Proposal Title: Estimating the size of the measurement volume for passive acoustic monitoring of Self-Generated Noise (SGN)

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Proposed start date, end date: January, 2014 – December, 2014.

Relation to FISP goals: Passive acoustic technology has the potential to allow continuous measurement of bedload moving through streams. The technology is relatively economical and is amenable to automated operation. While the magnitude of recorded sound has been shown to be well-correlated with bedload transport (e.g. Thorne, 1985 and 1986; Barton, 2006), substantial work is still needed before the technique is ready for wide-spread deployment. A key need for its advancement is a quantitative understanding of the measurement volume from which sounds are received so that field sites may be properly instrumented and data properly analyzed to estimate field-scale bedload movements. Continued development of SGN methodology is well-aligned with the FISP goals of improving technology for sediment measurement and development of indirect methods for measuring sediment transport.

Scientific Merit and Relevance: During previous efforts to aid in quantification of bedload transport using Self-Generated Noise (SGN), it was found that little information on underwater sound propagation over rough beds was available. Most of the work on acoustic propagation that has been done in shallow water depths relevant to SGN deployment was in support of bioacoustics research (e.g. Forrest et al., 1993; Forrest, 1994). Since the measurements were made in suitable habitat for certain aquatic animals, the beds were soft mud, which has different sound propagation characteristics from hard or rough beds. The rough semi-rigid bed imposed by gravel or cobbles presents a significant alteration to the aquatic acoustical environment relative to mud as multiple-scattering from the bed surface becomes important. At the present time, we do not know how different the propagation will be over rough beds of gravel, cobbles, or boulders or how acoustic energy will be reapportioned in the frequency domain. Without this knowledge, it is not possible to arrive at a reasonable estimate of the measurement volume of a hydrophone submerged in a stream. The development of more general calibrations for SGN conversion, which do not depend on the specific characteristics of the stream reach used for calibration, has been stymied by the lack of a technique for obtaining even a rough estimate of the distance or volume from which SGN can be detected. There are several reasons why an estimate of the measurement volume is important in SGN measurement:

- As a step towards development of a general approach to converting SGN data into bedload flux
- To determine how much of stream is being monitored and/or properly scale bedload estimates
- For planning number of instruments to place in channel

- For quantification of uncertainty and data quality

Even though high amplitude sounds originating from longer ranges can produce the same amplitude at a receiver as lower amplitude sounds originating from short distances, sound propagation characteristics and instrument parameters may be used to establish a maximum range from which sounds can be received. There are limits to the amplitude of sound generated by particle collision, and these will be a related to the bed material size distribution. By starting with an estimate of the highest amplitudes that are likely and combining this information with sound propagation and instrument parameters, an estimate of the measurement footprint can be established. Some of the parameters that will affect the size of the measurement volume follow:

- SGN properties
  - Amplitude
  - Frequency
- Physical location
  - Bed material size distribution
  - Water depth
  - Bed roughness
  - Position of hydrophone in stream channel (i.e., side vs. middle)
  - Ambient noise in and around stream
- Hydrophone parameters
  - Frequency response (also affected by recording system)
  - Directivity
  - Noise floor
- Recording system
  - Noise floor (also affected by hydrophone)
- Multi-path interference

Methodology: The primary effort will be in laboratory measurements of the propagation of sound over coarse beds with different geometries. In partnership with the National Center for Physical Acoustics (NCPA), we have made some preliminary measurements of sound propagation over glued-down gravel in a flume. These measurements represent a first step towards the goal of the proposed work, but they were only for one bed particle size The composition of the bed in these experiments was gravel with $D_{50} \approx 35$ mm, which represents only one possibility in a wide range of sizes. Additionally, the orientation of the gravel was not changed, which may make the result specific to that arrangement.

We propose to perform a series of experiments where sound is propagated over beds of varying roughness, recorded after passing over known distances, and compared to spreading models, such as cylindrical spreading for shallow-water environments. The frequency content of the signal will also be analyzed, since it has been shown (e.g., Urick, 1975), that wavelengths greater than about 4 times the water depth have sharply decreased amplitudes. The following experiments will be performed over the following bed types: plane; covered by 35 mm gravel; covered by 15 cm cobbles; covered by a mixture of gravel and cobbles. The height of the source will be varied, although it is most reasonable to have it near the bottom to simulate the sound made by particle impacts. The water depth will be varied, but it is limited by the height of flume walls to about 50 cm.

Teledyne-Reson TC4013 hydrophones and VP1000 voltage preamplifiers (owned by NSL) will be used to record the sounds. A Bruel and Kjaer 2713 power amplifier (owned by NCPA) will be used to excite another hydrophone (to represent a point source) across a range of frequencies of approximately 1-10 kHz. The experiments will be in a flume at the NSL or possibly in a new tank at the NCPA.

Timeline, budget, and partners:

Timeline:

December 2013:	Establish agreement with ARS
March 2014:	Receive funds
April 2014:	prepare flume for experiments, gather supplies
May-September 2014:	data collection
October-December:	data analysis and report preparation

Budget:
The salaries of the researchers working on the project are covered by other funds and will not be charged to this study.

Travel: NSL personnel to present results at conference:	$3000
Supplies for experiments:	$1000
Student employee to collect data and gather literature:	$7,000
Overhead (17.2%):	$1,892
Total:	$12,892

Partners:
Dr. J. R. Rigby, USDA-ARS, National Sedimentation Lab, Oxford, MS
Dr. Roger A. Kuhnle, USDA-ARS, National Sedimentation Lab, Oxford, MS
Dr. James Chambers, National Center for Physical Acoustics, University of MS
Brian Carpenter, National Center for Physical Acoustics, University of MS
Bradley Goodwiller, National Center for Physical Acoustics, University of MS

Deliverables:
A completion report will be provided to FISP. The primary result will be amplitude relative to distance for a range of frequencies, recorded over beds of different roughness. This information will be combined with other parameters listed above to begin developing a method for estimating SGN measurement range. Since there are a number of parameters, a finished technique may not be possible. At the very least, the

report will treat each parameter in detail and highlight other areas where more research is needed.

References:

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