Environment and Natural Resources Trust Fund
2017 Request for Proposals (RFP)

Project Title: **ENRTF ID: 060-B**

Monitoring Minnesota's Water with Continuous GPS Stations

Category: B. Water Resources

Total Project Budget: $ 437,316

Proposed Project Time Period for the Funding Requested: 3 years, July 2017 - June 2020

Summary:

Using a network of existing GPS stations, Minnesotas total water storage will be estimated, monitored, and predicted to quantify how and where it is changing.

Name: Kevin Ahlgren

Sponsoring Organization: St. Cloud State University

Address: 720 Fourth Ave S

St. Cloud MN 56301

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Email osp@stcloudstate.edu

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Better estimates, monitoring, and predictions of how and where MNs total water storage is changing.

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _____ TOTAL _____%

PROJECT TITLE: Monitoring Minnesota's water with continuous GPS stations

I. PROJECT STATEMENT

The total volume of Minnesota's water and how it changes in time and space is not adequately understood. Traditional monitoring sensors like stream gauges sense a single component of water but not the full **weight** of the water storage. Terrestrial water storage consists of vegetation and soil moisture, snow/ice, groundwater, and surface water. An existing network of continuous GPS stations funded by the State is present in MN that can provide a way to monitor this storage and monitor other water-related impacts like flooding. This proposed research aims to do that by uses the GPS data to determine how the earth's surface changes, which can then be used to estimate, monitor, and model the water storage and specific hydrologic events. This will tell us where and how Minnesota's water is impacted by water use, natural events, and climate change.

This will have statewide impacts from estimating the amount of water loss in a drought across the entire state to predicting flood hazards in the Red River valley. This will provide benefits to natural resource managers, local officials, and the public to better understand how Minnesota's water is changing in time and space. The results would supplement existing in situ water monitoring tools and provide a new way for managing and protecting Minnesota's total quantity of water.

As hydrologic masses including ice, snow, surface water, and near-surface water **change**, the ground surface moves. During times of high precipitation, the ground surface goes down. During a drought, the surface rises. GPS networks are very effective to observe this surface change at the millimeter level with a number of significant advantages and differences compared to traditional hydrologic monitoring:

Local Effects: Groundwater extraction, surface water changes, etc. can be felt in the immediate vicinity of a nearby GPS station. Unlike traditional hydrologic sensors, GPS stations don't have to be directly *on* the water.
Statewide Effects: Regional impacts can be felt due to changes in precipitation, water storage, and climate. For example, GPS positions in the western US have been used to estimate that a 10 cm layer of water over the entire western US has been lost during the 2013 drought.
Space/Time Sensitive: Water changes at specific locations can be determined at daily time scales versus satellite techniques that are available at monthly time frames. This allows flooding events, water diversions, and other rapid changes to be known within a few days rather than months.
Secondary Benefits: Understand how watersheds are changed due to tilting from glacial rebound. Use water vapor estimates from GPS to improve meteorological forecasting and measure climate change.

Minnesota currently has approximately 175 GPS stations most of which are maintained by MnDOT. These stations are primarily used for real-time GPS positioning in agricultural and engineering/surveying applications and lack daily coordinates at the millimeter level. This project will provide those precise coordinates and provide additional value to the state's investment; however, the processing of a network of this size is not a small endeavor requiring approximately 2-hours/processed day.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: GPS data processing of 175 stations over the time period from 2000 – 2016 **Budget: $72,659**
GPS data will be downloaded from online archives and stored at St. Cloud State University prior to processing. The National Geodetic Survey (NGS) stores approximately 100 stations dating back to 2000. The additional 75 stations are discarded by MnDOT but are held by the PI from June 2012 – present. Daily networks will be processed using GAMIT/GLOBK software with the Minnesota Supercomputing Institute (MSI).

Outcome	Completion Date
1. Establish processing strategy within context of software and MSI	Dec. 31 2017

2. Download daily GPS station data for approx. 100 stations archived at NGS for their entire lifespan (approx. 2000 – present).	Dec. 31 2017
3. Process daily network data with GAMIT/GLOBK for 2000-present.	June 30 2018
4. Establish modeling to describe individual stations' horizontal and vertical motions	June 30 2018

Activity 2: Model water storage change and hydrologic events based on GPS data and verify with traditional in-situ sensors, maps, and data. **Budget: $219,339**

We will estimate the change in the total quantity of water in time and space using GPS data that has been integrated with groundwater levels, soil moisture data, surface gauges, geologic atlas data, etc. for verification.

Outcome	Completion Date
1. Establish hydrologic modeling of total changes in the quantity of water to assess effects at local (i.e. station-specific) and regional scales using GPS results	Dec. 31 2019
2. Integrate modeling with additional monitoring sensors (groundwater levels, water-level gauges, topographic datasets, geologic atlas data, satellite photographs, etc.) for consistency and verification of the GPS-derived model(s) for forecasting purposes	June 30, 2020

Activity 3: Automatic GPS data processing and of 175 stations in real-time **Budget: $145,318**

The ultimate utility of this project will be in automatic GPS processing. This will require methods to automate the GPS data downloading and updating of software. The automated processing will require innovative algorithms to handle odd situations like stations with long-time lags and missing data.

Outcome	Completion Date
1. Develop method for automated data acquisition of previous day's data	Dec. 31 2018
2. Establish automated daily network processing strategy	Dec. 31 2018
3. Create and launch external web interface with automated positional time series results	Dec. 31 2019
4. Final report writing and dissemination	June 30 2020

III. PROJECT STRATEGY

A. Project Team/Partners

All members will receive ENRTF funding. Dr. Kevin M. Ahlgren (Assistant Professor - St. Cloud State University) will serve as the project principal investigator and handle all GPS-related activities. Dr. Deborah K. Nykanen (Professor - Minnesota State University – Mankato) will lead the hydrologic modeling activities. A graduate research assistant and an undergraduate student at SCSU will work with the GPS data, processing, time series modeling, integration with additional datasets, automation, and dissemination. A graduate research assistant and an undergraduate student will work with the hydrologic modeling activities at MSU-Mankato.

B. Project Impact and Long-Term Strategy

The proposed research will provide a new tool for natural resource managers and the hydrologic community to utilize for hydrologic investigations in Minnesota. Unlike other monitoring, this will show the total water storage at local scales. The time series modeling strategy and results will be available to the public via an external web interface. Specific storm events and geographic results will be disseminated through appropriate venues. The modeling and results will also be integrated into laboratory exercises in undergraduate courses in GIS and geodesy at SCSU.

C. Timeline Requirements

The total project timeline is expected to be 3 years. Completion dates for individual project activities were established based on estimated times required to complete the task. Since many of the GPS stations have relatively short histories (< 10 years), additional time will significantly improve results and subsequent models.

2017 Detailed Project Budget

Project Title: Monitoring Minnesota's water with continous GPS stations

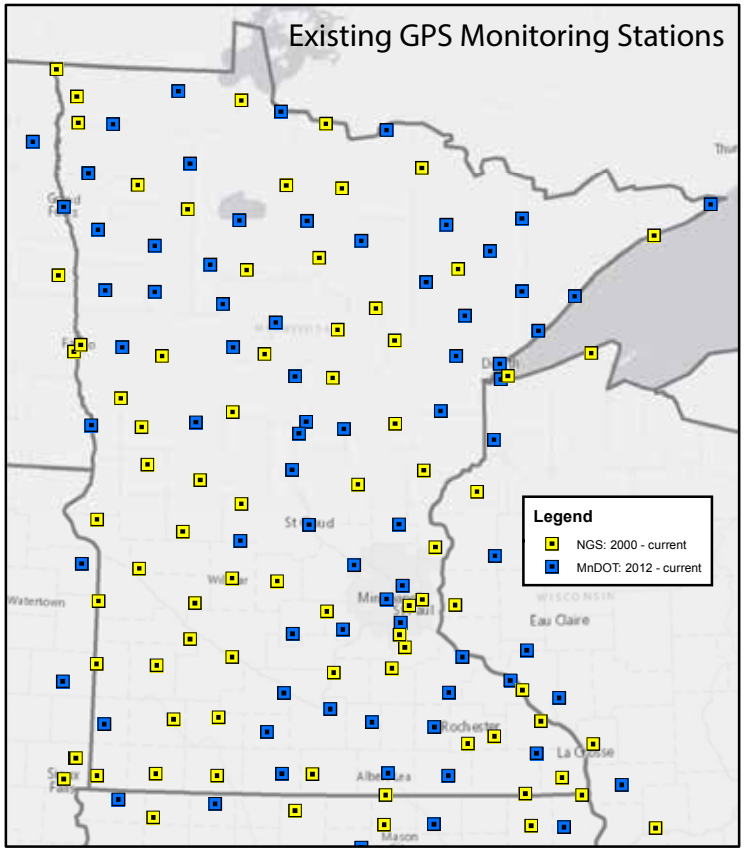
IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
Personnel:	
Kevin M. Ahlgren. Assistant Professor - Land Surveying/Mapping Sciences, SCSU. PI has a 9-month contract and budget will include summer salary ($38,395 avg. annual salary, $10,506 avg. annual fringe, 37% fringe rate; $48,901 annual average for 3 years) Period:7/2017 - 6/2020. 3 months/yr	$ 146,703
Graduate Assistant (1) at SCSU. Assist with GPS data collection, pre-processing, analysis/modeling of time series data, and dissemination of results. ($10,000 salary, $6,000 tuition; $16,000 annual average for 3 years). Period: 8/2017 - 6/2020. 6 months/yr	$ 48,000
Undergraduate Student Assistant (1) at SCSU. Assist with GPS data collection, pre-processing, and dissemination of results. (10 hrs/week for 30 weeks at $12/hr. - $3,600 annual salary; $10,800 total for 3 years). Period: 8/2017 - 6/2020. 3.5 months/yr	$ 10,800
Professional/Technical/Service Contracts: Minnesota State University-Mankato. The subcontract amount will include funding for carrying out the hydrologic modeling for verification of the GPS derived model. Funding includes in-state travel costs for project meetings and project dissemination at Minnesota Water Resources Conference ($7,877 total). Funding for Personnel includes: (1) undergraduate student assistant ($11,004 total salary - 3.5 months/yr.), (1) graduate student including summer salary ($28,094 total salary, $0 fringe, and $33,724 total tuition - 6 months/yr.), and co-PI Deborah K. Nykanen (Professor - Civil Engineering, MSU-Mankato - $35,030 avg. annual salary, $11,183 avg. annual fringe, 32% avg. fringe rate; $46,213 annual average for 3 years) Period: 7/2017 - 6/2020. 2.4 months/yr	$ 219,339
Professional/Technical/Service Contracts: Minnesota Supercomputing Institute. The subcontract amount will include funding for consulation services for assistance with GPS data storage and processing at the institute. No costs associated with actual data storage and processing ($6,750 total - 30 hrs/yr. at $75/hr.). Period: 7/2017 - 6/2020.	$ 6,750
Travel: In-state travel for visits to GPS stations, project meetings, and state conferences (1400 miles/yr with $0.47/mile; Minnesota Water Rescources Conference registration for PI and graduate student, lodging, & per diem ($1,250 per year for 1 conference/yr)	$ 5,724
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 437,316

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	NA	
Other State $ To Be Applied To Project During Project Period:	NA	
In-kind Services To Be Applied To Project During Project Period: SCSU indirect rate is 12% of modified direct cots (MDC). MDC $242,977 x 12% = $29,157 (if project is funded).	$29,157	*Pending*
Funding History:	NA	
Remaining $ From Current ENRTF Appropriation:	NA	

Monitoring Minnesota's water with continous GPS stations

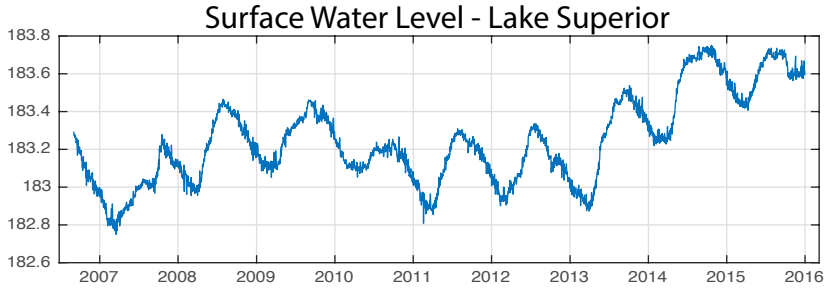


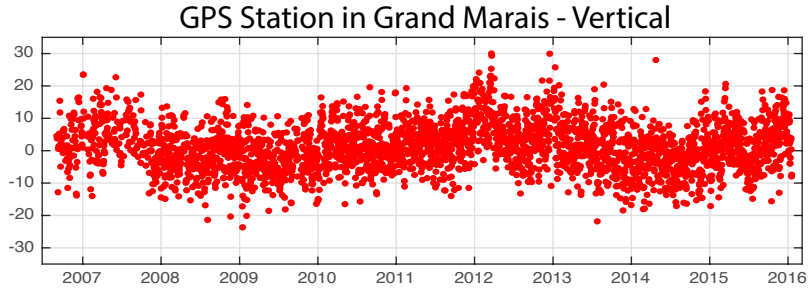
Minnesota's water storage: impacted by natural and man-made forces

Natural - Credit: MnDNR

Man-made - Credit: MPR

This project will quantify the changing volume of water in space and time at watershed levels with GPS and ground based sensors, water monitors, geological maps, etc. as shown below:





Better estimates, monitoring, and predictions of how and where the state's total water storage is changing

Project Title: Monitoring Minnesota's water with continuous GPS stations

Project Manager Qualifications & Organization Description:

PI:

Name: Kevin M. Ahlgren
Degrees: 2005 – B.C.E. - Civil Engineering, University of Minnesota
2011 – M.S. - Geodetic Science, Ohio State University
2015 - Ph.D. - Geodetic Science, Ohio State University
Affiliation: 2012 – current – Assistant Professor
Land Surveying/Mapping Sciences program - Department of Geography and Planning
St. Cloud State University
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Dr. Ahlgren teaches land surveying and other geospatial courses including courses in GPS/GNSS and GIS. He has managed field campaigns observing GPS and gravity in Bolivia for over 6 years. He has conducted and led extensive GPS and gravity surveys throughout Argentina, Bolivia, and Chile, processed kinematic positioning of airborne LiDAR surveys, and developed broad algorithmic processes for these projects.

Organization:

Minnesota's second-largest public university, with more than 15,400 students, is a regional comprehensive university and a member of the Minnesota State Colleges and Universities system. Undergraduate students can choose from more than 200 majors, minors and pre-professional programs, including regional rarities such as meteorology, geographic information systems, and land surveying/mapping sciences. St. Cloud State offers more than 60 graduate programs including an MS in geographic information science.