Select next, add field (Land use) and select finish.

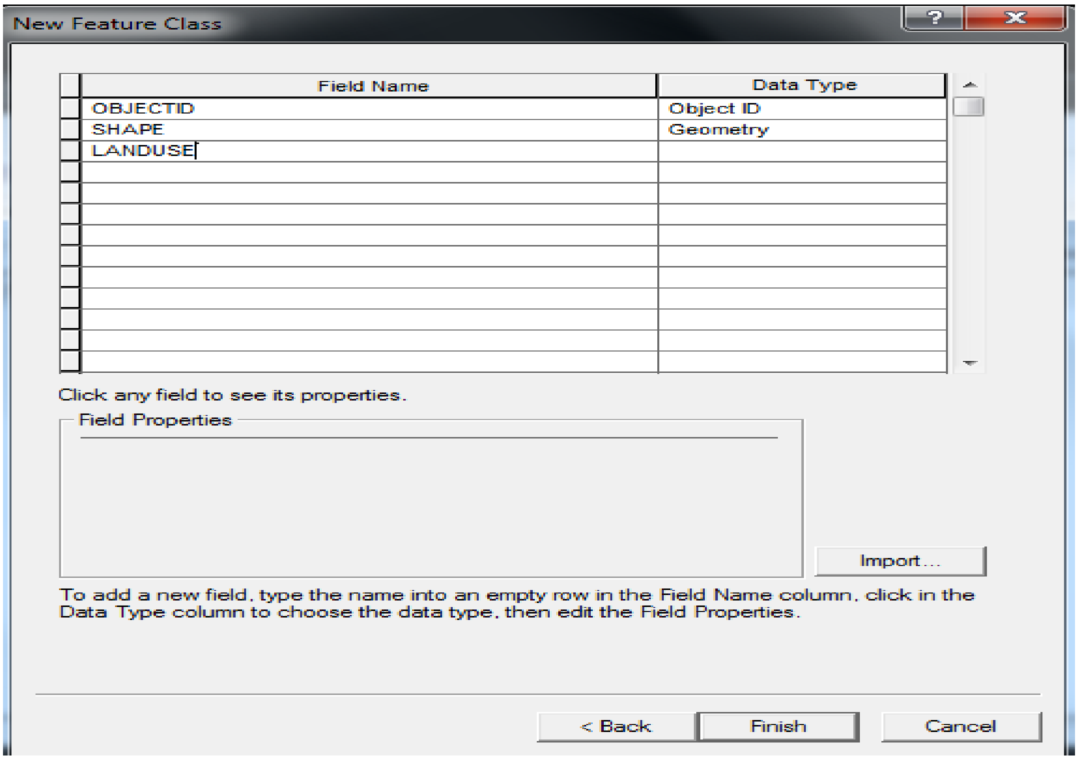

Figure.3.24.Add new field of landuse shape file.

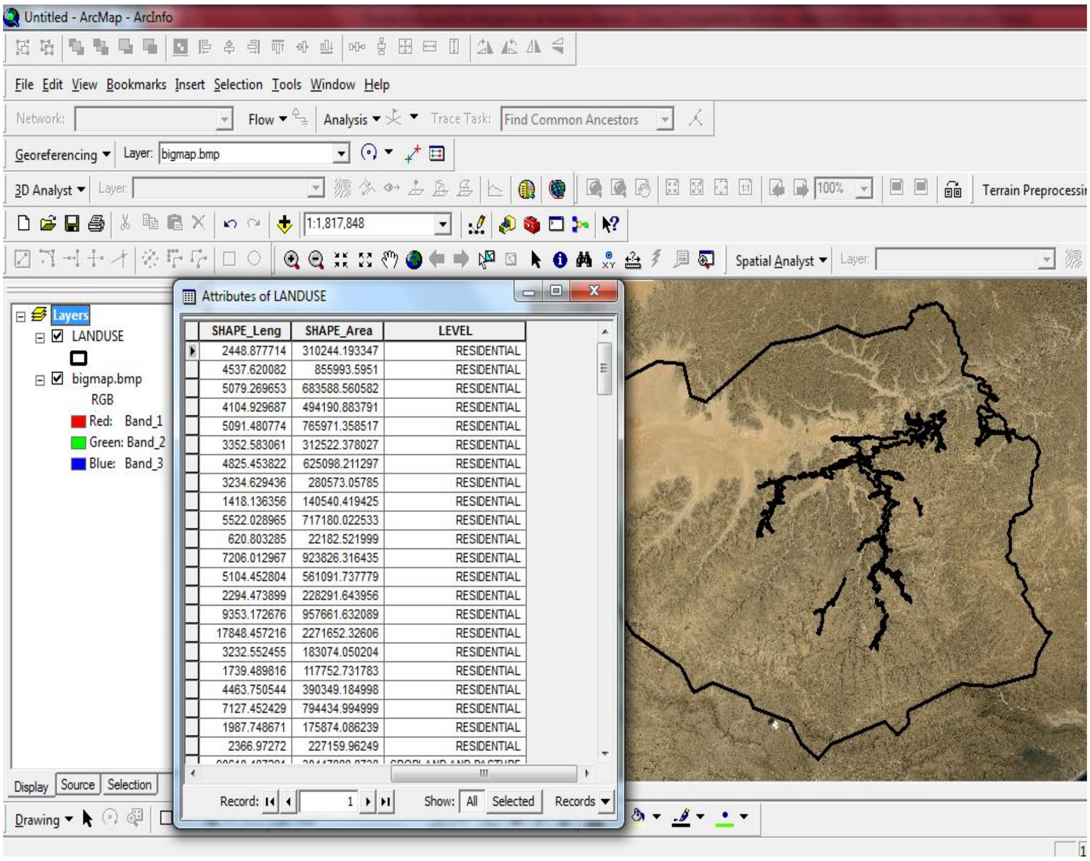

Figure.3.25. Attribute table of land use shape file

3.8.3 Importing coverage's of land use and soil type data

To describe the coverage of Wadi Hadramout Catchment surface in WMS, new coverage is added for Hydrological Group of soil types which is a Shape-File representing a schematic map of the polygonal shapes of entire Catchment.

Similarly, the shapefile for different land-use data is also a schematic map of polygonal shapes represents the limits of the catchment characteristics land use data. The method for importing these shape files in WMS is shown in Figure .3.29.

To add the component of land use and soil types cover.

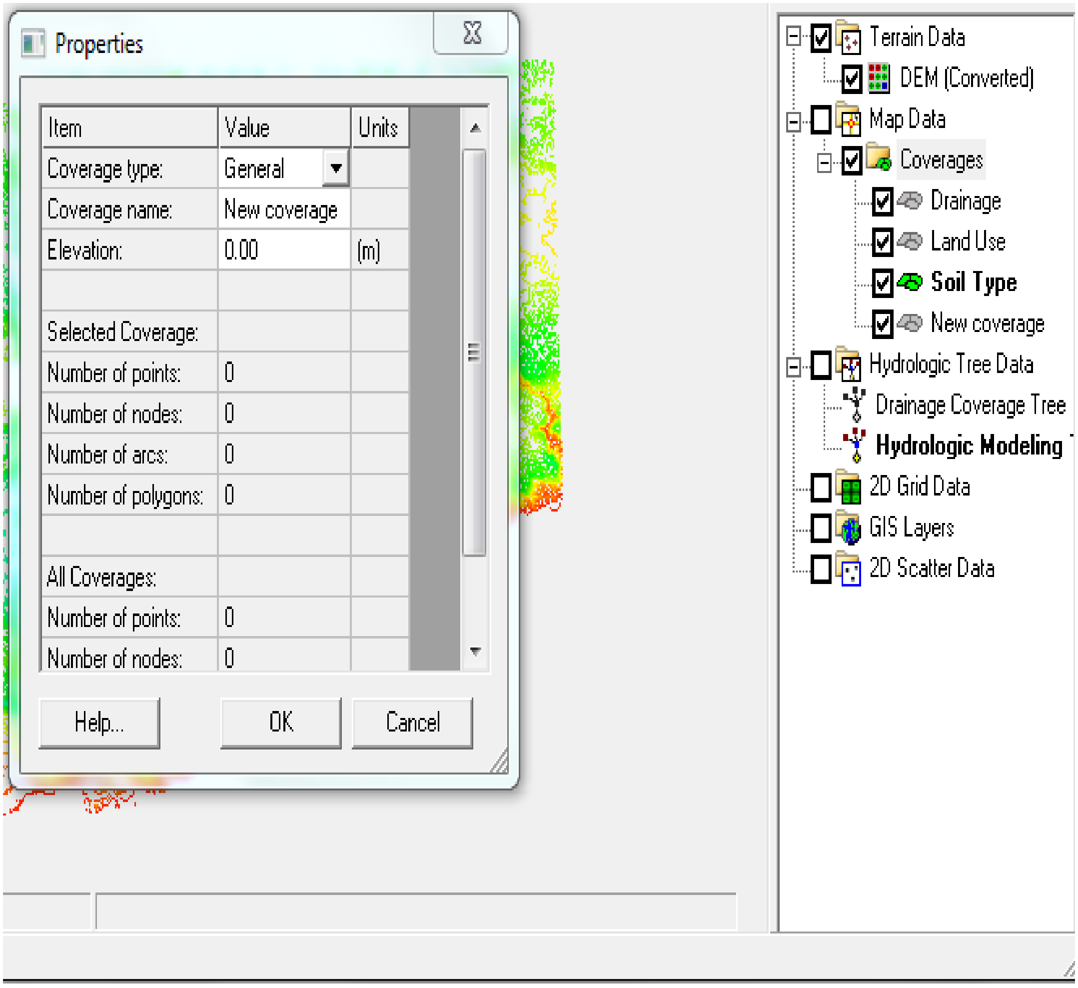

Figure.3.26. Create new coverage's land use and soil type.

Add the Soil type and Land use data by right click on GIS layer and select (add shape file data).

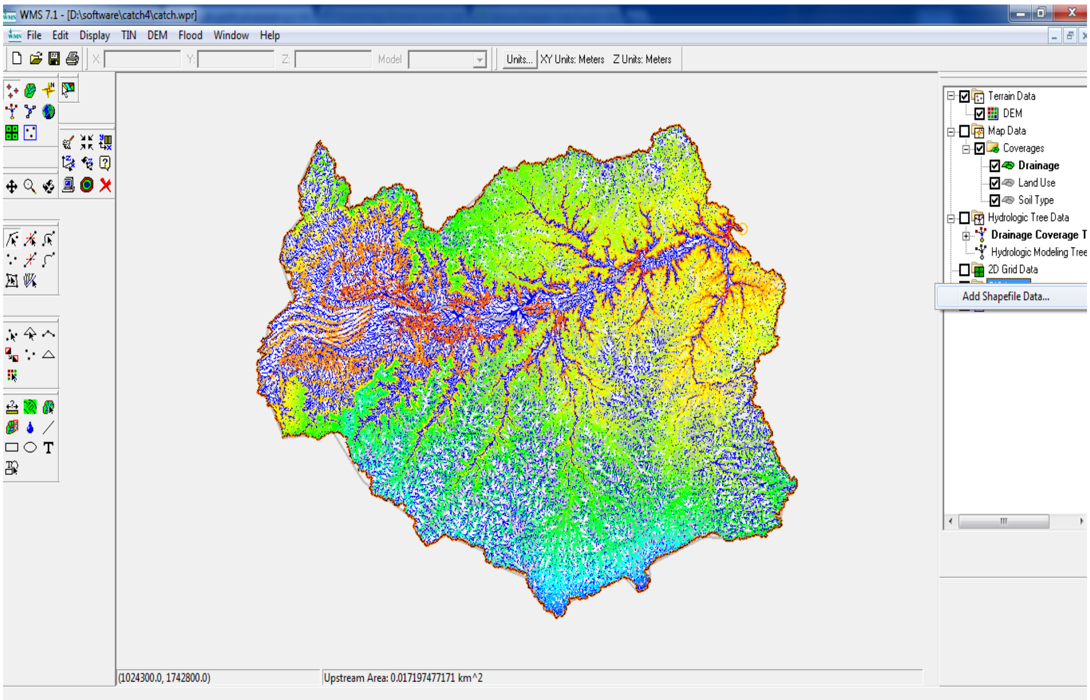

Figure.3.27. Import shapefile for land use and soil type.

Convert soil shapefile data to feature object to connect the digital information with the polygon spatial area, by switching GIS module. Select box around the DEM extent and select mapping / shapes feature object, then select SOIL_CLASS to SCS soil type and finish. This window shows all of the attribute fields in the soil shape file as shown in Figure.3.28.

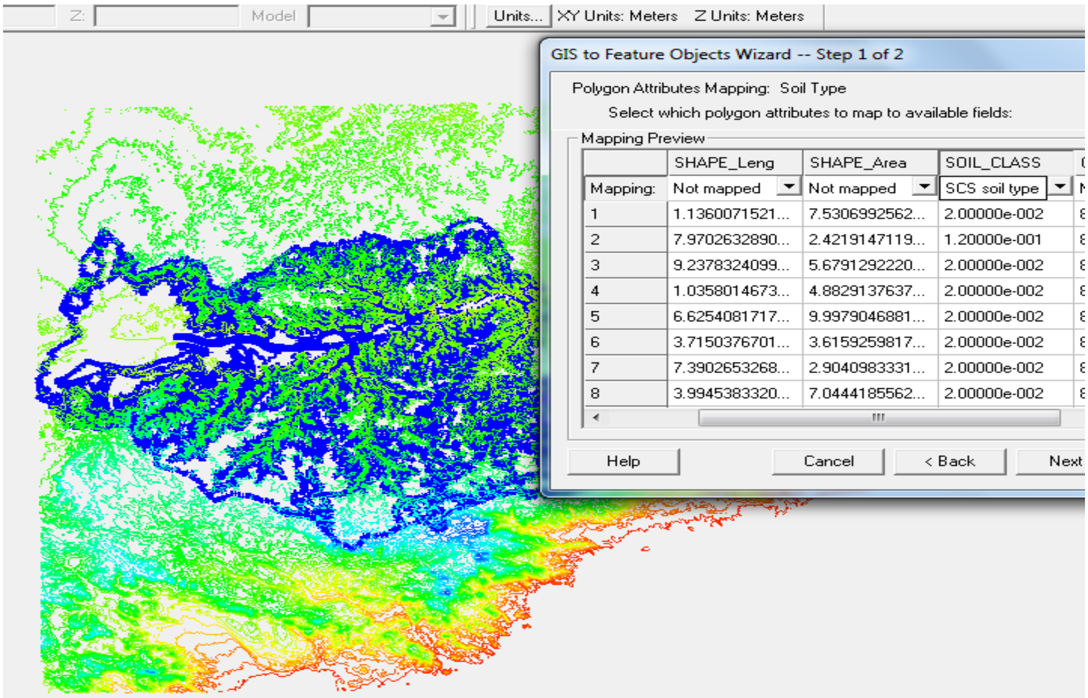

Figure.3.28. converted soil shape file data to feature object.

Hide soil shape file, convert Land use shape file data to feature object by clicking GIS module, select box around the DEM extent, select mapping, shapes feature object, next, select LEVEL to Land use and finish.

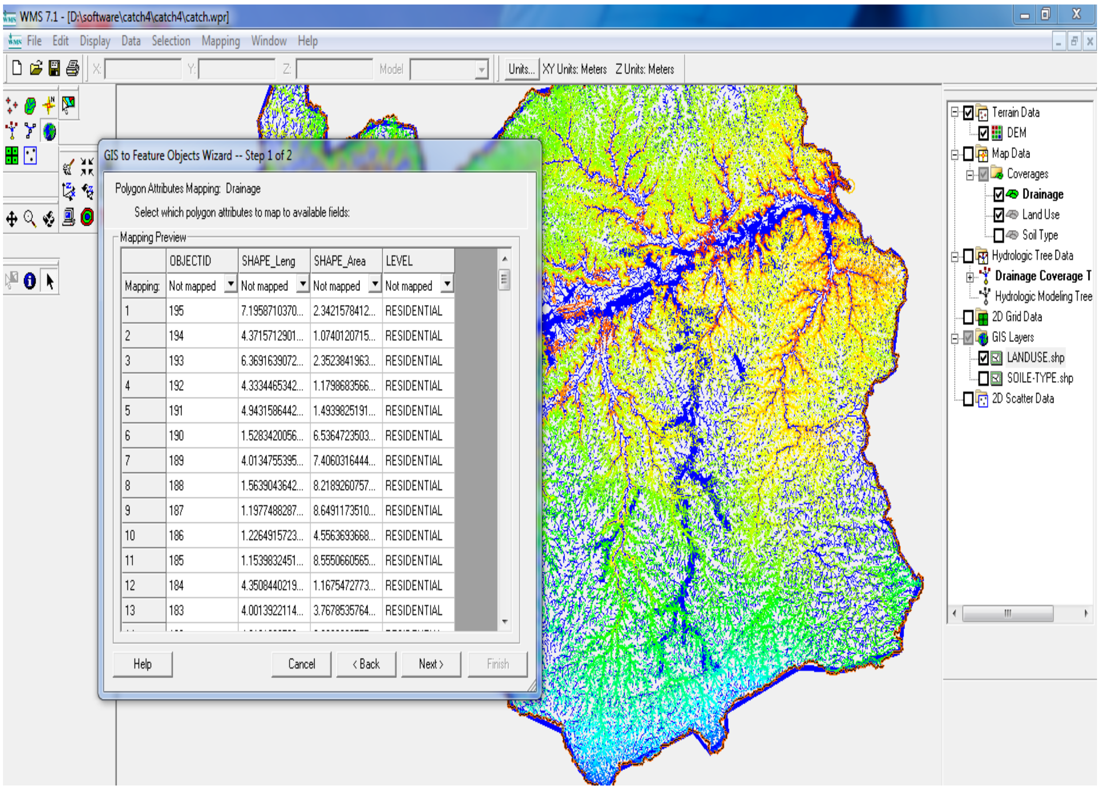

Figure.3.29. converted soil shape file data to feature object.

3.8.4 Curve Number of catchment

The value of the average curve number must be calculated. It is considered as an experimental way to provide an estimate of the runoff rate calculated depending on the land use and soil types. The value of the curve number of Wadi Hadramout catchment is entered in HEC-HMS to complete the simulation to estimate runoff hydrographs for the appropriate Catchment area.

To estimate the value of the curve number Wadi Hadramout catchment by following these steps:

The first step to determine the curve number is the hydrological group of soil that has been clarified by geological maps and using the Tables (3-5, 3-6) for the soil hydrological groups, drawn through shapefile.

The second step is identifying the land cover, land-use and vegetation by inspecting satellite images of Wadi Hadramout. Curve number for both soil types and surface cover can be determined from Table (3-7) and included in the attribute table.

Curve number directly affects the flow of water on the surface, the change in curve number works on the increase or decrease in runoff; refer to the permeability of soil and its impervious rate.

3.8.4.1 Determination of curve number for catchment

Curve number can be determined by geographic information systems (GIS) through shapefile import of soil types, import of satellite imagery for Wadi Hadramout catchment and curve number is determined from the following steps:

1- Open arc map, select add data of the land use and soil Shapefile.

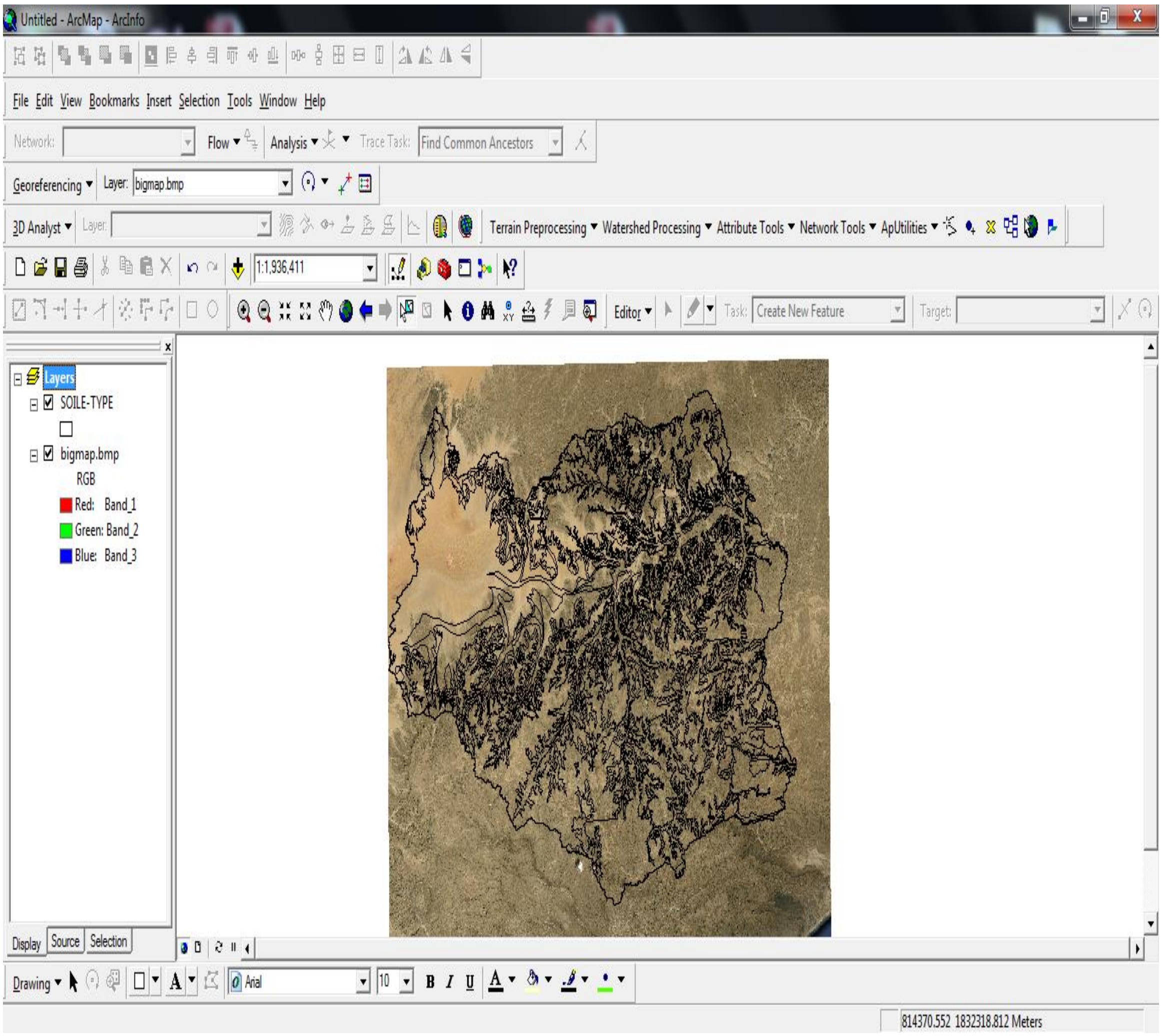

Figure.3.30. shows the soil type and landuse cover.

2- Open the attribute table of soil type shape file then add in new field and rename it as (CN).

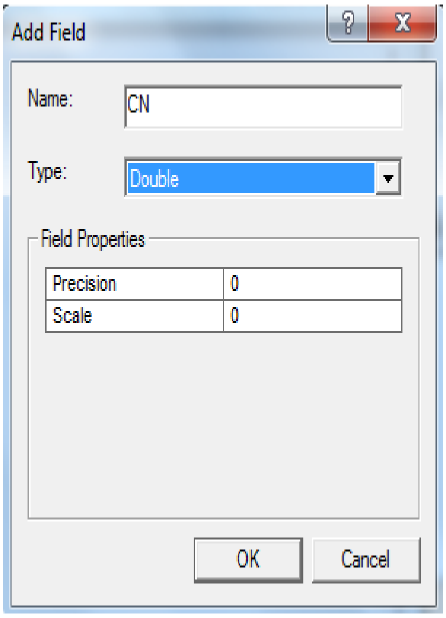

Figure.3.31. Create a New add field (CN).

3- In the attribute table for soil type, click on each row to show the polygon decree and previously specified soil type for this polygon.

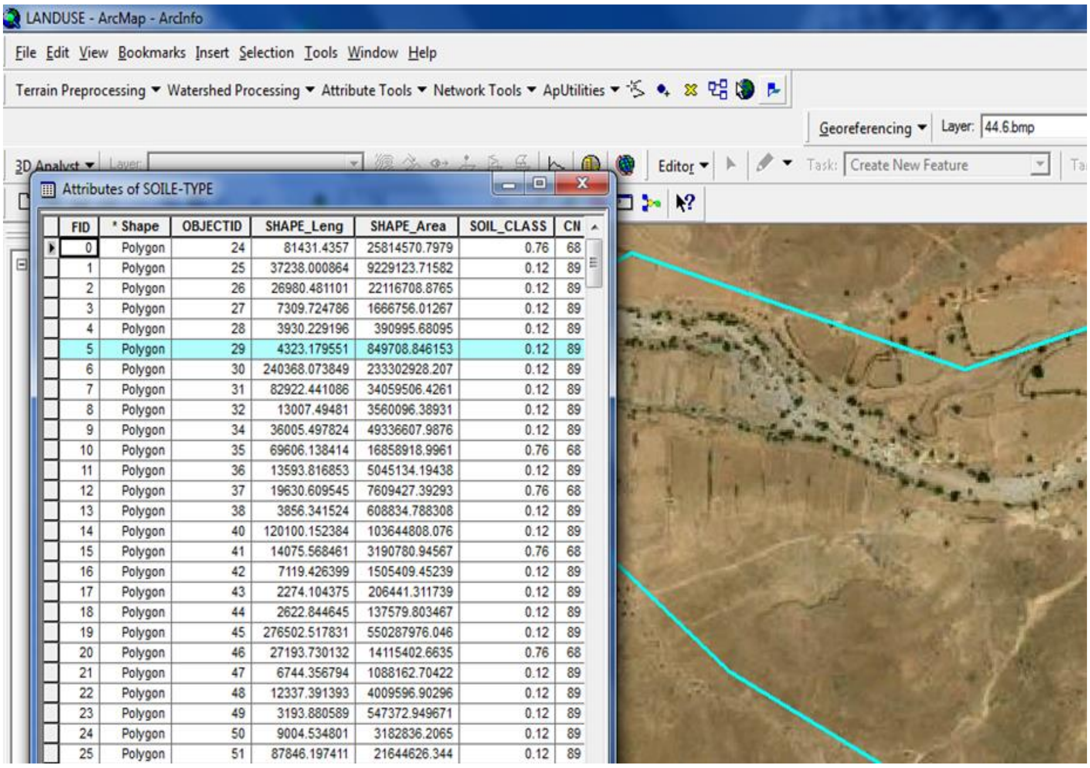

Figure.3.32.attribute table of curve number

4 – Depending on the shape that was specified in the satellite imagery identify the type of surface cover by visual inspection.

5 -In conjunction with the type of ground cover and soil group determine the curve number as in Table (3-7).

Table 3-7 Runoff Curve Number (Chow V. T., 1988)**.**

Cover Description	Hydrologic Soil Group			
Cover Type/Hydrologic Condition	A	B	C	D
Open Space				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover, 50 – 75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas (parking lots, etc.)	98	98	98	98
Urban districts				
Commercial and business	89	92	94	95
Industrial	81	88	91	93
Residential area (by average lot size)				
1/8 acre or (less town houses)	77	85	90	92
1/4 acre	61	75	83	87
1/3 acre	57	72	81	86
1/2 acre	54	70	80	85
1 acre	51	68	79	84
3 acre	46	65	77	82

6-All these steps are repeated for each row.

7- After selecting the curve number for each shape, Calculate the average curve number from attribute table in the shapefile of soil type. As given in the following manner.

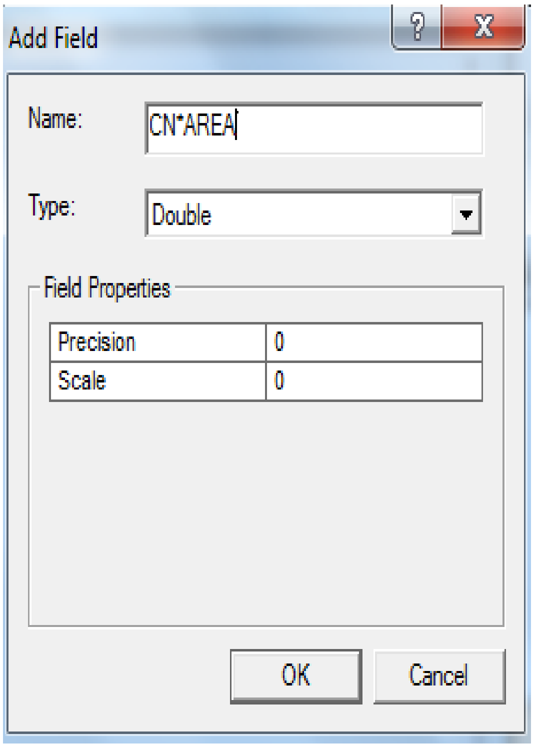

Figure.3.33. Create a New add field (CN*AREA).

7-The average Curve Number is calculated as follows:

$$CN(\text{average}) = \frac{\sum(CN \times A)}{\sum A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq\ 3.13$$

Where,

CN is the curve number for each area.

A Area of shape.

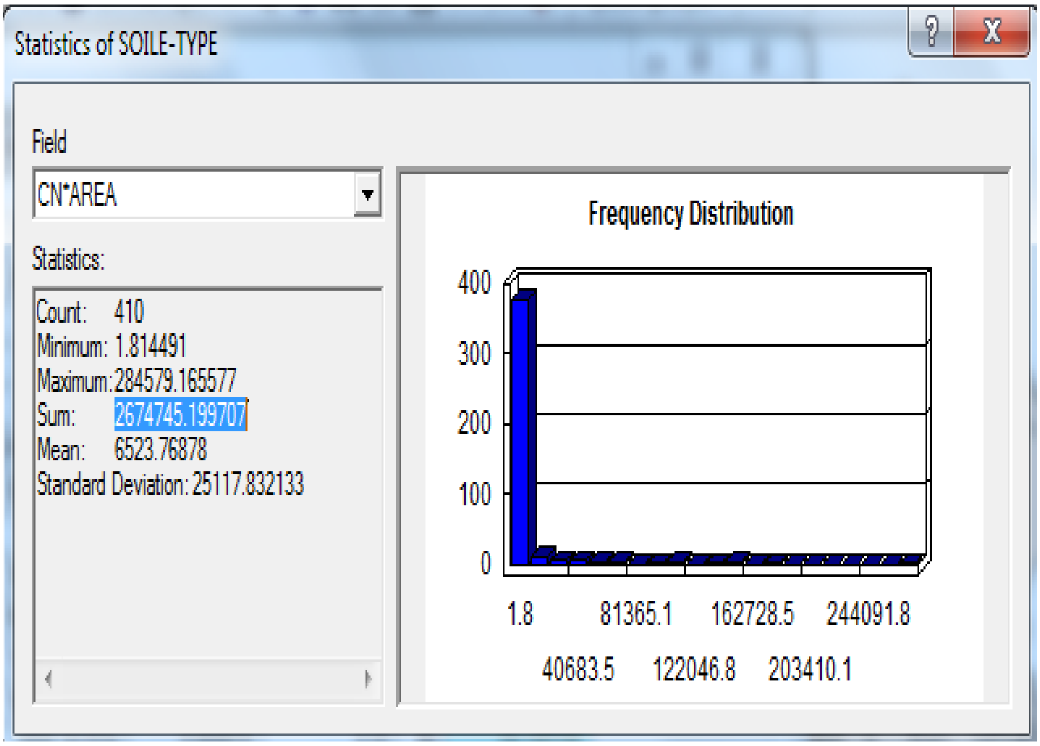

Figure.3.34. Total of (CN*AREA)

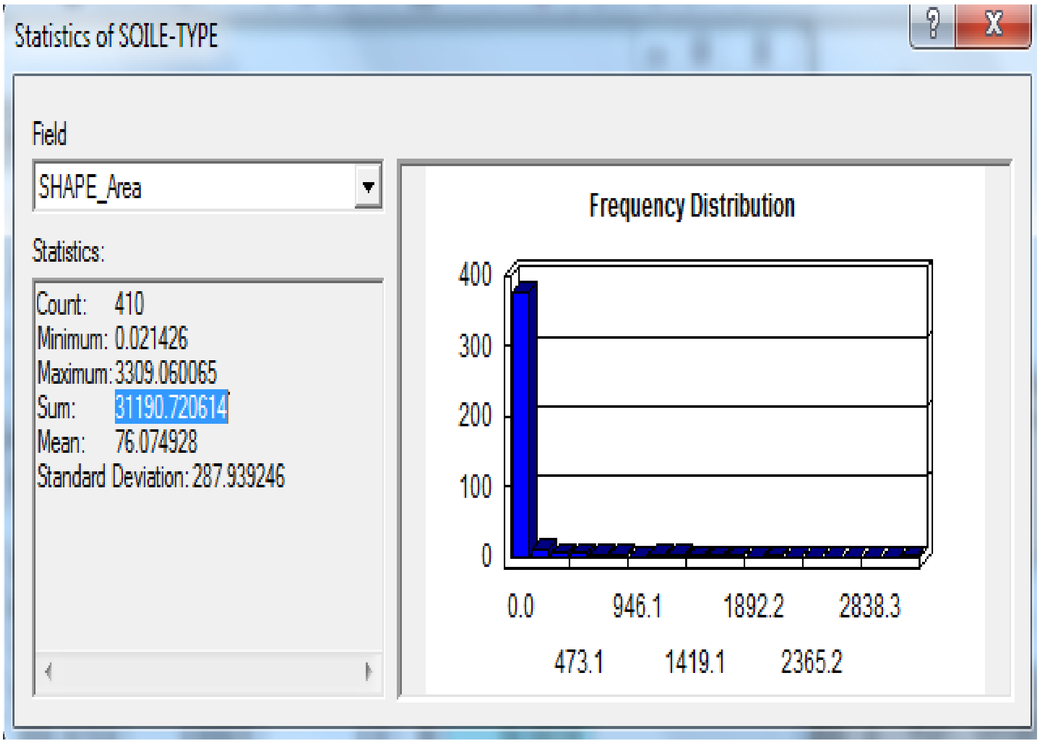

Figure.3.35. Total of area catchment

3.8.4.2 Determination of Curve number for sub-catchments.

The process of calculation of the curve number for each subcatchment by geographic information systems is shown through the following steps:

- Open arc map and Add data to import the sub-catchments shapefile.

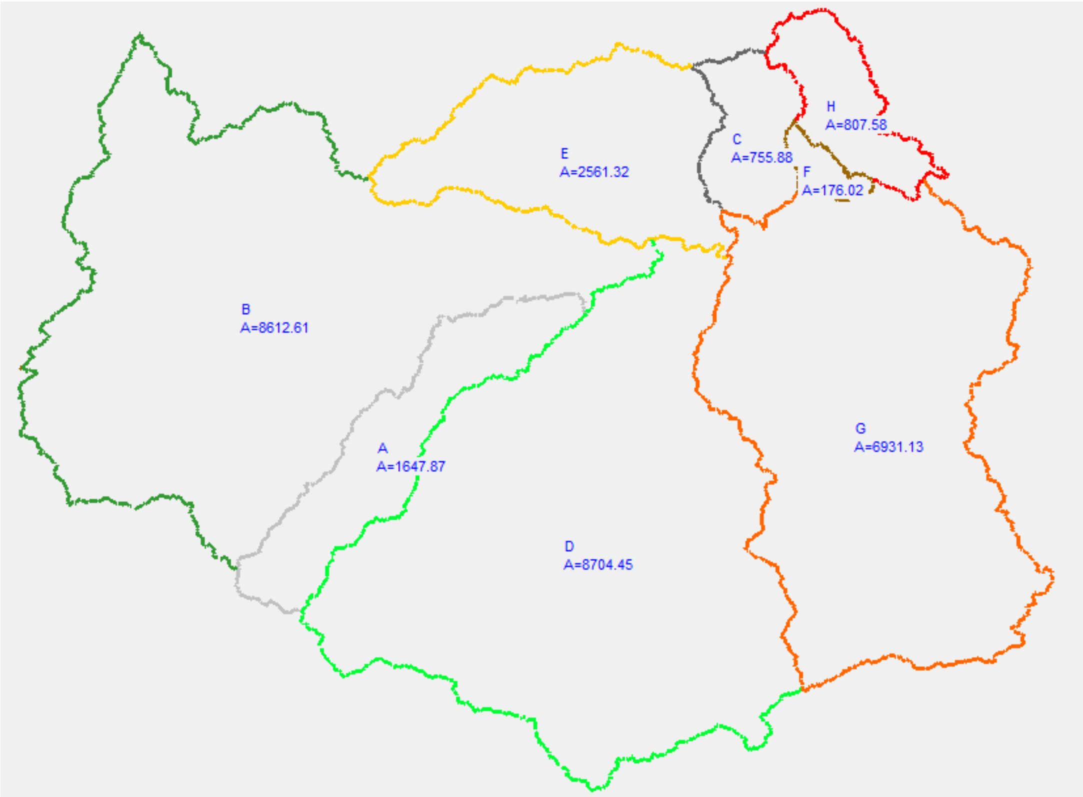

Figure.3.36.Subcatchment Shape file.

- Select any area polygon of sub-catchment and right click layer / Export Data shapefile.

- Clip each Subcatchment.

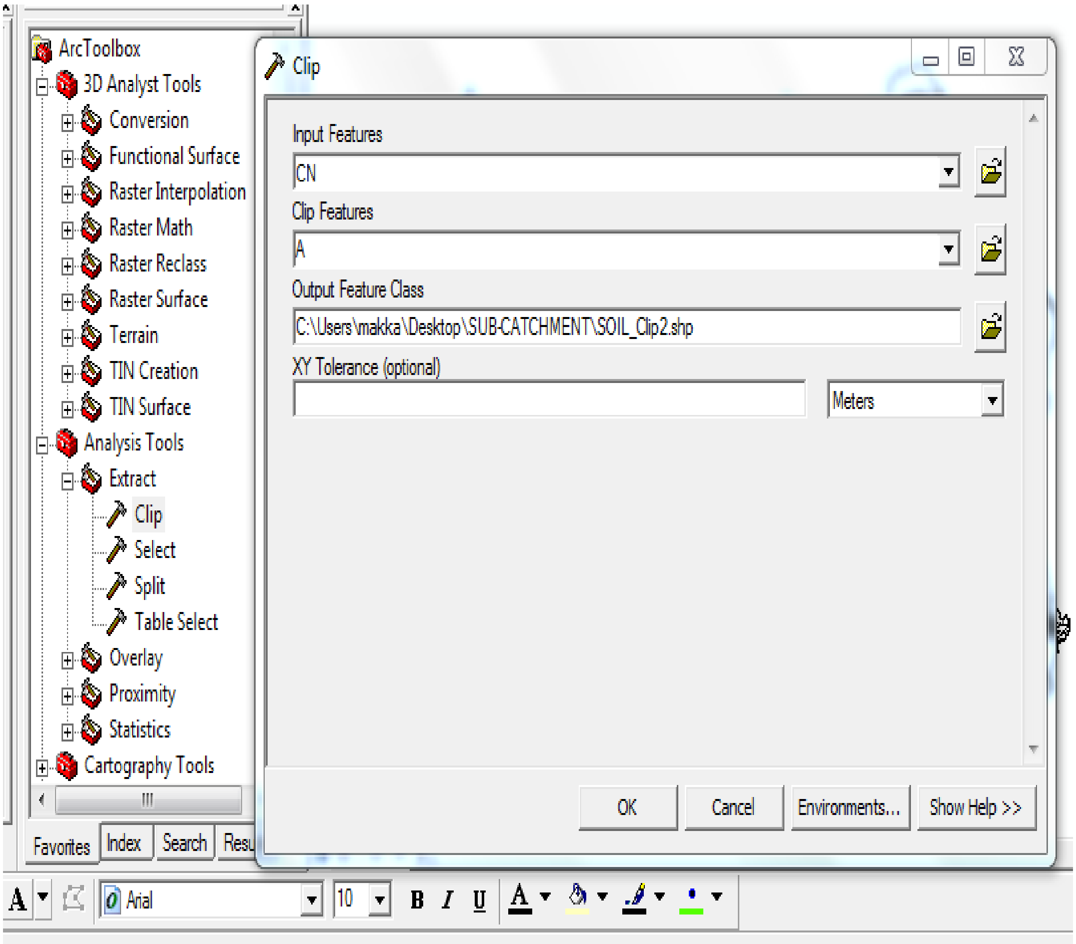

Figure.3.37. Clip Feature for polygon of sub catchment.

- The attributes table is opened for each sub-catchment and the curve number is calculated by equation 3.13.

3.9 Sub-catchment Characteristics

Delineation of Subcatchment Process has been achieved by WMS. This constitutes an important part in the simulation of sub-catchments to obtain the parameters as shown in Figure .3.38. The Sub-catchments differ in shape, area, volume and geographical. Spatial composition which represents the various activities of land use land covers type and different soils.

The curve number will be different for each subcatchment. The different properties of the sub-catchments have been clarified in Table (4-2).There are 7 reaches between the 8 sub-catchments.

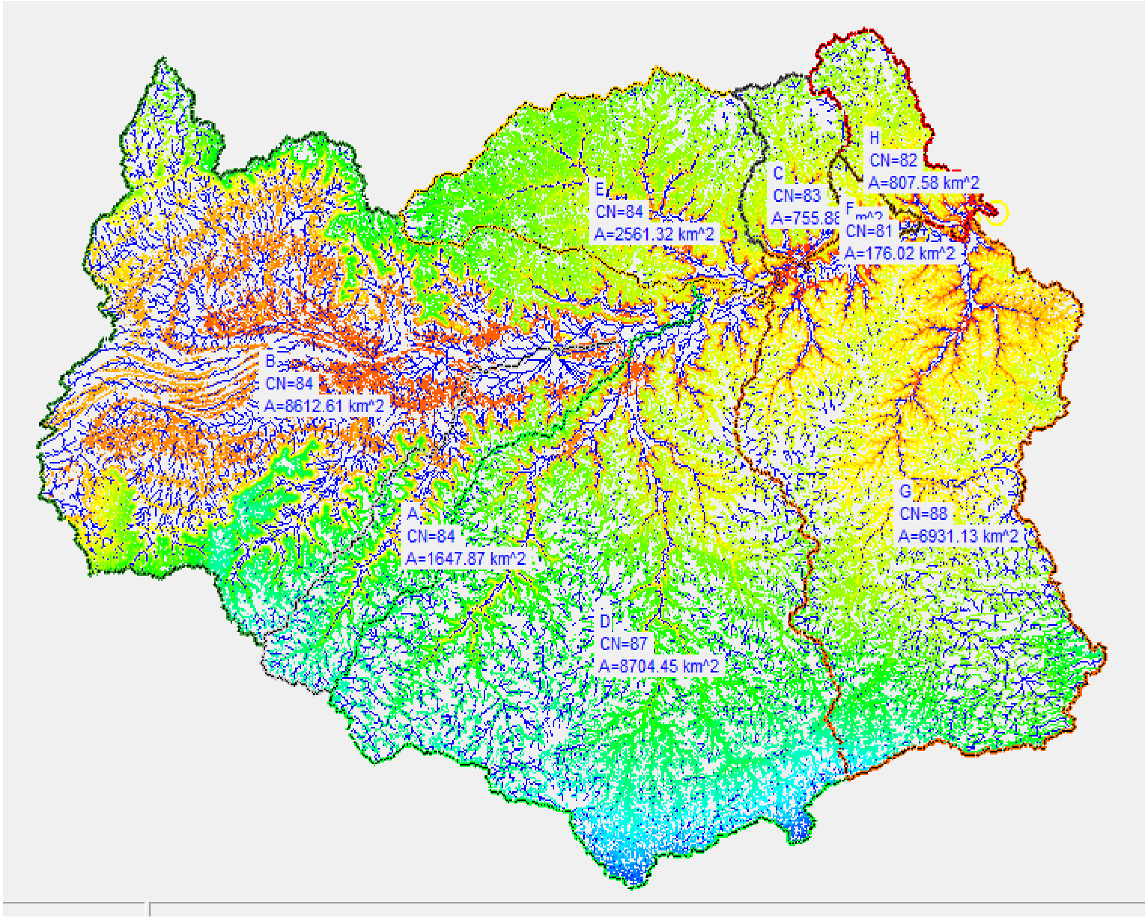

Figure.3.38. Subcatchment characters .WMS.

In WMS switch Hydrologic Modeling Module, Select the Basin Tool as shown in Figures (3.39, 3.40). Click on model choose HEC-HMS.

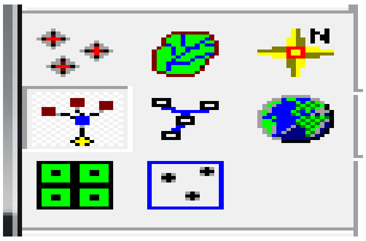

Figure 3.39. Hydrologic Modeling Module.

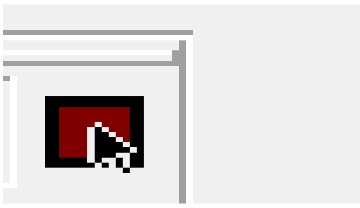

Figure .3.40.Basin Option.

Double click on the brown basin for any subcatchment, the HEC-HMS window will open. Select show all, Select on the display of the loss Rate Method option and Select the SCS Curve Number.

In HMS properties window select SCS Curve then for each sub catchment enter impervious rate and Initial loss.

Choose Transform Option, Select SCS, set the computation Type to Compute Lag Time, and Select the SCS Method for all the sub-catchments then click Ok.

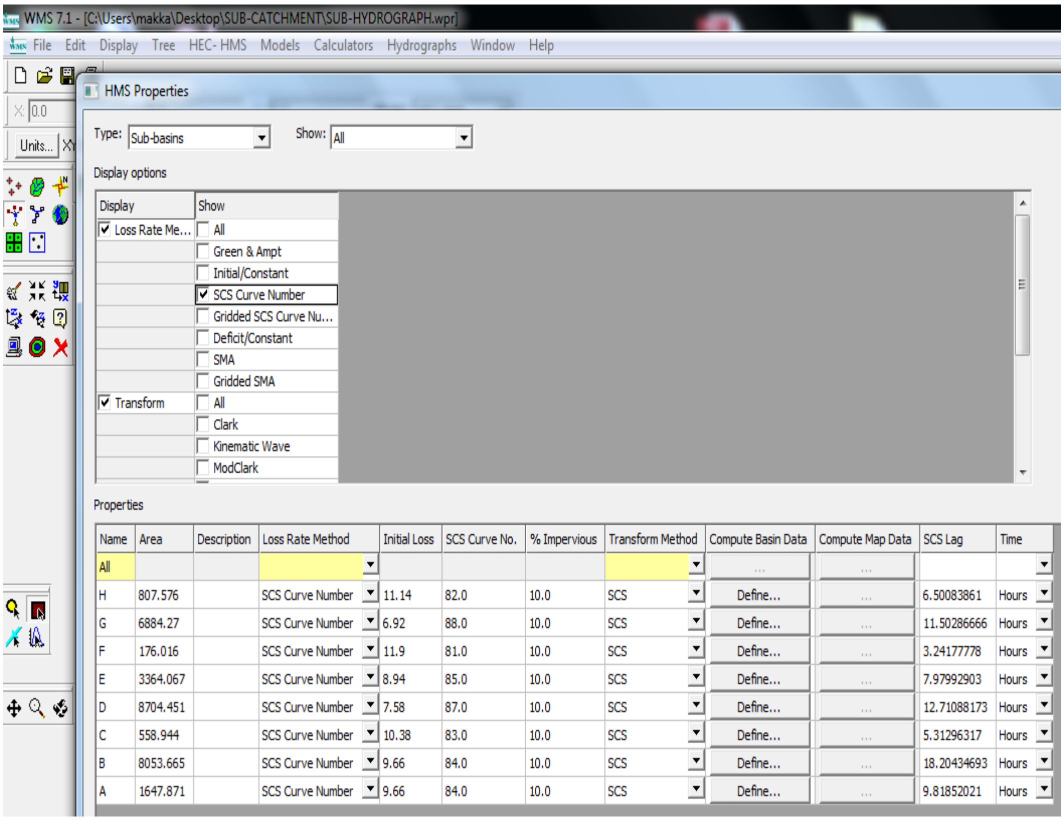

Figure 3.41 HMS Properties in WMS.

For routing it is essential to find the parameters for the process of routing to complete the simulation. These parameters are the reach length, slope, and side slope.

Select the Outlet Point in the WMS dialog box tool as Shown in Figure .3.42. And Double-click on any subwatershed outlet point (The yellow circle icon) as shown in Figure.3.43.A HEC HMS window as shown in Figure.3.44 will open.

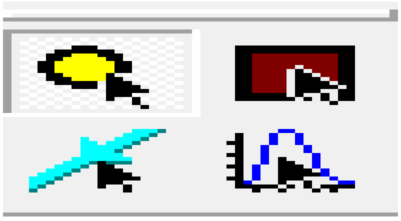

Figure.3.42. Outlet Point.

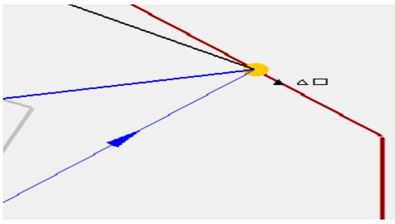

Figure.3.43. Yellow circle icon.

Click Type and in the drop down menu select reaches. From Display select Muskingum-cung method.

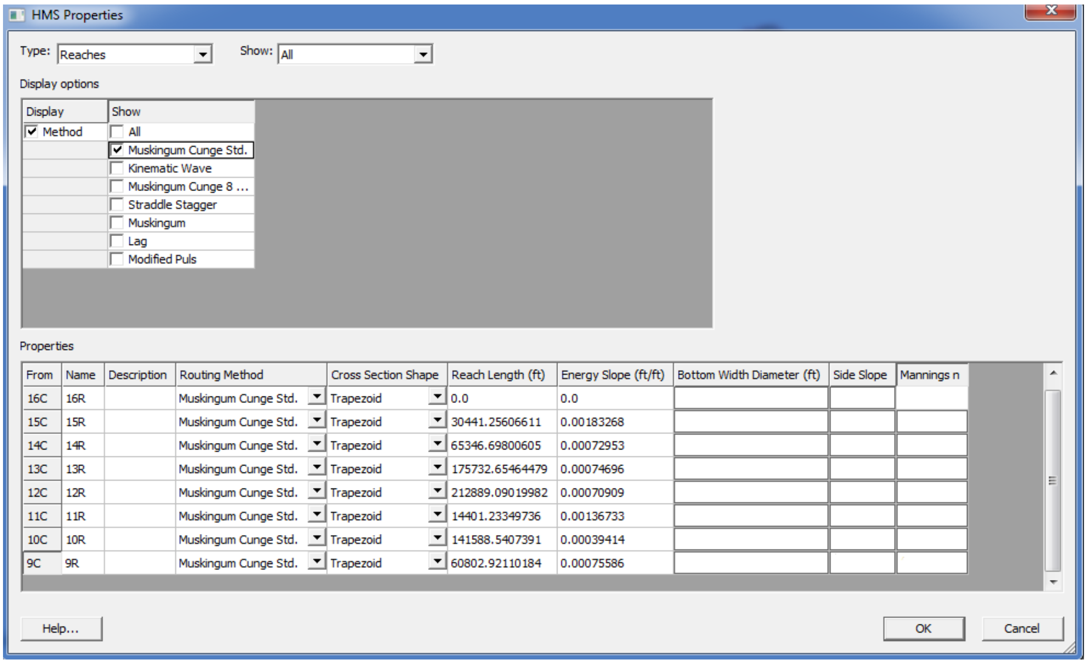

Figure.3.44. HMS Properties reaches.

The next steps areas follow:

1- Select hydrologic modeling in WMS as shown in Figure .3.45.

2- Select HEC-HMS and then save the file to be transferred to HEC-HMS file.

3- Open HEC- HMS software and import HMS file.

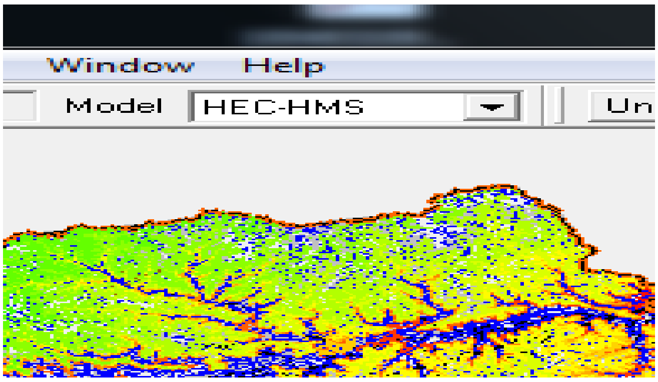

Figure.3.45. Model HEC-HMS in WMS.

CHAPTER 4

HYDROLOGIC MODELS

4.1 Introduction

A hydraulic model is essentially a representation of the processes that occur during a flood event (Bates, 2005) Hydrological models are important for a wide range of applications, including water resources planning, development and management, flood prediction, flood design and coupled systems modeling. In addition, there is a need to assess the likely hydrological impact of future system response (Singh V.P. and Woolhiser D.A., 2002).

In this chapter, modeling using HEC-HMS is described. The steps of work using the model are described in details. Different sceneries for modeling were calculated. The parameters needed for modeling with HEC-HMS were gathered, prepared and integrated. For comparison, two different scenarios have been studied; the main sub-catchment of Wadi Hadramout and in the second simulation Wadi Hadramout was divided to “eight” sub-catchment. After finishing the hydrological simulation a design for protection structure and its position were studied. Using HEC-HMS a simulation was performed with the protection structure implemented to find the change in runoff hydrograph after the construction.

4.2 Catchment simulation using (HEC – HMS)

The hydrological parameter resulting from the WMS is inserted for the simulation with HEC – HMS. Open HEC-HMS and Select file. The catchments were represented in the form of schematic diagram representing Wadi Hadramout catchment. Figure.4.1. shows the open file window of HEC-HMS through which HMS file is selected.

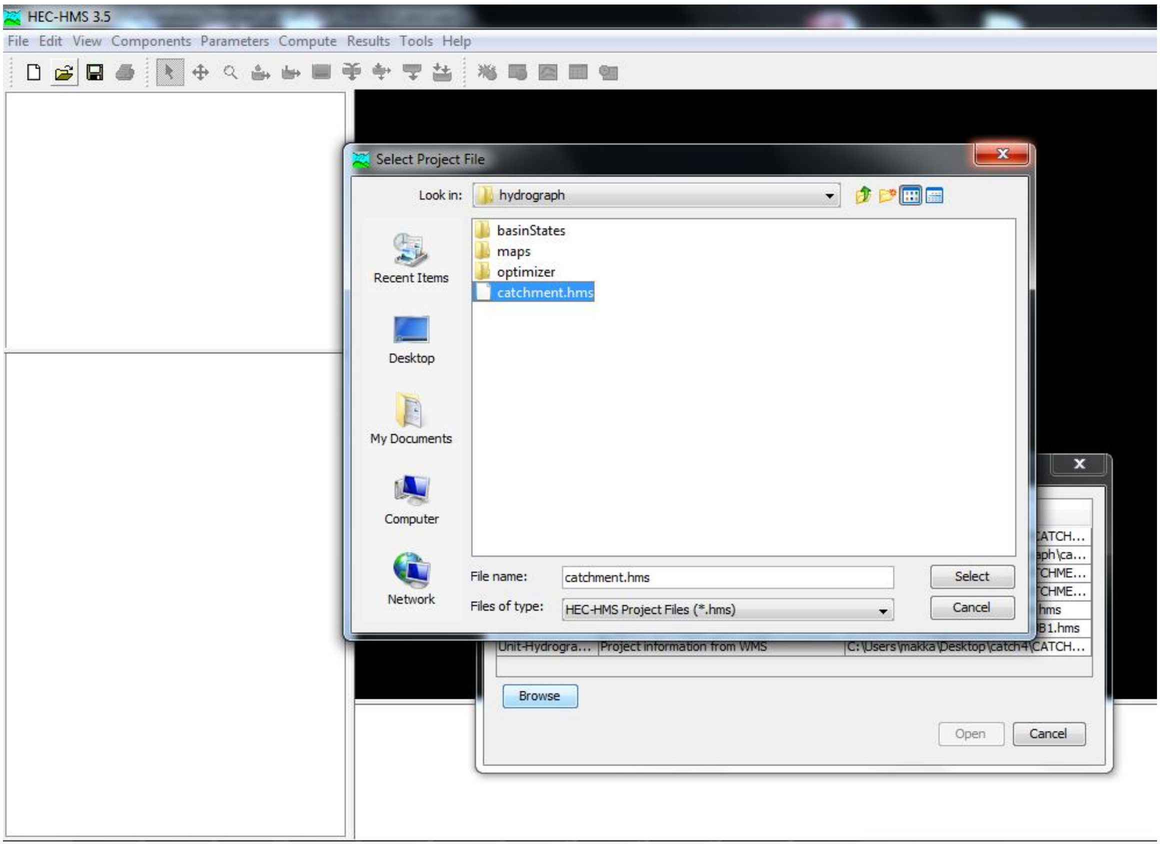

Figure.4.1 User Interface Display of HEC-HMS.

A Typical HEC-HMS model are made up of three components; a basin model, a meteorologic model, and a control specification model, the following present each model in detail and the steps of work by each of them.

4.2.1 Basin Model:

Basin Model is one of the components of the hydrological modeling which includes elements of catchment. It consists of the WMS watershade which contains the elements of the catchment. These elements are the sub basins, junctions and the reaches of Wadi Hadramout catchment. Each element contains parameters that describe the hydrological process for this element according to its role in the catchment.

Basin model includes the following hydrological parameters:

1. Sub basin includes :
   - Area.
   - Loss Method.

a. Initial Abstraction.

b. Curve Number

c. Impervious ratio.

- Transform Method as a Lag Time.

2. Junction includes:

- A selection for the downstream reach connected to the junction.

3. Reach includes:

- Length of reaches.
- Slope.
- Manning's n.
- Shape.
- Bottom width.
- Side slope.

Some of these parameters are exported from WMS and other parameters are entered through HEC-HMS. The values entered for each parameter at this stage are mentioned in details in the next sections.

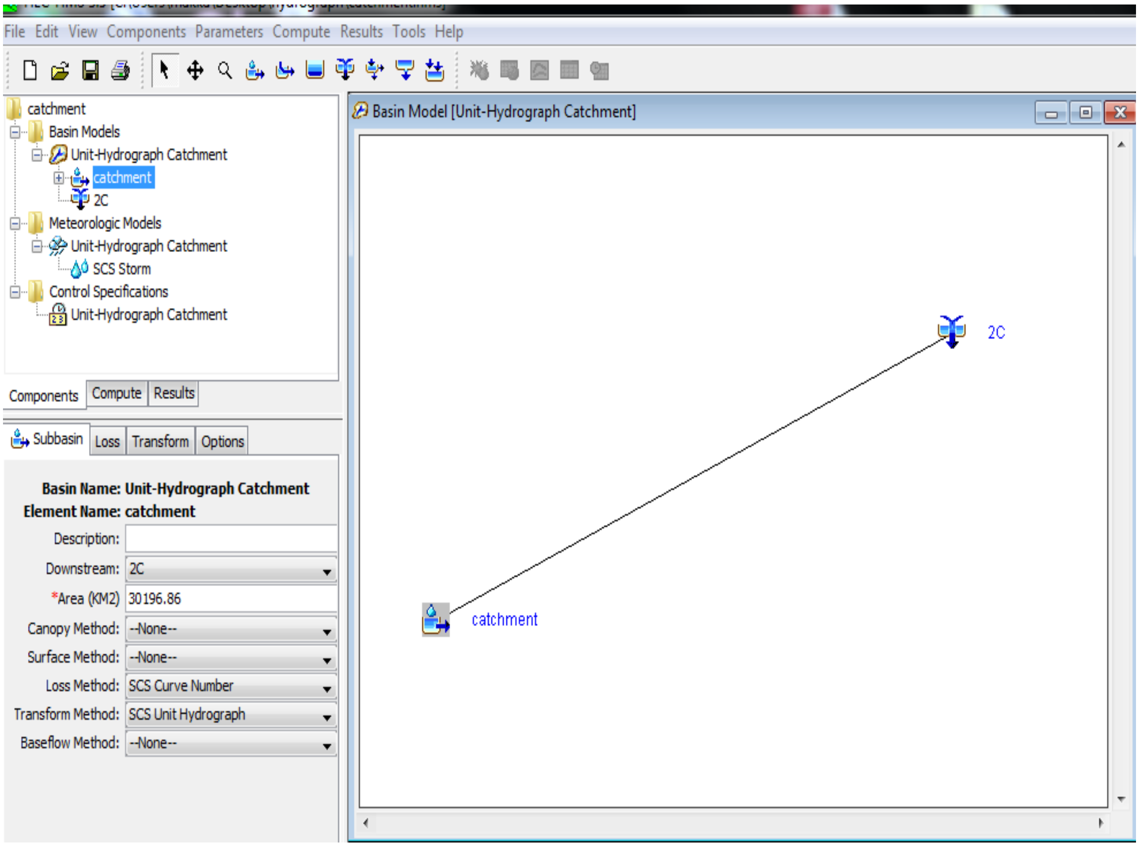

Figure.4.2.Catchment Wadi Hadramout representations in HMS Model.

4.2.2 Meteorlogic Model

Meteorlogic Model is one of the components of the hydrological modeling which includes data about the meteorology of Wadi Hadramout. It consists of the WMS meterologic data which contains the SCS storm data. The storm data are the type of the value of the depth of rainfall event was previously selected in chapter 3 in this thesis. A frequency analysis was performed on rainfall data to find the maximum value for simulation. This value was found to be 75 mm.

Type (1) represents the rainfall the maximum intensity in Yemen according to Yemen meteorological department. There for, type 1 will be selected for Wadi Hadramout.

4.2.3 Control Specification of HEC-HMS

A hydrologic simulation run cannot be accomplished without the time period over which the model is run. The control specifications shown in the window of Figure.4.3. Indicate when the simulation starts and stops as well as the time interval. The starting date, starting time, ending date, ending time, time interval are entered in this window. The time period of the simulation of flood period is from 22 to 25 October 2008. The time interval was selected according to the equation

$$T < 0.29\ T\ lag \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq 4.1}$$

Where T_{lag} is the shortest lag time in hours (Jessica, 2007) Time interval of 1 hour has been chosen.

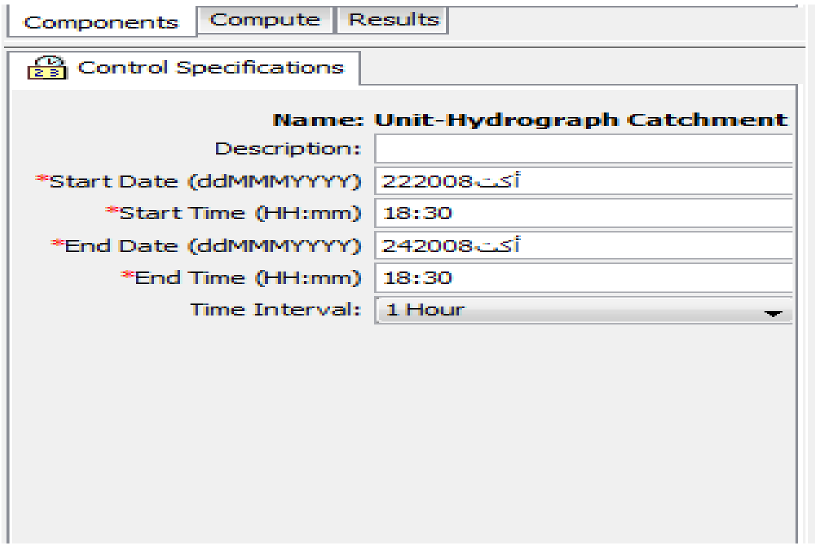

Figure .4.3. Control specification window

Table (4-1) presents all the parameters needed for the basin model, the metrologic model and the Control Specification.

Table 4-1 Limits Hydrologic Parameters for Catchment

Area (Km^2)	30196.86
Slope (m/m)	0.002
Loss	
Initial Abstraction (Mm)	8.26
Curve Number (CN)	86
Impervious(%)	10
Transform	
Lag Time Tp (Hr)	19.0
Meteorologic Models	
Method	Type 1

4.3 Hydrologic Simulation

The next step is to run the model. Select Compute / Create Simulation Run. Accept the default name for the run with a name (Catchment hydrograph). Click next to complete all the steps and finally click finish to complete the run. Now to run the model, select Run / catchment hydrograph, then go to compute as shown in Figure .4.4.

Compute Run (Catchment hydrograph) and select close.

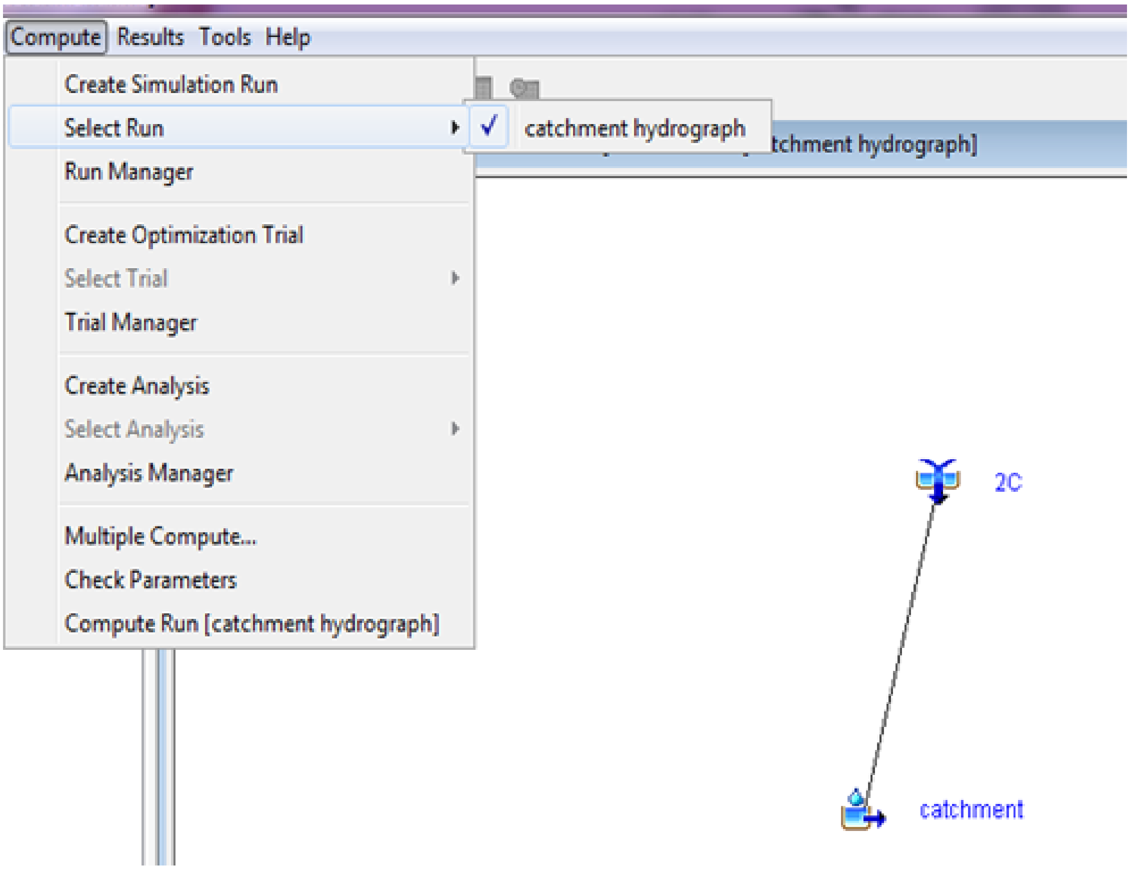

Figure.4.4.Simulation Run.

4.3.1 Subcatchment simulation (HEC – HMS)

To simulate the 8 sub catchment, WMS was used to import the data for HEC-HMS. The HEC-HMS opens the HMS file, select file and then opens Subcatchment /HMS file.

HEC HMS was used to estimate the flood hydrograph for the 8 sub-catchment using parameters as shown in Table (4-2). (Rainfall, losses, Land use and soil characters) the SCS method was used to get the lag time for the unit hydrograph. These steps were clearly described in the last sections what is new is that the catchment were divided in this section for comparison between the two runs outputs.

The hydrographs were obtained by HEC HMS where representation of the catchment model is as given in Figure.4.5.

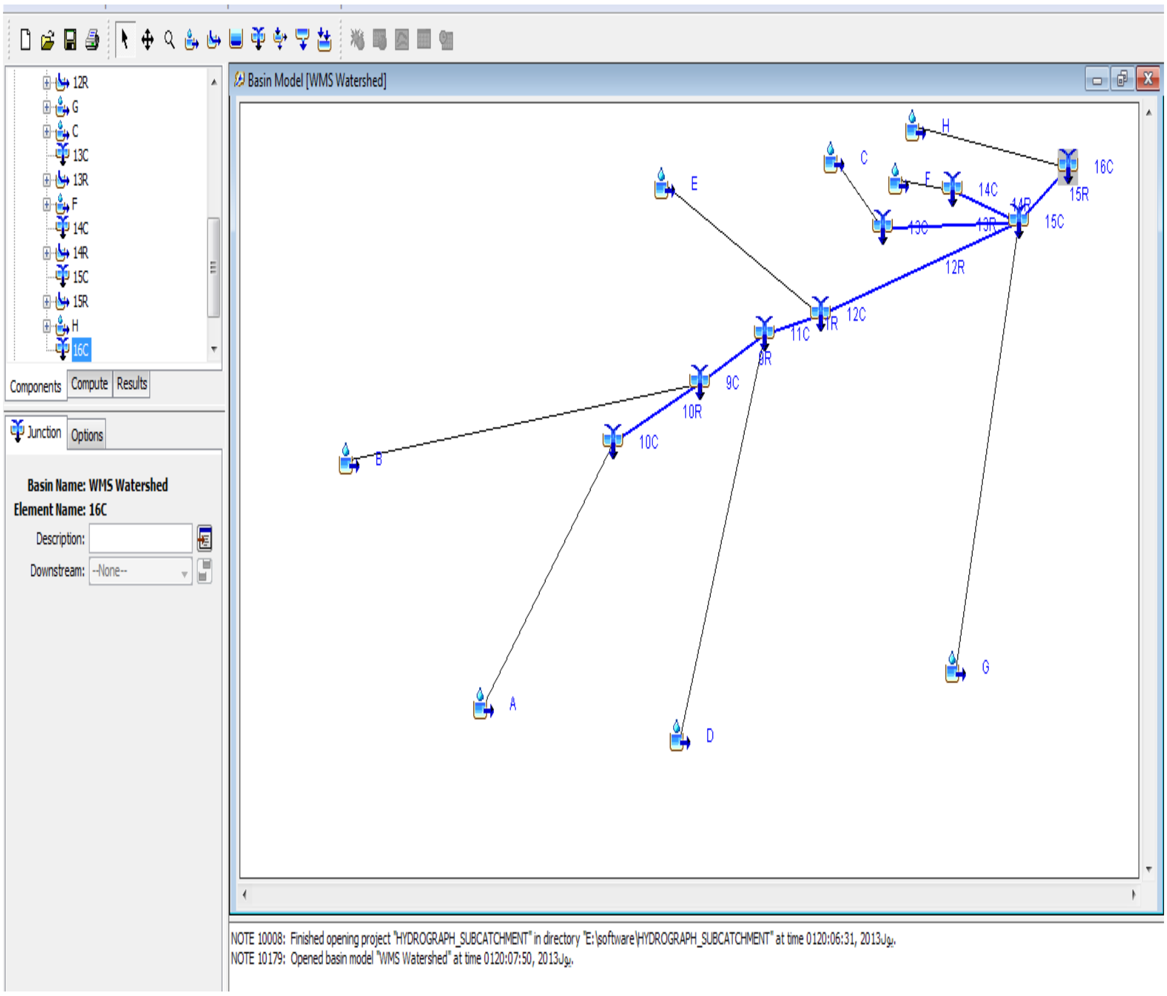

Figure.4.5. Sub-catchment Wadi Hadramout representation in HMS Model.

Table 4-2 Data for Sub-catchment.

Basin Name	Area Km^2	Loss			Transform
		Curve Number (CN)	Initial Abstraction (Mm)	Impervious (%)	Lag time (Hr)
A	1647.87	84	9.66	10	9.56
B	8612.61	84	9.66	10	18.21
C	755.88	83	10.38	10	4.42
D	8704.45	87	7.58	10	12.42
E	2561.32	85	8.94	10	7.31
F	176.02	81	11.9	10	3.14
G	6931.13	88	6.92	10	11.29
H	807.58	82	1.14	10	6.30

4.3.2 Routing Parameters

Runoff of excess precipitation has been routed to the outlet of the catchment.

Muskingum- cung method was used in routing the flood along the catchment.

The data in Table (4-3) was obtained from WMS and used as the routing parameters in HEC-HMS.

Table 4-3 Standard Parameters reaches.

Reach Name	Routing Method	Routing					
		Length (M)	**Shape**	**Slop (M/m)**	**Manning's n**	**Bottom Width (M)**	**Side slopes (M/M)**
(9R)	**Muskingum - cung**	18484.0	Trapezoid	0.000755	0.03	267.5	0.3
(10R)	**Muskingum - cung**	43042.9	Trapezoid	0.000394	0.03	315.5	0.3
(11R)	**Muskingum - cung**	4377.97	Trapezoid	0.001367	0.03	236.5	0.3
(12R)	**Muskingum - cung**	64718.2	Trapezoid	0.000709	0.03	221.2	0.3
(13R)	**Muskingum - cung**	53422.7	Trapezoid	0.000746	0.03	282.5	0.3
(14R)	**Muskingum - cung**	19865.3	Trapezoid	0.000729	0.03	286.5	0.3
(15R)	**Muskingum - cung**	9254.14	Trapezoid	0.001832	0.03	286.5	0.3

These data were required to complete the simulation process by HEC-HMS.

4.3.3 Simulation results

HEC-HMS enables us to display the results in the form of graphs and tabular form. It represents the estimation for the size of flows predicted in Wadi Hadramout catchment. All rainfall cannot be transferred to runoff. Some of water is being lost to water infiltration into soil which can lead to excess of rainfall. The excess of rainfall is obtained by subcatchment losses from the total rainfall. The flood hydrograph is presented in appendix (A). Table 4-4 shows the different output of the model result.

Table 4-4 Results of flood.

Catchment	
Peak discharge (m^3/s)	12519.902
Total losses (mm)	30.412
Total excess (mm)	44.588
Direct runoff (mm)	43.262

4.3.4 Results analysis for Wadi Hadramout subcatchment

Each sub-catchment contains its own properties need for simulation.

The properties can be seen as follow:

1. The size of runoff.
2. The peak time and peak discharge.
3. Loss value.
4. Excess rainfall.
5. Sub- catchment size.

The simulation results for the different sub-catchment are given in Table 4-5 and the flood hydrograph is presented in appendix (B).

The parameters of models reaches are shown in Table 4-6.

Table 4-5 Data resulted for "eight" sub-catchment.

Name of basin	**Area (Km²)**	**Total precipitation (mm)**	**Peak Discharge (m^3/s)**	**Total Loss (mm)**	**Total Excess (mm)**	**Depth Precipitation (mm)**	**Volume (mm)**	**Infiltration Soil (mm)**	**Total Run Off (m^3/s)**
A	1647.8	75	1008.9	33.71	41.29	19.8	41.29	10.1	1008.9
B	8612.61	75	3510	33.71	41.29	19.8	40.44	10.1	3510
C	755.88	75	663.7	35.29	39.71	19.8	39.71	10.9	663.7
D	8704.45	75	5155.5	28.68	46.32	19.8	46.26	8.2	5155.5
E	2561.32	75	1822.4	33.71	41.29	19.8	41.29	10.2	1822.4
F	176.02	75	170.4	38.29	36.71	19.8	36.71	12.1	170.4
G	6931.13	75	4549.1	26.89	48.11	19.8	48.09	7.6	4549.1
H	807.58	75	570.8	36.82	38.18	19.8	38.18	11.8	570.8