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Production of a Curve Number map for Hydrological simulation - Case study: Kalaya Watershed located in Northern Morocco

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ABSTRACT: The purpose of this study is to apply various techniques and models for catchment delineation, and developing methods to calculate a Curve Number values for the Kalaya river basin located in Northern Morocco, by implementing GIS software (ArcGIS, HEC-GeoHMS), Erdas Imagine and hydrologic modeling (HEC-HMS), in which the estimation of the direct runoff under the scenario with precipitation of 80 mm during the storm event that have occurred between 23 and 24 December 2009. In particular, SCS-CN (Soil Conservation Curve Number) is a model through which the estimation of the direct runoff can be achieved. This method includes several important properties of the watershed such as Hydrological Soil Groups and land use, which will be input for the HEC-HMS model.

KEYWORDS: Catchment delineation, Kalaya River, HEC-HMS model, Soil Conservation Curve Number.

1 INTRODUCTION

The traditional method used to delineate a watershed area from the topographic map takes time and is inaccurate. This method has been replaced by the automatic extraction from a Digital Elevation Model (DEM). The DEM data have been used to derive geomorphic and topographic characteristics such as terrain slope, Elevation, aspect, contour line, hillshade and view shade [1].

A catchment is usually delineated as many sub basins or one single basin using Geographical Information System (GIS) before the use of HEC-HMS model. To proceed the study through the ArcGIS and HEC-GeoHMS, selecting study area and collecting data are needed. These collected data were used in preprocessing in the ArcGIS 9.3 and ArcHydro 9 for computing Hydrologic parameters through HEC-GeoHMS which is capable to generate the watershed's boundary, and acts as an interface between ArcGIS and HEC-HMS software [2].

The HEC-HMS hydrologic model is among the most applicable ones. It has been chosen to estimate and simulate the flow in the hydrological units of the area. Among the different models provided in the HEC – HMS to estimate rainfall-runoff, the method developed by Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA) is one of the most popular methods for estimating the volume and peak rates of surface runoff [3]. To simulate rainfall-runoff for the Kalaya watershed through the HEC-HMS model, SCS Curve Number method was selected as an infiltration part of the model and direct runoff was transformed by US SCS unit hydrograph (UH).

In order to perform rainfall-runoff modeling, various types of information are required. Part of the necessary model input can be provided through processing and analysis of a Digital Elevation Model (DEM) of a selected area, Hydrological Soil Groups, and land use. SCS curve number grid is used by many hydrologic models to extract the curve number for watersheds. It is extracted from the soil type and land use data using HEC-GeoHMS (ArcGIS 9.3 version), which both affect the infiltration capacity of the soil.

2 STUDY AREA

Kalaya basin is located in the southern part of Tangier city in Northern Morocco. The basin is located between 35°38’ and 35°44’ northern latitudes and 5°38’ et 5°47’ eastern longitudes. The area of the basin is 37.3 km2 and the length of the main channel is 20 km with an elevation of 513 m above the mean sea level and a maximum of slope of 35.97°.The Average annual rainfall of the area is 720 mm.

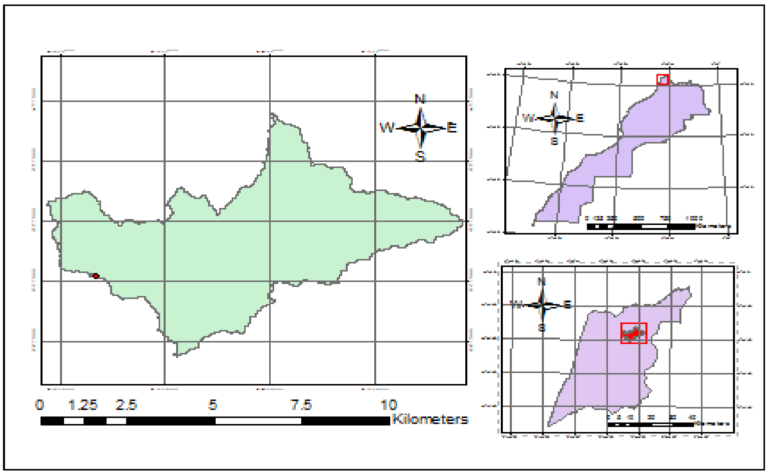

Fig. 1. Geographical position of the studied area

3 DATA PREPROCESSING

ArcGIS 9.3 and Arc Hydro Tools were used for pre-processing the collected data for the study area: ASTER-DEM (The Advanced Spaceborne Thermal Emission and Reflection Radiometer) at a horizontal spatial resolution of 30 meters has been downloaded freely, mosaiced and processed in this study. The land use and Hydrological Soil Group map (HSG) were generated to calculate the Curve Number and for the preparation of rainfall-runoff model by the mean of HEC-HMS.

3.1 DELINEATION OF THE KALAYA WATERSHED FROM ASTER DEM

The extraction of the drainage network of the study area was carried out from an ASTER DEM, in raster format with a 30m*30m grid cell size. Archydro tools in ArcGIS software, version 9.3 (ESRI 2008) was used to extract drainage channels through ArcHydro. The delineation of the watershed is followed by running the following functions (figure 4): Fill , flow accumulation, Flow direction, Stream definition, Stream Segmentation, Catchment Grid Delineation, Catchment Polygon, Drainage line, Adjoint Catchment processing and Drainage point [4].

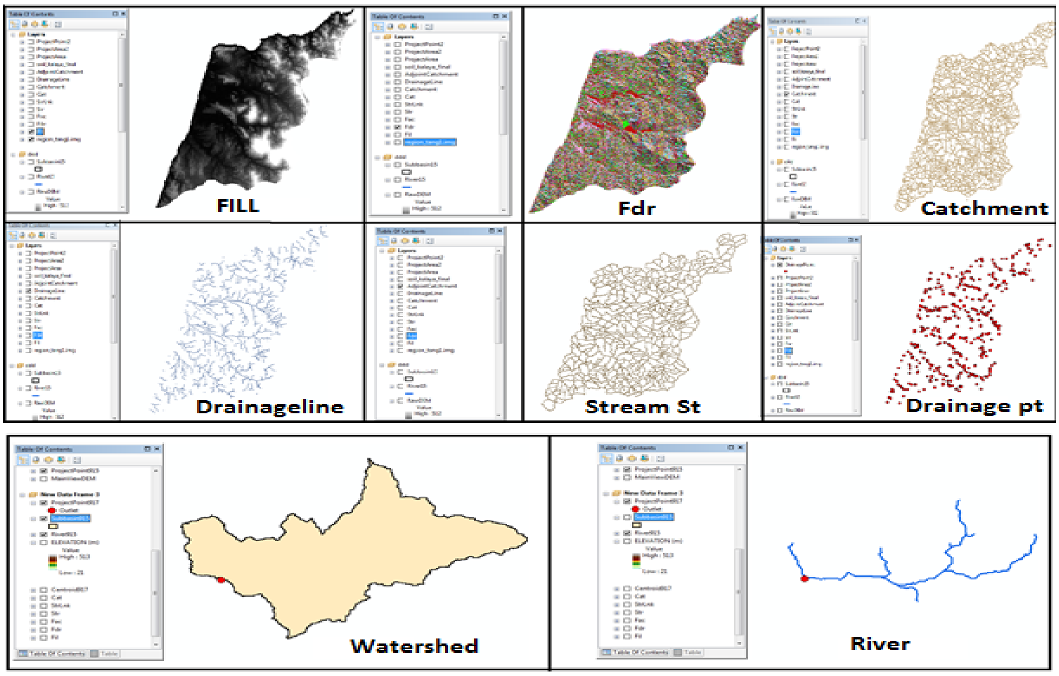

Fig. 2. Some results of Archydro model

Basin area, River length, the average slope value, CN lag time and Curve Number value are resulted from HEC-GeoHMS of US Army Corps Engineering (USACE) [5]. This Computed Hydrological data will be the input parameters of Rainfall-Runoff model in HEC-HMS. The basin characteristics such as the area, length, basin slope, CN Lag and initial abstraction are shown in Figure 3:

Subbasin917

Name	Area	Perimeter	LossMet	TransMet	BasinSlope	BasinCN	LagMeth	BasinLag	InitAbst
W230	37	51	SCS	SCS	8.474816	82.075851	CNLag	2.082715	7.46

Fig. 3. Hydrologic characteristics of kalaya basin from HEC-GEOHMS

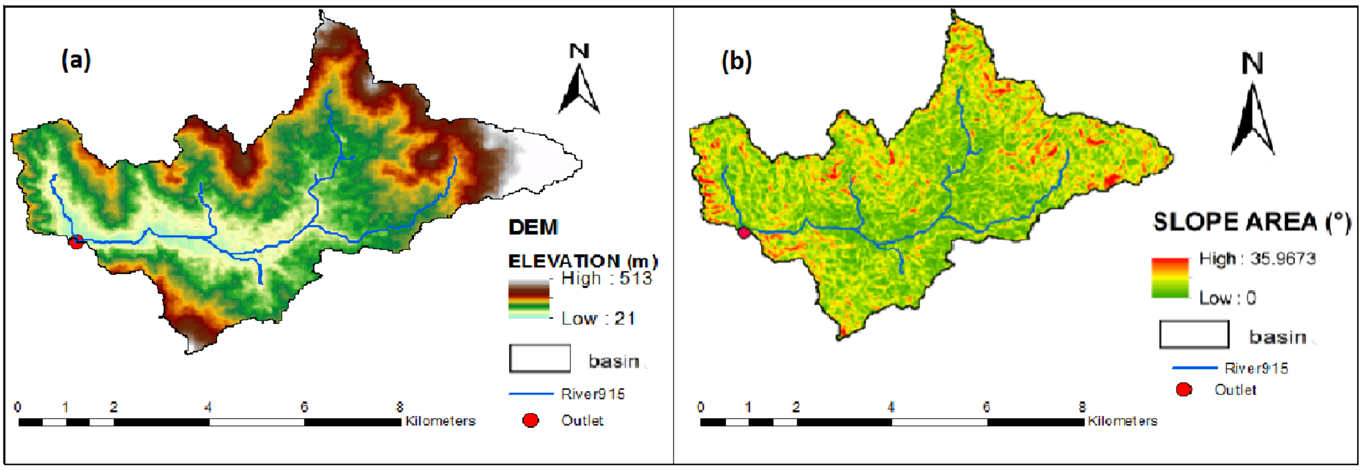

Fig. 4. (a) Topographies map of Kalaya Watershed, (b) Slope Area of Kalaya watershed

3.2 LAND USE MAP

Land use map was generated from Spot-5 image satellite data from 2005 with a resolution of 2.5 m. The supervised classification method with maximum likelihood clustering was employed for image classification through ERDAS 9.3 Software [6]. The Land use identified in watershed is primarily urban, bare soil, agricultural and forest areas. The Kalaya River basin is classified into 4 classes as shown in Table I:

Table 1. Land use classification

Land Use	Surface Area	
	In sq.km	%
Urban	11.465	30.74
Bare soil	7.1154	19.08
Agricultural	4.170	11.18
Forest	14.551	39.01
Total	37.30	100

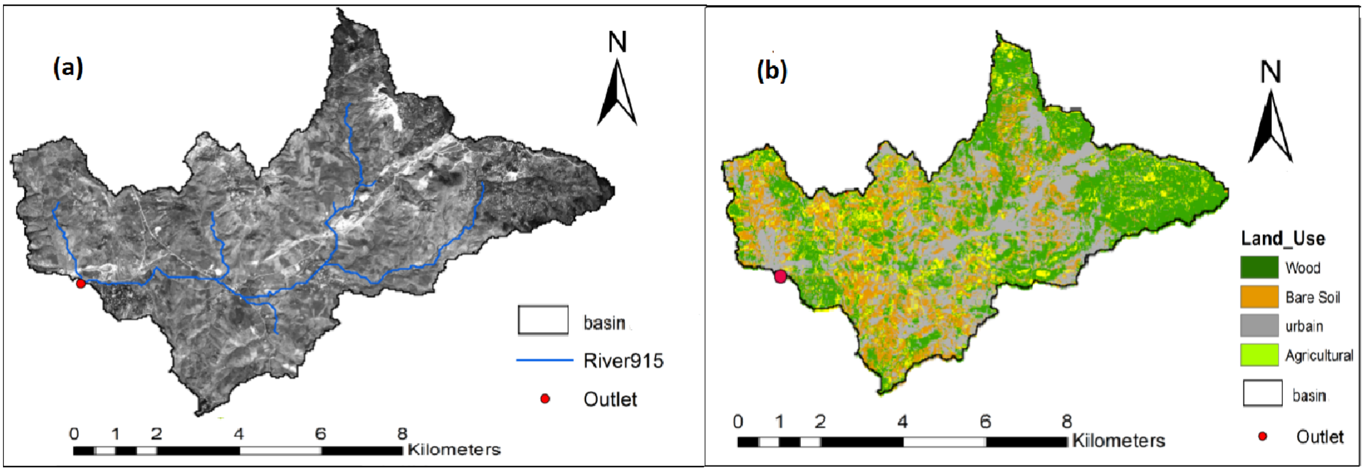

Fig. 5. (a) spot-5 image for the study area, (b) Basin Land use types

3.3 HYDROLOGIC SOIL GROUPS MAP

Different soil textures were digitized from the pedologic map of the region (digitized 1: 100000). It was assigned to represent different soil categories such as vertisol soil, paravertisol soil, lithosol soil and sesquioxides Soil [7]. Based on the rules of hydrologic soil group classifications developed by the US Natural Resource Conservation Service (NRCS), the hydrologic soil map of Kalaya watershed was generated and displayed in Figure 6:

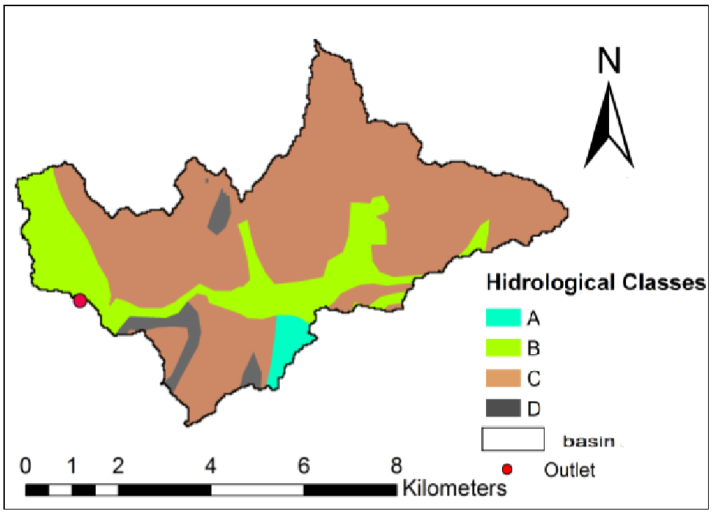

Fig. 6. Hydrologic soil groups of Kalaya watershed

Infiltration rates of soils are affected by subsurface permeability. As defined by SCS soil scientists, Soils may be classified into four hydrologic groups (A, B, C and D), (USDA, 1986): A; soil having high infiltration rates, B; soils having moderate infiltration rates, C; soils having slow infiltration rates, and D; soils having very slow infiltration rates [8]. The hydrologic soil group of Kalaya basin corresponds to the soil class that was obtained as shown in Table II:

Table 2. Surface of Hydrologic soil group of Kalaya watershed

Hydrologic Soil Groups	Surface Area	
	In sq.km	%
A	0.806	2.16
B	7.968	21.36
C	27.171	72.85
D	1.353	3.63
Total	37.30	100

3.4 Generation Of Curve Number Grid

The SCS curve number method (SCS, 1972), also known as the Hydrologic Soil Cover Complex Method was based on an empirical equation that estimates land use and soil type, the SCS CN method was also used to estimate excess rainfall and losses [9]. The CN is used to compute the volume of rainfall excess in the HEC-HMS and is therefore used as the description of watershed soil and land use characteristics in this modeling study.

The Curve number is calculated in ArcGIS trough the union processing attributes combined to one of the land and Hydrological soil groups. Using the SCS TR55 report from 1986, the creation of the CN table that has curve numbers values for different combinations of soil hydrologic groups and land uses has been made as shown in the table below:

CnLookUp

OID	OBJECTID	LUvalue	Descriptio	A	B	C	D
0	1	1	Water	100	100	100	100
1	2	2	Urban	77	85	90	92
2	3	3	Bare soil	77	86	91	94
3	4	4	Agricultural	64	75	82	85
4	5	5	Forest	43	65	76	82

Fig. 7. CN Lookup table

The SCS CN table gives CN for different combinations of land use and soil group, the Curve Number parameter is dimensionless and varies from 0 (maximum infiltration) to 100 (zero infiltration) [8]. After elaborating of the data necessary to compute the CN indicator, the CN map has been obtained from the intersection of the soil hydrological group and land use.

The values of CN of the Kalaya basin is between 94 and 43, the average CN is 82.0.75 as shown the figure above.

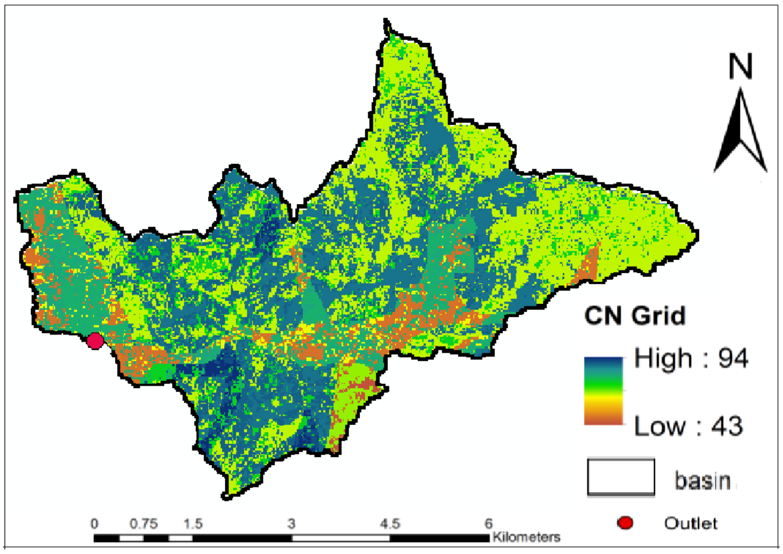

Fig. 8. Curve Number Grid map of Kalaya basin

4 **HEC-HMS** Model

HEC-HMS is designed to simulate the precipitation-runoff processes of watershed systems to identify drainage and overland flow and forecasting based on the resulted hydrograph. The physical representation of a watershed is accomplished with a basin model, where hydrologic elements (sub-basin, reach, junction, reservoir, diversion, source, and sink) are connected in a dendritic network to simulate runoff processes [10].

To calculate runoff for the kalaya watershed, the adopted method is SCS Curve Number Loss. This method computes incremental precipitation during a storm by recalculating the infiltration volume at the end of each time interval. The second approach was the application of the SCS Unit Hydrograph method as a transform method. In this case, the hydrograph is scaled by the lag time to produce unit hydrograph. The SCS runoff equation is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad (1)$$

Where:

Q = direct runoff (mm)

P = rainfall (mm)

S = potential maximum retention after runoff begins (mm)

I_a = initial abstraction (mm)

Initial abstraction computes all losses before runoff begin such as ponding in surface depressions, interception by vegetation, evaporation, and infiltration." Ia" can be approximated by equation:

$$I_a = 0.2S \qquad (2)$$

Combining equations (1) and (2) results in equation 3:

$$Q = \frac{(P - 0.2I_a)^2}{P + 0.8S} \quad (3)$$

Where the parameters S are related to soil and land use condition of basin through the Curve Number which has range of 43 to 94. The equation for the potential maximum retention is:

$$S = \frac{1000}{CN} - 10 \quad (4)$$

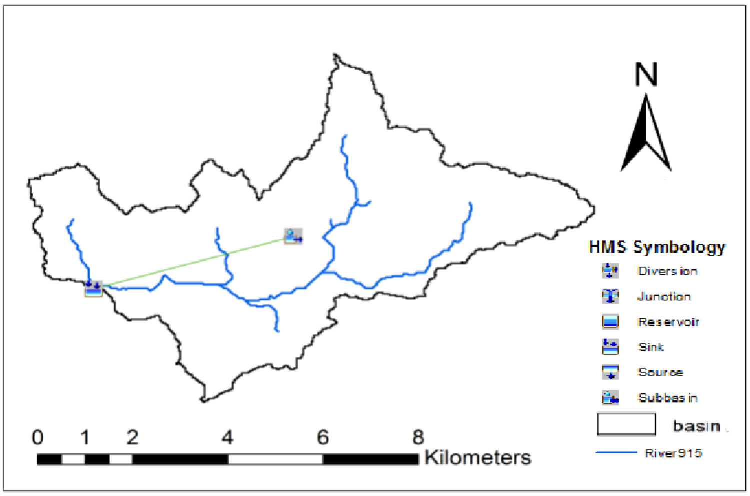

Fig. 9. HMS Schematic

For this study the soil conservation service (SCS), design storm with a Type II distribution was used to simulate rainfall event. This method requires 24-hour storm rainfall depths (80 mm) for Kalaya watershed, dated October 23, 2008. It is considered to have the severest intensity, and was selected for simulation in the HEC-HMS model [10].

Runoff of stream flow was finally estimated using HEC-HMS. All parameters needed for the HMS model were computed through ARCGIS and HEC-GeoHMS. The result of HEC-HMS is the hydrograph which generates the rainfall in function of the runoff. This results show the hydrograph of Kalaya basin located in the downstream in the periods from oct.23.2008 to oct.24.2008.

The figure below represents the summary of Peak discharge and discharge volume of the SCS methods:

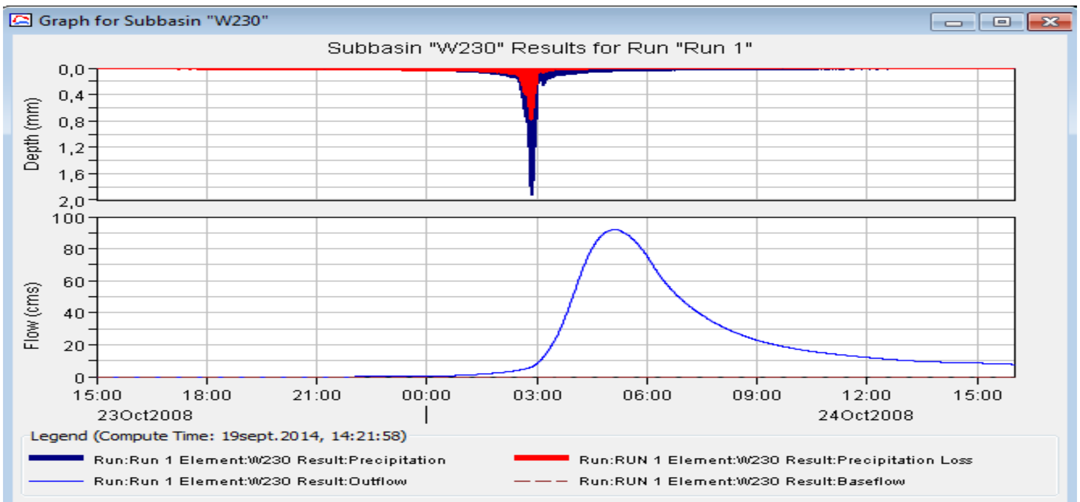

Fig. 10. runoff of SCS transform method

Figure 11 represents the summary of Peak discharge, discharge volume and Data derived from the Simulation of the hydrologic model for the event storm by SCS CN method:

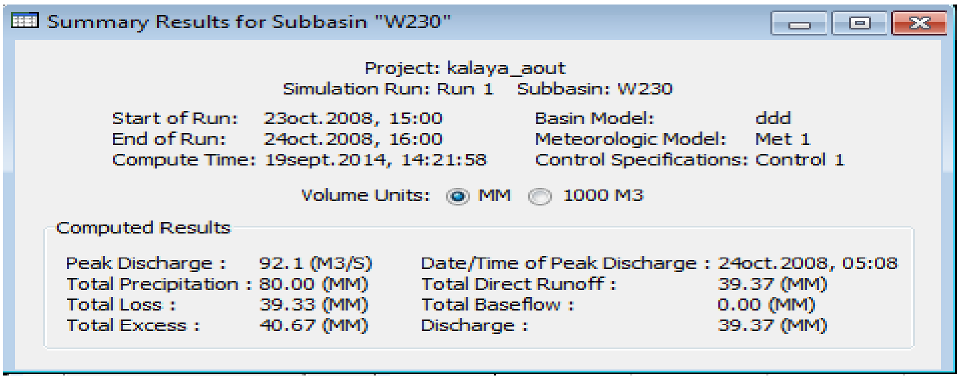

Fig. 11. Data derived from the Simulation of the hydrologic model

From the results of the hydrographs, the runoff volume, peak discharge and percent loss were determined. For the event storms, the peak discharge was 92.1 m3/s, the total precipitation was 80 mm, the total loss was 39.33 mm, and the total rainfall excess was 40.67 mm. Therefore, the total direct runoff volume is about 1468.3 m3.

5 CONCLUSION

As a result, the Kalaya basin was modeled using HEC-HMS through ArcGIS, Archydro and HEC-GEOHMS to determine Hydrologic parameters which have spatial characteristic and to compute the peak Discharge and loss infiltration using the SCS-CN method.

The present study demonstrates the interest of GIS techniques and remote sensing, and the utility of the delineation and estimation of the runoff for the storm event for the Kalaya watershed. This paper presents a reliable method for computing the CN values, which combines Land use and Hydrological soil group. The computation of the CN values was the key to a successful SCS-CN modeling. In order to test the feasibility and effectiveness of this method, surface runoff is simulated under the scenario of 80 mm precipitation for the Kalaya watershed. The result demonstrated that the SCS-CN method by using remote sensing to estimate runoff is convenient and effective.

REFERENCES

[1] Gyozo Jordan, "Morphometric Analysis and Tectonic Interpretation of Terrain Data: a case study," *Earth Surf. Process and Landforms 28, 807–822 (2003).*

[2] Kabiri, R.A, Ramani Baiv., B and Chan, A., "Using Green-Ampt Loss Method in Surface Runoff Simulation off Klang Watershed in West Malaysia)," *Advances in Environment, Computational Chemistry and Bioscience.*

[3] Fenglei Fan, Yingbin Deng, Xuefei Hu and Qihao Weng, "Estimating Composite Curve Number Using an Improved SCS-CN Method with Remotely Sensed Variables in Guangzhou, China," Remote Sensing ISSN 2072-4292

[4] Okirya Martin, Albert Rugumayo & Janka Ovcharovichova, "Application of Hec-Hms/Ras and GIs Tools in Flood Modeling: A Case Study for River Sironko,"*GLOBAL journal of engineering, design & technology, Vol. 1(2) 2012, pp.19-31, UGANDA.*

[5] USACE United States Army Corps of Engineers. (2010). Geospatial hydrologic modeling extension, HEC-GeoHMS, user's manual version 10. Davis, CA, USA.

[6] Rajesh.R Sawant, "*Land Use Land Cover Change Projection for use in Municipal Water Resource Planning in the Saugahatchee Watershed*," Thesis, Faculty of Auburn University, 2012.

[7] Osrirhi A. ElOumri M. Moussadek R. Moatamid Z. Ambri A. Goebel W., "Vocation agricole des terres de la Province de Tanger", Mars 2007, Ministère de l'Agriculture, du Développement Rural et des Pêches Maritimes.

[8] United States Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS). "Urban Hydrology for Small Watersheds"; Technical Release 55, United States Department of Agriculture, Natural Resources Conservation Services, Conservation Engineering Division, Washington, DC, USA, 1986.

[9] Brian C. McCormick,"*Distributed Hydrologic Modeling of the Upper Roanoke River Watershed using GIS and NEXRAD*" Thesis, faculty of Virginia Polytechnic Institute and State University, 2003.

[10] USACE United States Army Corps of Engineers. (2010). Hydrological modeling system HEC-HMS, user's manual, version 3.5. Davis, CA, USA.