PROJECT DESCRIPTION

1 Context and Objectives

This Accomplishment-Based Renewal (ABR) proposal is aimed at pursuing a clear understanding of the statistical physics of sediment transport, building on insights and lessons we have learned from our efforts most recently centered on an NSF project entitled, *Collaborative research: The statistical mechanics of bed load sediment transport: Meshing theory, experiments and advanced computations of coupled fluid-particle behavior* (EAR-1226076 to DJF, EAR-1226288 to MWS). To be clear, the results of our work on this project have fundamentally changed our own worldviews regarding the elements and workings of bed load sediment transport, and these results indicate a clear path forward for achieving further significant advances on this century-old problem. But let us also be clear that, as stated in our 2012 NSF proposal — and notwithstanding important advances in our thinking (Section 4) — the work proposed here is high risk. We nonetheless remain convinced that it has high payoff if we are successful.

Together with other research groups in the US and internationally, we are breaking through to a genuine statistical mechanics-based description and treatment of sediment particle motions and transport. This effort grows from a fundamental reconfiguring of our style of thinking — one that is centered on the formalism of classical statistical mechanics and kinetic theory, importantly folding in advanced numerics of coupled fluid-particle behavior — and which does not succumb at the outset to the lovely siren of continuum theory. Rather, from the start it grows a probabilistic formalism that is entirely honest to the hallmark qualities of sediment particle motions — their start-and-stop, patchy, intermittent and mostly rarefied behavior — conditions that are mostly at odds with conventional continuum-based treatments of transport. This work takes us to the particle scale, but with the understanding that the objective is in part to reemerge to larger scales of practical interest in studies of transport and morphodynamics — as reflected in the modified subtitle of this proposal, *Scaling particle motion to fluvial form*. Here is the key: Clarifying the physics of particle motions with the proper statistical averaging provides a foundation to do the reemerging to larger scales with fresh, physical insight.

Our interrelated objectives for this proposed four-year project are to elaborate the significance and consequences of rarefied transport conditions, and to examine applications of our formulations of transport to streambed dynamics. This includes further connecting our numerical work with theory and experiments. As with previous NSF projects, we plan to fully engage talented, young scientists during this proposed project (Section 3).

2 Publications from Recent Work

The guidelines for an ABR proposal request up to six reprints of publications resulting from research recently supported by NSF. As context for how these reprints fit into a broader effort, the papers, dissertations and manuscripts listed below represent recent publications most closely related to the research proposed here, and are based on work supported by NSF (EAR-0744934 and EAR-1226076 to DJF, EAR-1226288 to MWS). Those (six) marked with an asterisk are provided as supplementary documentation.

1) Furbish, D. J., P. K. Haff, J. C. Roseberry, and M. W. Schmeeckle (2012), A probabilistic description of the bed load sediment flux: 1. Theory, *Journal of Geophysical Research – Earth Surface*, 117, F03031, doi: 10.1029/2012JF002352.

2) Roseberry, J. C., M. W. Schmeeckle, and D. J. Furbish (2012), A probabilistic description

of the bed load sediment flux: 2. Particle activity and motions, *Journal of Geophysical Research – Earth Surface*, 117, F03032, doi: 10.1029/2012JF002353.

3) Furbish, D. J., J. C. Roseberry, and M. W. Schmeeckle (2012), A probabilistic description of the bed load sediment flux: 3. The particle velocity distribution and the diffusive flux, *Journal of Geophysical Research – Earth Surface*, 117, F03033, doi: 1029:/2012JF002355.

4) Furbish, D. J., A. E. Ball, and M. W. Schmeeckle (2012), A probabilistic description of the bed load sediment flux: 4. Fickian diffusion at low transport rates, *Journal of Geophysical Research – Earth Surface*, 117, F03034, doi: 10.1029/2012JF002356.

*5) Furbish, D. J., and M. W. Schmeeckle (2013), A probabilistic derivation of the exponential-like distribution of bed load particle velocities, *Water Resources Research*, 49, 1–15, doi: 10.1002/wrcr.20074.

*6) Schmeeckle, M. W. (2014), Numerical simulation of turbulence and sediment transport of medium sand, *Journal of Geophysical Research – Earth Surface*, doi: 10.1002/2013JF002911.

*7) Schmeeckle, M. W. (2014), The role of velocity, pressure, and bed stress fluctuations in bed load transport over bed forms: Numerical simulation downstream of a backward facing step, *Earth Surface Dynamics*, 2, 715–732, doi: 10.5194/esurfd-2-715-2014.

*8) Fathel, S. L., D. J. Furbish, and M. W. Schmeeckle (2015), Experimental evidence of statistical ensemble behavior in bed load sediment transport, *Journal of Geophysical Research – Earth Surface*, 120, doi: 10.1002/2015JF003552.

9) Furbish, D. J., S. L. Fathel, and M. W. Schmeeckle (2017), Particle motions and bed load theory: The entrainment forms of the flux and the Exner equation, in Tsutsumi, D. and Laronne, J. B. (eds.), *Gravel-bed Rivers: Processes and Disasters*, pp. 97–120, John Wiley and Sons. (*in press*)

*10) Fathel, S. L., D. J. Furbish, and M. W. Schmeeckle (2016), Parsing anomalous versus normal diffusive behavior of bed load sediment particles, *Earth Surface Processes and Landforms*, 41, 1797–1803, doi: 10.1002/esp.3994.

11) Furbish, D. J., S. L. Fathel, M. W. Schmeeckle, D. J. Jerolmack, and R. Schumer (2016), The elements and richness of particle diffusion during sediment transport at small timescales, *Earth Surface Processes and Landforms*, doi: 10.1002/esp.4084.

*12) Furbish, D. J., M. W. Schmeeckle, R. Schumer, and S. L. Fathel (2016), Probability distributions of bed-load particle velocities, accelerations, hop distances and travel times informed by Jaynes's principle of maximum entropy, *Journal of Geophysical Research – Earth Surface*, 121, doi: 10.1002/2016JF003833.

13) Fathel, S. F. (2016), Experimental analysis of bed load sediment motions using high-speed imagery in support of statistical mechanics theory, *Ph.D. thesis*, Vanderbilt University, Nashville, Tennessee.

14) Leary, K. C. P. (2017), Turbulence and grain-scale mechanics of bedload transport over bedforms, *Ph.D. thesis*, Arizona State University, Tempe, Arizona. (*in preparation*)

15) Ballio, F., A. Radice, S. L. Fathel, and D. J. Furbish (2016), Experimental censorship of bed load particle motions, and bias correction of the associated probability distributions. (*in preparation*)

16) Furbish, D. J., B. P. Kahn, D. M. Casler, and M. W. Schmeeckle (2017), Initial growth and wavelength selection of sand ripples based on probabilistic descriptions of particle motions. (*in preparation*)

17) Furbish, D. J. (2017), *The Probabilistic Analysis of Sediment Transport*, Cambridge University Press, Cambridge. (*in preparation*)

3 Human Resources Development

Our previous project partly supported the Ph.D. thesis work of two students, Siobhan Fathel (Vanderbilt) and Kate Potter Leary (Arizona State). Siobhan Fathel successfully defended her thesis last fall (2016) and currently is pursuing job opportunities in academics. Kate Leary is working on completing her Ph.D. this spring. In addition, four undergraduate students (Ashley Ball, Dylan Casler, Aaron Hurst and Timothy Watkins) pursued research projects in relation to our NSF-funded projects, closely interacting with us and with graduate students pursuing thesis research on Earth-surface processes related to this and other projects. These students currently are thriving in their varied paths, academic and otherwise. We are particularly proud of our record of helping and encouraging our women student scholars.

With respect to the work proposed here, we are aimed at supporting the work of two graduate students and one postdoctoral scholar, and we intend to engage several undergraduate students throughout the project period. The graduate students are to be centered at Vanderbilt and at Arizona State. The postdoctoral scholar is to be centered at Arizona State, with visits to Vanderbilt and the University of British Columbia. We plan to recruit an individual for this postdoctoral position who will focus on numerical aspects of the proposed work, but with engagement in other elements of the research. A postdoctoral mentoring plan is provided in the supplementary documentation. In addition, Shawn Chartrand, who is completing his Ph.D. at UBC under the supervision of Marwan Hassan, just received a Canadian NSERC postdoctoral fellowship and will be deeply involved in the project. Chartrand will be co-supervised by Furbish and Hassan.

As with our previous effort, we are aiming at a four-year project. Our experience suggests that this is the right time span to fully engage each student in the overall objectives of the project as well as the technical aspects of the work. We will again encourage all participants at both universities to interact with each other during the project. (For example, Kate Leary and Siobhan Fathel worked closely together during and after part of our experimental work in the previous project.) Moreover, this proposed project will provide the opportunity for the students and postdoctoral scholar to visit and interact with individuals — faculty, students, post-docs and technical staff — at the University of British Columbia (see below). In addition, we will as before encourage our students and the postdoctoral scholar to engage with the broader community through participation in professional meetings and workshops, as well as explore opportunities for collaboration and co-authorship with individuals nationally and internationally.

With respect to student education, elements of our previous project proposal merit restating here. We envision a collaborative structure of student education, capitalizing on strengths at Vanderbilt and Arizona State, now folding in the University of British Columbia, that will greatly enrich the intellectual experiences of all participating students. Specifically, as part of our effort to fully engage all participating students in the project, students from VU will travel to ASU or UBC during the summer (or academic-year breaks) to fully participate in the experimental work (Furbish will accompany them). In addition, we will periodically conduct Skype sessions between the groups to discuss aspects of the project, including progress updates and student projects. At the graduate level, participating students will gain through their course work and research a solid foundation in fluid mechanics and transport processes relevant to Earth-surface systems as well as other geoscience and engineering fields. Undergraduate students will work closely with the PIs and regularly interact with the graduate students. These undergraduates will pursue well defined pieces of the project that they can individually take intellectual ownership of while developing a clear understanding of how the pieces fit into the larger objectives. As alluded to above, we are particularly committed to helping our women student colleagues excel in aiming at their aspirations as young scientists.

4 Proposed Work

With this proposal format, starting here we have limited space to describe our proposed work with appropriate context. We trust that reviewers will understand that the limited number of citations below is about conserving space rather than omission of work that has influenced our thinking.

Rarefied transport conditions: One of the most significant accomplishments of our work has been to clarify the meaning and implications of rarefied versus continuum conditions of bed load transport — a disconnect that has been described by those measuring rarefied transport in experiments and in the field, and largely ignored by theoreticians focused on continuum descriptions of transport (but see, e.g., *Coleman and Nikora* [2009]). Our work includes describing the challenges involved in conceptualizing and quantifying rarefied conditions [*Furbish et al.*, 2016b, 2017a], and providing a probabilistic framework for explicitly treating these conditions. Indeed, transport in experiments and in natural rivers, notably gravel bed rivers, often is not far above a threshold state [*Pitlick and Cross*, 2002; *Mueller et al.*, 2005; *Fathel et al.*, 2015; *Phillips and Jerolmack*, 2016; *Papangelakis and Hassan*, 2016; *Masteller and Finnegan*, 2017], where particle motions are intermittent, patchy and rarefied — conditions that are entirely at odds with conventional continuum-based formulations of transport. We need to fully examine the consequences of rarefied transport conditions for which the effective Knudsen number is too large to justify a continuum description [*Furbish et al.*, 2016a; 2017a], and where collective entrainment involving, for example, particle-bed collisions [e.g., *Ancey et al.*, 2008; *Heyman et al.*, 2014, 2016; *Bohorquez and Ancey*, 2016] and micro-topographic rearrangements [e.g., *Masteller and Finnigan*, 2017], in addition to entrainment associated with fluid forces, may be an important ingredient of transport. From a theoretical point of view, this starts with elaborating the idea that formulations of the flux and its divergence using continuously differentiable equations are abstractions that represent the statistically expected behavior of ensemble-value fields (see below) — or that we are envisioning, for any particular realization, spatial or temporal averaging at scales that may be larger than important scales of interest [*Furbish et al.*, 2017a]. A key challenge consists of clarifying how uncertainties due to rarefied conditions translate to predictions of the flux and bed-surface evolution in any individual realization, the conditions and scales for which continuum averaging might be appropriate, and, more basically, what to expect of fluxes and streambed configurations in an average sense.

A theoretical component of our work will be centered on elaborating consequences of the formulation presented in *Furbish et al.* [2017a], which appeals to a straightforward idea. Namely the entrainment form of the Exner equation (and also its divergence form) can be written in terms of an ensemble-average behavior and an unstructured ("noise") part that is scale dependent. The beauty of the idea of a Gibbs-like ensemble (or "statistical ensemble") [*Furbish et al.*, 2012a, 2016b; 2017a; *Furbish and Schmeeckle*, 2013; *Fathel et al.*, 2015; *Fathel*, 2016] is that we can define the statistical equilibrium ensemble distributions of particle motions (e.g., particle velocities, hop distances, etc.) without reference to rarefied or, less likely, continuum conditions. These distributions are characteristic of the macroscopic flow conditions [*Fathel et al.*, 2015; *Furbish et al.*, 2016a]. Then, with reference to a particular realization involving rarefied conditions, the extant transport conditions associated with a specified bed area involve "samples" drawn from the ensemble probability distributions. These samples, depending on the size of the bed area, may not look like the smooth ensemble distributions (and more likely resemble irregular histograms). But we nonetheless know how to properly describe (real) variations about expected (ensemble) conditions, by knowing what the ensemble conditions are. This is analogous to recent efforts [e.g., *Heyman*, 2014; *Ancey and Heyman*, 2014, 2016; *Ma et al.*, 2014] to illustrate expected scale-dependent variability in the particle activity and flux. In this part of our effort we can initially lean on current, experimental information on particle entrainment and motions (distributions of particle velocities, accelerations, hop distances and travel times) in order to ground our theoretical descriptions of variability in particle fluxes and bed-surface responses to varying entrainment rates.

We propose to conduct experiments to examine patterns, rates and variability of entrainment and motion of gravel sediment under rarefied transport conditions using laboratory facilities at the University of British Columbia (see supporting letter from Marwan Hassan). The experimental conditions are not at the natural channel scale, but they are close to it, and will represent a significant increase in scale from our previous experimental work. The experiments will involve long-duration runs using both lapse-rate and high-speed imaging of particle motions. We note that in our previous experiments involving transport of coarse sand within a small imaging window, we aimed at extracting ensemble distributions of particle motions and therefore measured the motions of virtually all moving particles at high resolution, notably because these distributions are dominated by small motions [*Roseberry et al.*, 2012; *Furbish and Schmeeckle*, 2013; *Fathel et al.*, 2015]. We cannot pursue this level of detail in the next set of experiments, so these likely will involve a significant spin-up period needed to determine and refine our measurement and sampling strategy in terms of image resolution (space and time), duration, lighting requirements, etc., depending on the transport intensity. The flume has a particle silhouette imaging setup at its outlet, so we can with high precision determine the particle throughput and its variability.

Our aim is to demonstrate the ideas outlined above, focusing on the entrainment formulation of the flux and the Exner equation: that particle motions (entrainment, hop distances) represent samples drawn from ensemble distributions; that the timescales of convergence of sample statistics to the underlying ensemble parametric values depend on the sampling area and the transport intensity; that during convergence there is an expected variability in these quantities (and in the flux and its divergence) about the ensemble conditions that can be described by the entrainment formulation; and that with convergence the averaged conditions match the ensemble behavior (e.g., the ensemble-averaged part of the Exner equation). In addition, we note that the current Ph.D. work of Shawn Chartrand (using this flume) — which is focused in part on adjustment timescales of the gravel bed topography in response to variations in flow and sediment feed rates in the presence of variations in channel width — indicates that there is not a single "equilibrium" bed configuration. Rather, there is expected variability in this configuration, each configuration being mechanically compatible with the flow and feed rate. This suggests that, whereas particle motions represent an underlying statistically invariant behavior, *the cumulative effect of stochastic variability in transport during bed adjustment is to give different final (steady-state) outcomes* — or configurations that adjust too slowly with subsequent nominally steady-state transport to be recognized as transient. Clarifying this behavior is paramount in understanding natural variability in streambed adjustments to changing, and even steady, flow and sediment feed conditions.

Bedform dynamics: Toward the end of our previous project, we brought our work to the point of examining from a fresh perspective a longstanding problem: the initial growth and wavelength selection of sand ripples [*Furbish et al.*, 2017b]. Although centered topically on ripple growth, this work actually represents something much larger: a demonstration of the application of a probabilistic formalism to a classic well-defined problem — leading to new insights on bedform dynamics in a manner not previously apparent, and demonstrating that the formalism opens possibilities for examining bedform dynamics (not just ripples) from a new perspective on larger scales. For example, virtually all previous treatments of the bedform stability problem have been based on the divergence form of the Exner equation [*Colombini*, 2014], appealing to the idea of a saturation length (a measure of the lag between the bed stress and the sediment flux) in order to provide a stabilizing effect over small wavelengths (see reviews by *Kennedy* [1969], *Engelund and Fredsøe* [1982] and *Charru et al.* [2013], and the introductory material provided by *Fourrière et al.* [2010]). In effect this type of analysis is restricted to bedload transport, and neglects the fundamental length scales determined by particle hop distances. In our work to date, we have reexamined the initial growth and wavelength selection of sand ripples — the bedform stability problem — based on probabilistic formulations of the flux and the Exner equation. We have demonstrated how particle diffusion [*Furbish et al.*, 2012c; 2016a; 2017; *Ancey et al.*, 2015; *Bohorquez and Ancey*, 2016; *Fathel et al.*, 2016] influences initial wavelength selection, and to some extent represents the stabilizing effects embodied in the idea of a saturation length. This analysis is based on the Fokker-Planck version of the Exner equation [*Furbish et al.*, 2012a; *Ancey et al.*, 2015], but otherwise is similar to previous stability analyses. But we have gone far beyond this. Namely, we also have reformulated the stability problem in a novel manner using the entrainment form of the Exner equation [*Parker et al.*, 2000; *Furbish et al.*, 2012a, 2017]. As a precise, probabilistic formulation of conservation, this form of the Exner equation does not distinguish between advection and diffusion, and, because it directly accounts for all particle motions via a convolution of the distribution of particle hop distances, it pays no attention to the idea of a saturation length. The formulation of initial ripple growth and wavelength selection therefore inherently subsumes the effects embodied in the ideas of advection, diffusion and a saturation length as used in other formulations. Our analysis clarifies how deterministic and probabilistic formulations of the stability problem converge; and it demonstrates how, as *Nakagawa and Tsujimoto* [1980, 1984] pointed out, the length scales defined by the distribution of hop distances are more fundamental than the saturation length in determining the initial growth or decay of bedforms. Equally important, the formulation represents a strategy for connecting probabilistic ideas of transport with descriptions of bedform dynamics (beyond their initial instability) that are not limited to bed load transport, nor to the scale of ripples.

We have developed and tested a numerical model of sediment transport in which the 3D, spatially-filtered Navier-Stokes equations are coupled to Newton's second law of motion for every sediment grain. As well, the distinct element model (DEM) of grain motion resolves the interactions between grains via a force model. The large eddy simulation (LES) fluid model resolves turbulent motions larger than the grid scale and relies on a sub-grid parameterization for smaller turbulent eddies. The parallelized LES and DEM models are coupled in momentum. This sediment transport modeling system has been shown to recover experimentally-determined bed load and suspended load sediment fluxes and the full distribution of particle velocities of flat beds [*Furbish and Schmeeckle*, 2013; *Schmeeckle*, 2014]. Downstream of separated flow, sediment flux equations based on time-averaged bed stress do not work [*Nelson et al.*, 2005]; examples include sediment transport in the presence of vegetation [*Yager and Schmeeckle*, 2013] and ripples [*Leary and Schmeeckle*, 2016a]. Importantly, the LES-DEM sediment modeling system is able to predict the magnitude and spatiotemporal pattern of transport in these important instances where bed stress fails [*Schmeeckle*, 2015; *Leary and Schmeeckle*, 2016a, 2016b; *Leary*, in prep.).

Significant progress has been made using turbulence-resolving and particle-resolving modeling in the formation of bedforms. *Finn et al.* [2016] used an LES-DEM model to generate ripples under oscillatory wavers. *Kidanemariam and Uhlmann* [2014a, 2014b] used a fully resolved turbulence and and DEM model to generate small ripples. *Rui and Sun* [2016] used an LES-DEM model nearly identical to the model described above to generate bedforms in a unidirectional current. These important advances demonstrate that bedform generation, directly from numerical simulation of turbulence and particle motion is now possible and practical. What remains is the need to extract physical and kinematic details from these models to inform probabilistic models of sediment transport that can then be used to build a more complete theoretical basis for fluvial bedform morphodynamics. We propose to similarly generate bedforms numerically and compare them to experimental results. Our goal for the numerical experiments is to start with a flat bed of particles (a 0.5 m long bed of 1 mm grains to produce dunes and a 0.15 m bed of 0.35 mm grains to produce ripples) with long enough runs to produces fully developed bedforms. The experiments will mimic the conditions of flume experiments wherein particle motion of emerging bedforms will be tracked by high-speed video. These experiments will essentially be equivalent to those we have completed in the past [*Roseberry et al.*, 2012; *Leary and Schmeeckle*, in revision; *Leary and Schmeeckle*, 2016a, 2016b). In both numerics and experiments we will track the spatial pattern of particle activity, velocity distribution, and hop length from flat bed conditions. Our current work over fully-developed bedforms [*Leary and Schmeeckle*, 2016a, 2016b] shows that event-like, rarefied transport exists over much of the bedform stoss, even at high spatially-averaged transport rates. The occurrence and magnitude of transport events are positively correlated with the width of the distribution of near-bed vertical fluid velocity [*Schmeeckle*, 2014, 2015; *Leary and Schmeeckle*, 2016a, 2016b]. Our experimental and numerical results further suggest that relative spatial decorrelation between mean bed stress and transport rates is unlikely to be the result of saltation dynamics because the mean distance between particle-bed collisions is far too short. The data, thus obtained, will allow us to fully specify the probability distributions in the entrainment form of the Exner equation. *If successful, both the kinematic and dynamic theoretical basis for the generation of bedforms will be unambiguous* (at least for the flow and grain-size conditions we choose).

Gravel-bedded rivers are complex. At bankfull discharge only a portion of the channel may be in transport, giving rise to corridors of transport, and complex grain sorting patterns can lead to a decorrelation of bed stress and grain size [*Lisle et al.*, 2000]. In these patchy, rarefied conditions cross channel advection and diffusion are likely to play key roles in development of topography and texture [*Seizilles et al.*, 2014]. We cannot preclude the possibility that exhaustive and clever field experiments will be able to explain these complex patterns. However, such explanations are more likely if we have a theoretical basis to understand details of the lateral transport of sediment in rarefied conditions. We will start our quest to use probabilistic sediment models to build fluvial morphology by working on a problem for which much is known: alternate bars. Linear stability theory and numerical simulations using depth-averaged, quasi three-dimensional flow have provided explanation and reproduction of alternate bars. Despite this success, key questions remain. The modification of sediment flux on a sloping bed relative to a flat bed can be substantial, and changes to the parameterization of this effect is known to have large effects on simulated channel bedforms [*Nelson et al.*, 2015]. It is not clear that the path of sediment forming bars are well reproduced by 2D and quasi-3D models coupled to simple stress-based transport equations. We propose to conduct experiments in a laboratory channel producing alternate bars. We will track grains during bar formation and feed the information on motion statistics into our probabilistic flux and Exner equations. The results will be compared to the quasi-3D model to described in *Nelson et al.* [2015]. We will also conduct LES-DEM experiments of bar formation of an initially flat channel (This part of the project has already begun: https://www.youtube.com/watch?v=ZvVrzCgLloM). We will also compare near-bed flow velocity structure in the laboratory channel using both the quasi-3D model [*Nelson et al.*,2015] to the fully 3D, turbulence-resolving model of *Alvarez et al.* [2016]. The LES-DEM model will be used to perform numerous simulations on sloping beds with differing flow directions relative to the slope. We hope to improve upon the simple modification of transport equations for sloping beds. If our statistical mechanical theory is parameterized and shown to apply in the case of alternate bar formation, it should provide a basis for further channel-scale morphodynamics problems in which patchy, rarefied transport conditions exist.

Moreover, it is quite clear that the probabilistic basis of the entrainment formulation of transport (versus the divergence formulation) is ideal for treating the spreading behavior of tracer particles [*Ganti et al.*, 2010; *Furbish et al.*, 2012a], notably including the effects if rest times associated with burial and exhumation in the presence of dynamic bed topography, both structured [*Iwasaki et al.*, 2017] and unstructured [*Voepel et al.*, 2013]. Our proposed work on streambed morphodynamics therefore will naturally mesh with this approach to treating tracer particle behavior.

5 A Note on Broader Intellectual Impacts

We close by highlighting an important point about our proposed work in relation to broader impacts. Namely, we emphasize that much of the probabilistic framework we are pursuing in relation to sediment transport in rivers — both its conceptual and technical elements — is identical to the framework that we are using to clarify ingredients and implications of nonlocal versus local transport on hillslopes [*Furbish et al.*, 2009b, 2016a; *Furbish and Haff*, 2010; *Furbish and Roering*, 2013; *Doane*, 2014]. This is not unexpected, as the probabilistic framework, in its barest (kinematic) essence, is scale independent [*Riskin*, 1984; *Furbish et al.*, 2012a, 2017a] and relevant to stochastic sediment particle motions in virtually any setting [*Furbish et al.*, 2016a; *Furbish*, 2017a]. We therefore suggest that this commonality in conceptual and technical elements represents an important opportunity to explore connections in our descriptions of transport in these different settings — one involving relatively slow dynamics (hillslopes) and the other involving relatively fast dynamics (rivers) — with an eye toward generalizing our descriptions of sediment particle transport across scales, including the behavior of tracer particles and particle-borne substances on hillslopes [*Dreicer et al.*, 1984; *Bock et al.*, 2005; *Small et al.*, 1999; *McGonigle et al.*, 2005; *Furbish et al.*, 2009a, 2017c, d; *Johnson et al.*, 2014; *Anderson*, 2015] as well as in rivers.