.

The model results are a map of water levels and rates of flow in streams. You can understand the impacts of pumping, for example, by running the model with and without wells and comparing the results.

What types of data will be collected during the project?

We currently have 2 gages on local streams that measure flow. Several mining companies have installed monitoring wells to collect water levels. We have collected, or mining companies have shared, detailed geologic and hydrogeologic information at several sites (including geophysical logs and pump tests). The WGNHS maintains databases of well construction records and stratigraphic logs for Chippewa County that can be used in constructing the model layers.

What do we want to be able to learn from a SWB and MODFLOW model of western Chippewa County?

- a. The calibrated MODFLOW model will characterize current conditions, allowing us to estimate groundwater flow rates and time of travel from a mine to near-by off site wells and from a watershed divide to a point of stream discharge.
- b. The calibrated MODFLOW model will describe the extent and direction of vertical groundwater flow and the amount and rate of groundwater recharge/or discharge for each model scenario. The scenarios will evaluate conditions immediately prior to frac sand mining and two future scenarios representing anticipated landscape and pumping conditions in 2030 and 2050.

- c. The MODFLOW model will be used to estimate how much groundwater flows vertically between distinct geologic units.
- d. The MODFLOW model will focus on baseflow in streams and predict changes to stream baseflow and groundwater conditions under different groundwater use and recharge scenarios. The model will not be a transient model, and therefore it will not be used to estimate surface runoff (storm-flow discharge) from mined sites, how the discharge of spring runoff from snowmelt may be influenced by the mines, or how seasonal streamflows are affected.
- e. The MODFLOW model will simulate changes to stream baseflow as mines and irrigated agriculture are expected to change over time (scenarios representing 2030 and 2050). We anticipate using the SWB model to evaluate questions related to anticipated changes from mine reclamation, such as: How removal of the forested vegetation, topsoil, subsoil, and overburden (during the mining process) could affect groundwater recharge.
- f. The MODFLOW model will be used to evaluate the elevation of perennial streams and how that might change. For example, will the point in the landscape where baseflow first occurs become appreciably higher or lower in the landscape?
- g. The MODFLOW model will be used to simulate the aerial extent of drawdown from irrigation wells and wells used to supply wash plants. This will be performed by comparing current pumping conditions to a scenario with no pumping (pre-human development). The model cannot be used to simulate the recovery of water levels after pumping ceases in individual wells because it is not a transient model.
- h. The calibrated MODFLOW model will be used to identify groundwater divides and compare them to surface water divides. The SWB and MODFLOW models will be used to simulate the infiltration of water through the mine sites to deep groundwater flow systems that extend beyond the immediate surface watersheds.
- i. Data used by the model will be used to evaluate the proportion of groundwater consumption attributed to agriculture, municipal water supply, industrial and mining use. The MODFLOW model will be used to simulate a full built-out scenario (~2030) of mine expansion and resulting water-level changes throughout the area of focus.
- j. The SWB and MODFLOW models will be used to evaluate landscape and water use conditions immediately prior to frac sand mining and for two future scenarios representing maximum mine operation (~ 2030) and post-mine reclamation (~ 2050).

Can model results be “transferable” to other locations with similar geology?

The model is only generally transferable. What does this mean? It can be used to provide specific estimates of drawdown or changes in baseflow only in areas simulated directly in the model. Beyond that region, model results can be used to develop “rules of thumb” based on what is learned from the model results. We will develop a set of transferrable insights, which can help guide decision making within neighboring counties. An example may include an evaluation of baseflow reduction associated with distances between wells and streams. General rules of thumb will be developed for areas of similar hydrogeology, for example: Eau Claire, Dunn, and Barron counties, but not statewide.

APPENDIX B

Project Investigator Biographies

Michael Fienen is a Research Hydrologist with the U.S. Geological Survey Wisconsin Water Science Center in Middleton, WI and an Adjunct Assistant Professor in the Department of Geoscience at the University of Wisconsin—Madison. His expertise is in groundwater science, modeling, data analysis, uncertainty analysis, and the calibration of models. Michael's recent projects include calibration of a regional groundwater model evaluating groundwater impacts due to irrigation in the Northern High Plains Aquifer in Nebraska, assessment of impacts from Sea Level Rise at Assateague Island National Seashore in Maryland and Virginia, and characterization of hydrologic conditions in the Bad River Watershed in Wisconsin in the context of a large proposed iron mine. Michael also develops software and techniques for calibration and uncertainty analysis.

Madeline Gotkowitz is a Hydrogeologist at the Wisconsin Geological and Natural History Survey and a Professor at the University of Wisconsin – Extension. Her current research focuses on subsurface fate and transport of human enteric viruses, and groundwater flow and transport across aquitards. Madeline's field-based investigations of arsenic in groundwater address conditions in surficial and bedrock aquifers, and the affect of well disinfection on arsenic release. Several of her recent projects included working with local planning departments and land use managers to integrate hydrogeologic information with groundwater concerns in Sauk, Iowa and Columbia Counties.

Paul Juckem is a Hydrologist with the U.S. Geological Survey Wisconsin Water Science Center in Middleton, WI. His expertise in groundwater flow modeling is used in studies of regional water resource assessments, groundwater/surface-water interaction, and water quality characterization of lakes, streams, and aquifers. Some of his recent research involved evaluating effects of water diversions on water levels in northern Wisconsin lakes, visualizing groundwater and surface water interaction on Tribal reservations, assessing water resources on U.S. Forest Service lands in Wisconsin, and simulating groundwater flow to wells, lakes, and streams in the Rock River Watershed of southeast Wisconsin and in Polk, St. Croix and Pierce Counties in northwestern Wisconsin.

Michael Parsen is a Hydrogeologist at the Wisconsin Geological and Natural History Survey in Madison, WI. His recent work has focused on the development of an updated regional groundwater flow model for Dane County, Wisconsin. This model incorporated numerous regional datasets including LiDAR and high-quality geophysical logs to construct a detailed representation of the hydrogeologic system. Michael is also involved with ongoing efforts to improve the Statewide groundwater monitoring network in cooperation with the WI DNR and the USGS. His background in geological engineering and contaminant hydrogeology provides insights into groundwater monitoring and remediation. Michael is also committed to engaging the public in education and outreach opportunities as they relate to groundwater and water resources management.

APPENDIX C

Project Stakeholders Group Charge

The Project Stakeholders Group is advisory to the Chippewa County Department of Land Conservation & Forest Management (LCFM).

The group has been established to assist Chippewa County LCFM, the Wisconsin Geological and Natural History Survey (WGNHS), and the U.S. Geological Survey (USGS) to conduct a multi-year hydrologic investigation of western Chippewa County, Wisconsin.

The general purpose of the project is to:

1. Develop and calibrate soil water balance and groundwater flow models to evaluate the impacts of current and future water use and topography on the hydrologic system.

These models will be used to:

- A. Evaluate impacts that current groundwater use associated with frac sand mining and irrigated agriculture have on water resources,
 - B. Evaluate how changes in topography (i.e., mine reclamation) and water use (i.e., irrigated agriculture and industrial sand production) affect water resources through two scenario simulations representing peak frac sand production (~2030) and post-mine reclamation (~2050).
2. Disseminate the study results to project stakeholders and the general public

Results of the modeling study will be made available to all interested parties through a series of presentations and a final report. This will provide all parties with technical analyses regarding the effects of mining, irrigation and other high-capacity groundwater uses on streamflow and groundwater levels, to support informed decision making by facility operators, local units of government, regulatory agencies, and the general public.
 3. Transfer the study results to similar geologic/hydrologic settings as appropriate

Results of the groundwater flow modeling will form the basis for a set of insights regarding the response of expected groundwater resources to stressors (e.g., pumping) in neighboring areas with comparable geologic and hydrologic settings.

Duties and Responsibilities

The Project Stakeholders Group (PSG) members will:

1. Assure structured communication between the public agencies, who are conducting the study, and stakeholder interests who are participating in the study.
2. Serve as representatives and express the interests of their respective public and private sector organizations.

3. Actively participate in project meetings and pursue opportunities to collaborate on project tasks related to the technical investigation and outreach components of the modeling study.
4. Systematically review project status and provide feedback to support the successful completion of project tasks related to the technical investigation and outreach components of the modeling study.

Specific duties and assigned tasks are as follows:

1. Participate in annual project review and planning meetings conducted by the County to track progress, solicit feedback, and seek input on planned project tasks.
2. Assist in the dissemination of information generated through the project.
3. Provide input to and confirm the validity of data used in the technical investigation and modeling efforts (SWB and MODLFOW).
4. Provide input regarding the conditions (i.e., landscape and pumping) representing the current and two future scenarios (i.e., approximately 2030 and 2050) to be evaluated through model runs.
5. Review and provide comments on periodic status reports prepared by Chippewa County LCFM.
6. Review and provide comments on working draft(s) of the interim project report (2014 – 2015), and final project report (2016 – 2017).

Term of Ad Hoc Committee, Reimbursement, and Anticipated Meetings

The stakeholders group will serve during the full implementation phase of the study.

The group will meet on an annual basis to fulfill its charge and responsibilities.

A tentative schedule of anticipated meetings to initiate and implement the project is provided in Table 1 – Project Workflow and Activities Schedule.

Stakeholder Group Representation

Non-Metallic Mine Interests

- Superior Silica Sands
- Preferred Sands
- Chippewa Sand Company
- EOG Resources
- Taylor Creek Transit, LLC

Agricultural Interests

- Wisconsin Farmers Union
- (Irrigating Producer)

Environmental Interests

- Trout Unlimited

Agency Interests

- DNR Water
- DNR – Fish/Wildlife
- Chippewa Co. Extension

Citizen Interests

- (Citizen Representative)

Staff Support

- D. Masterpole, LCFM
- Seth Ebel, LCFM Project Engineer

APPENDIX D
PROJECT BUDGET 2012 - 2016

Calendar Year	2012			2013			2014			2015			2016			
Federal Fiscal Year (Oct 1 - Sept 30)	FY2013			FY2014			FY2015			2016			2017			
	LCFM	USGS	WGNHS	LCFM	USGS	WGNHS	LCFM	USGS	WGNHS	LCFM	USGS	WGNHS	LCFM	USGS	WGNHS	TOTAL
EXPENDITURES																
Groundwater Component																
Data Collection and Interpretation			\$45,985			\$11,943										57,928
Soil Water Balance (SWB) Modeling			\$3,261			\$3,323			\$10,486							\$17,070
Groundwater Modeling and Calibration		\$18,000			\$70,000											\$88,000
																\$0
Scenario Testing								\$70,000				\$10,092				\$80,092
Transferability											\$72,000					\$72,000
Public Outreach																\$0
Fact Sheet(s)			\$6,891			\$3,323										10,214
Initial Public Meetings			\$7,122			\$3,923			\$3,995			\$4,062			\$6,096	25,198
Reporting & Presentations									\$3,395			\$3,462		\$65,000	\$10,864	82,721
Agency Expenses Charged to County		\$12,600	\$63,259		\$49,000	\$22,512		\$49,000	\$17,876		\$50,400	\$17,616		\$45,500	\$16,960	\$344,723
Agency In Kind Expenses Not Charged to County		\$5,400			\$21,000			\$21,000			\$21,600			\$19,500		\$88,500
Total Project Expenditures		\$81,259			\$92,512			\$87,876			\$89,616			\$81,960		\$433,223
REVENUE/CONTRIBUTIONS																
Chippewa County	\$75,859			\$71,512			\$66,876			\$68,016			\$62,460			\$344,723
USGS		\$5,400			\$21,000			\$21,000			\$21,600			\$19,500		\$88,500
WGNHS																
Total Project Revenue/Contributions	\$75,859	\$5,400		\$71,512	\$21,000		\$66,876	\$21,000		\$68,016	\$21,600		\$62,460	\$19,500		\$433,223