Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-114

Proposal Title: Multi-scale Aquifer Characterization for Successful Aquifer Storage/Recovery

Project Manager Information

Name: Peter Kang

Organization: U of MN - St. Anthony Falls Laboratory

Office Telephone: (612) 624-5779

Email: pkkang@umn.edu

Project Basic Information

Project Summary: We develop a multi-scale aquifer characterization tool that quantifies ASR suitability and optimizes well operations. We will apply the tool to several vulnerable aquifers across Minnesota and perform field tests.

Funds Requested: $671,000

Proposed Project Completion: 2024-06-30

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 supplies 78% of Minnesotans' drinking water and dependence on groundwater has increased. Some regions are coming up short because, even though the water storage capacity of our aquifers is large, recharge is limited by the extent of recharge areas, land-use changes, and low infiltration rates. Several regions across Minnesota have reached environmental flow limits required to maintain healthy ecosystems due to declining groundwater levels and are being managed by the Department of Natural Resources. Decreases in groundwater level in suburban and ex-urban communities impacted their economies. Aquifer Storage and Recovery (ASR) can be a solution to groundwater sustainability. Moreover, ASR is often an economical option, and municipalities can have financial benefit by implementing ASR (as demonstrated at the ASR site in St. Michael).

Our team has been working on an ENRTF-supported project (Phase 1) to evaluate the engineering, hydrogeologic, economic and policy benefits of, and barriers to aquifer recharge. We identified four important aquifers across Minnesota and successfully identified data needs and knowledge gaps for the successful implementation of ASR. This proposed project (Phase 2) will tackle the identified main barriers, study ASR feasibility in an area of need, and demonstrate the potential for ASR with field tests.

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

We propose to develop a multi-scale characterization tool that quantifies and maps ASR suitability at aquifer scale, and a well operation optimization tool that maximizes the operation efficiency of ASR wells. We propose to develop aquifer-scale mapping tools to quantify: 1) how much water can be injected and 2) subsequently recovered and 3) what water quality issues may arise during ASR. The mapping tools will be based on GIS software and will calculate and produce spatial maps of ASR suitability once necessary data sets are given. We will apply the aquifer-scale characterization tools to several vulnerable aquifers across Minnesota. In addition to the aquifer-scale ASR suitability mapping, this project also addresses 4) well-operation optimization; efficient well operation is critical to the success of ASR. The well-operation optimization tool enables the real-time optimization of well-field pumping and withdrawal to maximize the injection capacity and recovery efficiency of ASR wells.

State agencies with water-management authority, including Minnesota's Departments of Natural Resources and Health, Metropolitan Council, and cities and their consultants will be kept informed of the project design, goals and assist in anticipating policy and economic considerations that might impact the implementation of ASR for the chosen aquifers.

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 tackle urgent water availability and ecological flow issues by developing innovative ASR tools and applying them to several vulnerable aquifers. ASR provides multiple benefits: seasonal water availability, drought and flood mitigation, ecological flow support, and financial benefit. The tool we develop can be applied to many other aquifers. We will produce ASR suitability maps for several vulnerable aquifers across Minnesota. Small-scale field tests are planned at the U of M hydrogeology field camp and ASR feasibility in Chanhassen will be studied. Our multidisciplinary team (UMN, MGS, USGS, Freshwater Society, and Barr Engineering) is well-positioned to undertake this important problem.

Activities and Milestones

Activity 1: Develop a comprehensive and quantitative framework for aquifer-scale ASR suitability mapping

Activity Budget: $107,947

Activity Description:
We develop a framework that predicts water quantity and quality evolution during ASR from key hydrogeological and geochemical properties. Three maps will be produced (injection capacity, recovery efficiency, and water quality) and then combined to produce an aquifer-scale ASR suitability map. Successful ASR implementation requires high efficiency in both injection and recovery. The maximum volume of water that can be injected through a well is defined as injection capacity, and recovery efficiency is the volume of recoverable water divided by the injected volume.
With an ENRTF-supported project (Phase 1), our team has successfully developed an efficient tool that quantifies the injection capacity of an ASR well. In this project (Phase 2), we will develop a tool that quantifies recovery efficiency. We will also develop a robust process to evaluate the most likely ASR-related water quality changes at the aquifer-scale. Both water quality improvements and degradation have been reported during ASR operations. Native aquifer water and injected water geochemical information will be inputs to the geochemical model. Evaluation of output will identify potential water quality changes. The developed water quantity and quality prediction tools will be integrated into a GIS-based ASR suitability mapping tool.

Activity Milestones:

Description	Completion Date
Develop a tool that quantifies water quality evolution during ASR	2022-06-30
Develop a tool that estimates recovery efficiency of an ASR well	2022-06-30
Integrate tools to develop GIS-based ASR suitability mapping tool	2022-12-31

Activity 2: Apply the developed mapping tool to generate ASR suitability maps for several aquifers in Minnesota

Activity Budget: $122,972

Activity Description:
We will apply the developed GIS-based mapping tool to produce comprehensive ASR suitability maps of several aquifers across Minnesota. Three maps will be produced for each aquifer (injection capacity, recovery efficiency, and water quality) and then combined to produce an aquifer-scale ASR suitability map. Hydrogeologic data from the MGS will be incorporated in the GIS-based mapping tool. This activity will be conducted in close collaboration between UMN, USGS, and MGS.

Activity Milestones:

Description	Completion Date
Estimate water quality evolution at several representative locations in the chosen Minnesotan aquifers	2023-06-30
Estimate injection capacity and recovery efficiency of several aquifers across Minnesota	2023-06-30
Produce comprehensive ASR suitability maps for at least four aquifers in Minnesota	2023-12-31

Activity 3: Develop a well operation optimization technology, demonstrate at a field test site, and conduct ASR feasibility study in Chanhassen

Activity Budget: $395,081

Activity Description:
We will develop a well-based characterization and optimization technology to characterize site hydrogeology and to maximize injection capacity and recovery efficiency. The well operation technology combines data assimilation and well-operation optimization. This will provide a seamless workflow from aquifer-scale ASR suitability analysis to local-scale ASR operation.
Small-scale ASR tests are planned at the U of M hydrogeology field camp. We will pursue permits for ASR runs at the University of Minnesota Field Hydrogeology (Hydrocamp) well field to validate the well optimization tool and also to integrate research outcomes into the existing teaching curriculum.
ASR feasibility in Chanhassen will be studied with modeling and site characterization. Chanhassen is considering ASR to fill an isolated, buried glacial aquifer that has been pumped dry. Water could be injected into the dry buried glacial aquifer to provide a buffer of water capacity during the summer or during extended droughts. However, hydrogeology of the site has to be better understood to consider ASR. We will perform a desktop study and high-level site characterization to understand the feasibility of ASR. Also, various water sources will be considered.

Activity Milestones:

Description	Completion Date
Pursue permits for field tests at the U of M hydrogeology field camp site	2022-06-30
Develop a well operation optimization tool	2022-12-31
Perform site characterization and ASR feasibility study at Chanhassen site	2024-06-30
Perform field tests at the UMN field camp site and integrate it into existing curriculum	2024-06-30

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

Activity Budget: $45,000

Activity Description:
This project directly addresses regulations that limit or prohibit ASR in Minnesota. Freshwater will review and document state and federal regulations that apply across EPA Region 5, serving Illinois, Indiana, Michigan, Minnesota, Ohio, and 35 Tribes. They will engage state executive branch agencies and tribal governments that have a role in water governance and the Metropolitan Council with a role in regional water planning in periodic reviews of the work as it progresses. Freshwater will make recommendations for state policy changes if ASR is to 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 ASR. The legislative branch will be kept apprised through visits with House and Senate leaders, and by testimony in key water committees. 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. Suitability maps will allow state agencies and stakeholders to assess aquifer-scale suitability and safety of ASR.

Activity Milestones:

Description	Completion Date
Review field sites, maps, cross sections, aquifer properties, cores for permitting and communication needs	2023-06-30
Give quarterly updates to state agency leaders (Interagency Groundwater Team)	2023-12-31

Develop and deliver derivative work to non-technical audience—talks, factsheets	2024-06-30
Summarize regulatory barriers to ASR with permitting recommendations	2024-06-30
Provide annual updates to legislators	2024-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Anthony Runkel	Minnesota Geological Survey	Dr. Runkel is Chief Geologist of the Minnesota Geological Survey and conducts research that targets geologic controls on groundwater flow. Dr. Runkel will be in charge of aquifer characterization, perform borehole geophysics, and participate in field tests.	Yes
Melinda Erickson	U.S. Geological Survey	Dr. Erickson will direct and participate in the activities related to evaluating and assessing potential or measured geochemical changes in aquifers considered or tested for ASR. These geochemistry-related activities would include directing, supervising, and collaborating with graduate research assistants and others in geochemical data compilation, geochemical modeling, and sample analysis.	Yes
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

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 be funded?

This project will produce practical tools that will assist current practices of water resources management and produce important water quantity and quality information for several vulnerable aquifers in Minnesota. The tool can be extended to many other aquifers across the state. We will continue to work with state executive branch agencies and EPA Region 5 that have a role in water governance (MnDNR and MDH) to create safe and efficient review and permitting processes for ASR. Our team will actively apply for additional research grants (federal, state and industry) to further develop and apply the multi-scale characterization 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 an assistant professor and the Gibson Chair of Hydrogeology in the Department of Earth & Environmental Sciences at the University of Minnesota-Twin Cities. Before joining UMN, Kang was a research scientist at Korea Institute of Science & Technology (KIST) in South Korea where he conducted various practical research projects. Prior to his research scientist position, he was a postdoctoral associate in the Earth Resources Laboratory at MIT, and received his Ph.D. in hydrology from MIT.

PI Kang has strong expertise and research experiences in aquifer storage and recovery. Kang is currently in charge of estimating injection capacity of four aquifers in Minnesota (ENRTF supported project). As a research scientist at KIST,

Kang participated in a government funded ASR project to secure sustainable water resources for a metropolitan city. Kang also has a strong expertise in groundwater modeling and well operation optimization. Kang is also passionate about teaching, mentoring and increasing public awareness in water resources related issues. Kang teaches general hydrogeology, field hydrogeology, fracture 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. Melinda Erickson is a research hydrologist in the Minnesota office of the US Geological Survey, and a licensed professional engineer. Melinda has been working in the hydrogeology field since 1993, and for the past 20 years Dr. Erickson's research has focused on groundwater contaminants. Dr. Anthony (Tony) Runkel is Chief Geologist of the Minnesota Geological Survey and conducts research that targets geologic controls on groundwater flow. Tony has 30 years of experience mapping and conducting hydrogeologic projects.

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 tasks related to injection capacity and recovery efficiency estimation, and well operation optimization.			27%	0.18		$29,062
Post-doctoral Researcher		Develop a well operation optimization tool and demonstrate the developed tool at a field site.			25%	1.5		$100,320
Graduate Student		Develop an aquifer-scale ASR suitability mapping tool and apply the mapping tool to several aquifers in Minnesota. Participate in field characterization and field tests.			33%	1.5		$114,461
Tony Runkel		Lead aquifer characterization, perform borehole geophysics, and participate in field tests.			24%	0.21		$30,048
Scott Alexander		Lead field tests at the UMN field camp site and assist in the site characterization of an aquifer in Chanhassen.			24%	0.48		$39,322
							Sub Total	**$313,213**
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 ASR is to be more easily implemented in the future.				0.99		$45,000
U.S. Geological Survey	Sub award	Dr. Erickson at USGS will direct and participate in the activities related to evaluating and assessing potential or measured geochemical changes in aquifers considered or tested for ASR. These geochemistry-related activities include directing, supervising, and collaborating with graduate students and others in geochemical modeling, sample collection, and sample laboratory analysis.				0.99		$80,000
Barr Engineering	Professional or Technical	Professional services for Barr Engineering to characterize an aquifer in Chanhassen				1		$100,000

	Service Contract							
TBD	Professional or Technical Service Contract	Professional services for drilling, obtaining cores, and constructing monitoring wells				1		$100,000
							Sub Total	**$325,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Supplies for field experiments and lab analysis	To purchase supplies necessary for conducting field tests and analyzing sampled water and sediment					$5,000
	Equipment	Pressure/conductivity/temp/tracer probes	To obtain field data from monitoring wells for site characterization					$11,000
							Sub Total	**$16,000**
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.					$5,787
							Sub Total	**$5,787**
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					$11,000
							Sub Total	**$11,000**
							Grand Total	**$671,000**

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	$315,769
			Non State Sub Total	**$315,769**
			Funds Total	**$315,769**

Attachments

Required Attachments

Visual Component

File: d484e707-861.pdf

Alternate Text for Visual Component

The illustration of the multi-scale ASR characterization framework that will enhance water availability. Three maps will be produced (injection capacity, recovery efficiency, and water quality) and then combined to produce an aquifer-scale ASR suitability map. After regulation and socioeconomic considerations, several candidate ASR sites can be identified. Finally, we perform site-specific characterization and well operation optimization with an innovative well operation tool to secure water availability.

Optional Attachments

Support Letter or Other

Title	File
Chanhassen - Support letter	fe0a3ae4-df9.pdf
Riley Purgatory Bluff Creek Watershed District - Support letter	12bd0cb2-80d.pdf
U of M Earth Sciences - Support letter	a53947f5-456.pdf
U.S. Geological Survey - Support letter	fe73c6f8-bac.pdf
Freshwater Society - Support letter	bd8c7bc6-c9e.pdf
Minnesota Department of Health - Support letter	6f1a5f21-932.pdf
Letter of Intent - U of M	50d5bebf-86d.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

No

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Aquifer-scale Mapping

Injection Capacity

Recovery Efficiency

Water Quality Index

ASR Suitability Map

Regulation Index

Candidate ASR sites

Secure Water Availability

Water Quantity
+ Water Quality
+ Public Acceptance

Site specific characterization
& Well Operation Optimization