

**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

**Office Telephone:** (218) 726-7406

**Email:** kgran@d.umn.edu

## **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. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified 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](https://lccmrprojectmgmt.leg.mn/media/map/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](https://lccmrprojectmgmt.leg.mn/media/attachments/150939de-82f.pdf) |
| Letter of Support MnDOT | [c05edb3f-95e.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/c05edb3f-95e.pdf) |
| Letter of Support - Hennepin County | [8aa65f83-46c.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/8aa65f83-46c.pdf) |
| Letter of Support USGS | [a84cb2fb-e8e.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/a84cb2fb-e8e.pdf) |
| Approval from Sponsored Projects Administration UMN | [fcc86acb-e2c.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/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