A Novel Framework for Simulating Particle Deposition with Moving Bedforms

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Key Points:

- A moving-interface model for particle deposition in streambeds under moving bedform conditions is introduced.
- Model reproduces experimental observations of the formation of a clay layer below the bedform scour zone.
- Bedform celerity and particle filtration have interacting effects on the rate and location of particle deposition.

Abstract

Previous modeling studies of hyporheic exchange induced by moving bedforms have used a moving reference frame, typically corresponding to an individual moving bedform. However, this approach is not suitable for simulating the exchange and accumulation of immobile fine particles beneath moving bedforms, which commonly occurs in sand-bed streams, as both moving and stationary features must be considered. Here we present a novel simulation framework that may represent arbitrarily-shaped, generally aperiodic mobile bedforms within a stationary reference frame. We combine this approach with particle tracking to successfully reproduce observations of clay deposition in sand beds, and the resulting development of a low-conductivity layer near the scour zone. We find that increased bedform celerity and filtration both lead to shallower depth of clay deposition, and a more compact deposition layer. While increased filtration causes more clay to deposit, increased celerity reduces deposition by flattening hyporheic exchange flowpaths.

Plain Language Summary

Stream water flows into and out of sand ripples along the stream bed. It is also common for streambed sand ripples to migrate downstream due to erosion and deposition of sediment. Mathematical models that simulate flow of stream water into and out of streambed ripples have typically done so from the perspective of a viewer who moves downstream with the ripple. This approach can be useful, but is less suitable for representing accumulation of material deposited by the water flowing through the ripple. We present a novel mathematical model that represents moving sand ripples from the perspective of a viewer who is standing still and watching the ripples go by. Simulation results successfully reproduce experimental observations of accumulation of material deposited by water flowing through the ripple. Ripples that move faster deposit material at shallower depths and deposit less of the material that flows through the ripple. Deposited particles with a higher tendency to become trapped between streambed sand grains will also deposit at shallower depths. This model will provide new insights about transport and deposition of contaminants that enter streams and rivers.

1 Introduction

Fine suspended particles are ubiquitous in streams and rivers. Suspended material typically includes sedimentary particles (Wharton et al., 2017), particulate organic matter (Johnson et al., 2018), microplastics (Li et al., 2020), and microbiota such as bacteria, algae and viruses (Lenaker et al., 2018). Transport and deposition of fine suspended particles plays a key role in regulating river-groundwater interactions, river morphodynamics, and hyporheic biogeochemistry (Boano et al., 2014). Clay particle deposition decreases streambed hydraulic conductivity by filling porespace, ultimately clogging the bed, altering patterns of porewater flow, and degrading the benthic and hyporheic ecosystem (Brunke, 1999; Brunke & Gonser, 1997; Fox et al., 2018). Clay in the streambed can also reduce bed sediment motion (Dallmann et al., 2020). The deposition of fine particulate organic matter drives hyporheic metabolism (Newbold et al., 2005) and plays an important role in fluvial carbon cycling (Brunke & Gonser, 1997; Hope et al., 1994). Additionally, fine sediment particles play an important role in the colloid-facilitated transport of sorbed metals (Droppo et al., 2014; Foster & Charlesworth, 1996), as well as accumulation of contaminants in bed sediment (Arce et al., 2017; Stone & Droppo, 1994). Despite the importance of spatial patterns of particle deposition for hyporheic ecosystems, fluvial biogeochemical processes, and river contamination most studies of riverine fine particles focus on the water column (Drummond et al., 2019; Park & Hunt, 2018; Wolke et al., 2020). Considerably less effort has been put into understanding the dynamics of fine particle transport within the bed and the resulting spatial patterns of particle accumulation (e.g., Drummond et al., 2017; Harvey et al., 2012; Phillips et al., 2019).

A principal mechanism of fine suspended particle delivery into streambeds is hyporheic exchange flux (HEF), particularly advective HEF induced by stream bedforms (Packman & Mackay, 2003; Partington et al., 2017). Particle deposition in streambeds due to HEF induced by stationary bedforms has been observed in both flume experiments (Fox et al., 2018; Jin et al., 2019; Packman et al., 2000b; Rehg et al., 2005) and simulated using numerical models (Packman et al., 2000a; Preziosi-Ribero et al., 2020). However, many natural sand-bed streams have continuous bed sediment transport (Einstein, 1950; Engelund & Hansen, 1967). Bed sediment is eroded from the upstream (stoss) side of the bedform and redeposited on the downstream (lee) side, causing the bedforms to migrate downstream. During bedform movement fine particles and pore water are released from the stoss side of the bedform by erosion, while surface water and suspended fine particles become trapped by lee-side re-deposition of bed sediment (Packman & Brooks, 2001). Hyporheic exchange due to the aforementioned mechanism is referred to as "turnover" (Elliott & Brooks, 1997).

Previous analyses of HEF under moving bedforms have employed a Lagrangian frame of reference that travels downstream with the bedform, starting with Elliott and Brooks (1997) for solutes. In recent work, the Lagrangian reference frame has been adopted by several researchers to study oxygen consumption and nutrient transformation in the hyporheic zone (Kessler et al., 2015; Zheng et al., 2019) and marine sediments (Ahmerkamp et al., 2015). This approach is adequate for analyses of the fate of mobile species, but is less suitable for tracking the accumulation of immobilized particles at a given location over arbitrary lengths of time.

Here we present a model that combines four key features needed to capture the spatiotemporal dynamics of fine particle deposition under moving bedforms: realistic bedform shape, passage of a series of bedforms through a fixed frame of reference, hyporheic particle transport and deposition, and long-term particle accumulation that produces spatial patterns in the bed. We then use this model to explain coupled clay-sand dynamics that control short-term particle transport and, over longer timescales, yield depositional patterns commonly found in rivers.

2 Methods

We implemented a 2D model of particle deposition with moving bedforms in Python (Harris et al., 2020; Hunter, 2007; McKinney, 2010; Virtanen et al., 2020), with the bed surface specified analytically using mathematical functions in order to discretize natural bedform geometries. The modeling framework and processes captured by the model are illustrated in Figure 1. We use a Bezier curve to define the upstream face of the bedform and a linear function to define the downstream face (Supporting Information Text S1). Since a Bezier curve is a polynomial defined based on user-specified control points, this choice provides an intuitive way to represent arbitrary bedform shapes. The two-part function delineates the top boundary of the domain, which represents the sediment-water interface. At each timestep, the top boundary shape changes as bedforms are migrated downstream at a constant celerity.

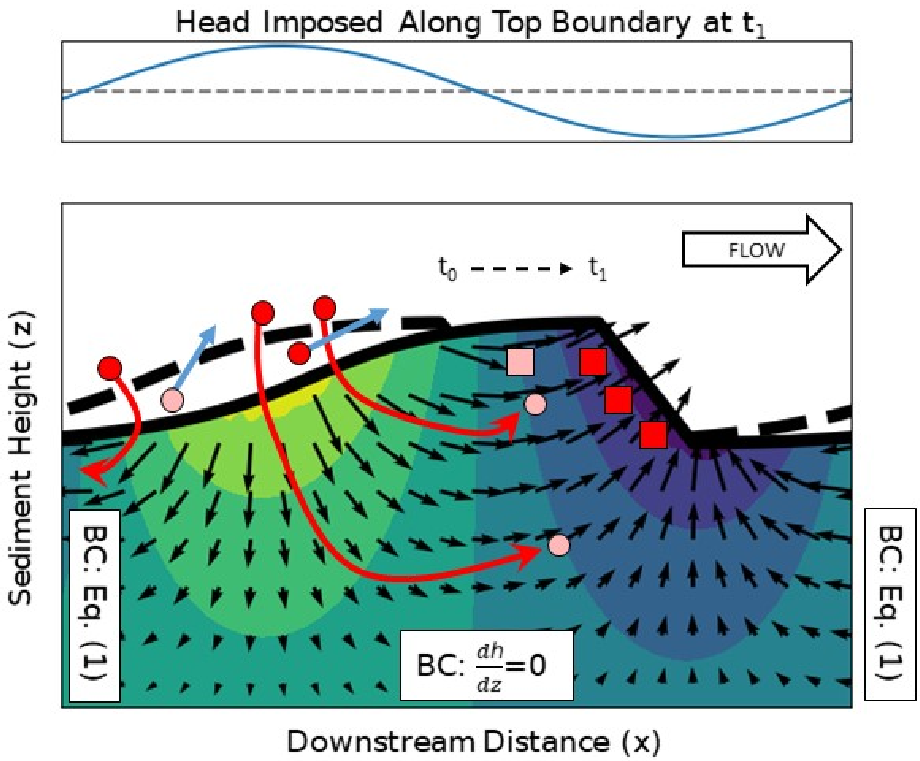

Figure 1: Schematic diagram of moving-boundary model for fine particle transport and deposition. The model represents the passage of a series of bedforms, but only a single bedform is illustrated here for simplicity. The dashed line shows the shape of the domain top boundary (sediment-water interface) at time t_0, while the solid line shows the boundary shape after migration at t_1. Head within the bed at t_1 is shown by the colored contours; bright colors are high-pressure areas, while dark colors show low-pressure areas. Black arrows show instantaneous hyporheic streamlines that result from the head gradients within the bed at t_1.

Circles and squares indicate particles that enter the bed via pumping (at the upstream face of the bedform) and turnover (at the downstream face of the bedform), respectively. Particles with a red interior are mobile in the streamwater and hyporheic porewater, while particles with a pink interior have deposited. Red lines illustrate example flow paths followed by particles. Particle remobilization from the bed by scour between t_0 and t_1 is represented by blue arrows.

Head is imposed along the top boundary of the domain using a sinusoidal head function (Elliott & Brooks, 1997) (Supporting Information Text S2). A no-flux boundary condition is imposed along the bottom of the domain. At the left and right boundaries of the domain, the head at the surface is attenuated toward zero with increasing depth using an exponential decay function (Elliott & Brooks, 1997):

$$\boldsymbol{h}(\boldsymbol{z}) = \boldsymbol{h}(\boldsymbol{z_0}) \cdot \exp(-\mathrm{rd}) \quad (1)$$

where *h(z)* is head at bed height with vertical coordinate z measured upward from the base of the bed, z_0 is the height of the top of the bed, r is the decay rate $2\pi / \lambda$, and $d = (z_0 - z)$ is the depth of z below the bed surface. Previous works have all utilized periodic boundary conditions along the side boundary, an unduly restrictive choice because the shape of hyporheic flow paths is dictated by the shape of the bed surface, which is typically not periodic in sand-bed rivers (McElroy & Mohrig, 2009). Exponentially attenuating head along the side boundary removes the reliance on this assumption, as it relies only on the imposed head at the top of the side boundary without making assertions about any other point in the domain.

At each timestep, the model is treated as being at steady state. The instantaneous system geometry is treated as fixed at each timestep, and the effects of sand and water compressibility are assumed to be negligible at the scale addressed by this model. Thus, at each timestep, the instantaneous head field in the bed is computed based on the bed surface geometry using the Laplace equation, which describes steady-state groundwater flow (Elliott & Brooks, 1997; Zheng et al., 2019):

$$\nabla^2 h = 0 \quad (2)$$

where h is hydraulic head (cm). This equation is solved using a 2D finite-difference scheme over the domain grid (Supporting Information Text S1). Streamlines in the bed are then computed using Darcy's law.

Porewater flow, solute transport, and particle transport and deposition within the bed are represented using a particle-tracking method. Fluid and suspended particles within the bed are propagated in each timestep in accordance with the instantaneous porewater velocity field obtained from the pseudo-steady velocity distributions. Particle deposition is represented using colloid filtration theory, following the earlier work of Packman et al. (2000a):

$$\frac{dC_m}{ds} = -\lambda_f C_m \tag{3}$$

where C_m is the suspended particle concentration, s is the distance traveled in the bed, and λ_f is the filtration coefficient. Consequently, the distance that an individual particle travels before depositing follows an exponential distribution:

$$D \sim Exp(s;\lambda_f) \tag{4}$$

where D is the distance traveled by the particle. The particle's probability of depositing at any location in the bed within a given timestep is given by the cumulative distribution function (CDF) of (4):

$$F(s) = 1 - e^{-\lambda_f s} \tag{5}$$

In each timestep, each particle's displacement due to advection is computed. The advective displacement is then used to compute the particle's probability of depositing on that timestep using (5). If the particle has not deposited during the current timestep, the particle is propagated by displacement due to both advection and dispersion. Longitudinal dispersivity α_L was set to 0.063 cm (Toride et al., 1995). Transverse dispersivity was set to $\alpha_T = 0.1\alpha_L$.

Once a particle has deposited, it is assumed not to remobilize except due to bedform scour. The average particle residence time in the bed is greater than the average time required for bedforms to travel one wavelength downstream. Thus, particle transport in the bed reflects the passage of multiple bedforms (and associated porewater flow), and the particle tracking model incorporates the full time-history of the bed profile and hyporheic flow field. The number and location of particles entering the bed due to pumping is calculated using the spatial distribution of HEF along the stoss side of the bedform (Supporting Information Text S1). The number of particles entering the lee face of the bedform is simulated using the incoming flux due to turnover, which is calculated by the following equation:

$$Q_t = c \cdot dt \cdot h_l \cdot w \cdot \theta \quad (6)$$

where Q_t is the flux (cm^3/s), c is the celerity (cm/s), dt (s) is the amount of time that passes per model timestep, h_l is the height of the lee face of the bedform, w is the width of the channel, and θ is the porosity of the sand. No particles are released within one bedform wavelength of the side boundaries in order to avoid any possible effects of the side boundary conditions (Supporting Information Text S2). The channel width w is included to convert 2D flow paths computed by the model into volumetric flux across the sediment-water interface. We impose a constant concentration of particles in the water column, which does not change in response to particle exchange with the bed and deposition. This corresponds to the common case of large input of fine particles from upstream relative to the instantaneous exchange flux.

The modeled domain that we use in the simulations is 150 cm long. The bedforms are 25 cm long and 2.5 cm in height. The domain thus accommodates six bedforms (Supporting Information Text S2). The bed sediment below the bedforms is 20 cm thick, allowing domain height to vary from 20 to 22.5 cm. Channel width w is 30 cm to facilitate comparison with simulation results with the experimental observations of Teitelbaum et al. (2021). Stream water depth is 12 cm. The sand has a porosity of $\theta = 0.33$, hydraulic conductivity of 0.12 cm/s, and D_{50} of 0.31 mm. The sediment bed and its properties are assumed to be homogeneous and unchanging over time. Thus, for example, particle erosion, sorting, and compaction are not considered. The choice of the modeled physical conditions is based on typical characteristics of sand material, as used by Teitelbaum et al. (2021), to facilitate comparison of simulation results with the experimental observations. Because we use a wider range of flow conditions in the simulations than appear in Teitelbaum et al. (2021), criteria for bedform formation and movement were implemented to ensure that the model is used under realistic conditions (Supporting Information Text S3, Supporting Information Data Set S1).

Simulations are run at filtration coefficients of 0.1 to 0.9/cm and bedform celerities of 0.6, 6, 30, 60, and 90 cm/hr. For each celerity, the corresponding streamwater velocity is calculated using the relationship from Snishchenko & Kopaliani (1978):

$$c = 0.019V \cdot Fr^{2.9} \tag{7}$$

where c is bedform celerity (m/s), V is the average streamwater velocity (m/s), Fr is the Froude number ($V/(gH)^{1/2}$), g is the gravitational constant and H is the water depth (m). We then use the physical parameters of the sand and the water to calculate a set of metrics to ensure that the criteria for bedform formation are fulfilled. Detailed calculations are represented in Supporting Information Text S3 and Supporting Information Data Set S1. The first criterion for bedform formation is that $Fr \leq Ft$ (Karim, 1995). If that condition holds, D^* and T^* are calculated to test whether and what type of bedforms will form (van Rijn, 1993). It is expected that ripples will form when $1 < D^* < 10$ and $0 < T^* < 10$. This implies that the bed will be stationary under a flow velocity of 0.1 m/s, while the rest of the flow conditions are expected to form ripples. Ripple wavelength and height depends on particle D_{50} (Lichtman et al., 2018; Raudkivi, 1997; Soulsby et al., 2012). Thus we used the same ripple geometry in all the simulations. Finally, the shear velocity, shear stress and shields parameter are reported as parameters that control the movement of the bed.

3 Results and Discussion

Model validation occurred in two steps. First, simulated HEF was compared against HEF observed during experiments under similar conditions (Fox et al., 2018; Teitelbaum et al., 2021)and to the estimation to the classical analytical model by Elliot and Brooks (1997). The correlations wasasere found to be 0.96 (Supporting Information Text S4). Additionally, Ddeposition profiles from model simulations were compared with the experimental observations of Teitelbaum et al. (2021) and found to be statistically equivalent (paired z-test, $z = -5.34 \times 10^{-16}$, $p > 0.05$) (Supporting Information Text S5). Furthermore, the evolution of the vertical deposition profile over time was calculated and was found to converge to a pattern similar to that seen in experiments (Supporting Information Text S6). The convergence of the profile is indicative of the fact that the clay layer is the result of the passage of many bedforms, which has an averaging effect. Since both the flow and deposition have been confirmed against experimental observations, we consider the model to be reliable for simulating various scenarios.

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Simulations reproduced experimental observations of both a conservative tracer and kaolinite deposition previously presented by Teitelbaum et al. (2021) (Figure 2). The distribution of conservative tracer in the bed creates a conchoidally-shaped plume beneath each bedform (Figure 2b), as water and solutes enter the bed on the stoss side of the bedform (high pressure zone) and migrate along flow paths that eventually return to the stream at the low-pressure zones near the lee side of the bedform (see also Fig. 1). This shape resembles the dye plumes that were observed during experiments by Teitelbaum et al. (2021) (Figure 2c). The flow field imposed by the bedform migrates with the bedform as it moves downstream, so the solute plumes migrate with the bedforms as well (see Supporting Information Movie 1 and Teitelbaum et al. (2021)). The highest concentration of the dye in the bed occurred between the heights of 19.5-20 cm above model bottom, i.e. just below the line of most frequent scour depth (MFSD) (Fig. 2a). For the purposes of this calculation, the bed was divided into horizontal layers of 0.5 cm depth, and particle concentration versus depth was expressed as percentage of particles in a given layer.

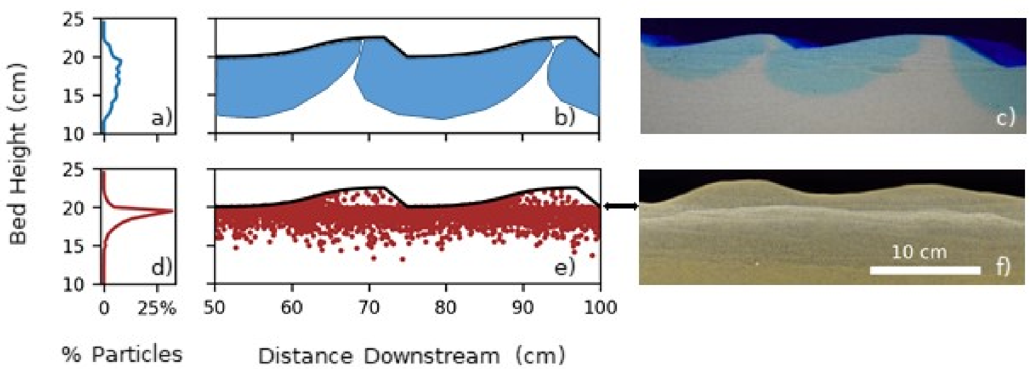

Figure 2: Comparison of particle transport simulations against experimental observations. The first row shows the distribution of conservative tracer in (a) and (b) from the simulation while panel (c) shows a photograph of conservative dye plumes that were observed during tracer experiments in a flume. The second row shows the model results for deposited particles in (d) and (e) and a picture (f) from an experiment with kaolinite clay deposition under moving bedforms (Teitelbaum et al., 2021). Deposited clay is visible as a horizontal white layer just below the level of the troughs (f). The arrows between (e) and (f) represent the depth of most frequent scour, below which most of the deposition occurs. The profiles in panels (a) and (d) show particle concentration by depth as a percentage of all particles shown in (b) and (e), respectively. Height is measured from the bottom of the model domain. The distance downstream shows the horizontal location within the modeling domain.

Particle deposition resulted in accumulation primarily within a layer just below the MFSD (Fig. 2d-f, Supporting Information Movie 2). This location was also where the maximum concentration of deposited particles was found (Fig. 2d). ~~Deposition profiles from model~~

~~simulations were compared with the experimental observations of Teitelbaum et al. (2021) and found to be statistically equivalent (paired z-test, $z = -5.34 \times 10^{-16}$, $p > 0.05$) (Supporting Information Text S4).~~ This deposition pattern has also been observed in various flume experiments that used kaolinite clay particles (Dallmann et al., 2020; Packman & Brooks, 2001; Rehg et al., 2005; Teitelbaum et al., 2021), and field measurements (Harvey et al., 2012). Particle concentration decreased sharply with depth in the bed and the concentration dropped to zero within several cm (Figure 2d). Fewer particles deposited at deeper locations than at shallower ones because particle concentration in porewater decreases exponentially with distance traveled in the bed due to filtration (Eq. 3). At the end of each simulation, only a relatively small number of deposited particles could be found above the line of MFSD, i.e. in the moving fraction of the bed. Particles that deposit there will necessarily be resuspended by erosion after spending some time in the bed (Fig. 1, Supporting Information Movie 2). The vertical pattern of particle deposition is ~~a~~ clear evidence of the averaging effect caused by the passage of multiple bedforms, which was observed in many cases in the past but is captured for the first time by our modeling approach.

After confirming that the model reproduces experimentally observed patterns, we assess how clay-sand interactions (i.e., filtration) and bedform celerity influence particle deposition. Increasing the filtration coefficient causes the layer of deposited particles to become more compact, which can be seen most clearly in the 2D profile plots in Figure 3 (a-c), and is quantified using the standard deviation of deposition depth (σ_d, Fig. 3h). Keeping celerity constant and varying filtration coefficient from 0.1 to 0.9/cm decreases σ_d by magnitudes of 1.48, 0.88, 0.47, 0.31, and 0.24 cm for celerities 0.6, 6, 30, 60, and 90 cm/hr, respectively (Supporting Information Figure S1). Increased filtration coefficients shorten the distance within which a particle can be expected to deposit. Therefore, particles deposit within shorter distances and before they travel deep into the bed. This results in a more compact deposition layer.

For all celerities, increasing the filtration coefficient led to an increase and then a slight decrease in the percentage of particles that deposited (Fig. 3g, Supporting Information Figure S2 and Data Set S2). The filtration coefficient for which maximal deposition occurred (λ_f^{max}, indicated by black rectangles in Supporting Information Figure S2) was 0.3, 0.4, 0.4, 0.6, and 0.6/cm for celerities 0.6, 6, 30, 60, and 90 cm/hr, respectively. Increases in deposition percentage from $\lambda_f = 0.1$/cm to λ_f^{max} were 14.5, 16.1, 18.4, 20.1, and 20.0 % for the same celerities. Decreases in deposition percentage from λ_f^{max} to $\lambda_f = 0.9$/cm were 6.9, 6.5, 3.9, 3.0, and 1.5 % for the same celerities. Increasing filtration coefficient means that the average distance that particles travel before depositing is shorter. The increase for low filtration coefficients ($\lambda_f < \lambda_f^{max}$) occurs because more particles deposit instead of advecting out of the bed. The decrease for higher filtration coefficients ($\lambda_f > \lambda_f^{max}$) is indicative of particles that would otherwise travel below the MFSD instead depositing above it and later being scoured away.

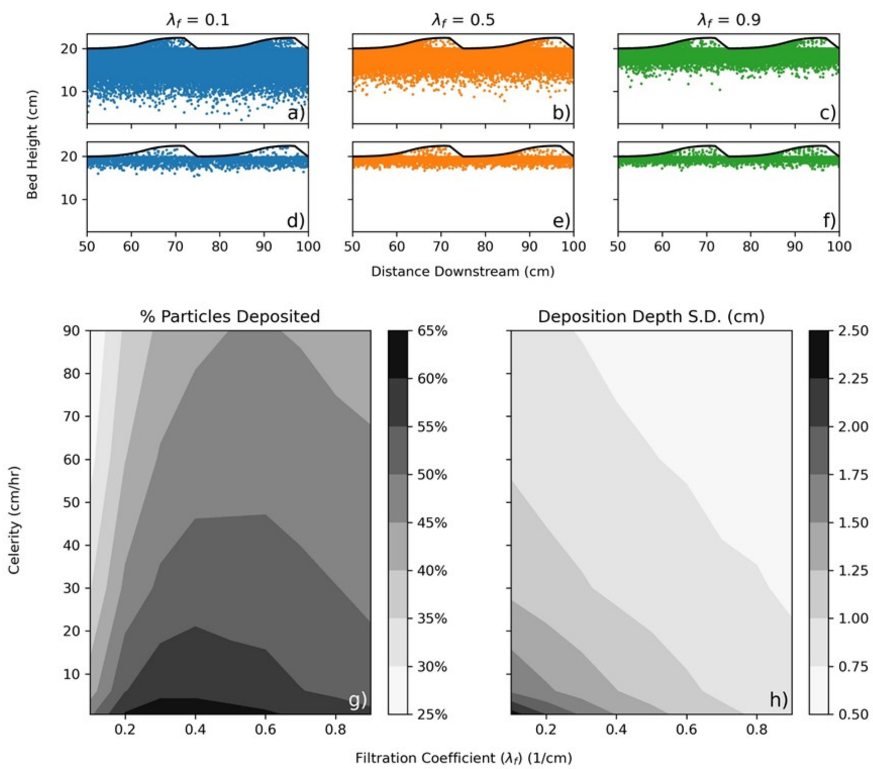

Figure 3: Effects of celerity and filtration coefficient on particle deposition. All panels show results after passage of five bedforms through the model domain. Panels (a)-(f) show 2D spatial distributions of particles for the slowest and fastest celerities (0.6 and 90 cm/hr). Panels (g) and

(h) show phase spaces of filtration coefficient versus celerity in terms of percentage of particles deposited in the bed and standard deviation of deposition depth (σ_d).

Increasing celerity also causes the deposition layer to become more compact. σ_d decreases with increasing celerity in all cases (Fig. 3h and Supporting Information Figure S3). The decrease in σ_d is greatest for the smallest filtration coefficient (λ_f = 0.1/cm, decrease of 1.52 cm) and conversely the smallest decline in σ_d occurs for the largest filtration coefficient (λ_f = 0.9/cm, decrease of 0.27 cm). Increasing celerity flattens particle flow paths within the bed (Supporting Information Movie 3) restricting particles to a shallower portion of the bed, resulting in a more compact deposition layer (Fig. 3a-f). Flow paths flatten as a result of the migration of the flow field. This occurs due to the faster migration of the upwelling zone relative to the velocities of the particles within the bed, resulting in particles being drawn into an upwelling zone sooner than under stationary bed conditions. Unlike the filtration coefficient, increasing celerity decreased the percentage of particles deposited over the entire range of celerities examined (Fig. 3g, Supporting Information Figure S4). The greatest decrease is found for λ_f = 0.1/cm, for which the percentage of particles released decreases from 49% to 25% between celerities 0.6 and 90 cm/hr. The smallest decrease is for λ_f = 0.9/cm, for which the decrease is from 56% to 44% between the same celerities.

4 Conclusions

Our results clearly show that there is an interaction between the effects of celerity and filtration coefficient on particle deposition and remobilization. An increase in either bedform celerity or filtration causes particles to deposit at shallower locations (Supporting Information Figures S5-S9). However, an increase in filtration coefficient causes more particles to accumulate in the deposition layer only in some cases, while an increase in celerity results in less accumulation for all cases examined. The decrease in particle accumulation under increased celerity is due to the fact that higher celerity flattens particle flow paths, causing particles to travel less distance in the bed before flowing back out to the water column. Furthermore, the effect of either parameter is modulated by the other. Increasing either parameter causes a more compact deposition layer, but this effect is less prevalent if the other parameter value is high. Similarly, each parameter has a different effect on deposition rate if the other parameter value is high. These findings imply that when studying particle deposition in streams it is important to include measurements of both the bed morphodynamics and interactions between bed sediments and suspended particles (as represented here by the filtration coefficient).

One main consequence of particle deposition in streambeds is clogging due to clay accumulation in the bed (Dallmann et al., 2020; Fox et al., 2014; Shrivastava et al., 2020). The common assumption is that high-flow events and scour prevent clogging from being significant, however, it is clear that the compactness and depth of the clogging layer will affect the scour due to increased cohesion of the bed (Baas et al., 2016; Debnath & Chaudhuri, 2010; Molinas & Hosni, 1999; Wan, 1985). Clogging and reduction in streambed hydraulic conductivity have also been widely observed, but previous studies have not evaluated how the depth of deposition may influence the long-term persistence of the clogging problem (Cheng et al., 2013; Fetzer et al., 2017; Korus et al., 2018, 2020). Depth of deposition is also critical for evaluating the link between streambed morphodynamics and water column turbidity (Bash et al., 2001; Lloyd et al., 1987; Wharton et al., 2017).

Particle deposition also has implications for the health of humans and other organisms. For example, deposited pathogens are released back into the water during bedform scour (Drummond et al., 2017; Rebaudet et al., 2013). Thus, risk for pathogen resuspension is higher when deposition occurs at shallow depths, as when filtration and celerity increase. Increased depth of deposition means longer residence time in the bed (Harvey et al., 2012; Phillips et al., 2019; Voepel et al., 2013). Longer residence time in turn increases the chances of sediment-dwelling creatures or burrowers ingesting fine particles, such as microplastics, with harmful effects (Garcia et al., 2020; López-Rojo et al., 2020; Wright et al., 2013).

Increased depth of deposition and residence time also have far-reaching implications for microbial respiration and the health of the stream ecosystem. For instance, longer residence time often means enhanced nutrient removal (Briggs et al., 2014; Reeder et al., 2018; Zarnetske et al., 2011). Burial of particulate organic matter has direct influence on its availability, respiration rates and metabolic hot spots (Rowland et al., 2017; Stelzer et al., 2014). Enhanced microbial activity and biomass growth may also influence flow paths in the bed due to clogging (Mendoza-

Lera & Datry, 2017; Newcomer et al., 2016; Nowinski et al., 2011), and should be taken into account when sampling of sediment is conducted in the field.

The model presented here, adopting a stationary frame of reference, enables the quantification of fine particle accumulation at fixed locations in the bed, within and below the scour zone. Use of a moving boundary to represent the sediment-water interface enables resolving the effects of realistic, time-varying bed morphologies that are commonly found in sand-bed rivers (McElroy & Mohrig, 2009), including the effects of unsteadiness that is commonly found in systems with mixed clay-sand beds (Baas & Best, 2002).

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Acknowledgments, Samples, and Data

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The Hydroshare repository can be accessed via the following DOI: https://doi.org/10.4211/hs.90acd3c1c2754e839e1e12d73154eaff and can be cited as follows:

Teitelbaum, Y. (2021). A Novel Framework for Simulating Particle Deposition with Moving Bedforms, HydroShare, http://www.hydroshare.org/resource/90acd3c1c2754e839e1e12d73154eaff

The authors have no known conflicts of interest.

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