Environment and Natural Resources Trust Fund

2023 Request for Proposal

General Information

Proposal ID: 2023-134

Proposal Title: Mapping Aquifer Recharge Potential

Project Manager Information

Name: Peter Kang

Organization: U of MN - St. Anthony Falls Laboratory

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Project Basic Information

Project Summary: We develop a practical tool for mapping aquifer recharge potential; demonstrate it with laboratory and field tests; and use it to evaluate the recharge potential of several aquifers in Minnesota.

Funds Requested: $417,000

Proposed Project Completion: June 30, 2026

LCCMR Funding Category: Water Resources (B)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Groundwater is the world's largest freshwater resource and sustains stream levels through baseflow. In Minnesota, groundwater supplies about 80% of Minnesotans' drinking water and is critically important for irrigation. However, some regions are coming up short on groundwater supply and experiencing declines in groundwater levels. In 40 years of records, the record number of complaints was filed to the Minnesota Department of Natural Resources (DNR) in 2021 due to dry well issues. Several regions across Minnesota have reached environmental flow limits that are required to maintain healthy ecosystems, and this has led the DNR to designate them as Groundwater Management Areas. According to a publication in Nature (one of the most respected academic journals), many parts of Minnesota were indeed classified as regions where the environmental flow limits are reached. The decreases in groundwater levels have the potential to severely restrict population and economic growth, especially in the groundwater-dependent suburban and ex-urban communities. With anticipated climate change impacts, the situation will be exacerbated. Managed aquifer recharge (MAR), also known as water banking, is water management technology that recharges an aquifer using either surface or underground recharge techniques. Managed aquifer recharge can be a powerful solution for securing sustainable water resources.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

For successful implementation of MAR, we need the ability to quantify aquifer recharge potential, which can be defined as the maximum volume of water that can be sustainably recharged over a target duration. MAR achieves aquifer recharge through infiltration basins (surface recharge) or injection wells (direct underground recharge). However, various factors such as the clogging of infiltration basins and inter-aquifer leakage affect aquifer recharge potential. Currently, there is no practical tool that quantifies the aquifer recharge potential of infiltration basins and injection wells.

This project develops a first-of-its-kind GIS-based mapping tool that quantifies aquifer recharge potential from key hydrogeological and operational parameters. The tool will efficiently produce recharge potential maps either using infiltration basins or injection wells. We will demonstrate the tool with large-scale laboratory experiments that visualize the infiltration and clogging processes, and also with field tests at the UMN hydrogeology field campsite. The validated tool will be applied to map the aquifer recharge potential of vulnerable aquifers in Minnesota. Throughout the project period, agencies with water-management authority, including Minnesota's departments of Natural Resources and Health, and other interested stakeholders, including the Metropolitan Council, cities, and their consultants, will be kept informed of the project design and goals.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

We address the urgent issues of groundwater availability and environmental flow limits by developing a practical tool for mapping aquifer recharge potential. The tool will be validated and applied to vulnerable aquifers in MN. The ability to predict and control aquifer recharge potential will bring multiple benefits: seasonal water availability, drought and flood mitigation, ecological flow support, contaminant mitigation, and financial benefit. This project will foster the MAR implementation in MN, and also contribute to the improved hydrogeologic characterization of target aquifers and to strengthening the existing field hydrogeology curriculum at the UMN, which is critical for training future hydrogeologists.

Activities and Milestones

Activity 1: Develop and apply a practical tool for estimating aquifer recharge potential of injection wells

Activity Budget: $106,620

Activity Description:
In this activity, we develop a practical mapping tool that quantifies aquifer recharge potential using injection wells. The tool will enable us to quantify how much water can be safely injected (injection capacity) using a well as a function of hydrogeologic and well operation parameters. The mapping tool will be implemented on GIS software and will calculate and produce spatial maps of well-based injection capacity once necessary data sets are given. We will apply the developed mapping tool to several vulnerable aquifers (at least two) across Minnesota. PI Kang successfully estimated the injection capacity of three aquifers in Minnesota through a previous ENRTF-supported project (Banking Groundwater), and has been supporting MPCA to consider aquifer storage and recovery as a potential solution for addressing PFAS contamination in Washington County. However, the existing methodology is based on simplifying assumptions and thus has limited applicability. The injection capacity estimation tool will be extended such that it can consider more diverse hydrogeologic conditions such as inter-aquifer leakage and fracture flows.

Activity Milestones:

Description	Completion Date
Develop a methodology that quantifies aquifer recharge potential of an injection well	June 30, 2024
Develop a user-friendly, GIS-based mapping tool for well-based aquifer recharge potential	October 31, 2024
Apply the developed mapping tool to several aquifers in Minnesota	June 30, 2025

Activity 2: Develop and demonstrate a practical tool for estimating aquifer recharge potential of surface infiltration basins

Activity Budget: $174,127

Activity Description:
We will develop a simple methodology that quantifies the aquifer recharge potential of an infiltration basin. The tool will estimate aquifer recharge potential as a function of hydrogeologic parameters and parameters that characterize an infiltration basin. The developed tool will be demonstrated by conducting large-scale laboratory experiments that visualize the infiltration and clogging processes at the St. Anthony Falls Lab (SAFL), Univ. of Minn. The effects of basin geometry and clogging of infiltration basin will be elucidated, and ways to control and enhance the infiltration rate will be investigated. Then, the methodology will be implemented as a user-friendly, GIS-based tool for mapping the aquifer recharge potential of infiltration basins. Combined with activity 1, maps showing aquifer recharge potential using either injection well or infiltration basin will be produced, which will enable us to compare between the well-based injection and surface infiltration. The tool will also enable us to identify ideal site locations for aquifer recharge implementation.

Activity Milestones:

Description	Completion Date
Develop a methodology that quantifies aquifer recharge potential of an infiltration basin	September 30, 2024
Demonstrate the developed methodology by conducting large-scale laboratory experiments	June 30, 2025
Develop a user-friendly, GIS-based mapping tool for aquifer recharge potential using infiltration basin	December 31, 2025

Activity 3: Field demonstration at the UMN hydrogeology field campsite

Activity Budget: $106,253

Activity Description:
To perform a field demonstration, we will first pursue the required permits from the Minn. Dept. of Health and USEPA for infiltration and injection tests at the University of Minnesota Field Hydrogeology (Hydrocamp) well field following the permit path established by the St. Michael aquifer storage and recovery site approval. The hydrocamp site has multiple pumping and monitoring wells, and the site is more than 1,500 feet away from any domestic water supply well. Thus, the potential risk related to field tests is minimal. Well-based injection capacity will be estimated by measuring injection rate and hydraulic head at the pumping well, and infiltration-based recharge potential will be estimated by creating an infiltration basin and measuring the basin level and the aquifer responses during the infiltration. Finally, research and design outcomes from the fieldwork will be incorporated into the existing curriculum of the field hydrogeology course at UMN.

Activity Milestones:

Description	Completion Date
Pursue permits for field tests at the U of M hydrogeology field camp site	June 30, 2024
Perform field tests at the UMN field camp site, if permitted	December 31, 2025
Integrate research outcomes into the existing field hydrogeology curriculum	June 30, 2026

Activity 4: Address regulatory factors and engage stakeholders throughout the planning and implementation stages of the project

Activity Budget: $30,000

Activity Description:
This project directly addresses the gaps in permitting the application of managed aquifer recharge in Minnesota. Freshwater will be the public-facing liaison for this research, staying engaged in the technical work in a way that allows for communication of key concepts through fact sheets or white papers, public talks, one-on-one discussions or whatever means are appropriate for the varied stakeholders. Aquifer recharge potential maps will allow state agencies and stakeholders to assess the aquifer-scale suitability of MAR. Freshwater will review the two prior times that Minnesota considered assuming primacy over injection wells from the USEPA (once by the MPCA and once by MDH); the reasons behind not pursuing primacy, and costs associated with doing so. They will review the permitting path established by the St. Michael example, and review State Well Code for changes needed to allow injection for Class V wells. Freshwater will make recommendations for state policy changes so that MAR can be more easily implemented in the future and identify other stakeholders such as professional or technical societies or coalitions of cities that may be interested in MAR. The legislative branch will be kept apprised through visits with House and Senate leaders.

Activity Milestones:

Description	Completion Date
Review potential field sites, maps, cross sections, aquifer properties, cores for permitting and communication needs	June 30, 2025
Give quarterly updates to state agency leaders (Interagency Groundwater Team)	December 31, 2025
Provide annual updates to legislators	June 30, 2026
Summarize regulatory barriers to aquifer recharge with permitting recommendations	June 30, 2026
Develop and deliver derivative work to non-technical audience—talks, factsheets	June 30, 2026

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Carrie Jennings	Freshwater Society	Dr. Jennings will be the public-facing team member who will keep the State regulatory agencies informed of the project work, applying for permits to conduct the work, and making recommendations for policy changes if ASR is to be more easily implemented in the future.	Yes
Anthony Runkel	Minnesota Geological Survey	Dr. Runkel is Lead Geologist of the Minnesota Geological Survey and conducts research that targets geologic controls on groundwater flow. Dr. Runkel will support aquifer characterization and mapping.	Yes
John Nieber	University of Minnesota	Dr. Nieber has strong expertise in vadose zone hydrology. Dr. Nieber will support activities related to quantifying the recharge potential of infiltration basins.	Yes
John Gulliver	University of Minnesota	Dr. Gulliver will support activities related to measuring and optimizing recharge rates of infiltration basins.	Yes

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?

This project will produce practical tools that will assist current practices of water resources management and produce important hydrogeologic information for several vulnerable aquifers in Minnesota. The tool can be extended to other aquifers across the state and beyond. We will continue to work with state executive branch agencies and EPA Region 5 that have a role in water governance to create safe and efficient review and permitting processes for managed aquifer recharge. Our team will actively apply for additional research grants (e.g., NSF, USGS, USDA) to further develop and apply the tool.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Managed Aquifer Recharge	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04t	$350,000

Project Manager and Organization Qualifications

Project Manager Name: Peter Kang

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.

PI Kang is a McKnight Land-Grant Assistant Professor and the Gibson Chair of Hydrogeology in the Department of Earth & Environmental Sciences at the University of Minnesota-Twin Cities. Kang received an NSF CAREER award in 2021. Before joining UMN, Kang was a researcher at Korea Institute of Science & Technology (KIST) in South Korea where he conducted various practical research projects, including aquifer storage and recovery. Prior to his research scientist position, he was a postdoctoral associate at MIT and received his Ph.D. in hydrology from MIT.

PI Kang has strong expertise and research experience in aquifer storage. Kang successfully estimated the injection capacity of three aquifers in Minnesota through an ENRTF-supported project. As a research scientist at KIST, Kang participated in a government-funded aquifer storage and recovery project to secure sustainable water resources for a metropolitan city. Kang has strong expertise in groundwater modeling and is also passionate about teaching, mentoring, and increasing public awareness in water resources related issues. Kang teaches general hydrogeology, field

hydrogeology, fractured rock hydrogeology, and fluid earth dynamics.

This project has a strong multidisciplinary team of Co-PIs. Dr. Carrie Jennings is Research and Policy Director for Freshwater and was formerly a field geologist for 24 years, 22 of those with the Minnesota Geological Survey and two with the DNR, Division of Lands and Minerals. Dr. John Gulliver is a Professor Emeritus in the Department of Civil, Environmental and Geo- Engineering, with 40 years of experience leading projects in water resources research. Dr. John Nieber is a professor in the Department of Bioproducts and Biosystems Engineering and conducts research on hydrologic processes including streamflow, infiltration, groundwater recharge, groundwater-surface water interaction, and contaminant transport. Dr. Anthony (Tony) Runkel is Lead Geologist of the Minnesota Geological Survey and conducts research that targets geologic controls on groundwater flow.

Organization: U of MN - St. Anthony Falls Laboratory

Organization Description:
Saint Anthony Falls Laboratory (SAFL) at the University of Minnesota functions at the intersection of science and engineering to collaborate solutions to real-world fluid flow problems. SAFL serves as a resource for departments across the Twin Cities campus, the statewide University system, and the broader research community. Our connections and collaborations reach across the country and all over the world. We partner with local, state and federal agencies; private consulting firms; businesses of many kinds; technical associations; and other educational institutions to expand knowledge and solve problems. Research at SAFL is categorized into four primary categories: renewable energy; earth surface, water, and life; global environmental change; and biomedical and fluid mechanics.

Our mission is threefold:
1. To advance fundamental knowledge in engineering, environmental, geophysical, and biological fluid mechanics by conducting cross-cutting research that integrates disciplines in science and engineering;
2. To benefit society by implementing this knowledge to develop physics-based, affordable, and sustainable engineering solutions to major environmental, water, ecosystem, health, and energy-related problems; and
3. To disseminate new knowledge to UMN students, the engineering and scientific community, and the public by educational and outreach activities and partnerships with government and industry.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Peter Kang		PI and project manager; will be in charge of overall project management and tasks related to well-based injection capacity estimation.			27%	0.15		$19,871
Post-doctoral Researcher		Develop and apply a tool for estimating well-based aquifer recharge potential.			20%	0.7		$89,310
Graduate Student		Develop and apply a tool for estimating aquifer recharge potential of infiltration basins. Participate in field characterization and field tests.			48%	1.5		$148,122
Tony Runkel		Support aquifer characterization and mapping.			24%	0.12		$14,749
SAFL engineer		Support large-scale laboratory experiments			24%	0.45		$42,840
John Nieber		Co-PI, support activities related to infiltration basins.			27%	0.15		$23,952
Undergraduate Student		Support laboratory and field experiments.			0%	0.25		$7,800
John Gulliver		Co-PI, support activities related to measuring and interpreting infiltration rates.			8%	0.06		$13,457
							Sub Total	**$360,101**
Contracts and Services								
Freshwater Society	Sub award	Dr. Jennings at Freshwater will be the public-facing team member who will keep the State regulatory agencies informed of the project work, applying for permits to conduct the work, and making recommendations for policy changes if MAR is to be more easily implemented in the future.				0.33		$30,000
							Sub Total	**$30,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Supplies for field experiments and lab analysis	To purchase supplies necessary for conducting laboratory and field tests and analyzing sampled water and sediment					$4,899
	Equipment	Pressure/conductivity/temp/tracer probes	To obtain laboratory and field data for recharge rate estimation					$5,000

	Equipment	Computer for student	To conduct data analysis and mapping of aquifer recharge potential					$3,000
							Sub Total	**$12,899**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Other	Travel costs to visit field sites	To visit field sites for data collection, site characterization, and field tests.					$8,000
							Sub Total	**$8,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Water and Sediment Analysis	To conduct various lab analyses on sampled water and sediment					$6,000
							Sub Total	**$6,000**
							Grand Total	**$417,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered F&A	Support of SAFL facilities where research will be conducted.	Secured	$186,839
			Non State Sub Total	**$186,839**
			Funds Total	**$186,839**

Attachments

Required Attachments

Visual Component

File: dd78833b-520.pdf

Alternate Text for Visual Component

The illustration of managed aquifer recharge. Both well-based aquifer storage and infiltration basin-based aquifer recharge will be considered. The practical tool that quantifies aquifer recharge potential will be developed and demonstrated with laboratory and field tests. Finally, the tool will be used to map the recharge potential of several aquifers....

Optional Attachments

Support Letter or Other

Title	File
Support letter from MDH	4ebc1afa-25b.pdf
Support letter from MPCA	ede6f49e-538.pdf
Support letter from University of Minnesota	ddf4371a-065.doc
Support letter from Freshwater Society	1e7d7bd6-25a.docx

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

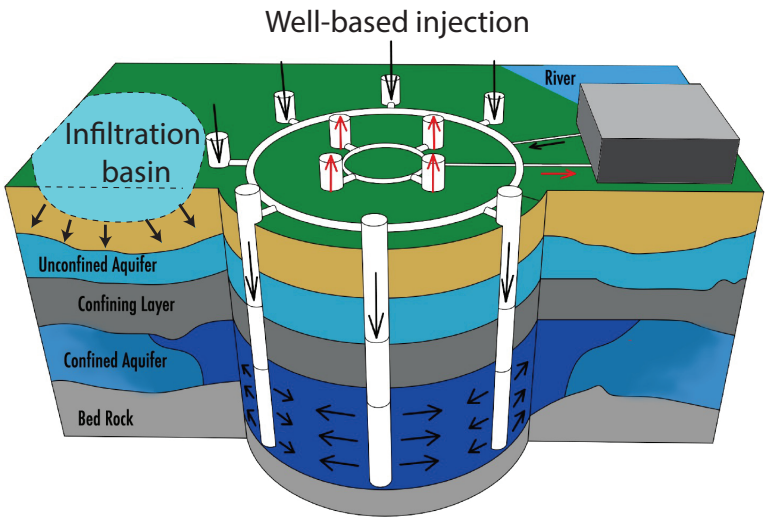
Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Mapping Aquifer Recharge Potential

- Groundwater supplies about 80% of Minnesotans' drinking water and is critically important for irrigation.
- However, the decrease in groundwater level is becoming a major issue.

➢ Managed aquifer recharge can be a powerful solution.



Map aquifer recharge potential