Description and Development of a Database for Bedload Trap Measurements in Rocky Mountain Streams

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Abstract

This publication describes a large collection of gravel bedload transport measurements taken in numerous small Rocky Mountain streams (the database is available at https://www.fs.fed.us/biology/nsaec/projects-bedloadtraps.html). The database was developed for gravel bedload data collected between 1998 and 2015 during 14 campaigns at 12 field sites in 9 Rocky Mountain streams in Colorado and Wyoming and 1 stream in the Cascade Mountains in eastern Oregon. The data were collected with bedload traps—large, unflared samplers that had been specially developed to obtain representative samples of gravel bedload in mountain streams. The database contains about 1,700 estimates of cross-sectionally averaged transport rates derived from almost 8,500 individual samples collected. At most study sites, bedload was also collected using a Helley-Smith sampler, and those data are included in the database as well. The bedload measurements, which form the centerpiece of the database, are complemented by a wide range of ancillary data that provide a watershed-scale and channel reach-scale context to the bedload data collected. Ancillary data include surface and subsurface bed-material size distributions, discharge measurements, seasonal hydrographs, peak-flow recurrence intervals, site maps, surveyed longitudinal profiles and channel cross sections, annotated site photographs, and site study reports. Numerical information for each stream site, i.e., bedload transport and ancillary data, is presented in Excel spreadsheets with a separate file for each topic. The spreadsheets are extensively annotated. Each spreadsheet starts with a navigation section that guides the user through the various worksheets, while a methods section explains how field data were collected and analyzed. Text boxes on the individual worksheets offer site-specific information and additional explanation. References to relevant reports and other publications are provided.

Cover: Field photos from Halfmoon Creek 2004, Hayden Creek 2005, and East Dallas Creek 2007 study sites

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A. Introduction and Overview

Field-based measurements of gravel bedload transport rates, together with ancillary data that characterize flows and channel properties, are needed to address many questions in fluvial research and flow management. Those questions include understanding fluvial processes, quantification of bedload sediment export, stream restoration, and watershed assessment. In small coarse-bedded mountain streams, comprehensive and accurate measurements of gravel transport are especially scarce: Sites are often remote and without gauging stations to indicate current flows or suggest the trajectory of the season's hydrograph; discharges may span a 10-fold range between a season's base-flow and peak flows and high flows may become unwadeable; and funding for baseline studies at sites without imminent problems is often hard to come by.

Similarly, the characteristics of gravel transport post challenges to accurate field measurements. Gravel transport in small gravel-cobble-bed mountain streams covers a very wide range of transport rates and particle sizes that start with just one 4-mm gravel particle per hour (about 1E-6 g/m·s) at the beginning of a high-flow event. By contrast, high-flow events that occur every couple of years can also produce transport rates of 100 g/m·s comprising a mixture of gravel sizes and small cobbles that may fill a 5-gallon bucket within minutes. The other characteristic of small mountain streams is that gravel transport is a temporally unsteady process: occasionally, a group of particles burst into motion before relative stillness sets in again. Transport for given flows may also vary between days and between the start and end of a high-flow season, producing marked hysteresis.

This publication describes a large collection of gravel bedload transport measurements taken in numerous small Rocky Mountain streams; the actual field data are presented in a spreadsheet database and available at the National Stream and Aquatic Ecology Center, https://www.fs.fed.us/biology/nsaec/projects-bedloadtraps.html. The samples were collected using bedload traps, a new type of sampler especially designed for coping with transport characteristics of gravel and cobble bedload in small mountain streams and hence believed to produce measurements more reliable than were previously available. Design of this sampler and its deployment to measure gravel bedload at our field sites is described in section 1 below. The samples cover the rising limbs of snowmelt high-flow seasons. The falling limb of a high-flow season could, unfortunately, not always be included in the measurements. The field data are presented both at the most granular level possible as well as in summary worksheets and include many ancillary data. To preserve the greatest level of detail in the collected field data, the format of the resulting spreadsheet database necessarily differs from that used by other USGS and bedload databases. Our summary worksheets list each sample's cross-sectionally

averaged fractional and total bedload transport rates as well as the largest particle sizes and flow discharge for each site. A large amount of information is contained in various worksheets that allow a user to create summary worksheets formatted for user-specific applications and investigations.

The following sections discuss the design and field use of bedload traps, study field sites, and ancillary data collected at each site to better understand the factors controlling bedload transport dynamics. Additionally, we discuss why our bedload data were organized in this spreadsheet database format.

1. Gravel Transport Measurements With Bedload Traps Specifically Designed for Accurate Samples

The primary force motivating the Forest Service when tasking us with the development of a new sampler was the need to accurately and easily measure the onset of coarse gravel and cobble bedload transport in remote mountain streams for the purpose of quantifying channel maintenance instream flows on National Forest System lands (Schmidt and Potyondy 2004). The narrow 3 by 3 inch opening and brief deployment of 0.5 to 2 minutes per cross-sectional sampling location by the Helley-Smith sampler (Helley and Smith 1971) in common use at that time raised doubts on whether the coarsest moving gravels could be representatively sampled for instream flow studies.

The development of our new type of bedload trap was based on experiences from using a large, unflared sampler for collecting gravel bedload in a mountain stream on the Gallatin National Forest, Montana. That big homebuilt construction, referred to as large net-frame sampler, had a 1.5 by 0.3 m opening to which a fishing net 1.5 m long with a 10 mm mesh was attached that was tied shut at the end with a piece of string. The frame bottom rested on a wooden log in the streambed and was held in place by two vertical rails (Bunte 1996). This assemblage could collect large volumes of gravel no matter whether they accumulated in minutes or in hours. Other design ideas for bedload traps came from our field experiences of using Helley-Smith samplers as well as from Beschta (1981), Johnson et al. (1977), and O'Leary and Beschta (1981).

We designed bedload traps specifically for sampling gravel transport in coarse-bedded mountain streams where transport needed to be accurately sampled over a wide range of rates and particle sizes (Bunte and Abt 2005, 2009; Bunte and Swingle 2009; Bunte et al. 2004, 2007, 2008, 2010, 2013, 2015, 2019). The main design features of our bedload traps are a large unflared opening (0.3 m wide and 0.2 m high and 0.1 m wide) that accepts coarse gravel and small cobbles. Bedload is collected in an attached sturdy net that is 1 to 1.4 m long and has a 3.6 mm mesh width (fig. 1). The large net size allows large bedload volumes to be collected. The net is knitted and flexible, hence it handles easily.

The net has a good through-flow because the coarse mesh lets sand and pea gravel pass freely, while the collected gravel and organic debris accumulate in a bulge at the stretched-out net end, out of the way from disturbing flow hydraulics at the sampler entrance. In order to avoid direct interaction of the sampler with the bed—which may cause inadvertent particle entrainment and sampling bias—our bedload traps are deployed on ground plates anchored onto the streambed by metal stakes. Strapping bedload traps to those stakes—rather than having to hold them by hand—facilitates long sampling durations, typically of an hour, which is important for collecting a representative sample of the largest mobile particles that move infrequently. Being able to empty the bedload trap net from behind while the frame remains deployed on the ground plate allows for back-to-back sampling and the ability to collect 8 or more 1-hour samples in a given day. Depending on channel width, we typically deployed and sampled with 4 to 6 bedload traps that were spaced 1 to 2 m apart across the stream channel. Hence, collecting samples over much of the channel width and much of a high-flow day and over most days of the high-flow season, we were able to generate quasi-continuous records of gravel transport at most sites. We did not attempt to sample after it became truly dark, however.
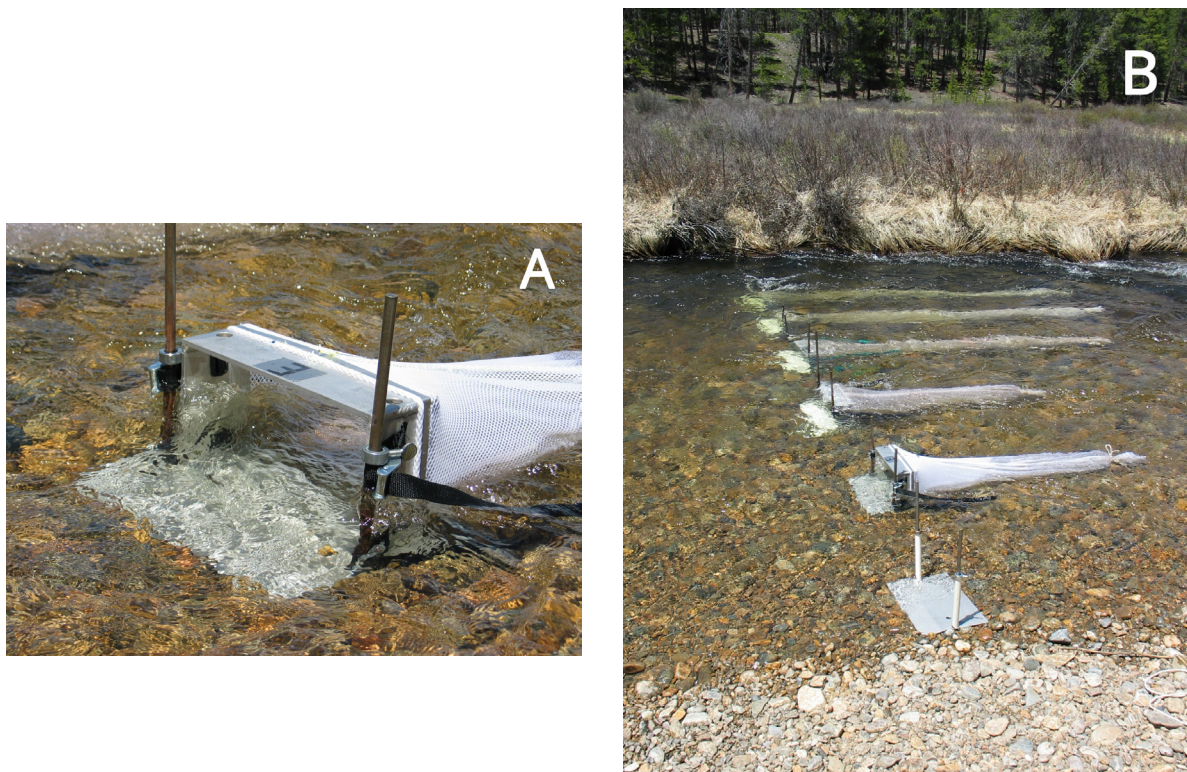
Figure 1— (a) Detail of a bedload trap deployed on a ground plate. (b) Five bedload traps installed in a cross-section.

The bedload trap design was fine-tuned over time. The first deployment in a stream channel clearly showed that the bedload trap frame had to have a flexible attachment to the stakes, rather than be held by steel rods driven through holes close to the sides of the frame, because stakes cannot be driven into the channel bed perfectly perpendicular and parallel to each other. The strap-and-buckle attachment of the trap to the metal stakes was improved early on by using longer and more flexible straps with stronger and more durable spring-loaded buckles. As soon as we started to use homebuilt, low footbridges as a sampling platform, it became clear that the net length had to be increased from about 1 m to about 1.4 m to reach a bucket held down from the bridge. Using bedload traps in fast and deep flows further necessitated fine-tuning deployment details. Ground plates were lengthened by a few inches in the back to counteract the pressure exerted on the downstream side as fast flow over the top of the bedload trap exerts a downward pressure towards the downstream end of the plate. At some sampling locations, large washers and a heavy metal bar were placed across the bedload trap top to keep the frame from tilting backwards in fast flow.

The 12 sampling sites are located in 9 Rocky Mountain streams in Colorado and Wyoming and 1 stream in the Cascade Mountains in eastern Oregon (fig. 2). The characteristics of the study sites (e.g., basin area, stream gradient, $Q_{1.5}$ flow, bed material sizes) as well as the total number of cross-sectional samples collected with bedload traps and the number of traps installed, are summarized in table 1. At most sites, bedload was also measured with a 3-inch by 3-inch Helley-Smith sampler for comparison, and those data are included in the database as well. At many of our sites, Helley-Smith samples had also been collected in previous years by S. Ryan-Burkett (Ryan-Burkett n.d.). Our bedload trap database also includes detailed ancillary data such as bed-material grain-size distributions, all discharge measurements, hydrographs, peak-flow recurrence intervals, topographic surveys, site or sketch maps, and photographs.

Table 1—Study site characteristics (sites sorted by stream gradient and dominant morphology).

Stream	Year sampled	A [km²]	Q₁.₅ [m³/s]	W₁.₅ [m]	d₁.₅ [m]	R₁.₅ [m]	Percentile particle sizes (mm)				No. of samples	No. of traps	Site elev. [m]	Dominant lithology	Dominant morphology
							D_{16}	D_{50}	D_{84}	D_{50s}					
St. Louis Creek, lower site	1998	54	4.7	8.4	0.40	0.37	17	53	120	39	10	4	2833	Gneiss, granite	Mixed plane-bed and pool riffle
Little Granite Creek, upper site	2002	13	2.8	6.3	0.32	0.29	23	67	138	37	153	4	2027	Mixed sedimentary	
Halfmoon Creek, riffle	2004	61	6.1	8.6	0.71	0.61	14	49	119	26	178	6			
Halfmoon Creek, bar		61	6.1	8.6	0.55	0.49	22	46	73	26	138	6	2990	Granite, gneiss	Plane-bed with isolated, forced pool-riffle sequences
Halfmoon Creek, riffle	2015	61	6.2	8.6	0.71	0.61	19	52	136	22	133	6			
East Dallas Creek	2007	34	3.7	7.5	0.33	0.30	16	60	131	21	170	6	2781	Andesite and other volcanic	
Little Granite Creek, lower site	1999	55	5.7	14.3	0.39	0.37	23	59	133	45	58	6	1974	Mixed sedimentary	
St. Louis Creek, upper site	1998	34	4.0	6.5	0.38	0.34	22	76	163	41	41	5	2912	Gneiss, granite	
Cherry Creek	1999	41	3.1	9.5	0.42	0.39	6.4	52	140	27	21	5	1314	Andesite, other volcanic	Plane-bed with low steps
North Fork Swan Creek	2011	16	1.1	5.6	0.20	0.19	7.6; 8.8	39; 54	124; 134	22	212	5	3006	Gneiss, schist	
Hayden Creek	2005	40	2.0	7.0	0.26	0.25	14; 18	63; 63	163; 172	36	192	6	2270	Mixed sedimentary	
Fool Creek	2009/ 2010	3	0.30	1.3	0.17	0.14	12	52	122	24	109/ 63	2	2940	Gneiss, schist	Step-pool
E. St. Louis	2001/ 2003	8	0.76	3.7	0.35	0.35	15	108	258	54	94/ 133	4	2907		

Notes: A = basin area; $Q_{1.5}$ = 1.5 year recurrence interval flow; $w_{1.5}$, $d_{1.5}$, and $R_{1.5}$ = width, depth, and hydraulic radius associated with the $Q_{1.5}$ flow; S_x = reach-averaged stream gradient; D_{16}, D_{50}, and D_{84} = bed surface particle-sizes of which 16, 50, and 84%, respectively, are finer; D_{50s} = median of the subsurface particle-size distribution. If two grain-size values are given in one cell, the first refers to conditions before and the second to conditions after the high-flow season. Data in this table are based on a re-analysis and may differ from those given in earlier publications.
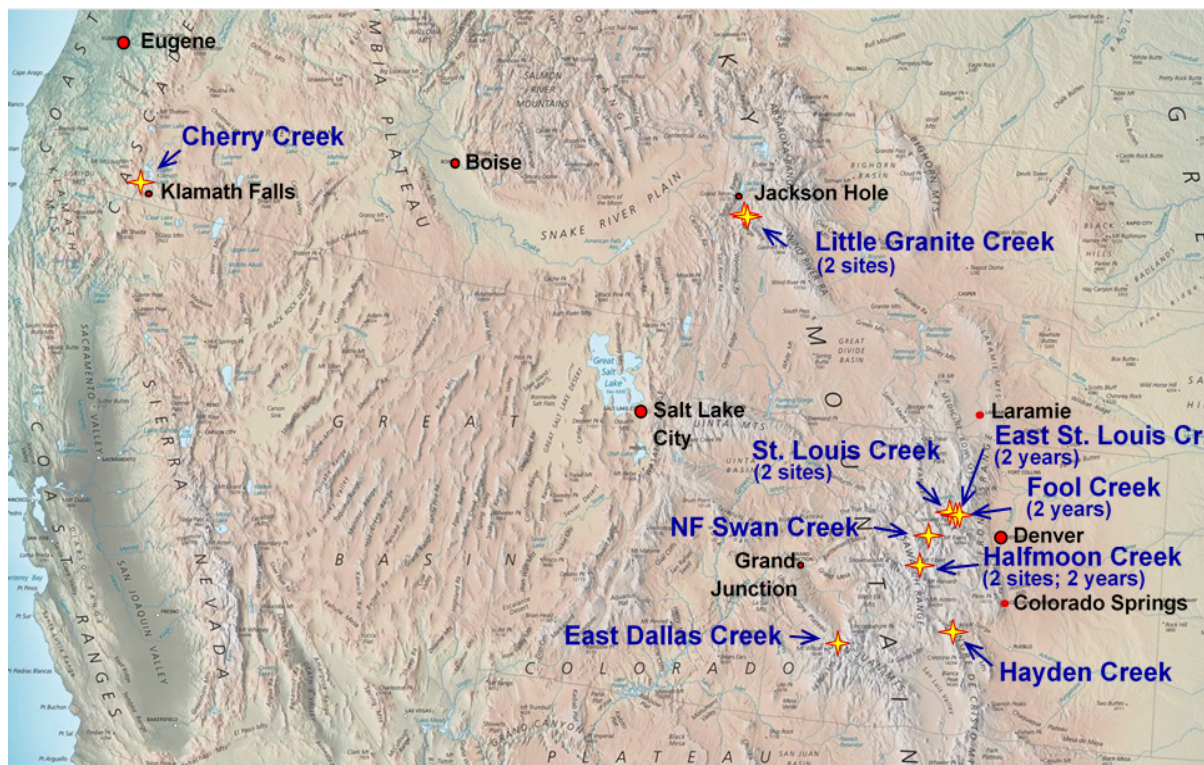
Figure 2—Bedload trap study sites. At some of the streams, sampling occurred at more than one site and extended over more than one high-flow season.

2. Description of Field Sites, Sampled High-Flow Seasons, and Special Study Aims Pursued

Apart from the site characteristics listed in table 1, brief descriptions of the sampling sites are presented here. Together with high flor and other conditions encountered during the field campaigns, these descriptions are to offer guidance to the reader as to what sites might best suit their study interest.

Testing bedload trap performance, deriving unique bedload rating curves for each stream, and comparing sampling results with those from a 3-inch Helley-Smith sampler deployed nearby were the general aims of our field campaigns. Additional aims were posed for some sites or arose opportunistically from a site's current flow and sediment conditions.

St. Louis Creek_lower site_1998 is a relatively large (A = 54 km²) gravel-bed valley stream in the Fraser Experimental Forest in central Colorado. This is the first field site at which we tried out bedload traps. Only a few samples were collected here, which are included in the data compilation for completeness.

St. Louis Creek_upper site_1998 is a small plane-bed stream (A = 13 km²) about 1.5 miles upstream from the lower site and with a coarse-gravel/cobble

bed. This smaller channel was more suited for gaining first experiences with bedload traps.

Little Granite Creek_lower site_1999 is a large plane-bed stream (A = 59 m²) in the Gros Ventre Range in northwestern Wyoming. Although the widest cross-section available was selected as the sampling site, the large flows (> 120 percent $Q_{1.5}$) of the 1999 high-flow season made the site nearly unwadeable and caused channel change and some very large transport rates.

Cherry_1999 is a mid-sized plane-bed stream (A = 41 km²) draining the western slope of the Cascade Range in Oregon. Here, too, flows were almost unwadeably deep at times, such that our 1999 field experiences drove home the message that bedload traps are best used with footbridges.

East St. Louis Creek_2001 is a small (A = 8.3 km²), incised, step-pool, headwater stream of the Colorado River in the Fraser Experimental Forest. The sampling site was located immediately upstream of a debris basin that is emptied annually. The aim at this site was validating the bedload traps' sampling efficiency by comparing annual gravel load computed from intensive sampling with bedload traps with the gravel mass accumulated in the debris basin. However, the very low 2001 high-flow season peaked at only 75 percent of the $Q_{1.5}$ flow and did not provide enough entrained gravel to make a proper comparison with the debris basin. A second study aim picked up in this low-flow year was quantifying transport rates and export of coarse particulate organic material (CPOM) over the high-flow season.

Little Granite Creek_upper site_2002 is a mid-sized (A = 13 km²) plane-bed stream located more than 1.5 miles upstream from the 1999 study site at Little Granite Creek (see above). The 2002 high-flow season produced two distinct peaks, the second of which briefly reached $Q_{1.5}$. In those moderate flows, a slowly dissolving crust of algae and mud on the channel bed affected gravel transport. Apart from the usual inter-sampler comparison, special study aims were evaluating the effects of sampling duration on sampled gravel transport and quantifying CPOM transport and export. First experiences were gathered with a fine-mesh net for bedload traps.

East St. Louis Creek_2003 was carried out at the same location as 2001 and with the same goal of comparing annual gravel loads computed from bedload trap samples with the gravel accumulation in the adjacent debris basin. Flows in 2003 rose very quickly, and a brief rain-on-snow event caused a single, large, night-time peak-flow (150 percent $Q_{1.5}$) that transported most of the season's gravel load, which unfortunately was not sampled. Thus, gravel bedload transport on the rising limb and at peak flow were mostly unsampled and were estimated for the unsampled periods. Velocity profiles of the flow approaching bedload traps were measured during the long falling limb of the high-flow

season. Two years of bedload data from the same location offered a glimpse into the interannual variability of transport relations.

Halfmoon Creek_pool exit & bar_2004 is a relatively large plane-bed valley stream (A = 61 km^2) with forced pool-riffle sequences in the Sawatch Range in central Colorado. The site was 0.5 miles downstream from a long-term USGS (benchmark) gauging station. The 2004 high-flow season was generally low and segregated into multiple peaks, the largest of which reached about 67 percent of the $Q_{1.5}$ flow. This field campaign specialized in monitoring gravel transport paths between two sampling cross-sections spaced 8–10 m apart between a pool-exit and a bar-head.

Hayden Creek_2005 is a mid-sized stream (A = 40 km^2) on the eastern side of the Sangre De Cristo Range in southcentral Colorado. The channel had a coarse gravel-cobble bed arranged in low steps. The sampling site was placed at a small aggradational area. Runoff at this ungauged site increased steadily in 2005 and culminated in a single large peak (approx. 120 percent $Q_{1.5}$). Apart from the usual inter-sampler comparison, this field campaign evaluated the effects of deploying a Helley-Smith sampler on ground plates. Standing waves developed in the large 2005 flows and re-shaped the sampling cross-section. This provided an opportunity for observing lateral and temporal variability of transport associated with local bed scour and fill.

East Dallas_2007 is a mid-sized plane-bed stream (A = 34 km^2) with a coarse gravel bed draining Mount Sneffels in the San Juan Range in southwestern Colorado. Flows at this ungauged site were moderately high in 2007, reaching $Q_{1.5}$ on a few days and exceeding it on one. The study took advantage of the varied bed-material sizes within the reach to evaluate how differences in sampling results between bedload traps and a Helley-Smith sampler deployed on the bed and on ground plates play out on beds with different mobility. An unexpected study aim presented itself by a sudden release of medium gravel from some shifted log jam upstream: Testing bedload traps during very high transport rates and observing bedload waves as the large gravel input passed over a coarse channel bed.

Fool Creek_2009 and 2010 is a very small headwater stream (A = 3 km^2) in the Fraser Experimental Forest. The channel is straight and has low steps near the study site but upstream turns into a narrow and incised step-pool sequence that finds a tortuous course around logs and buried boulders. Flows remained below $Q_{1.5}$ in both years. In 2009, studies focused on testing bedload traps with a net of 1.18 mm mesh width. The aim was to evaluate how small mesh sizes and a stiff net affect sampled transport rates, particle sizes, and hydraulics of the approach flow. The 2010 study aimed at simply determining a transport relation for the highly variable transport rates in this log-affected channel.

North Fork Swan Creek_2011 is a mid-sized stream (A = 16 km^2) with a coarse gravel/cobble bed and a low step morphology draining the Continental Divide east of Breckenridge in central Colorado. The relatively small and ungauged channel is affected by beaver activity and takes a winding course through filled-in or breeched beaver dams. The channel developed tight bends and pools along the way, forcing bedload transport to negotiate various obstacles. The large 2011 snowpack generated a drawn-out one-month long high-flow season in which flows exceeded 150 percent $Q_{1.5}$ for more than 2 weeks. A large, fresh beaver dam appeared from under the deep snow and shut off the upstream sediment supply. This caused bedload transport rates and particle sizes to drop sharply despite the large flows. The results were pronounced seasonal hysteresis in the gravel transport relations, a coarsening of the bed, and an unusual gravel transport path through the stream channel.

Halfmoon Creek_pool exit_2015 was sampled at the same site as in 2004 (see above). The snowpack kept accumulating during the cold and wet spring of 2015, and high flow, once finally started, climbed to 150 percent $Q_{1.5}$. This relatively large channel is only wadeable until about 80 percent of $Q_{1.5}$ but samples could still be collected at the two right-bank traps at which, fortunately, gravel transport was concentrated. Not much difference was noted between the 2015 and 2004 gravel transport relations.

3. Ancillary Data Provide Context for Understanding Bedload Transport Dynamics

Bedload data are most useful if presented within the context of other sedimentary, hydraulic, hydrological, and topographical information at the study site, which in turn allows for a more complete interpretation of factors controlling bedload transport dynamics. The following ancillary data and their basic analyses are provided for each site in the database:

a. **Bed-material grain-size distributions:** surface pebble counts and volumetric samples of the subsurface sediment (at some sites this also includes volumetric samples of the armor/subarmor sediment).

b. **Discharge:** all individual cross-sectional measurements, stage-discharge and hydraulic geometry relations. In order not to disturb bedload trap operation, discharge was typically measured in a cross-section a few meters farther downstream from the sampling transect.

c. **Hydrographs:** stage records, sometimes from various locations per site, as well as the derived final time series of stage and discharge.

d. **Peak-flow recurrence interval analyses:** based on a site's long-term flow record, otherwise extrapolated and interpreted from flow records of gauge sites nearby or at least within a similar hydrological region.

e. **Topographic surveys:** x-y-z survey data; longitudinal profiles along banks, the thalweg, and its water surface; channel cross-sections, as well as a site map and/or sketch map.

f. **Photographs:** at some sites, the detailed annotations describe the study's history.

g. **Reports and publications:**

    i.   The original, detailed reports prepared after a field season as well as two shorter data reports prepared for the two sites without an original report.

    ii. PDF files of the authors' publications based on bedload trap samples (journal articles, monographs, conference proceedings, and technical reports).

    iii. A reference list of all site reports and a listing of publications that are based on the data of one or more specific field sites.

4. Making Data Available and Comprehensible

Making field data available to the scientific community is important to further scientific progress. However, those data need to be fully understandable to a new user to avoid misinterpretation and out-of-context use. Here, effort was taken in the database preparation to develop structured and annotated worksheets. Because the original spreadsheets that worked up a site's data were never intended for publication, they initially were site-specific and differed widely. Also, the bedload trap field data were collected with a then-new device, and our protocols evolved over time. Additionally, research questions and channel/watershed conditions varied between study sites. A common format was clearly needed for the database that nevertheless accommodated differences in the data structure between sites. During database preparation, the original spreadsheets were converted into Excel—a widely used spreadsheet program—and a unified format was created for all worksheets in the database. After much revision, the database now presents worksheets for all study sites in a very similar format for each respective topic, i.e., all worksheets for bedload data follow a similar format and so do all worksheets for the various ancillary data (see list of eight topics in section B. 1).

5. Database Was Made as Detailed as Possible

In order to allow users the most comprehensive access to our data, we made a point of publishing field measurements with as much detail as possible, starting with raw values and proceeding through the steps of data reduction and basic analyses. For bedload transport, data go back to samples collected at each individual bedload trap installed in the stream and to the mass and number of particles in each sampled grain-size fraction. Similarly, for stream discharge computations, we provide the width-depth-velocity measurements from each vertical measured in each cross-section, while the bed-material data go back to the location and size of each particle measured in a pebble count. This detailed information may provide opportunities for more comprehensive and creative data analyses in the future.

B. DATABASE DESCRIPTION

1. Database Structure with Seven Files and One Folder in the Subdirectory for Each Field Site

The Database of Bedload Transport is segregated into 14 databases (here sorted alphabetically based on stream name) based on field measurements at 12 different sites:

1. Database Cherry_1999

2. Database East Dallas_2007

3. Database East St. Louis Creek_2001

4. Database East St. Louis Creek_2003

5. Database Fool Creek_2009

6. Database Fool Creek_2010

7. Database Halfmoon Creek_pool exit & bar_2004

8. Database Halfmoon Creek_pool exit_2015

9. Database Hayden Creek_2005

10. Database Little Granite Creek_lower site_1999

11. Database Little Granite Creek_upper site_2002

12. Database NF Swan Creek_2011

13. Database St. Louis Creek_lower site_1998

14. Database St. Louis Creek_upper site_1998

Generally, for each of the 14 field campaigns, the database provides information on eight topics (see list below) that are presented in six Excel spreadsheet files, as well as in a folder containing a photo collection of JPEG images and a PDF with a report written specifically for the site. Hence, for each field campaign there are usually six spreadsheets containing:

1. Bedload data named **QB-Dmax**, referring to transport rates and flow competence,

2. Bed-material data named **BEDMAT**,

3. Discharge data named **Discharge**,

4. Stage data and a plotted site hydrograph named **Hydrograph**,

5. Computed peak-flow recurrence intervals named **Recurrence**, and

6. Topographic site survey data named **Survey**,

as well as

7. A folder containing a site's photo collection named **Photos**, and

8. A PDF document named Bunte (year) or Bunte and Swingle (year)_site name_**Report**_Title of report.

Altogether, the bedload database comprises 84 Excel spreadsheet files, 14 for bedload data, and 70 with numerical ancillary data. The files and folders for all field sites in the database are listed in table 2. The file naming convention is **Sampled Stream_Year sampled_(additional site specification as needed)_ Topic** (i.e., one of the eight topics listed above). For example, the file name for bed-material data collected at the upper site in St. Louis Creek in 1998 is **St. Louis_1998_upper site_BEDMAT**.

There are exceptions to the pattern described above. At one of the field sites (Halfmoon Creek_2004), bedload was collected on two neighboring transects during one field season and resulted in two distinct transport and flow competence relationships, but most ancillary information was shared between transects. In this case, bedload data for the two transects were presented in the same spreadsheet file, but on different worksheets. By contrast, when bedload was sampled at a lower and an upper site in the same stream, but a considerable distance apart (such as at St. Louis Creek_1998), or the field site was resampled in later years (e.g., East St. Louis Creek), bedload data are presented on different spreadsheets for each year, but may share most ancillary information. Hence, not each site-year or site-location combination has its own set of ancillary data files, and some ancillary information was never collected because that information was obtained elsewhere. For example, if the USDA Forest Service provided discharge information for the sampled high-flow season at a site, those data are presented in the Hydrograph spreadsheet. We then typically did not measure discharge and, in that case, there is no spreadsheet with field-measured discharge data. The discharge for each bedload transport measurement is listed on the summary pages of the bedload spreadsheets (QB-Dmax).

Table 2—Overview of files included in the Bedload Database.

Stream and site	Year sampled	Bedload	Bed material	Discharge	Hydrograph
Cherry Creek	1999	Cherry_1999_QB-Dmax	Cherry_1999_BEDMAT	Cherry_1999_Discharge	Cherry_1999_Hydrograph
East Dallas Creek	2007	East Dallas_2007_QB-Dmax	East Dallas_2007_BEDMAT	East Dallas_2007_Discharge	East Dallas_2007_Hydrograph
East St. Louis Creek	2001	East St. Louis_2001_QB-Dmax	East St Louis_2001 & 2003_BEDMAT	No data	East St Louis_2001 & 2003_Hydrograph
East St. Louis Creek	2003	East St. Louis_2003_QB-Dmax		No data	
Fool Creek	2009	Fool_2009_QB-Dmax	Fool_2009 & 2010_BEDMAT	Fool_2009_Discharge	Fool_2009 & 2010_Hydrograph
Fool Creek	2010	Fool_2010_QB-Dmax		No data	
Halfmoon Creek, pool exit & bar	2004	Halfmoon_2004_QB-Dmax	Halfmoon_2004_BEDMAT	Halfmoon_2004_Discharge	Halfmoon_2004_Hydrograph
Halfmoon Creek, pool exit	2015	Halfmoon_2015_QB-Dmax	Halfmoon_2015_BEDMAT	Halfmoon_2015_Discharge	Halfmoon_2015_Hydrograph
Hayden Creek	2005	Hayden_2005_QB-Dmax	Hayden_2005_BEDMAT	Hayden_2005_Discharge	Hayden_2005_Hydrograph
Little Granite Creek, lower site	1999	Little Granite_1999_lower site_QB-Dmax	Little Granite_1999_lower site_BEDMAT	Little Granite_1999_lower site_Discharge	Little Granite_1999_lower site_Hydrograph
Little Granite Creek, upper site	2002	Little Granite_2002_upper site_QB-Dmax	Little Granite_2002_lower site_BEDMAT	Little Granite_2002_upper site_Discharge	Little Granite_2002_lower site_Hydrograph
North Fork Swan Creek	2011	NF Swan_2011_QB-Dmax	NF Swan_2011_BEDMAT	NF Swan_2011_Discharge	NF Swan_2011_Hydrograph
St. Louis Creek, lower site	1998	St Louis_1998_lower site_QB-Dmax	St Louis_1998_lower site_BEDMAT	St Louis_1998_lower site_Discharge	St Louis_1998_lower site_Hydrograph
St. Louis Creek, upper site	1998	St Louis_1998_upper site_QB-Dmax	St Louis_1998_upper site_BEDMAT	St Louis_1998_upper site_Discharge	St Louis_1998_upper site_Hydrograph

Table 2 continued.

Stream and site	Year sampled	Recurrence interval	Topographic survey	Photos	Report[a]
Cherry Creek	1999	No data	Cherry_1999_Survey	Cherry_1999_Photo	Bunte (1999b)
East Dallas Creek	2007	East Dallas_2007_Recurrence	East Dallas_2007_Survey	East Dallas_2007_Photo	Bunte and Swingle (2008)
East St. Louis Creek	2001	East St Louis_2001 & 2003_Recurrence	East St Louis_2001 & 2003_Survey	East St. Louis_2001_Photo	Bunte (2001, 2002)
East St. Louis Creek	2003			East St. Louis_2003_Photo	Bunte and Swingle (2003b, 2004)
Fool Creek	2009	Fool_2009 & 2010_Recurrence	Fool_2009 & 2010_Survey	Fool_2009_Photo	Bunte and Swingle (2009)
Fool Creek	2010			Fool_2010_Photo	No data
Halfmoon Creek, pool exit & bar	2004	Halfmoon_2004 & 2015_Recurrence	Halfmoon_2004_Survey	Halfmoon_2004_Photo	Bunte and Swingle (2005)
Halfmoon Creek, pool exit	2015		Halfmoon_2015_Survey	Halfmoon_2015_Photo	Bunte (2015)
Hayden Creek	2005	Hayden_2005_Recurrence	Hayden_2005_Survey	Hayden_2005_Photo	Bunte and Swingle (2018a)
Little Granite Creek, lower site	1999	Little Granite_1999_lower site_Recurrence	Little Granite_1999_lower site_Survey	Little Granite_1999_lower site_Photo	Bunte (1999a)
Little Granite Creek, upper site	2002	Little Granite_2002_upper site_Recurrence	Little Granite_2002_upper site_Survey	Little Granite_2002_upper site_Photo	Bunte and Swingle (2003a)
North Fork Swan Creek	2011	NF Swan_2011_Recurrence	NF Swan_2011_Survey	NF Swan_2011_Photo	Bunte and Swingle (2018b)
St. Louis Creek, lower site	1998	St Louis_1998_upper & lower site_Recurrence	St Louis_1998_lower site_Survey	St. Louis_1998_lower site_Photo	Bunte (1998)
St. Louis Creek, upper site	1998		St Louis_1998_upper site_Survey	St. Louis_1998_upper site_Photo	

[a] These reports are not listed in the reference section of this GTR. They are included with each study site in the online database.

2. General Worksheet Structure for Spreadsheets

Each database spreadsheet file (i.e., except photos and PDF documents) includes worksheets organized by at least the following four categories:

- [Navigation]

- [Methods]

- Details regarding data and computations: [-----], [-----], [-----], ...

- [Reports & Refs.]

The [Navigation] worksheet consists of a textbox that explains, in general terms, the contents of the various worksheets in the spreadsheet file as well as the overall organization and naming of those worksheets. The extensive [Methods] worksheet explains field data collection, data processing and reduction, and data analyses. The [Navigation] and [Methods] worksheets are included in each database spreadsheet topic and for all of the study sites.

Details regarding data and computations for a given database spreadsheet topic may be presented on one or on multiple worksheets. Their naming reflects the worksheet contents and hence differs depending on the topic and also somewhat between sites. A strict separation between raw field data, data reduction, and basic data analysis into three separate worksheets was considered to be neither the most feasible nor the most easy-to-understand approach. This is because field data (e.g., sampling duration, sampled width, sediment mass per sieve) are closely tied to data reduction (e.g., computation of one fractional transport rate for one bedload trap). The bedload worksheets are segregated into raw field data and data reduction on one worksheet, while basic data analyses in the form of transport and flow competence relations are computed on separate worksheets. In the discharge and bed-material sampling spreadsheets, field data presentation, data reduction, and basic data analyses all occur on the same worksheet. For other spreadsheets such as survey data, recurrence interval, and hydrographs, the number of worksheets varied depending on how data were collected and analyzed. More detail is provided in section C.

Graphs were developed from the data in most spreadsheets to accompany basic data analyses such as transport and flow competence relations for bedload data and cumulative frequency grain-size distributions for bed-material data.

All worksheets are thoroughly annotated with text boxes, starting with one or more text boxes offering site-specific information at the top of almost each worksheet. Explanatory text boxes are sometimes placed into the heading

sections over a group of columns, and any unexpected values in some cells are annotated using Excel's comment function.

The [Reports & Refs.] worksheet in each database spreadsheet file provides a text box listing the site-specific report(s) and other references that pertain specifically to a given field site.

C. OVERVIEW OF CONTENTS IN SPREADSHEETS AND OTHER FILES

Apart from the [Navigation], [Methods], and [Report] worksheets common to all spreadsheet files, each spreadsheet features one or multiple worksheets that present the data, data reduction, and basic data analyses. Overviews of the information contained in the worksheets and other files for each of the eight database topics are provided below.

1. Bedload Transport: Stream_Year_QB-Dmax

The bedload data spreadsheets form the centerpiece of the database, and its worksheets are the most extensive and elaborate ones. The [Data] worksheets combine both field data and data reduction, but with separate worksheets for data from bedload traps and the Helley-Smith sampler. The [QB] and [Dmax] worksheets provide transport and flow competence relations, respectively, again segregated by sampling device. Plotted results are compared between bedload traps and the Helley-Smith sampler on the [traps vs HS] worksheet and also between years or between sampling locations where applicable.

The format of the [Data] worksheets for bedload trap data deviates from that in other bedload databases such as those by the USGS or the Forest Service (e.g., Emmett et al. 1982; King et al. 2004; Ryan-Burkett n.d.; Williams and Rosgen 1989) that typically present information from a single cross-section-averaged sample in one row. A different format was needed for the bedload trap study sites because bedload was simultaneously sampled with two to six traps per cross-section. To reflect the lateral sampling arrangement, transport rates in the database are first computed for the channel width-section represented by each trap. The data from the individual traps are then combined and summarized below the individual trap data to produce a cross-sectionally averaged transport rate. Maintaining the information from each individual trap allows a user to evaluate patterns of lateral variability of bedload transport and how those patterns might change over a high-flow season.

2. Bed-Material Size Distributions for Surface and Subsurface Sediment: Stream_Year_BEDMAT

Data in this spreadsheet present all stages of bed-material sampling. Generally, bed material was collected using the techniques described in Bunte and Abt (2001). The size of each surface particle measured from the streambed along each sampling transect during a pebble count is listed on the [peb cnt] worksheet(s). The sieve results of subsurface sediment collected from various pits in the streambed are recorded on the [bed mat] worksheet. Both worksheets lead the user through the various steps of the bed-material size analyses taken to produce cumulative frequency distributions and percentile particle sizes. The particle-size distribution curves are graphically compared between sampled strata. Apart from the reach-spanning pebble count, some sites also include a

[grid cnt] worksheet with data from a grid count on a small sampling area a few square feet in size.

The database worksheets for pebble count and subsurface bed-material analyses are site-specific and not designed for a user to enter and process their own data. However, they can certainly serve as a template for a user's own spreadsheets. Automated worksheets to compute pebble count grain-size distributions are online available in the "Size-class pebble count analyzer (2007-9)" by Potyondy and Bunte (2002) as well as in Gary Parker's (2006) "Morphodynamics e-book."

3. Discharge: Stream_Year_Discharge

On the discharge database spreadsheets, the main [Discharge] worksheet displays all field data (width, depth, velocity) associated with each measured vertical. The actual discharges (m^3/s or ft^3/s) computed for each measurement, the cross-sectional flow area, as well as stage readings and their time stamps are then transferred into a summary table. From the summary table, stage-discharge relations are plotted and computed. Hydraulic information such as channel width, mean flow depth, and mean flow velocity are computed here as well and used to plot and compute hydraulic geometry relations.

What this database does not have are individual measurements of the flow depth and velocity at the location of each individual trap. For multiple reasons, those measurements were impractical in the field and potentially misleading if combined with the individual trap transport data. An averaged depth and velocity for any time interval can be computed from a hydraulics program such as WinXS PRO (Hardy et al. 2005) or HEC-RAS (Hydrologic Engineering Center 2016) using the measured discharge data and the channel geometry surveys of the bedload trap cross-section.

4. Hydrographs: Stream_Year_Hydrograph

The hydrograph database spreadsheet provides stage records from various locations per site. The information density varies between sites. The early sites typically have only discrete stage readings made several times throughout a field day. Later sites that deployed automated water-level recorders provide stage records in 10- or 15-minute intervals at one or more locations within the study reach. The records span the bedload sampling period during the high-flow season. For some sites, determining a time series for stage and discharge over the high-flow season was not a straightforward process because channel-bed aggradation, channel-bed scour, and water-surface waves and undulations caused the stage record to be scattered, jumpy, or discontinuous.

5. Peak-Flow Recurrence Interval Analyses: Stream_Year_ Recurrence

A peak-flow recurrence interval analysis is important for a study site because it provides a hydrological context for the sampled flood event: Was the flood small, moderate, or large and how did the flood magnitude relate to the $Q_{1.5}$ flood event? Ideally, peak-flow recurrence interval analysis is based on a site's long-term flow record. For ungauged study sites, peak-flow recurrence intervals were extrapolated and interpreted from flow records from nearby or at least hydrologically similar gauging stations.

6. Topographic Surveys: Stream_Year_Survey

Topographic surveys were conducted with varying intensity at the study sites. Survey data are presented as x, y, and z in tabular form and then plotted on a site map and/or sketch map. The survey data are further analyzed to develop longitudinal profile plots along banks of the channel, the channel thalweg, and the water-surface above the thalweg (at some sites). A channel cross-section is plotted for the bedload trap transect, and sometimes a sequence of cross-section transects was surveyed near the study site. Please note that additional cross-section information for a study site can be obtained from a site's discharge database spreadsheet based on the channel geometry data collected during discharge measurements.

7. Photo Compilations: Stream_Year_Photos

A collection of photos was compiled for each study site. Photo documentation is scarce for the early study sites, but quite extensive for the later sites. The arrangement of photos in various folders aims at "telling the story" of a site-specific field campaign.

8. Site Reports: (Report Reference)

The original, detailed report usually submitted to the USDA Forest Service after a field season is provided as a PDF for each site. Exceptions are Hayden Creek_2005 and NF Swan Creek_2011 for which shorter data reports only were prepared as part of the database preparation. At St. Louis Creek, one report encompasses the two sites, while no report was prepared for the 2010 field data collection at Fool Creek.

D. DATABASE ACCESS

The bedload trap database files referenced in this document can be found at the National Stream and Aquatic Ecology Center website, https://www.fs.fed.us/biology/nsaec/projects-bedloadtraps.html.

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