



STREAM NOTES

To Aid In Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station

October 2004

A Bedload Trap for Sampling Coarse Gravel and Cobble Transport in Wadeable Mountain Streams

by Kristin Bunte and John Potyondy

Gravel- and cobble-bed streams are formed by the transport of coarse bedload. However, accurate measurements of gravel and cobble transport rates and particle sizes are still difficult to obtain.

Vortex samplers and continuously weighing pit samplers can provide representative measurements of instantaneous transport rates of gravel and cobble bedload in mountain streams. However, substantial streambed construction is involved in the installation, which makes these devices difficult, time-consuming, costly to deploy, and unsuitable for remote sites.

Small non-recording pit trap samplers can be installed in a streambed by a small field crew with shovels and buckets. However, trap operation is limited to flows in which an operator can reach down to the stream bottom to empty the traps. Pit traps also have highly variable sampling efficiencies. During high flow, sand and fine gravel may travel in suspension and even mid-sized gravel particles may skip over the trap opening. Together with the

problem of resuspending particles already captured in the trap and losing them from the sample, these processes lead to diminished trap efficiency and under-prediction of transport rates at high flows.

Net-frame bedload samplers have openings several square feet large and collect gravel and cobble particles in long and relatively coarse-meshed, trailing fishing nets. These large samplers have been successfully used to sample gravel and cobble bedload over a wide range of flows. However, applicability of net-frame samplers is limited because they require a bridge with sturdy vertical bars for support, a sill on the stream bottom for good streambed contact, and the strength of several people to operate.

Finally, electronic bedload measuring devices are being developed, but they are not yet sufficiently advanced to provide a reliable conversion between the recorded signals and the number and size of particles moved.

STREAM NOTES is produced quarterly by the Stream Systems Technology Center located at Rocky Mountain Research Station, Fort Collins, Colorado. *STREAM* is a unit of the Washington Office Watershed, Fish and Wildlife Staff. 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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Portable Bedload Traps

The portable bedload traps discussed in this article overcome many of the deficiencies discussed above and were developed under a cooperative agreement between the USDA Forest Service's Stream Systems Technology Center and the Engineering Research Center at Colorado State University. The primary motivating force behind development was a need by the Forest Service to accurately and easily measure the onset of gravel and cobble bedload transport in remote mountain streams for the purpose of quantifying channel maintenance instream flows on National Forest System lands. While the original intent was limited to the determination of incipient motion, subsequent analysis has demonstrated that data collected with the bedload traps in coarse-bedded streams can also be used to determine cross-sectional transport rates and establish bedload transport rating curves.

To achieve the objective of accurately measuring the onset of gravel and cobble bedload transport, bedload traps have to representatively collect all mobile gravel particle sizes, cause minimal stream bed disturbance, and be easy to operate in wadeable flow.

Bedload Trap Design Criteria

A suitable bedload trap would therefore have to meet the following design criteria:

- Have a sufficiently large sampler entrance to allow cobbles to easily enter,
- Be stationary to allow for long sampling times to increase the probability of sampling infrequently moving particle sizes,
- Have a large bag to collect a large sample volume without reducing sampling efficiency,
- Have a comparatively large mesh width to keep flow resistance at a minimum,
- Be lightweight for portability,
- Be operable in flow depths and velocities as long as the stream remained wadeable, and
- Require no more than two persons to operate in the field.

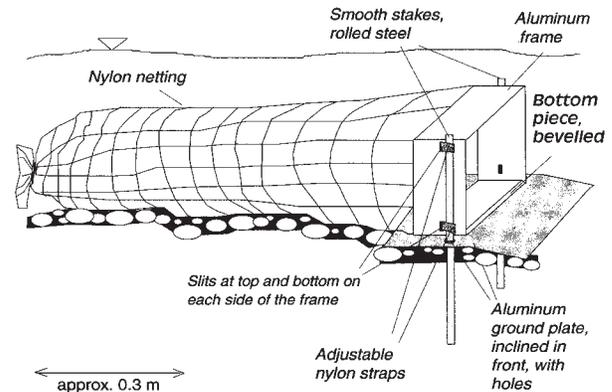


Figure 1. Schematic diagram of the bedload trap.

Bedload Trap Design

The prominent characteristics of the bedload sampling device are a large opening and a long sampling time--attributes more typical of a "trap" than a "sampler." The term "bedload trap" is therefore used to describe these devices, even though they are not installed below the bed surface.

The bedload traps have a sturdy aluminum frame 0.3 m wide, 0.2 m high, and 0.1 m deep (figures 1 and 2). Dimensions were selected to accommodate particles up to small cobble sizes (approximately 128 mm). In the field, the frame is placed onto a ground plate to ensure good contact with the stream bottom. The front edge of the ground plate is inclined down in the upstream direction to provide a smooth transition between the streambed and the trap entrance. The ground plates have holes on either side through which metal stakes are driven into the streambed to anchor the ground plates and the traps. Slits near the top and bottom on both sides of the frame serve to hold nylon straps, which are adjustable to hold the traps in place. A flexible connection is essential because the stakes can rarely be driven into the bed parallel to the bedload trap frame in coarse gravel-bed streams.

Sediment is collected in a trailing net that extends approximately 1 m downstream of the frame. The netting is sturdy, knotless, and abrasion-resistant, crocheted of thin nylon yarn, and available from fishery aquaculture suppliers. A mesh opening of 3.5 mm combines the advantages of relatively unobstructed water flow with





Figure 2. A photograph of a bedload trap installed on a ground plate in a stream channel ready for sampling. The metal stakes hold the trap in place to the stream bottom and the nylon straps and shaft collars secure the trap to the ground plate. The trailing 3.5 mm fishnet serves to trap sediment particles. The trap can be left in place during the entire sampling period without disturbing the stream bottom.



Figure 3. Six bedload traps installed in a meander bend in a gravel-bed stream at approximately 60 percent of bankfull discharge. The three traps on the far bank in the thalweg have extra long nets to make it easier to emptying them during high flows. The next two traps have the standard 1 meter length net. The ground plate on the far right still needs to have a sampling frame with net attached to it.

the ability to trap gravel particles as small as 4 mm. The downstream end of the net is tied shut with a short-length cotton rope that can easily be opened to remove collected sediment. The net has a fill volume of about 0.025 m³, equivalent to about 50 kg of gravel. This mass permits deployment of bedload traps for long time periods, one or more hours, during low and moderate transport events.

Bedload Trap Streambed Location

Bedload trap installation is best done at relatively low flows, a few days prior to the onset of bedload transporting flows. A small area of the streambed is cleared of large surface particles to obtain a level space onto which the ground plate flush is positioned with the average height of the streambed.

Traps are best installed at a wide riffle since this is the most wadeable part of the stream and provides the best chances for servicing traps during high flow (figure 3). The combined widths of all traps installed across the stream should cover 20–40% of the active streambed, depending on the desired sampling intensity or accuracy with respect to lateral variability of bedload transport.

Emptying Bedload Traps

An important feature of bedload traps is that they can be emptied while the frame remains in place on the ground plate, avoiding disturbance of the stream bottom. For emptying, the net is held shut above the accumulated sediment and the end of the net is lifted out of the water. The cotton line is untied, and the content of the net is emptied into a bucket. The net may be left open in the flow until the next sample starts or can be immediately retied and dropped into the current for another sampling period. We typically use 1 hour sampling periods.

Wading must be restricted to the downstream side of the bedload traps to avoid dislodging bed-material that may enter the traps. Wading near the traps should generally be kept to a minimum as foot traffic can dislodge particles that may cause bed scour behind and beneath the ground plates, destabilizing them.

Operation of the bedload traps is easy in wadeable flows but becomes increasingly more difficult as flows reach the limit of wadeability, a combination of depth and velocity. Safety devices are recommended for high flows.



Comparison to Helley-Smith Bedload Data

We compared transport rates sampled with the bedload traps to those obtained with a standard 3-inch Helley–Smith sampler. The Helley–Smith sampler, although not designed for collecting gravel greater than 10 mm in size, is frequently used in gravel/cobble beds due to its portability and ease of use. To account for the mesh size of 3.5 mm in the bedload traps, the bedload portion less than 4 mm was excluded from all Helley–Smith samples when making comparisons.

A striking difference consistently exists between the bedload rating curves of the bedload traps and the Helley–Smith sampler (figure 4). Rating curves for the bedload traps are considerably steeper than those for the Helley–Smith samples with bedload trap exponents ranging between 8 to 16, compared to exponents ranging between 2 to 4 for Helley–Smith samples. At flows 50% of bankfull, gravel transport rates from the bedload traps are typically two to four orders of magnitude less than gravel transport rates from the Helley–Smith data sets. Helley-Smith based transport curves also tend to have more scatter and greater variability than the well-defined curves derived using bedload traps. Transport rates from both samplers become similar at flows near or above bankfull.

The discrepancy between transport rates from the two samplers at low transport rates may be attributed to several factors that include:

1. Differences in sampling intensity and sampling time;
2. Hydraulic and sampling efficiency of the bedload traps;
3. Occasional inadvertent entrainment of small to medium gravel particles during the sampling process; and
4. The sampling time required for representative sampling.

Identifying Initiation of Motion

Direct measurement of the critical flow needed to transport gravel and cobble is important for channel

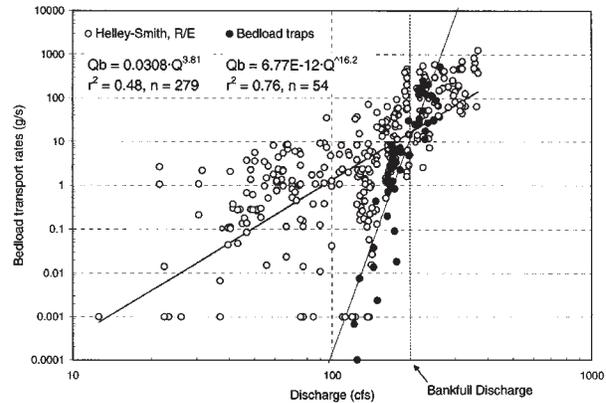


Figure 4. Comparison of gravel transport rates sampled with bedload traps and the Helley-Smith sampler at Little Granite Creek, Wyoming. The solid line has a steep exponent of 16.2 and shows the bedload transport rating curve from the bedload trap data. The dashed lines with an exponent of 3.8 shows less steep curves for the Helley-Smith data collected at the same site.

maintenance instream flows analyses because these are the morphology-forming materials of the channel. Flows adequate to cause onset of Phase 2 transport, or the point at which both the size and quantity of coarse materials significantly increases, is essential to maintain a channel. One effective way to determine this for a particular stream is by direct measurement.

Figure 5 shows a comparison of bedload data collected using Helley-Smith samplers and the bed load traps. The upper graph shows the onset of Phase 2 transport measured during a single runoff year (1999). The distribution of the data is remarkably similar to the onset of Phase 2 transport pattern measured over a 15 year period (1982-1997) by Bill Emmett of the U.S. Geological Survey. While Emmett's data covers a larger range of discharges, both data sets identify approximately the same initiation flow for Phase 2 transport.

We have found similar relationships for other streams suggesting that bedload traps are a quick and efficient way to determine this critical flow value. Data should be collected within the range of 20 to 100 percent of bankfull flows, the range within which onset of significant bedload transport has been observed.



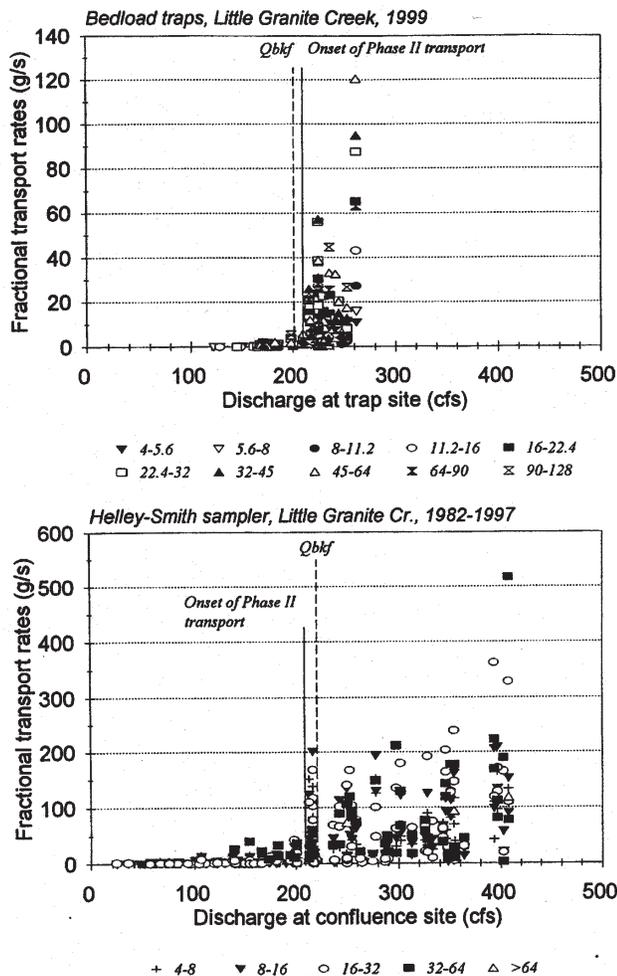


Figure 5. Comparison of fractional bedload transport rates measured with bedload traps and Helley-Smith samplers. While the data results in remarkably different transport curves, both devices identify similar patterns of bedload transport with respect to the movement of course bedload particles.

Summary and Conclusions

Portable bedload traps were originally developed to provide representative samples of gravel and small cobble transport during low and high transport rates in wadeable streams at undeveloped and remote sites. They were designed to allow deployment for a relatively long sampling duration of about 1 hour per sample while maintaining optimal ground contact and without inadvertent particle entrainment near the bedload trap entrances.

We have field tested bedload traps at several mountain gravel and cobble-bed streams and found them easy to

operate in moderately high flows. The practical limit of bedload trap operation is the limit of wadeability.

Bedload rating curves obtained from bedload traps are generally different from those obtained from Helley-Smith samples. Bedload rating curves fitted to Helley-Smith samples are flatter and have lower exponents. At flows below bankfull, gravel transport rates from Helley-Smith samples are generally higher than those from the bedload traps (two to four orders at 50% of bankfull flow), while at near bankfull flow, transport rates measured with both samplers become more similar. Data from traps and Helley-Smith samplers are, however, comparable with respect to their ability to identify the onset of course particle motion (Phase 2 transport), which was the primary motivation for their development.

Bedload traps are a portable and easy-to-use way to measure gravel transport in wadeable coarse-grained channels and the method appears to properly characterize the nature of coarse sediment transport. However, while bedload traps seem to be well-suited in wadeable streams, they are not suitable for collecting particles smaller than 4 mm. In situations where a significant portion of the total load consists of fines, or at sites where conditions prohibit the use of a fixed-bed sampler, a hand-held Helley-Smith sampler may be more useful.

More Information About Bedload Traps

For more detailed discussion of our work with bedload traps, please see the following publication:

Bunte, K., S.R. Abt, J.P. Potyondy and S.E. Ryan, 2004. Measurement of coarse gravel and cobble transport using portable bedload traps. *Journal of Hydraulic Engineering*, Vol. 130(9): 879-893.



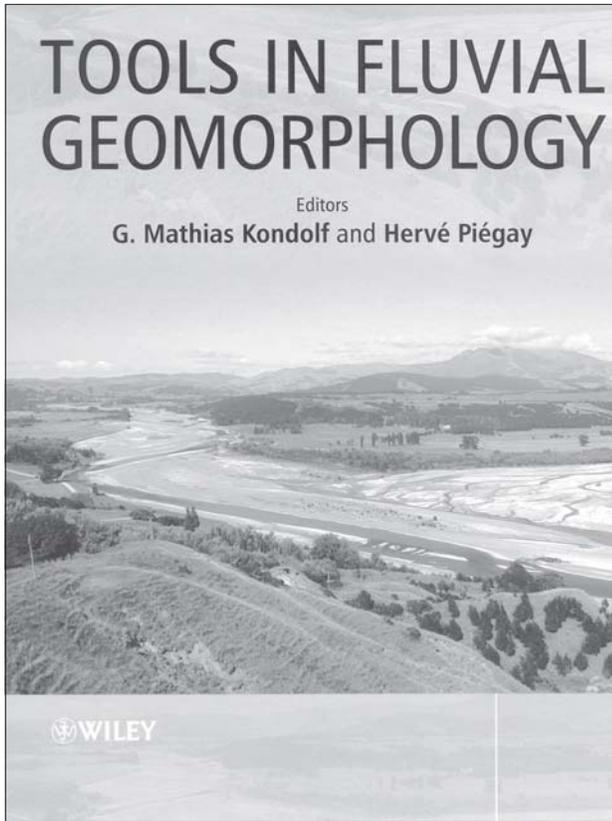
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Tools in Fluvial Geomorphology: **The Book**



A tool is defined as anything used for accomplishing a task or purpose. The word “tool” as used in the title of this book refers to concepts, theories, methods, and techniques fluvial geomorphologists apply to solve problems.

Fluvial geomorphology involves channel form and processes and the interactions of channels, floodplains, networks, and catchments. Fluvial geomorphology is largely a discipline of synthesis with roots in geology, geography, and river engineering that draws upon fields such as hydrology, chemistry, physics, ecology, and human and natural history. Due to this broad foundation, large numbers of individuals with varying backgrounds frequently consider themselves to be geomorphologists and the choice of tools used by any geomorphologist tends to be strongly influenced by the individual’s disciplinary training.

The purpose of *Tools in Fluvial Geomorphology* is to review the range of tools employed by geomorphologists and to clearly link the choice of the tool to the question posed, thereby providing guidance about methods available to address questions in the field, and the relative advantages and disadvantages of each. The book presents summaries of tools used in various areas of fluvial geomorphology, and is written at a level that falls between broad generalization and highly specific instruction on technique. Chapters are written by specialists in each field and are oriented toward providing guidance into how to approach problems and how to select appropriate tools to answer the question posed.

The book covers five main types of geomorphological questions and their associated tools:

1. Historical framework;
2. Spatial framework;
3. Chemical, physical, and biological methods;
4. Analysis of processes and forms; and
5. Framework for modeling future behavior.

The book includes case studies and chapters that cover the evolution of methods, guiding concepts, when to apply specific tools, advantages and limitations of tools, sources of data, equipment and supplies, and examples of the application.

Tools in Fluvial Geomorphology was written by G. Mathias Kondolf and Hervé Piégay (Editors) and is published by John Wiley & Sons Ltd. The book may be purchased from www.wiley.com for \$160. Reduced prices may be available from other vendors.

In spite of the book's high price tag, researchers and professional geomorphologists, hydrologists, geologists, ecologists, engineers, and planners will find it an essential and a valuable addition to their professional libraries. Take a look at it; you might learn something new!



Geomorphologist Daniel Cenderelli Joins Stream Systems Technology Center Staff

Dr. Daniel A. Cenderelli is the newest member of the Stream Systems Technology Center. Dr. Cenderelli will serve as a technical specialist for the Stream Systems Technology Center and be responsible for the full scope of technical issues addressed by STREAM. Some of the FY2005 work activities that Dan will be involved with include a variety of channel maintenance technical issues, fish passage technical guides, diversion studies, bedload transport prediction in gravel-bed rivers, streamflow data reduction software, water yield estimation technology, and improving the application of BMPs in the Forest Service.

Dan is coming from the Olympic National Forest where he provided input in fluvial geomorphology, hydrology, and geology for a variety of forest projects and planning activities. His responsibilities while there included quantifying and analyzing fluvial processes and channel characteristics, monitoring stream health and water quality, assessing watershed conditions and processes in response to natural climatic disturbances and land-use practices, designing and implementing channel and riparian restoration activities, and analyzing and designing road-stream crossings for aquatic organism passage.

For the past two years, Dan has worked with a team of experts assembled by the USDA Forest Service, San Dimas Technology and Development Center to give workshops and develop a technical guideline that provides engineers, hydrologists, geomorphologists, and biologists with the necessary skills to design stream crossing structures that will accommodate aquatic organism passage, provide more natural stream processes and channel function at crossings, and maximize the long-term durability and stability of the structure.

Prior to joining the USDA Forest Service, Dan was an assistant professor at the University of Alabama where he taught undergraduate courses in introductory geology, geomorphology, and field geology and graduate courses in fluvial geomorphology and watershed hydrology.



Dan received his Ph.D. in Earth Resources in 1998 from Colorado State University. For his doctoral research, Dan investigated the flood hydrology, flow hydraulics, and geomorphic effects of glacial-lake outburst floods in the Mount Everest region of Nepal. Dan received his M.S. degree from West Virginia University where his research evaluated the geomorphic effects of debris flows (triggered by extreme rainfall) on channel morphology in the Appalachian Mountains of West Virginia.

Dan Cenderelli can be contacted by e-mail at dcenderelli@fs.fed.us. Dan reports to the Stream Systems Technology Center in November and can be contacted at (970) 295-5984 after that time.



STREAM SYSTEMS TECHNOLOGY CENTER



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