Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2017 LCCMR Work Plan

Date of Submission: Sept. 14, 2016

Date of Next Status Update Report: January 30, 2018

Date of Work Plan Approval:

Project Completion Date: June 30, 2020

Does this submission include an amendment request? N

PROJECT TITLE: Landslide hazards and impacts on Minnesota's natural environment

Project Manager: Karen Gran

Organization: University of Minnesota, Duluth

Mailing Address: Dept. of Earth and Environmental Sciences, UMD, 1114 Kirby Dr.

City/State/Zip Code: Duluth MN, 55812

Telephone Number: (218)726-7406

Email Address: kgran@umn.edu

Web Address: http://www.d.umn.edu/~kgran/

Location: Statewide

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$500,000**
	Amount Spent:	**$0**
	Balance:	**$500,000**

Legal Citation: M.L. 2017, Chp. xx, Sec. xx, Subd. xx

Appropriation Language:
[To be inserted following the MN Legislative Session in Spring 2017. This will be blank for the initial submission and will be provided to you at a later date.]

I. PROJECT TITLE: Landslide hazards and impacts on Minnesota's natural environment

II. PROJECT STATEMENT: The state of Minnesota faces threats to environmental sustainability due to excessive sediment that ***negatively affects water quality, riparian ecosystems, trout and other fisheries and recreational facilities.*** Recent research by members of this proposal team identified that ***the majority of sediment delivered to many watersheds comes from bluff erosion and landslides adjacent to stream channels***. Furthermore, landslides have caused considerable damage to infrastructure and even loss of life in Minnesota. Eroding, hazardous slopes present an acute natural resource management challenge, yet the state lacks a landslide hazards map and mitigation strategy. Our proposed research will provide information on the distribution, failure mechanisms, and frequency of landslides in order to make sound mitigation decisions. We will address this challenge through the following actions:

- **Inventory the locations of recent landslides in Minnesota**
- **Evaluate the types of landslides, their geologic and topographic settings and their causes**
- **Use high-resolution data (lidar) to map of landslide susceptibility quantitatively**
- **Provide tools for land managers to make informed decisions about mitigation and restoration.**

In June 2014, widespread landslides occurred in south-central Minnesota; a similarly rainy period in 2012 caused two deaths. In June 2012, a two-day rain event in Duluth generated hundreds of landslides, extensively damaging Jay Cooke State Park and limiting access to Thomson Dam, which was in jeopardy of failing. In August 2007, a year's worth of rain fell in 36 hours in southeastern Minnesota causing extensive landsliding. Weak clay soils in the Red River valley frequently fail, undermining homes and roads. These events defined our study areas:

- **Mississippi River in southeast Minnesota**
- **Minnesota River valley from New Ulm to Chaska**
- **Lake Superior watershed**
- **Red River Valley**
- **7-county Metropolitan area**.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of *January 30, 2018:*

Project Status as of *July 30, 2018:*

Project Status as of *January 30, 2019***:**

Project Status as of *July 30, 2019:*

Project Status as of *January 30, 2020***:**

Project Status as of *June 30, 2020:*

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: ***Landslide inventory data collection***

Budget: $50,357

Description: Conduct historical research; perform lidar and air photo analyses to identify slide locations.

Each of the five study areas has experienced landslides in the past. They have caused infrastructure damage and contributed to excess sediment loading in major rivers. The first activity involves developing an inventory of historic landslides. Each of the five regions in the state will be covered by a different partner using established data standards and protocols. Each partner institution will conduct historical research in local archives to find all documented landslides in their region. Stephanie Day at NDSU will cover the Red River valley, Dylan Blumentritt at Winona State University will cover SE Minnesota, Laura Triplett at Gustavus Adolphus College will cover the Minnesota River valley from St. Peter to Chaska, and Phil Larson at Minnesota State University Mankato will cover the Minnesota River from New Ulm to St. Peter. Preliminary work in the Minneapolis-St. Paul metropolitan area has been conducted by Carrie Jennings at the University of Minnesota. She will continue that work in collaboration with Jeni McDermott at the University of St. Thomas. Andrew Breckenridge at the University of Wisconsin-Superior has already mapped landslides associated with the 2012 flood in the Nemadji River area near Duluth. He will contribute those data and help with the integrated mapping. The rest of the Lake Superior watershed will be covered by Karen Gran at the University of Minnesota Duluth.

All of the historical landslides will be compiled into a master database containing information on when and where each event occurred, and contain information about the nature of the landslide. The geospatial database will be overlain on statewide aerial lidar data. The topographic and geologic settings of historically-documented slides will then be used to map other sites where slides are likely to have occurred.

The outcome of this activity will be a database covering the five regions of the state noted above (Red River valley, Minnesota River valley, SE Minnesota, Lake Superior watershed, and Metro area), a geospatial database with documented slide locations and locations of apparent past landslides as indicated by landscape morphology.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 50,357
Amount Spent: $ 0
Balance: $ 50,357

Outcome	Completion Date
1. Completed historical records search for the 5 landslide regions	January 2018
2. Compiled digital database of landslide locations to guide follow-up work	May 2018

Activity 1 Status as of *January 30, 2018***:**

Activity 1 Status as of *July 30, 2018***:**

Activity 1 Status as of *January 30, 2019:*

Activity 1 Status as of *July 30, 2019:*

Activity 1 Status as of *January 30, 2020:*

Activity 1 Status as of *June 30, 2020:*

ACTIVITY 2: ***Preliminary landslide susceptibility map***

Budget: $252,896

Description: Identify relationships among landslide process, local topography, geography, geology, and hydrology.
Following the geospatial database assembled in activity 1, slide sites and likely slides sites will be field-checked. The partners responsible for the historical mapping in each region will be in charge of the field data collection for the same regions. While in the field, observations on slope composition, underlying geology, potential perched aquifers, seeps and springs, vegetation cover, and land use will be noted. Field-based interpretation of landslide process domain will be made, where possible.

GIS layers for all potential drivers of landslides will be compiled across all five study regions including, but not limited to, surficial geology, soils, bedrock geology, depth to bedrock, vegetation cover, and land use. These will be added to the lidar topographic database along with topographically-derived parameters including slope, relief, and aspect. In addition, all of the data from landslide sites visited in the field will be compiled in the same GIS framework for use in developing a predictive landslide hazards map.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 252,896
Amount Spent: $ 0
Balance: $ 252,896

Outcome	Completion Date
1. Field work to check historical records and GIS analyses	Oct. 2018
2. Identification of geology and topography at landslide sites	Oct. 2019
3. Interpretation of landslide process and domain	May 2020

Activity 2 Status as of *January 30, 2018***:**

Activity 2 Status as of *July 30, 2018***:**

Activity 2 Status as of *January 30, 2019:*

Activity 2 Status as of *July 30, 2019:*

Activity 2 Status as of *January 30, 2020:*

Activity 2 Status as of *June 30, 2020:*

ACTIVITY 3: ***Analysis of multitemporal and multi-source lidar to better understand landslide process and extents***

Budget: $196,747

Description: Process repeat airborne lidar data in regions where available, compare to terrestrial lidar data, create digital database of findings

This last activity will focus on several major objectives. The first focuses on the use of repeat lidar data to quantify landslide impacts, with an emphasis on sediment loading to major rivers. Lidar data map the land surface in high-resolution (meter-scale horizontal resolution with decimeter vertical accuracy) at a single point in time. By using lidar-derived topographic data collected before and after landslides occur, it is possible to quantify how much change occurred between the two scans. This allows us to calculate the volume of sediment that was eroded as a result of that slide event.

The Minnesota DNR collected lidar just prior to and following the dramatic 2012 storms that led to widespread flooding and landsliding. Unfortunately, there are internal processing and georeferencing issues within the existing 3D data that have made prevented use of the repeat lidar data for quantitative measurements. Andrew Wickert at the University of Minnesota and Stephen DeLong of the USGS will address these issues using advanced processing methods to correct internal errors and to properly align the pre-and post-event lidar data. The alignment will be verified at select locations where we have repeat terrestrial lidar data collected over the same time period by Karen Gran at the University of Minnesota Duluth.

A similar dataset consisting of repeat airborne lidar data over a longer time period (2005-2012) exists in Blue Earth County. It has been aligned and evaluated by Schaffroth et al. (2015) and can be compared with data collected by Stephanie Day at NDSU. On-going data collection by both Gran and Day in the Duluth-area and the Minnesota River valley will provide erosion rates from landslides along river valleys that can be used to assess the impact of landslides on sediment loading in rivers.

DeLong and Wickert will work on establishing best practices for using lidar data for change detection associated with landslides. The change detection data will be included as another dataset in the geospatial database combining all of the historic and likely landslide sites across the study regions. These data will all be combined to develop a landslide susceptibility and hazard map for the five study regions in the state, which covers most of the area where landslides are a concern. The database, map, and a factsheet on landslides in Minnesota will be QA/QC'd and disseminated through the USGS as official USGS publication, and results of the 2012 Duluth area lidar analysis will be published in a peer-reviewed scientific journal.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 196,747
Amount Spent: $ 0
Balance: $ 196,747

Outcome	Completion Date
1. Analyze repeat airborne lidar in the Duluth area	May 2018
2. Use ongoing terrestrial lidar scans in each region for comparison with airborne lidar	May 2020
3. Develop best management practices for using lidar for meaningful change detection	June 2020
4. Create and disseminate preliminary landslide hazard map based on lidar topographic analyses, underlying geology, and empirical evidence from landslide inventory	June 2020

Activity 3 Status as of *January 30, 2018***:**

Activity 3 Status as of *July 30, 2018***:**

Activity 3 Status as of *January 30, 2019:*

Activity 3 Status as of *July 30, 2019:*

Activity 3 Status as of *January 30, 2020:*

Activity 3 Status as of *June 30, 2020:*

Final Report Summary:

Copy and paste the above structure for each additional project activity (e.g., Activity 2, Activity 3, etc.), starting at the activity title through the activity "Final Report Summary" entry.

V. DISSEMINATION:
Description: We propose to produce a USGS Fact-Sheet on landslides in Minnesota and a USGS Digital Database detailing the distribution of landslide hazards across the five study regions. To get our results into the hands of policy-makers, we plan to give at least two talks over the course of our project on the results of the findings at venues appropriate to reach regional and statewide environmental and land management agency staff (MPCA, MDA, BWSR, SWCDs, DNR, etc.). Results will be disseminated to the scientific community via journal articles detailing our scientific methods, observations, and conclusions in addition to presentations at the regional meeting of the Geological Society of America in 2020 (to be held in Duluth, MN).

Status as of *January 30, 2018*

Status as of *July 30, 2018*

Status as of *January 30, 2019*

Status as of *July 30, 2019*

Status as of *January 30, 2020*

Status as of *June 30, 2020*

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. Preliminary ENRTF Budget Overview:

***This section represents an overview of the preliminary budget at the start of the project. It will be reconciled with actual expenditures at the time of the final report.**

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 167,812	UMN personnel: Gran ($17,476), Jennings ($24,671), Wickert ($16,372), 2 graduate students ($100,930), and summer research assistants ($8,364)
Professional/Technical/Service Contracts:	$ 324,692	Collaborations with USGS (DeLong and geologist TBD) ($161,142), Minnesota State University at Mankato (Larson) ($51,964), Gustavus Adolphus College (Triplett) ($18,034), NDSU (Day) ($50,903), UW Superior (Breckenridge) ($6,674), Univ. of St. Thomas (McDermott) ($18,922), and Winona State Univ. (Blumentritt) ($17,053)
Equipment/Tools/Supplies:	$ 1,500	Field equipment, supplies for lidar scanning
Printing:	$ 1,000	Fact sheet and poster presentations
Travel Expenses in MN:	$ 4,996	Travel for field work and to attend annual collaboration meetings
Other:	$	
TOTAL ENRTF BUDGET:	**$ 500,000**	

Explanation of Use of Classified Staff: None used

Explanation of Capital Expenditures Greater Than $5,000: None requested

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 2 FTEs

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 5.6 FTEs

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
University of Minnesota	$67,665	$	Waived overhead (52% of direct costs)
North Dakota State University	$22,902	$	Waived overhead (45% of direct costs)
University of St. Thomas	$7,760	$	Waived overhead (41% of direct costs)
Winona State University	$4,520	$	Waived overhead (40% of direct costs)
U.S. Geological Survey	$10,000	$	In-kind salary
Minnesota State Univ., Mankato	$6,236	$	Waived overhead (12% of direct costs)
State			
	$	$	
TOTAL OTHER FUNDS:	**$**	**$**	

VII. PROJECT STRATEGY:

A. Project Partners:

The team was assembled because of their scientific and technical competence and their experience in each of the five study areas. Most received degrees from the U of M. The USGS Landslide Hazard Program's limited budget is focused on the Mountain West. One of their experts (DeLong) is based in Mounds View, Minn. and has joined this team. The USGS is a trusted source of geologic information and they will increase the quality and impact of our work including dissemination through USGS publications. All project partners listed here that are collaborating with University of Minnesota and UMD investigators would be funded with ENRTF funds, with additional in-kind support being provided from the University of Minnesota, MNSU, and the USGS.

Partners receiving ENRTF funding

1. *USGS Hazards Mission Area, Stephen DeLong and geologist to be named: fix issues with 2011-2012 Duluth lidar; do spatial analyses on statewide lidar; align efforts with USGS Landslide Hazard Program; mentor students, produce USGS publications.*
2. *North Dakota State University, Stephanie Day, Geosciences Department: supervise students mapping and doing historical research; advise grad-level project in terrestrial lidar in Red River valley and Le Sueur basin.*
3. *Minnesota State University, Mankato, Phil Larson, Geography Department and Earth Science Program: Supervise student mapping, hazard assessment and historical work; cover area between New Ulm and St. Peter.*
4. *Gustavus Adolphus College, Laura Triplett, Geology and Environmental Studies: supervise students mapping and doing historical research; cover area from St. Peter to Chaska.*
5. *University of Wiscosin Superior, Andy Breckenridge, Natural Sciences Department & Adjunct, Earth & Environmental Sciences, University of Minnesota Duluth: create metadata for prior work in lower St. Louis watershed; evaluate lidar difference map to be created for this area.*
6. *University of St. Thomas, Jeni McDermott, Geology Department: supervise undergraduates to inventory slope modifications and repairs in the metro area; field area metro to Red Wing.*
7. *Winona State University, Dylan Blumentritt, Geosciences Department: supervise students mapping and doing historical research in SE Minnesota along Mississippi and its tributaries.*

B. Project Impact and Long-term Strategy: This work acquires, analyzes, and distributes new data on landslides across the state of Minnesota. We propose to produce a USGS Fact-Sheet on landslides in Minnesota, a USGS Digital Database detailing the distribution of landslide hazard and journal articles detailing our scientific methods, observations, and conclusions. This work will include the development and application of innovative lidar processing techniques, making use of the state's investment in lidar data acquisition. Publication of landslide hazard assessments will provide science-based information to support decision-making to help:

- the MPCA implement targeted sediment-reduction strategies
- the DNR manage critical river corridors and avoid home buyouts
- communities manage land use in vulnerable areas
- a wide range of stakeholders plan for emergency response

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	$ Amount
Hennepin County and FEMA funds to start the Twin Cities landslide inventory – grant to Jennings	2015-2016	$40,000
*MPCA funds to document erosion rates on river bluffs in Minnesota River – grant to NDSU	2012-2016	$118,600
*GLRI funds to UMD to assess impact of stream stabilization efforts on river bluff erosion rates in Duluth-area streams	7/11-9/14	$60,588
*MN DNR Coastal Zone grant for lidar-based bluff assessment for coastal zone planning	8/12-12/14	$34,723
*UMN Water Resources Center funds from USGS to UMD to study erosional hotspots in North Shore streams using high-resolution spatial data	5/12-2/16	$39,047
Minnesota State University, Mankato, Funding for 2 graduate students to begin work on impact of landslides + in-kind time and travel for Larson	Current	$32,415

*Portions of these grants have provided initial data on sediment loading to rivers from landslides and other bluff failures and on spatial data analyses to map potential slide locations in the MN River basin and the North Shore.

VIII. REPORTING REQUIREMENTS:

Three years (7/1/17 – 6/30/20) to allow two full field seasons and three academic years.

- The project is for 3 years, will begin on 07/01/2017, and end on 06/30/2020.
- Periodic project status update reports will be submitted *January 30* and *July 30* of each year.
- A final report and associated products will be submitted between June 30 and August 15, 2020.

IX. VISUAL COMPONENT or MAP(S): (attached)

X. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS: NA

Restoration N/A

Environment and Natural Resources Trust Fund
M.L. 2017 Project Budget

Project Title: *Landslide hazards and impacts on Minnesota's natural environment*
Legal Citation:
Project Manager: *Karen Gran*
Organization: *University of Minnesota*
M.L. 2017 ENRTF Appropriation: $*500,000*
Project Length and Completion Date: *3 Years, June 30, 2020*
Date of Report: *Sept. 14, 2016*

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Landslide inventory***			***Landslide process and domain mapping***			***Lidar analyses, hazards, dissemination***				
Personnel (Wages and Benefits)	$13,765			$86,291			$67,757			$167,813	
Karen Gran ($17,476), UMD , Co-PI, (75% salary+25% benefits, 4% FTE/yr for 3 years) (summer): Supervise student mapping and historical research, graduate student synthesis project & terrestrial lidar scanning, Superior Basin.											
Carrie Jennings ($24,671), U of M, Project Manager, Co-PI, (75% salary+25% benefits, 6% FTE/yr for 3 years) (summer): Coordinate work, reports and budget; field characterization; result dissemination. Metro MN											
Andrew Wickert ($16,372), U of M , Geologist, (75% salary+25% benefits, 4%FTE/yr for 3 years) (summer): Supervise statewide LiDAR analyses and alignment of repeat Duluth lidar.											
Graduate research assistants (2) ($100,930), UMD and U of M , (51% salary+49% fringe) GRA1:(50% FTE for 1 year, 7/1/17-6/30/18) GRA2: (50% time for year 1, 19% FTE for year 2, 9/1/18-6/30/20). 1) Assist with synthesis of 5 regional maps; develop process domain model to aid with hazards delineation. 2) Statewide lidar and repeat lidar analyses.											
Undergraduate research assistants (1) ($8,364), UMD , (100% salary, 19% FTE) (summer). Conduct historical research, field mapping & verification; terrestrial lidar collection; Superior basin.											
Professional/Technical/Service Contracts	$36,017			$163,958			$124,716			$324,692	
U.S. Geological Survey ($161,142): Stephen DeLong (GS-13), Mounds View, MN, Landslide Hazards Program, 20% FTE/yr for 3 years; GIS Specialist (GS-7), 33% FTE/yr for 3 years: Properly align 2011-2012 repeat Duluth LiDAR; spatial analyses on statewide LiDAR; align efforts with USGS Landslide Hazard Program; mentor students; assist with QA/QC and data publication and dissemination.											

Minnesota State University, Mankato, ($51,964) Phil Larson 4% FTE/yr for 3 years; undergraduate assistants (20% FTE/yr for 2 yrs); graduate assistant (50% FTE for 1 yr); Mapping, hazard assessment and historical work between New Ulm and St. Peter.											
North Dakota State University ($50,903), Stephanie Day 2 % FTE/yr for 3 years; Undergraduate assistant (20% FTE/yr for 2 yrs), Graduate assistant (50% FTE/yr for 2 yrs); Terrestrial Lidar rental: Mapping, hazard assessment and historical research in Red River; repeat terrestrial LiDAR analyses in Red River and Le Sueur.											
Gustavus Adolphus College ($18,034), Laura Triplett 4% FTE.yr for 3 years; undergraduate assistants 20% FTE/yr for 2 yrs. Mapping and historical research in area from St. Peter to Chaska.											
University of St. Thomas ($18,922), Jeni McDermott 4% FTE.yr for 3 years; undergraduate assistants (20% FTE/yr for 2 yrs): Mapping and historical research in Twin Cities.											
UW Superior ($6,674), Andy Breckenridge: 2% FTE/yr for 3 years. Create metadata for prior work in lower St. Louis watershed; evaluate LiDAR difference map to be created for this area.											
Winona State University ($17,053), Dylan Blumentritt 4% FTE/yr for 3 years; undergraduate assistants (20% FTE/yr for 2 years): Mapping and historical research in SE MN.											
Equipment/Tools/Supplies				$1,500						$1,500	
Equipment/Tools/Supplies: Field books, shovels, TLS storage cards, sample bags, Munsell charts (1,500)											
Printing							$1,000			$1,000	
Fact Sheet for Landslide Hazards in Minnesota; Poster printing (1000)											
Travel expenses in Minnesota	$575			$1,147			$3,273			$4,996	
Quarterly meetings (1280 mi/yr); Field work (1063 mi/yr); NC GSA meeting (4,996)											
Other											
COLUMN TOTAL	**$50,357**	**$0**	**$0**	**$252,896**	**$0**	**$0**	**$196,747**	**$0**	**$0**	**$500,000**	

The cost of landslides in Minnesota

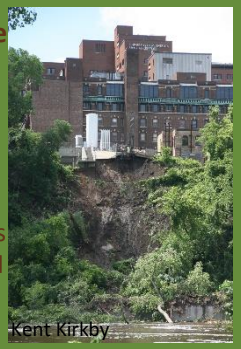
Landslides in Crookston has led to compromised house foundations.

Slow mass wasting between 2012 and 2015 in Moorhead damaged this new fishing pier that was later removed.

A landslide in the spring of 2013 made news when two elementary students were killed during a class field trip.

Flooding in the Summer of 2012 caused landslides leading to significant infrastructure damage in Duluth.

A landslide in June 2014 caused the West River parkway in Minneapolis to be closed and 20 people at The Fairview Hospital to be temporarily evacuated. The hospital was declared safe, but the hospital steam site sits just 10 feet from the cliff edge.



A massive failure in the summer of 2014 didn't damage any infrastructure, but contributed to high sediment loads in the Minnesota River watershed.

June 2014 in Henderson several landslides occurred on a ravine. One of these landslides destroyed a home causing well over $100,000 in damage.

Landslides in southeastern Minnesota damage agricultural fields.