# Federal Interagency Sedimentation Project

## FY2019 Call for Proposals

**Proposal Title:** Evaluation of the AOBS Surrogate Method Using the LISST-ABS and NEP5000 Sensors to Provide Improved Estimates of Suspended-Sediment Concentrations and Loads.

**Principal Investigator (PI):** Christopher A. Ellison

**Additional Investigators:** Tom Sabol, Chad Billings

**PI Location and Study Location:** PI Location: Wyoming-Montana Water Science Center, Helena, Montana; Study Location: Yellowstone River near the town of Sidney, in northeastern Montana (USGS ID 06329500)

**Introduction:** Application of acoustics and optical technology has a proven record of success for use as a surrogate for estimating suspended-sediment concentrations (SSCs) (Rasmussen and others, 2009; Landers and others, 2016). Acoustic and optical (turbidity) sensors have primarily been installed independently of each other and calibrated using collected sediment samples to develop surrogate relations. The relations among acoustic backscatter and turbidity with SSCs have substantially improved the ability to estimate SSCs and sediment loads. However, studies have identified limitations associated with the use of acoustics and turbidity sensors attributed to variations in particle sizes. For example, Merten and others (2013) determined that the presence of sand-sized particles in a water-sediment mixture linearly reduced the turbidity signal for three different turbidity sensors, whereas Teri Snazelle's (2017) assessment of the accuracy of the LISST-ABS to estimate SSCs, performed at the U.S. Geological Survey (USGS) Hydrological Instrumentation Facility demonstrated that acoustic backscatter had low sensitivity to finer-sized particles in suspended-sediment solutions with varying particle-size distributions.

This proposal presents an approach to evaluate the application of the acoustic-optical backscatter sensor (AOBS) method, which coalesces acoustics and optics technology, to improve estimates of suspended-sediment concentrations (SSCs). If funded, we will collect suspended-sediment data in FY 19, and we will use these data to develop regression models and prepare a formal report of the results in FY 20. This study will leverage funding from a long-term cooperative agreement between the USGS and the US Army Corps of Engineers (USACE) to monitor SSCs and loads at the Yellowstone River near Sidney, Montana. This proposal supports the FISP mission to develop standardized, consistent, and accurate quantification of sediment characteristics and transport in surface waters. Specifically, this study would evaluate the accuracy and efficiency of the AOBS method using the LISST-ABS® (Sequoia, Inc.) and NEP5000® (Observator Instruments) acoustics and optics sensors, independently and in tandem, to predict SSCs at the sediment-laden Yellowstone River in northeastern, Montana.

**Background:** The USGS streamgage (06329500) on the Yellowstone River near the town of Sidney (fig. 1) is Montana's only active long-term sediment-monitoring site. Measurements of SSCs support the USACE management plan for Lake Sakakawea on the Missouri River in North Dakota (not shown in figure 1). For 40 years (1972 through 2012), near-daily SSC samples were collected on the Yellowstone River near Sidney by a contracted observer. In 2013, daily observer sediment sampling was replaced with turbidity monitoring as a surrogate for SSCs. Following a calibration period from 2013 through 2016, both streamflow and turbidity were evaluated for estimating SSCs. The relation between SSCs and streamflow was marginally significant ($r^2 = 0.18$) and the relation was populated with a high proportion of outliers. Inspection of outliers indicated that samples were associated with episodic pulses of high concentrations of suspended sediment primarily originating from an upstream tributary, the Powder River (fig. 1). SSCs exceeding 20,000 milligrams per liter (Miller and others, 2004) have been documented in the Powder River and episodically contribute disproportionate SSCs to the Yellowstone River, confounding the streamflow/SSC relation at the monitoring site at Sidney. Furthermore, notable gaps in the data occur periodically and are attributed to high SSCs that exceed the detection capabilities of the turbidity sensor (YSI 600 series). In the fall of 2018, a LISST-ABS and an NEP5000 turbidity sensor were installed at the long-term monitoring site at the Yellowstone River near Sidney in collaboration with the USACE to improve estimates of SSC and eliminate data gaps. The current agreement is to collect 8-10 samples per year during the initial phase of model development. However, it will take 2-3 years to collect the 20-30 samples needed (following statistical theory as dictated by the central limit theorem), to develop the relations between the LISST-ABS acoustic and NEP5000 turbidity sensors with SSCs. The current funding is not sufficient for data analysis or model development to determine surrogate relations.

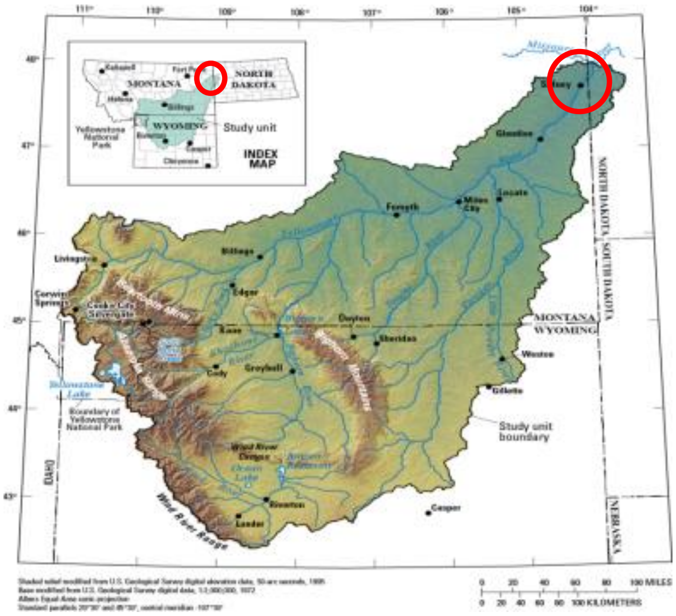


Figure 1. Location of the USGS streamgage (06329500) on the Yellowstone River Sidney, Montana.

Purpose and Scope: The purpose of this study is to evaluate the effectiveness of the AOBS method using the LISST-ABS acoustic and NEP5000 turbidity sensors, independently and in tandem, to predict SSCs in a large, sediment-laden river. Using collected SSC samples, the relations among acoustic backscatter, turbidity, streamflow and SSC will be developed. We propose to assess multiple measures of goodness-of-fit to determine the effectiveness of the dual application of LISST-ABS and NEP5000 as explanatory variables in a multiple regression model to predict SSCs. The measures of goodness-of-fit will include the proximity of the developed model(s) fitted line to the observed values (variance, standard deviation, confidence intervals), Nash-Sutcliffe Efficiency values, and model biases. This study will leverage funds provided by the USACE that fund the collection of 8-10 SSC samples by adding 12-14 samples in FY19 to be funded by the FISP.

Technical Requirements: The proposed approach will follow standard USGS data collection methods (Edwards and Glysson, 1999; Davis, 2005) and statistical theory and procedure (Rasmussen and others, 2009; Landers and others, 2016) to develop multiple parameter regression equation(s) using acoustic backscatter, turbidity, streamflow, and SSC data collected at the USGS streamgage on the Yellowstone River near Sidney, Montana. SSC samples will be analyzed (Guy, 1977) for particle size distribution (percentage of fines) and delineated by classes of streamflow to allow investigation of the LISST-ABS and NEP5000 sensors response to particle-size distribution. The installation of the LISST-ABS and NEP5000 sensors was completed in October 2018 according to the USGS/USACE collaborative agreement. Following the installation of the sensors, SSC samples (20-30) will be collected in concert with the continuous recording of acoustic, turbidity, and streamflow data. The number of samples (20-30) needed to provide confidence in the results stems from the central-limit theorem statistical theory. Collection of SSC samples are expensive and only about 45 percent of the samples needed to meet the model-building requirements will be funded through the existing USGS/USACE agreement. Therefore, we request additional funds from the FISP to collect 12-14 additional suspended-sediment samples. Together with the 8-10 samples funded by the USGS/USACE agreement, this would provide 20-24 total samples during the data collection phase (Phase 1) of the project. It is notable that FISP support in FY19 is highly valued by the USACE and would substantially accelerate USGS efforts to develop the surrogate relations in support of the long-term sediment monitoring in the Yellowstone River. Phase 2, which would entail model-building, assessment of the AOBS method, and report writing, is currently unfunded through the USGS/USACE agreement. However, we expect that around 20 percent of the funding needed to write the report would come from USACE and would be incorporated in the FY20 Scope of Work. Phase 2 funding would mostly be dependent upon FISP support.

Deliverables: A USGS SIR would be published documenting the application and assessment of the AOBS method. Application of the method at an existing long-term monitoring site is highly valuable because it will substantially enhance USGS data delivery to the USACE. This study provides an opportunity to transfer these assets to other extensive and developing sediment-related projects by the USACE and other federal agencies such as the Bureau of Reclamation and Environmental Protection Agency. Real-time estimates of SSCs and loads for the USACE site at the Yellowstone River near Sidney, Montana will be made available to the public via the USGS national real-time water quality portal at https://nrtwq.usgs.gov/. The application of the AOBS method will improve existing surrogate methods by quantifying the effectiveness of the using both sensors through multiple measures of goodness-of-fit testing and would help standardize AOBS methods.

Timeline: The proposed timeline for the project is 2 years (2019 – 2020). The major activities and scheduled completion dates are presented in table 1.

Table 1. Timeline of major activities and completion dates.

| Activities and Components | Completion Date |
|---|---|
| 1. Install LISST-ABS and NEP5000 sensors | 31-Oct-18 |
| 2. Collect episodic SSC samples for 20-24 events | 30-Sep-19 |
| 3. Compile data and develop regression models | 30-Nov-19 |
| 4. Complete draft SIR and submit for peer review | 30-Mar-20 |
| 5. Submit model to USGS national water quality web portal | 15-May-20 |
| 6. Submit SIR for final publication; release to public | 30-Sep-20 |

Budget: The proposed budget is to support a 2-year study. This project leverages funding provided by the USACE during phase 1 (FY19) and phase 2 (FY20) of the study. The total cost of the project from FISP funding for FY19 is $29.7K and for FY20 is $29.2K. The USACE funds to be leveraged for the project include $25K for FY19 and $6.2K for FY20. The complete itemized budget is presented in Table 2.

Table 2. Itemized budget.

| **Budget Category** | **Cost FY 19**<br>**Data Collection** | ~~**Cost FY 20**~~<br>~~**Report**~~ | **Explanation and Comments** |
|---|---|---|---|
| Personnel | $14,085 | ~~$21,392~~ | 2 USGS hydrologists - analysis and report writing; 1 USGS hydrologic technician - data collection, data formatting and records processing |
| Travel: Lodging/MI&E | $3,363 | ~~$0~~ | 12 days for sample collection |
| Vehicles: 2 Trucks | $2,970 | ~~$0~~ | Transportation for maintenance and sample collection. |
| Equipment/Supplies | $200 | ~~$100~~ | miscellaneous supplies for equipment maintenance and sample collection. |

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|---|---|---|---|
| Laboratory Analyses | $1,465 | ~~$300~~ | Analytical costs for supplementary samples (12-14 samples include QC samples). |
| Center Overhead | $7,660 | ~~$7,455~~ | |
| **FISP funding** | **$29,743** | **~~$29,247~~** | |
| **USACE funding** | **$25,000** | **~~$6,250~~** | $25K for phase 1 (data collection) and $6,250 for phase 2 (model building) |
| Total for each FY | $54,743 | ~~$35,497~~ | |
| **TOTAL COST (FISP+USACE)** | **~~$90,240~~** | | |

Unique Qualifications: USGS staff assigned to this project will be Chris Ellison, PhD, as principal investigator, and Tom Sabol and Chad Billings in supporting roles. Their combined USGS experience collecting, analyzing, and reporting water-quality data exceeds 25 years. Chris Ellison developed extensive expertise in installation and analysis of hydroacoustics and turbidity sensors and datasets while studying suspended-sediment transport in rivers in Minnesota and Montana during 2008–18. He has authored or co-authored seven SIRs in the past eight years. Tom Sabol is a USGS hydrologist with expertise in collecting water quality and sediment samples and sediment laboratory analyses methods. He is the lead scientist overseeing the data-collection activities supporting the Grand Canyon Monitoring and Research Center in Flagstaff, AZ. Chad Billings is a hydrologic technician and has 4 years of experience collecting suspended-sediment samples in Montana and Wyoming.

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## References:


Edwards, T.K., and Glysson, G.D., 1999. Field methods for measurements of fluvial sediment. Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 3 Applications of Hydraulics, Chapter C2, 89 p.

Davis, B.E., 2005, A guide to the proper selection and use of federally approved sediment and water-quality samplers: U.S. Geological Survey Open-File Report 2005–1087, 20 p., available at http://pubs.usgs.gov/of/2005/1087/.

Guy, H.P., 1977. Laboratory theory and methods for sediment analysis. Techniques of Water-Resources Investigations of the U.S.Geological Survey, Book 5, Chapter C1. 58 p.

Landers, M.N., Straub, T.D., Wood, M.S., and Domanski, M.M., 2016, Sediment acoustic index method for computing continuous suspended-sediment concentrations: U.S. Geological Survey Techniques and Methods, book 3, chap. C5, 63 p., available at http://dx.doi.org/10.3133/tm3C5.

Merten, H.M., Capel, P.D., Minella, J.P.G., 2013, Effects of suspended sediment concentration and grain size on three optical turbidity sensors, Journal of Soils and Sediments (2014) 14:1235-1241, available at https://pubs.er.usgs.gov/publication/70123974.

Miller, K.A., Clark, M.L., and Wright, P.R., 2004, Water-quality assessment of the Yellowstone River basin, Montana and Wyoming – water quality of fixed sites, 1999-2001, U.S. Geological Survey Scientific Investigation Report 2004-5113, available at https://pubs.usgs.gov/sir/2004/5113/pdf/sir20045113.pdf

Rasmussen, P.P., Gray, J.R., Glysson, G.D., and Ziegler, A.C., 2009, Guidelines and procedures for computing time-series suspended-sediment concentrations and loads from in-stream turbidity-sensor and streamflow data: U.S. Geological Survey Techniques and Methods, book 3, chap. C4, 52 p.

Snazelle, T.T, 2017, Laboratory evaluation of the Sequoia scientific LISST-ABS acoustic backscatter sediment sensor: U.S. Geological Survey Open-File Report 2017-1154, 21 p., available at https://doi.org/10.3133/ofr20171154.