Proposal Title: Development and Testing of a Pressure-Difference Bedload Sampler Attachment to Mitigate Scooping

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PI Location and Study Location (if different): Fort Collins, CO

Introduction: This proposal seeks FISP leadership and funding to develop and test an improvement to pressure-difference bedload samplers to prevent bias introduced by scooping. Specifically, the improvement is an attachment to the nozzle of bedload samplers (Figure 1). This attachment has an operable door that prevents sediment from entering the sampler except when the door is open (Figure 2). Development and testing of this improvement is expected to lead to a standardized, calibrated piece of FISP-maintained equipment that will facilitate more-consistent and more-accurate measurements of bedload transport.

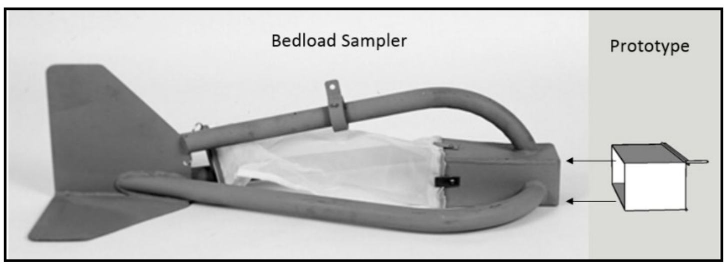

Figure 1. BL-84 pressure-difference bedload sampler and prototype of proposed attachment

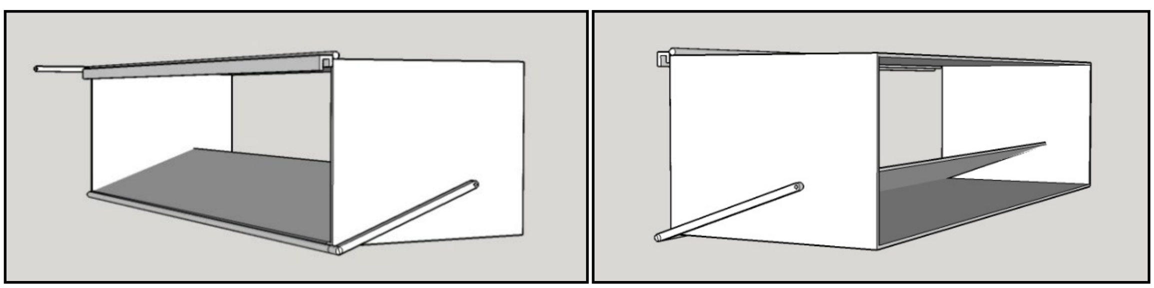

Figure 2. Schematics of proposed attachment – front (left) and back (right) views

Background: In FY 2016, the FISP funded testing of the influence of sampler bag mesh size and type on the hydraulic efficiency of pressure-difference bedload samplers (Bunte et al. 2017), results of which identified, in part, that scooping a few gravel particles into a sampler may well introduce more error than bag mesh size and type. Tetra Tech regularly encounters challenges in bedload sampling driven by uncertainty in knowing whether scooping of the bed surface has biased a bedload measurement collected using a pressure-difference sampler. This uncertainty has been compounded when working from raft-based platforms, and in flows too deep or too turbid to visually confirm (either directly or from underwater photos or videos) if the sampler scooped the bed.

In early 2017, Tetra Tech contacted the USGS's Hydrological Instrumentation Facility (HIF) to ask whether equipment was available to prevent scooped sediment from biasing a bedload measurement; HIF staff reported that no such equipment was available. By the end of 2017, Tetra Tech completed a patentability search for a bedload sampler attachment, which indicated that such an attachment may be novel and eligible for a patent. However, financial considerations prevented Tetra Tech from internally pursuing development and testing of such an attachment. Thus, there is no known solution, either available or in development, to mitigate the effects of scooping on measurements of bedload transport collected using pressure-difference samplers.

The lack of a solution is problematic because pressure-difference bedload samplers are so widely-used for measuring bedload transport in streams and rivers. Bedload measurements using pressure-difference samplers have historically been, and continue to be, collected as a component of operational monitoring programs. Consequently, eliminating bias introduced by scooping would provide near-universal benefit to these monitoring programs, as well as to any other bedload measurements collected using pressure-difference samplers. Recent informal conversations with engineers and hydrologists at Reclamation's Technical Service Center, the Corps of Engineers Hydrologic Engineering Center, and the U.S. Geological Survey's New Mexico Water Science Center confirm support for developing and testing an attachment that would improve the quality of bedload measurements collected with pressure-difference samplers.

Because of hydraulic forces exerted by flow on such samplers while lowered to, and raised from, the channel bed, the sampler is susceptible to scooping bed material (Figure 3). Scooping can introduce substantial error to the collected measurement, leading to inaccurate quantification of bedload transport and confounding interpretation of the largest-size sediment in transport. Current practice relies on the equipment operators to evaluate scooping-induced bias, which is challenging under ideal conditions with experienced operators, and nearly-hopeless otherwise. Measurements frequently define the prototype against which numerical models of bedload transport are compared, so substantial error in the prototype can (1) confound the calibration and application of a model, (2) compromise the reliability of interpretations of modeled results, and (3) prevent appropriate consideration of risk in decisions based on modeled results.

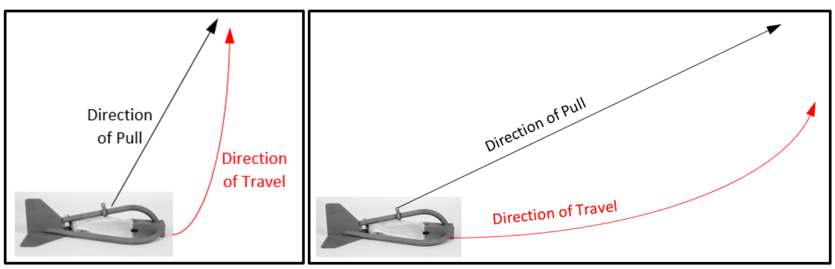

Figure 3. *Schematics of the effects of hydraulic drag on the bedload sampler as it traverses the water column (near water-surface, left; near bed, right), and the increased potential for scooping*

The proposed improvement precludes the need for operators to observe the sampler contacting or lifting from the bed. The attachment will allow the operator to open a door on the attachment such that water and bedload can enter the sampler nozzle only when the operator is ready; the operator then closes the door to exclude water and sediment from entering the sampler nozzle before raising it from the bed. The potential drawback to such an attachment is that it could induce differences in the hydraulic efficiency and sediment efficiency of the sampler, differences which could impair reliable comparisons to previous samples measured without the attachment. The ideal situation is to eliminate scooping-induced bias from future measurements while maintaining consistency in sampler performance to facilitate comparisons of future and historical measurements. This proposal focuses on the development and testing of an attachment to determine if this ideal situation can be achieved.

Purpose and Scope: The goal of this proposal is for Tetra Tech to work with Colorado State University (CSU) staff to develop and test an attachment to pressure-difference bedload samplers that will lead to a standardized, calibrated piece of equipment that will facilitate more-consistent and more-accurate measurements of bedload transport by preventing bias introduced by scooping. To achieve this goal, the purpose of the work presented in this proposal is two-fold: (1) to collaborate with the FISP to identify the approach for developing and testing the proposed attachment that best fits within the FISP funding and schedule, and (2) to carry out the initial development and testing of the proposed attachment. It is expected that future phases of work will expand the development and testing of attachments for different pressure-difference bedload sampler nozzle sizes, and lead to the manufacturing and distribution of these attachments through the FISP.

The proposed scope starts with consulting the FISP to identify how to best tailor the development and testing of the proposed attachment to FISP's available funding and timeline. For example, Tetra Tech previously envisioned developing and testing a few prototypes for the BL-84 and Toutle River samplers; a more manageable initial phase is likely to select a single sampler (Tetra Tech owns both samplers and can provide both without fee for testing) and pursue development and testing of a single prototype. Under Tetra Tech guidance, the staff at CSU's Engineering Research Center (ERC) will efficiently fabricate an attachment for testing, and the testing can be carried out in one of the flumes at the ERC, and budget and time permitting, in rivers near Fort Collins. The results of the development and testing will be documented in a technical note, a presentation, or a formal report, depending on the preference of the FISP.

Technical Requirements: The key technical requirement is the development (design and fabrication) of a prototype attachment for testing. With the prototype in hand, the hydraulic efficiency of the sampler with the attachment needs to be compared to the hydraulic efficiency of the sampler without the attachment (ideally, using data from the FISP's FY 2016 funding testing (Bunte et al. 2017)). Tetra Tech envisions the design and fabrication of the prototype as well as the testing will be funded by the FISP.

Deliverables: The prototype attachment, design plans for the attachment, and testing results

Timeline: The consultation with the FISP to refine the scope, fee, and schedule is expected to occur during Month 1 following receipt of funds. Pending refinement of the scope, fee, and schedule, what follows is a generalized projection of how the development and testing of the proposed attachment could be carried out. Design and fabrication of the prototype attachment(s) is targeted for Month 2. The testing of the prototype attachment(s) is targeted for Months 3 and 4, pending availability of the flumes at CSU's ERC. Data analysis and documentation of the results is targeted for Months 5 and 6, respectively. The targeted duration of the work is 6 months following receipt of funds.

Budget: Like the timeline, the budget presented herein (Table 1) is a generalized projection assuming a future, agreed-upon scope to develop and test a single prototype for a single pressure-difference bedload sampler. Tetra Tech will both offer discounted rates on labor and continue to provide supplemental in-kind labor (i.e. sweat equity) and will also provide free use of the bedload samplers. Final negotiations on the cost for CSU's support will be conducted pending refinement of the scope and fee, but in previous conversations, CSU expressed a willingness to help reduce cost by absorbing some management labor and fees, minimizing overhead markups, and using efficient labor rates for students. As projected in Table 1, the total fee is envisioned as being divided approximately equally between Tetra Tech and CSU, with Tetra Tech focusing on the analyses and documentation and CSU focusing on the fabrication and testing.

Table 1. Generalized Budget Projection (to be refined through coordination with the FISP)

Task	Labor ($)	Materials ($)	Equipment ($)	Subtotal ($)
Funding Coordination	500			500
Coordinate Design with FISP	1,500			1,500
Fabricate Prototype	5,000	1,000		6,000
Hydraulic Test Prototype	4,500		1,000	5,500
Scoop Test Prototype	4,500	1,000	1,000	6,500
Data Analyses	5,000			5,000
Documentation	4,500			4,500
Subtotals ($)	25,500	2,000	2,000	29,500

Unique Qualifications: Tetra Tech's experience with bedload measurements collected using pressure-difference samplers deployed from fixed and raft-based platforms in sand- and gravel-dominated channels at low- and flood-flows, and CSU's FY 2016 pressure-difference bedload sampler research carried out for the FISP (Bunte et al. 2017) ideally positions us to continue with the development and testing of the proposed attachment. Tetra Tech and CSU have a long history of successful partnerships, and both Dave and Mike earned graduate degrees through the civil engineering program at CSU. The experience of investigators at CSU, such as Drs. Chris Thornton and Kristen Bunte, especially with the recent testing of the influence of sampler bag mesh size and type on the hydraulic efficiency of pressure-difference bedload samplers (Bunte et al. 2017), will directly bring additional value to the FISP by providing input on the development and testing protocol and continuity with previous studies.

Tetra Tech staff have already invested about $5,000 in sweat-equity to advance this proposal from a napkin-sketch. Should FISP choose to award funds to this proposal, Tetra Tech staff will continue to contribute sweat-equity; while a solution will benefit the industry, we have a keen interest in leading a solution to an issue that has plagued our bedload measurements for years now.

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References:

Bunte, K., Klema, M., Hogan, T., and C. Thornton. 2017. *Testing the Hydraulic Efficiency of Pressure Difference Samplers While Varying Mesh Size and Type.* Submitted to the Technical Committee of the Federal Interagency Sedimentation Project. Colorado State University, Engineering Research Center, Fort Collins, CO. 75 p., plus appendix.