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StreamLab Collaboratory: Experiments, data sets, and research synthesis

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[1] A series of community-led, large-scale laboratory experiments, termed "StreamLab", were performed by the National Center for Earth-surface Dynamics (NCED) with the purpose of advancing multidisciplinary research, education, and knowledge transfer at the interface of physical/chemical/biological processes in streams, science-based stream restoration practice, and environmental sensing technologies. Two series of experiments, StreamLab06 and StreamLab08, were conducted in the Main Channel of the St. Anthony Falls Laboratory at the University of Minnesota, a flume 84 m long and 2.75 m wide with water fed by the Mississippi River at a rate of up to 8.5 m^3/s. The purpose of this paper is to share with the broader community the data collected with the hope of stimulating further analysis and future experimental campaigns toward advancing our predictive understanding of the physical, chemical, and biological processes in streams. Toward this end, a brief summary of the results to date is included and some ideas for further research are provided.

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1. Introduction

[2] Experimental studies are critical for advancing scientific understanding of river processes but essential features of river systems (e.g., bed composition, bed form morphodynamics, stream vegetation, bio-geochemical cycling, microorganism growth and transport, etc.) are difficult or impossible to simultaneously scale down to laboratory dimensions. Yet improving predictive ability in river science requires models that can reliably represent organism and grain-scale processes within the larger-scale river system dynamics, and requires consistent observations of local mechanisms and their broader interactions [*Wilcock et al.*, 2008]. To this end, the National Center for Earth-surface Dynamics (NCED), a National Science Foundation (NSF) Science and Technology Center, developed a new standard of performing experiments at field scale while maintaining experimental control and using instrumentation that can resolve both local and field-scale processes. These experiments, termed "StreamLab", were codesigned and coexecuted by an interdisciplinary group of multi-institutional academic and federal agency researchers, as well as practicing engineers. StreamLab provides a platform for new interdisciplinary research, student training, international exchange of ideas, and transfer of science into the practice of environmental monitoring and stream restoration. The StreamLab experiments capitalized on the unique experimental facilities and expertise of the St. Anthony Falls Laboratory (SAFL) at the University of Minnesota.

[3] The Main Channel facility of SAFL has been at the forefront of advancing sediment transport research and bed-load monitoring technologies since the early 1980s. The experiments performed in 1980, for example, as a joint venture between SAFL and the U.S. Geological Survey [see *Hubbell et al.*, 1987], resulted in unique findings and provided data sets that fed the research and practicing community for a few decades [e.g., see *Gomez et al.,* 1989, and references therein]. These data have limited accessibility by now as digital archives were not in place and paper copies are hard to maintain. In 2005, as part of NCED's investment in community-wide experimental earth-surface dynamics research, several improvements to the Main Channel facility were made, including upgrades to the flow controls and the sediment recirculation system, high-resolution topography scanners, and installation of a sediment flux monitoring system. The goal was to equip this facility with state-of-the-art technology and open it up to the broader community for advancing the science and practice of river eco-hydromorphodynamics. This upgraded facility formed the basis of

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the StreamLab06 and StreamLab08 experiments described herein.

[4] The scientific questions driving the StreamLab experiments included: How can we improve the reliability of bed-load monitoring technologies given the complexity and stochastic nature of sediment transport? What patterns (grain sorting and bed forms) are formed in a river bed as a function of bed material and flow conditions? How does the mutual interaction between the physical and biological state of a river system respond to variable discharge conditions and alternating hydrographs? How does it respond to a variable sediment supply, as for example, to excess sediment after a dam removal? What is the nature of turbulence above a migrating bed form and how can it be parameterized concisely for developing closure schemes in numerical models of sediment transport? How does bed morphology affect hyporheic exchange and nutrient uptake? How does light availability mediate periphyton growth and the biological control of phosphorous and nutrient removal? How does oxygen get transported at the sediment-water interface and how can it be parameterized in terms of the turbulence structure near the bed? Finally, how can science inform stream restoration practice regarding interventions that can be successful in driving a deteriorating stream to a desired stable state? Although considerable progress has been made over the past decade on these questions, many open problems still exist and further progress requires an integrated interdisciplinary approach which includes theoretical frameworks, field work, and controlled laboratory experiments.

[5] The purpose of this paper is to disseminate the StreamLab06 and StreamLab08 experimental data sets to the broader scientific and practice community in order to: (1) instigate further exploration of this data to advance basic understanding of river systems and its application in stream restoration practice, and (2) share experimental technology and expertise with those interested to perform similar experiments in the future. Given the space limitations of this data article, we present here only a brief overview of the experimental system and the data collected, referring the reader to the Supplementary material and permanent data archives for more details. Also, studies that have used these data to advance hypotheses and scientific questions are briefly reviewed with reference to the original articles for details.

2. Main Channel Facility

[6] The Main Channel facility of SAFL at the University of Minnesota is 84 m long with a 55 m test section and has a rectangular cross section 2.75 m wide and 1.8 m deep (see Figure S1, Supplementary material). Water for the channel is drawn at rates up to 8.5 m^3/s from the Mississippi River, which provides not only the benefits of ambient levels of nutrients and microorganisms in the water, but also the challenges of the seasonal variability of the river. Water discharge is controlled by a sluice gate at the upstream end of the facility and flow depth is controlled by a sharp crested weir at the downstream end of the channel.

[7] The sediment monitoring and recirculation system (SMRS) of the Main Channel is located at the downstream end of the test section. Sediment transported in the flume enters the SMRS through 7.6 cm slots in the flume floor and continuous monitoring of sediment flux is provided by five adjacent, identical, and independent aluminum weigh drums that are 0.55 m wide and together span the width of the flume. The weigh drums have three radial baffles welded at 120° to each other and the rotation axis of the drums is aligned parallel to the water surface and transverse to the flow. Each drum is attached to a load cell with a maximum load of 113 kg and an accuracy of 45 g force. To avoid exceeding the maximum load cell capacity, the weigh drums empty when the accumulated weight exceeds a user-specified value (20–40 kg). Sediment emptied out of the weigh drums collects in a hopper below the drums, where a horizontal auger, driven by a variable-speed motor, spans the full width of the channel and conveys sediment from the hopper into the recirculation-pump (dredging-pump) intake. Sediment is recirculated by a large three-phase recessed-impeller centrifugal pump to the upstream end of the flume. The sediment recirculation system is capable of recirculating sediment at 20 kg/s with particle sizes of up to 75 mm in diameter.

[8] The Main Channel facility features a central data-acquisition (CDAQ) system that serves as the master time clock, controls the data-acquisition (DAQ) carriage, and continuously records essential environmental conditions (referred to as the backbone data) in ASCII-formatted files. The DAQ carriage is used for high-accuracy positioning of a number of data-collection instruments including a digital camera, high-resolution topographic laser and bathymetric sonar scanners, and an acoustic Doppler velocimeter (ADV). The DAQ carriage is capable of traversing the entire 55 m × 2.75 m test section at travel speeds of up to 2 m/s and can position probes to within 1 mm in all three axes. The backbone data recorded by the CDAQ system include water temperature, tail-water and sharp crested weir elevation (water discharge), and the weight on each of the 5 load cells (sediment flux). These data, along with the date and time, are written to and stored in a single ASCII-formatted file at approximately 1 Hz. More details on the Main Channel facility are provided by *Marr et al.* [2010] and *Singh et al.* [2009b].

3. StreamLab Experiments

3.1. StreamLab06

[9] StreamLab06 was a collaboration among more than 40 members of a multidisciplinary team of engineers, geologists, hydrologists, geomorphologists, and ecologists. StreamLab06 experiments were divided into two categories that included seven phases (Table 1). The first category included testing of conventional and surrogate bed-load monitoring technologies (phases I–II) and the second category included a suite of experiments designed to examine the interactions between geomorphology, nutrient cycling, and biomass accumulation (phases III–VII).

[10] In phases I and II, collaborators from academia, federal agencies, and private practice [*Gray et al.*, 2010] performed colocated tests of a variety of bed-load samplers, including four conventional bed-load samplers (Helley-Smith, Elwha, BLH-84, and Toutle River II) [*Marr et al.*, 2010], two surrogate bed-load samplers (stationary-mounted down-looking 600 and 1200 kHz Rio Grande acoustic

Table 1. Experimental Conditions and Data Collected

	Phase	Bed Composition	Bed Morphology	Flow in m^3/s	Focus	Data Collected	Data Analyzed in:
StreamLab06	I	Sand		2.0, 2.5, 2.9, 3.2, 3.6	Bed-load monitoring technologies	Hydraulic conditions, temporal bed elevations, sediment flux	*Singh et al.* [2011]; *Ramooz and Rennie* [2010]; *Marr et al.* [2010]; *Gray et al.* [2010]
	II	Gravel		4.0, 4.3, 4.9, 5.5	Bed-load monitoring technologies	Hydraulic conditions, temporal bed elevations, sediment flux	*Bunte and Swingle* [2007]; *Singh et al.* [2009a, 2009b]; *Ganti et al.* [2009]; *Fienberg et al.* [2010]; *Ramooz and Rennie* [2010]; *Marr et al.* [2010]; *Gray et al.* [2010]
	IIIa	Gravel	Plane bed	2.1, 2.45	Baseline conditions	Hydraulic conditions, morphologic conditions, sediment flux, bed texture	*Orr et al.* [2009]; *Nelson et al.* [2010, 2012]; *Venditti et al.* [2012]
	IIIb	Gravel	Alternate bar	0.375, 0.4			
	IVa	Gravel	Alternate bar	0.4	Bed armoring	Hydraulic conditions, morphologic conditions, sediment flux	*Venditti et al.* [2012]
	IVb	Gravel	Alternate bar	0.4	Gravel augmentation		
	IVc	Gravel	Alternate bar	0.4	Sand infiltration		
	Va	Sandy gravel	Plane bed	1.9	Baseline conditions	Hydraulic conditions, morphologic conditions, sediment flux, bed texture	*Orr et al.* [2009]
	Vb	Sandy gravel	Alternate bar	0.32, 0.36			*O'Connor and Hondzo* [2008]
	VI	Sandy gravel	Alternate bar	Variable, up to 0.32	Eco-geomorphology response to high flow events (Periphyton growth)	Hydraulic conditions, morphologic conditions, sediment flux, water chemistry, biological conditions, bed texture	*Orr et al.* [2009]
	VIIa	Sandy gravel	Plane bed	2.4	Aggradational wedge	Hydraulic conditions, morphologic conditions, sediment flux	
	VIIb	Sandy gravel	Plane bed	0.78			
StreamLab08		Sandy gravel		1.5, 2.0, 2.6, 2.8	Response of migrating bed topography to flow turbulence and sediment transport	Hydraulic conditions, morphologic conditions, high res. turbulence fluctuations, sediment flux, GSD	*Singh et al.* [2010, 2011, 2012a, 2012b]; *Singh and Foufoula-Georgiou* [2013]

Doppler current profilers [ADCPs]) [*Ramooz and Rennie*, 2010], and stationary bed-load traps [*Bunte and Swingle*, 2007]. Phases III–VII focused on the effect of bed composition (gravel or sandy gravel), bed morphology (plane bed or alternate bars), and transport rate (moderate or high), on surface and subsurface grain sorting, surface and subsurface water storage and flow paths, autotrophic and heterotrophic biomass accumulation, metabolic rates, and the uptake and retention of ecologically important nutrients. Phase IV focused on bed armoring (IVa), gravel augmentation (IVb), and sand infiltration (IVc). Both the gravel augmentation and sand infiltration experiments were extensions of experiments at the Richmond Field Station at the University of California at Berkeley (an NCED partner institution) but at a larger scale and with variable bed topography [*Wooster et al.,* 2008; *Nelson et al*., 2009; *Sklar et al*., 2009; *Venditti et al*., 2010a, 2010b]. Phase IVa involved elimination of sediment recirculation used in Phase IIIb, resulting in bed armoring intended to replicate a sediment supply reduction as might occur downstream of a dam. Phase IVb supplied fine-grained gravel augmentation pulses, as opposed to commonly used coarse gravel, to the armored bed of phase IVa to test the hypothesis presented by *Venditti et al*. [2010b] that fine-grained gravel augmentation pulses are capable of mobilizing coarser gravel bed surfaces, coarsening bed load, fining the bed surface, and reestablishing a mobile bed regime. Phase IVc examined the infiltration of fine sand into a gravel bed to determine how bed topography affects the spatial patterns of depth, grain-size distribution, and quantity of infiltrated fine sediments. This phase also examined whether infiltration relationships determined in one-dimensional (1-D) (plane-bed) and 2-D (dune) flume experiments accurately predict the infiltration into a bed with 3-D topography.

[11] After exploring physical relations among flow, sediment supply, transport, and bed condition, Phase VI of StreamLab06 added a biological dimension by using grow lights for two 2 week periods to develop an abundant crop of periphyton on the sandy gravel alternate bar conditions remaining from phase Vb (Figure 1). Periods of growth were separated by a bed-scouring flood. The periphyton growth was used to investigate the interaction among bed configuration, sediment composition, heterotrophic biomass accumulation, hyporheic exchange, nutrient retention, and dissolved oxygen profiles near the sediment-water interface [*Orr et al*., 2009]. Phase VII of StreamLab06 focused on understanding bed adjustment under large-scale aggradation and degradation. Phase VIIa involved hydraulic degradation (erosion) of the upper half of the flume test section and deposition in the downstream half of the flume. Phase VIIb involved hydraulically eroding the downstream portion of the channel and, via the recirculation system, progradational deposition in the upstream half of the channel. These experiments were also used to evaluate the efficacy of RFID-tagged pebbles in tracking transport rates. It was found that signal interference among grains prevented reliable measurement of particle flux with the available technology, even though grain recovery and removal could be accomplished with existing antennas.

[12] Overall, the StreamLab06 experiments utilized an array of advanced technologies to monitor the physical, chemical, and biological conditions in the channel and included measurements of:

Figure 1. The St. Anthony Falls Laboratory Main Channel showing grow lights and periphyton growth during phase VI of StreamLab06. Inset is a close-up of a colony-forming river diatom (*Fragilaria* ssp.) that rapidly colonized the bed in response to light availability.

[13] 1. Hydraulic conditions (discharge, water slope, bed slope, depth-average velocity, and flow field mapping)

[14] 2. Morphologic conditions (bed topography, bar locations and shape, and bed imagery)

[15] 3. Bed texture (surface and subsurface grain size distribution (GSD), patch location and GSD, and surface patch topography and images)

[16] 4. Sediment flux (continuous sediment flux and recirculation GSD)

[17] 5. Water chemistry (temperature, dissolved oxygen, and pH)

[18] 6. Biological conditions (heterotrophic respiration, biomass accumulation, and nutrient processing rates).

[19] The data collected as part of the StreamLab06 experiments are available to the public through the NCED Data Repository (https://repository.nced.umn.edu/) under the heading "St. Anthony Falls Lab/ Streamlab 2006". In the "Streamlab 2006" directory within the "*Metadata/*" folder is a spreadsheet, "*StreamLab Metadata.xls*," that describes the detailed experimental conditions, the data collected, and file names for the data collected during each phase of the experiments. This folder also includes a

comprehensive report, "*StreamLab06_FinalReport.docx*," which is also archived at the University of Minnesota digital conservancy (http://purl.umn.edu/144023) that provides details on the experimental setting and the instrumentation used in these experiments.

3.2. StreamLab08

[20] The StreamLab08 experiments were designed to gain quantitative understanding of the interactions between migrating gravel-bed topography, flow velocity above the bed, and sediment transport. These experiments took full advantage of the Main Channel instrumentation in developing long duration records of turbulence, bed topography, and sediment transport in a field-scale flume. The StreamLab08 experiments included 4 flow conditions (1.5, 2.0, 2.6, and 2.8 m^3/s) over a bed composed of 85% gravel and 15% sand. The data collected as part of the StreamLab08 experiments are also available through the NCED Data Repository under the heading "St. Anthony Falls Lab/ Stream Lab 2008". All data associated with each of the four flow conditions are located within their respective folders "*1500lps/",* "*2000lps/*", "*2600lps/*", "*2800lps/*" within the "Stream Lab 2008" directory.

4. Synthesis of Research Findings

[21] Research from the StreamLab06 and StreamLab08 experiments focused on ecogeomorphology, bed morphodynamics, and the stochastic nature of bed-load transport. A brief summary of this research is provided below.

4.1. Ecogeomorphology

[22] A major focus of StreamLab06 was to examine the physical-biogeochemical interactions in streams. Measurements of fluctuations in dissolved oxygen concentration along with detailed fluid-flow measurements showed that large-scale, coherent turbulent flow structures (turbulent sweeps and ejections) were mostly responsible for transferring dissolved oxygen to the sediment-water interface [*O'Connor and Hondzo*, 2008]. The specific mechanism by which geomorphology could influence nutrient retention was examined by *Orr et al*. [2009]. The change from a sandy gravel bed to a gravel bed, which had a higher hydraulic conductivity, was found to have a greater influence on nutrient uptake than changing the bed morphology from plane bed to alternate bars, even though the transient storage area and the influence of transient storage on transport time were larger for the alternate-bar morphology. When algal biomass was sparse, physical conditions (such as bed morphology and texture) controlled hyporheic exchange and bed permeability, which limited nutrient uptake in the hyporheic zone. Periphyton growth, dominated by a colony-forming river diatom (*Fragilaria spp*.), rapidly colonized the bed in response to light availability (Figure 1) [*Orr et al*., 2009], which resulted in greater uptake of phosphorous than any experimental changes in bed morphology, bed composition, or flow. Periphyton growth clogged pores in the bed, reduced hyporheic exchange over time, shifted the location of nutrient uptake from the hyporheic zone to the benthic surface, and signaled a shift from physically controlled hyporheic nutrient uptake to biologically controlled benthic uptake. These results point to the fundamental importance of factors that control algal biomass (limiting nutrients, light, grazers) in regulating nutrient removal and hydrologic exchange in streams, two key parameters for the ecology of streams [*Orr et al*., 2009].

4.2. Bed Morphodynamics

[23] StreamLab06 introduced field-scale complexity under controlled laboratory conditions with detailed measurements of sediment transport, bed topography, and bed grain size, allowing for detailed investigation of bed morphodynamics. The influence of bed topography on sediment transport and bed-surface patches was examined by *Nelson et al*. [2010]. Interaction between the flow and alternate-bar topography led to decreased shear stress over the bars and increased shear stress in the pools, resulting in size-selective cross-stream sediment transport that created forced bed-surface patches that were coarse on the bars and fine in the pools [*Nelson et al.,* 2010]. Additionally, *Nelson et al*. [2012] investigated methods of bed-surface patch delineation by applying clustering techniques to the high-resolution spatial grain-size data from StreamLab06.

[24] The response of alternate bars and grain-size heterogeneity described by *Nelson et al*. [2010] to the elimination and reestablishment of sediment supply was described by *Venditti et al*. [2012]. Eliminating sediment supply led to the erosion of bed topography, loss of bars, coarsening of the bed surface, loss of bed-surface patches, and reduction of the slope. When sediment supply was reestablished, the original alternate-bar topography reemerged only after deposition sufficient to reconstruct the original channel slope. These results show that the loss of bars is reversible by reestablishing the previous flow and sediment supply conditions, which are critically important for bar formation [*Venditti et al*., 2012].

4.3. Stochastic Bed-Load Transport and Turbulence

[25] The high spatial and temporal resolution of the StreamLab06 and StreamLab08 sediment transport, flow turbulence, and bed topography observations allowed for an in-depth investigation of the coupling between the self-organized bed morphology, the turbulence above the bed, and the resulting sediment-transport rates, seeking statistical/physical descriptions and predictive scaling relationships.

[26] The temporal dynamics of bed morphology and the predictability of sediment transport rates can be described by either a linear or inherently nonlinear model (see Figure S2, Supplementary material, for temporal series of bed elevation and sediment transport rates). *Singh et al*. [2009a] observed a highly nonlinear underlying dynamical structure of bed morphology at higher discharges and highlighted the implications for estimating the upper limit to prediction by any model, deterministic or stochastic. Statistical renormalizations and scaling relationships, akin to those of turbulence but for sediment transport and bed elevation series, were studied by *Singh et al*. [2009b] who reported a complex multiscale structure requiring a series of scaling exponents (beyond the spectral slope) to be fully characterized. This multifractal characterization allowed the derivation of an expression for the dependence of the probability distribution of bed-load sediment transport rate on the sampling time interval and showed that the mean bed load transport

rate decreases with increasing sampling time at low-transport conditions while it increases at high-transport conditions [*Singh et al.*, 2009b; *Fienberg et al.*, 2010]. This finding was consistent with the field observations of *Bunte and Abt* [2005] and opened the door to interpreting extreme fluctuations and allowing extrapolation of sediment transport rates measured at one scale to those at another scale.

[27] The signature of migrating bed forms on near-bed turbulence was investigated in *Singh et al.* [2010] who reported an interesting spectral gap and a dynamic scaling range due to evolving multiscale bed topography with a spectral slope of -1.1 at lower frequencies, i.e., wavelengths corresponding to the bed form travel time. This finding contributes to our understanding of the coupling between bed form structure and near bed turbulence, but also has practical significance in the prediction of bed form scale and travel time from high-resolution velocity measurements collected above the bed [*Singh et al.,* 2010]. The dependence of the complex bed topography on the instantaneous Reynolds stress and the feedbacks between bed form dynamics and near-bed turbulence were further investigated in Singh and Foufoula-Georgiou (Effect of migrating bed topography on flow turbulence: implications for modeling sediment transport, submitted to *Coherent Flow Structures in Geophysical Flows at Earth's Surface*, edited by J. Venditti, J. Best, M. Church and R. Hardy, Book Chapter, 2013) and *Singh et al.* [2012a]. The latter study analyzed the joint distribution of longitudinal u' and vertical w' turbulence fluctuations above the moving bed forms and reported an asymmetric structure with excess fluctuations corresponding to "ejection" events ($u' < 0$, $w' > 0$) with important implications for sediment transport formulations. This asymmetry was found to increase with increasing discharge leading to grain sorting within the bed form as documented in Singh and Foufoula-Georgiou (Effect of migrating bed topography on flow turbulence: implications for modeling sediment transport, submitted to *Coherent Flow Structures in Geophysical Flows at Earth's Surface*, edited by J. Venditti, J. Best, M. Church and R. Hardy, Book Chapter, 2013) and further verified in *Singh et al.* [2012b] who used data on grain size distribution available from surface sampling of the bed.

[28] The question as to whether bed forms of different size propagate with different speeds was examined by *Singh et al.* [2011] who reported a scale-dependent celerity with smaller scales moving faster than the larger scales. Also, the spatial variability of bed form heights as a function of discharge and an unexpected shape invariance of the probability distribution of bed form heights with discharge was reported by *Singh et al.* [2011] allowing for generalization of statistical parameterizations under variable flow conditions. Given the stochastic nature of most sediment transport processes (turbulence, grain-to-grain interactions, local bed heterogeneities, etc.), there is a persistent interest in models that can capture the movement of tracers and bed sediment with only a few parameters. This work dates to the Brownian motion model of *Einstein* [1956], which was extended by *Ganti et al.* [2009], to accommodate occasional but very large waiting times of particles due to subsurface burial, using sediment transport data from StreamLab06.

5. Future Research

[29] The StreamLab06 experiments were the first of their kind in which a multidisciplinary team of engineers, geologists, hydrologist, geomorphologists, and ecologists worked together to test hypotheses in fully controlled, field-scale experiments with high-resolution measurements. These experiments provided a unique research platform to explore the physical, chemical, and biological processes in streams, such as turbulence-bed interactions, the effect of substrate composition and bed topography on hyporheic exchange, nutrient and phosphorous uptake, periphyton distribution and abundance and the interaction of these ecosystem properties with sediment-transport rates and patterns, and bed-surface sorting. The StreamLab06 and StreamLab08 data are available to the broader research community through the NCED Data Repository (https://repository.nced.umn.edu/). Although analysis of these data has resulted in considerable insight on many processes as discussed in the brief overview, further analysis is needed and many research questions still remain unanswered. For example, data from the gravel augmentation (StreamLab06 phase IVb), sand infiltration (StreamLab06 phase IVc), and aggradation and degradation (StreamLab06 phase VII) experiments should provide valuable insight regarding the controlling factors of large-scale bed morphodynamic changes. Also, much remains to be learned on stream ecogeomorphology from the analysis of the StreamLab06 phase III, V, and VI data, including comparison of bed morphodynamics and sediment transport rates under the presence or absence of algal growth.

[30] The use of river process observations not only for model calibration and verification but also in a data assimilation mode is an area of future research promising improved predictions and guidance for effective sampling in the field and the StreamLab data offer opportunities for thorough investigation of this area of research [see also, *Paola et al.,* 2006]. Emergent behavior, threshold regimes, and nonlinear amplifications of interacting processes in a river system are key to stream sustainability and much remains to be understood by analysis of StreamLab's simultaneous observations of flow, bio-geochemical cycling, and sediment transport. Finally, detailed analysis of the turbulence structure above the migrating bed forms offers promise to quantify sub bed form scale turbulence regimes opening the door to more accurate closure schemes in numerical river transport models.

[31] Following the success of the StreamLab experiments and acknowledging the need for a more realistic account for channel-floodplain interactions, time scales of nutrient cycling, and real-life food web structure and function as affecting stream processes, an even larger platform for collaborative interdisciplinary research and education on stream eco-hydro-geomorphology was established at SAFL/NCED. This experimental facility, developed in 2008 and termed "Outdoor StreamLab" (OSL), bridges the gap between indoor large-scale fully controlled laboratory experiments and field-scale natural stream setting (channel is approximately 50 m long, 3 m wide, and 0.3 m deep at bankfull conditions), while still allowing for laboratory-precision monitoring. The OSL facility, the data collected, and a research synthesis of major findings is expected to be presented in the near future.

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