HYDROLOGICAL PARAMETER EXTRACTION AND ANALYSIS OF MANGALA VALLES OF MARS.
Praveen K. Thakur1, Ashutosh Bhardwaj1, and Aggarwal S.P1. 1Water Resources Division, Indian Institute of Remote Sensing – Dehradun, 248001, NRSA-ISRO, India. Corresponding author: praveen@iirs.gov.in.

Introduction: Mars is the only planet/satellite, other than Earth, for which there is evidence that liquid water has been abundant at the surface. There is strong resemblance between the Martian outflow channels and large terrestrial flood channels [2, 3]. Based on analysis of channel dimensions and slope, the discharge ranging from $10^7 \text{ m}^3/\text{s}$ for some smaller channels of around Chryse Planitia to $3 \times 10^9 \text{ m}^3/\text{s}$ for Kasei Vallis has been found for outflow channels of Mars [2].

Mangala Valles Flood channels: Mangala Valles of Mars are one of the large Martian channels which have been carved by historic catastrophic floods. This area falls in Mars chart 16, Memnonia region. The high resolution view (fig.2), of MOC narrow angle image (MOC-NA-M1101809) shows that surface mesa tops, buttes, and channel floor are all covered-up with a thick blanket of wind-eroded, ridged and grooved material. Some of the buttes and mesas have boulders on their surfaces, and wind has hollowed-out circular depressions around these boulders (MSSS 2001) [3].

Data Sources and Visualization: The MGS mission carried MOLA, which has given elevation of the order of 30m per pixel for the Mars. This study uses the 128 pixels/deg or 463 m/pixel MOLA data as processed by USGS astrogeology and planetary GIS group. [4]. The MDIM 2.1 based map of MC-16 with 231.54 m/pixel is used as base map for photographic visualization of terrain. Terrain visualization and hydroprocessing of Mars has previously been done in detail by Peter Dorninger et al 2002 based of HRSC and MOLA DTMs for valley mariner and kasei valley network of mars [5].

Hydroprocessing of MOLA DEM: This study has made an attempt to extract the major drainage lines of Mangala Valles using MGS-MOLA digital elevation model and GIS based hydrological processing tools. The ILWIS 3.3 software was used to derive the basic hydrological parameters. The Arc info Grid data of MOLA was masked and imported in ILWIS. A new coordinate system “Equidistance Cylindrical” was defined, with sphere radius of 3396190m for further processing of DEM. The raw DEM was than processed to remove no flow condition using fill sinks operation. Fill sinks operation 'removes' local depressions (of single pixels and of multiple pixels). Fig. 2 show processed DEM of Mangala Valles. This filled DEM was than used to find flow direction and flow accumulation maps of Mangala region.

Fig. 1: Mangala Valley near 8.7°S, 151.2°W; Source: MSSS/JPL/NASA
The dark streaks on slopes as in fig. 1 are places where dry accumulations of “dust” or possible “water” through groundwater sapping process have slid downhill, much like a “snow avalanche”. Similar streaks have been seen elsewhere on the dusty surfaces of Mars, and some have been found to change over time.

Fig. 2: Filled DEM of Mangala valleys
**Flow Direction Map:** The filled DEM was then used to find the flow direction map using standard D-8 algorithm [1]. Flow direction is calculated for every central pixel of input blocks of 3 by 3 pixels, each time comparing the value of the central pixel with the value of its 8 neighbors. The output map contains flow directions as N (to the North), NE (to the North East), etc. The steepest slope method was used for this study to find the steepest downhill slope of a central pixel to one of its 8 neighbour pixels and assign to flow directions.

**Flow Accumulation Map:** The processed flow direction was then used as base map for calculating the flow accumulation map of mangala valleys. The flow accumulation map contains cumulative hydrologic flow values that represent the number of input pixels which contribute any water to any outlets; the outlets of the largest streams, rivers etc. will have the largest values. We have found minimum of 1 and maximum of 12779736 pixels values for computed flow accumulation matrix.

**Stream Network Extraction and Ordering:** The flow accumulation matrix map was used for the extraction of stream network map with threshold value of 9000 pixels. The extracted stream network matches with MDIM 2.1 base map of same region, as shown in fig. 3. The DEM shadow base map was created in three steps in ILWIS. First three shadow maps are created using the shadow filters Shadow W (West), Shadow (North-West) and Shadow N (North). The three shadow maps are stretched using linear stretching, ignoring 5%. The color composite is than created from these stretched shadow maps which is a 24-bit color composite with linear stretching. Finally, temporary raster maps are removed, and the output color composite map is shown.

Finally the stream statistics were generated using the derived stream maps. The morphometric parameters such as upstream and downstream elevations, Strahler and Shreve stream order, sinuosity, stream length, and slope along stream were calculated. The plot of Strahler stream order and stream length is given in fig. 4. It is evident form the figure that this region has well defined geomorphic features with stream length of 1st order streams varying from 10 km to 700 km, and 5th order streams with length varying from 10 to 200 km.

**Discussions:** The terrain visualization and Hydrological processing has been completed for one of outflow channels of Mars using standard GIS operations. This study can further be improved by incorporating the higher resolution DTMs of Mars. Future work will involve simulation the paleo-flood at the mangala valleys. The basic Saint-Venant’s equation of unsteady flood flow and Manning’s roughness coefficient will be modified to take into account the gravity and regolith properties of Mars.