Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-286

Proposal Title: Downscaling Water Storage for Comprehensive Water Resources Management

Project Manager Information

Name: John Nieber

Organization: U of MN, College of Food, Agricultural and Natural Resource Sciences

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Project Basic Information

Project Summary: Water storage estimates (groundwater, soil moisture, lakes) are essential to comprehensive water management. We will integrate satellite monitoring with ground-based measurements to derive water storage estimates at useful spatial scales.

Funds Requested: $592,000

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

Narrative

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

The water stored in lakes, wetlands, streams, soil and groundwater aquifers determine the function of ecosystems and the benefits that humans gain from them. When lake and wetlands water levels, or streamflows are reduced during periods of low precipitation or excessive water use, recreational activities, wildlife and commerce suffer as a result. When surface water levels and streamflows increase during periods of excessive precipitation, damage can occur to commerce and the environment. Effective management of these diverse water resources requires information about the temporal and spatial trends in water storage. Minnesota does have a first class ground-based network for monitoring lake levels, groundwater levels, and streamflow but the network covers only a tiny fraction of the state's water resources. How well do these represent the overall resource? Until recently nobody has determined how much water is stored at a given moment of time in Minnesota, and the change of storage with time is also unknown. We propose that by monitoring water storage by location and time water managers will be able to foresee encroaching water deficit or excess problems and take actions to reduce potential damages to ecosystems, human infrastructure, and losses to commerce.

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.

Currently water storage in aquifers can be estimated using networks of observation wells (MNDNR, MDA, USGS, and other entities), and water storage in lakes and wetlands can be estimated from water level measurements at MNDNR/citizen monitoring sites. In a phase 1 project we have completed a water storage survey for 17 major (HUC 8) watersheds located in the central part of Minnesota. Storage estimates are at the spatial scale of about 1,000 square miles and include the change of storage over the period 2002 – 2015. This has been accomplished by putting together the vast amount of available satellite data with the ground-based measurements and water balance modeling. In the current proposal we intend to complete the same survey for the remaining 63 of the 81 major (HUC 8) Minnesota watersheds, and in addition we will provide downscaled quantities of storage water for the entire state to a scale of about 100 square miles for the time period spanning 2002 to 2021. The methodology developed for water storage quantification will be available to track the annual water storage distribution throughout the state.

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?

Quantifying water storage at appropriate spatial scales will assist decision makers to make informed decisions about water allocations and to be forewarned of approaching water deficit/excess problems. Example results from the Phase 1 project: Lake water volume in the project area is 1% of total water volume (Lake Mille Lacs is ¼ of this 1%), while groundwater is 98%. Due to drier conditions in 2012, the total surface area of lakes in the study region dropped by 4%, and wetlands were affected too. This downturn in volume was clearly evident in the data record from the GRACE satellite.

Activities and Milestones

Activity 1: Acquire archived data and calibration data for HSPF (Hydrologic Simulation Program Fortran) models.

Activity Budget: $70,000

Activity Description:

Ground-based data: Available data will be acquired for streamflows, river and lake water levels, wetland water levels, soil moisture, groundwater levels, and meteorological variables. The data will be acquired for the period 2002-2021. Satellite data: Used to observe large-scale changes in water storage and thereby extend ground-based monitoring data. Available data will be acquired from NASA and associated database sources. Models: Used to conduct water balances to explain storage changes observed by satellites and ground-based data. Through contract the MPCA has calibrated HSPF models for all of the major watersheds in the state.

Activity Milestones:

Description	Completion Date
Complete set of hydrologic, soil, geologic, groundwater level, meteorological, and topographic data, prepared for use.	2022-03-31
All data archived and available on the project website.	2022-06-30

Activity 2: Develop estimates of groundwater, soil moisture and surface water storage for each of the 81 major watersheds for years, 2002-2021

Activity Budget: $206,000

Activity Description:

In our current study (Phase 1) we have developed estimates of water storage in groundwater, soil moisture and surface water for the 17 major watersheds for each year of the period 2002-2015. We will use the same methodologies for estimating water storages of all 81 major watersheds of the state, and for each year 2002-2021. The methodology involves the use of groundwater level data from the MNDNR monitoring well network along with aquifer property information (e.g., available Minnesota County Geologic Maps), river stage data, and lake/wetland water level data along with lake/wetland bathymetry data. Pointwise estimates of water storage are extended with statistical methods to provide areal estimates across whole watersheds. These estimates of water storage will be tested, as done in the Phase I project, by using satellite data from the GRACE satellite (total water storage), SMAP satellite (soil moisture storage), and LANDSAT satellite (lake water storage), and using a water balance model. These estimates of storage will be done at the scale of the HUC 8 watersheds (about 1,000 sq. miles).

Activity Milestones:

Description	Completion Date
Pointwise estimates of annual baseline water storage for 2002 through 2021	2022-09-30
Maps of estimates of annual water storage in all components across the state	2022-12-31

Activity 3: Downscale the estimates of water storage to from HUC 8 level to 100 square miles.

Activity Budget: $316,000

Activity Description:

The estimates of water storage (groundwater, soil moisture, lake water, wetlands) from Activity 2 are all at the 1,000 square mile scale. To be more useful to managers it is important to be able to refine the scale of the water storage information, and here we propose to derive water storage estimates at the scale of 100 square miles. To accomplish this downscaling we will adopt the methodologies employed in downscaling of climate models. Those methodologies can be put into one of two categories, statistical downscaling and dynamic downscaling. We will make use of these two approaches but with a preference for dynamic downscaling. With dynamic downscaling an appropriate water balance model is used along with the large-scale data (satellite data) and with ground-based data (field measurements). The model proposed for this project is the HSPF model which will facilitate downscaling water storage into the components of surface water (lakes, wetlands streamflow), soil moisture and groundwater. The HSPF model is proposed for use because we have used it in the Phase 1 project, and the MPCA has calibrated HSPF model for all of the 81 HUC 8 watersheds in the state.

Activity Milestones:

Description	Completion Date
Complete methodology and testing for downscaling water storage for one of the HUC 8 watersheds	2023-07-31
Complete downscaling of water storage for the entire state.	2024-03-31
Complete project website and project report	2024-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Jared Trost	USGS	Will work on the estimate of water storage in the aquifers of the state. Jared has developed a scheme for taking pointwise observations of groundwater and converting it into an accurate representation of the spatial distribution of groundwater, and then calculating water volume from that distribution.	Yes
Zhenong Jin	University of Minnesota	Will work with the various satellite projects available for estimating soil moisture and evapotranspiration. He will assist with advising the graduate students involved in the project.	Yes
Bruce N. Wilson	University of Minnesota	Assist with statistical analysis of data with particular attention to uncertainty analysis. He will also assist with advising the graduate students, research scientist, and undergraduate students on the project.	No

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?

A permanent, publicly available, interactive map-based web page will be produced to make the results broadly available to state, national, and international users. Processed data for 2002 through 2021 will be available through the website, and procedures for acquiring data beyond 2021 will be outlined. The methodology will be presented to the Minnesota water community, including resource managers at state and local agencies and scientists at academic institutions, through workshops and seminars held at the University of Minnesota. Due to the potential of the methods for assisting with flood and drought forecasting we will meet with the National Weather Service.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Setting Realistic Nitrate Reduction Goals in Southeast Minnesota	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04m	$350,000
Techniques for Water Storage Estimates in Central Minnesota	M.L. 2017, Chp. 96, Sec. 2, Subd. 04h	$250,000

Project Manager and Organization Qualifications

Project Manager Name: John Nieber

Job Title: Professor

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

John Nieber has over 36 years of experience working as a professional hydrologist in conducting teaching and research activities related to hydrology and water quality. In the 1980's he collaborated on research involving remote sensing of soil moisture and is currently managing the Phase 1 study on water storage estimation for Central Minnesota. He managed a LCCMR project on freshwater sustainability from 2007-2009, from which maps of groundwater recharge were derived. The work resulting in three publications in the scientific literature and has influenced freshwater sustainability planning activities within Minnesota. In 2014 Dr. Nieber took a 5-month sabbatical leave to the University of Padova in Italy to study the topic of travel time distributions for water in watersheds. The purpose was to learn techniques that could be used to estimate the lag time required for contaminants to be flushed out of watershed surface waters, soils and groundwater. This technique is being employed in a current LCCMR funded project on setting

goals for nitrogen BMPs in southeastern Minnesota. Starting in September 2019 he has been on sabbatical leave with an objective to learn how to use gravimetry technology to be able to measure water storage at the field scale. John Nieber has managed numerous other projects as well, including being the manager of a five-year contract with the MPCA for the Impaired Waters Program. He is an editor for the Journal of Hydrologic Processes, and is the author of over 80 refereed articles in the scientific literature.

Organization: U of MN - Twin Cities

Organization Description:
The University of Minnesota Twin Cities campus is one of the Big Ten universities. It ranks very highly in many of its programs including its College of Food, Agriculture and Natural Sciences, and it College of Sciences and Engineering. It has excellent library resources and its resources for supercomputing are exceptional. In addition to all of the high quality features at the University of Minnesota, faculty at the University of Minnesota have developed excellent working collaborative relationships with scientists and engineers at the state and federal agencies within Minnesota.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Zhenong Jin		Co-PI			36.5%	0.24		$41,689
Graduate Research Assistant		Research Assistant			45%	1.5		$151,922
Graduate Research Assistant		Research Assistant			45%	0.75		$75,961
Undergraduate Research Assistant		Research Assistant			0%	0.75		$6,243
Civil Service		Researcher			31.8%	1.5		$102,857
							Sub Total	**$378,672**
Contracts and Services								
US Geological Survey	Sub award	The estimation of groundwater storage component of this study will be led by project members from the United States Geological Survey (USGS).				-		$183,000
							Sub Total	**$183,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Lab Supplies	Some satellite products require processing of satellite data to get the data in a format useful for our analysis. While the satellite data is free for download, some of the the processed data is made available only at cost by different vendors. Some processed data is available for free from NASA, JPL, and other government agencies around the world. We propose to purchase the					$30,328

			processed data when processed data is not made available for free.					
							Sub Total	$30,328
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
							Sub Total	-
Travel Outside Minnesota								
							Sub Total	-
Printing and Publication								
							Sub Total	-
Other Expenses								
							Sub Total	-
							Grand Total	**$592,000**

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				
Cash	USGS Cooperative Matching Funds if the proposal is funded. The availability of these matching funds will depend on congressional appropriations for the 2021-2024 Federal fiscal years.	To support this work of merging ground-based monitoring data with remote sensing data to understand how much water is stored in Minnesota and how it is changing through time	Potential	$60,800
			Non State Sub Total	$60,800
			Funds Total	$60,800

Attachments

Required Attachments
Visual Component
File: [1e42f434-1f3.pdf](1e42f434-1f3.pdf)

Alternate Text for Visual Component
1. The estimated water storage in groundwater, soil moisture, lakes and wetlands for a specific date in the Central Minnesota project area (Phase 1). 2. This map shows the tiny fraction of lakes that are monitored in the Central Minnesota region, and is an example of the relative scarcity of water resource measurements available to estimate water storage. 3. The Phase 2 project will make use of satellite data with ground-based data (ground truth) and water balance modeling to estimate water storage in groundwater, soil moisture, lakes and wetlands for areas as small as 100 square miles.

Optional Attachments
Support Letter or Other

Title	File
Letter of Intent from the USGS	[257a2a68-3b4.pdf](257a2a68-3b4.pdf)
Letter from University of Minnesota SPA	[e59e838d-fb0.pdf](e59e838d-fb0.pdf)

Administrative Use

Does your project include restoration or acquisition of land rights?
>   No

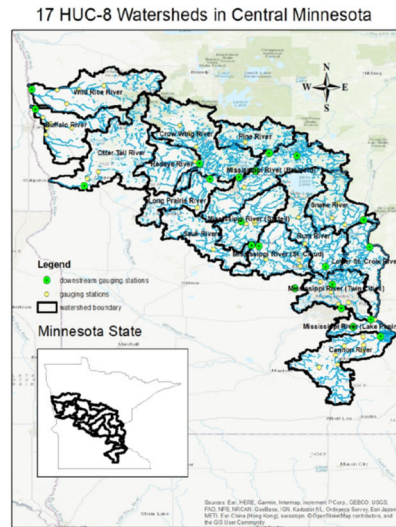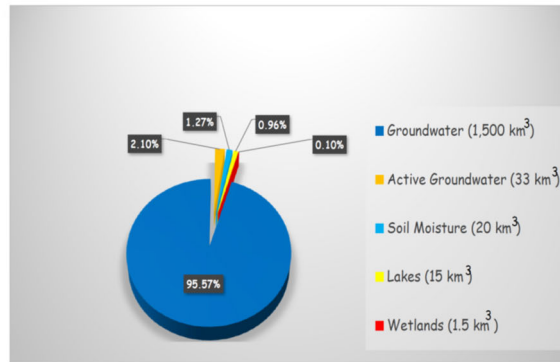**Does your project have patent, royalties, or revenue potential?**
>   No

Does your project include research?
>   Yes

Does the organization have a fiscal agent for this project?
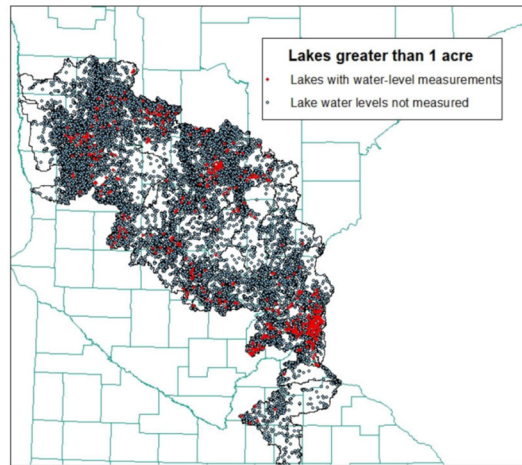>   Yes, Sponsored Projects Administration

1

17 HUC-8 Watersheds in Central Minnesota

Water Storage Estimation in Central Minnesota (Phase 1)

2

2.5% of Project Area Lakes are Monitored (411 of 16,756)

Lakes monitored using ground-based methods

3

Satellite data and ground-based data are linked using select water balance models

GRACE   SMAP   Landsat

Observation wells   Stream and lake stages   weather
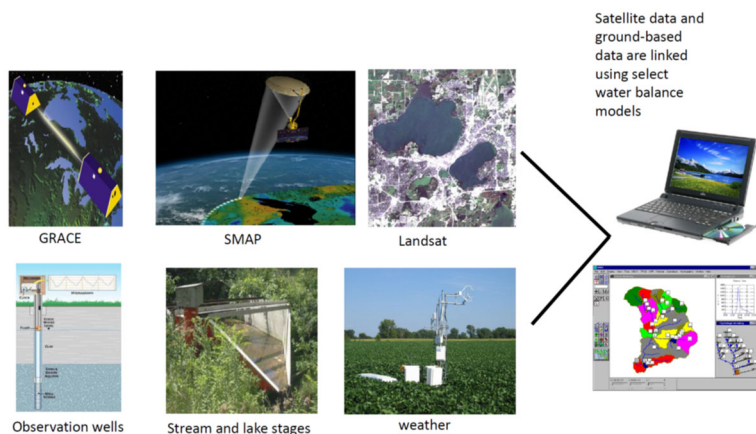
Project Approach (Phase 2)