FISP PROPOSAL FORM

Proposal Title: Pilot Study for Evaluation of Multi-Frequency Acoustics as a Surrogate for Bedload Transport
Project Chief: Molly Wood, Hydraulic Engineer and Surface-Water Specialist
Project Chief Location: USGS, Idaho Water Science Center
Proposed Start Date: December 2011 **Proposed End Date:** September 2012

1. Relation to FISP goals

This proposal is directly related to the FISP goal of identifying, developing, and testing surrogate methodologies in different environments, particularly for bedload-transport monitoring. The U.S. Geological Survey (USGS) is proposing a pilot study to evaluate whether acoustic Doppler current profilers (ADCPs) of various frequencies can be used to estimate bedload transport in the Kootenai River at Crossport, ID (USGS gage #12308500) (fig. 1). This is an emerging sediment surrogate technique that has had limited evaluation in the field. If the technique proves useful, the USGS may pursue future funding for evaluating fixed acoustic deployments that can provide continuous estimates of bedload transport. The secondary FISP goal of developing improvements to physical samplers is indirectly met by a project element that involves attaching an underwater video camera to the top of a bedload sampler. The video work will help the project team to (1) qualitatively assess the performance of the sampler in capturing true bed movement in a specific location and (2) provide recommendations for the sampler's future use in similar studies.

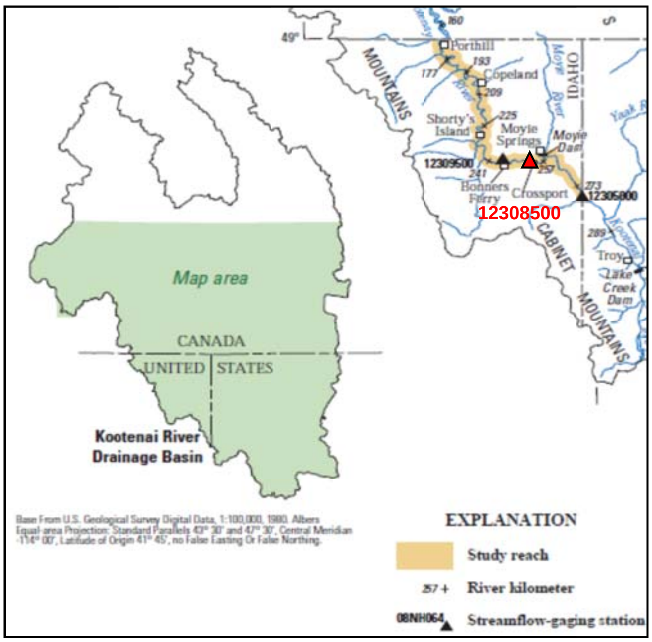

Figure 1. Study area for existing and proposed work.

2. Technical merit (Scientific merit)

Active acoustics, through deployment of ADCPs, have been tested as a surrogate for bedload transport in Canada's Fraser River (Rennie and others, 2002) and the United States' Trinity River (Gaeuman and Pittman, 2007) and lower Missouri River (Gaeuman and Jacobson, 2006). However, little work has been done to evaluate the performance of multiple frequency ADCPs outside a laboratory environment and whether the response of the various frequencies can help identify types of moving bed based on differing depths and velocities of the moving layer.

One feature of an ADCP is that it transmits a sound wave, called a bottom track pulse, to keep track of its position as it moves across a stream (Gordon, 1996). If material is moving along the bed at a particular site, the ADCP will falsely appear to move upstream, which introduces bias in the streamflow measurement unless it is corrected (Mueller and Wagner, 2006). If the exact location of the ADCP is known (by fixing its position or by connecting it to a differential global positioning system (DGPS)), and the apparent or false position of the ADCP is measured over time, an apparent bed velocity can be inferred. Bedload transport rate can be estimated based on the apparent bed velocity and empirical parameters or through correlations between near-simultaneous measurements of apparent bed velocity and bed material movement.

The average velocity of the bedload layer depends on the various sizes and velocities of the particles. Apparent bed velocity should be representative of the average surface velocity within the volume measured by the ADCP; however, the measurement is influenced by the frequency of the instrument and the characteristic size of the particles. An ADCP preferentially measures reflections from particles with a diameter equal to or greater than the wavelength of the instrument's sound wave (Thorne and others, 1995). For example, a 1.2 MHz ADCP will be most sensitive to particles with diameters equal to or greater than 0.8 mm, and the weighting of these particles in the apparent bed velocity should be greater. The use of multiple ADCPs with different frequencies should theoretically allow the computation of apparent bed velocities for different grain sizes. As a result, relations between bedload transport and apparent bed velocity may be developed separately for various grain size classes.

The use of ADCP-measured apparent bed velocity as a surrogate for bedload transport is a technique that shows considerable potential, although calibrations are site-specific, and instrument and sampling errors can be substantial. However, because conventional bedload transport measurements are typically difficult and unsafe, surrogate techniques that can provide quantifiably reliable bedload data are desirable. If the technique is deemed an adequate surrogate for bedload transport, ADCPs could be used to obtain an instantaneous estimate of bedload or could theoretically be installed at a fixed station in the river for estimating bedload transport on a continuous basis. In addition, qualitative results from this study will help in characterizing the variability of bedload transport in a natural channel, thus allowing for better sampling design whether using new or traditional methods.

The proposed Project Chief, Molly Wood, is a Hydraulic Engineer and has worked with acoustic instruments for 10 years and sediment surrogate concepts for 5 years. She has evaluated the use of acoustics as a suspended sediment surrogate in the Kootenai, Boise, Clearwater, and Snake Rivers in Idaho. She is also co-chair of the multi-agency Hydroacoustic Work Group (HaWG), sponsored by USGS Office of Surface Water, and is an instructor for USGS training courses on the use of acoustics for velocity and streamflow measurements. Ryan Fosness, another Hydraulic Engineer on the project, has extensive experience with bedload sampling and has used underwater video camera equipment to record bedload transport on the Kootenai River. An example of these video surveys can be viewed at: http://gallery.usgs.gov/videos/289. Ryan has also co-authored several USGS reports on sediment transport in the Kootenai River.

3. Technical context (Relevance and importance)

The USGS Idaho Water Science Center, in cooperation with the Kootenai Tribe of Idaho, U.S. Army Corps of Engineers, and U.S. Fish and Wildlife Service, has operated a sediment monitoring and hydrodynamic modeling project in the Kootenai River basin since 2003 as part of the Kootenai River White Sturgeon Recovery Plan. Recovery efforts for the endangered Kootenai River population of white sturgeon require an understanding of the characteristics and transport of suspended and bedload sediment which have an effect on egg suffocation and mortality rates in the critical habitat reach of the river. Key objectives of the project are to: (1) supply suspended and bedload-transport information for sediment transport modeling and (2) evaluate acoustics as a surrogate for estimating suspended sediment concentration (SSC) at three locations in the river. The work described in this proposal would enhance the existing program and may help determine whether acoustics can be used as a surrogate for bedload in similar rivers.

The Kootenai River is partially-regulated, meaning that some but not all of the flow is controlled by dams. Some flow passing the study site is contributed by unregulated tributaries. The site is thus a good candidate for sediment surrogate studies because the relation between flow and sediment transport is often poor. The USGS has found acoustics to be an excellent surrogate of SSC at similar study sites elsewhere on the Kootenai and in the Snake and Clearwater Rivers, resulting in improved estimates of SSC over short (hydrologic event) and long (annual) time scales in comparison with traditional transport curves that relate streamflow to SSC (Wood, 2010). Given the success with SSC, the project team hopes that acoustics will also prove to be a good bedload surrogate so that total sediment loading through the white sturgeon critical habitat reach can be more accurately and safely estimated.

4. Timeline, budget (feasibility), and partners

The pilot project is expected to last approximately 10 months, from December 2011 – September 2012. Field work will be conducted during 1 trip in the spring/summer of 2012, depending on flow conditions. Some costs for labor, equipment, and travel in FY2012 are already covered by base funding from the existing monitoring project. The Kootenai Tribe of Idaho and other project partners are expected to contribute about $200,000 to the USGS for related sediment monitoring on the Kootenai River in FY2012.

Proposed work elements include:

- During 1 sampling event at higher flow when the bed is moving, deploy 3 ADCPs of different frequencies (3 MHz, 1.2 MHz, and 0.6 MHz) with DGPS using a special mount off a boat. The ADCPs will collect apparent bed velocity data for approximately 5 to 10 minutes at each of 40 discrete stations (20 stations left to right, repeat same 20 stations right to left).
- Collect bedload samples using conventional techniques during the sampling event described above. Samples will be collected using an Elwha US-ER1 bedload sampler from the same 40 discrete stations (20 left-right and 20 right-left) within the stream cross-section, immediately after the ADCP data are collected at a particular station. Samples will be collected according to USGS policy in Edwards and Glysson (1999), but will not be composited into 1 sample.
- Correlate apparent bed velocities measured by each ADCP with the bedload mass and grain size distribution collected at each station at each site (up to 40 data points). Evaluate data separately for each frequency ADCP to determine if separate relations could be developed for various grain sizes of bedload.
- Attempt to quantify an approximate thickness of the moving bed layer by examining the difference in depths measured by the different frequency ADCPs. Acoustic signals from the lower frequency ADCP may be able to penetrate finer material moving along the bed and therefore may report a larger depth than the other frequency ADCPs. Some uncertainty is expected due to slight differences in area ensonified by each ADCP.
- Evaluate cross-sectional variability in bedload to determine whether one or more ADCPs deployed permanently at one station could represent the average bedload in the entire cross-section.
- Attach an underwater video camera looking down onto the opening of the bedload sampler during the sampling event to qualitatively assess performance of the bedload sampler during measurement.
- Develop suggestions for future work that might help further evaluate the use of bedload surrogates.
- Summarize findings in a peer-reviewed paper submitted to the FISP and for presentation at a conference or in a journal.

Approximate schedule:

Task	Estimated Duration	Timeframe
Prepare ADCP mounts, field prep	Varies	December 2011 – April 2012
Data collection	1 day	May – June 2012, flow dependent
Data analysis	2 weeks	June – July 2012
Prepare draft conference paper	2 weeks	August – September 2012
Submission of article to conference	TBD	After peer review and approval

Personnel:
The following USGS personnel will be included in the project:

- Molly Wood – Project Chief, acoustic data collection, data analysis
- Ryan Fosness – Hydraulic Engineer, underwater video camera operation, data analysis
- Greg Pachman – Hydrologic Technician, bedload sampling, field support

Costs:

Work performed with funds from this agreement will be conducted on a fixed-price basis. Total funding needed to cover labor, travel, equipment/supplies, and analytical services is $27,000.

Budget for Kootenai River Bedload Surrogate Pilot Study, Gross Dollars

	FY12 Cost
Labor*	$ 22,000
Travel*	$ 1,200
Equipment/Supplies*	$ 500
Analytical Services (USGS CVO Sediment Laboratory)	$ 3,300
TOTAL	**$ 27,000**

**These costs are kept low because some of the base funding for sampling, equipment, and travel is already covered by the existing monitoring program.*

References

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