“Sound Science”: Sediment Monitoring Using Acoustic Surrogates in the U.S. Geological Survey

Continuous Monitoring: Innovations in Applications and Instrumentation

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U.S. Department of the Interior
U.S. Geological Survey
## Relevance of Sediment Monitoring

### Causes of Impairment for 303(d) Listed Waters

**NOTE:** Click on a cause of impairment (e.g. pathogens) to see the specific state-reported causes that are grouped to make up this category. See "Causes of Impairment Reported" to see a list of waters with that cause of impairment.

<table>
<thead>
<tr>
<th>Cause of Impairment Group Name</th>
<th>Number of Causes of Impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathogens</td>
<td>10,722</td>
</tr>
<tr>
<td>Metals (other than Mercury)</td>
<td>7,621</td>
</tr>
<tr>
<td>Nutrients</td>
<td>6,893</td>
</tr>
<tr>
<td>Organic Enrichment/Oxygen Depletion</td>
<td>6,367</td>
</tr>
<tr>
<td><strong>Sediment</strong></td>
<td><strong>6,142</strong></td>
</tr>
<tr>
<td>Polychlorinated Biphenyls (PCBs)</td>
<td>5,452</td>
</tr>
<tr>
<td>Mercury</td>
<td>4,747</td>
</tr>
<tr>
<td>pH/Acidity/Caustic Conditions</td>
<td>4,096</td>
</tr>
<tr>
<td>Cause Unknown - Impaired Biota</td>
<td>3,366</td>
</tr>
<tr>
<td>Turbidity</td>
<td>3,129</td>
</tr>
<tr>
<td>Temperature</td>
<td>3,013</td>
</tr>
<tr>
<td>Salinity/Total Dissolved Solids/Chlorides/Sulfates</td>
<td>1,897</td>
</tr>
<tr>
<td>Pesticides</td>
<td>1,872</td>
</tr>
</tbody>
</table>
Overview of USGS Streamflow and Sediment Monitoring

Number of Daily USGS Streamflow and Sediment Gages Operated per Year
1/2013, source for daily sediment data: NAWQA/Casey Lee

- Max Daily USGS Sediment Gages, Left Axis
- Daily USGS Streamflow Gages
- Max Daily USGS Sediment Gages, right axis

Same data series, different axes
Traditional Suspended-Sediment Monitoring

Physical Samples and Gravimetric Analyses
- Difficult
- Expensive
- Labor intensive
- Essential

Limited samples often provide inadequate resolution of variability and require large interpolations
Greater Accuracy & Information Content
Potential continuous surrogate measures for SSC:

- Streamflow
- Turbidity
- Acoustics
- Laser-Diffraction
- Density Difference
USGS operates over 500 index velocity gages for continuous flow records. Each one could likely be used as a continuous sediment surrogate site.

Methods and Tools are developed and being documented

**Question:** Can we leverage these data and installations for sediment acoustics?
Yellow River at Gees Mill Road near Metro Atlanta, GA, 02207335

Acoustic Doppler Current Profilers:
(A) 1.2MHz  (B) 1.5MHz  (C) 3.0MHz

Physical Sediment Sampler
ADVM Battery, Solar Panel, Cables

Acoustic Doppler Velocity Meters
Acoustic Surrogates of SSC -- principles

\[ SSC = 10^{(b_0 + b_1 SCB + b_2 SAC)} \times BCF \]

\[ SCB = MB + 20 \log_{10}(\psi R) + 2R\alpha_w + 2R(SAC) \]
Surrogate Analysis and Index Developer (SAID) Tool

Assists in the creation of regression models that relate response and predictor (surrogate) variables.

Processes acoustic parameters to be used as predictor variables for suspended-sediment concentrations.

Supports guidelines Multi-agency sediment acoustic methods work USGS Techniques & Methods 3-C4 for turbidity and SSC
The Surrogate Analysis and Index Developer (SAID) tool is a stand-alone tool to assist in the creation of ordinary least squares (OLS) regression models by providing visual and quantitative diagnostics to the user. The tool also processes acoustic parameters to be used as predictor variables using a constant spatial suspended sediment concentration method. The method uses acoustic backscatter data from fixed-mount stationary acoustic Doppler velocity meters (ADVM).

Within the program, you can:

Website

http://water.usgs.gov/osw/SALT/SAID/
Elwha River at Diversion Structure near Port Angeles, WA

Graph showing suspended-sediment concentration in ng/L from 02/07/13 to 05/08/13. The mean prediction, prediction interval, model observations, and observations excluded from the model are indicated.
Utility of Real-Time Sediment

- Early warning for municipal water supply and hydropower facilities
- Track sediment loads after wildfire, construction activities, levee failures, etc.
- Monitor river response to remediation activities and changing land uses

nwis.usgs.gov  nrtwq.usgs.gov
Discrete Measurements of SSC by Acoustics

Level 1: Develop a calibration

Level 2: Apply calibration to cross section

Level 3: Validate calibration with EDI sample

Concurrent measurements of acoustic backscatter (stationary profile) and suspended sediment concentration (point samples)

Image from Justin Boldt
Discrete Measurements of SSC by Acoustics

Cowlitz River at Castle Rock, WA
March 24, 2014

Image from Ryan Jackson
Measured Backscatter (dB)

Suspended Sediment Concentration (mg/L)  EDI = 71.4 mg/L

Image from Ryan Jackson
Acoustic Surrogates of Sediment

Advantages
- Continuous, High Temporal Resolution & Real Time
- Discrete, High Spatial Resolution
- Greater Accuracy
- Greater Understanding
- Concurrent Velocity
- Highly Robust
- Ubiquitous in Streamflow Monitoring
- Reduced Cost
- Large Sample Volume
- Multi-frequency indicates Sediment Size

Disadvantages
- Complexity of Signal Processing
- SSC~Acoustics Varies with Instrument & Site
- Resolution and Low Concentration Limit
SEDIMENT ACOUSTIC LEADERSHIP TEAM (SALT)

- **Research**: Promote and conduct to address next issues
- **Methods**: Training and Guidance on Best Practices
- **Tools**: Surrogate Analysis & Index Developer Tool (SAID); Real Time processing tools (for NWIS & NRTWQ); Stationary Time-Series Analysis
- **Demonstration Sites**: Continuous real-time acoustic-SSC.
- **Representatives**: OSW, WSCs [IL, ID, TX, CO, CA], OFAs