Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-174

Proposal Title: Slope Failures in Minnesota: Drivers, Projections, and Mitigation

Project Manager Information

Name: Karen Gran

Organization: U of MN - Duluth

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Project Basic Information

Project Summary: This project investigates the hydrologic triggers of landslides in Minnesota and the processes by which they occur in order to better predict impacts in the future.

Funds Requested: $396,000

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?

Region(s): NE, Metro, Central,

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

Statewide

When will the work impact occur?

In the Future

Narrative

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

Excessive sediment negatively affects water quality, riparian ecosystems, fisheries and recreational facilities. Bluff erosion by landsliding delivers the majority of sediment to many Minnesota watersheds. Furthermore, landslides damage public and private infrastructure and have led to loss of life in Minnesota. Eroding, hazardous slopes present an acute natural-resource and infrastructure-management challenge. Previous work by this group, funded by the LCCMR, has helped fill knowledge gaps in the state's understanding of the location of historic landslides and geologic conditions that lead to high susceptibility for landslides in different regions across the state. This project is designed to investigate the meteorological and hydrologic triggers of landslides and the processes by which landslides occur. By understanding what triggers landslides, we can move towards better projections of when landslides are likely to occur and inform policy makers and stakeholders as they make decisions about implementation of mitigation efforts. In addition, we can apply future climate scenarios that forecast rainfall intensity and duration to investigate if the conditions that promote landslides in Minnesota may be more common in the future.

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.

To help make decisions about natural-resource management, safety, and infrastructure management, we propose to provide a new level of connection between weather forecasts, climate projections, and the natural hazards and threat to freshwater resources presented by landsliding in Minnesota. Mitigation of unstable slopes is expensive and difficult, and understanding the link between weather, geology, land use and landslides needs to be the foundation of mitigation decision making. This information can be used to alert road crews, first responders, and the public about increased periods of landslide activity, as well as providing longer-term forecasts of landslide activity given future climate scenarios.

Our group has mapped thousands of landslides across Minnesota, many along river corridors, but we still lack an understanding of the meteorological and hydrologic triggers for slope failure. This proposal seeks to fill the gap in our ability to predict which storms may trigger landslides or how changes in storm intensity and frequency impact slope stability. We will couple the landslide inventory with hydrologic data before and during triggering events. Second, we will deploy instrumentation at active landslides to measure on-the-ground conditions when slopes fail. Finally, we will couple these observations with future climate scenarios to project the future trajectory

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 will provide estimates of precipitation intensity and duration that trigger landslides on steep slopes in Minnesota and detailed data on the physical processes and environmental conditions that lead to slope failure on active landslides. We will provide this through intensive monitoring using environmental sensor networks and detailed analysis of landscape change occurring during weather events that cause landslides. Finally, we will forecast how future climate scenarios in Minnesota may impact landslides. Information will be shared with state agencies, environmental managers, and emergency managers to help better predict failures in the future and environmental and societal consequences.

Activities and Milestones

Activity 1: Hydrologic triggers for landslides in Minnesota: Assessing historical events

Activity Budget: $91,420

Activity Description:
What hydrologic conditions trigger landslides in Minnesota? Research elsewhere has connected long duration rainfall followed by high intensity events to slope failures. The historical inventory compiled for Minnesota includes many landslides with known. Records also exist through agencies like the Minnesota Department of Transportation when slope failures triggered road clean-up activities. By utilizing all the data sources, we will have an inventory of known events to compare with precipitation data.

We will compile rainfall records from the National Weather Service (NWS) over periods of landslide occurrence to estimate slope weakening due to soil moisture prior to failure. These data are captured in the Standard Precipitation Index (SPI), which provides deviations in long-term precipitation patterns, and the NOAA Atlas 14, which puts rainfall into a historical context. We need to better understand the window of time that needs to be examined to best estimate soil moisture from weather and climate data. We will also examine wet periods that did not trigger landslides to bracket conditions that do and do not trigger slope failures in Minnesota.

The goal is to provide guidance into moisture conditions that prime systems for failure and thresholds for precipitation intensity and duration above which landsliding occurs.

Activity Milestones:

Description	Completion Date
Compiling precipitation records from extreme events without known landslides	2022-05-31
Compare precipitation records for known and documented historic events	2022-05-31
Developing relationships between precipitation conditions, antecedent conditions, and presence/absence of landslides	2022-12-31

Activity 2: Monitoring active slope failures to determine conditions at which failure occurs

Activity Budget: $233,026

Activity Description:
Geologic conditions known to create a high susceptibility to landslides vary regionally across the state. For example, in northeastern Minnesota, there is a connection between landslide susceptibility, topographic properties like slope, and underlying geology including the thickness of glacial sediments above impermeable bedrock. Knowing the geologic conditions that lead to high susceptibility helps, but it does not fully explain how and under what conditions landslides are triggered in each region.

We propose instrumenting active slides prone to failure in two different regions across the state to identify the hydrologic conditions under which slope failures occur. We will instrument one slide in northeastern Minnesota and one in south-central Minnesota. Instrumentation will comprise sensors to detect soil moisture, pore pressure, and ground movement. Local weather stations will be installed to record precipitation and temperature. Monitoring will take place over the course of two years in an effort to capture conditions under which slides move, with landscape changes recorded using high-resolution lidar or photogrammetry. Our detailed monitoring can be compared with sites where active landslides are being monitored by state agencies for example, Upper Sioux Agency State Park and Highway 210.

Activity Milestones:

Description	Completion Date
Instrument two sites and start data collection	2022-06-30
Complete geotechnical data analyses	2023-10-31
Complete monitoring data collection	2024-05-31
Slope stability modeling complete	2024-06-30

Activity 3: Forecasting future landslide activity under changing climate regimes and dissemination of results

Activity Budget: $71,554

Activity Description:
This activity has two components: 1) Dissemination of findings of relationships detected between precipitation, soil moisture and landslide activity, and 2) Using that information to help guide forecasts of future activity. The first will be accomplished through meetings with state and local agencies including resource management agencies like the MnDNR, infrastructure management agencies like MnDOT, and county and state emergency managers. We will also disseminate information to the scientific community. These various entities can then utilize the information about landslide susceptibility and precipitation drivers to make informed decisions about how to manage Minnesota resources and infrastructure.

The second component focuses on understanding how landslide frequency may change in the future. Climate change projections have been developed at finer spatial resolution for Minnesota through recent LCCMR-funded work by Bonnie Keeler and collaborators. These forecasts include estimates of how precipitation will vary, both in terms of annual means and extreme events. Once we have established rainfall duration/intensity threshold curves for landslide initiation that have predictive power, we can forecast how the ensuing changes in precipitation may impact landslides in Minnesota.

Activity Milestones:

Description	Completion Date
Apply relationships developed between precipitation and landsliding to future climate scenarios	2023-12-31
Meet with stakeholders, agency staff, and the public	2024-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Eric Waage	Hennepin County Emergency Management	Eric Waage, the Director of Emergency Management in Hennepin County, has been collaborating with members of this research team on landslide susceptibility mapping and will assist with site selection for sites to monitor in the metro area.	No
Dr. Raul Velasquez	Minnesota Department of Transportation	MnDOT geomechanics research engineer Dr. Velasquez will assist with sharing of existing data that include the timing of slope failures that have impacted roadways, and collaborate by sharing publicly available data at sites with existing monitoring.	No
Craig Schmidt	National Weather Service	Service Hydrologist with the National Weather Service in Chanassen, MN, Craig Schmidt will assist with acquisition of weather data needed for determination of hydrologic connections between landslide triggering events and precipitation.	No
Stephen DeLong	United States Geological Survey	Supervisory Research Geologist Dr. DeLong will help design and deploy sensor networks, measure landscape change, analyze data, and participate in generation of results and publications. He will provide connections to the USGS Landslide Hazards program to collaborate with other experts on precipitation analyses and review all results.	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?

Results will be disseminated to local and state agencies responsible for managing natural resources and infrastructure that are impacted by landslides. This can include the Minnesota Department of Transportation, the Minnesota Department of Natural Resources, and county and state emergency managers. We will produce a project report accessible to a broad audience with additional details in a peer-reviewed publication. Local agency staff can move to implement any changes in monitoring, protocols, or zoning based on the findings.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Landslide Susceptibility, Mapping, and Management Tools	M.L. 2017, Chp. 96, Sec. 2, Subd. 03i	$500,000

Project Manager and Organization Qualifications

Project Manager Name: Karen Gran

Job Title: Professor

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

Dr. Karen Gran (UMD) is a professor in Earth and Environmental Sciences at the University of Minnesota Duluth, with expertise in geomorphology. She has been studying river systems and sediment loading across the state of Minnesota for over a decade, with a focus on applied research to help inform land management decisions. Dr. Gran is currently the project manager on a large ENTRF-funded project leading a team of nine different institutions to develop a landslide inventory and susceptibility map for landslide-prone areas within the state of Minnesota. She has managed large multidisciplinary, collaborative projects funded by the Minnesota Pollution Control Agency, the Minnesota Department of Agriculture, and the National Science Foundation. For this project, Dr. Gran will lead project management, supervise

and advise graduate and undergraduate research students, and assist with all aspects of the science.

We have assembled a highly skilled team of scientists. Dr. Carrie Jennings (UMN) is a field geologist, applying her understanding of glacial geology and landscape evolution to shape policy and approaches for managing surface water, groundwater, and natural hazards. She builds teams to tackle applied research challenges; promotes results; implements solutions to achieve results; interacts with the legislative branch to shape laws; and works with executive branch agencies on rules. For this project she will help with field site selection, interpretation, and communication. Dr. Stephen DeLong is a Supervisory Research Geologist in the Natural Hazards Mission Area of the U.S. Geological Survey. He will help design and deploy sensor networks, measure landscape change, analyze data, and participate in generation of results and publications. Dr. Andrew Wickert (UMN) will coordinate field instrumentation, help assemble and interpret precipitation data, and link these to slope-stability mechanics. His technical engineering staff will assist with development, installation, and maintenance of monitoring equipment.

Organization: U of MN - Duluth

Organization Description:
The University of Minnesota Duluth is a mid-sized regional comprehensive university. The Department of Earth & Environmental Sciences (EES) lies within the Swenson College of Science and Engineering (SCSE), the largest of the five colleges on the UMD campus. The University of Minnesota system allows for multi-campus grants to be easily managed within the internal system, streamlining grant processing, hiring across campuses, and proposal reporting. We are able to tap into expertise across both campuses, allowing multiple investigators, students, research staff, and technicians to collaborate seamlessly.

The United States Geological Survey (USGS) has a mission to provide reliable science information to minimize loss of life and property from natural disasters. The USGS Natural Hazards Mission area has a specific program element focused on landslide hazards. The scientific focus of this program is risk reduction by improving the understanding of causes of ground failure. The only USGS Natural Hazards Mission Area scientist in the upper Midwest is Stephen DeLong. The USGS has rigorous process for conduct of scientific research, data review and release of scientific information that will be followed through all stages of this project, ensuring high quality information is disseminated to stakeholders and the public.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Karen Gran		Project Manager and Research Support. Supervise research assistants in Duluth; Assist with all aspects of data analysis and interpretation.			26.7%	0.12		$23,049
Andrew Wickert		Project Research Support. Coordinate field instrumentation, help assemble and interpret precipitation data, and link these to slope-stability mechanics.			26.7%	0.12		$22,470
Carrie Jennings		Project Research Support and Outreach Coordinator. Help with field site selection, interpretation, and communication.			26.7%	0.24		$43,464
Research Technician		Project Research Support. Data instrumentation development, installation, and maintenance			24.1%	0.76		$70,108
Graduate Research Assistant		Project Research Support. Data collection and analysis for precipitation and field monitoring.			47.7%	1		$87,365
Undergraduate research assistants (2)		Project Research Support including geotechnical analyses, field data maintenance and monitoring, laboratory support			0%	0.6		$16,369
							Sub Total	**$262,825**
Contracts and Services								
United States Geological Survey, Dr. Stephen DeLong	Professional or Technical Service Contract	Help design and deploy sensor networks, measure landscape change, analyze data, and participate in generation of results and publications. Provide connections to the USGS Landslide Hazards program to collaborate with other experts on precipitation analyses and review all results.				0.63		$95,531
							Sub Total	**$95,531**
Equipment, Tools, and Supplies								
	Equipment	Sensors, loggers, and telemetry installations	Onset Hobo rain gages (1/site)					$900

	Equipment	Sensors, loggers, and telemetry installations	Meter/Decagon soil-moisture sensors (3x set of 3/site)					$2,700
	Equipment	Sensors, loggers, and telemetry installations	Soil-termperature stakes (2/site)					$1,200
	Equipment	Sensors, loggers, and telemetry installations	GPS sensors (4/site)					$2,400
	Equipment	Sensors, loggers, and telemetry installations	Temperature, relative humidity, pressure sensors (1/site)					$300
	Equipment	Sensors, loggers, and telemetry installations	Tiltmeters (1/site)					$500
	Equipment	Sensors, loggers, and telemetry installations	VW piezometers ($400 each + $100 for cable; 4 per site (we have 4 already))					$2,000
	Equipment	Sensors, loggers, and telemetry installations	Retroreflective monuments for repeat surveying					$600
	Equipment	Sensors, loggers, and telemetry installations	Time lapse cameras with logger-enabled triggering mechanisms					$3,200
	Equipment	Sensors, loggers, and telemetry installations	Overland flow wire sensors					$400
	Equipment	Sensors, loggers, and telemetry installations	Cable strainmeter(Geokon) 1/site					$5,000
	Equipment	Sensors, loggers, and telemetry installations	Vibrating wire interface (1/site)					$2,500
	Equipment	Sensors, loggers, and telemetry installations	Data loggers with telemetry and solar power (1 assembly/site)					$4,800
	Tools and Supplies	Sensors, loggers, and telemetry installations	Telemetry charges ($144/site/yr+inflation)					$891
	Tools and Supplies	Geotechnical investigations	Borehole drilling, casing, grout					$2,500
	Tools and Supplies	Sensors, loggers, and telemetry installations	Installation hardware, mounts, and tools					$1,500
	Tools and Supplies	Field supplies	Field notebooks, sample bags, data sheets, maps					$250
							Sub Total	**$31,641**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								

	Conference Registration Miles/ Meals/ Lodging	1) Travel to field sites, 2) travel for research group meetings, and 3) travel to disseminate research results	1) Travel to 2 field sites in Cities and Duluth, 5 times/yr each, 50 miles RT at $0.575/mile. 2 times each in last year; 2) Travel between Duluth and Twin Cities for research group meetings, once per year. Travel includes RT mileage (314 miles at $0.575/mile), 2 hotel rooms for one night (157/night*2), and per diem for 2 people for 2 days (57/day/person), 3) Travel to regional meeting to disseminate results (2 people) ($96/night hotel (2 rooms), 200 registration (*2), 320 for mileage, perdiem (55/day*2 days * 2 people) Travel to meet with stakeholders, 434 miles (314*1, 40*3)*$.575/miles.					$4,156
							Sub Total	**$4,156**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Geotechnical investigations	Grain size analyses, direct shear tests, and other geotechnical analyses					$1,847
							Sub Total	**$1,847**
							Grand Total	**$396,000**

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	Waived indirect cost recovery fees by University of Minnesota	University of Minnesota does not charge indirect cost recovery of 55% on state funding allocations. The work that would have been paid for by ICR is in-kind.	Secured	$199,640
			Non State Sub Total	**$199,640**
			Funds Total	**$199,640**

Attachments

Required Attachments

Visual Component

File: aa5aca8c-9a7.pdf

Alternate Text for Visual Component

Images include a Google Earth air photo and lidar hillshade map of an area in northeastern Minnesota that has abundant landslides. Also shown are a photo of one of the slides adjacent to a river and a map showing the historic landslide inventory along the lower St. Louis River corridor. The landslide inventory for Minnesota will be completed in summer 2020. This inventory highlights locations where landslides have occurred previously across landslide-prone parts of the state. The inventory used historic imagery, statewide lidar data, and historic records. Many sites were field checked.

Below the inventory images lie an example of a precipitation-driven landslide trigger model that has been developed for Seattle, Washington, by the US Geological Survey. On the left is a graph plotting 3-day cumulative precipitation vs. 15-day cumulative precipitation. A diagonal line shows conditions under which landslides are more or less likely to occur. On the right there is a plot of rainfall intensity vs. duration. In the upper-right are conditions in which landslides are very likely, along with data from several events in the Seattle area which triggered numerous landslides. The proposed project seeks to understand the hydrologic conditions under which landslides occur, including precipitation event intensity and duration and antecedent rainfall conditions. The examples shown come from https://www.usgs.gov/natural-hazards/landslide-hazards/science/seattle-area-washington?qt-science_center_objects=0#qt-science_center_objects

Optional Attachments

Support Letter or Other

Title	File
Letter of Support NWS	150939de-82f.pdf
Letter of Support MnDOT	c05edb3f-95e.pdf
Letter of Support - Hennepin County	8aa65f83-46c.pdf
Letter of Support USGS	a84cb2fb-e8e.pdf
Approval from Sponsored Projects Administration UMN	fcc86acb-e2c.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

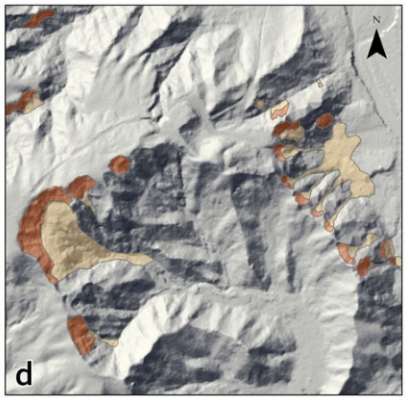
No

Does your project include research?

Yes

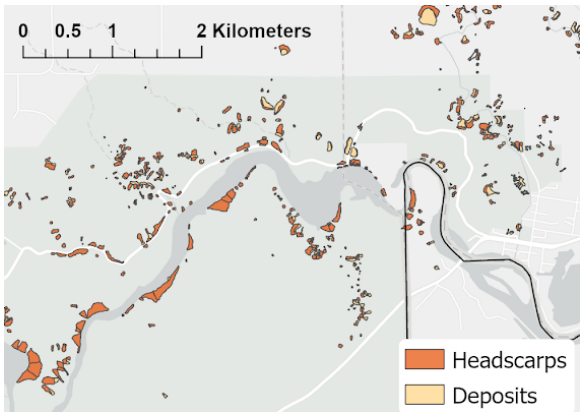
Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration



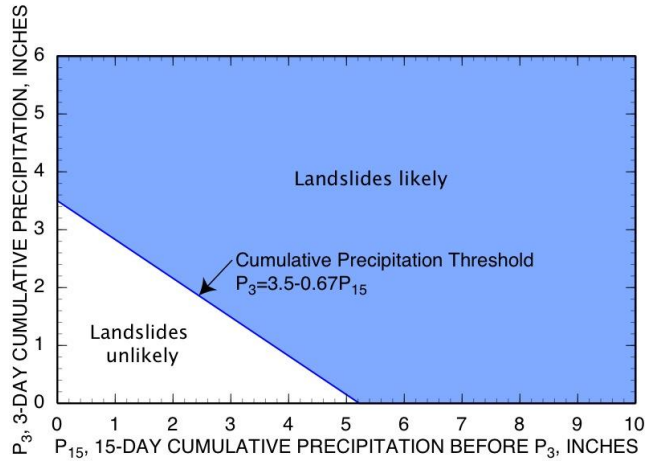
The landslide inventory for Minnesota will be completed in summer 2020. This inventory highlights locations where landslides have occurred previously across landslide-prone parts of the state.

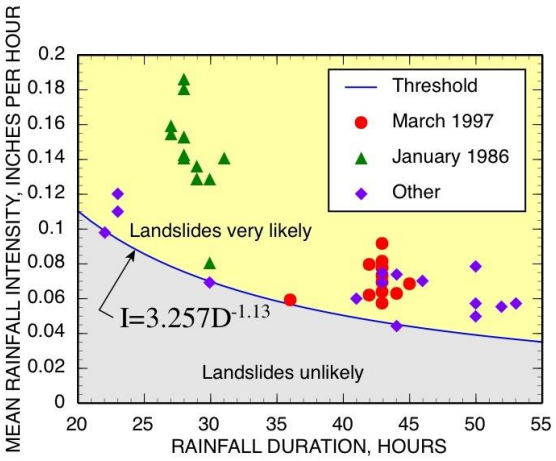
The inventory used historic imagery (far-left), statewide lidar data (left), and historic records. Many sites were field checked (below).



The landslide inventory and susceptibility maps show how prevalent landslides are in Minnesota and where high-hazard zones are located. Landslides are particularly common along rivers where they provide an abundant source of sediment. Figures shown above are from E. Richard from northeastern Minnesota.

The proposed project seeks to understand the hydrologic conditions under which landslides occur, including precipitation event intensity and duration and antecedent rainfall conditions. (Examples below shown for the Seattle area from U.S. Geological Survey.)





https://www.usgs.gov/natural-hazards/landslide-hazards/science/seattle-area-washington?qt-science_center_objects=0#qt-science_center_objects