Editing a Digital Elevation Model to Achieve a Correct Stream Network: An Application to Kalu-ganga River in Sri Lanka

***Nandalal HK and Ratnayake UR**
Department of Civil Engineering, Faculty of Engineering, University of Peradeniya
*Corresponding author; e-mail: hemalin@pdn.ac.lk

Abstract: Modelling a watershed accurately is an important step in water resources management. Geographic Information Systems (GIS) together with mathematical models have made modelling watersheds an easy task. Digital Elevation Model (DEM) is a primary data set necessary to model a watershed. DEMs are developed using many methods and DEMs developed from remotely sensed data are the cheapest. Some of them are freely available on-line. In modelling watersheds, it is a common practice to delineate the stream network from a DEM. Matching of the delineated stream network with the natural stream network will depend on the accuracy of the DEM. Some hydrologic models contain built-in functions to edit DEMs to overcome this problem. Hydrologic model, HEC GeoHMS, contains such a function to edit DEM as required by the user. To edit the DEM it is necessary to have the exact stream network to compare with the delineated network. In this work, Kalu-ganga River stream network was delineated using a DEM available freely on-line and it was compared with the natural stream network of Kalu-ganga River digitized from 1:50,000 maps produced by the Department of Survey. Then the DEM was edited using the HEC GeoHMS model to achieve the desired stream network.

Key words: Geographic Information System, Modelling, Watersheds

1. Introduction

During the last several decades, the application of computers in planning and operation of water resource systems has rapidly become an important field of research. Recently, Geographic Information System (GIS) has gained much attention in many research fields including research in water resources, wherein the research outputs can be displayed in a way that could be easily understood. In the field of water resources planning and management, mathematical models are important tools to provide insight into water resources problems. Application of these models could benefit from the spatial analysis and display capability of GIS while GIS could benefit from the capability of mathematical models. Combining the strengths of each will result in more powerful tools for the planning and management of water

Nandalal HK, BSc. Eng. (Hons) (Peradeniya), MSc. (The Netherlands), CEng., MIE(SL), Lecturer, Department of Civil Engineering, University of Peradeniya.
Rathnayake UR, BSc.Eng.(Hons) (Peradeniya), MEng. (AIT), DEng(AIT), CEng., MIE(SL), Senior Lecturer, Department of Civil Engineering, University of Peradeniya.

resource systems.

The increasing availability of spatial data in electronic format and GIS software to manage and prepare spatial data has led to a renewed interest in the use of hydrological models. Also, this growth generates new questions with respect to the source, accuracy, storage requirements, and applicability of spatial data (Garbrecht et al., 2001). Therefore, it is of paramount importance to learn to edit such data to fit to the local environment. Digital Elevation Model (DEM) is such GIS based data used to interpret the topography of the earth surface.

This paper presents how to incorporate the spatial analysis capabilities of GIS into hydrologic modelling of a watershed. It presents how a DEM can be edited to delineate a stream network that matches with the natural stream network using HEC-GeoHMS.

2. Methodology

Watershed modelling requires a large set of spatial and temporal data. Topographic data are crucial for hydrologic modelling and it is better to use recent and highly accurate topographic data. In practice, however, the availability and quality of these data are often an issue one needs to cope with. Financial constraints also come up when the researches are carried out in developing countries.

2.1 Study Area

Kalu-ganga River is still an untamed river compared to the other rivers in Sri Lanka, though it captures a large portion of the rainfall and drains freely to the Indian Ocean at Kalutara. Total catchment area is 2719 km^2 and entire basin lies within the wet zone. Average annual runoff is around 7600×10^6 m^3. Lower catchment experiences an average annual rainfall of 4000 mm. It varies from 2800 mm the lower reaches to 5300 mm in higher elevations. Lower catchment from Ratnapura to Kalutara experiences floods due to Monsoon rains and depressions. Geographically, it lies between the 6.32° and 6.90°N, and 79.90° and 80.75°E as per WGS84 coordinate system and flows from a height of about 2250 m MSL.

Tributaries of the Kalu-ganga River collect the first drops of water from Sri Pada and Sinharaja virgin rainforests and quickly drain from its upper catchments. The rainfalls onto the Sri Pada rainforest flow through a length of 36 km from an elevation of 2250 m MSL to 14 m MSL at Ratnapura town. There onwards the Kalu-ganga River travels through a comparatively flat terrain from 14 m MSL to sea level through a distance of about 70 km collecting the water flowing from the Sinharaja rainforest, which causes the floods from Ratnapura onwards.

2.2 Digital Elevation Model (DEM) Used

DEMs are developed from contour maps or remotely sensed data. DEMs developed from contours are found to be more accurate than DEMs developed using remotely sensed data. However, DEMs developed from contours are very expensive when compared with DEMs developed using remotely sensed data.

DEMs developed from remotely sensed data are freely available in several web sites. DEM data sets for developed countries are available in high resolution, i.e. as 3 m (Sanders, 2007). However, DEM data sets, which include Sri Lanka, are available in 3 arc second (approximate grid size of 90 m) resolution or coarser resolutions.

The Shuttle Radar Topography Mission (SRTM) DEM (Jarvis et al., 2008) data, which is feely available is used in this study.

2.3 Real Stream network

The stream network that exists in a particular area in the real world has to be viewed in GIS. In order to achieve this, the stream network of the river has to be taken from maps. The existing stream network of the Kalu-ganga River was digitized using 1:50,000 maps. Initially, the maps in the river basin were scanned and geo-referenced. Then the stream network was digitized as a line feature in vector file format, which was used to verify the delineated stream network from DEM.

2.4 Method

Arc View with HEC-GeoHMS (USACE-HEC, 2006) extension was used for the delineation of the stream network. Stream network delineated was compared with the natural stream network and the places where modifications needed were identified. Then a line shape file was created and lines were introduced where fencing (increasing the height of grid cells) or burning (decreasing the height of the grid cells) of the DEM were required. Using this shape file and the DEM the terrain preprocessing program was run to edit the DEM. As the next step, the stream network was delineated using the edited DEM and compared with the natural stream network. This process was repeated until the stream network delineated matches with the natural stream network. It was not possible to burn and fence at the same time. Therefore, one should run the program repeatedly to burn and fence the DEM as required.

2.5 Comparison of the stream networks

The two stream networks were compared using the overlay analysis of GIS.

3. Results

When the raw DEM was processed, several mismatches were occurred between delineated stream network and natural stream network (Figure 1) after Nandalal and Rathnayake (2008).

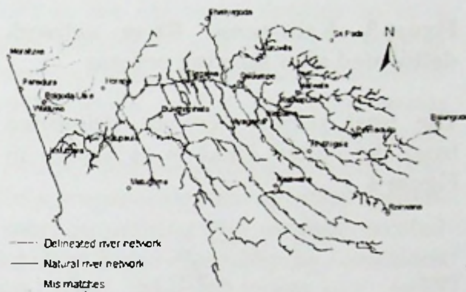

Figure 1. Comparison of the delineated stream network with the natural stream network

The line shape file developed to edit the DEM overlaid on the natural stream network is shown in Figure 2.

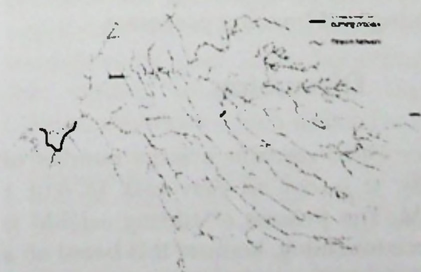

Figure 2. Linemap used to edit the DEM

Delineated stream network using edited DEM almost agrees with the natural stream network (Figure 3). However, a stream that was not connected to the Kalu-ganga River according to the natural stream network was observed near the river mouth. This was also eliminated by fencing using a line shape file (Figure 3).

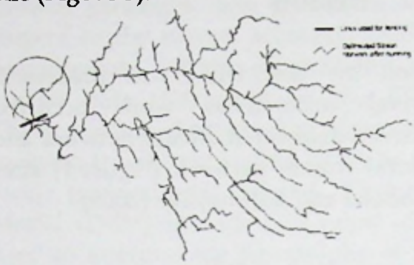

Figure 3. Kalu-ganga River network delineated after burning process

The final stream network delineated from the edited DEM is as shown in Figure 4.

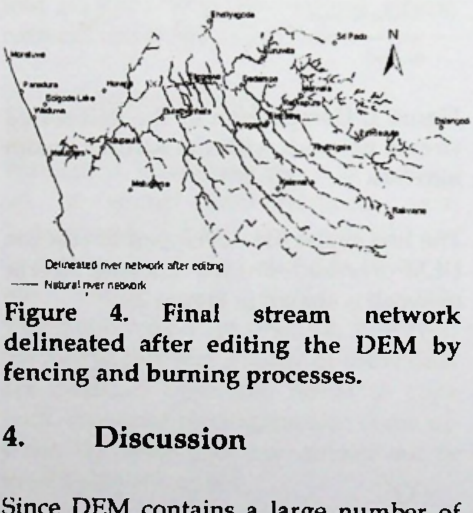

Figure 4. Final stream network delineated after editing the DEM by fencing and burning processes.

4. Discussion

Since DEM contains a large number of grids, it is not an easy task to edit a DEM. The process of editing a DEM is time consuming, because it is based on a trial and error procedure. Once the accurate DEM is achieved, it can be used in further analysis of the watershed successfully.

5. Conclusions

According to the results of this study, when the DEM generated stream network does not totally match with its natural network, it can be corrected using the facilities available in modern software. The results show that an edited DEM can be used to generate the stream network that totally agrees or matches with the natural stream network.

Initially, a comparison of the DEM generated stream network with the actual stream network is essential before further application of the DEM for the modelling of watersheds as it is important to use the actual stream network in real world water resources management.

References

Garbrecht, J., Ogden, F. L., DeBarry, P. A. and Maidment D. R. (2001) GIS and Distributed Watershed Models. I: Data Coverages and Sources, *Journal of Hydrologic Engineering*, 6(6), pp.506–514.

Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2006, Hole-filled SRTM for the globe Version 3, available from the CGIAR-CSI SRTM 90m Database: http://srtm.csi.cgiar.org.

Nandalal, H.K. and U. Ratnayake (2008), "Verification of a delineated stream network from a DEM: Application to Kalu-ganga River in Sri Lanka", Proceedings, The fifth National Symposium on Geo-Informatics, Colombo, Sri Lanka, pp. 187

Sanders B. F., 2007. Evaluation of on-line DEMs for flood inundation modelling. Advances in Water Resources, 30, pp.1831-1843.

United States Army Corps of Engineers, Hydrologic Engineering Center (USACE_HEC). (2006). Hydrologic modelling system HEC-HMS technical user's manual, Davis, California.