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Hydraulic modeling of the tributary and the outlet of a Martian paleolake

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Abstract

This contribution presents the results of a detailed hydraulic study of the tributary and the outlet of a Martian paleolake located in the Memnonia quadrangle between 167°0'0"W and 167°20'0"W longitude and between 9°25'0"S and 9°45'0"S latitude [1] (Fig. 1). We used an hydraulic model capable of performing one-dimensional water surface profile calculations for steady gradually varied flow in natural channels adapted to the Martian conditions (e.g. martian gravity equal to 0.38 Earth's) [2]. Geomorphic evidences, i.e. fluvial terraces, were used to identify the probable bankfull level of the tributary and the outlet [2,3,4]. The identified terracing levels were used to constrain the past water discharge flowing on the surface, the Manning's roughness coefficient of the channels and the water level of the paleolake. The Mars Express high-resolution stereo camera digital elevation model, HRSC DEM, H31850000DA4, presents a spatial resolution of 75 m and it was used to characterize the geometry of the channels, i.e. their cross sections and the fluvial terraces elevation. The outlet and the tributary reaches are 10.0 km-long and 22.2 km-long, respectively. Fifty-one cross-sections along the outlet were extracted from the DEM and were used to characterize the geometry of this river-reach in the hydraulic model, whereas the hydraulic model of the tributary is composed of 111 cross sections. The mean distance between cross sections is Δx = 200 m. Fig 1 shows the upper and the lower cross sections for both the outlet and the tributary studied through the above mentioned hydraulic model.
Note that the water surface profiles are computed from one cross section to the following one by solving the Energy equation through an iterative procedure called the standard step method [5]; where the energy equation is not considered applicable, we computed the water level by using the momentum equation [5].
The steady state water profile computations were applied on the outlet and on the tributary separately. For each river reach, 5000 flow rates (Q) and Manning's roughness coefficients (n) were sampled from two uniform distributions, and consequently inserted into the hydraulic model. The lower and upper limits of the roughness coefficient (adapted to the Martian gravity) have been chosen following [2,4]. The downstream boundary condition used in the hydraulic model is the normal depth based on the average bed slope. The identified terracing levels were used to constrain the water discharge and the roughness coefficient. The "best estimate" we derived, is the flow

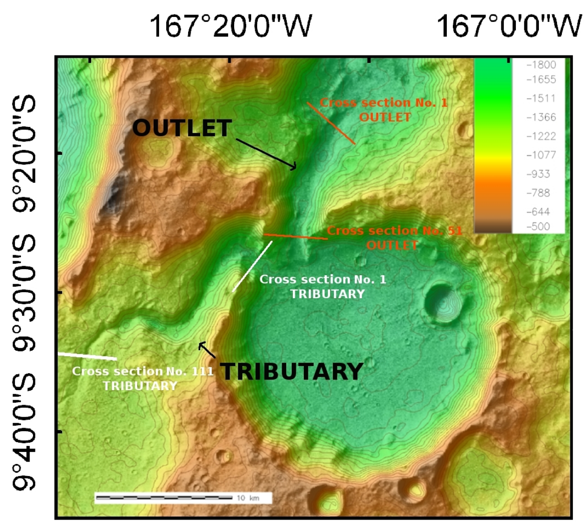

Figure 1: Context map of the case study area showing HRSC H3185000DA4 DEM elevation values in meters, the latitude and longitude grid and a scale bar reference. The upper and lower cross section of the outlet (red) and the tributary (white) are marked.

profile that has the minimum root mean square error fitting the bankfull levels. The bound of uncertainty in the bankfull level is defined by the 95 percentiles of the bankfull levels around a "best estimate" flow profile. The relative frequency of the most probable discharge and roughness coefficient were derived (Fig. 2 and 3). The results reveals a good agreement between the distribution of the plausible discharges and Manning's roughness coefficients computed both for the outlet and the tributary, presenting median discharges equal to $\overline{Q}_{OUTLET}$ = 3 699 $m^3 s^{-1}$ and $\overline{Q}_{TRIBUTARY}$ = 3 523 $m^3 s^{-1}$ and the Manning's coefficient equal to $\overline{n}_{OUTLET}$ = 0.074 $sm^{-1/3}$ and $\overline{n}_{TRIBUTARY}$ = 0.075 $sm^{-1/3}$). The distribution of the water elevation at the last cross section of the outlet (i.e. cross section No. 51) point out a median value of $\overline{Z}_{OUTLET}$ = -1400 m. This value is consistent with the elevation of the lowest lacustrine terraces found into the lake [1].

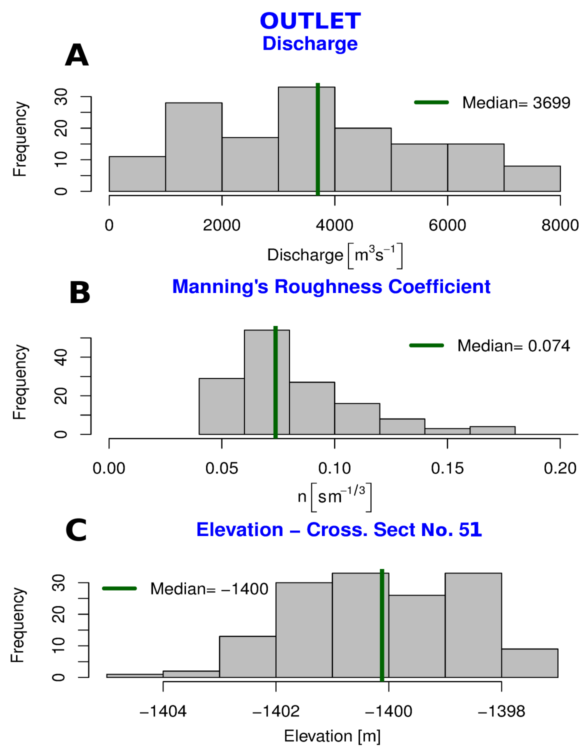

Figure 2: Outlet - Frequency distributions of the discharges and the Manning's roughness coefficients that are consistent with the assumed bankfull levels (Fig A and B). Fig. C shows the frequency distribution of the elevation of the water computed at the cross section No. 51.

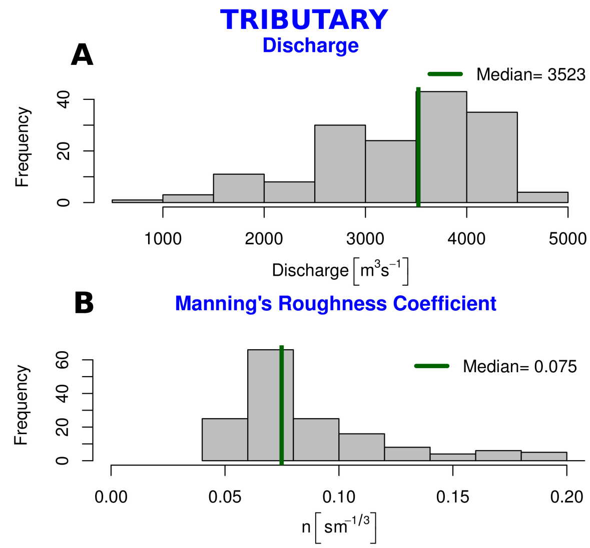

Figure 3: Tributary - Frequency distributions of the discharges and Manning's roughness coefficients that are consistent with the assumed bankfull levels (Fig A and B).

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