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A new series of sediment collectors for developing bed load sediment budgets and restoring streams

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Abstract Streamside Systems offers a variety of bed load monitoring collectors to sample targeted sizes of bed load sediment for developing watershed sediment budgets, and to remove sediment to restore streams. Prototypes of portable units have been tested for continuous operation (3- to 5-month periods) for sand to medium gravel moving as bed load. The Streamside collectors sample true bed load, and avoid the collection of suspended sediment and organic matter. In low-gradient streams, the Streamside collectors are pumped out and can easily be backflushed or "zeroed" with no safety hazard (i.e. no need to enter a flooded stream). In higher-gradient streams, a siphon removal system will work continuously with a localized drop adequate to flush the sediments (e.g. 1.5 l s^{-1} through a 600 mm wide collector, using a 50 mm hose). The outlet hose allows samples to be collected safely from the bank, even under high flow conditions and for any desired sample period (seconds to months). The collectors can continue to operate unattended and can stockpile bed load material for later sieve analyses. For medium and large gravel, cobble and even boulders, much larger Streamside Systems' bed load collectors utilize removable hopper assemblies downstream from the pumpout or siphon hopper for fines. This is a clear design advantage over pit traps for large material, in that fine sediments are removed on a continuous basis and will not fill the collector basin(s) intended for coarser material. In contrast to small (76 or 152 mm wide) bed load samplers used for short-duration samples, Streamside Systems' bed load samplers can virtually eliminate subsample variability by targeting total bed load over extended periods.

Key words acid mine drainage; bed load; fluvial sediment; habitat restoration; measuring equipment; monitoring; sediment budgets; sediment impacts; total maximum daily load (TMDL)

INTRODUCTION

Sedimentation is generally identified as one of the leading water quality and aquatic habitat problems in the United States of America. Streamside Systems LLC (Findlay, Ohio, USA) was formed to research, design and market equipment to aid in the prevention of sediment impacts to surface waters and to restore sediment-impacted aquatic habitats. One series of products was designed to remove targeted sizes of sediment (generally sand and finer) as they move downstream as bed load. These collectors are passive, non-invasive and scaleable to any size stream or river. As a new, best available technology (BAT) alternative to dredging, the collectors can avoid the common adverse impacts of dredging such as:

– habitat damage via unselective removal of gravel and cobble;
– biological damage via removal of fish eggs, invertebrates and organic matter;

- resuspension of sediment-associated contaminants;
- reduced water quality and increased turbidity due to substrate disruption; and
- morphological damage that can lead to headcutting.

A wide variety of applications exist for this new type of passive bed load sediment collector, including:

- habitat improvement for fish spawning or for endangered mussels, through selective removal of harmful fine sediments, an increase in the substrate median particle size (D_{50}) and reduced embeddedness;
- reduction in pond and reservoir sedimentation, by removal of bed load at the mouths of tributary streams;
- solution to "hungry waters" below dams, by collecting the bed load in tributary streams, bypassing the reservoir and re-introducing the sediment below the dam;
- selective removal of a clean-washed commercial product (sand), with no increase in turbidity over ambient, while improving habitat;
- reduction in water treatment costs for industrial, municipal and agricultural water users;
- prevention of downstream sediment impacts below dam-removal projects, below logging operations and at stream crossings for roads and utilities;
- maintenance of navigation channel depth in major rivers and sediment bypass systems for coastal inlets;
- supplying clean, sorted sand for beach nourishment programmes;
- restoration of aggrading channels or individual pools by installing collectors as grade control structures that remove excess sediments; and
- collecting bed load data to develop watershed sediment budgets; to develop a total maximum daily load (TMDL) for fine sediments; to measure nonpoint source (NPS) sediment impacts throughout a watershed; and to collect bed load data to document damages, identify sources and assess liability for sediment impacts.

INSTALLATION AND OPERATION

Bed load sampling is the specific application of Streamside collectors addressed here. The screened collectors are of pre-cast concrete or stainless steel construction and are dug into the streambed and anchored. They can be portable, semi-permanent, or permanent installations. As bed load moves downstream over the collector, it drops through the screen into a hopper and is continuously removed by siphon suction or by pumping. A computerized controller can be added to electric systems, to pump on a timed cycle or with respect to stream stage or discharge. Maximum particle sizes sampled depend on the width of screen slotting used, the size of the collector, the hopper capacity and the output hose diameter. Prototype collectors that have been used for three to five-month periods of continuous operation had screen slots of 5, 12.7, or 25.4 mm, with a 51-mm outlet hose. Another Streamside bed load sampler design uses three separate collection chambers, with screening slots of 2, 8 and 64 mm. The largest current bed load sampler design is 3.05 m wide by 5.8 m long by 1.2 m high, weighs 25 t and also uses three separate chambers to collect all bed load sediment up to 300+ mm.

The collectors are scaleable to any size stream and multiple units (e.g. 10-t pre-cast concrete collectors, with large capacity urethane hopper assemblies) can be linked together to completely cross major rivers. The collectors can be constructed with or without sidewalls. For small streams, a 0.6-m wide sidewall collector can use supplementary wing walls to channel and collect 100% of the bed load (of the screen-selected sizes) from a 1.2 to 1.8-m wide channel over the collector. Collectors without sidewalls can be emplaced adjacent to each other, or small units can be installed at various locations within a cross-section.

Streamside collectors measure the sediment that moves along the stream bottom and falls into the hopper. Leaf litter, invertebrates, eggs and other organic matter all pass over the collector unaffected. When a collector without sidewalls is dug into the streambed, it is virtually snag-free and passively removes the targeted sediments on a continuous basis. Sediment samples can be collected in a large bin or truck bed or sediment basin while the equipment is unattended; manual samples can be safely taken over any time interval (from seconds to months) or any hydrograph category (rising, falling, or flat). Small, portable collectors can be used as bed load subsampling devices, or collectors can be sized to target the entire stream width. Streamside Systems offers 10 and 20-t pre-cast concrete collectors to commercial sand mining operations, that can target 100% of bed load sand transport in large rivers. This sediment monitoring and removal method can provide invaluable data on continuous bed load transport rates that have never before been available for major rivers. The flexibility of collecting extremely long-term and large-volume samples, greatly reduces the variability and sub-sampling error inherent in bed load sampling with alternative methods.

DISCUSSION

Traditional bed load net samplers such as the Helley-Smith sampler obviously fail to collect any sediment particles smaller than their net mesh. This results in the lack of bed load transport data (for models, for TMDLs and for impact assessment) for the particle sizes of bed sediments that are generally most responsible for negatively impacting aquatic habitats and biological populations. The greatest biological and habitat impacts from sedimentation are related to the finest particle sizes (clay to medium sand). Clay usually travels in suspension and the flocs, silts and fine sands have the greatest negative impact as bed load. These fines fill the interstitial spaces of the substrate; reduce subsurface pore space and water flows; reduce or deplete dissolved oxygen levels; decimate hyporheic and benthic invertebrate fauna; and, negatively impact fish spawning success and native mussel survival. Traditional bed load net samplers use coarse meshes (0.25, 0.5, 1.0 mm, or even 3.6 mm or greater) in the interest of hydraulic efficiency and therefore may completely miss the bed load fines that are most responsible for habitat impacts. Alternatively, traditional net samplers that use fine mesh screens (0.06–0.25 mm) have extremely poor hydraulic efficiency; extremely high variability due to short sample periods before the net clogs; and high variability due to the small “sampler width to stream width” ratio. These traditional samplers also include a suspended sediment bias, by sampling a partial cross-section of the water column, at the bottom of the stream, where suspended

sediment concentrations are the highest. Any sediment transport models that have been developed using data from these traditional samplers, or "validated" by such data, will share their limitations. Improved bed load monitoring equipment from Streamside Systems, LLC, can selectively monitor the transport of fine bed load sediments for purposes of developing watershed sediment budgets, setting water quality and habitat standards, localizing NPS sediment source areas and developing TMDLs for fine bed load sediment.

As an example of the successful application of Streamside Systems sediment collectors for removing even the finest particles moving along the bed, Koski & Herricks (2004) found that "blanketing of the substrate by the iron floc impairs the exchange of surface water with intragravel water, thus keeping dissolved oxygen (DO) levels low." The iron floc is of concern because it reduces DO, increases turbidity, covers the substrate, is toxic to some invertebrates and degrades estuarine habitat downstream, "Water quality in most of the stream has been severely impacted by the iron floc and anadromous salmon and trout have been directly impacted by the low DO, the elimination of macroinvertebrates (i.e. food source) and the covering of available spawning and rearing habitat. The approach using the Streamside Systems Inc. collector worked well in collecting the iron floc and pumping it to the dewatering bags" (Koski & Herricks, 2004). We are unaware of any traditional bed load samplers ever having been used to collect and remove bed sediments as fine as iron floc, especially on a continuous (24-h) basis. This demonstrates widespread potential application for Streamside Systems sediment collectors for monitoring and removing many similar sediments (e.g. iron and other flocculants relating to acid mine drainage) as well as for the broad ecologically impacting fine and very fine sands. The Streamside collectors can capture the full range of total bed load particle sizes, or can target removal and quantification of selected ranges of particle sizes previously missed by traditional bed load monitoring methods.

Numerous potential applications for Streamside Systems collectors are mentioned in this paper because they highlight the wide range of interest groups that may fund and operate sediment removal installations to meet their own commercial or restoration objectives. As a side benefit and at no cost to the "bed load community" they provide, simultaneously, bed load data on a wide range of stream types and stream sizes. Adoption of Streamside Systems collectors as a Best Available Technology (BAT) alternative to dredging for instream sand mining operations, would give the aggregate industry a better product at a lower cost, while eliminating significant environmental impacts and positively improving instream habitat and also providing some of the best available bed load transport data for sand-bed streams. Many impacted sites also hold the potential to "turn the pollutant into a commercial product", while restoring sediment-impacted streams and providing a funding source for riparian restoration, for conservation easements and for monitoring programs. Clearly, cooperation and co-funding need to be encouraged among the broad community of "sediment stakeholders" in every watershed.

INDEPENDENT ASSESSMENTS

Accuracy is a major issue yet to be addressed in detail. We have conducted simple measurements upstream and downstream from Streamside collectors, with a Helley-Smith sampler. Representative results showed that Streamside collectors were 94% efficient.

However, Streamside Systems' collectors capture sediments that are moving along the stream bottom (i.e. bed load) and drop into the hopper, while the Helley-Smith uses a net that sieves a cross-section of the water column at the bottom of the stream (where suspended sediment concentrations are highest). It seems logical to consider that Streamside collectors capture 100% of the "true" bed load and that they should be used to estimate the degree of oversampling bias from water column nets that capture suspended sediment plus bed load and to correct and further refine bed load transport models. We find it difficult to consider a net clogged with loads of organic matter, invertebrate drift and suspended sediment to be a "bed load sample".

The paper by Koski & Herricks (2004) confirms the value of Streamside collectors in capturing even the finest bed load sediments. Streamside Systems collectors appear to hold great promise, particularly for measuring fines, sand and gravel transport. We have not yet built or tested the collectors for cobble or boulders; nevertheless, several custom designs are currently available and they are scaleable to any size stream and any desired range of particle sizes.

Additional independent field assessments are in their second year, on three streams in western North Carolina, by North Carolina State University, but final results are not yet available. Similarly, independent laboratory performance testing is currently under way in the Hydraulics Laboratory at the Engineering Research Centre of Colorado State University, using a variety of bed materials and velocities to assess the efficiency of Streamside Systems' sediment collectors for both selective removal of fine bed sediments, as well as for total bed load capture for monitoring bed load transport. Results of these independent studies and updates, as well as additional research results will be posted on the Streamside Systems web site http://www.streamsidesystems.com as they become available.

REFERENCES

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