Design, Calibration and Deployment of a Hydrophone Based Bed Load Monitoring Surrogate

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Abstract

The use of sediment generated noise (SGN) has been studied as a potential surrogate method for determining bedload transport rates. Laboratory and preliminary field experiments have shown multiple characteristics of this acoustic signal that correspond with properties of the bedload in transport. A portable passive-acoustic data collection system was designed by researchers at the National Center for Physical Acoustics at the University of Mississippi along with researchers at the National Sedimentation Laboratory in Oxford, Mississippi. The system uses two hydrophones (High Tech Inc 96 MIN-Exportable) to record the sound generated by coarse bedload movement. A portable data recorder (Zoom H4N) streamed the continuous acoustic data to audio files that were then processed. The data collection hardware was placed in a waterproof container. The system is compact, robust, portable and can operate for long periods of time with minimal user input. A custom hydrophone case was designed to allow multiple mounting techniques, thus providing adaptability to a wide range of gravel-bed fluvial systems. The data collection system was deployed on Halfmoon Creek near Leadville, Colorado, during the summer of 2015, collecting nearly one month of continuous acoustic data. The system was also deployed on the Elwha River near Port Angeles, Washington and on the Trinity River in Weaverville, California. Multiple analysis techniques have been tested on the data sets and compared with similar measurements made in laboratory flumes and tanks. Design of the system and its calibration will be presented as well as multiple deployment techniques.

Introduction

Passive acoustic methods for monitoring bed load transport have been explored for some time. Several methods of determining bedload based on gravel impacts with instrumented plates have been investigated world-wide (Rickenmann and McArdell 2007; Rickenmann, Turowski et al. 2014; Hilldale, Carpenter et al. 2015). The acoustic properties of bed load discharge of single-sized particles were investigated in a laboratory flume (Johnson and Muir 1969), as well as the
acoustic properties of impacting glass spheres and gravel of mixed sizes (Thorne 1985). These and other laboratory studies have consistently shown that the sound generated by impacting gravel particles can be used to determine a relationship between gravel transport and acoustic energy. Recent field studies have been conducted using hydrophones to detect gravel movement in the Trinity River (Barton 2006; Barton, Slingerland et al. 2010). To continue this research, a passive acoustic system was tested at four different field sites: Trinity River in Weaverville, CA; the Elwha River in Port Angeles, CA; the Walnut Gulch Watershed near Tombstone, AZ at the Lucky Hills sub-watershed; and Bear Creek in Evergreen, CO. Following these deployments, a more robust and portable system was developed (Figure 1). The system uses two HTI 96-MIN Exportable hydrophones. The voltage generated by these hydrophones is digitized and recorded using a Zoom H4N wave recorder. The data collection components are housed in a weatherproof case, and the hydrophones are placed in a custom case that provides a variety of mounting options.

**Figure 1.** Left: Casing for the hydrophone with collar that fits inside a 1" PVC coupler. Right: Zoom H4N and connections housed in a weatherproof case

**Deployments**

The portable system was deployed on Halfmoon Creek, a small mountain stream near Leadville, Colorado. The deployment lasted one month in the summer of 2015, and the hydrophone system collected nearly continuous data during this deployment. In conjunction with the acoustic data collection, physical samples were collected using portable bedload traps (Bunte, Abt et al. 2004; Bunte, Swingle et al. 2007). The hydrophones were mounted on metal poles driven into the stream bed upstream of the bedload traps. A fairing with a teardrop cross-section was placed over the poles to reduce flow noise from the surface disturbance. The hydrophone cables were strung across the creek to the data collection box on the bank (Figure 2).
In the summer of 2016, the system was deployed on the Elwha River in Port Angeles, Washington. At the time of deployment, the Elwha River was not wadeable. For this reason, the hydrophones were mounted to a modified kayak (Figure 3). The data collection box was mounted on top of the kayak, which was tethered to a line strung across the river. The deployment was made in conjunction with physical sampling by Graham Matthews and Associates. Three different hydrophone systems were deployed. One kayak was mounted in a stationary position, while another was moveable (this system was moved laterally in order to be directly upstream of the physical sampling raft). The third hydrophone system was mounted directly to the physical sampling raft.
In the summer of 2017, the system was deployed on the Trinity River in Weaverville, CA during the scheduled dam release and gravel augmentation. The same raft configuration was used on the Trinity as the Elwha. However, due to the high flow of the Trinity during the time of testing, the raft could not be safely placed in the middle of the river. Instead the raft had to be floated in an eddy behind a tree to which the raft was tethered (Figure 4).

![Hydrophone raft deployed on the Trinity River](image)

**Figure 4.** Hydrophone raft deployed on the Trinity River

A summary of some properties of the three deployments is shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Halfmoon Creek</th>
<th>Elwha River</th>
<th>Trinity River</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Leadville, Colorado</td>
<td>Port Angeles, Washington</td>
<td>Weaverville, California</td>
</tr>
<tr>
<td><strong>Deployment Dates</strong></td>
<td>May 20 - June 16, 2015</td>
<td>May 21 - 26, 2016</td>
<td>April 25 - 28, 2017</td>
</tr>
<tr>
<td><strong>Discharge Range (m³/s)</strong></td>
<td>0.61-5.5 (21.6-195 cfs)</td>
<td>44-48 (1,560 - 1,680 cfs)</td>
<td>245-374 (8,650 - 13,200 cfs)</td>
</tr>
<tr>
<td><strong>Water Depth Range (m)</strong></td>
<td>0.130 - 0.475</td>
<td>Not Available</td>
<td>~0.75</td>
</tr>
<tr>
<td><strong>Approx. Width (m)</strong></td>
<td>8.7 (at low flow)</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td><strong>Bed Type</strong></td>
<td>Gravel</td>
<td>Gravel</td>
<td>Gravel</td>
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<tr>
<td><strong>River Access</strong></td>
<td>Wadable</td>
<td>Partially Wadable</td>
<td>Not Wadable</td>
</tr>
</tbody>
</table>
Conclusions

The development of a user-friendly portable hydrophone system was a success. Approximately 272 GB of acoustic data were collected on Halfmoon Creek, 32 GB on the Elwha River, and 30 GB on the Trinity River. The system is adaptable to many different situations and requirements. The data collection is straightforward and requires minimal operator input. In addition, when connected to an external 12 V battery, the system can operate until the memory is full (approximately 36 hours).

Analysis of the data from all three deployments is ongoing. Preliminary results indicate that raw RMS voltage may not be a valid metric for determining bed load transport, as it is highly correlated with flow discharge but not very well correlated with bedload discharge. The flow noise must be removed from the data before an accurate method of estimating bed load transport can be determined. Various analysis techniques are being investigated to isolate the SGN from the total acoustic recording.

References


