

COMPARABILITY AND ACCURACY OF FLUVIAL-SEDIMENT DATA – A VIEW FROM THE U.S. GEOLOGICAL SURVEY

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Abstract

The quality of historical fluvial-sediment data cannot be taken for granted, based on a review of upper Colorado River basin suspended-sediment discharges, and on an evaluation of the reliability of Total Suspended Solids (TSS) data. Additionally, the quality of future fluvial-sediment data are not assured. Sediment-surrogate technologies, including those that operate on acoustic, laser, bulk optic, digital optic, or pressure differential principles, are being used with increasing frequency to measure in-stream and (or) laboratory fluvial-sediment characteristics. Data from sediment-surrogate technologies may yield results that differ significantly from those obtained by traditional methods for the same sedimentary conditions. Development of national sediment data-quality criteria and rigorous comparisons of data derived from sediment-surrogate technologies to those obtained by traditional techniques will minimize the potential for future fluvial-sediment data-quality concerns.

Some Perspectives on Sediment Data Quality

All data – including fluvial sediment data – are not created equal. For example, a general decrease in suspended-sediment transport was inferred from measurements at streamgages in the upper Colorado River basin in the mid-1940's. Hypotheses for this relatively sudden and dramatic change included the effects of overgrazing, and global climate change. Topping and others (1996) have more or less verified that the perceived change in sediment-transport characteristics was a result of replacing the Colorado River Sampler – an open-bottle-type sampler – with the US D-43 suspended-sediment sampler, the first of the US-series depth-integrating isokinetic samplers for suspended-sediment data collection (Federal Interagency Sedimentation Project, 2002) (see figure 1).

Data quality, consistency, and comparability issues persist today. For example, the Total Suspended Solids (TSS) analytical method (American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1995) can produce substantially different results than those derived from the suspended-sediment analytical technique (Glysson and others, 2000, 2001; Gray, and others, 2000). Data produced by the suspended-sediment concentration analytical procedure (American Society for Testing and Materials, 1999; Gordon and others, 2000), tend to be

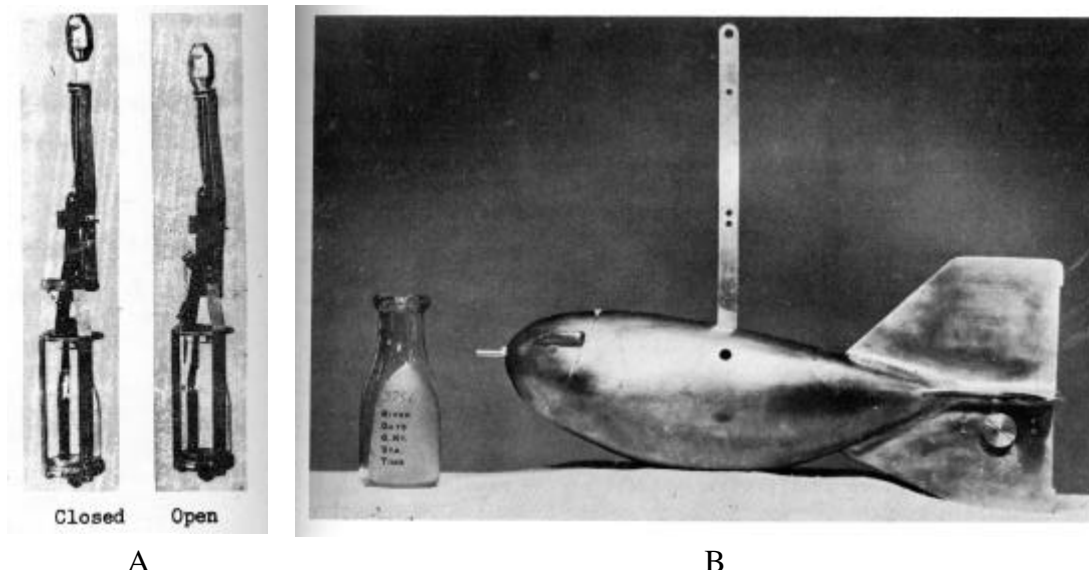


Figure 1. A: Colorado River Sampler (from Federal Interagency Sedimentation Project, 1940; 1941); B: US D-43 suspended-sediment sampler (from Federal Interagency Sedimentation Project, 1952)

considerably more accurate than TSS data. The TSS method tends to under-predict solid-phase concentrations when the sand content of the sample exceeds about a quarter of the sediment by weight. These conditions are most prevalent at higher streamflows, which are inordinately influential in mass transport of sediment. Instantaneous suspended solid-phase discharges computed from TSS and water-discharge data can differ from those computed using suspended-sediment data and the same water-discharge values by an order of magnitude or more (Glysson and others, 2000).

There is reason to believe that sediment-data quality and compatibility concerns may increase in the 21st century. Surrogate technologies and instruments to monitor concentrations and other characteristics of fluvial sediments and associated variables have proliferated over the last decade (Wren and others, 2000; Gray and Schmidt, 1997). Devices that operate on one or more of the following principles – acoustic, laser, bulk optic, digital optic, and pressure differential – show great promise toward providing less expensive and quantifiably more accurate fluvial sediment data with fewer safety concerns than those being produced by traditional collection methods as described by Edwards and Glysson (1999). Most of the devices that may eventually be applied for measuring fluvial-sediment characteristics are produced commercially.

Two primary drawbacks may impede wide-scale implementation of sediment-surrogate technologies. First, each sediment-surrogate technology – and some techniques that rely on a given technology – measure a different characteristic of fluvial sediment to compute selected statistics, including concentration values, particle-size distributions, and particle shapes. Additionally, sediment data analyzed based on shape characteristics instead of by particle hydraulic properties (“fall diameter”) used for some measurement techniques may be incompatible. Consequently, derived statistics for a given sedimentary

characteristic may differ in part as a function of the instruments used to produce the statistics.

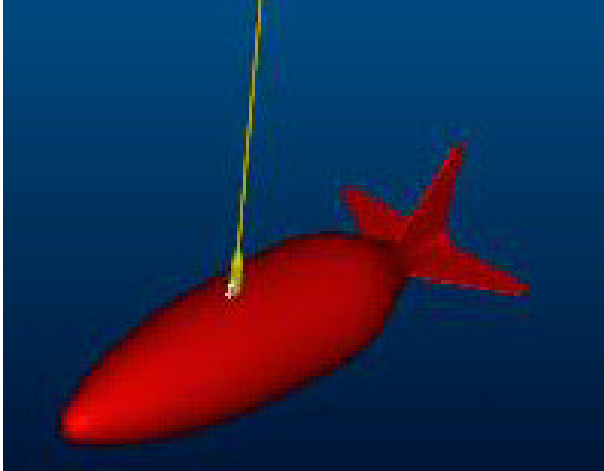
Second, the potential for deploying instruments operating on new technologies without proper calibration, and (or) lacking comparisons to traditional techniques, may result in the proliferation of sediment data that are not uniformly comparable, and may be biased. Even if some or all of these data are of superior quality to those collected by traditional techniques (less biased and (or) with less variance), changing collection techniques without an appropriate period of comparison testing – probably years – could result in the perception of changes in the sedimentological character of sampled rivers whereas the perceived changes may simply be an artifact of the implementation of different sampling equipment and (or) techniques.

Sediment Surrogate Technologies and an Example of Data Quality Criteria

The U.S. Geological Survey, in concert with the Subcommittee on Sedimentation (Glysson and Gray, 1997) is a proponent of developing data-type and -quality requirements for measuring characteristics of suspended sediment, bed material, bed topography, and bedload. Protocols for use of sediment-surrogate technologies to accomplish these measurements should be established. Advertising a reasonable set of criteria for fluvial-sediment measurements may stimulate free-enterprise development of sediment-measuring instruments needed by the Federal Government. Instruments deemed sufficiently compelling for operational data-collection purposes would warrant quality-control testing. Those that meet or exceed the published criteria would be commercially available to any buyer for deployment to produce the reliable and comparable data needed by the Nation and the world (Gray and Schmidt, 2000).

One example of development of a surrogated technology for suspended-sediment based on data-type and -quality requirements is that developed as part of a cooperative research and development agreement (CRADA) between Sequoia Scientific, Inc., and the USGS (U.S. Geological Survey, 2002). The purpose of the CRADA is to determine if a LISST-100, a commercially available laser-scattering device for measuring properties of suspended sediments developed for oceanic and estuarine applications (Agrawal and Pottsmith, 2000), can be retrofitted for manual deployment in rivers¹. The LISST-100 operates on the principle of laser diffraction to measure dimensional characteristics of suspended particles, computes particle-size statistics, and estimates suspended-sediment concentrations based on an assumption of a mean particle density of 2.65. There exist two principal causes of calibration errors that are encountered during concentration measurements with the more ubiquitous turbidity sensors or transmissometers that rely on the bulk properties of light to infer suspended-sediment concentrations (Agrawal and Pottsmith, 2000). These are known to arise from changes in sediment color and (or) grain size. The LISST-100 overcomes both these deficiencies.

¹ Use of brand and firm names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.



A bank-mounted LISST-100 has successfully inferred sand concentrations in the Colorado River at Grand Canyon, Arizona (Melis and others, 2002). The goal of the riverine version of the LISST-100, termed the LISST-StreamLined (LISST-SL) (see figure 2) will be to provide real-time representative suspended-sediment concentrations and particle-size distributions at an unlimited number of points in river cross-section.

Figure 2. LISST-SL conceptual drawing (from Sequoia Scientific, Inc., 2002)

A modified version of the CRADA will specify that the LISST-SL should be deployable from a standard single-conductor cable using a USGS B-56 reel (Rantz and others, 1982), remain stable in flows up to about 3 meters/second, and weigh 35 kilograms or less. It should be capable of measuring suspended-sediment particles in a range from 0.002 to 0.5 millimeter median diameter within 25 percent for 90 percent of the measured values. It should compute suspended-sediment concentrations from zero to at least 5,000 mg/L for 90 percent of measured values to within:

- 50 percent of actual concentration values less than 10 mg/L,
- From 50 percent of actual concentrations of 10 mg/L to 25 percent at actual concentrations of 100 mg/L, computed linearly,
- 25 percent of actual concentration values at 100 mg/L to 15 percent at actual concentrations of 1,000 mg/L, computed linearly, and
- 15 percent of actual concentration values above 1,000 mg/L.

The benefits of developing and using a commercially available LISST-SL include:

- Availability of a state-of-the-art technology that provides fluvial-sediment data on temporal and spatial scales heretofore impossible to obtain, thus providing new information on the sediment-transport characteristics of rivers.
- A long-term savings of time and money – with the ability to obtain instant reliable results without having to process and analyze physical samples as a matter of routine operation, although periodic calibration data will be required.

- An improvement in the quality of sediment data with the ability to review derivative data on-site to insure reliability and comparability; and
- A manually deployable device to provide “ground truth” data by which other sediment-surrogate technologies may be evaluated.

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