A 2.5D HYDRAULIC MODEL FOR FLOODS IN ATHABASCA VALLES, MARS L. Keszthelyi[1], D.R.H. O'Connell[2], R.P Denlinger[3], D. Burr[4] [1]U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001; [2]Seismotectonics and Geophysics Group, U.S. Bureau of Reclamation, Denver Federal Center, Denver, CO 80225; [3]U.S. Geological Survey, Vancouver, WA 98683-9589; SETI Institute, Mountain View, CA 94043-2172.

Introduction: The role of past and present water is the current focus of the Mars Exploration Program. Athabasca Valles is widely considered to be the site of the most recent major aqueous floods on Mars [1-5]. However, the previous models used to investigate the hydraulics of this flood had significant limitations. The goal of this project is to modify and apply a cutting-edge hydraulic model to Mars.

Athabasca Valles: Athabasca Valles is located in north-central Elysium Planitia [1]. It is a 10 to 30-km-wide, 300-km-long valley that follows the northwestern side of a wrinkle ridge. The source of the channel is a pair of shallow depressions that straddle a branch of the Cerberus Fossae [2-4]. The average down-flow slope is only 0.05 %. While there is some debate about the precise age of the valley carving, the surrounding plains are reliably dated as no more than a few hundred Ma, firmly placing the last major flooding in the very latest Amazonian Period. Model ages from impact crater size frequency distributions allow ages as young as a few Ma [4,6,7] but an age of several tens of Ma is considered more likely [5,8,9].

Of particular note is that fact that Athabasca Valles debouches into a nearly fully enclosed topographic basin [9]. This basin is filled with "platy-ridged" material that has been variously interpreted as mudflows, lava flows, glacio-fluvial deposits, casts from icebergs, and an extant frozen sea [1-13]. A better understanding of the fluvial activity within Athabasca Valles can only help to resolve this debate.

The evidence for floods within Athabasca Valles is irrefutable. A series of streamlined forms surround surviving impact craters and knobs of older highlands terrain. Distributary channels cut across the wrinkle ridge in several locations. Other flood-related landforms that have been reported include dunes, longitudinal grooves, and layered sediments [4].

Previous Models: While there is general consensus that water-rich fluids carved Athabasca Valles, the nature of this flow is less well understood. The most quantitative work to date uses the HEC-RAS model from U.S. Army Corp of Engineers. Assuming bank-full flow and a floor roughness with a Manning coefficient of n=0.04, a peak water flux of 1-2 x 10^6 m^3 s^{-1} was estimated [13].

There are a number of issues with this estimate. First, the use of the Manning coefficient derived from empirical terrestrial data has been shown to be inappropriate for Mars [14]. Second, the earlier models could not properly take into account the real (complex) topography that has clearly affected flood hydraulics. Third, the assumption of bank-full flow is unlikely to be realistic. Finally, the floodwaters may have carried enough sediment to affect the flow hydraulics. Our immediate goal is to correct the first and second problem and investigate the third. Modeling viscous mudflows is beyond the scope of this project.

Department of Interior 2.5D Hydraulic Model: This numerical model was developed jointly by the USGS and the USBR over 5 years. It solves the shallow-water flow equations over rugged three-dimensional terrain. For each increment in time, the flow calculation divides the domain of interest into finite volume cells, calculates the mass and momentum transfer between cells using Riemann methods, then sums the changes to update the cell variables and proceeds to the next time increment. The method is naturally conservative, though care must be taken to properly conserve mass along the boundaries of the flow. We discuss some of the key improvements provided by this model below:

Chezy C friction factor. This form of the friction factor is based upon the scale of channel roughness and, unlike the Manning *n*, is not affected by changes in gravity. The model has already been used with values of *C* appropriate for Athabasca Valles (i.e., those used for the Missoula Floods). Those terrestrial floods cut through flood lavas covered by eolian dust – a geologic setting analogous to Athabasca Valles.

Flow over complex topography. By explicitly accounting for flow transitions over drops, through chutes and pools, and across multiple current streams, the 2.5D model is able to accurately calculate flow over rugged 3D terrain. Given an adequate topographic model, the effects of in-channel obstacles and distributary flow can be fully described. The accuracy of the model has been demonstrated for a variety of historical terrestrial floods [15-19].

Unsteady flow. The model calculates changes in flow with time, and has been used to demonstrate the effect of kinematic waves on routing of the Missoula Floods. The interaction of unsteady flood waves with the three dimensional channel topography are likely to be responsible for many of the high-water marks seen in Athabasca Valles.

Spatially distributed hydraulic parameters. The model outputs water surface elevation and velocity across the computational grid. Combining this information with surface roughness, we calculate stream power per unit area, a measure of the erosive potential of the flood. This information can be used to determine how erosion and/or deposition will change with time. The model output has been verified for a number of historical floods, where field data are compared with predictions of simulated flow over three dimensional model terrain [15-19].

The First Step – DEM production: As we prepared to ingest the MOLA topographic data into the model, we realized that the standard interpolated product has artifacts that would cause unrealistic flow hydraulics. Figure 1 highlights three examples from one area from the 256 pixels/degree product. The root cause for these artifacts is that the cross-track distance between MOLA shots in this area can be >10 km. We have tried a range of different interpolation methods with some success, but no method can recreate features that were entirely missed by MOLA. Therefore, we are manually adding fictitious MOLA shots using 100-m/pixel THEMIS IR images as a guide. This is significantly improving the DEM.

Next Steps: The adjustment of the numerical code for Mars gravity is the only modification required before running the first run for Athabasca Valles. These initial results are expected by the end of February. This will provide the first real test of the quality of the manually adjusted MOLA DEM. We expect to have to iteratively refine the DEM over some locations before we can report realistic results.

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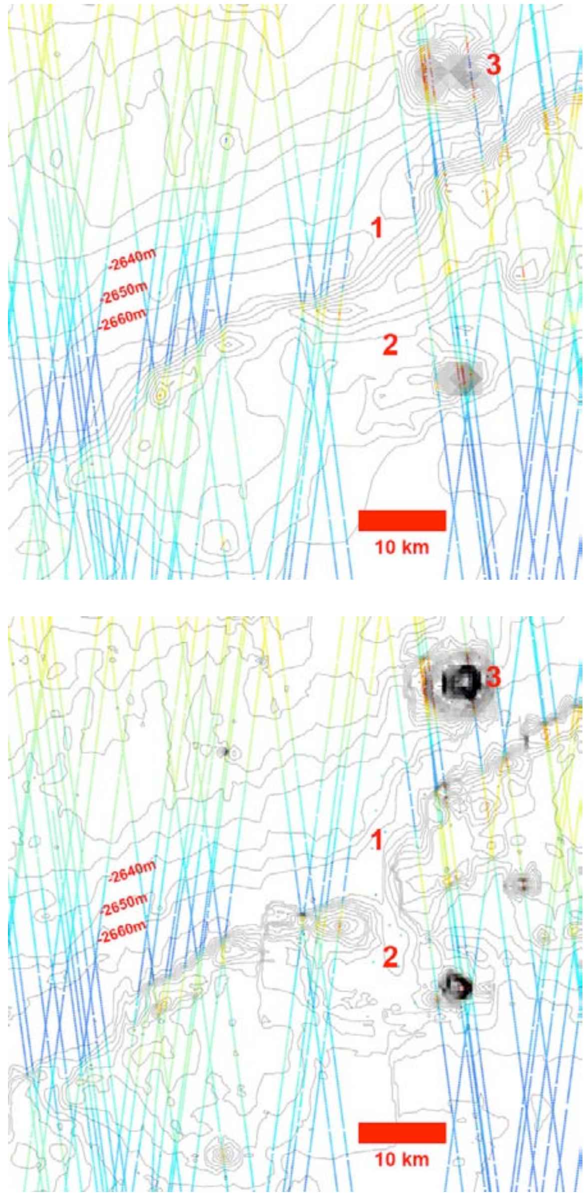

Figure 1. Raw and edited MOLA DEMs. Central Athabasca Valles. Lines of colored dots show real and edited MOLA shots. Colors change at 20 m elevation intervals, North is up, 10-m contour interval. Examples of serious artifacts: (1) ridge perpendicular to flow in what is actually a continuous channel, (2) absence of a real distributary channel, and (3) fictitious breach into an impact crater. Each obvious artifact can be corrected by manually adding 3-5 simulated MOLA shots. Elevations are chosen (i.e., guessed) using THEMIS IR images and the real MOLA elevations as guides.