M.L. 2015 Project Abstract
For the Period Ending June 30, 2017

PROJECT TITLE: Hydrologic Effects of Contemporary Forest Practices in Minnesota
PROJECT MANAGER: Dr. Diana Karwan
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2015, Chp. 76, Sec. 2, Subd. 03r

APPROPRIATION AMOUNT: $150,000
AMOUNT SPENT: $150,000
AMOUNT REMAINING: $0

Overall Project Outcome and Results

In forested landscapes, runoff amount and timing and sediment concentration and load are major water quality concerns. Previous studies on the effects of forest harvesting practices on water resources in Minnesota and throughout the Lake States region were conducted decades ago and their results have been widely applied beyond the conditions under which they were conducted. To facilitate effective, science-based forest management decisions, water quantity and quality information associated with contemporary forest harvesting practices is needed. To increase data on the hydrologic effects of contemporary forest management, we monitored stream discharge and water quality from early August 2016 to July 2018 at two river locations along the West Swan River in St. Louis county – one upstream and one downstream of ~100-acre growing season timber harvest. Average streamflow was approximately two times greater at the downstream site than the upstream site during the pre-harvest phase and increased to three times greater during the monitored post-harvest period. At the upstream site, average (± standard deviation) total suspended solids (TSS) concentrations remained relatively constant throughout the study (pre-harvest: 18.53 ± 21.49 mg/L; post-harvest: 19.81 ± 12.16 mg/L) whereas TSS concentrations at the downstream site very slightly increased from 22.13 ± 14.73 mg/L in the pre-harvest phase to 25.56 ± 24.85 mg/L in the post-harvest period.

Overall, this two-year data collection project quantified the variability of river flow and water quality as Total Suspended Solids concentrations. The variation water quality with approximately one year of pre- and post- timber harvest data showed slight differences that, for the most part, remain within the overall variability of pre-harvest conditions. Meaning that while the harvest had a nominal effect, this was seen only very local in space and near in time to the harvest. This relatively short case study provides data that is otherwise uncollected in this region. The results highlight the need to collect further data within the region and state to quantify the larger spatial effects of timber harvesting on water quality. In particular, additional efforts are needed to determine how site-level timber harvest effects scale up in space and factor into water quality planning at the watershed and/or hydrologic unit scale (e.g. in the Total Maximum Daily Load or One Watershed One Plan assessment and planning efforts).

Project Results Use and Dissemination

In the granting period, preliminary results of this project have been presented in 7 formal talks given by Dr. Karwan and Dr. Rose, as listed below. In addition to formal presentations, information learned from this project has been incorporated into teaching and broader conversation with forest management professionals by Dr. Karwan. First, Dr. Karwan provides forest hydrology instruction to silviculturists in the U.S.D.A. Forest Service National Advanced Silviculture Program every summer in Cloquet, MN. Lessons learned from this project, including working in mid-sized rivers and examining the effects of harvesting beyond small watersheds, are discussed as a part of this program. Second, information generated as a result of this project has been shared by Dr. Karwan as an invited participant to two groups affiliated with the State of Minnesota: (1) a 2018 panel convened to inform the research direction of the Minnesota Forest Resources Council, and (2) in meetings with a Technical Advisory Committee to the Minnesota Pollution Control Agency's team working to represent forestry Best Management Practices in hydrologic model scenarios (HSPF – SAM). Finally, work on this project formed the basis of an internship experience for two female high school students in Dr. Karwan's lab through the YWCA Minneapolis Girls Inc. *Eureka!* Program – a multi-year program for girls focused on STEM. In June – July 2018, two students assisted with water quality sample processing and traveled to the field site associated with this project. This experience formed a 4-week internship in which the high-school students experienced a STEM job first-hand and learned about both work in STEM fields and a university setting.

Upon completion of this project, we now have additional data and results to present. We are looking forward to doing this through venues that bring together scientists with forest and landscape managers, such as the annual Sustainable Forests Education Cooperative (SFEC) Forestry and Wildlife Research Review and the regional meetings of the National Council of Air and Stream Improvement, a timber industry group, which take places in the Great Lakes region in the spring/summer of odd years. Furthermore, data from this project can be incorporated into graduate research and further work on the watershed functioning of northern MN forests.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2015 Work Plan Final Report

Date of Report: August 17, 2018

Final Report

Date of Work Plan Approval: June 11, 2015

Project Completion Date: June 30, 2018

PROJECT TITLE: Hydrologic Effects of Contemporary Forest Practices in Minnesota

Project Manager: Dr. Diana Karwan

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Location: Itasca County and St. Louis County (field site) and Ramsey County (University of Minnesota Twin Cities, St. Paul campus)

Total ENRTF Project Budget: $150,000	**ENRTF Appropriation:**	**$150,000**
	Amount Spent:	**$150,000**
	Balance:	**$0**

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03r

Appropriation Language:
$150,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to install hydrologic monitoring stations to collect water quantity and quality data from lands managed for timber production to better understand the relationship between harvest practices and water resources and related responses to changing climate and other disturbance factors in order to inform forest management practices. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Hydrologic Effects of Contemporary Forest Practices in Minnesota

II. PROJECT STATEMENT:

Lack of understanding exists in Minnesota and the Lake States region regarding the effects of contemporary forest harvest practices on water resources. In forested landscapes, runoff amount and timing and sediment concentration and load are the major water quality concerns[1]. Previous studies in the region were conducted decades ago[2] and their results have been widely applied beyond the conditions under which they were conducted. For example, the strong preference for winter timber harvest is based on these previous studies and assumes certain temperature, soil, and other hydrologic conditions will occur. Climate, as measured by temperature and precipitation, has shifted and will likely continue to shift in the region causing further changes in watershed response to vegetation change. Additionally, forest health is further affected by pests, such as the Emerald Ash Borer (EAB), and fire, such as the Pagami Creek Fire of 2011. In order to make effective, science-based forest management decisions, water quantity and quality information is needed. Such information is difficult to find on managed timberlands within the state outside of the Marcell Experimental Forest. In order to understand the effects of timber harvests as they are currently conducted, this project will establish water resource monitoring sites for stream flow and associated fine sediments on lands managed for timber.

A need exists to collect and analyze time-series hydrologic data in order to evaluate the relationship between forest harvesting and stream water quantity and quality. This project will fill that need by collecting stream discharge and water quality data associated with managed timberlands in upland-dominated watersheds. The paired-watershed study design allows for comparison of results to previous studies, such as those in the Marcell Experimental Forest, in order to evaluate differences with watershed characteristics and harvest practices. Furthermore, time-series data and individual stream water samples will be collected in such a way to develop a mechanistic understanding behind correlations between contemporary forest management practices and stream hydrology. Results of this study will be shared widely within the forest management and scientific hydrology communities.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of *January 29, 2016***:**

Throughout the summer and fall of 2015 the project manager worked with Cheryl Adams and the UPM Blandin forestry team to evaluate possible field sites for stream monitoring stations. After in-depth discussions and field visits, sites in St. Louis County, just south of Hibbing, were selected. The map addendum to this workplan has been updated to show the sites and planned harvest area. As a result of specific site location, St. Louis County has been added to the project location section on page 1. Further information on this site is presented under Activity 1 below. The project team is now obtaining up-to-date quotes on field instruments for installation this coming spring.

Postdoctoral research, Dr. Lucy Rose, was hired and began work August 31, 2015. Dr. Rose will manage the site installation as well as ongoing monitoring and data collection at the stream stations. Her work is further detailed under the Activity 1 section below.

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[1] Knife River-Turbidity TMDL Project, 2010. Deer Creek Turbidity TMDL Project, 2013. Nemadji River-Turbidity TMDL Project, ongoing. Poplar River –Turbidity TMDL Project, 2013. Information online: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/lake-superior-basin-tmdl/lake-superior-basin-tmdls.html

[2] Summarized in Verry, E. S. (2004), Land Fragmentation and Impacts to Streams and Fish in the Central and Upper Midwest, in *A Century of Forest and Wildland Watershed Lessons*, edited by G. G. Ice and J. D. Stednick, pp. 129–154, Society of American Foresters, Bethesda, MD.

The National Council for Air and Stream Improvement (NCASI) had previously expressed interest in this project and has provided $40,000 to supplement the project budget. This money will be used to purchase additional stream monitoring equipment (to get more accurate discharge measurements under changing flow conditions) as well as supplement in-state travel and personnel needs. This is indicated under section VI.A. (Project Budget Summary, Other Funds).

Project Status as of *July 31, 2016***:**

Since January 2016, multiple site visits have been conducted. Activities during these visits included stream channel mapping at the two research sites, (herein referred to as 'Above' and 'Below' sites), instantaneous discharge measurements, and stream water sample collection for chemical analysis. In addition, measurement sensors and dataloggers necessary for the Above and Below stream stations have been purchased. Further details on measurement instrumentation are provided in Activity 1 below.

On June 1, 2016, undergraduate student Mark Houle was hired and has been assisting with laboratory and field tasks in support of this project. Specifically, Mark has worked with postdoctoral researcher Dr. Lucy Rose to locate suppliers for field equipment to be used in this project, maintained laboratory equipment necessary to support chemical analysis of samples, and assisted with taking measurements of stream characteristics and discharge during site visits. Mark will continue to work as an assistant on this project throughout the summer of 2017.

Project Status as of *January 31, 2017***:**

Since July 2016, all stream measurement, sampling, and datalogging instrumentation has been installed at the Above and Below study sites on the West Swan River. The suite of instruments at each site includes a turbidity sensor; a conductivity, temperature, and depth sensor; an automated stream water sampler; and a datalogger with data streaming functionality to enable real-time viewing and downloading of sensor data. One acoustic Doppler velocity meter (ADV) was installed in the stream channel at the Below site. Since the installation of measurement instruments, Dr. Rose has conducted regular trips to the study sites, accompanied by Dr. Karwan or her graduate students, to retrieve sensor data from the dataloggers and maintain the equipment. Additionally, two new awards have been made from external grantors that build upon this work. First, Dr Andrew Wickert (UMN Twin Cities, Department of Earth Sciences) and Dr. Karwan have received a grant from the Water Resources Center at the University of Minnesota to develop a new open-source turbidity sensor. The Above and Below sites on the West Swan River, associated with this project, will serve as a testing location for the development of an open-source turbidity meter.

Project Status as of *July 2017***:**

We were asked by LCCMR staff to forego this report based upon on-target project status and timing coincident with heavy staff workload due to review of proposals in the 2018 call.

Project Status as of *January 2018***:**

Since January 2017, all measurement, sampling, and datalogging equipment had remained at the Above and Below study sites on the West Swan River. In May 2017, two additional dataloggers were purchased for use with the electrical conductivity/temperature/depth (CTD) sensors deployed at each site. From mid-August to mid-September 2017, the 100-acre upland timber harvest was completed at the study site; all timber was removed from the site by November 2017 and only logging slash currently remains at the site. In November 2017, the Doppler velocity meter (ADV) was removed from the Below site on the West Swan River and installed in the stream channel at the Above site to collect data necessary to characterize the stage-discharge relationship at the Above site. Dr. Rose has continued to conduct regular trips to the study sites, accompanied by Dr. Karwan or her graduate students, to retrieve sensor data from the dataloggers and maintain field equipment. In addition, two undergraduate students at the University of Minnesota began working with Dr. Karwan and Dr. Rose in January 2018 to assist with field work, sample analysis, and data analysis related to this project. One

student will focus primarily on suspended sediments while the other will focus on stream water chemistry. Their work will form the basis for a "capstone research project" course, which all undergraduate students enrolled in the Environmental Sciences, Policy, and Management academic track must complete prior to graduating. Updates relevant to specific project activities are given below.

An amendment is requested to move funds between Activities within this project as well as from equipment/tools/supplies to personnel. Throughout the duration of this project, we request $7690 to be moved to personnel from equipment/tools/supplies ($6727) and within-state travel ($963). The additional resources were needed for personnel due to the timing involved for data processing and maintenance of equipment at the field sites. We were able to achieve the savings on the equipment through the additional resources provided by the National Council for Air and Stream Improvement (NCASI) (shown under Other Funds in Section VI.B below). The NCASI funds were used to purchase equipment utilized by this project. Further details of this request are given below:

- Activity 1: Move $9274 from Equipment/Tools/Supplies to Personnel. This is due to increased personnel needed to prepare and deploy equipment and enabled by the NCASI funding used to purchase initial round of equipment.
- Personnel: Move $29282 from Personnel under Activity 2 to Personnel under Activity 3. This is due to a shift in the timing of the timber harvest per the landowner's best practices. This shortened pre-timber-harvest monitoring (Activity 2) period by several months and lengthened post-timber-harvest monitoring (Activity 3) by several months.
- Travel: Move $931 from Activity 1 and $632 from Activity 2 to Activity 3. This accounted for additional travel needed to field site under this activity to ensure maintenance of equipment and collect samples during the snowmelt season in 2018. Savings earlier in the project were achieved through less over-night trips (more day-trips not requiring hotel stay) and the shortened timeline of Activity 2.
- The balance of resources $1584 (Activity 2, Personnel), $297 (Activity 1, Equipment) and $963 (Activity 1, Travel) to Equipment under Activity 2 ($2387) and Activity 3 ($466) in order to account for additional datalogging capacity that was needed during the later activities in this project.

Overall Project Outcomes and Results:

In forested landscapes, runoff amount and timing and sediment concentration and load are major water quality concerns. Previous studies on the effects of forest harvesting practices on water resources in Minnesota and throughout the Lake States region were conducted decades ago and their results have been widely applied beyond the conditions under which they were conducted. To facilitate effective, science-based forest management decisions, water quantity and quality information associated with contemporary forest harvesting practices is needed. To increase data on the hydrologic effects of contemporary forest management, we monitored stream discharge and water quality from early August 2016 to July 2018 at two river locations along the West Swan River in St. Louis county – one upstream and one downstream of ~100-acre growing season timber harvest. Average streamflow was approximately two times greater at the downstream site than the upstream site during the pre-harvest phase and increased to three times greater during the monitored post-harvest period. At the upstream site, average (± standard deviation) total suspended solids (TSS) concentrations remained relatively constant throughout the study (pre-harvest: 18.53 ± 21.49 mg/L; post-harvest: 19.81 ± 12.16 mg/L) whereas TSS concentrations at the downstream site very slightly increased from 22.13 ± 14.73 mg/L in the pre-harvest phase to 25.56 ± 24.85 mg/L in the post-harvest period. Overall, this two-year data collection project quantified the variability of river flow and water quality as Total Suspended Solids concentrations. The variation water quality with approximately one year of pre- and post- timber harvest data showed slight differences that, for the most part, remain within the overall variability of pre-harvest conditions. This relatively short case study provides data that is otherwise uncollected in this region.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Site Selection and Instrumentation
Description:

Site selection is critical to this field-based study. Activity 1 will result in the selection of 2 sites in watersheds near each other in which stream gaging/monitoring stations (described below) will be established. These two sites will be selected from land owned and managed by UPM Blandin in Itasca County, such as the creeks draining to Pokegama Lake, south of Grand Rapids (shown in Map attachment). Information from Pokegama Creek and other previous locations of water quality studies will be compiled during the first few months of this study in order to inform final site selection (Activity 1, Outcome 1).

Pokegama Creek has a history of research, including point-in-time characterizations of stream channel substrate and sediment [*Merten et al.*, 2010] and stream habitat for fish communities [*Hemstad et al.*, 2008]. As a part of previous studies, stream discharge was measured at individual times during the summer and fall of 2006. Historical data provides valuable information on the range of hydrologic conditions to expect and will be used to select stream monitoring locations (Activity 1, Outcome 2) and tailor the precise instrumentation for each site. For example, instruments with different calibrations will be selected based on the range of stream flows and turbidity expected at the two individual sites.

Installation of the two stream gaging stations will take place, one gage at each of the two selected sites, to allow for the most possible data to be collected during the project time. Stream gaging will consist of establishing a stable channel cross section at each of the two chosen research sites, either through the installation of a pre-calibrated control structure, such as a weir or flume, or through the selection of a stream cross section with stable bed/banks not prone to erosion or deposition under extreme flooding events. Final selection of the stream cross-section infrastructure will occur during site selection (Activity 1, Outcome 2) and will be informed by existing and historical measurements as well as the individual characteristics of each site.

Two stream gaging stations will be instrumented in order to continuously measure stream volumetric discharge and turbidity and to withdraw water samples for chemical analysis (for example biweekly during hydrologic baseflow and more frequently during rainfall and snowmelt events). Necessary instrumentation for each of the two sites includes a water depth sensor (e.g Teledyne Isco 720 flow module or similar pressure transducer), optical turbidity meter (e.g. Campbell Scientific Obs 3+ turbidity meter or similar optical sensor with data logging module), and automatic water sampler (e.g. Teledyne Isco Model 6712). This suite of sensors will allow for the continuous measurement of water level, which will be converted to stream discharge through a rating equation, continuous turbidity measurements, and systematic sampling of 1-liter stream water samples. Continuous water depth measurements will be converted to stream volumetric discharge through a site-specific rating equation. One-liter stream water samples will be withdrawn by the automatic sampler and subsequently analyzed for total suspended solids and basic water chemistry (under Activities 2-3 below). This sampler was selected because, when connected to the pressure transducer (e.g. ISCO Model 6712 with 729 flow module), it collects streamwater based on changes in water depth and allows for sampling throughout rainfall or snowmelt events. The emplacement of water monitoring and sampling equipment comprises Activity 1, Outcome 3.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 68,646
Amount Spent: $ 68,646
Balance: $ 0

Outcome	Completion Date
1. Compiled list of managed timberlands in Itasca County with previous stream hydrologic research. This list will include the measurements taken, range of stream discharge values, and associated scientific papers or reports.	*November 30, 2015*

2. Selection of 2 sites on nearby watersheds	*November 30, 2015*
3. Instrumentation of 2 gaging stations, one station on each of two watersheds, (identified in Task 2) to measure water depth and turbidity, and to collect samples for suspended sediment, and water chemistry	*May 31, 2016*

Activity Status as of *January 2016***:**

A list of previous water quality monitoring sites with information was compiled for Itasca County, focusing on areas on and near UPM Blandin ownership. A brief report on previous water quantity and quality monitoring sites is attached to this update. Despite initial site scouting in Itasca County, the project team plans to instrument two sites just to the east in St. Louis County. These sites were selected due to (1) the presence of stream water year round, and (2) an upcoming timber harvest on upland site of approximately 100 acres in size in the lower watershed. Nested watersheds will allow for quantification of harvest effects by placing one stream site above the harvest and another below.

The proposed harvest area and stream sampling sites are located in the Lake Superior Basin (8-digit HUC number 04010201). The harvest area encompasses 100 acres, and is located immediately adjacent to the West Swan River in St. Louis County (see updated map and inset panel). Vegetation in the harvest area is dominated by ~40 year old aspen (*Populus tremuloides*), with additional small areas (approximately 10% of total harvest area) of ~75 year old balsam fir (*Abies balsamea*) and ~100 year old ash (*Fraxinus* sp.) near the stream.

Stream measurements and event-based samples will be collected in two locations on West Swan River. The first location (hereafter referred to as "Above") will be located immediately upstream of the harvest area; this site is expected to reflect stream conditions that are unaffected by the timber harvest. The second location (hereafter referred to as "Below") will be located immediately downstream of the harvest area; we expect that this stream location will be influenced by similar factors to those operating at the Above location, as well as any effects of the 100 acre timber harvest. The stream distance between the Above and Below sampling locations is approximately 2.8 miles (4.5 km).

We have also investigated these sites relative to previous MPCA water quality sampling locations. MPCA stream sampling station MNPCA_S007_156 is located approximately 3.1 miles (5.0 km) upstream of the Above sampling location. In 2012 and 2013, water quality analyses were conducted periodically from June through September at this MPCA station; the most recent sample was collected on 26 September 2013. In addition, MPCA stream sampling station MPCA_S006-544 is located on the West Swan River approximately 3.1 miles (5.0 km) downstream of the Below sampling location. Water quality analyses were conducted on an approximately monthly basis at this station from April to December 2011, and again during April and June of 2013. Water quality was last assessed at this station on 25 June 2013. In summary, our sites are well poised to capture the immediate hydrologic conditions upstream and downstream of a planned 100-acre timber harvest.

As of this update, we have identified a suite of instruments for use at our stream monitoring stations. Identical stream gaging stations will be installed at both the Above and Below sampling locations in Spring 2016. Stream sampling instrumentation at each of two locations will include the following:

- One CTD sensor (Decagon Devices) for high temporal resolution measurement of electrical conductivity, temperature, and depth in the stream
- One turbidity sensor (Campbell Scientific OBS-3+) for high temporal resolution optical measurement of suspended solids and stream turbidity
- One 24-bottle automated sampler (Teledyne ISCO) for the collection of sequential streamwater grab samples under a variety of flow regimes.
- One Mayfly datalogger (Arduino/Stroud Water Research Center) for the collection and storage of all sensor data. All data is stored on a MicroSD memory card that can be removed from the datalogger and inserted into a field laptop for data retrieval.

In addition to this instrumentation, a single acoustic doppler flow velocity meter (SonTek IQ+) will be alternately deployed at the Above and Below stream locations to facilitate the development of a site-specific

rating curve at each location. The flow velocity meter will remain at each site until sufficient measurements have been taken across a diverse range of flow conditions to enable the development of site-specific rating curves. These rating curves will be used to accurately calculate discharge at each location. During its deployment at each site, the flow velocity meter will be connected to the Mayfly datalogger.

For the next 6 months, the main work of this project will be to purchase the necessary equipment and install the stream monitoring stations in the two locations on West Swan River.

Activity Status as of *July 2016***:**

To date, all of the water sampling equipment, sensors, and dataloggers necessary for initial deployment and sample collection have been purchased for this project. Both Teledyne ISCO automated samplers and their required power supplies (one 12-volt deep cycle marine battery for each autosampler) have been delivered. The SonTek IQ+ acoustic Doppler flow velocity meter has also been delivered, and pre-deployment testing and calibration of this instrument is complete. Due to a manufacturing defect in the Mayfly dataloggers that was discovered in June 2016, shipment of these dataloggers and the CTD and turbidity sensors from the Stroud Water Research Center was delayed. The manufacturing defect has been corrected and the dataloggers and sensors are currently being tested at the Stroud Water Research Center to ensure proper functionality of these dataloggers and sensors. We anticipate shipment and receipt of these dataloggers and sensors by the end of July. Upon receipt of this equipment, the entire suite of sensors and automated water samplers will be connected to the Mayfly dataloggers and deployed at the Above and Below stream sites. In the meantime, we have surveyed the stream channel at each site and taken stream discharge measurements during our visits. Measurements are described below under Activity 2.

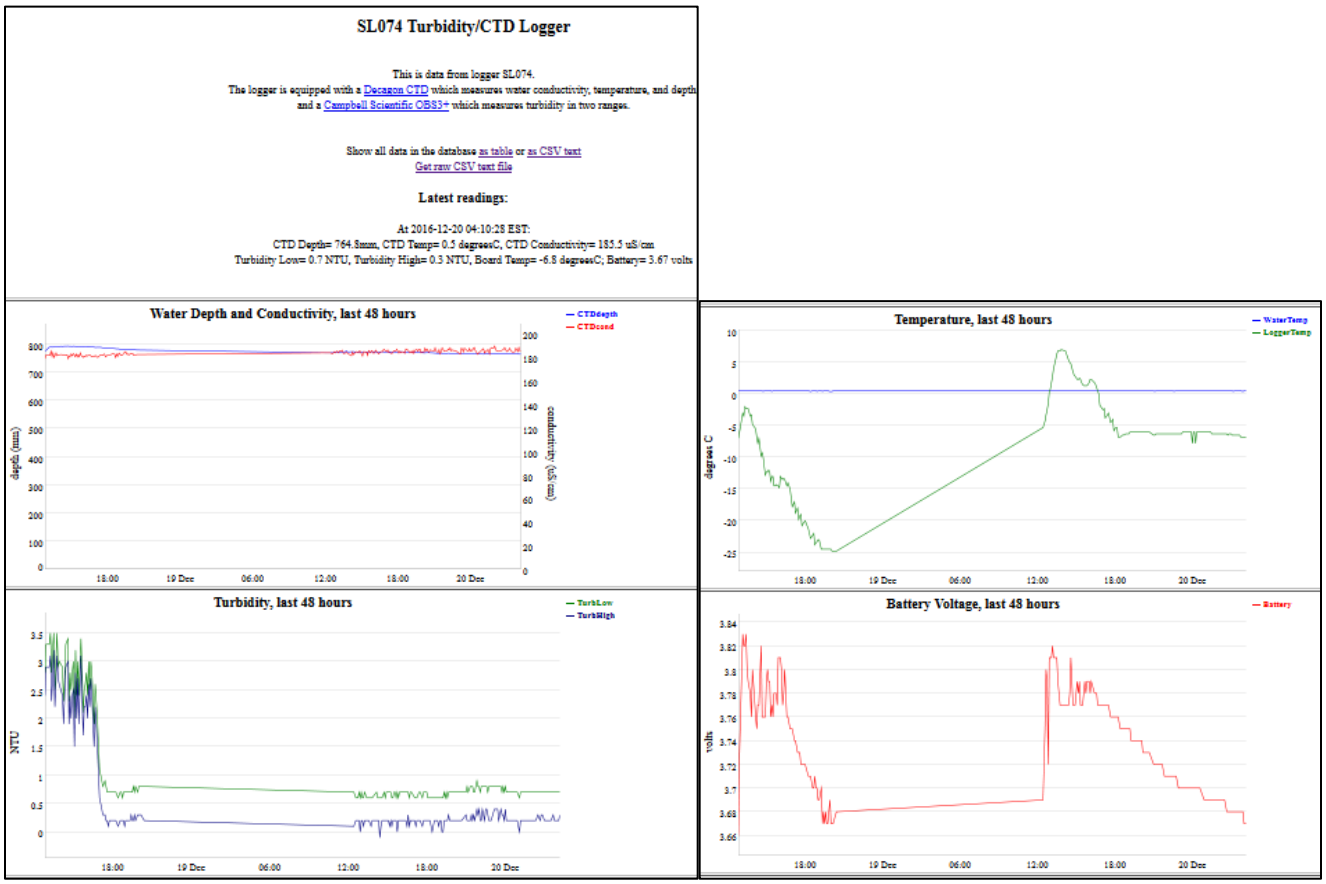
Activity Status as of *January 2017***:**

A turbidity sensor; conductivity, temperature, and depth (CTD) sensor; and a datalogger were installed at each study site on West Swan River in August 2016. An automated water sampler was installed at each site in late September 2016. Due to a damaged sensor on the acoustic Doppler velocity meter prior to its deployment in West Swan River, this instrument had to be sent back to the manufacturer for repairs. As a result, velocity measurements began at the Below site in October 2016. The turbidity and CTD sensors take measurements at 5-minute intervals and those data are stored in the datalogger installed at each site. In addition, each datalogger uploads the data to a website in near real-time so that the sensor information can be viewed and downloaded remotely (Figure 1 - below). As this real-time streaming capability relies on the availability of cellular network reception at the study sites, some gaps in data availability can occur on the website when cellular reception is inadequate. However, the complete record of sensor data is stored within each datalogger on-site, and Dr. Rose has made regular trips to the study site since the initiation of measurements to retrieve these data. Some gaps in the data record have occurred due to inadequate power supply to the dataloggers in cold temperature conditions. To address this problem, the 2-watt solar panels currently installed at each site will be replaced with larger-capacity 3.5-watt solar panels to ensure more efficient charging of the battery used to power each datalogger.

The acoustic Doppler velocity meter currently records data on stream flow rates at the Below site every 15 minutes. Data from this instrument are not available for real-time viewing and download on the website; however, Dr. Rose retrieves the data from this instrument as part of regular visits to the study site. This instrument will remain at the Below site until the spring snowmelt is completed, after which it will be moved to the Above site.

Automated water samplers were in place at the Above and Below sites from September through November 2016. Each sampler was equipped with a triggering mechanism to initiate the collection of sequential 1-liter stream samples (24 samples total) when the stream stage reached a pre-determined height above the streambed. Due to prolonged dry conditions at the study site during the period of water sampler deployment, stream stage did not fluctuate significantly enough to trigger the automated water samplers at either site. The samplers were removed from the site at the end of November after the West Swan River became iced over and

no further storm pulses were anticipated prior to the onset of spring snowmelt. The samplers will be re-deployed at each site prior to the onset of spring snowmelt to ensure that sequential stream samples can be collected during these important seasonal hydrologic events.



(Figure 1 – Example of online streaming data in near-real time).

Activity Status as of *July 2017***:**

We were asked by LCCMR staff to forego this report based upon on-target project status and timing coincident with heavy staff workload due to review of proposals in the 2018 call.

Activity Status as of *January 2018***:**

The stream turbidity, electrical conductivity, temperature, and depth (CTD), and acoustic doppler velocimeter (ADV) sensors all continue to collect measurements at the study sites. The ADV was moved from the Below site to the Above site in November 2017. Intermittent gaps in the data record have occurred, associated with malfunctioning dataloggers. We therefore installed a staff gauge in the stream channel at each site in April 2017 and programmed an outdoor trail camera at each site to take a photo of the water level indicated on the staff gauge once per hour during daylight hours each day. Although they do not provide a continuous record of stream level changes, these photos allow us to fill in gaps in the data record in the event of a datalogger malfunction. In early 2017, the cellular carrier AT&T ended its 2G cellular coverage nationwide, thereby significantly reducing the cellular coverage necessary for the web-based near-real time data viewing capabilities we previously described (e.g., as shown in Figure 1). Because we suspect that intermittent cellular coverage likely also contributed to the periodic datalogger malfunction we experienced, we disconnected the cellular-enabled module from the Mayfly dataloggers altogether. This has improved datalogger performance

and reliability. In order to ensure that potential future datalogger issues do not result in data gaps from multiple sensors, we installed one additional Decagon datalogger at each site in June 2017. These new dataloggers are only connected to the CTD sensor. Thus, the Mayfly dataloggers currently record measurements only for the turbidity sensors. Due to a broken cable (which was chewed on by an animal) that we discovered in late June 2017, we replaced the CTD sensor at the Above site in early July 2017. Thus, as of March 2017, we have instrumented the sites with redundancies to monitor water level and as of June 2017, we have implemented changes to ensure a more consistent record of water quality data. This monitoring will continue for the duration of the project.

Final Report Summary:

Dataloggers, sensors, water samplers, and staff gauges were employed at both project sites to measure discharge, water depth, turbidity, and TSS concentrations throughout the study period. These instruments remained in place at the study sites for the duration of the project, actively collecting data from August 2016 – July 2017. Using a variety of instrumentation including pressure transducers and staff gauges for stream depth measurement, and an acoustic doppler velocimeter (ADV) for flow measurement at 5-minute intervals, we reconstructed discharge records whenever possible over the two-year study period for the upstream and downstream sites. While the discharge and water depth sensors functioned properly throughout most of the study period, occasional gaps in the data record occurred due to malfunctions and winter conditions which made accessing instruments in the stream difficult. Reconstruction of the flow record during the winter months presented a unique challenge, as ice-covered stream conditions periodically interfered with stream depth measurements on the staff gauge or CTD sensors.

Automated sequential water samplers (ISCOs) were programmed to collect 1-liter samples of stream water at regular intervals during rain storms and snowmelt events to quantify TSS concentrations through time during hydrologic events. A total of 12 events were sampled at the upstream and 10 at the downstream site, including multi-week snowmelt events in 2017 and 2018. An extremely flashy snowmelt event from late March to early April of 2017 resulted in the loss of all TSS samples collected at the downstream site during the snowmelt period (the ISCO sampler became submerged and overturned by the rising stream level, leading to the loss of all discrete samples collected during this period). Therefore, we were only able to quantify TSS concentrations at the downstream site during events on 26 April, 5 June, and 26 June during the pre-harvest period; corresponding discharge data for these samples were only available for the June events. Stream water collection during the post-harvest period was more successful and we were able to characterize the TSS concentration dynamics at both sites during several hydrologic events from the fall of 2017 through the summer of 2018.

The turbidity sensors periodically suffered from “fouling”, which occurs when biological film growth on the optical window of the sensor prevents the accurate measurement of stream turbidity. Whenever the turbidity sensors were accessible (i.e., the stream level was low enough to allow them to be reached safely and the stream was not frozen), we cleaned the optical window physically, by wiping it. However, the relatively infrequent accessibility of these sensors throughout the study period resulting in little usable turbidity data from either site. In future projects aimed at measuring stream turbidity year-round, it is advisable to install turbidity sensors equipped with automatic wipers to regularly clear the optical window, despite their relatively high financial cost.

Figure 1A (below) shows CTD and turbidity sensor installation (left panel) and the accompanying stream cross-section measurements (right panel) taken at deployment and repeated throughout the project. Further details on the pre-harvest and post-harvest dynamics at both sites are given below under Activities 2 and 3, respectively.


Figure 1A: LEFT: CTD and turbidity sensor installation at the downstream site. RIGHT: Dr. Rose with students collecting stream-cross section measurements to accompany sensor installation.

ACTIVITY 2: Pre-treatment Monitoring

Description:

Water stage and quality will be monitored in the research site for a minimum of 1-2 years prior to timber harvest, beginning at the time of site instrumentation (Outcome 3 of Activity 1) through the winter of 2017 - 2018, when a harvest will take place based on the land owner's business-as-usual operations. During Activity 2, water quantity and quality data will be collected in order to quantify the pre-harvest condition of the watershed.

Stage (water depth) measurements will be recorded continuously by the pressure transducer and converted to stream discharge by a site-specific rating equation. Turbidity measurement will also be recorded continuously with the optical turbidity sensor. One-liter stream water samples will be withdrawn by the automatic sampler on an approximately biweekly basis during baseflow conditions but more frequently during storm events or time of rapid change in stream condition. Once collected, water samples will be analyzed for Total Suspended Solids (TSS) and stream anions and cations at the University of Minnesota – Twin Cities based on standard methods. TSS data will be used to calibrate turbidity sensors and provide site-specific relationships between turbidity and TSS, thus enabling a continuous time-series record of TSS for the project duration that includes monitoring during rainfall and snowmelt events.

In addition to TSS, water samples will be analyzed for dissolved chemical species, such as cations and anions, which can be used with nearby precipitation data to evaluate contributions of surface and subsurface waters to the stream (e.g. [*Hooper*, 2003; *Klaus and McDonnell*, 2013]). These samples provide the necessary data to evaluate the relative importance of different hydrologic pathways linking the forested watershed to the stream. Ultimately, these water flow pathways will be important to understand and predict hydrologic response to forest management. The data collected under Activity 2 will be used in conjunction with that collected in Activity 3 for an analysis of change in hydrologic condition with forest harvest.

Hydrologic output (stream discharge and turbidity/suspended sediment) from each of the two instrumented sites will be related to each other through a linear model, as is typical in paired watershed studies [*United States Environmental Protection Agency*, 1993]. This model will be reported as Activity 2, Outcome 4 and used to allow for comparison of sites during and after timber harvest (Activity 3).

Because the duration of this study includes approximately 18 months of monitoring pre-timber harvest, rainfall-runoff models may be used to evaluate a larger range of hydrologic conditions than we experience between the spring of 2016 and the winter of 2018 (e.g. if the study years are anomalously wet or dry, rainfall or snowmelt events that are larger or smaller than what the site experiences during this project will be evaluated using a model). In this manner, a model can be used robustly evaluate the hydrologic effects of timber harvest

over a broader range of conditions [*Zégre et al.*, 2010]. During the time the project team is gathering the calibration data, a review of the scientific literature will be conducted to determine the successful application of rainfall-runoff modeling in upland-dominated watersheds of the Great Lakes region (Activity 2, Outcome 3).

Summary Budget Information for Activity 2:

ENRTF Budget: $ 27,909
Amount Spent: $ 27,909
Balance: $ 0

Outcome	Completion Date
1. Data set of stream discharge at each of the two instrumented gaging sites (one site to receive a harvest, the other to serve as its unharvested control)	*February 2018*
2. Data set of turbidity and suspended sediment at each of the two instrumented gaging sites (one site to receive a harvest, the other to serve as its unharvested control)	*February 2018*
3. Report containing the review of scientific literature on application of rainfall-runoff models in Great Lakes watersheds	*February 2018*
4. Comparison of the stream discharge data at each of the two instrumented gaging sites to each other. A relationship will be developed to relate the stream discharge at the gage in the watershed to remain unharvested to the gage in the watershed to receive a harvest.	*March 2018*

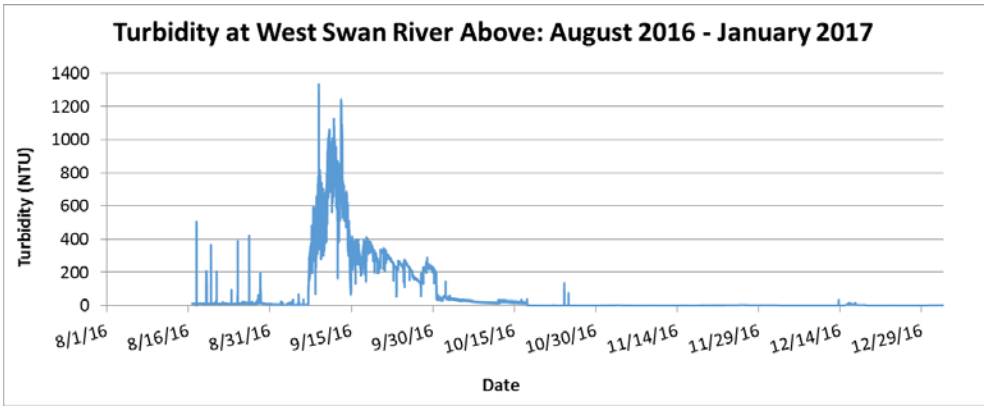
Activity Status as of *January 2016***:**
No activity

Activity Status as of *July 2016***:**

Calibration of the SonTek IQ+ acoustic Doppler flow velocity meter (Activity 1) required the collection of multi-point depth profile information for stream cross-sections at the Above and Below stream locations. Data collection for these stream cross-sections was completed in May and June of 2016. While conducting these stream cross-section measurements, we also measured instantaneous discharge rates at both stream locations using a hand-held flow velocity meter. On May 25, 2016, average instantaneous discharge at the Above site was 0.38 m^3/s; on June 8, 2016, average instantaneous discharge at the Below site was 0.19 m^3/s. We also collected instantaneous stream water grab samples at the Above and Below stream locations during this time. These samples are currently stored in Dr. Karwan's laboratory at the University of Minnesota. During a site visit on July 21, 2016, an additional instantaneous stream water grab sample was collected at the Above stream site (sample collection at the Below site was precluded by site inaccessibility due to multiple downed trees across the site access road). All of these water samples are currently awaiting chemical analysis.

Activity Status as of *January 2017***:**

Data collection at the Above site began in mid-August 2016 and is currently ongoing. Few gaps in the measurement and recording of data have occurred at this site. Initial measurements of turbidity at the Above site in West Swan River showed particularly interesting temporal patterns (Figure 2). From August 2016 to January 2017, turbidity values ranged from 0.0 Nephelometric Turbidity Units (NTU) to 1644.1 NTU, with a median value of 8.8 NTU. The stream at this site was particularly turbid throughout the month of September when the median turbidity was 264.5 NTU. This is in contrast to the rest of the measurement period (i.e., August 2016 and October 2016 to January 2017), during which the median turbidity was only 1.6 NTU.



(Figure 2 – Example of stream turbidity measurements at the West Swan River Above site)

At the Below site, data collection began in mid-August 2016 and continued with few interruptions through mid-November 2016. Since mid-November, datalogger performance has been highly intermittent. After discussing the possible causes of this problem with the developers of the datalogger, we concluded that the poor performance is likely attributable to inadequate charging of the datalogger battery through the solar panel currently in place at this site. We have installed higher capacity solar panels at the Above and Below sites in order to fix this issue. For the period from August 2016 to November 2016, turbidity measurements at the Below site were similar to those at the Above site, ranging from 0.0 NTU to 1749.9 NTU, with a median value of 4.8 NTU. Temporal patterns in turbidity were less distinct at the Below site compared to the Above site, with no sustained elevation in turbidity throughout September at the Below site.

Due to a damaged sensor, the acoustic Doppler velocity meter was returned the manufacturer for repairs prior to its originally planned deployment date. Therefore, velocity measurements began at the Below site in October 2016, with measurements recorded every 15-minutes. From October to December 2016, instantaneous discharge rates ranged from 0.01 m^3/s to 15.98 m^3/s at the Below site.

Activity Status as of *July 2017***:**

We were asked by LCCMR staff to forego this report based upon on-target project status and timing coincident with heavy staff workload due to review of proposals in the 2018 call.

Activity Status as of *January 2018***:**

We continued to collect pre-treatment measurements of stream turbidity, electrical conductivity, temperature, and depth at 5-minute intervals at the Above and Below study sites through September 2017. Discharge measurements were also collected at 5-minute intervals at the Below site until November 2017; at that time, the ADV was moved to the Above site so that 5-minute discharge measurements could be initiated there. These discharge measurements will continue through the duration of the study.

Baseflow stream water samples have been collected at each site during each visit to the study site. In addition, sequential stormflow samples were collected at the Above and Below sites during the 2017 snowmelt (Above site only) and rain storms in April, May (Above site only), June, July (Above site only), and September 2017). The TSS concentrations measured at the Above and Below sites during these hydrologic events are shown in Figure 3.

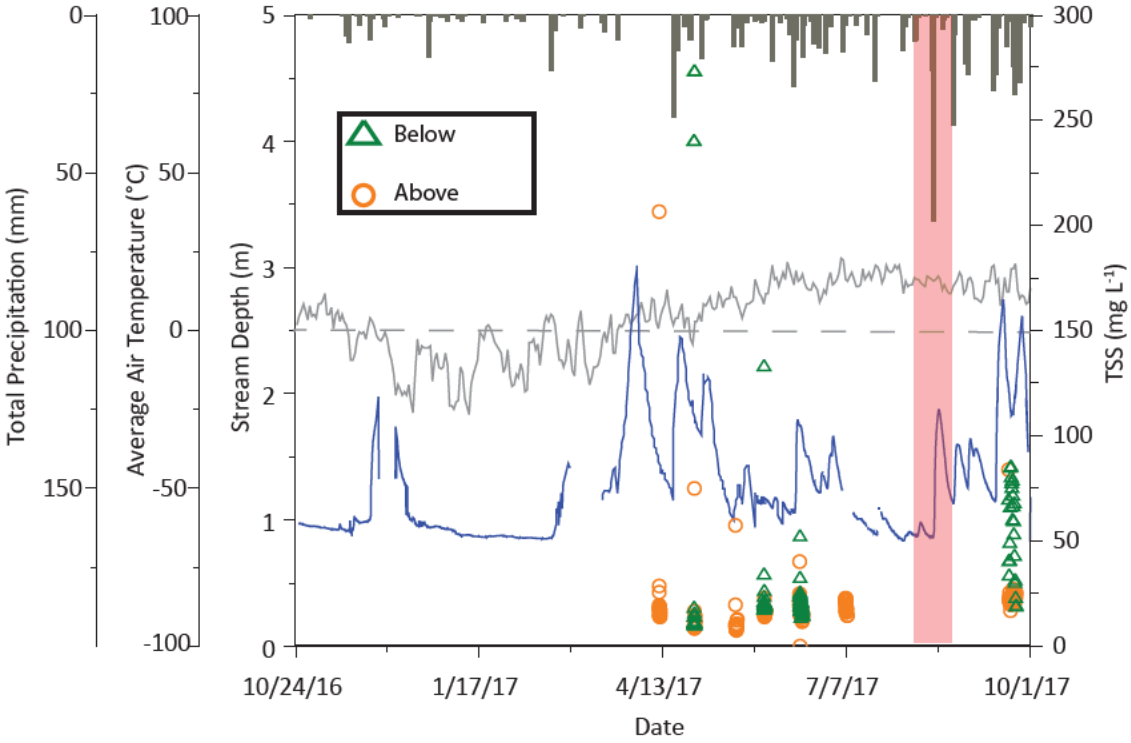


Figure 3. Total daily precipitation (dark gray bars), average daily air temperature (light gray line), stream depth (blue line), and TSS concentrations at the Above and Below sites during sampled hydrologic events on West Swan River. Dashed gray line shows the boundary between below and above freezing temperatures. Shaded red area shows the approximate time of the timber harvest at the study site.

Final Report Summary:

Pre-harvest monitoring of discharge rates and water quality occurred at both sites until early September 2017, when the timber harvest was completed. Timber harvesting activities occurred at the site from early August through mid-September 2017. Despite occasional interruptions in data collection due to datalogger or sensor malfunctions, several important insights regarding water quality and quantity can be gleaned from the pre-harvest data. First, the average discharge rate during the pre-harvest period was higher and more variable at the downstream site than the upstream site (downstream average ± standard deviation: 1.49 ± 2.10 $m^3 s^{-1}$; upstream average ± standard deviation: 0.65 ± 0.49 $m^3 s^{-1}$). We are also providing a video showing the downstream site streamflow time-lapse during the snowmelt / spring 2017 season to provide frame of reference for the variability of this river.

To calculate average TSS concentrations at the upstream and downstream sites, we used a widely-accepted data analysis tool developed by the USGS: "Weighted Regressions on Time, Discharge and Season" (WRTDS)[3]. This tool considers the variation in discharge rates during sample collection in order to account for the influence of water flux on constituent, here TSS, concentrations. It is particularly important to consider this factor when drawing comparisons among sites that might differ with respect to flow dynamics. TSS concentrations during the pre-harvest period were slightly higher on average at the downstream site; however, concentrations were more variable at the upstream site (downstream: 22.13 ± 14.73 mg L^{-1}; upstream: 18.53 ±

[3] Hirsch, R.M., and De Cicco, L.A., 2015, User guide to Exploration and Graphics for RivEr Trends (EGRET) and dataRetrieval—R packages for hydrologic data (version 2.0, February 2015): U.S. Geological Survey Techniques and Methods book 4, chap. A10, 93 p., *http://dx.doi.org/10.3133/tm4A10.*

21.49 mg L^{-1}). Discharge and TSS concentrations at both sites are shown in Figure 4. The pre-harvest period is to the left of the shaded area. Given the high degree of variability and relatively low average TSS concentrations observed at both sites, we did not find the two sites to differ substantially with respect to TSS concentrations during the pre-harvest period. Further discussion of the post-harvest time and comparison of discharge and TSS between pre- and post-harvest, see the Final Report Summary for Activity 3 below.

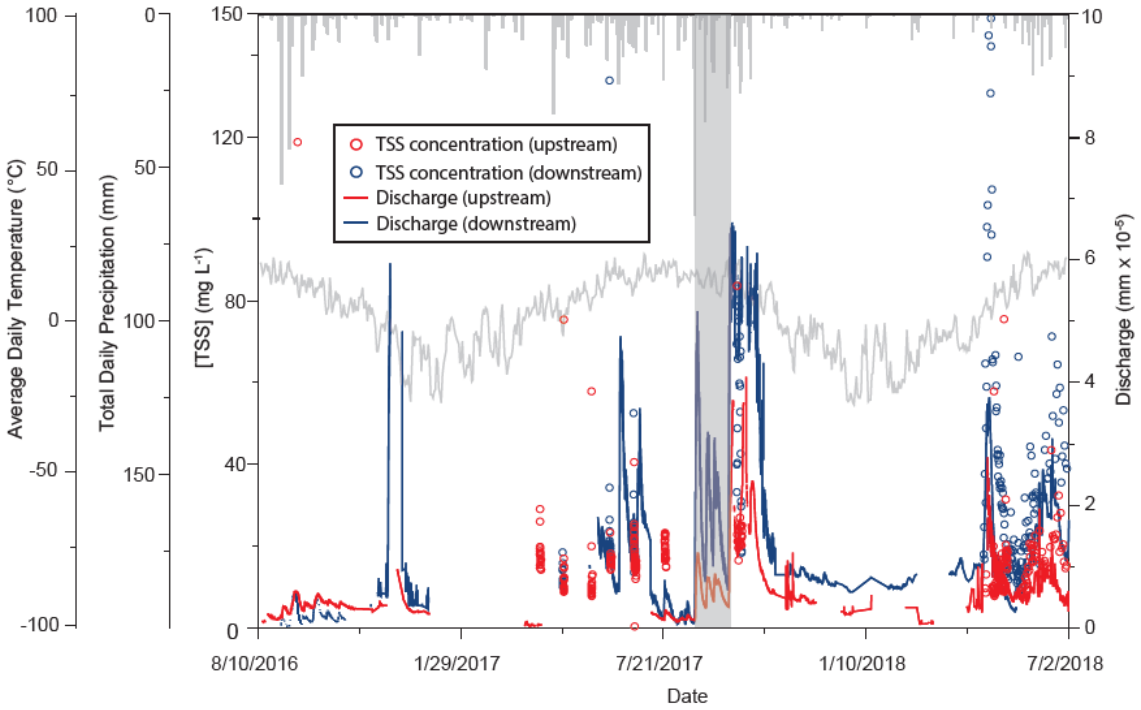


Figure 4. Stream discharge at the upstream site (red line) and downstream site (blue line), and TSS concentrations at the upstream (red circles) and downstream (blue circles) sites during sampled hydrologic events on West Swan River. Discharge is normalized by the watershed area of each site. Shaded gray area shows the time of the timber harvest at the study site. Gray bars from top of graph show total daily precipitation (note inverted y-axis) and gray line shows average daily air temperature.

ACTIVITY 3: Timber Harvest Treatment Monitoring

Description:

This project will monitor stream discharge and sediment export responses to timber harvest, conducted by the landowner according to the contemporary practices during the late winter months (January – February 2018) (Activity 3, Outcome 1). During site selection (Activity 1), communication with the landowner/manager will begin regarding their plans for forest management over the coming years and this information will be considered when selecting a site. The current study is designed to provide hydrologic monitoring around planned, business-as-usual forest management activities. Because the harvest activity is not funded by this study and presumably would be conducted in the absence of this study, it is not listed as a study-specific outcome. Hydrologic monitoring, as described above under Activity 2, will continue during and after the harvest in order to evaluate hydrologic changes during and after timber harvest. This monitoring data comprises Activity 3, Outcome 1. There will be two stream gaging stations – one of these two watersheds will receive a harvest treatment while the other will not and will be considered a control. In order to compare stream hydrology with and without timber harvest, the watershed containing harvest units will be compared to the second instrumented watershed, which does not experience a harvest (Activity 3, Outcome 2). Results of these

comparisons will be subsequently presented at one state or regional conference, such as the Minnesota Water Resources Conference or Northern Regional Meeting of the National Council for Air and Stream Improvement and will contribute to scientific peer reviewed publications on forest hydrology in the region.

Additionally, comparisons may be made between the during- and post-harvest data and the results of a rainfall-runoff model (selected from the review conducted under Activity 2, Outcome 3). This model will be used in the case the range of rainfall/snowmelt conditions experienced following harvest are outside of the range of those observed during the calibration period (the duration of Activity 2). For example, if the project years are unusually wet or dry a rainfall-runoff model (e.g. as in [*Zégre et al.*, 2010]), calibrated using historical and ancillary information, can be used to simulate how the watersheds would respond to a precipitation event larger or smaller than what is experienced during the study. Such a model would not be a substitute for collecting data during the project period but can be used as a way to test watershed response to a precipitation event size not experienced during the timeframe of this study. If deemed necessary, such a model will be calibrated during Activity 3. The selection of a particular existing model will take place based on review of successful modeling efforts in the region, which was performed under Activity 2.

The main outcome of Activity 3 will be a comparison of the water quantity and quality in watersheds with and without harvest during the harvest and immediate post-harvest time intervals (Activity 3 Outcome 2). This study will provide valuable information on the water quantity and quality differences between a watershed receiving a timber harvest and a nearby unharvested, or control, watershed. After the three-year duration of this project, rather than retire the study sites, the project team intends to continue collecting data and seek additional funds to extend the study and monitor the two watersheds as the forest regrows in the harvest area.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 53,445
Amount Spent: $ 53,445
Balance: $ 0

Outcome	Completion Date
1. Data on stream discharge, suspended sediment, and turbidity data during and immediately following harvest in treatment and control sites assembled	*June 2018*
2. Comparison of hydrologic data between harvested and unharvested watershed	*June 2018*

Activity Status as of *January 2016***:**
No activity

Activity Status as of *July 2016***:**
No activity

Activity Status as of *January 2017***:**
No activity

Activity Status as of *July 2017***:**
No activity

Activity Status as of *January 2018***:**

Timber harvesting at the site began in mid-August and concluded in mid-September 2017. Since the completion of the harvest, the identical suite of discharge and water quality metrics monitored prior to the harvest have continued to be monitored at the Above and Below sites. In addition, sequential stream water samples were collected for one storm event following completion of the harvest (on 21 September 2017). The range TSS concentrations at the Above and Below sites during this event are shown in Figure 3. Measurements

of turbidity, electrical conductivity, temperature, and water depth will continue to be recorded every 5 minutes at the Above and Below sites through the end of the project. Similarly, near continuous discharge measurements will be recorded at the Above site through the summer of 2018 so that the data can be used to quantify the stage-discharge relationship at this site.

Final Report Summary:

Post-harvest monitoring of discharge rates and water quality occurred at both sites until early July 2018. Stream discharge and TSS concentration data for the post-harvest period are shown in Figure 4 (to the right of the shaded gray area) above in the Final Report Section of Activity 2. Data and sample collections were less problematic during the post-harvest period, providing robust information on water quantity and quality parameters at both sites following the harvest. Similar to the pre-harvest period, average discharge was higher and more variable at the downstream site than the upstream site during the post-harvest period (downstream average ± standard deviation: 2.33 ± 1.69 $m^3 s^{-1}$; upstream average ± standard deviation: 0.76 ± 0.89 $m^3 s^{-1}$).

Like the pre-harvest time interval, higher TSS concentrations were measured at times of higher flow. Average TSS concentrations were higher at both sites during the post-harvest period compared to the pre-harvest phase and measured TSS concentrations became more variable at the downstream site and less variable at the upstream site. Average TSS concentrations accounting for variation in flows, determined using the WRTDS tool, were 25.56 ± 24.85 mg L^{-1} at the downstream site and 19.81 ± 12.16 mg L^{-1} at the upstream site. TSS concentration versus discharge during the pre- and post-harvest phases is shown in Figure 5. Concentrations increased with discharge at both sites, particularly in the post-harvest period. However, the much larger range of discharge rates observed at the downstream site following the harvest also contributed to higher TSS concentrations at this monitoring location. Although the highest discharge rates were observed during a growing season rain storm event that occurred in September 2017 (immediately following the timber harvest), these storm flows were not associated with the highest TSS concentrations during the study. Rather, the highest TSS concentrations at the downstream site coincided with the snowmelt period in April 2018 (Figure 5). At their peak, TSS concentrations during this snowmelt event were nearly 200 mg L^{-1} (Figure 5).

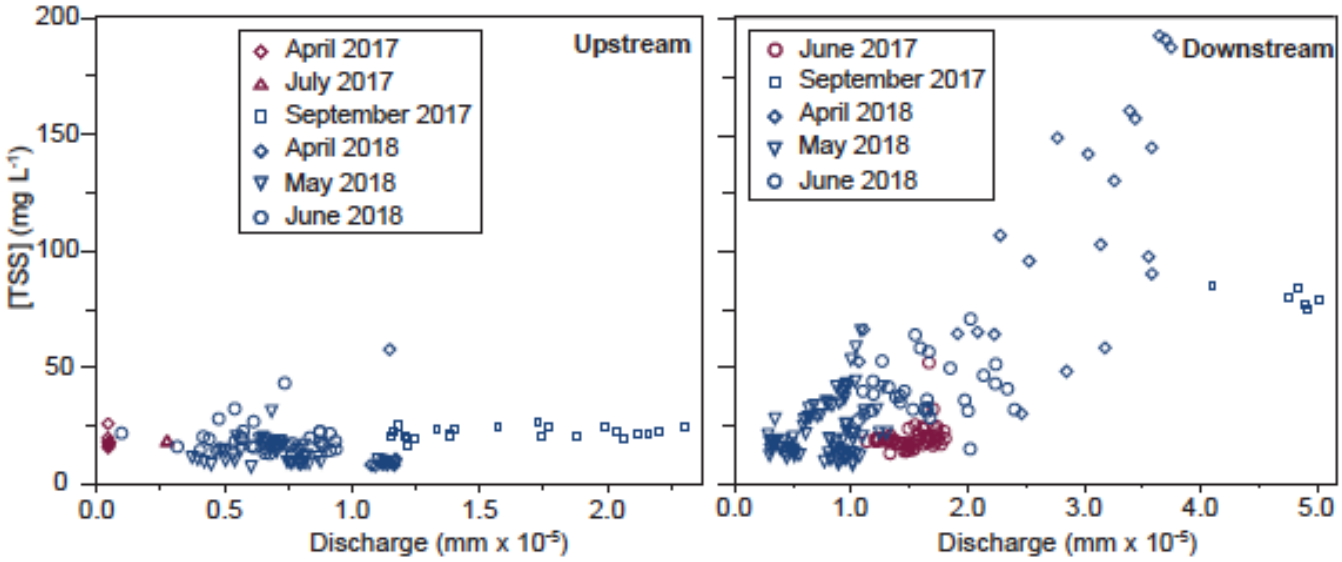


Figure 5. TSS concentrations versus area-normalized discharge (e.g. Discharge / Watershed Area) at upstream and downstream monitoring sites. Different shapes indicate different months during which TSS samples were collected; different colors indicate pre-harvest (red) and post-harvest (blue) phases. Notice the difference in x-axis between the two panels – the upstream site maximum discharge was approximately half that of the

Downstream site.

Although our dataset for the pre-harvest period is somewhat limited, we observed similar TSS concentrations at the upstream and downstream sites as prior to the timber harvest. During the post-harvest phase, the range of discharge rates was greater at the downstream site (Figure 5) and TSS concentrations also showed a stronger response to increasing discharge at the downstream site (R^2=0.58, p<0.0001) compared to the upstream site (R^2=0.05, p=0.01). Strong seasonal differences in TSS concentrations are apparent at the downstream site, with maximum TSS concentrations nearly three times higher during the spring snowmelt than during growing season rain events, despite the highest rates of stormflow occurring during growing season rain events in September 2017, as shown in Figure 5. It is important to emphasize that sample collection for this study was biased toward events (rain and snowmelt), as these are typically the conditions during which TSS mobilization is greatest. Viewed within that context, the average TSS concentrations of 25.56 ± 24.85 mg L^{-1} at the downstream site and 19.81 ± 12.16 mg L^{-1} at the upstream site suggest that during the period immediately following the stream-adjacent timber harvest, no serious water quality changes related to TSS were evident. Again, we realize the limitations of this sampling in accordance with the grant timeline, means we have approximately one year of pre- and post- harvest data. We strongly recommend future work examine the extent to which TSS mobilized in this stream during growing season and snowmelt events originates from landscape sources (e.g., within the harvest area) or from within-channel processes (e.g., streambank erosion and resuspension of streambed sediments) and whether the sources and concentrations of TSS change with increasing time since harvest.

V. DISSEMINATION:

Description:

The findings of this project and future projects based on this monitoring network will contribute to the knowledge of the hydrologic effects of forest management activities in the region.
The data generated by this project will be used to generate one graduate dissertation, peer-reviewed scientific publications, and presentations at state and national water resource conferences. In particular, we will target conferences for forest and water resource managers in the region, such as Minnesota Water Resources Conference and Northern Regional Meeting of the National Council for Air and Stream Improvement.

Status as of *January 2016***:**
No Activity

Status as of *July 2016***:**

Dr. Karwan has presented two formal talks which include information about this project as well as historical studies on the hydrologic effects of forest management in Minnesota and nationwide. In both presentations this project was described and the LCCMR funding was acknowledged. The first presentation titled "Review of the Science: Forests, Sediment, BMPs, Watershed Landscape and In-Channel Processes" was delivered at the Minnesota Society of American Foresters and American Fisheries Society Joint Meeting in Duluth, MN, on February 2, 2016. Dr. Karwan also gave a lunchtime presentation /webinar to the Sustainable Forests Education Cooperative (SFEC) on March 15, 2016, titled "Forest Management Effects on Water." A recording of this presentation is available online at http://sfec.cfans.umn.edu/2016-webinar-forest-management-effects-on-water/.

Status as of *January 2017:*

Nothing additional to report.

Status as of *July 2017***:**

We were asked by LCCMR staff to forego this report based upon on-target project status and timing coincident with heavy staff workload due to review of proposals in the 2018 call.

Status as of *January 2018***:**

Preliminary results of this project have been presented in four formal talks given by Dr. Karwan and Dr. Rose. In all presentations, the aims and scope of the project were described and the LCCMR funding was acknowledged. The first presentation was given by Dr. Karwan to the Soil Water Conservation District Forestry Association, held on March 16, 2017 in McGregor, MN. A subsequent presentation was given on November 29, 2017 as part of a departmental seminar series in the Department of Forest Resources at the University of Minnesota; the talk was titled "Measuring the Complicated Relationships between Land Cover, Management, and Surface Water". A recording of the presentation is available at https://www.youtube.com/watch?v=zkxxJb5K1H0&feature=youtu.be. Preliminary results of this project were also presented at the Sustainable Forests Education Cooperative (SFEC) 2018 Forestry and Wildlife Research Review at the Cloquet Forestry Center in Cloquet, MN on January 11, 2018. The final presentation was given at the Water Resources Assembly and Research Symposium, organized by the University of Minnesota Water Resources Center on January 19, 2018. This presentation focused primarily on the suite of sensors and samplers currently deployed at both study sites in support of this project.

Final Report Summary:

In the granting period, preliminary results of this project have been presented in 7 formal talks given by Dr. Karwan and Dr. Rose, as listed in above sections based on when they occured. We also list full citations for them below the text in this section. In addition to formal presentations, information learned from this project has been incorporated into teaching and broader conversation with forest management professionals by Dr. Karwan. First, Dr. Karwan provides forest hydrology instruction to silviculturists in the U.S.D.A. Forest Service National Advanced Silviculture Program every summer in Cloquet, MN. Lessons learned from this project, including working in mid-sized rivers and examining the effects of harvesting beyond small watersheds, are discussed as a part of this program. Second, information generated as a result of this project has been shared by Dr. Karwan as an invited participant to two groups affiliated with the State of Minnesota: (1) a 2018 panel convened to inform the research direction of the Minnesota Forest Resources Council, and (2) in meetings with a Technical Advisory Committee to the Minnesota Pollution Control Agency's team working to represent forestry Best Management Practices in hydrologic model scenarios (HSPF – SAM). Finally, work on this project formed the basis of an internship experience for two female high school students in Dr. Karwan's lab through the YWCA Minneapolis Girls Inc. *Eureka!* Program – a multi-year program for girls focused on STEM. In June – July 2018, two students assisted with water quality sample processing and traveled to the field site associated with this project. This experience formed a 4-week internship in which the high-school students experienced a STEM job first-hand and learned about both work in STEM fields and a university setting. This experience was profiled in the Department of Forest Resources newsletter (see: https://www.forestry.umn.edu/hydrointerns).

Upon completion of this project, we now have additional data and results to present. We are looking forward to doing this through venues that bring together scientists with forest and landscape managers, such as the annual Sustainable Forests Education Cooperative (SFEC) Forestry and Wildlife Research Review and the regional meetings of the National Council of Air and Stream Improvement, a timber industry group, which take places in the Great Lakes region in the spring/summer of odd years. Furthermore, data from this project can be incorporated into graduate research and further work on the watershed functioning of northern MN forests.

List of formal presentations:
L.Rose, *Preliminary Results of Forest Harvesting Effects on Water Quantity and Quality in the West Swan River*, Sustainable Forests Education Cooperative (SFEC) Forestry and Wildlife Research Review, Cloquet, MN, January 11, 2018

L. Rose for D. Karwan, *Opportunities and Challenges for High-Temporal Resolution Hydrologic Monitoring in Northern Minnesota*, University of Minnesota Water Resources Center, January 19, 2018.

D. Karwan and L. Rose. Measuring the complicated relationships between land cover, management, and surface water. University of Minnesota Department of Forest Resources Departmental Seminar. November 29, 2017. St. Paul, MN. Online at: https://www.youtube.com/watch?v=zkxxJb5K1H0&feature=youtu.be

D. L. Karwan, *Forest Management and Water Quality in a Minnesota Watershed*. National Council for Air and Stream Improvement Northern Regional Meeting. May 3, 2017. Wausau, WI.

D. Karwan, *Hydrologic Effects of Forest Management*, given to the Minnesota Soil Water Conservation District Forestry Association, March 16, 2017, McGregor, MN

D. Karwan, *Forest Management Effects on Water*, Sustainable Forests Education Cooperative (SFEC) Webinar. March 15, 2016. Online: http://sfec.cfans.umn.edu/2016-webinar-forest-management-effects-on-water/.

D.L. Karwan, *Review of the Science: Forests, Sediment, BMPs, Watershed Landscape and In-Channel Processes.* Minnesota Society of American Foresters and American Fisheries Society Joint Meeting. Duluth, MN February 1-2, 2016.

VI. PROJECT BUDGET SUMMARY:
A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 113,150	(1) Salary for 3 weeks per year (0.1 FTE) and fringe (19.83%) for Dr. Karwan during each year of the project. Dr. Karwan will manage all aspects of the project. (2) Salary and fringe (98.1%) for 1 PhD student for 2.0 years (0.5 FTE per year of funding). Fringe rate includes graduate student tuition. (3) Hourly salary for 1 undergraduate student 10 hours per week (0.25 FTE) without fringe during the academic year and with fringe (7.34%) during summer in years 2 and 3 of project. Undergraduate will assist with field collection and analysis of water samples and hydrologic data.
Equipment/Tools/Supplies:	$ 26,850	Funds are requested to instrument two stream gaging/sampling sites for continuous water

		depth, discharge, and turbidity measurement as well as automatic water samples for chemical analysis. Quotes have been obtained for the necessary pressure transducer, turbidity meter, data loggers, and water samplers. Each of these pieces could be used individually and range in price from approximately $1000 - $3300. The exact structure or cross section modification necessary for measuring discharge will be suited to the site chosen, but will cost approximately $2000 to install. The remaining $1000 will be used for laboratory analysis of water samples for total suspended solids and dissolved anions and cations in university facilities.
Travel Expenses in MN:	$10,000	Funds are requested for travel between the University campus in St. Paul and research area in Itasca County. This includes money for mileage and vehicle rental from the University's fleet services as well as for over-night stays in Grand Rapids, near the study sites, for multiple-day periods of field work.
TOTAL ENRTF BUDGET:	**$150,000**	

Explanation of Use of Classified Staff:

N/A

Explanation of Capital Expenditures Greater Than $5,000:

N/A

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

In year one, 0.6 FTE will be funded by this appropriation (0.1 for the project manager and 0.5 for the graduate student). In years two and three, 0.6 FTE will be directly funded by this appropriation (0.1 – project manager, 0.25 – graduate student, 0.25 – undergraduate research assistant).

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

N/A

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
University of Minnesota	$6,872	$0	**In-kind Services To Be Applied To Project During Project Period:** 2% (0.02 FTE) of Karwan's salary during project years provided by the University of Minnesota
National Council for Air and Stream Improvement	$40,000	$40,000	Purchase additional stream monitoring equipment, add to in-state travel resources, and supplement project personnel (e.g. fund higher portion of

			postdoctoral researcher's time).
National Council for Air and Stream Improvement	$65,000	$35,000	Additional water quality and chemical sampling and additional labor in years 2-3 of this project.
State			
	$	$	
TOTAL OTHER FUNDS:	**$111,872**	**$75,000**	

VII. PROJECT STRATEGY:

A. Project Partners:

The project will be led by Dr. Diana Karwan (University of Minnesota Department of Forest Resources), who receives funds from this request. Mr. Tim O'Hara (Minnesota Forest Industries), who does not receive funds from this project, will assist Dr. Karwan in identifying candidate research sites and with landowner introductions and communications. Partners will be sought among the private and state forest owners within Minnesota. For example, UPM-Blandin Paper Company (Grand Rapids, MN) manages approximately 190,000 acres in northern Minnesota for forest products, subject to conservation easement. UPM-Blandin has participated in past research projects and has shown interest in cooperating with additional research on their lands (see Map). An initial set of candidate sites has been identified on Blandin lands and Dr. Karwan has conducted preliminary site visits with scientists from UPM-Blandin. The National Council for Air and Stream Improvement (NCASI) is an independent, non-profit research organization whose mission involves scientific research to enhance the technical, environmental, and sustainability understanding of forest management. They are interested in monitoring the hydrologic effects of forest management in the Lake States and have stated they see this project as a pilot on which to base a network of sites.

B. Project Impact and Long-term Strategy:

The findings of this project based on this monitoring network will contribute to the knowledge of the hydrologic effects of forest management activities in the region. Gathering time-series on-the-ground data is essential to understanding how watersheds respond to vegetation changes within them. The current project will allow on-the-ground quantification of the surface water hydrologic effects of a business-as-usual timber harvest. Currently our only source of such time-series information is from the Marcell Experimental Forest (MEF). This study will provide data from a watershed of different condition (e.g. upland dominated) that will facilitate comparisons with the wetland-dominated watersheds of the MEF. It is important for land managers to have hydrologic information from these different types of watersheds (with and without large wetland systems near their outlets) in order to make appropriate decisions and predictions for how land and vegetation management activities will affect water resources. By conducting this study in a nearby but different set of two watersheds (compared to previous studies at MEF), the scientific and land management communities will have more data to draw from as there will be this additional study on a different case with different dominant landform and current vegetation management practices.

The data generated by this project will be used to generate one graduate dissertation, at least one peer-reviewed scientific publications, and at least one presentation at state and national water resource conferences. In particular, we will target conferences for forest and water resource managers in the region, such as Minnesota Water Resources Conference and Northern Regional Meeting of the National Council for Air and Stream Improvement.

Other groups, in particular forest management and non-profit groups, have expressed interest in this project as a pilot on which to expand. Future funds will be sought from a variety of sources to continue and expand upon this work in order to quantify the long-term hydrologic processes which link current forest management practices to surface water quantity and quality. Currently, one proposal is in review with the National Council for Air and Stream Improvement.

C. Funding History:
While previous studies exist in the area, such as the long-term research funded by the USDA Forest Service at the Marcell Experimental Forest, this study is new and has received no prior funding.

Funding Source and Use of Funds	Funding Timeframe	$ Amount
		$
		$
		$

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:

A. Parcel List:
N/A

B. Acquisition/Restoration Information:
N/A

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

X. RESEARCH ADDENDUM:
See attached Research Addendum.

XI. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than January 31, 2016, July 31, 2016, January 31, 2017, July 31, 2017, January 31, 2018. A final report and associated products will be submitted between June 30 and August 15, 2018.

References:

Hemstad, N. a., E. C. Merten, and R. M. Newman (2008), Effects of riparian forest thinning by two types of mechanical harvest on stream fish and habitat in northern Minnesota, *Canadian Journal of Forest Research*, *38*(2), 247–256, doi:10.1139/X07-157.

Hirsch, R.M., and De Cicco, L.A., 2015, User guide to Exploration and Graphics for RivEr Trends (EGRET) and dataRetrieval—R packages for hydrologic data (version 2.0, February 2015): U.S. Geological Survey Techniques and Methods book 4, chap. A10, 93 p., *http://dx.doi.org/10.3133/tm4A10*

Hooper, R. P. (2003), Diagnostic tools for mixing models of stream water chemistry, *Water Resources Research*, *39*(3), n/a–n/a, doi:10.1029/2002WR001528.

Klaus, J., and J. J. McDonnell (2013), Hydrograph separation using stable isotopes: Review and evaluation, *Journal of Hydrology*, *505*, 47–64, doi:10.1016/j.jhydrol.2013.09.006.

Merten, E. C., N. a. Hemstad, R. K. Kolka, R. M. Newman, E. S. Verry, and B. Vondracek (2010), Recovery of Sediment Characteristics in Moraine, Headwater Streams of Northern Minnesota After Forest Harvest, *Journal of the American Water Resources Association*, *46*(4), 733–743, doi:10.1111/j.1752-1688.2010.00445.x.

United States Environmental Protection Agency (1993), *Paired Watershed Study Design*, Washington D.C.

Zégre, N., A. E. Skaugset, N. a. Som, J. J. McDonnell, and L. M. Ganio (2010), In lieu of the paired catchment

approach: Hydrologic model change detection at the catchment scale, *Water Resources Research*, *46*(11), n/a–n/a, doi:10.1029/2009WR008601.

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**Project Title:** *Hydrologic Effects of Contemporary Forest Practices in Minnesota*
**Legal Citation:** *M.L. 2015, Chp. 76, Sec. 2, Subd. 03r*
**Project Manager:** *Diana Karwan*
**Organization:** *University of Minnesota - Twin Cities*
**M.L. 2015 ENRTF Appropriation: $** *150,000*
**Project Length and Completion Date: 3** *Years, June 30, 2018*
**Date of Report:** *June 30, 2018*

| 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** | ***Site Selection and Instrumentation*** | | | ***Pre-treatment Monitoring*** | | | ***Timber Harvest Treatment Monitoring*** | | | | |
| **Personnel (Wages and Benefits) OVERALL** | 50861 | 50861 | 0 | 20713 | 20713 | 0 | 49266 | 49266 | 0 | 120840 | 0 |
| Project Manager: Salary for 3 weeks per year (0.1 FTE) and fringe (19.83%) for D. Karwan during each year of the project. Karwan will manage all aspects of the project. | | | | | | | | | | | |
| Graduate Student: Salary and fringe (98.1%) for 1 PhD student for 2.5 years. Fringe rate includes graduate student tuition. | | | | | | | | | | | |
| Undergraduate Student: Hourly salary for 1 undergraduate student 10 hours per week (0.25 FTE) without fringe during the academic year and with fringe (7.34%) during summer in years 2 and 3 of project. Undergraduate will assist with field collection and analysis of water samples and hydrologic data. | | | | | | | | | | | |
| **Equipment/Tools/Supplies** | 16279 | 16279 | 0 | 2878 | 2878 | 0 | 966 | 966 | 0 | 20123 | 0 |
| Funds are requested to instrument one stream gaging/sampling site for continuous water depth, discharge, and turbidity measurement as well as automatic water samples for chemical analysis. Quotes have been obtained for the necessary pressure transducer, turbidity meter, data loggers, and water samplers (approx. $12,000 in total). The exact structure or cross section modification necessary for measuring discharge will be suited to the site chosen, but will cost approximately $2000 to install. The remaining $1000 will be used for laboratory analysis of water samples for total suspended solids and dissolved anions and cations in facilities at the University of Minnesota. This includes a portion of the reduction in funding recommendation amount from the original proposed budget. | | | | | | | | | | | |
| **Travel expenses in Minnesota** | 1506 | **1506** | 0 | 4318 | **4318** | 0 | 3213 | **3213** | 0 | 9037 | 0 |
| Funds are requested for travel between the University campus in St. Paul and research area in Itasca County. This includes money for mileage and vehicle rental from the University's fleet services as well as for over-night stays in Grand Rapids, near the study sites under consideration, for longer periods of field work | | | | | | | | | | | |
| **COLUMN TOTAL** | **68646** | **68646** | **0** | **27909** | **27909** | **0** | **53445** | **53445** | **0** | **150000** | **0** |
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