Streamflow Analysis using GIS Techniquesand HEC-GeoHms

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Abstract:*In the few last year's devastating flash floods descending downstream through valleys have occurred in East Nile Locality-Sudan. A flash flood can be caused by intense rain, particularly when it takes place in a saturated area where rain has previously fallen. Under these conditions the additional rain runs off over the surface and accumulates in streams and channels at a much accelerated pace. Runoff is the one of the components consists of water cycle and useful water resources to stand human life. The aim of this study is to estimate analysis and predict the runoff to make stable water use and flood control. Haseeb, Soba, Green, Kabbashi and Selait Valleys (East Nile Locality-Sudan) selected as study area. Various raster and feature class data were used for computing Hydrologic parameters and used in estimating runoff Soil Conservation Service. Transformation was adopted for calculating runoff and Muskingum method were chosen for loss method and routing method. The runoff model was created and the annual runoff for streams was calculated. The simulated runoff values can be used for flood control and flood damage estimation studies.*

Keywords:*Flash Flood, HEC-HMS Model, Soil Conservation Service, GIS*

I. INTRODUCTION

Water is one of the main requirements for healthy plant growth. Most arid and semi-arid regions, suffer from insufficient and unreliable rainfall. A high rate of evaporation in the growing season is also common. When it rains in semiarid areas, the rain- storms are usually heavy. The prevailing soils generally cannot absorb the amount of the water which falls in such a short time. As a result, rainfall in semiarid areas is often accompanied by a large amount of surface runoff.A flash flood is, in short, a sudden local flood of great volume and short duration which follows within a few (usually less than six hours) of heavy rainfall, or due to dam or levee failure [1, 2].The flash flood management plan it is very important to face the large problem. Remote sensing and GIS technique has successfully established its application in following areas of flash flood management such as flood inundation mapping, Flood plain zoning and river morphological studies can provide great capabilities in creating suitable data and models for best decision making [3,4,5,6,7,8,9,10, 11].

Intensive utilization of GIS and RS augmented with other environmental data will help in monitoring of environmental hazards in the affected area. The aim of this paper is to estimate discharges for the natural drains that affect the study area and identify of the catchment areas routes by building runoff model and calculating annual runoff stream in the study area.

I.1 NEGATIVE IMPACTS OF FLASH FLOOD
I.1.1 Residential areas

Housing, schools, hospitals and public facilities etc. are affected by the flash floods, causing loss of properties, lives and the displacement of the population that impacts negatively social, health, economic and psychological aspects among residents of the area [3, 4].

Severe effects are caused to the road layers that lead to collapse of surface layer (asphalt layer) and washing away several meters of the road, disabling the transportation system (i.e. residents and commercial transportation). (Fig. 1)

Fig.**1:** Washed away Highways

I.1.2 Environmental

Stagnant waters left after the floods form shallow ponds within and around the residential areas, mixed with pit latrines waste water and garbage dumps infusion; flood water becomes a good environment for breeding of mosquitoes, flies and microbes that cause diseases and like malaria, typhoid, cholera etc. (Fig. 2)

Fig. 2: Water mixed with garbage dumps infusion

I.1.3 Agricultural areas:-

The infrastructure of Irrigation schemes and farms such as canals, hydraulic structures, pumping stations and cultivable fields are damaged.

I.1.4Grazing land and soil:-

Grazing routes are interrupted as well as lead to animal deaths.Soil degradation may also be caused within steep streams. Therefore to reduce the above mentioned consequences reviewing the technical side of the problems makes it an absolute necessity to conduct water harvesting multipurpose environment friendly projects study for the natural drainage system that causes the catastrophe.

II.   METHODOLOGY

II.1 Study area

The study area consists of East-Nile and Bahri localities in Khartoum state and north east Gezira state, and the catchments of the natural streams that flow through them, between latitudes (16°40'59"N-14°50'26"N) and Longitudes (34°38'52"E- 32°05'23"E) as in (Fig. 3).
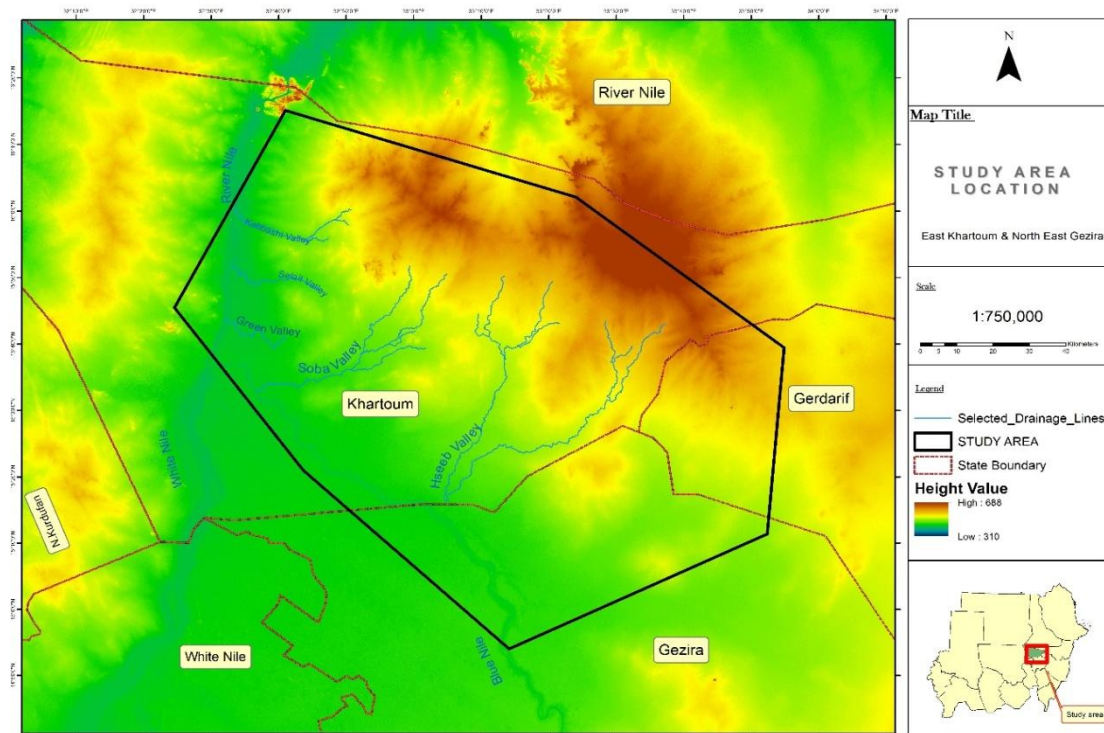
Fig 3 : Study Area

II.2 Data and Material

The soil, landuse, terrain model and Intensity Duration Frequency curve (IDFC) was collected from Ministry of Water Resources and Electricity in 2014. The rainfall data (listed in table 1) was collected based on the hydrologic event periods.

Table 1 shows the hydrologic event periods. Under these periods rainfall data were collected

Event Periods
Aug-03-1988 ~ Aug-10-1988
July-20-1999 ~ Aug-10-1999
July-20-2010 ~ Aug-27-2010

Different software were been used such as ArcGIS, Arc hudro, Hec-GeoHMS, Hec-HMS and ERDAS Computing loss, hydrograph, routing methods are included to estimate runoff. Among several methods to proceed the rainfall-runoff calculation SCS loss method, SCS hydrograph, and Muskingum routing methods were adopted. These above methods essentially need parameters which can reflect the spatial and geomorphologic information to execute the runoff estimation. Hydrologic parameters were computed through ArcGIS, Arc Hydro, HEC-GeoHM and HEC-HMS to provide runoff model.

II.3 Computing SCS Curve Number (CN) in GIS

Landused data was reclassified and converted to polygon. Soil database table and landuse table were combined through union process then CN value was computed from them. CNLookup table was created to give index for relating land use and soil data with CN.

II.4 Unit HydrographMethod

The Purpose of unit hydrograph is to generate the hydrographs for the storm in the hydrologic events periods. SCS unit hydrograph, Snyder synthetic unit hydrograph and Clark Synthetic hydrograph methods are commonly used [12]. This study adopted the SCS unit hydrograph method.

II.5 SCS Unit Hydrograph

SCS Unit Hydrograph was developed by NRCS in the 1950's based on analyses of many unit hydrographs for gagged watersheds in various conditions. Due to simplicity and easy to use SCS hydrograph have been used and applied throughout the United States and the world. The SCS Unit hydrograph only has two

parameters, which are watershed area A and lag time tL. The time to peak TP is estimated as a function of rainfall duration (D) and the peak of the unit hydrograph (Qp) is estimated as follow [12].

$$TP = \frac{D}{2} + tL \dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (1)$$

$$Q_P = \frac{484A}{TP} \dots\dots\dots\dots\dots\dots\dots\dots \quad (2)$$

II.6 Computing Parameters for Unit Hydrograph in GIS

Basin area, channel length, centroid of basin, longest flow path, CN basin lag time, Time of concentration can be computed for the unit hydrograph. These parameters are computed through the HEC-GeoHMS. Before operating HEC-HMS, DEM preprocessing is needed through ArcHydro.

II.7 Archydro Process

DEM preprocessing was executed through ArcHydro, such as Fill sink (Fig. 4), flow accumulation, flow direction, stream definition, Stream Segmentation, Catchment Grid Delineation (Fig. 5), Catchment Polygon, Drainage lineand (Fig. 6), andadjoint Catchment processing.
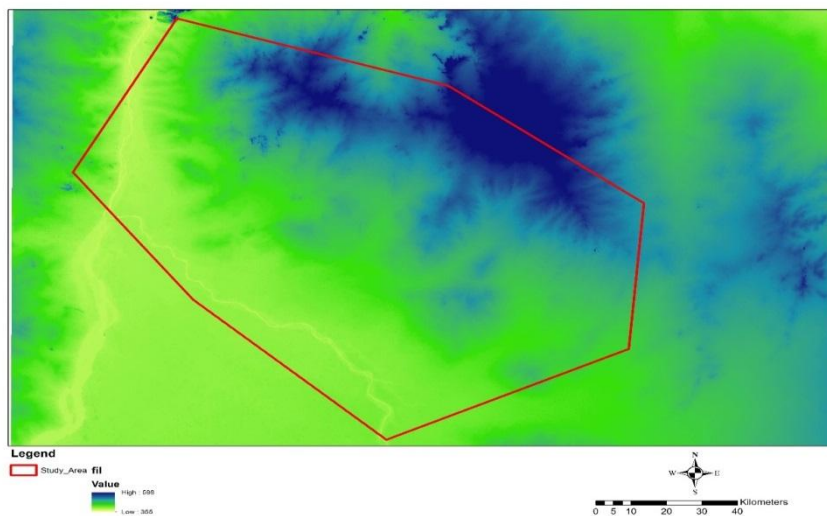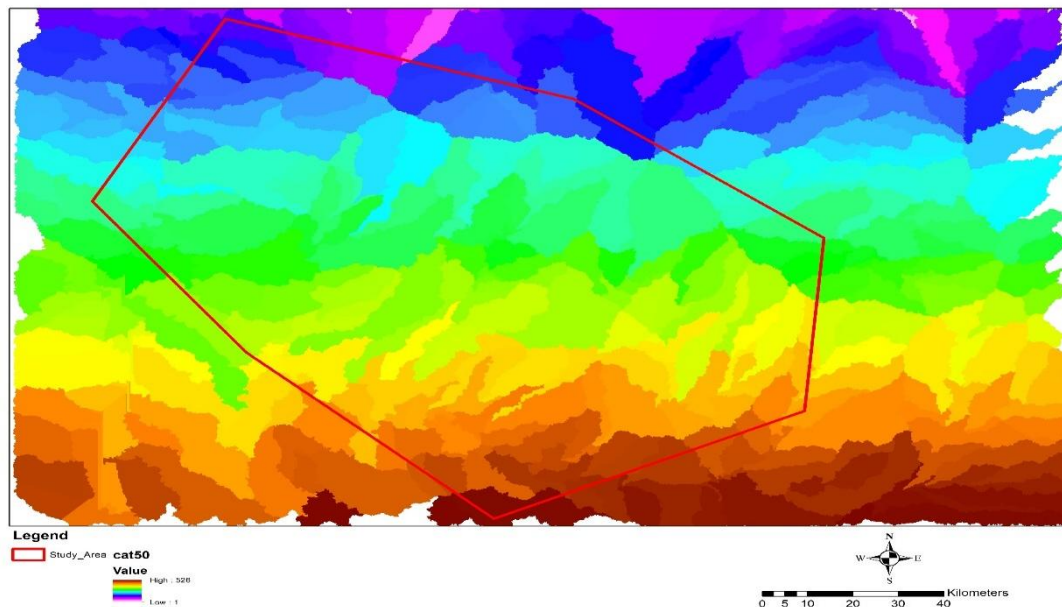

Fig. 4: Fill Sink
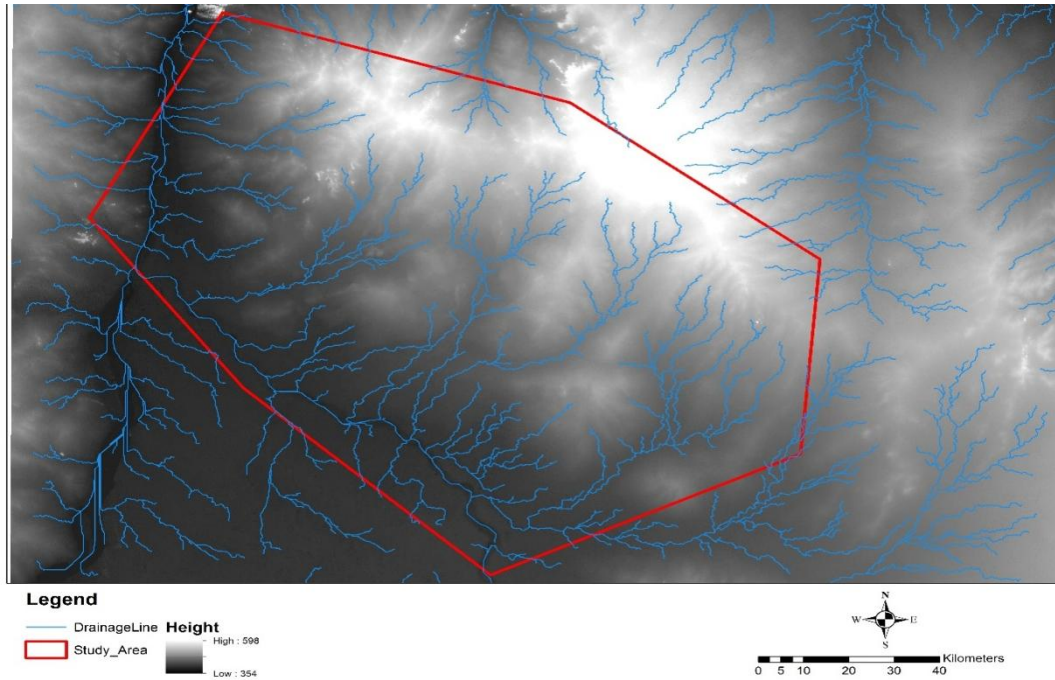

Fig. 5: Catchment Grid Delineation

Fig. 6: Drainage line

II.8 Hec-GeoHMS Process

Basin is divided on the basis of streamflow gage station. To make single subbasin the catchments in the same subbasin is merged.After merge and split of basin river reach can be divided and multi routing can be avoided. River length, basin area, longest flow length centroid of basin were calculated to be used in HMS.

CN Lag time was calculated to be used in SCS transform method in HMS. Using CN Lag time of concentration HMS setting is executed. HMS setting assign the loss method, transform method and routing method will be used in HMS and generate the HMS schematic, such as river reach, junction and subbasin as presented in (Fig. 7 and Fig 8).
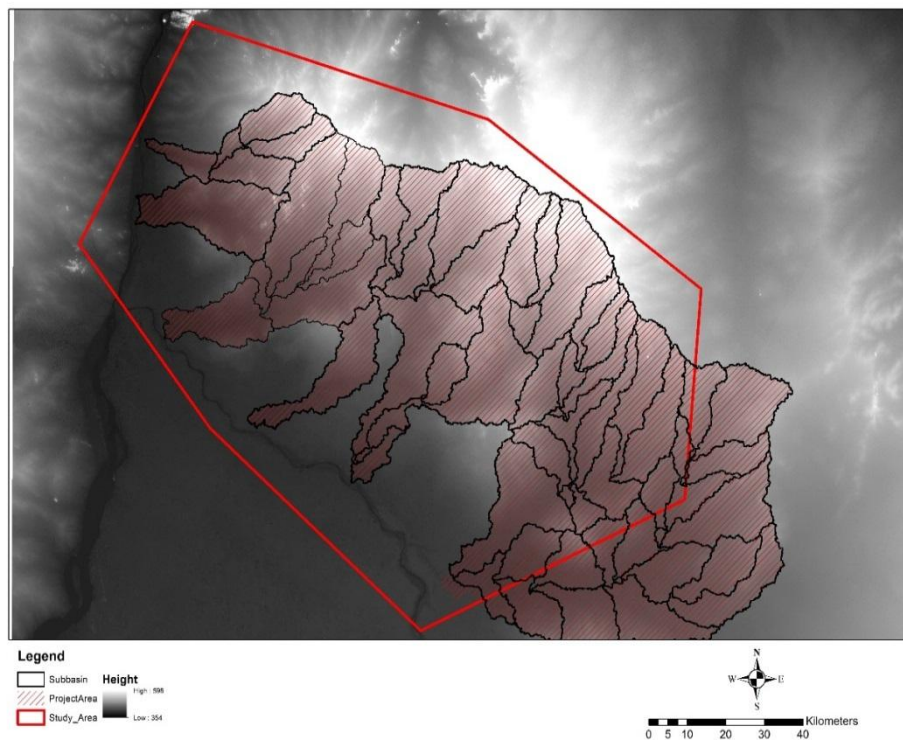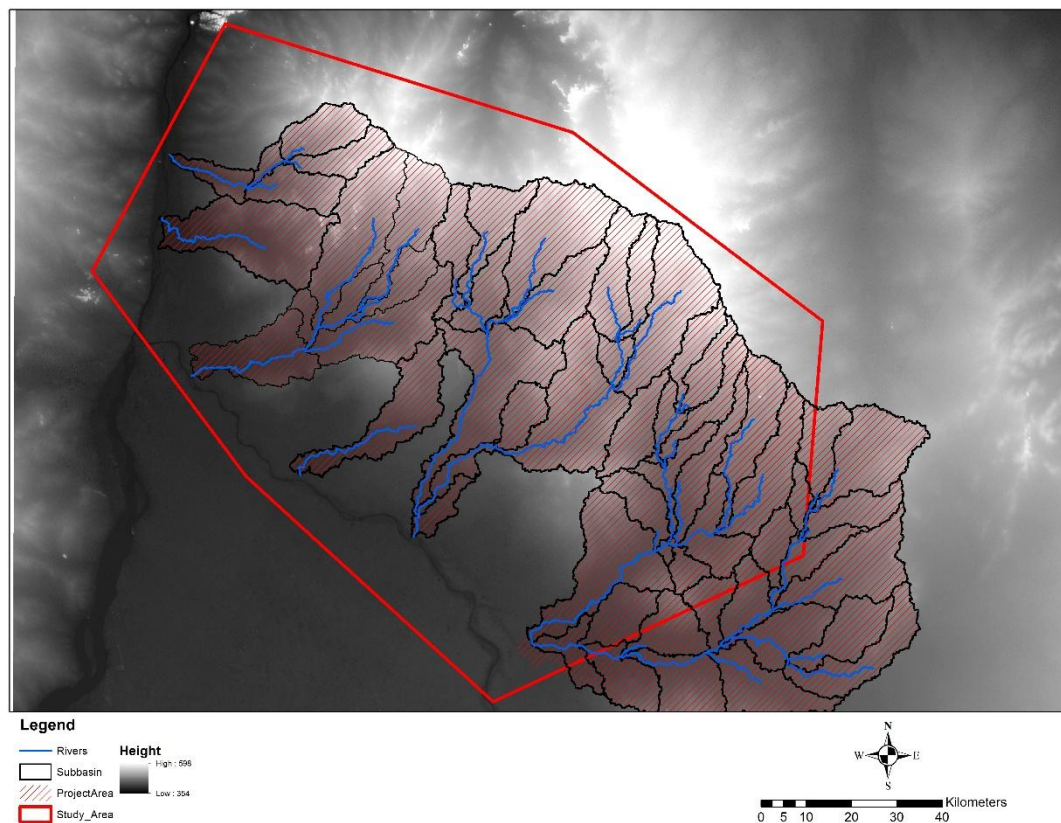

Fig. 7: Generated Subbasins

Fig. 8 Generated Rivers

III. ROUTING METHOD

Routing is procedure to predict the changing magnitude, speed and shape of flood wave as s function of time at the points along the watercourse. Routing is classified into lumped and distributed. Hydrologic routing belongs to the lumped routing and Hydraulics routing belongs to distributed routing [13]. This study adopted the Muskingum routing method of hydrologic routing method.

III.1 Muskingum River Routing

Muskingum routing is based on the storage-outflow relationship and relates the storage to both inflow and outflow [13]. Muskingum routing method is represented as follow

$$S = K (XI+ (1-X) O \ldots\ldots\ldots\ldots (3)$$
$$O_2 = C_1I_2 + C_2I_1 + C_3I_1 \ldots\ldots (4)$$

Where, S is storage, I is inflow,O is outflow, t is travel time, k and x is constant

$$C_1 = \frac{0.5\Delta t - Kx}{K - Kx + 0.5\Delta t}$$

$$C_2 = \frac{0.5\Delta t + Kx}{K - Kx + 0.5\Delta t}$$

$$C_3 = \frac{K - Kx - 0.5\Delta t}{K - Kx + 0.5\Delta t}$$

$$C_1 + C_2 + C_3 = 1$$

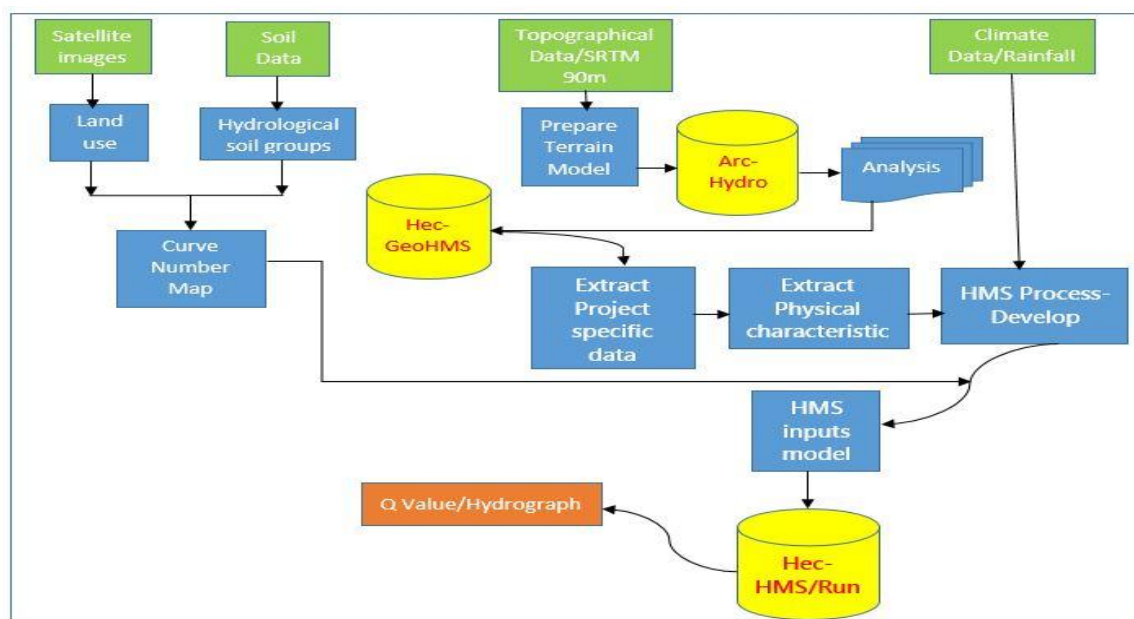The flowchart of the methodology was summarized in Fig. 9

Fig. 9: Flowchart of the Methodology

IV.   RESULT AND DISCUSSION

Runoff of Valleys was finally estimated using HEC-HMS. All parameters needed for the HMS were computed through, ArcGIS and HEC-GeoHMS. The hydrograph of each subbasins and routed hydrograph at each junction were created. This results show the hydrograph of W90 basin located in the downstream of Soba Valley in the periods from Aug.03.1988 to Aug.10.1988. (Fig 9 &10) represents the runoff of SCS transform method and Table 2 represents the summary of Peak discharge and discharge volume.
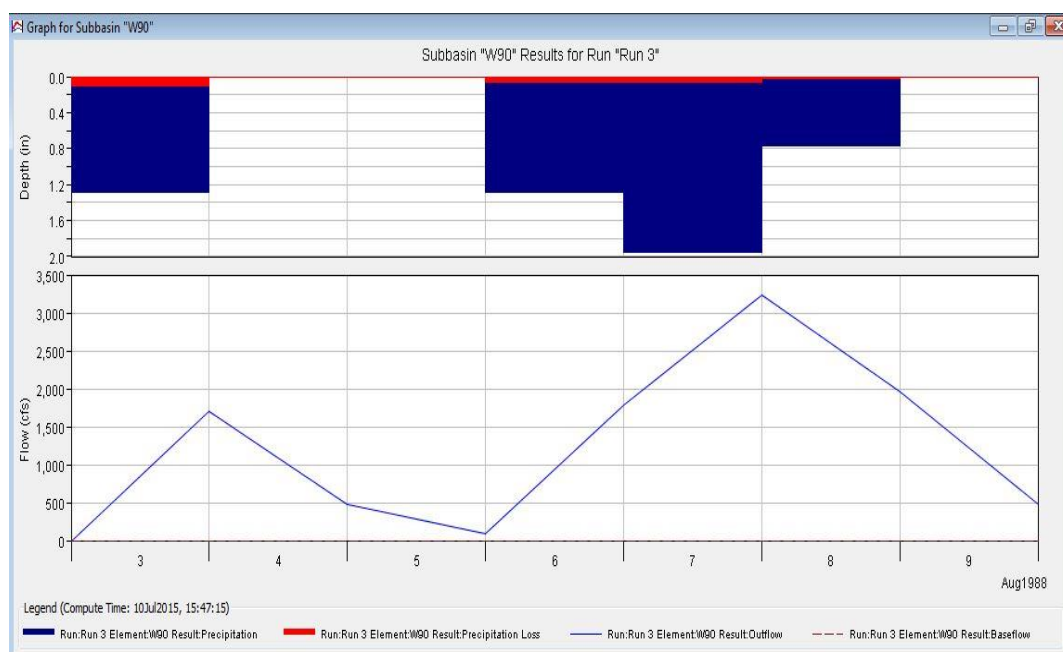

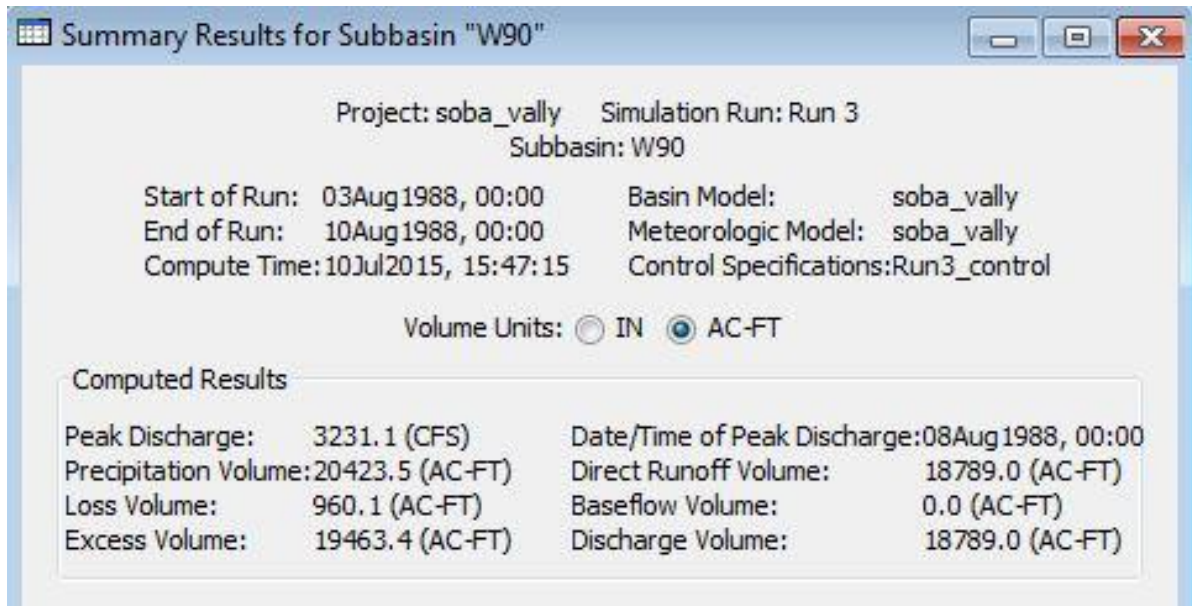Fig 9: Runoff of SCS Transform method

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Summary Results for Subbasin "W90"                    [_] [□] [×]

              Project: soba_vally    Simulation Run: Run 3
                          Subbasin: W90

    Start of Run:   03Aug1988, 00:00    Basin Model:        soba_vally
    End of Run:     10Aug1988, 00:00    Meteorologic Model:  soba_vally
    Compute Time:10Jul2015, 15:47:15    Control Specifications:Run3_control

                   Volume Units: ○ IN  ● AC-FT

    Computed Results

    Peak Discharge:     3231.1 (CFS)    Date/Time of Peak Discharge:08Aug1988, 00:00
    Precipitation Volume:20423.5 (AC-FT) Direct Runoff Volume:      18789.0 (AC-FT)
    Loss Volume:         960.1 (AC-FT)   Baseflow Volume:           0.0 (AC-FT)
    Excess Volume:      19463.4 (AC-FT)  Discharge Volume:          18789.0 (AC-FT)
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Fig.10: Summary of Result

Table 1: Summary of Runoff of W90 Basin

SCS Transform Peak Q (CMS)	91.49
Discharge (AC-FT)	18789.0

V. CONCLUSION

Haseeb, Soba, Green, Kabbashi and Selaitalleys watershed's boundary was defined in ArcGIS 10.1 software using DEM (90m). For rainfall-runoff simulation HEC-HMS model, version 4 was used. To run the model it is necessary to complete sub-models which one of them is watershed loss. For this sub-model, SCS unit hydrograph method was selected. SCS unit hydrograph model is a conceptual model to calculate Rainfall loss in permeable surfaces in a specific period. Initial loss and percentage of impervious surfaces are input parameters in loss Sub-model. Values of curve number (CN) obtained for each sub-basin using raster maps prepared from soil hydrologic groups and land use layer in ArcGIS 10.1 software. Then initial loss values for each sub-basin were determined from CN values. Percentage of impervious surface for each sub-basin determined using Landuse in ArcGIS. To convert excess rainfall to runoff, SCS unit hydrograph method was selected and values of lag time were introduced to the model for each sub-basin. The model was run without base flow

ArcGIS, ArcHydro and HEC-GeoHMS supply efficient and pragmatic environmental to compute Hydrologic parameters which have spatial characteristic. Especially, AcrHydro and HEC-GeoHMS supply easy and straightforward method to treat the raster data for Hydrologic computing.

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