Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-059

Proposal Title: Site Suitability for Aquifer Storage and Recovery

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 GIS-based, site suitability mapping tool for aquifer storage and recovery; use it to evaluate several aquifers; and demonstrate it with field tests in a controlled setting.

Funds Requested: $394,000

Proposed Project Completion: June 30 2025

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 but some regions are coming up short on groundwater supply and experiencing decline in groundwater levels. Aquifer Storage and Recovery (ASR) can be a promising solution. The number of ASR systems implemented around the world is increasing exponentially, and they provide models for safe implementation. ASR can also be the economical option as demonstrated at the existing ASR site in St. Michael, Minnesota. However, ASR has not seen expanded application here, in part because we currently lack a comprehensive assessment tool that characterizes the site suitability for ASR. The Minnesota Department of Health generally feels that ASR can be done effectively and might offer good management options for some public water systems, but they currently lack the capacity to develop tools for cities.

Our team recently completed an ENRTF-supported project (Phase 1), Banking Groundwater, to evaluate the engineering, hydrogeologic, economic and policy benefits of, and barriers to aquifer recharge. We focused on four aquifers across Minnesota and successfully identified the data needs and knowledge gaps for ASR implementation. This proposed project (Phase 2) follows-up on the recommended critical next steps for ASR site evaluation. Our multidisciplinary team is well-positioned to address these steps.

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.

Successful ASR implementation requires high efficiency in both injection and recovery. Injection capacity is the maximum volume of water that can be safely injected through a well for a given duration, and recovery efficiency is the volume of recoverable water divided by the injected volume. Also, the ability to predict potential geochemical reactions is critical to evaluate treatment needs to address potential water-quality issues. Currently, there is no existing tool that comprehensively quantifies injection capacity, recovery efficiency, and water quality changes.

In this project, we will develop a first-of-a-kind GIS-based ASR suitability mapping tool that quantifies injection capacity, recovery efficiency, and water-quality from key hydrogeological and geochemical properties. The tool will combine the information (injection capacity, recovery efficiency, and water quality) to produce a suitability map for an entire aquifer (see Figure). We will apply the tool to at least three vulnerable aquifers across Minnesota and demonstrate the tool with field tests in a controlled setting at the UMN hydrogeology field campsite. 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 tackle urgent water availability and ecological flow issues by developing this ASR suitability mapping tool and testing it in the field at the UMN hydrogeology field campsite. ASR provides multiple benefits: seasonal water availability, drought and flood mitigation, ecological flow support, and financial benefit. This project will 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. Moreover, the developed mapping tool will be released as a user-friendly tool, and the project team will give tutorials to state agencies with interest.

Activities and Milestones

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

Activity Budget: $81,361

Activity Description:
In this activity, we develop a comprehensive mapping tool that quantifies ASR suitability at the aquifer scale. The tool will enable us to quantify: 1) how much water can be injected (injection capacity), 2) how much of the injected water can be subsequently recovered (recovery efficiency), and 3) potential water quality changes due to biogeochemical reactions during ASR (water quality). The mapping tool 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 developed mapping tool to several vulnerable aquifers (at least three) across Minnesota.
Inter-aquifer leakage will be considered in the injection capacity estimation tool, and various factors such as dispersive mixing between injected water and ambient groundwater, regional groundwater flow that could migrate the injected water, storage duration, and fracture flows will be considered for calculating recovery efficiency. Water quality prediction will be achieved with geochemical modeling. Aquifer-scale geochemistry, injected water quality, and sediment geochemistry will be inputs to the geochemical model, and the model output will enable us to identify potential water-quality changes. The geochemical modeling framework will enable us to identify the "most likely" groundwater quality changes during ASR.

Activity Milestones:

Description	Completion Date
Develop a tool that quantifies injection capacity and recovery efficiency of an ASR well	June 30 2023
Develop a tool that predicts water quality evolution during ASR	September 30 2023
Integrate tools to develop a user-friendly, GIS-based ASR suitability mapping tool	December 31 2023

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

Activity Budget: $131,496

Activity Description:
Several regions across Minnesota have reached environmental flow limits that are required to maintain healthy ecosystems, and this has led the Minnesota Department of Natural Resources to designate them as Groundwater Management Areas. In these and other parts of the state, decreases in groundwater level have the potential to severely restrict population and economic growth, especially in the groundwater-dependent suburban and ex-urban communities. We will apply the developed GIS-based mapping tool to produce comprehensive ASR suitability maps of several vulnerable aquifers (at least three) across Minnesota. Hydrogeologic data, geochemistry data, and sediment data will be compiled and will be incorporated in the GIS-based mapping tool. Using the mapping tool, 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. The produced ASR suitability maps will enable us to compare between aquifers and also within an aquifer to identify ideal site locations for ASR implementation. This activity will be conducted in close collaboration between the UMN, USGS, and MGS. The tool will be released as a user-friendly tool, and tutorial sessions will be organized for state agencies with interest.

Activity Milestones:

Description	Completion Date

Apply injection capacity and recovery efficiency estimation tool to at least three aquifers across Minnesota	June 30 2024
Apply the water quality prediction tool to at least three aquifers across Minnesota	September 30 2024
Produce comprehensive ASR suitability maps for at least three aquifers in Minnesota	December 31 2024
Provide tutorial sessions to state agencies	June 30 2025

Activity 3: Field demonstration at the UMN hydrogeology field campsite

Activity Budget: $151,143

Activity Description:

To perform a field demonstration, we will first pursue the required permits from the Minn. Dept. of Health and USEPA for ASR tests at the University of Minnesota Field Hydrogeology (Hydrocamp) well field following the permit path established by the St. Michael ASR 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. One or two more monitoring wells will be constructed at the Hydrocamp site, with new core and water samples to compare with existing data for a thorough hydrogeologic and geochemical characterization. Injection capacity will be estimated by measuring injection rate and hydraulic head at the pumping well, and recovery efficiency will be estimated by injecting water with tracers and measuring tracer concentration during the recovery phase. The developed water-quality prediction tool will be validated by collecting water samples during the recovery phase and performing water chemistry analysis. Finally, research and design outcomes from the fieldwork will be incorporated into the existing curriculum of the field hydrogeology course.

Activity Milestones:

Description	Completion Date
Pursue permits for field tests at the U of M hydrogeology field camp site	June 30 2023
Perform field tests at the UMN field camp site, if permitted	December 31 2024
Integrate research outcomes into the existing curriculum	June 30 2025

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 ASR 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. Suitability maps will allow state agencies and stakeholders to assess aquifer-scale suitability and safety of ASR. 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 ASR 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 ASR. The legislative branch will be kept apprised through visits with House and Senate leaders, and by testimony in key water committees.

Activity Milestones:

Description	Completion Date

Review field sites, maps, cross sections, aquifer properties, cores for permitting and communication needs	June 30 2024
Give quarterly updates to state agency leaders (Interagency Groundwater Team)	December 31 2024
Provide annual updates to legislators	June 30 2025
Summarize regulatory barriers to ASR with permitting recommendations	June 30 2025
Develop and deliver derivative work to non-technical audience—talks, factsheets	June 30 2025

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
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
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
Scott Alexander	University of Minnesota	Scott Alexander is a researcher in the Department of Earth and Environmental Sciences at the University of Minnesota. Scott has been managing the UMN field hydrogeology campsite and will lead field tests at the UMN field campsite.	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 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 ASR and for recommended changes to statute and rule. Our team will actively apply for additional research grants 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 research scientist at Korea Institute of Science & Technology (KIST) in South Korea where he conducted various practical research projects including ASR. 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 ASR. Kang successfully estimated injection capacity of three

aquifers in Minnesota through an 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 has a 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. 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 her research has focused on groundwater contaminants. Dr. Anthony (Tony) Runkel is Lead 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 ASR suitability mapping.			27%	0.18		$19,373
Post-doctoral Researcher		Develop a tool for estimating recovery efficiency.			20%	0.5		$57,012
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.			46%	1.5		$143,361
Tony Runkel		Support aquifer characterization and mapping.			24%	0.21		$14,727
Scott Alexander		Lead field tests at the UMN field camp site.			24%	0.45		$18,316
Patrick Arnold		IT and computation support			24%	0.45		$17,108
							Sub Total	**$269,897**
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.				0.33		$30,000
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		$50,000
TBD	Professional or Technical	Professional services for drilling, obtaining cores, and constructing monitoring wells				1		$15,000

	Service Contract							
							Sub Total	**$95,000**
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					$5,103
	Equipment	Pressure/conductivity/temp/tracer probes	To obtain field data from monitoring wells for site characterization					$6,000
							Sub Total	**$11,103**
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.					$9,000
							Sub Total	**$9,000**
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					$9,000
							Sub Total	**$9,000**
							Grand Total	**$394,000**

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	$188,774
			Non State Sub Total	**$188,774**
			Funds Total	**$188,774**

Attachments

Required Attachments

Visual Component

File: c4ae1c84-c8e.pdf

Alternate Text for Visual Component

The illustration of the ASR suitability mapping tool. The tool produces three maps (injection capacity, recovery efficiency, and water quality), which will then be combined to produce an aquifer-scale ASR suitability map. After socio-economic and regulation considerations, candidate ASR locations can be identified. We will perform field tests to validate the developed tool....

Optional Attachments

Support Letter or Other

Title	File
MPCA support letter	8f4b9ef7-9c1.pdf
MDH support letter	b38e2682-53d.pdf
USGS support letter	fb9a2e87-3e9.pdf
Freshwater support letter	c5e61842-5c1.pdf
UMN ESCI support letter	bec2bd1a-cda.pdf

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?

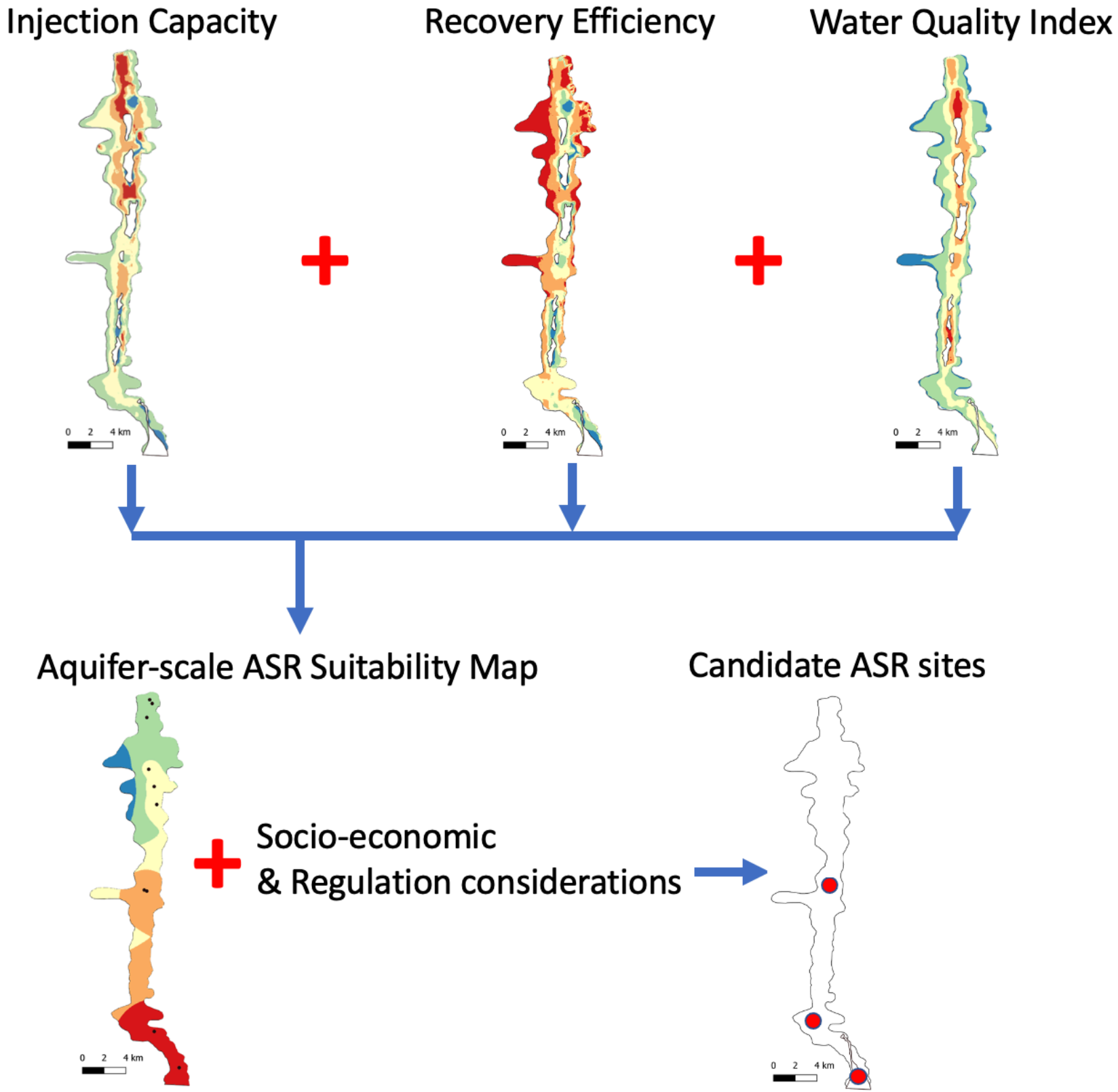
N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration


Injection Capacity
Recovery Efficiency
Water Quality Index
0 2 4 km
0 2 4 km
0 2 4 km
Aquifer-scale ASR Suitability Map
Candidate ASR sites
Socio-economic
& Regulation considerations
0 2 4 km
0 2 4 km