

STREAM NOTES

To Aid in Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station

October 2007

Guidelines for Using Bedload Traps in Coarse-Bedded Mountain Streams: Construction, Installation, Operation, and Sample Processing

by Kristin Bunte, Kurt W. Swingle, and Steven R. Abt

Gravel and cobble transport is a stochastic process in which discrete particles ranging in size from 2 to 256 mm hop, roll, slide, and bounce over an uneven streambed surface. At a given flow, particles will move fitfully and infrequently, particularly the largest ones. Although sampling these particles to determine transport capacity and flow competence is often a primary study goal, doing it without bias is a challenge.

Due to irregular particle movement, bedload transport rates fluctuate over time. Consecutive short-term samples collected at near constant flow typically comprise transport rates that range from almost zero to four or more times the mean transport rate. To average over short-term fluctuations, sampling time should be relatively long.

Gravel and cobble transport measured over a highflow event has a wide range of particle sizes and transport rates. At the beginning of a highflow event, only a single pea-

sized particle may be collected over a sampling period lasting several hours. At flows exceeding bankfull, several 10-liter buckets of gravel and cobbles can be collected within only a few minutes. Described in terms of mass transport rates, this difference ranges from 0.00001 g/s to 100 g/s and covers seven orders of magnitude.

Most samplers are designed to collect only a relatively narrow range of particle sizes or transport rates. Accurate measurements of gravel and cobble transport rates are difficult to obtain given the wide spectrum of particle sizes and transport rates, the infrequent movement of larger particles, and the fluctuating nature of transport. Poor measurement results have limited our understanding of bedload transport processes in gravel-bed streams. In order to address these challenges, bedload traps were designed to facilitate sampling irregularly and infrequently moving gravel and small cobble particles over a wide

STREAM NOTES is produced quarterly by the Stream Systems Technology Center located at the Rocky Mountain Research Station, Fort Collins, Colorado. STREAM is a unit of the Watershed, Fish, Wildlife, Air, and Rare Plants Staff in Washington, D.C. John Potyondy, Program Manager.

The PRIMARY AIM is to exchange technical ideas and transfer technology among scientists working with wildland stream systems.

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range of transport rates in wadeable mountain streams.

Development of Bedload Traps

The 3-inch Helley-Smith sampler is the device most frequently used to sample bedload in mountain streams. However, with its small sampler opening, its small bag with a fine mesh, a hydraulic efficiency of about 150%, a short sampling time, and direct placement onto the bed, the Helley-Smith sampler is not well suited for collecting representative samples of gravel and cobble bedload in coarse-bedded streams. Larger Helley-Smith type samplers such as the Toutle River and the Elwha sampler solve the problem of a small opening, but are difficult to hold at high flows and require tethers or a crane.

The development of bedload traps was a joint effort between the Colorado State University (CSU) Engineering Research Center, and the USDA Forest Service (FS) Stream Systems Technology Center. Work on the CSU/FS bedload traps began in 1998. The motivation behind the development was to find a device that could be easily deployed during the onset of spring runoff to determine the onset of gravel transport in gravel-bed streams for the purpose of quantifying channel maintenance instream flows. Although not originally intended as a device for developing bedload transport and flow competence curves, bedload traps have proven useful for those purposes.

Desirable Sampler Attributes

The CSU/FS bedload traps were specifically designed for use in gravel-bed streams and needed to include the following attributes:

- A large opening that permits large particles to enter the sampler.
- A deployment technique that permits long sampling times and thus integration over fluctuating transport rates.
- A large capacity that permits collection of large volumes of gravel and cobble bedload.
- Satisfactory hydraulic efficiency (good through-flow rate with little retardation or acceleration of flow).
- Satisfactory sampler efficiency (neither involuntary particle pick-up nor hindrance of

particle entry).

- Coverage of a large percentage of the stream width.
- Portability for use at remote sites.
- Relative low cost.
- Ease of installation.
- Usable by a two-person team in wadeable flow.

Bedload Trap Dimensions and Use

Bedload traps have an aluminum frame 1 ft (0.3 m) wide at the sampler opening (fig. 1). This width allows coarse gravel and small cobble particles to enter the trap. The frame has a trailing net with a 3.6 mm mesh opening that stores the collected gravel bedload. The net, 3 ft (0.9 m) in length or longer, is designed to be opened, emptied, and closed from the back without removing the frame from the streambed. Bedload traps are placed on 12 by 16-inch (0.3 by 0.41 m) ground plates that are anchored to the stream bottom with metal stakes. Adjustable nylon webbing straps are used to fasten the frame to the stakes.

Ground plates not only prevent involuntary particle entrainment at the sampler entrance, but their smoothness increases the near-bottom flow velocity, which ensures that all particles that have moved onto the ground plate will enter the trap without much delay. The large-capacity nets and fixed position of the traps on ground plates permit a long sampling time, usually an hour. During this time, an operator does not need to attend to the sampler. Long sampling times allow infrequently

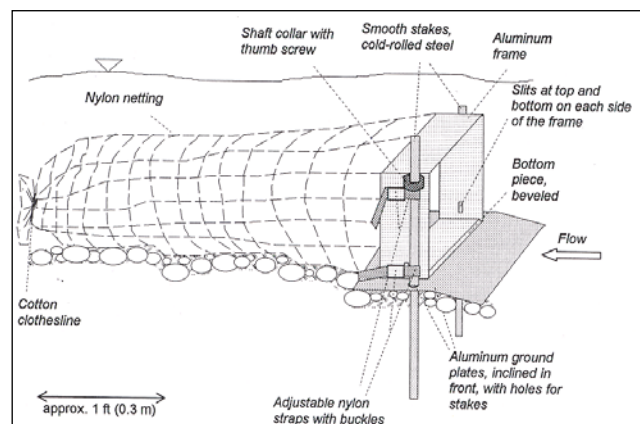


Figure 1. Schematic diagram of a bedload trap.

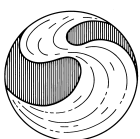




Figure 2. Four bedload traps installed in a relatively small stream, Little Granite Creek, WY.

moving large particles (in other words, particles of the size near the threshold of motion) to be collected, which averages out short-term temporal variations in transport rates. This reduces variability in sampled transport rates and avoids sampling bias when the distribution of transport rates is skewed. Hour-long sample times also allow for sampling a much larger proportion of the total bedload than a 1 to 2 minute deployment typical of a Helley-Smith type sampler.

Bedload traps are portable samplers that provide sievable samples of gravel- and cobble-sized bedload material. They are easy to install in the stream, operable at wadeable flow, and are not prohibitively expensive. Several traps are typically installed across the stream, covering much of the stream width (fig. 2). The combination of these properties (especially the large opening, the large sampler capacity, installation on ground plates, and long sampling times) are essential for obtaining representative samples of gravel and cobble bedload transport. These attributes are more typical of a “trap,” which collects all sediment supplied to it until filled to capacity, than a “sampler,” which provides a small sample of what is currently being transported. The term “bedload trap” is therefore more characteristic of our device in most sampling situations, even though bedload traps are not installed below the bed surface.

Field Testing of Bedload Traps

Over the past eight years, we have tested bedload traps at eight study sites in coarse-bedded, armored, mountain streams. Sampled bedload transport rates

and the maximum bedload particle sizes produced steep and well defined bedload transport and flow competence curves at all sites. Transport and flow competence curves were also established from samples collected with a 3-inch Helley-Smith sampler at all sites. At near bankfull flows, transport rates from bedload traps and the Helley-Smith sampler are similar, but at low flows of 50 percent of bankfull discharge, transport rates from bedload traps were 2-4 orders of magnitude smaller. Consequently, transport curves obtained from bedload trap samples are considerably steeper than those from the Helley-Smith sampler (fig. 3). Similarly, bedload traps sampled smaller maximum bedload particles at low flows compared to the Helley-Smith sampler and larger particle sizes at the highest measured flows. Flow competence curves from bedload trap samples are also steeper than those from Helley-Smith samples (Bunte and others, 2004, 2007). Nevertheless, the use of Helley-Smith samplers in coarse-bedded, high gradient channels may still be appropriate during high transport rates and for sampling sediment finer than 4 mm that bedload traps are unable to measure.

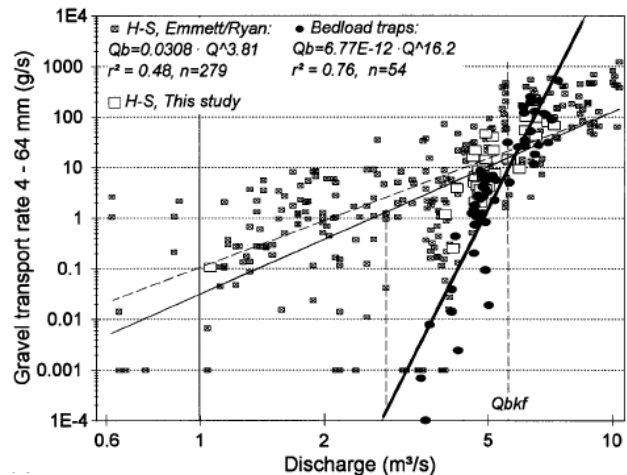
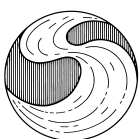


Figure 3. A comparison of gravel transport rates sampled with the bedload traps and the Helley-Smith sampler at Little Granite Creek, WY. The bedload transport curve developed from Helley-Smith data has a slope of about 4, while the transport curve from bedload traps has a slope of 16, which is 4 times steeper. Typically, transport curves from both samplers tend to converge at high flows near bankfull discharge when a large number of gravel particles are in transport.



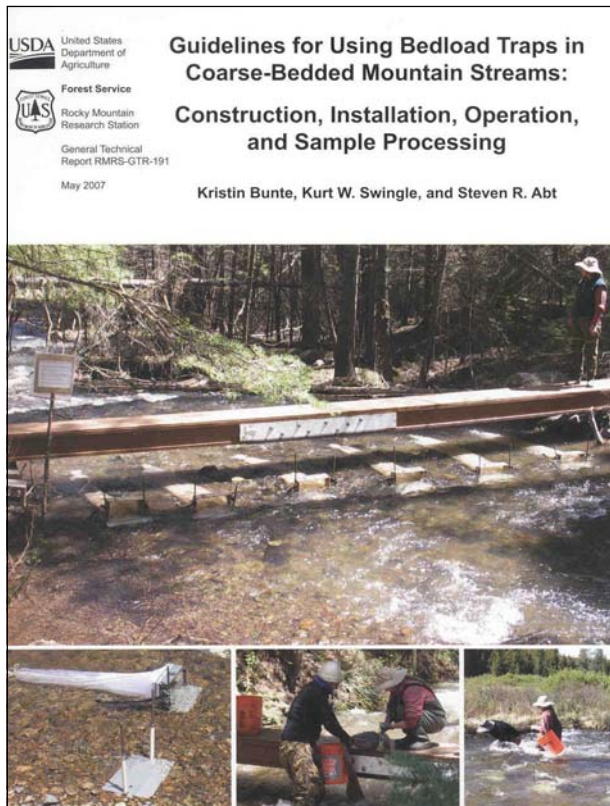


Figure 4. Cover of RMRS-GTR-191 showing six bedload traps and a footbridge installed at Hayden Creek at the beginning of the high flow season. Bottom left to right: Two ground plates—one with a bedload trap ready for sampling; Operators untying the trap net to retrieve the bedload sample; Two operators emptying bedload traps at a site without a footbridge.

Guidelines for Using Bedload Traps

These guidelines, now published as Rocky Mountain Research Station General Technical Report RMRS-GTR-191 (fig. 4), were assembled in response to the many inquiries received about how to make and use bedload traps. The guide is the result of seven years of field experience using the traps during numerous high flows. Over this period, the design of bedload traps has evolved, and the techniques of operation and sample processing were continuously modified and refined. We recognize that the techniques described in these guidelines are adapted to the conditions in Rocky Mountain streams during snowmelt high flows. Streams in other climatic and hydrologic regimes undoubtedly will pose different problems requiring creative solutions from the bedload

investigator. Nevertheless, in the hope that others will not have to repeat our mistakes, we suggest first trying the procedures as described in these guidelines and only then, as necessary, altering them as seems fit.

RMRS-GTR-191 provides detailed guidelines for bedload trap construction and operation. It describes the component parts and offers instructions for making nets and assembling the sampler. Appropriate site selection and preparation are discussed as well as bedload trap installation, use, and maintenance. The guidelines also explain how to process the collected bedload samples in the field and how to perform some of the typical calculations used in bedload evaluation. The guidelines are geared toward project managers and graduate students, as well as research hydrologists and fluvial geomorphologists who plan to use bedload traps in field studies.

Copies of RMRS-GTR-191, *Guideline for Using Bedload Traps in Coarse-Bedded Mountain Streams: Construction, Installation, Operation, and Sample Processing*, may be downloaded from: http://www.fs.fed.us/rm/pubs/rmrs_gtr191.html. The Web page also has a link for ordering a hard copy of the spiral-bound field manual.

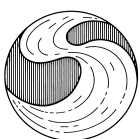
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Initial Recommendations from the International Bedload-Surrogate Monitoring Workshop, Minneapolis, Minnesota, 11-14 April 2007

By Jonathan B. Laronne, Jeffrey G.D. Marr, and John R. Gray

The International Bedload-Surrogate Monitoring Workshop (www.nced.umn.edu/BRIC_2007), organized by the Bedload Research International Cooperative (BRIC) (Gray and others, 2007; Gray and others, in press; www.bedloadresearch.org) on 11-14 April 2007, in Minneapolis, Minnesota, was held to:

- a. determine the extent to which available bedload-surrogate technologies have progressed toward potential operational applications based on calibrations under laboratory and field conditions,
- b. further the development and verification of novel bedload-surrogate technologies and methodologies toward their routine application in large-scale monitoring programs, and
- c. identify needs related to international standards on bedload-data collection, storage, and dissemination protocols.

About 50 geomorphologists, sedimentologists, hydraulic engineers, hydrologists, and others with expertise and (or) interest in bedload monitoring representing nine countries convened at the St. Anthony Falls Laboratory (www.safl.umn.edu). Others from around the world participated via live webstream on 11-13 April 2007. Archived videos may be viewed at (www.nced.umn.edu/BRIC_ArchivedStreams.html).

Outcomes from the workshop include proceedings to be released by 2008 with at least 24 peer-reviewed papers primarily addressing issues of calibration of bedload-surrogate technologies and state of the art bedload-surrogate monitoring. The proceedings will include the principal workshop recommendations; identification of compelling bedload-surrogate technologies and related issues in data acquisition; recommendations of methods to bring selected technologies to fruition; and identification of other issues and needs germane to

the international bedload-research community.

The workshop was predicated on recognition of the research community's long-standing inability to resolve a variety of difficulties in measuring and monitoring bedload discharge (transport), particularly in gravel and mixed gravel-sand bedded rivers. Direct bedload measurements, particularly during medium and high flows when most bedload occurs, tend to be time-consuming, expensive, and potentially hazardous. Indirect or surrogate technologies developed largely over the last decade have been used at a number of research sites around the world and show considerable promise for providing relatively dense, robust, and quantifiably reliable bedload datasets. However, information on the relative performance, scope of applicability and ultimate efficacy of selected technologies for use in monitoring programs is needed, as is identifying methods for bringing the most promising and tractable of the technologies to fruition. Three principal recommendations emanated from the workshop:

1. summarize the status of progress in bedload-surrogate technologies,
2. provide access to bedload and ancillary data worldwide, and
3. form and implement a BRIC benchmark network.

Workshop Recommendations

Summarize the Status of Progress in Bedload-Surrogate Technologies

A primary thrust of the workshop was to compile and evaluate information on bedload-surrogate technologies and to identify those that show the most promise for monitoring bedload as part of operational programs in a quantifiably reliable way. Papers presented at the workshop will be published in a U.S. Geological Survey Scientific Investigations Report, on a range of technologies, most of which were based on active- or passive-



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Figure 1. Active-type acoustic-bedload monitoring apparatus over a sand bed in the drained Main Flume, St. Anthony Falls Laboratory, Minneapolis, Minnesota, February, 2006. A: Acoustic-Doppler current profiler; B: Near-field flow-velocity sensor; C: Submersible lights (photo courtesy of Colin Rennie and Rauf Ramooz, University of Ottawa). Downstream view.

hydroacoustic techniques. Surrogate technologies based on magnetic and impact sensing are presently less developed for use in the near future.

Active Hydroacoustics: This technology focuses on stationary deployment of an acoustic Doppler current profiler (ADCP) in sand-bed systems (fig. 1). The net downstream movement of near-bed sediments causes a bottom-referenced ADCP to incorrectly infer that the device is moving in the upstream direction. Hence, for ADCP flow measurements, a “moving-bed correction” is required (Mueller and Wagner, 2006). The “moving-bed correction” is being used to infer bedload transport in conjunction with bedload measurements, such as in a flume with a slot-sampler or portable bedload samplers.

Passive Hydroacoustics: This technology uses hydrophones or geophones to measure the intensity of natural sounds emitted in gravel-bed channels during runoff. The sound intensity is related to bedload-transport rates, and has been demonstrated in field (fig. 2) and flume studies. Geophones resting on the bed and consisting of a pipe or impact plate (e.g., Rickenmann and McArde, 2007) and hydrophones deployed within the water near the bed have been tested. Geophones have been satisfactorily calibrated either in the lab (plates) or also in a natural channel (within a pipe set perpendicular to flow).

A review of papers based on the workshop presentations indicates that:

- Acoustic-monitoring techniques are considerably more advanced and potentially more robust than available magnetic, radar and impact bedload-monitoring techniques.
- Some of the surrogate techniques tested and calibrated in the laboratory and field have yielded encouraging results.
- The mostly off-the-shelf components that constitute many surrogate-monitoring instruments are in many cases quite affordable; however, costs associated with data analysis, presently substantial with respect to time and expertise requirements, will remain so until the analytical techniques are refined and captured as protocols.

Provide Access to Bedload and Ancillary Data Worldwide

The desire for access to a broad spectrum of bedload data from around the world was unanimous among workshop participants. Anticipated limitations in resources seem to preclude development, population, and maintenance of a central database. An alternate approach to bedload-data access was described:

- Form an ad hoc committee to define the objectives and approach toward accessing bedload and ancillary data worldwide. Identify potential partners in this effort, such as the National Center for Earth-surface Dynamics (www.nced.umn.edu/).



Figure 2. Passive-type acoustic-bedload monitoring in the Uonogawa River, Japan, 2006. A: Pipe geophone; B: Reid-type (formerly referred to as a Birkbeck-type) slot sampler. Downstream view.



- Locate and post on-line static (historical) bedload and ancillary databases that do not require refreshment and maintenance.
- Identify and access dynamic databases with bedload and ancillary data worldwide, such as the U.S. Geological Survey's National Water Information System (www.waterdata.usgs.gov/nwis). Provide metadata on each database, including protocols by which the data were collected and analyzed.
- Develop sequential query language or other script-type language that can extract data on request from the static and dynamic databases.
- Enable access, or provide information to access a suite of bedload and ancillary databases through the Bedload Research International Cooperative website (www.bedloadresearch.org) free-of-charge.

This concept has been articulated in some detail by Gray and Osterkamp (2007). Organizations expressing interest in this general concept include the National Center for Earth-surface Dynamics (www.nced.umn.edu/) and the World Association for Sedimentation and Erosion Research (www.waser.cn/). A questionnaire designed to identify useful, quality-assured databases will be developed and distributed in the near future.

Form and Implement a BRIC Benchmark Network

A number of bedload researchers have developed novel techniques for intermittently or continuously monitoring bedload transport. However, some lack the capacity or access to appropriate facilities to compare their techniques to "ground truth." Ironically, there are a large number of sites – both controlled, such as laboratory flumes equipped with sediment-measuring devices; and uncontrolled, such as Reid-type (formerly termed Birkbeck) slot samplers set in natural channels and operational during runoff – where reliable bedload-transport rates can be derived.

Recognizing this fundamental need and the availability of a number of facilities capable of providing bedload-transport ground truth, the workshop attendees were unanimous in their recommendation for the BRIC to develop a Bedload Benchmark Network. Such a network would consist of sites that:

- a. possess the facilities and capabilities that enable reliable computations of bedload transport,
- b. agree to join and collaborate as part of the BRIC Benchmark Network, and
- c. are coordinated by a BRIC-organized committee to help researchers in the selection of an appropriate bedload-research venue.

At least 20 such venues have already been identified as potential BRIC Benchmark Network research sites (Gray and others, in press).

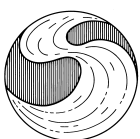
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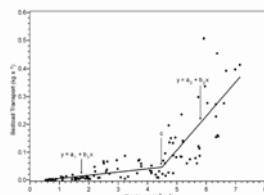
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A Tutorial on the Piecewise Regression Approach Applied to Bedload Transport Data

Sandra E. Ryan
Laurie S. Porth



United States
Department
of Agriculture
Forest Service
Rocky Mountain Research Station

General Technical Report RMRS-GTR-189
May 2007

The USDA Forest Service, Rocky Mountain Research Station recently published RMRS-GTR-189, *A Tutorial on the Piecewise Regression Approach Applied to Bedload Transport Data* (Ryan and Porth, 2007), that demonstrates the application of piecewise regression to define the shift or breakpoint from low rates of sand transport (Phase I) to higher rates of sand and coarse gravel transport (Phase II) in bedload data. The statistical theory behind piecewise regression analysis and its procedural approaches for analyzing bedload data are presented. The application of piecewise regression analysis is illustrated using several bedload datasets to help the reader understand the (1) range of estimated values and confidence limits from the analysis, (2) potential problems of identifying and resolving breakpoints from the analysis, and (3) minimal number of samples required for the analysis.

Hardcopies of RMRS-GTR-189 can be obtained by placing an order to the Rocky Mountain Research Station by telephone (970-498-1392), facsimile (970-498-1122), or e-mail (rschneider@fs.fed.us). Electronic copies of RMRS-GTR-189 can be downloaded at http://www.fs.fed.us/rm/pubs/rmrs_gtr189.pdf.

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