Environment and Natural Resources Trust Fund (ENRTF) M.L. 2016 Work Plan

Date of Report: May 29, 2016

Date of Next Status Update Report: December 31, 2016

Date of Work Plan Approval: June 7, 2016

Project Completion Date: June 30, 2019

Does this submission include an amendment request? No

PROJECT TITLE: Assessment of Surface Water Quality with Satellite Sensors

Project Manager: Jacques Finlay

Organization: University of Minnesota

Mailing Address: 140 Gortner Lab, 1479 Gortner Avenue
City/State/Zip Code: St. Paul, MN 55108

Telephone Number: (612) 624-6777

Email Address: jfinlay@umn.edu

Web Address: http://cbs.umn.edu/finlay-lab/home

Location: Statewide

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$345,000**
	Amount Spent:	**$0**
	Balance:	**$345,000**

Legal Citation: M.L. 2016, Chp. 186, Sec. 2, Subd. 04i

Appropriation Language:

$345,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for a statewide assessment of water quality using new satellite sensors for high frequency measurement of major water quality indicators in lakes and rivers. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Assessment of Surface Water Quality with Satellite Sensors

II. PROJECT STATEMENT:

Minnesota's abundant surface waters face multiple threats related to land use change, eutrophication and invasive species. Water clarity is a key water quality indicator that can be monitored on many thousands of lakes in Minnesota with a simple Secchi disk or remotely using satellites. While water clarity data are highly valuable due to the ability to measure most water bodies on a frequent basis, current methods cannot distinguish between the three factors that affect water clarity in our lakes and rivers: algae, colored dissolved organic matter, and suspended solids (e.g., clay minerals). Because they have distinctly different impacts on water quality, the ability to measure them directly increases our understanding of the causes and consequences of water quality degradation. Technology now exists to make this advance. **This proposal takes an innovative next step in statewide assessment of water quality using new satellite sensors to remotely measure major water quality indicators in Minnesota's 10,000 lakes at high frequency and low cost.**

Background

The three major water quality drivers that are the focus of our project have distinct sources and impacts on surface waters. Algae are present in all surface waters and are a primary resource for lake and river food webs. *Algal biomass* is strongly affected by levels of phosphorus and nitrogen. When these nutrients are present at high levels, they result in eutrophication. Eutrophication reduces water quality by degrading habitat for native species, enhancing invasive species, reducing water quality for human use, and causing algal dominance by cyanobacteria, including species that produce harmful liver and neurotoxins. As a consequence, ability to monitor changes in algal biomass is a key part of understanding functioning of Minnesota's surfaces waters. *Colored dissolved organic matter* (CDOM) also occurs in all surface waters, and is the most abundant organic matter pool in many setting, especially in forested watersheds with wetlands. CDOM strongly affects water quality because it mobilizes metals and hydrophobic chemicals, serves as a source of reactive photochemical intermediates, controls many aquatic ecosystem processes, and has negative effects on production of safe drinking water. The paucity of data for CDOM distribution limits our understanding the quality and characteristics of surface waters in Minnesota and the US in general. *Suspended sediment* enters surface waters during large storm events that cause erosion. Sediments can also be reintroduced to surface water when sediments from lake and river bottoms are resuspended due to wind, or invasive species such as the common carp which destroy aquatic plants and stir up sediment deposits.

Conventional methods for water quality assessment rely heavily on manual collection and analyses of surface water samples to characterize these constituents and other water quality variables. While Minnesota has an excellent surface water quality monitoring program, water quality conditions are highly variable in space, and can change very rapidly due to climate, land management and invasive species. Effective lake management requires long-term water quality information on a large number of lakes and streams so that managers can take into account differences among lakes, as well as changes through time for individual lakes at the watershed or regional scale. Unfortunately, only a small percentage of inland waters are currently monitored regularly by conventional methods, and long term (i.e. at least 20 years) water quality data are lacking for most inland water bodies. Comprehensive assessment of water quality is not practical with conventional point sampling methods due to limited resources, and thus water quality data are sparse in many areas. Furthermore, traditional ground-based monitoring programs target larger recreational lakes and thus are not randomly selected. Extrapolation from these lakes to the larger population would likely bias conclusions). Remote sensing methods can provide a solution to many of these issues and generally complement ground based monitoring by providing frequent and extensive measurements in virtually all lakes larger than 10 acre surface area in the state. This project will develop methods to allow assessment of an unprecedented number of lakes, and lays the groundwork for future remote sensing based monitoring programs that can provide comprehensive data and near real-time monitoring of important water quality variables.

The quality of our lakes and rivers directly affects the availability of clean drinking water and habitat for fish and other wildlife. In much of Minnesota, lake and river water quality is influenced mainly by excessive algae (from nutrients), colored organic matter from decaying woody plants in forests and wetlands, and suspended solids from stormwater runoff and invasive carp. These factors thus have distinct causes, and each also requires different management responses in watersheds. Each also has distinct effects on water resources: too much algae decreases water quality and habitat; high levels of colored organic matter decrease fish growth and interfere with natural contaminant degradation processes and drinking water treatment processes; suspended solids destroy fish habitats and clog waterways. The ability to detect these problems in lakes on a regular basis would provide an early warning system for changes and allow management of watersheds and surface waters in ways that are specific to the particular stressors causing the degradation.

Major Project Objectives

Our goals are to: 1) develop remote sensing methods to permit routine measurement of colored organic matter, algae, and suspended solids levels in Minnesota's waters; 2) apply these methods to our 10,000 lakes and large rivers, creating a database and corresponding maps; and 3) explore how variations in these water quality indicators influence the fate of contaminants (e.g., pesticides, mercury) and the suitability of water bodies to serve as drinking water supplies. Dissemination of information gained in this project on lake conditions and methods for satellite based monitoring of conditions will reach diverse stakeholder in the state and the nation via publications, integration into Lake Brower and meeting presentations.

General Project Activities and Methods

The project develops methods to use recently enhanced satellite based remote sensing capabilities to measure key water quality parameters: algae, dissolved color, and suspended sediments. The project will acquire optical remote sensing imagery from Landsat and Sentinel satellites concurrently with sampling of surface waters for these three parameters. Using these datasets, analyses will be conducted to determine the most robust relationships between remotely sensed reflectance measurements and field conditions. These models will be validated with independent datasets. Data describing distributions of these parameters will be integrated into Lake Browser, and disseminated to state and federal agencies via presentations and peer reviewed publications.

Project Significance

By developing methods to measure algae, dissolved color, and suspended sediments by remote sensing, this project will provide the means to greatly increase understanding of our water resources in Minnesota. The capabilities developed in this project will enable measurement of indicators of key ecosystem parameters (e.g. algal biomass, light regimes, thermal properties) and functions (e.g. fish productivity, contaminant reactions). Future monitoring programs using methods developed here could gain high frequency records (up to one measurement per week with normal weather conditions) on all lakes and larger river reaches in the state. This information complements detailed ground based sampling programs at a smaller number of sites that provides information that can be used to interpret patterns detected by regional analyses conducted via satellite based monitoring.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of January 2017:

Project Status as of July 2017:

Project Status as of January 2018:

Project Status as of July 2018:

Project Status as of January 2019:

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: ***Build advanced methods for measuring water quality in surface waters of Minnesota***

Description: Physically-based predictive relationships will be developed to determine dissolved organic matter, chlorophyll (algae), and suspended solid levels from available satellite data. The predictive relationships will be developed or "calibrated" using approximately 150 lake and river sites, plus additional ~50 sites used for validation. We will evaluate the frequency with which state or region-wide assessments of these water quality indicators are possible within a given year by assessing availability of clear imagery and testing assumptions related to efficacy of automated image processing.

Field sampling methods. To obtain sufficient calibration data to map chlorophyll, suspended solids (SS), and CDOM at the statewide scale, we will sample ~200 lakes in summer 2017 to measure their optically-related water quality characteristics nearly contemporaneously with Landsat 8 and/or Sentinel-2 image acquisitions. We will select sites to obtain a wide range of CDOM, chlorophyll and SS values, including systems where one of these variables dominates the optical (reflectance) properties of the water body and systems where various combinations of the three variables also affect reflectance. Samples will be collected across the state in proportion to the density of lakes in a given region.

We will leverage sampling to be done in 2016 on a related study to refine sampling procedures for the 2017 field season and to collect preliminary calibration data. To the extent possible, we also will use Secchi depth (SD) data from the citizen monitoring program and water quality data from ongoing monitoring programs of the MPCA to expand the database for calibration/validation of images. The usability of these ancillary data will depend on close in time the sampling was done in relation to acquisition of the satellite images we will use for the statewide mapping.

Field data collected at each site will include clarity (as Secchi depth), temperature, dissolved O_2, pH and conductivity. Samples will be collected for measurement in the laboratory of the following water quality variables: dissolved organic carbon (DOC), total suspended solids (TSS), volatile suspended solids (VSS, a measure of suspended organic matter), turbidity, color (CDOM by absorbance measurements on filtered samples), and chlorophyll *a*. SD will be measured with a standard 20-cm disk from the sunny side of the boat using the average of the depths where the disk just disappears and re-appears when raised from below. Dissolved oxygen, temperature, pH and conductivity will be measured using calibrated field meters. Water samples for dissolved organic carbon (DOC) and CDOM will be filtered through ashed glass filters (Whatman GF/F) in the field and stored in the dark in washed polycarbonate or ashed glass bottles at 4 C until analysis. Field-filtered chlorophyll *a* samples will be stored frozen in foil until analysis following acetone extraction. Water samples for TSS, VSS and turbidity will be stored on ice at collection and processed on return to the lab.

UV/Vis absorbance scans (250-700 nm) will be obtained in 1- and/or 5-cm quartz cells on filtered (Whatman GF/F) samples using a Shimadzu UV-1601PC UV-Visible spectrophotometer. Results will be used to compute a_{440}, $SUVA_{254}$, and spectral slope, S, over the ranges: 275-295, 350-400, and 400-460 nm. Filtered water will be analyzed for DOC using a Sievers 900 Portable Analyzer or a Shimadzu Vcpn Analyzer calibrated with dilutions of potassium hydrogen phthalate. Blanks prepared with ultrahigh purity water will be used to confirm that contamination is not occurring in sample handling. Procedures from *Standard Methods* will be used to measure TSS, VSS, turbidity, and chlorophyll.

Two state-of-the-art characterization techniques, fluorescence spectroscopy and Fourier transform-ion cyclotron resonance mass spectrometry (FT-ICR-MS), will be used to obtain information on the chemical composition of fractionated dissolved organic matter (DOM) collected from selected lakes. We will relate the compositional information with data from satellite images and results from DOM reactivity testing. Fluorescence excitation-emission matrices (EEMs) will be generated on filtered samples (Millipore 0.2 µm nitrocellulose membrane filters) using a Horiba Aqualog fluorometer over an excitation range of 200-400 nm (5 nm intervals) and emission range of 290-550 nm (2 nm intervals). Scans will be corrected for variations in Raman scattering, lamp intensity, and cuvette imperfections. Contour plots representing the resulting matrix will be created and parallel factor analysis will be performed using reference components identified in similar work of others. FT-ICR-MS analyses will be done at the Old Dominion University Major Instrumentation Cluster, Norfolk, VA (http://www.sci.odu.edu/sci/cosmic/ index.shtml) by electrospray ionization using a Bruker Daltonics 12 Tesla Apex Qe FT-ICR-MS following standard procedures. We have worked previously with this group to characterize DOM from wetlands; they analyze samples on a fee for service basis.

Satellite imagery processing. Cloud-free satellite imagery for Minnesota will be downloaded from the Earth Resources Observation and Science (EROS) Center operated by USGS in Sioux Falls, South Dakota. We will rely primarily on Sentinel-2, which has some advantages of image size and frequency of repeat coverage, but will also use Landsat 8 imagery. Image processing will be based on methods we developed previously.

We will evaluate several methods for atmospheric correction: the Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH), based on the MODerate resolution atmospheric TRANsmission (MODTRAN) v5 algorithm, and QUick Atmospheric Correction (QUAC), Atmospheric Correction for OLI 'lite' (ACOLITE), along with Landsat Surface Reflectance Data Products provided by EROS. Areas obscured by clouds and haze will be masked out during preprocessing, and images will be processed in ERDAS IMAGINE. After preprocessing, spectral data for each lake will be extracted using the signature editor and used for modeling and data analysis.

Final image processing will use procedures that produce superior results, as determined by comparison with in situ data. To use satellite imagery to develop colored organic matter, algae, and suspended solids measurements, we will need in situ lake data that represent the wide range of optical conditions found in the imagery. Measurements of CDOM, chlorophyll and TSS will be used to develop robust algorithms and determine whether they work well under all optical conditions or if different algorithms are needed for optically complex waters and also to evaluate atmospheric correction methods. If we find that different algorithms are needed, we will develop screening techniques to group water bodies into appropriate optical classes prior to applying retrieval algorithms. The maps produced for Minnesota will include over 10,000 lakes and many large rivers.

Summary Budget Information for Activity 1: **ENRTF Budget: $ 205,000**
Amount Spent: $ 0
Balance: $ 205,000

Outcome	**Completion Date**
1. Measurements of algae, colored organic matter, and suspended solids in 125 selected lake and river sites to obtain a data set for developing predictive relationships	*December 2017*
2. Analysis of field and satellite data to develop predictive relationships to permit routine monitoring of algae, organic matter, and suspended solids in the state's waters	*February 2018*
3. A method for comprehensive water quality monitoring for Minnesota's 10,000 lakes	*June 2018*

Activity Status as of January 2017:

Activity Status as of July 2017:

Activity Status as of January 2018:

Activity Status as of July 2018:

Activity Status as of January 2019:

Final Report Summary:

ACTIVITY 2: ***Relate surface water composition to pollutant fate and drinking water quality***

Description: Lakes and rivers in the state are influenced by algae, colored dissolved organic matter, and suspended solids, but we do not fully understand how these constituents affect drinking water production or the fate of pollutants. We will conduct studies to understand how these features of surface waters, measured for all lakes in the state, influence formation of disinfection byproducts during drinking water treatment and degradation of pesticides and pharmaceuticals in surface waters. Experiments will be performed in laboratory systems that simulate drinking water treatment and natural processes (the latter leveraged through an active LCCMR project led by Arnold).

Laboratory experiments will be performed with water samples collected during field sampling (in Activity 1) to assess the reactivity of the natural organic matter in the sampled waters. Water samples will be collected from a variety of lakes that represent a range of water quality conditions including CDOM levels and algae levels. The water samples will be filtered and stored in the dark in the refrigerator until further use.

The first set of experiments will be designed to assess the reactivity of the organic matter with chlorine to form so-called disinfection byproducts (DBPs). DBP formation is a significant concern in the water treatment industry because chlorine is the most common chemical used for disinfection and because many DBPs are known or suspected human carcinogens. In our DBP experiments, we will focus on a specific class of DBP compounds referred to as trihalomethanes (THMs), one of which is the organochlorine compound chloroform. We will perform THM formation potential tests on each water sample. In the test, excess chlorine is added to a water sample, and the sample is incubated at 25°C for 7 days. At the end of the incubation period, the chlorine residual is measured and then quenched with sodium sulfite. Then, the THMs are analyzed via gas chromatography with an electron capture detector.

The second set of experiments is designed to assess the role of CDOM in sunlight-mediated or 'photochemical' reactions. Photochemistry is important in the fate of pollutants in surface water bodies such as lakes because sunlight can react both directly with pollutants and indirectly via formation of reactive oxygen species (ROS) when sunlight reacts with other constituents in the water. CDOM can play two roles in photochemistry. One is to absorb sunlight and diminish the role of direct photolysis and photochemically-mediated contaminant degradation. Conversely, CDOM can act as a photosensitizer and convert sunlight into ROS (such as hydroxyl radical). These ROS can then react with the pollutants to transform or degrade them. In our experiments, the target pollutants will be pesticides. A few pesticides will be selected to represent the range of chemicals commonly used in Minnesota including atrazine and imidacloprid (i.e., Roundup). We will select water samples that have different spectral characteristics based on the satellite and laboratory measurements. These experiments will be performed by adding the pesticide to the water sample and incubating the sample in a solar simulator that mimics the light spectrum of natural sunlight. At the end of the incubation period, the target contaminant will be analyzed by appropriate techniques (e.g., liquid chromatography). Additional experiments will be performed with the same water samples but without added pollutants to quantify the formation of specific ROS during exposure to simulated sunlight using chemical probes. Leveraging current LCCMR funding for Arnold, we will evaluate whether the satellite and laboratory measured spectral characteristics provide predictive power in regards to ROS production.

After the experiments are completed, we will investigate relationships between indicators of DOM composition and content generated in Activity 1, including DOC, CDOM, chlorophyll *a*, spectral slope, UV absorption, EEMs indicators, and molecular structure information from FT-ICR-MS, and both DBP formation potential and the potential for photochemical intermediate formation. We will investigate single parameter correlations as well as multivariate relationships. These analyses will help develop the use of satellite data to perform large-scale assessments of water treatability and photochemical contaminant degradation rates.

Summary Budget Information for Activity 2:

ENRTF Budget:	**$ 95,000**
Amount Spent:	**$ 0**
Balance:	**$ 95,000**

Outcome	**Completion Date**
1. Evaluate the influence of algae and organic matter on formation of disinfection byproducts upon chlorination	*December 2018*
2. Identify waters least and most likely to degrade pesticides by photolysis	*December 2018*

Activity Status as of January 2017:

Activity Status as of July 2017:

Activity Status as of January 2018:

Activity Status as of July 2018:

Activity Status as of January 2019:

Final Report Summary:

ACTIVITY 3: ***Dissemination and application for surface water monitoring and management***

Description: We have maintained a web site (http://water.umn.edu) for over ten years to provide public access to results of our remote sensing studies on lake water clarity and quality. The Minnesota Lake Browser provides easy access of information for individual lakes or regions for seven time periods at five-year intervals from 1975 to 2008. Lake Browser is a Google Earth format mapping application that allows users to query for individual lakes or zoom into an area of interest to get not only the information for individual lakes but for all of the lakes in the area.

We will update the Lake Browser site to include the new data gained in Activity 1 during 2016 and 2017. This information will be used to construct a web-accessible statewide database of colored dissolved organic matter, algae, and suspended solid levels and descriptions of their relevance to citizens. Lake Browser will use information based on both pixel level maps, that allow identification of within lake differences, and lake level maps, that enable statistical analysis of geospatial and temporal trends. These additions will greatly enhance the site by providing up to date and more detailed information for >10,500 lakes. The site is currently extensively used with on average 8,000 unique visitors per month, and we expect that data and products provided by this project will increase use of Lake Brower substantially.

We expect at least 3-4 publications in high-impact, refereed journals will result from this research. Results will be presented at local and national conferences on environmental engineering, ecosystem ecology, humic substances, and remote sensing. The PIs have close relationships with scientists in regional water management agencies, and we will organize meeting for staff of those agencies (e.g., MPCA) and at state conferences to demonstrate capacity and effectiveness of remote sensing methods and to enhance their integration into water quality monitoring programs and assessments.

Summary Budget Information for Activity 3:

ENRTF Budget:	**$ 45,000**
Amount Spent:	**$ 0**
Balance:	**$ 45,000**

Outcome	**Completion Date**
1. Enhancements and expansion of Lake Browser	*June 2019*
2. Peer reviewed papers describing methods for submission to peer reviewed journals	*June 2019*
3. Presentations to MPCA describing remote sensing capabilities and methods	*June 2019*

Activity Status as of January 2017:

Activity Status as of July 2017:

Activity Status as of January 2018:

Activity Status as of July 2018:

Activity Status as of January 2019:

Final Report Summary:

V. DISSEMINATION:

Description: Project results will be communicated using a range of outlets. A primary mode of dissemination is the expansion of Lake Browser. This website provides content for diverse users including citizen scientists, homeowners, classes, natural resource managers, researchers at agencies and academic institutions. Results will also be disseminated in the peer reviewed literature, and in presentations made at conferences and at state agencies.

Activity Status as of January 2017:

Activity Status as of July 2017:

Activity Status as of January 2018:

Activity Status as of July 2018:

Activity Status as of January 2019:

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	**$ Amount**	**Overview Explanation**
Personnel:	$ 303,000	Salary support for project partners, postdoctoral researchers, a junior scientist, and undergraduate researchers
Professional/Technical/Service Contracts:	$ n/a	

Equipment/Tools/Supplies:	$ 11,000	Laboratory supplies and analytical time/costs
Capital Expenditures over $5,000:	$ 20,000	Multi parameter water quality datalogger
Fee Title Acquisition:	$ n/a	
Easement Acquisition:	$ n/a	
Professional Services for Acquisition:	$ n/a	
Printing:	$ 1,000	
Travel Expenses in MN:	$ 6,000	In state travel for sample collection and presentation of results
Other:	$ 4,000	Laboratory services
TOTAL ENRTF BUDGET:	**$345,000**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: YSI Sensor package - A Yellow Springs Instruments (YSI) sonde capable of measuring and data logging multiple parameters including algal pigments and DOM fluorescence is requested. This instrument will be used to verify the correspondence between remotely sensed parameters and field observed values. The equipment will be used throughout the project for collection of data to needed to ensure that sampling sites are representative, to examine assumptions related to effects of shoreline and water depth effects on satellite data, and to monitor pH, oxygen and organic matter levels in laboratory experiments. We will continue to use the equipment for purposes related to the proposed research throughout the life of the instrument as new satellite sensors added to the ones currently available.

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 4.73 total

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			
n/a			
State			
n/a	$	$	
TOTAL OTHER FUNDS:	**$**	**$**	

VII. PROJECT STRATEGY:

A. Project Partners:

Project Partners Receiving Funds:

- Dr. Jacques Finlay (Project Manager, University of Minnesota)
- Patrick Brezonik (Co PI, University of Minnesota)
- Leif Olmanson (Co PI, University of Minnesota)
- William Arnold (Co PI, University of Minnesota)
- Raymond Hozalski (Co PI, University of Minnesota)

B. Project Impact and Long-term Strategy: This project directly addresses LCCMR funding priorities in *Water Resources* and *Foundational Natural Resource Data and Information.* Our project brings together expertise in remote sensing, aquatic ecology, contaminant cycling, water quality analysis, and drinking water treatment to advance our abilities to detect and understand spatial and temporal patterns in water quality. Our past development of remote sensing methods for water clarity, funded in part by LCCMR, has allowed routine monitoring of >10,000 Minnesota lakes. Expansion of these capabilities through the use of new satellite capabilities to include organic matter, algal abundance, and suspended sediments will be a major step in the development of more cost-effective and spatially comprehensive methods to monitor, understand and manage Minnesota's freshwater resources. Because water quality affects fisheries, drinking water, ecosystem integrity, and human enjoyment of water bodies, results from our project will be of immediate use to the Minnesota Pollution Control Agency and the Department of Natural Resources in decision making and prioritization of resources. At the end of this project, we will be able to provide these and other relevant agencies with the basic tools needed to initiate their own use of remote sensing techniques as operational tools for frequent, statewide assessments of surface water quality throughout the state. Subsequent integration by natural resources agencies of satellite-based monitoring based on the methods we will develop would be enabled by increasing the GIS expertise of the agencies, thus allowing them greater ability to process high-quality satellite imagery, which is becoming increasingly available at no cost. It is feasible that such an advanced monitoring program could be in place following the end of this project in summer 2019 if resources were devoted to this task. We also expect that techniques for detection of blue-green algae (the primary cause of harmful algal blooms) will become feasible within the next few years, and we further envision subsequent development of ways to further automate image processing to the point that near real-time assessments of important water quality conditions will be possible.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	$ Amount
"Solar Driven Destruction of Pesticides, Pharmaceuticals, Contaminants in Water" Arnold is currently investigating pesticide/pharmaceutical fate in wetlands and the role of DOM plays in photolysis. The techniques developed will be used on the lake and river samples in this project.	July 1, 2014-June 30,2017	$291,000

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 figure.

X. RESEARCH ADDENDUM: Research addendum is an unfunded but well reviewed proposal to USGS from 2016

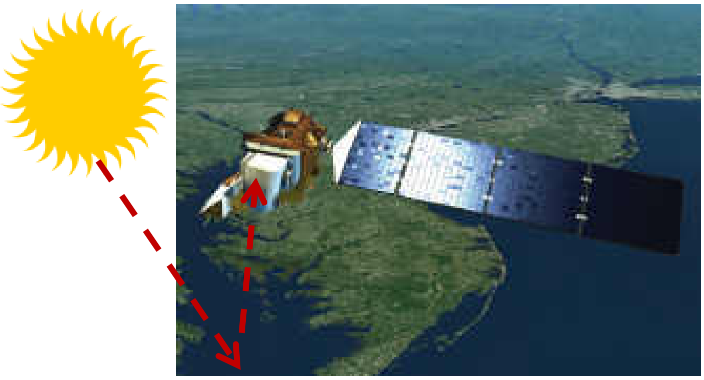
XI. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than January 2017, July 2017, January 2018, July 2018, and January 2019. A final report and associated products will be submitted between June 30 and August 15, 2019.

Environment and Natural Resources Trust Fund
M.L. 2016 Project Budget
Project Title: Assessment of Surface Water Quality with Satellite Sensors
Legal Citation: M.L. 2016, Chp. 186, Sec. 2, Subd. 04i
Project Manager: Jacques Finlay
Organization: University of Minnesota
M.L. 2016 ENRTF Appropriation: $345,000
Project Length and Completion Date: 3 Years, June 30, 2019
Date of Report: May 29, 2016

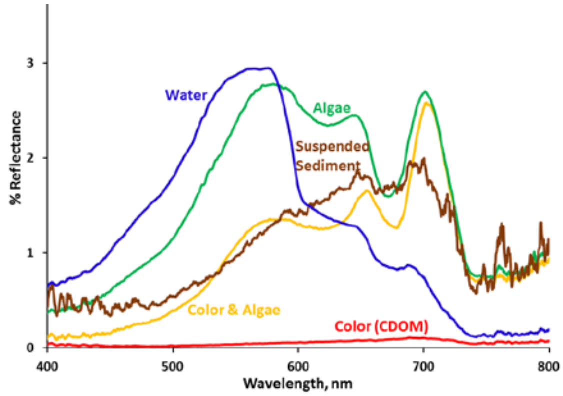
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM											
Personnel (Wages and Benefits)	$170,000		$170,000	$90,500		$90,500	$42,000		$42,000	$303,000	$303,000
Jacques Finlay, Project Manager: $14,000 (75% salary, 25% benefits): 4% FTE each year for 2 years.											
Patrick Brezonik, Project Collaborator: $12,000 (93% salary, 7% benefits): 4% FTE each year for 2 years.											
Raymond Hozalski, Project Collaborator: $17,000 (75% salary, 25% benefits): Year 1 = 4% FTE, Year 2 = 3% FTE.											
William Arnold, Project Collaborator: $19,000 (75% salary, 25% benefits): Year 1 = 4% FTE, Year 2 = 3% FTE											
Leif Olmanson, Project Collaborator: $66,000 (75% salary, 25% fringe); Year 1 = 33% FTE, Year 2 = 25% FTE, Year 3 = 25% FTE											
Post doctoral associate: $83,000 (82% salary, 18% fringe); Year 1 = 100% FTE, Year 2 = 50% FTE, Year 3 = 0% FTE											
Post doctoral associate: $55,000 (82% salary, 18% fringe); Year 1 = 50% FTE, Year 2 = 50% FTE, Year 3 = 0% FTE											
Undergraduate Research Assistant: $15,000 (100% salary, 0% fringe) - One student at 22% FTE for year 1 and 2 students at 22% for year 2.											
1 Junior Scientist: $22,000 (79% salary, 21% fringe) - 22% FTE for year 1 and for year 2.											
Equipment/Tools/Supplies	$27,000		$27,000	$4,500		$4,500	$0			$31,000	$31,000
Lab and analysis consumables. Examples of laboratory supplies required for this research include glassware, sample bottles, filters, pipette tips, chemicals, and reagents needed for analyses of chemical constituents in water samples. Costs of analyses of a suite of basic parameters in our labs for each site sampled in the field sampling, and for lab experiments are included. The lab analyses cost includes instrument time, gases, reference standards and reagents for colored organic matter concentration and spectral properties/EEMS, total phosphorus and nitrogen, suspended sediments, particulate organic carbon and chlorophyll a.											

Field supplies including bottles, gloves, and filters required for collection, transport, and storage of samples, and for preparation for lab manipulations											
YSI Sensor package - A YSI sonde capable of measuring and data logging multiple parameters including algal pigments and DOM fluorescence is requested. This instrument will be used to verify the correspondence between remotely sensed parameters and field observed values. The equipment will be used throughout the project for collection of data to needed to ensure that sampling sites are representative, to examine assumptions related to effects of shoreline and water depth effects on satellite data, and to monitor pH, oxygen and organic matter levels in laboratory experiments. We will continue to use the equipment for purposes related to the proposed research throughout the life of the instrument as new satellite sensors added to the ones currently available. All other equipment needed for the project is currently available for the use of the research team in on-campus laboratories or in shared (core) facilities.	$20,000										
Printing							$1,000		$1,000	$1,000	$1,000
Travel expenses in Minnesota	$4,000		$4,000				$2,000		$2,000	$6,000	$6,000
Travel funds are requested for travel to field sites in year 1 and 2. This includes vehicle rental, mileage, hotel, and meals, estimated according to UMN guidelines, for PIs, post docs, and undergraduates during year 1 and for the field sampling campaign in the second year. In addition, funds are requested for travel to meetings with collaborators and state agencies, and for registration at the Minnesota Resources Conference in years 2 and 3.											
Other	$4,000		$4,000				$0			$4,000	$4,000
Lab Services - Lab services includes costs of sample analyses at external labs for metals and major ions via ICP and IC in the Dept. of Earth Sciences at the University of Minnesota ($31.50 per sample), and charges for FT-ICR-MS analyses ($100 per sample) to characterize DOC/DOM properties											
COLUMN TOTAL	**$205,000**		$205,000	**$95,000**		$95,000	**$45,000**		$45,000	**$345,000**	$345,000

New satellite technology allows us to measure the ***causes*** of changes in water clarity.



Color, algae and suspended solids, three factors that affect water clarity, have different effects on the spectrum of reflected light measured by satellites.



This project develops satellite-based methods to measure water color, algae, and suspended sediment, the 3 main factors affecting water clarity, on all MN lakes and large rivers.

Water Color

Algae

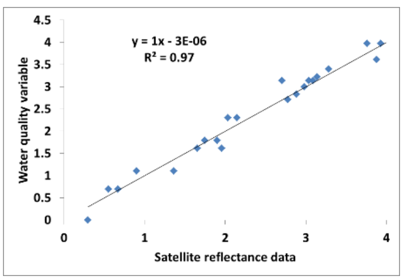
Sediment

What we will do to map the causes of water clarity

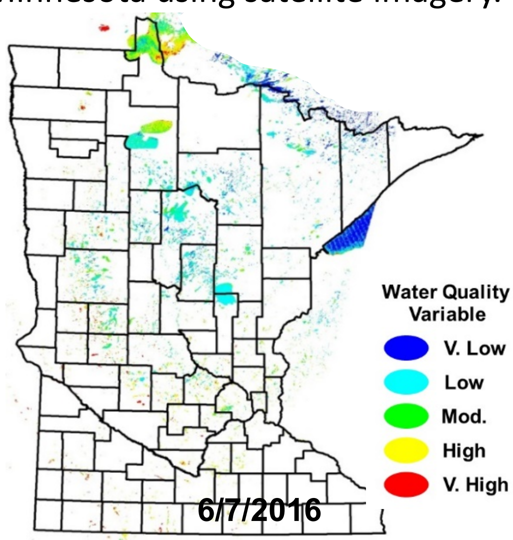
1. **Collect** samples from calibration and validation lakes to measure water quality variables that affect light reflectance from water bodies.

Such variables include: suspended solids, chlorophyll and colored dissolved organic matter (CDOM), also known as aquatic humic matter.

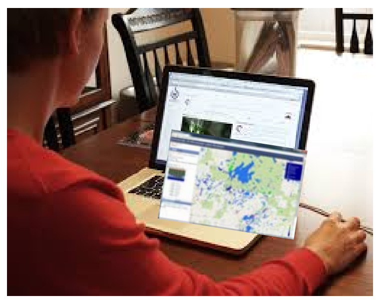
2. Build and validate predictive **models** using the water quality data:



3. Apply the models to lakes across Minnesota using satellite imagery.



4. Add the data, maps, and background information to a "**Lake Browser**" to make it readily available to citizens, scientists, and lake managers.



The ability to routinely monitor these three water quality drivers in all lakes will provide a resource that can **be used by managers, scientists and the public to understand and improve water quality**