Continuous River Bed Monitoring at Hydroelectric Intakes Using Dual-Axis Sonar Scanners

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Introduction

Bedload transport, particularly coarse gravel, is of interest to hydroelectric facilities that must monitor and manage their facilities. Yet bedload transport is naturally stochastic and both transport and supply driven. Traditional bedload measurements have proven difficult in events that transport substantial bedload, while modeling bedload transport accurately remains a contemporary challenge. Here we show through several deployments, at two sites, how we utilize the Dual-Axis Sonar (DAS) to monitor both bed elevation and debris management on a variety of hydroelectric dams. The observations, in lieu of models, provide a robust direct method in which to manage hydroelectric facilities in real-time. The results can also be used with models and other direct measurements to provide valuable information to support model development and operational rules for rarely occurring high consequence scenarios.

In general, observations from the sites prove more useful than general sediment operational rules and have enabled operators to produce more power at times of the year when the sediment supply rates are slower. At times of high bedload transport, adjustment of operations can be made when sluicing needs to be more aggressive to prevent sediment clogging trash racks and damaging turbine runners. The sonar data has also been used in real-time to adjust dredging activities at sites with scans as frequent as every 10 minutes.

Site Descriptions and Instrument Setup

We have utilized DAS scanners at four sites, two of which are described herein. The Northern British Columbia site is located at a run-of-the-river hydroelectric facility on McLymont Creek, a tributary to the Iskut River, and is operated by AltaGas. The hydrology is dominated by a snowmelt and glacier melt freshet, but also impacted by fall rain storms that cause the largest floods on the river and are particularly flashy. Bed material is coarse gravel and cobble.

The second site located in Southwestern Washington is operated by Lewis County Public Utility District (LCPUD) and is on the Cowlitz River. Though the Cowlitz also relies on snowmelt fall rain storms result in the largest floods. The sediment load at Cowlitz is considerably finer and composed largely of sand that can deposit in the reservoir created by the facility. The operational rules of the reservoir require the water levels to be drawn down during floods, which can result in a dramatic increase in sediment loading at the site as the sand in the reservoir is dewatered, and the river transitions from reservoir conditions to riverine conditions.

Dual-Axis Sonar Setup:

We deploy DAS scanners developed by Kongsberg Mesotech. The sonar uses a 330 kHz frequency and max range of 300m, with an applicable range dependent on the sonar settings.

The scanner covers 360° in the horizontal and ranges from 10° to -90° in the vertical. The step size varies between 0.225° and 7.2° which determines the total time to complete a scan. The scans can take between a few minutes to a day in duration, with most scans set to run every half hour to two hours, depending on the desired resolution and extents. The system is integrated with the plant control networks so that plant operators can respond to changes in bed elevation quickly. Figure 1 (left) shows the DAS deployment at the Cowlitz Hydroelectric facility and the instrument mount that was hung off a debris prevention boom (left). Figure 1 (right) = shows an image of the head pond empty, which lends perspective to the scans described below.

Figure 1. Images showing the DAS deployment at the Cowlitz Hydroelectric facility.

Continuous River Bed Monitoring:

Bedload Transport Events

To monitor bedload at a site, we scan the bed over a predetermined time. Time intervals are based off the resolution needed. Most deployments range from 30 minutes to a couple hours. Longer scans are collected to create base digital elevation models (DEM), while shorter scans are done in smaller areas. Figure 2 shows an event from the McLymont facility during peak discharge (Figure 2 top). The DEM shows bedforms moving through the head pond from left to right (Figure 2 bottom left), along with the change in elevation from the prior scan (Figure 2 bottom right). To provide facility managers and operators information on the river bed dynamics, we average spatially specific areas (~4 m^2) as point data to provide time-series of the elevation changes, in addition to the DEMs. Between the more temporally resolute time-series data and the more spatially dynamic bed scans, managers and engineers are able to track the river bed and identify issues in both the short and long term. Management decisions can be made in real-time, while engineers and managers gain more insight into the local processes that come with longer data sets, allowing for more efficient management practices.

The data from the sonars has enabled us to continuously track dunes and gravel bars. Additionally, we gain information on sediment transport around a multitude of structures where both long-term (aggradation/degradation) and short-term (scour) sediment transport processes are of interest. Figure 2 shows dunes moving left to right towards the intake of the facility that is at the bottom of the image.

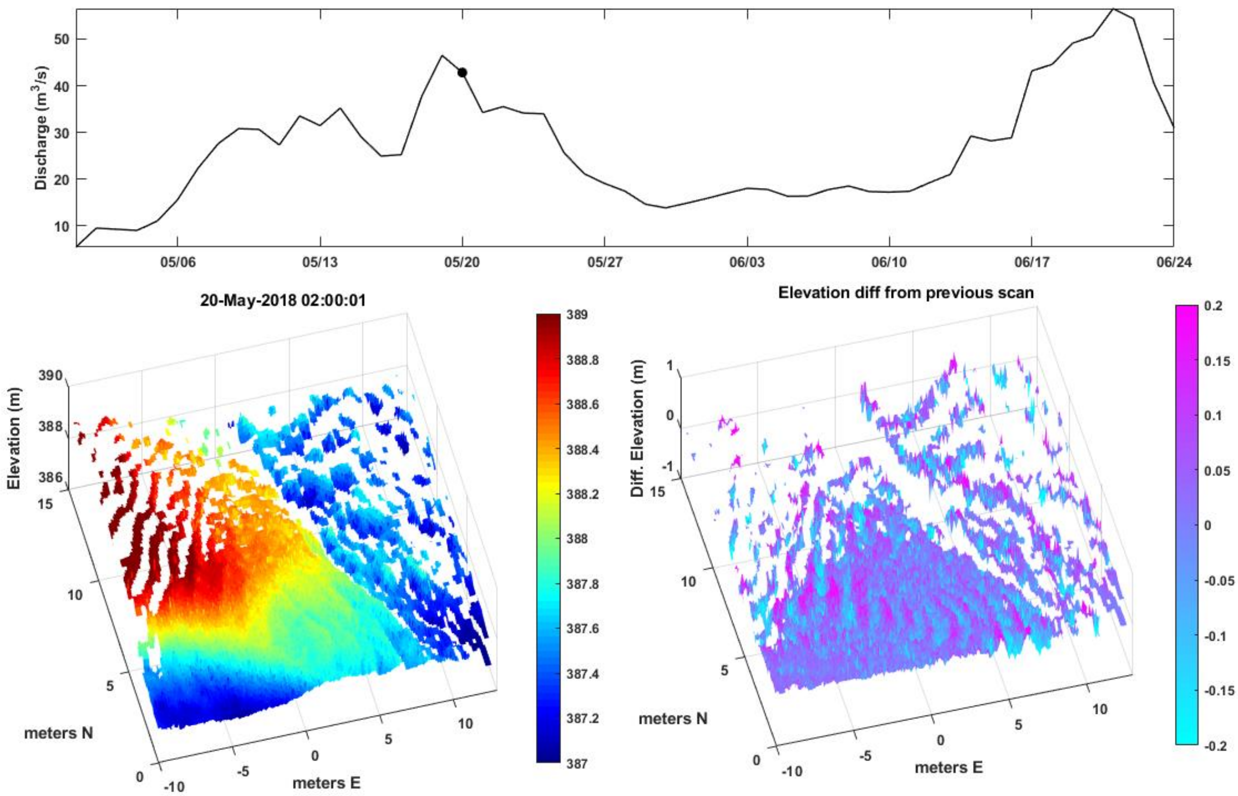

Figure 2. Time series showing the discharge (top), the DAS scan DEM (bottom left), and the difference between the DEM and the scan prior (i.e. change in elevation over two hours).

Sediment and Debris Monitoring

Our monitoring setup and analysis provides important information to dam managers and operators with respect to the effectiveness of debris prevention and efficient sluicing. Figure 3 shows a scan of the Cowlitz River hydroelectric facility. This scan was fit to a model of the structure. The scan captures a large log, large rock that is positioned near the gates, and the existing concrete divide wall used to direct flow and sediment through the sluice gates. The DEM captured by the scan can also be seen in the empty headpond shown in Figure 4. At this facility the intent of the sonar is to track bed elevations in front of the sluice gates and power generation intakes and watch for sediment and debris accumulation during floods while the reservoir is being drawn down and converted to a river.

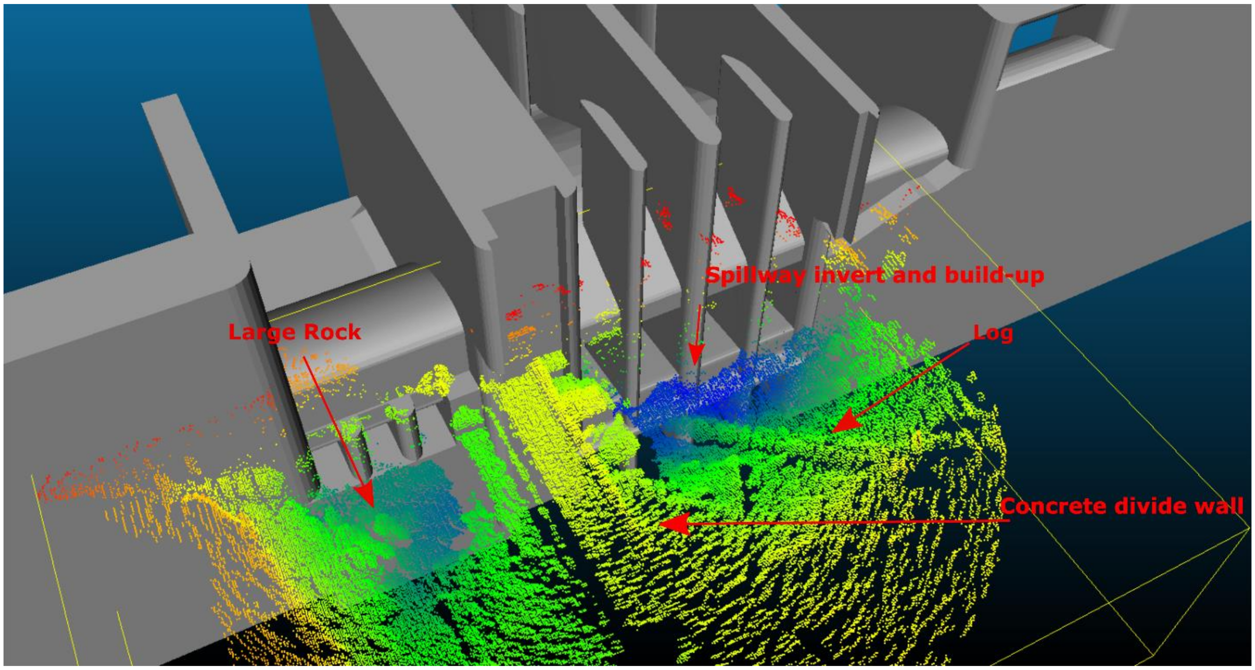

Figure 3. DAS scan from Cowlitz Hydroelectric facility showing the structure and the bathymetry of the head pond.

Figure 4. Photo of the hydroelectric structure during drawdown illustrating many of the same structures that the scan shows.

Conclusion

The DAS installs that we have completed to date clearly show the passage of dunes, gravel bars, logs and woody debris as well as the location of rocks and concrete structures. We use these scans to select areas of interest where we spatially average the data over small areas to produce single points that we track in time. This simple analysis provides dam operators with both spatial and temporal information on sediment transport and debris build-up. The points that are tracked in time are commonly imported into the Programable Logical Controller (PLC) and alarms are set for when the bed elevation exceeds a preset threshold. Additionally, we show how this monitoring can capture sediment transport processes that have proven difficult to model or measure directly. Differentiating the scans both spatially and temporally could allow for estimates of transport rates, while hydraulic and bed sediment information could better develop local transport models. Analyzing these methods to provide sediment fluxes is the next frontier and would provide exceptionally high-quality direct measures of sediment transport in large rivers with complicated hydraulics.