HOW ACCURATE ARE PALEODISCHARGE ESTIMATES FOR MARTIAN RIVERS? A. M. Morgan* and R. A. Craddock, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution; *morgana@si.edu.

Introduction: Fluvially eroded landscapes on Mars are a testament to a planet that was once warm and wet enough to sustain liquid water on its surface. The duration and timing of these wetter periods remains controversial, with constraints imposed by a faint young sun for Noachian-aged features and a thin atmosphere for Hesperian-aged features. Deciphering the climate from the geologic record requires knowledge about the frequency, magnitude, and duration of precipitation, which can be constrained by estimating channel discharge. Several methods have been used to estimate discharges on Mars [1], but there are uncertainties as to which of these methods are most accurate. We aim to assess this by using these same commonly used methodologies on terrestrial rivers, and comparing the calculated estimates with the gauge-measured discharges.

Background: Alluvial rivers adjust their geometry in response to flood magnitude and frequency, with a "channel-forming" bankfull discharge occurring with a recurrence interval of about 1.5 to 2 years [2].

The threshold channel method uses assumptions of bedload sediment size to approximate the channel depth H which when combined with width w and estimated velocity u yields discharge: $Q = uHw$. Width is either directly measured or inferred from channel sinuosity wavelength, while flow velocity is derived using the Darcy-Weisbach equation $u = (\frac{8gHS}{f})^{0.5}$, where g is gravity and S is gradient. f is a coefficient that represents frictional resistance to flow, empirically derived as $\left(\frac{8}{f}\right)^{0.5} = 17.7\frac{H}{D_{84}}\left[56.3 + 5.57\left(\frac{H}{D_{84}}\right)^{\frac{5}{3}}\right]^{-0.5}$ [3], where D_{84} is the grain diameter for which 84% of grains are smaller. The remaining input parameter, channel depth, is not directly measurable, but is derived by assuming that significant transport of bedload does not occur until the flow reaches bankfull discharge, at which point the bedload shear stress is just above a critical level [4]. Combined with observations that this critical shear stress is slope dependent [5] yields the relation $H = 0.15S^{-0.75}(SG/a)D_{84}$, where a represents the sorting of sediment ($D_{84} = aD_{50}$) and is assumed to be 2 (typical for terrestrial coarse-grained alluvial rivers), and SG is the specific gravity of the sediment.

Paleodischarge estimates from such physically-derived equations require input parameters and assumptions about grain size, channel slope, and sediment load, which are generally not available for martian channels. The two year discharge has been shown to correlate with channel width according to $Q_{2\,yr} = 1.9W^{1.22}$ [6]. A causal relationship, derived utilizing at-many-stations hydrology is $Q = 0.1W^{1.866}$ [7]. When used for martian channels, both of these width-discharge relations have been scaled for martian gravity [8, 9], though studies of transport in submarine canyons suggest that a gravity correction may not be necessary [10].

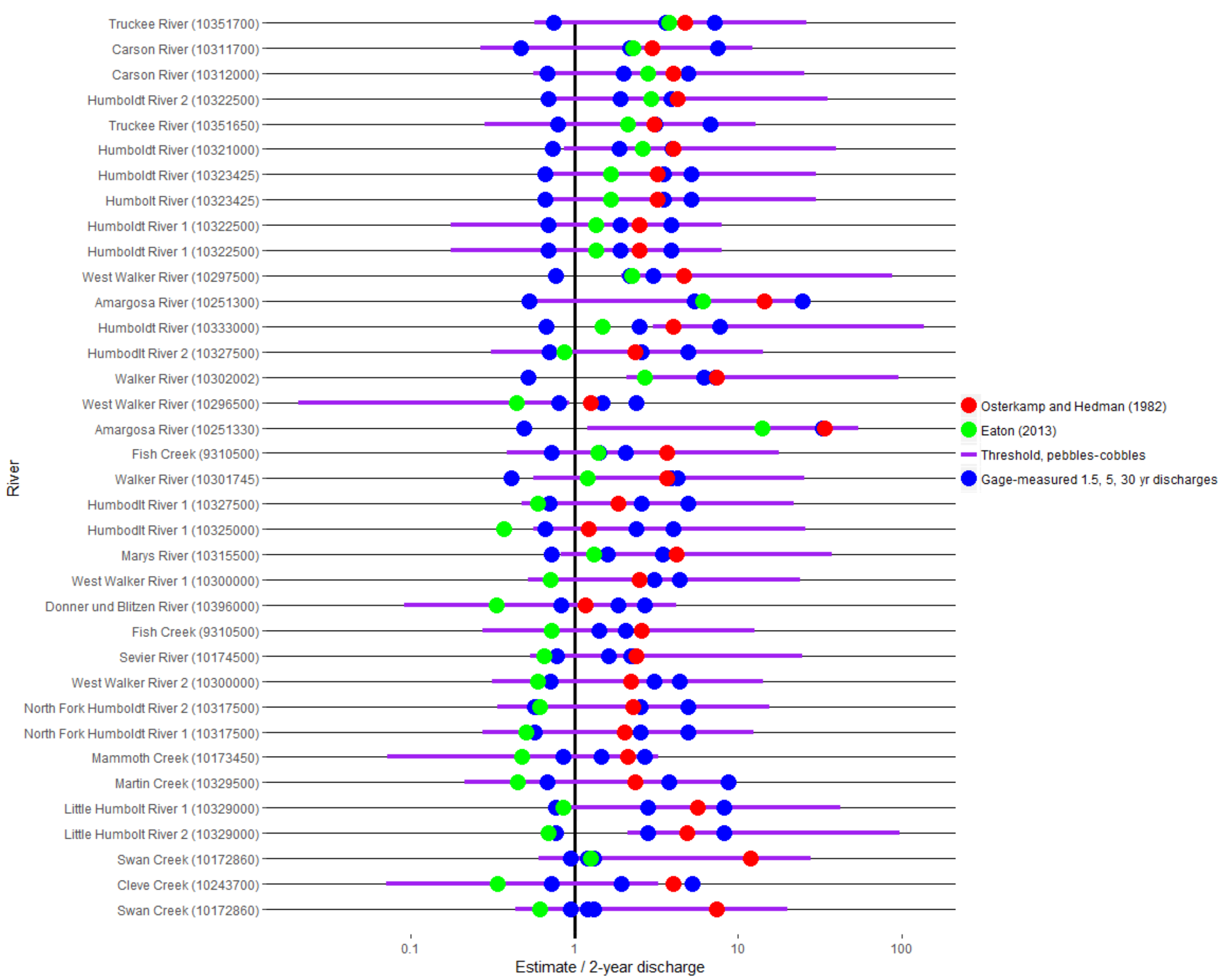
Methods: We selected 36 gauged river reaches in the Great Basin region that had at least 10 years of USGS gauge data. The Great Basin was chosen as a study region because (1) the limited vegetation in the predominately arid environment simplifies channel boundary mapping, and (2) the low level of human development limits the impact of anthropogenic factors on river geometry. To further limit the impact of human activity, we utilized the 2016 National Inventory of Dams to avoid gauges that were immediately upstream or downstream of any dam or within 50 km (measured along the river) of a dam that was constructed in the past 50 years.

We mapped the edges of each river using 30-50 cm/pixel resolution images from DigitalGlobe satellites, accessed with the Esri Global Imagery Layer. This resolution is similar to images of the martian surface obtained by the HiRISE camera. Elevations used for the threshold method were obtained from the 10 meter national USGS digital elevation model (DEM), similar in resolution to DEMs constructed from CTX camera stereo pairs. We ceased mapping river reaches at any confluences or branches with other National Hydrogeography Database water bodies (including both natural and man-made features). As the discharge estimate methods discussed above are only valid for alluvial rivers, we avoided areas where it was uncertain whether the channel may have been a bedrock channel. The mapped river reach distance therefore varied but in almost all cases was at least 2 km. We then extracted a distribution of channel widths (measured every 10 m) and computed the average width (with confidence errors) for each river.

Results: As previously observed by [11] the causal geometry method appears to be more accurate than the correlative width-discharge relationship. However, we find that the causal width-discharge relation underestimates the discharge of smaller rivers and overestimates the discharge of larger rivers, the opposite conclusion of [11]. When estimating martian discharges using the threshold method, grain size is extremely difficult to constrain (this is true for both Earth and Mars), and the selected size range can yield wide variations in resulting discharges. We use a range to account for pebble or cobble sized D_{84}, which results in a discharge range that that generally includes but tends to overestimate the two year discharge.

Conclusions: Our analysis indicates that care should be taken when calculating stream discharge in martian channels from any of the commonly applied methods. The derived values can vary widely, and this should be considered before using such values to evaluate precipitation rates or intensities or when trying to derive past climatic conditions. Additional measurements of terrestrial stream channels may help constrain the amount of possible errors or perhaps result in new methods that are more accurate and applicable to Mars.

References: [1] Dietrich et al. (2017) in:*Gravel Bed Rivers* pp. 755-783, doi:10.1002/9781118971437.ch28, [2] Leopold, L. B. & Maddock, T. (1953) USGS Prof. Paper 252, doi: 10.3133/pp252, [3] Ferguson, R. (2007) Water Resour. Res. 43, doi:10.1029/2006wr005422, [4] Parker, G. (2008) in:Sedimentation Engineering pp. 165–252, doi: 10.1061/9780784408148.ch03, [5] Prancevic, J. P. & Lamb, M. P. (2015) JGR: Earth Surf., doi:10.1002/2014JF003323, [6] Osterkamp, W. R. & Hedman, E. R. (1982) USGS Prof. Paper 1242, doi:10.3133/pp1242, [7] Eaton, B. C. (2013) in:*Treatise on Geomorphology* pp. 313-329,[8] Irwin, R. P. (2005) *Geology*, 33, doi: 10.1130/G21333.1, [9] Kite, E.S., et al. *EPSL*, 420, doi:10.1016/j.epsl.2015.03.019, [10] Konsoer, K., et al., 2013. *JGR: Earth Surf.*, 118, doi:10.1029/2012JF002422, [11] Jacobsen, R. E. & Burr, D. M. (2016) *GRL*, doi:10.1002/2016GL070535.



Results of our discharge estimate analysis for 36 gauged river reaches in the Great Basin region. Rivers are listed in order of measured width on the vertical axis, numbers are the USGS gauge site ID. The horizontal axis is the calculated discharge divided by the two year recurrence interval discharge.