**Exploring the Timescales that Storms Do Geomorphic Work in Last Chance Canyon, New Mexico**

**ABSTRACT**

Here, we investigate how discrete storm events influence sediment flux, grain size distributions, and alluvial residence times in two first and second order streams in Last Chance canyon, New Mexico, USA. Many studies assume that sediment flux out of erosional landscapes is constant, however, in ephemeral desert stream channels this assumption is likely invalid. In this study, we identify the storm properties necessary to overcome grain motion thresholds and transport differently sized sediment. To accomplish this, we used a updated OverlandFlow model (Adams [et al., 2001](#_ENREF_30)) , from the LandLab library, which routs water from storms across a landscape. We coupled OverlandFlow to RiverBedDynamics, which uses water velocity and discharge to determine if sediment of certain sizes can be mobilized. We used precipitation data (NOAA) to reconstruct realistic storm durations and intensities for Last Chance canyon. We used drone photos to construct high resolution DEMs and orthomosaics to determine grain size distributions in different channel sections. With these methods, we plan to determine the 1) hydrograph characteristics necessary to remove the differently sized sediment armor, 2) the residence times of the differently sized sediment within channel sections of varying steepness, and 3) if the larger sediment has armored channels at timescales necessary for landscape morphology to be reflective of their presence in the channel. We hypothesize that only very intense storms will ‘do geomorphic work’ by removing larger grains from the steep dolomitic channel section, while smaller storms will be able to carry off smaller sandstone sediment from the shallow channel section. We further hypothesize that the large sediment armors bedrock at timescales necessary for stream channel morphology to reflect their presence. This study will help to constrain the imprint storms have on landscape morphology and elucidate geomorphic processes between shorter time scales and timescales necessary for the landscape to adjust.

**INTRODUCTION**

The topographic signal from variance in bedrock properties can be blurred, removed, or exaggerated by the presence of sediment armor (Duval et al., 2004; Johnson et al., 2009; Finnegan et al., 2017). Rock properties, specifically bed thickness and discontinuity spacing, has been shown to influence sediment production and grain size (Spotila et al., 2015; Keen-Zeebert et al., 2017; Sklar et al., 2017). The presence of larger boulders, sourced from thicker units and bedrock with larger discontinuity spacing, causes stream channels to steepen (Thaler and Covington, 2016; DiBiase et al. 2018). But, to imprint their signal into topography, alluvium must effectively armor stream channels for time periods which stretch over many storm events. Because intense storms are the primary drivers of sediment flux out of stream channels (Schuerch et al, 2006), residence time of boulders in stream channels depends primarily on the storm hydrograph and on relevant sediment properties like size and competency. How large must sediment be to armor channels, withstand mobilization by storms, and remain in streams at timescales necessary for the landscape to reflect their presence? How intense must storms be to do remove large boulders and incise into bedrock? Without an answer to these questions, attempts to link geomorphic processes across temporal scales will be confounded.

In this study, we explore the relationship between the storm hydrograph and the size of sediment armoring the channel on landscape morphology. More specifically, we ask: (1) how immobile is larger sediment than smaller sediment in last chance canyon? (2) is it possible for storm events to remove these large boulders? And (3) What is the relationship between channels steepness and the residence times of large alluvial armor? To address these questions, we will couple a landscape evolution model which calculates movement of sediment based on shear stress with the overland flow component developed by Jordan Adams and inform our modeled experiments from storm and sediment size data from Last Chance canyon, New Mexico. This study will rectify assumptions about the effect of differently sized sediment on topography from the storm hydrograph to time scales relevant for the landscape to reflect geomorphic processes. Furthermore, I seek to demonstrate that baselevel is effectively pinned at the transition from large to smaller sediment and knickpoint celerity is slowed in stream channels with larger sediment armor.

**HYPOTHESIS**

Intense storms are required to overcome the threshold shear stress necessary to move large sediment. Storm duration is an important hydrograph characteristic in removing smaller sediment out of the system but will not influence sediment flux of larger sediment. Because of this, storms will more frequently incise into bedrock which is armored by smaller grains than channels with larger alluvial armor and channels will shallow.

The larger sediment grains, which are sourced from thicker bedrock, are mostly immobile on timescales necessary for landscape morphology to reflect their presence. Because these grains are so immobile, and because they armor the channel and prevent bedrock erosion, knickpoint celerity is slowed and baselevel is pinned at points above where they exist.

**FIELD AREA**

This study focuses on 2 different, first to second order channels with intermittent flow in Last Chance canyon (Figure 1). During Permian time, a shallow lagoon existed behind a reef complex to the south and deposited what would become interbedded carbonate and siliciclastic bedrock of various thicknesses (Hill, 2000; Phelps et al., 2008; Kerans et al., 2017). The Guadalupe mountains were uplifted during basin and range extension beginning 27 million years ago, exposing the previously buried bedrock (Chapin and Cather, 1994; Ricketts et al.., 2014, Hoffman, 2014; Decker et al., 2018).

Because of their differing morphology and grain size distributions, we use data gathered from different sections of two channels, called LC1 and LC3 (grain size figure, chi, and steepness vs grain size), to identify the potential control differently sized alluvial armor has on stream channel morphology. In both channels, grain size distributions increase with channel steepness. This simple variation in grain size distribution makes LC1 and 3 ideal locations to explore the effect of varying sediment sizes on stream channel morphology.

**METHODS**

We used Landlab, a Python-language, open-source, flexible library of different components that can be easily coupled together (Adams et al., 2014; Tucker et al., 2016; Hobley et al., 2017) to model sediment transport during storm events. The Landlab OverlandFlow component (Adams citation), which is based on a simplified calculation of the shallow water equations (de Almeida et al., 2012), routs rainfall during storm events across a DEM and determines flow depth, velocity, and stream discharge at each cell. We used an updated OverlandFlow component which allowed us to include a spatially variable roughness attribute which we altered for each grain size distribution.

We coupled OverlandFlow to RiverBedDynamics (Monsalve et al., 2023), which allowed us to calculate bed load transport and elevation change due to erosion or deposition. RiverBedDynamics takes surface flow variables from OverlandFlow and grain sizes, both of which are stored in a raster grid. Sediment fluxes for each cell are then calculated, and bed surface elevation and bed properties like bed grain size distributions are updated.

We used depth-duration plots (climate figure) for Last Chance canyon from NOAA (citation). These data are used to inform the OverLandFlow component and generate storms which mimic real storms from our study area.

We used a DJI mavik 2 pro to take photos of three segments of each of the two channels- a downstream, intermediate, and upstream- from elevations of approximately 20 meters above LC1 and LC3. We then used Agisoft Metashape software to process these images and to produce orthomosaics and DEM’s with a spatial resolution that varied from # to #. We used the PebbleCounts image analysis package (Purinton and Bookhagen, 2019), to determine the b axis diameter of alluvium.

**RESULTS**

To link the hydrograph and sediment size, we examine sediment flux in different channel sections for different storms. Storms which strip sediment armor of different sizes will have difference recurrence intervals. We expect that sediment residences times will vary with storm intensity and storms with higher recurrence intervals will be required to move larger alluvium. Storms will be able to remove sediment armor and do geomorphic work less frequently and for higher recurrence intervals in channel sections with larger sediment armor. However, the more frequent, less intense storms should be able to remove sediment and erode into the shallower channel sections which are armored by smaller sediments more often. We expect our modeled storms to remove smaller sediments, leaving larger alluvium behind for storms under a certain recurrence interval. We will compare modeled sediment size distributions with distributions we measured in Last Chance canyon by photosieving orthophotos generated with drone surveys. This methodology will help elucidate how variance in storm characteristics affects sediment size distributions and alluvial residence times.

To quantify the influence of storms on the time for landscape morphology to respond to the changes in sediment size, we measure the size of sediment in the channels and the recurrence interval required to remove sediments of differing sizes. We will determine the residence time of sediment necessary for the channel morphology to steepen to reflect the presence of alluvial armor. We seek to quantify a link between channel steepness and the residence time of large sediment armor. Variance in sediment size affects channel and landscape morphology (figure 4), and we will relate residence time in channel with degree of steepening. To validate our modeled results, we plan on comparing the landscape relief of bedrock armored with sediment of varying sizes (figure 5). We expect that sediment sourced from dolomite is large and competent enough (figure 6) to pin baselevel at channel sections above it. Furthermore, we will quantify the degree to which celerity in the steep knickzone has been slowed by the presence of large dolomitic armor.

Citations

Nativ, R., Turowski, J. M., Goren, L., Laronne, J. B., & Shyu, J. B. H. (2022). Influence of rarely mobile boulders on channel width and slope: Theory and field application. Journal of Geophysical Research: Earth Surface, 127, e2021JF006537. <https://doi.org/10.1029/2021JF006537>

A comparison of different types of soil samples

Description automatically generated with medium confidence

**Figure 4 – Two options. Either the figure above, or if fig2-option2 is chosen then figure4a will be removed**

Channel steepness is controlled by sediment diameter in the channel reaches at the base of the 7 hillslope transects we measured (figure4). An increase in sediment diameter corresponds to a concurrent increase in channel steepness, demonstrating a clear positive correlation between larger sediment sizes and the steepness of the channel profile. This observation emphasizes the significant influence of sediment dynamics on the fluvial system's morphology. Conversely, our findings also indicate that smaller sediment sizes are generally associated with shallower upstream hillslopes. This outcome underscores the role of particle size in shaping the topographic characteristics of hillslopes in proximity to the channel.

## 4.4 Bed thickness affects size and shape of Alluvium and Boulders

Variations in the maximum bed thickness were correlated with changes in the sediment diameter at the base of each hillslope transect (figures of bed thickness effect on grain size, and on channel steepness). The analyses revealed that as the maximum bed thickness increased, there were discernible effects on the D10, D50, and D90 of sediments present within the alluvium at the base of each hillslope transect, as well as the average sediment diameter. Conversely, the average bed thickness along a hillslope transect did not appear to significantly influence the diameter of sediment in the channel reaches below. These findings illuminate the intricate interplay between bedrock properties, sediment dynamics, and channel morphology, underscoring the importance of considering maximum bed thickness as a key factor in understanding the complex processes governing landscape evolution.

Isn't D84 coarser than D10?

Both maximum bed thickness and the average bed thickness along hillslope transects had a significant impact on the average dimensions of boulders, including their axis length (a, b, and c) and overall volume (figure of max and average bed thickness vs boulder volume and dimensions). The boulders were measured in the field and were the largest boulder in each reach. It's noteworthy that the relationship between average bed thickness and boulder dimensions, particularly axis length and volume, demonstrated a stronger correlation with boulder geometry than the maximum bed thickness. This finding underscores the importance of average bed thickness as a prominent factor in determining the dimensions of the large boulders within Last Chance canyon.

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## 4.5 Bed thickness affects Channel Morph

In our results, we observed distinct relationships between bed thickness and channel steepness across hillslope transects. Specifically, we found that the maximum bed thickness along these transects exhibited a particularly strong influence on channel steepness, with a notable coefficient of determination (r^2 value) of 0.68. In contrast, the average bed thickness and the total bed thickness across the same transects also displayed correlations with channel steepness, albeit with comparatively lower r^2 values of 0.45 and 0.27, respectively. These findings underscore the significance of maximum bed thickness as a key factor in determining the steepness of the channels within the landscape, while also highlighting the varying degrees of influence associated with average and total bed thicknesses.

. At every contour interval along the 2 channels, we measured the size of the largest, assumedly most immobile, boulder in the channel. Previous work suggests that boulders and the coarsest sediment size fractions can significantly influence reach topography, erosion, and transport (e.g. REFS). For each boulder we measured the longest (a), intermediate (b) and shortest (c) axes (dog on rock figure). We multiply these dimensions together to approximate boulder volumes. We also constrain differences in boulder shape using the Corey Shape Factor (REF ):

(#)

It hurts in places where theres lots of bones.

## 3.5 Photogrammetry to make Sediment Size Measurements

We measured the diameter of alluvium in channels at the base of the seven hillslope transects with the PebbleCounts image analysis package (Purinton and Bookhagen, 2019). PebbleCounts is a Python library for the detection and sizing of sediment grains from drone images. We used the k means with manual (KMS) method, which allows an operator to validate measured grains to mitigate error. To account for the large size of the orthomosaics, we first subset the images into manageable sizes. We then validated the results of the initial automatic counting with the k-means with manual (KMS) method, which allows an operator to validate measured grains and mitigate error. Finally, we compiled all the data for each channel section into a single file.