Table 4-6 Result of reaches

Name of Reach	Length (m)	Peak Inflow (m^3/s)	Peak Outflow (m^3/s)	Total Outflow (mm)	Total Inflow (mm)	Flow Velocity (m/s)
9R	18484.08	4435.8	4425.2	40.37	40.53	2.7
10R	43042.21	1008.9	977	40.99	41.29	1.21
11R	4377.974	9034.7	9023.9	43.06	43.07	4.6
12R	64718.2	10069	9959.1	42.50	42.85	4.1
13R	53422.727	663.7	631.1	39.73	39.71	1.3
14R	19865.39	170.4	62.5	27.72	36.71	0.13
15R	9254.141	14032.6	140.21.6	43.63	43.66	6

4.4 Hydraulic Structural for Flood Mitigation

A hydraulic structure was used to reduce the size of the flood event in Wadi Hadramout by storing the flow of rainwater, which is one of the appropriate measures that could be used to defend urban areas for flood risk. Mitigation that reduces flood impact consists of non-structural and structural mitigation (Carter W. N., 1992).

Non-structural mitigation may include:

a) A legal framework: the application of building codes and land-use planning to reduce the effects of floods.

b) Incentives: persuading insurance companies to reduce insurance costs for buildings that use hazard-resistant measures.

c) Training and education: to ensure a successful mitigation, all persons involved in the mitigation process must be well trained and educated.

d) Public awareness: a strong understanding of local hazards, awareness of appropriate mitigation to cope with these hazards, and public participation in community preparation programs are important for effective implementation of the mitigation program.

e) Warning systems: an effective warning system can provide a way to reduce flood impact. For example, by using a warning system, the groups who are exposed to flood hazard can evacuate in appropriate time and Emergency services and resources can be mobilized.

Structural mitigation for reducing floods may include:

a) Increasing the channel capacity in order to reduce flood water levels which will cover the neighboring lands of the channel.

b) Storing floodwaters upstream of the area affected and releasing them slowly after the event.

In this research, a dam structure solution is introduced to decrease the flood by storing flood water upstream the dam structure. There are several kinds of dam structure for storage; storage dams and detention dams.

However the first kind is the most suitable dam to store the water for Wadi Hadramout catchment since it is located in an arid region; therefore storage of water is favorable and more appropriate in this case. This stored water can be used during the dry season for different purposes as irrigation, water supply for neighboring urban and rural societies.

The detention dam will not store water which will be drained within and after the rainfall storm and will prevent using water like the storage dam benefits.

Another useful objective of creating a reservoir upstream the dam is to reduce the flood peak to a safe value. The amount of water stored upstream at the storage dam can be released by a gated orifice in the dam structure.

The storage dam choice will be constructed at the outlet of the subcatchment which gives the biggest flood hydrograph. Both sub-catchments (D) and (G) were selected accordingly.

Table (4-7) shows the flood peaks at the sub-catchments outlet.

Table 4-7 Parameters used in the design of the reservoir

Sub-catchment	Discharge (m^3/s)	Volume (m^3)
D	5155.5	402675821
G	4549.1	333347631

4.4.1 Creating Reservoir in HEC - HMS Model

As continuation of the subcatchment simulation, a reservoir was added in the model. To create reservoir from the main interface for the HEC-HMS, click on reservoir button, while still holding the mouse button, drag the cursor to a point where a specific reservoir site is needed. Connect the sub-catchment, with the downstream reach(R) and then to the junction which connects the main stream.

Determine the data needed for elevation-storage and elevation-discharge relations the process of addition of the data is as follows.

1. Select Components / Paired Data Manager and select Elevation-Storage-Functions for Data Type.

2. Click new Table-1 and type Elevation-Storage- Functions for Data Type for the name and click Create.

3. Change the data type to Elevation-Discharge Functions and click on new Table-2.

Enter to Elevation-Discharge Functions for name and click Create. Close the Paired Data Manager dialog.

4. Now on the catchment Explorer window expand Paired Data where you can see Elevation-Storage- Functions and Elevation-Discharge Functions. Expand both of them.

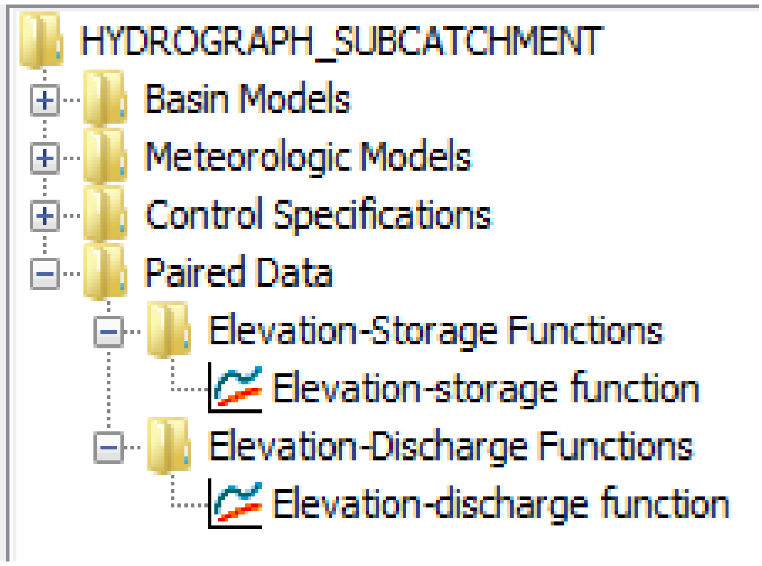

Figure.4.6.Reservoir routing data

5. In paired Data Tab, change Data source to Manual Entry and Units to m^3/s.

6. In Table, fill in the values from Table1 for reservoir1 and Table 2 for reservoir 2.

7. Click on graph for Elevation-Storage- Functions. This will bring the Elevation-Storage curve.

8. Click on graph Elevation-Discharge Functions. This will bring the Elevation-Discharge curve.

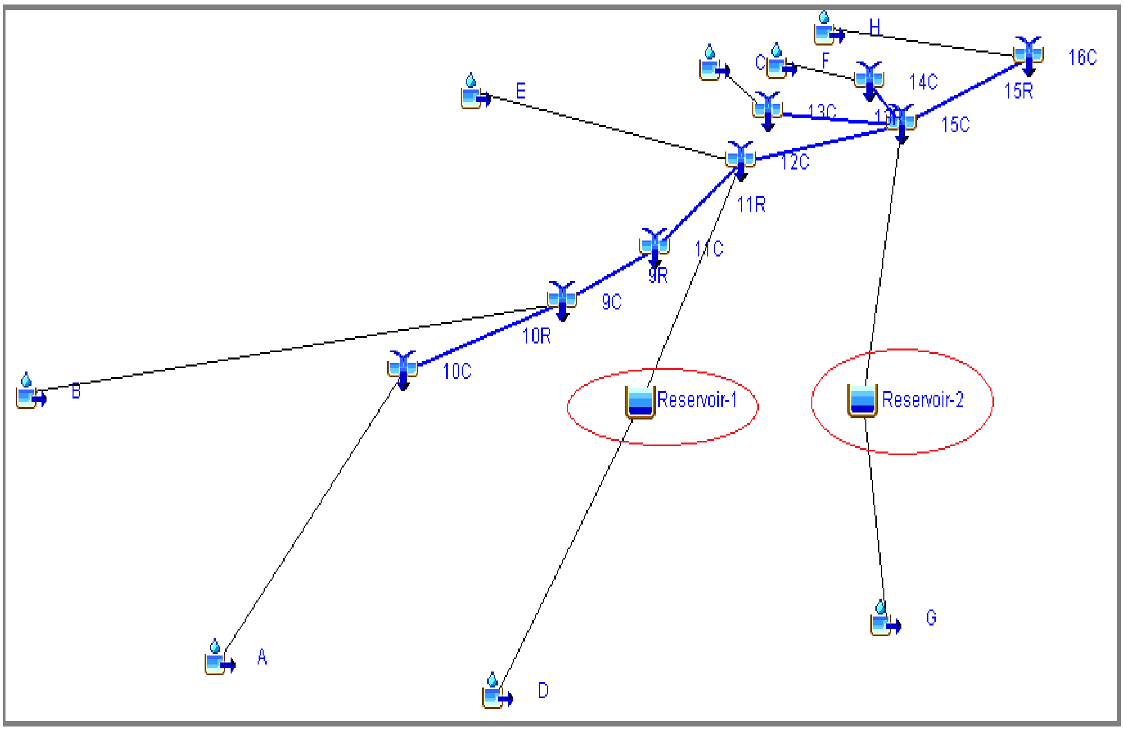

Figure.4.7.Reservoir representation in HMS Model.

4.4.2 Manning’s Roughness Coefficient

Manning roughness, n, should be selected to cope with sub-catchment soil type. Manning's roughness coefficient values can be found in the Table (4-8).

Table 4-8 Manning's roughness coefficient values

Surface Material	Manning's Roughness Coefficient-n-
Earth channel – clean	0.02
Earth channel – gravelly	0.025
Earth channel – weedy	0.03
Earth channel - stony, cobbles	0.035
Earth channel - rock cut	0.045

4.4.3 Capacity of the channel

In the design of open channels, the Manning's Formula is the most widely accepted equation to calculate discharge (Chow V. T., 1959)

$$Q = (A)\left(\frac{1}{n}\right)\left(R^{\frac{2}{3}}\right)\left(S^{\frac{1}{2}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq } 4.2$$

The variables in the formula are denoted as discharge Q = (m^3/s).

A = cross-sectional area of flow perpendicular to the flow direction, (m^2).

S = bottom slope of channel, m/m (dimensionless),

n = Manning roughness coefficient (empirical constant)

R = hydraulic radius = A/P in (m), A = cross-sectional area of flow

P = wetted perimeters (m).

The safe flow capacity for Wadi Hadramout main outlet was calculated using manning equation; the following are the parameters of the Wadi as shown in Table (4-9).

Table 4-9 parameters of the Wadi Hadramout channel

Average depths (m)	Bottom width (m)	Bed slope (m/m)	Manning n (Table4-8)
3.5	400	0.002	0.025

The cross section to be assume to be a wide rectangular cross section (R = depth of flow). The outlet channel capacity was found to be 5797.338 m^3/s. This means that the total discharge of 14241.378 m^3/s should be reduced to the channel capacity. Therefore two dams were found appropriate to reduce this flood.

4.4.4 Hydraulic design of the spillway

Spillway is necessary to provide capability to release an adequate rate of water from the reservoir to satisfy dam safety and water control regulation (United States Army Corps, 1997).

The broad-crested spillway allows for controlled flow over the top of the reservoir according to the weir flow assumptions (United States Army Crops, 2010).

The spillway was design to pass the excess of flood flow beyond the 50 year flood. Since this flood is stored upstream the dam .For this reason it is assumed that 100 year flood will be used as the maximum probable flood the difference the two floods will pass above the spillway. The excess difference of flow between the two floods was found to be 1201.42 m^3/s for reservoir 1 and 1042.1 m^3/s for reservoir 2 which gave the length of the spillway crest using Eq4-3. After a series of calculation the Hydraulic parameter for spillway are shown in Tables (4-10, 4-11).
The broad-crested type spillway equation by James B. Francis (Horton, 1907).

$$Q = CLH^{1.5} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..... Eq\ 4.3$$

Where: Q = discharge (m^3/s), C = spillway coefficient, where c from (1.7 to 2.0).

L = spillway width (m), H = head above weir crest (m)

Table 4-10 spillway data reservoir 1subcatchment (D)

Item	**Spillway structure**
Spillway type	**broad-crested type Spillway**
Crest Elevation (m)	719
Bottom level	701.50
Length (m)	60
Coefficient	2.0
Weir Height (m)	17.5
Head above weir crest (m)	4.65

Table 4-11 spillway data reservoir 2 subcatchment (G)

Item	**Spillway structure**
Spillway type	**broad-crested type Spillway**
Crest Elevation (m)	631
Bottom level	617.5
Length (m)	60
Coefficient	2.0
Weir Height (m)	13.5
Head above weir crest (m)	4.3

4.4.5 Reservoir Routing

The method for reservoir routing follows the procedure explained by (Wurbs, 2002). Reservoir routing consists of routing inflow hydrograph at the upstream side of the reservoir to its downstream side. The method employed in the model to route flows through reservoirs is a variation of hydrologic routing technique, called Storage- Outflow routing.

As defined by (Tewolde, 2006) , flood routing is a mathematical method for predicting the changing magnitude and celerity of a flood wave as it propagates through reservoirs.

Tables (4-12, 4-13) displays the data calculated for the relationship between Elevation, storage and discharge, a form of accounts that have been conducted.

The storage equation governing the rate of change of reservoir storage volume is (Carter R. W., 1960).

$$\bar{O} = \bar{I} - \frac{\Delta S}{\Delta t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq\ 4.4$$

Where

$\bar{O}$ Mean outflow during routing period Δt

$\bar{I}$ Mean inflow during routing periodΔt

ΔS Net change in storage during routing period Δt

Table 4-12 Elevation and storage for reservoir at sub-catchment (D).

	Elevation (m)	Storage (m^3)
1	701.50	0.00
2	703.53	8612337.38
3	705.55	18128093.57
4	707.58	33919376.04
5	709.61	57323440.64
6	711.63	88858434.70
7	713.66	129820134.39
8	715.68	181768640.95
9	717.71	245919802.90
10	719.74	323979985.50
11	721.76	417094182.83
12	723.79	526200567.26
13	725.82	650298027.05
14	727.84	789969518.94
15	729.87	944515188.34
16	731.89	1112927512.27
17	733.92	1294192615.38
18	735.95	1488117055.55
19	737.97	1695296316.98
20	740.00	1916854015.31

Table 4-13 Elevation and storage for reservoir at sub-catchment (G).

	Elevation (m)	Storage (m^3)
1	617.50	0.00
2	618.74	22542205.72
3	619.97	31086727.46
4	621.21	42928313.90
5	622.45	59599812.86
6	623.68	81872489.27
7	624.92	110842209.18
8	626.16	147347229.02
9	627.39	192021092.49
10	628.63	244708209.59
11	629.87	304484784.79
12	631.11	369999960.87
13	632.34	440660871.62
14	633.58	515784021.64
15	634.82	595362920.12
16	636.05	678866612.30
17	637.29	765581314.76
18	638.53	855134857.69
19	639.76	947357839.03
20	641.00	1041854470.37

The relation between the reservoir volumes against, elevation upstream the dam, the inlet hydrograph to the reservoir 1 in subcatchment (D) is given in Figure 4.8 and the reservoir 2 in subcatchment (G) is given in Figure .4.9.

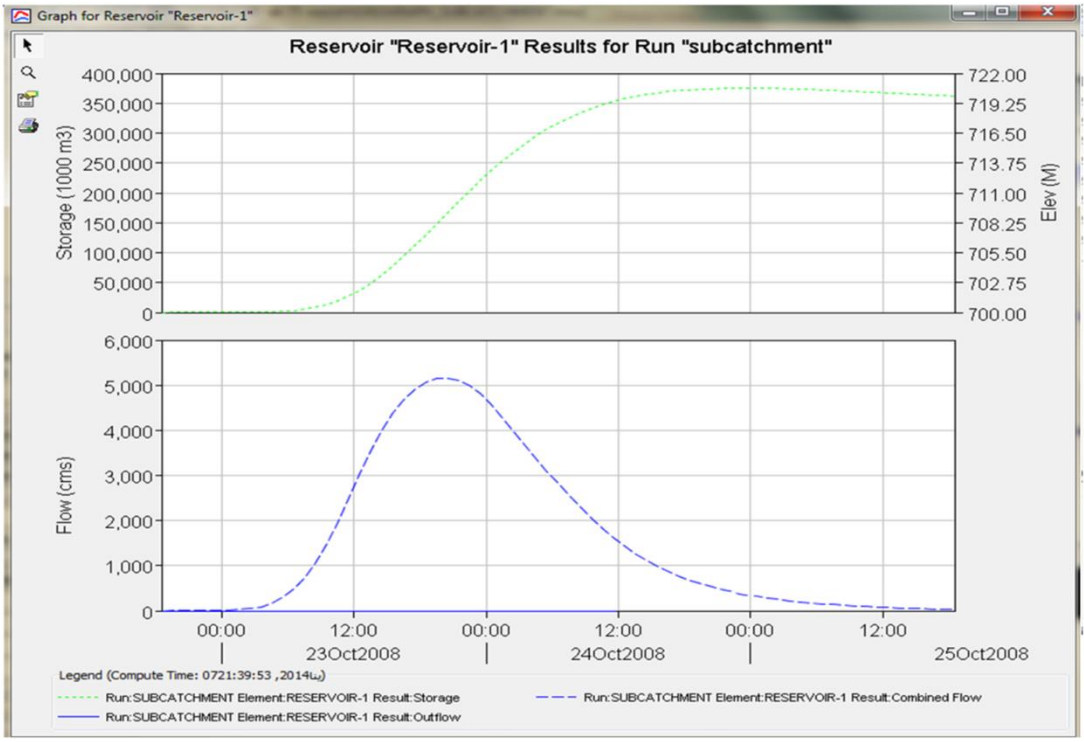

Figure.4.8.Reservoir-1 result subcatchment (D)

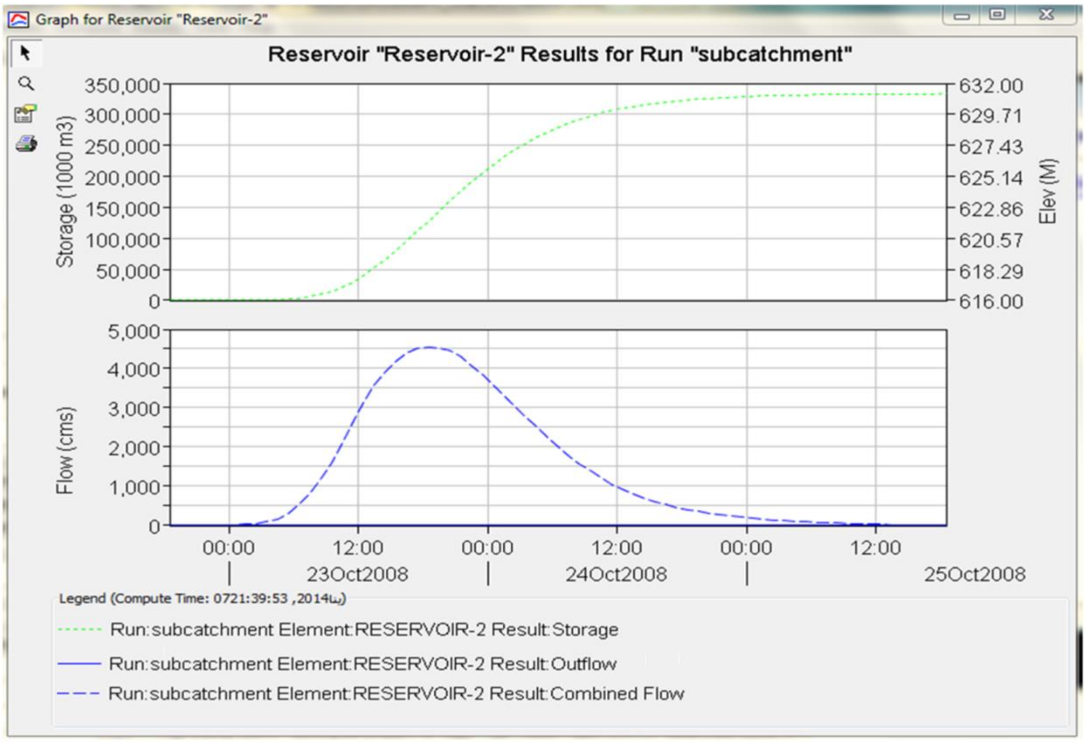

Figure.4.9.Reservoir-2 result subcatchment (G)

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Analysis

The approach of analysis and mitigation of flood risk proposed in this study used three different effective tools. Each of those tools has an attribute for a comprehensive study to limit the risks of floods and to mitigate its risk in Wadi Hadramout.

The Geographical Information Systems has the main role in an accurate, complete study as it has the properties of storage, representation, analysis of a wide group of geological data. It also analyzes maps of flood risks which were drawn on basic topographical maps and satellites photos. It categories the Geographical and spatial frame of Wadi Hadramout. It also helps to determine the effects of flood risk in Simulation. In addition, it aims to facilitate planning activities and to control water management in area of study.

5.1.1 Land Use / Land Cover

The Surface land Cover Analysis is important and was created for Wadi Hadramout in this thesis. The Satellites photos were interpreted visually to obtain information on land cover and land use by Geographical Information Systems to get spatial Analysis.

- The Land Cover analysis showed that 1.85 % of Area is being cultivated whereas the population areas represent only 0.14% of the total area of catchment. The bare lands are estimated as 97.8 %as shown in Figure 5.1.

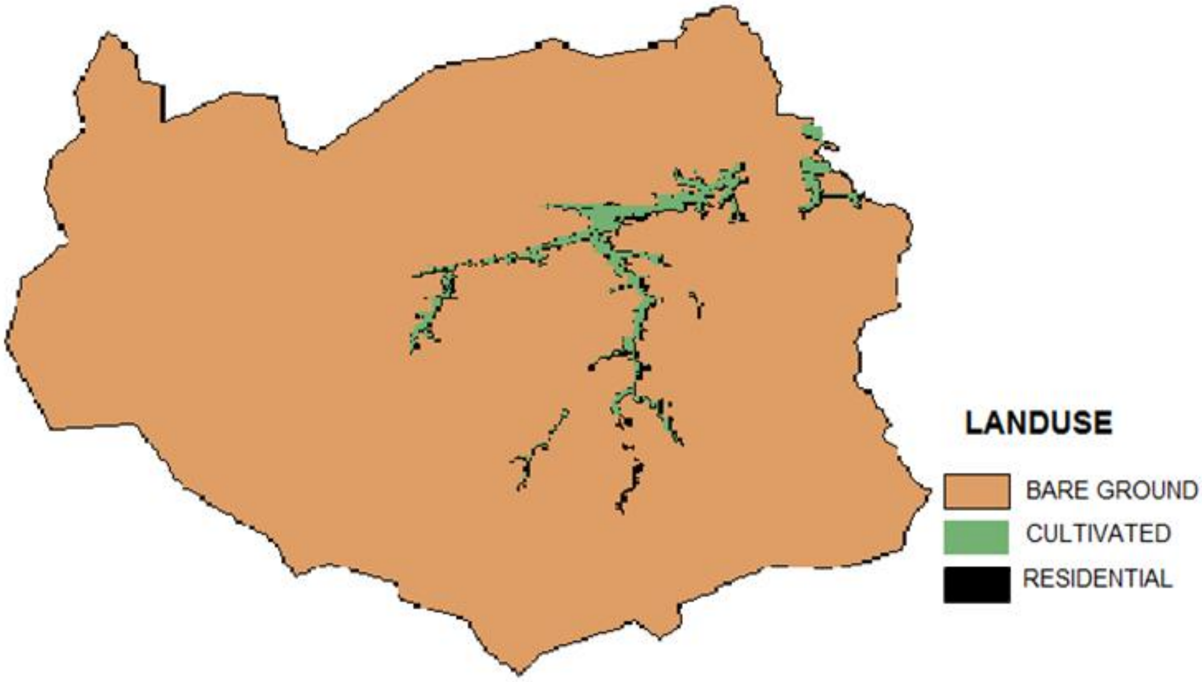

Figure.5.1. Land use/ Land cover of Wadi Hadramout

5.1.2 Soil Texture

Classification of soil types based on their physical Texture, Classified Wadi Hadramout soil to Gravel(A), Sand(B), Silt & Clay(C) and Rock(D).

By analyzing geological coverage for different soil types, classifications indicate the presence of the majority of rock, classified as type (D) with a percentage of 73.09%.It is considered the largest percentage of the area of the region and represents a decrease in the infiltration rate of the soil. This ratio is very high because of their direct impact on increasing the amount of runoff.

In the second category comes the Gravels soil which is classified as (A) Class with a percentage of 13.18%. This shows that there is rational possibility of soil infiltration and Surface Water Flow (Runoff). The sandy is still in low averages as 0.187 % and it is classified as (B) Class. Clay and Silt which is classified as Soil Type (C) with a percentage of 13.52%.

As a whole these soils indicate that there is loss of rain water in soils and reduction in runoff as shown in Figure 5.2.

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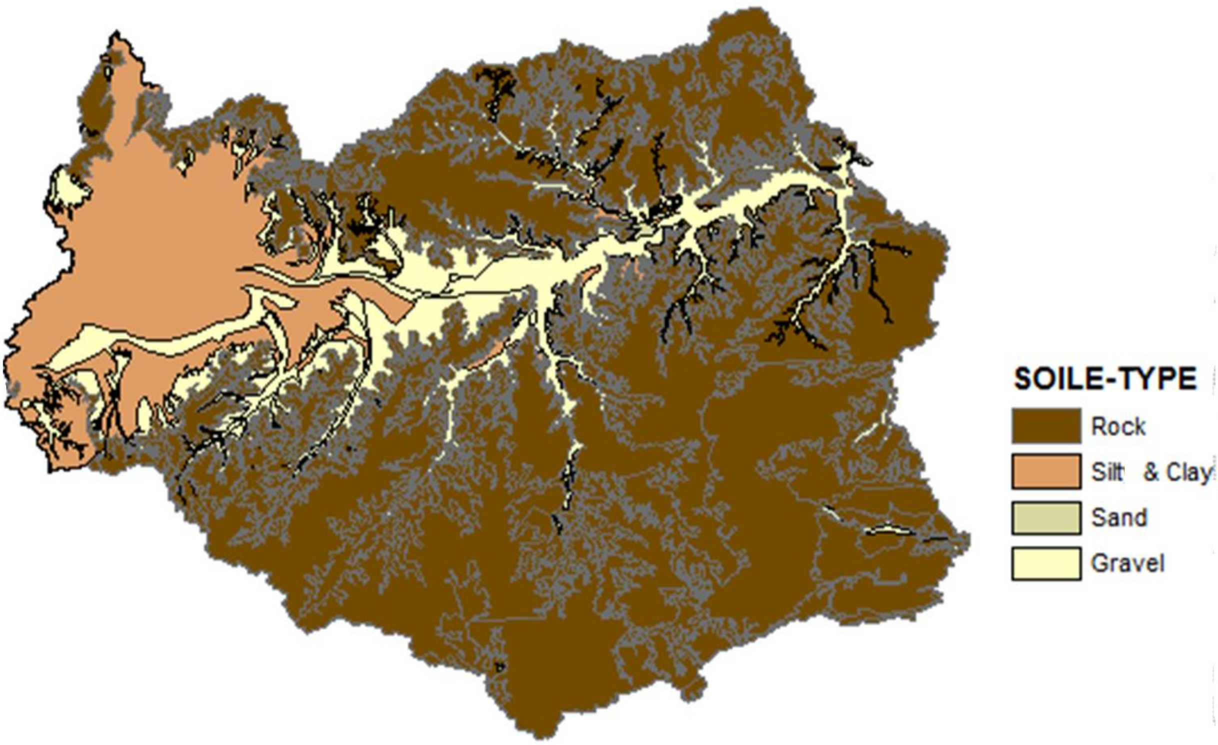

Figure.5.2.Mean soil classification map Wadi Hadramout.

5.1.3 Analysis of the Curve Number of Wadi Hadramout

The Curve Number is used to describe the nature and status of Land Coverage. It is calculated by Geographical Information Systems (GIS).

It was found to be as a suitable method to study Geographical features and land classification. In applying this method the soil have been identified as various types of soil and land use. To get the average value of curve number for catchment Wadi Hadramout and curve number of Sub-catchments. The Curve Number of Wadi Hadramout was classified into Eight (8) different Curve Numbers as follows:

- Curve Number (89) represents 69.74 % for soil (D) which is considered the largest area in the Hadramout catchment.
- Curve Number (68) represents (17.9%) for soil (A) that is considered the second largest area of the Wadi.
- Curve Number (86) represents (7.29 %) for soil (C).
- Curve Number (84) represents (1.79 %) for soil (D).
- Curve Number (79) represents (1.45 %) for soil (B).
- Curve Number (39) represents (0.97%) for soil (A).
- Curve Number (92) represents (0.243%) for soil (B)
- Curve Number (82) represents (0.243 %) for soil (D).

All these curve numbers were selected from Table (3-7) as given in Figure.5.3.

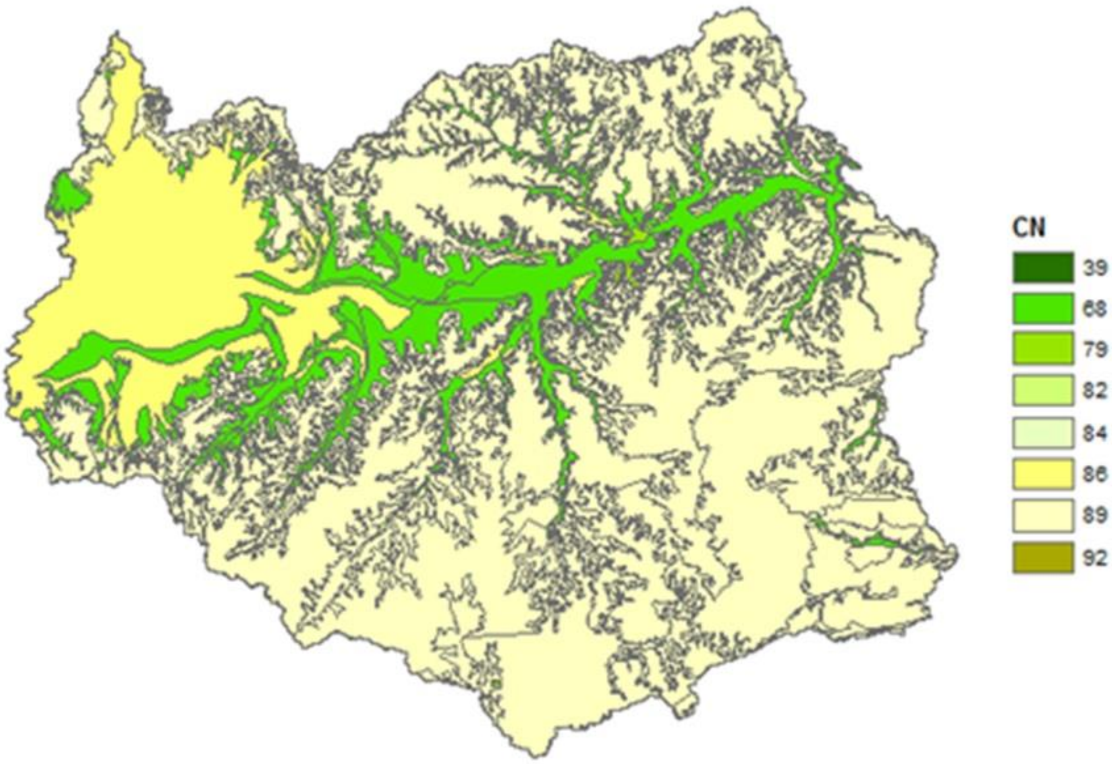

Figure.5.3. Type of curve number in Wadi Hadramout catchment

5.1.4 Simulation Scenarios for Wadi Hadramout Catchment

The HEC-HMS specifies simulation in order to get the floods of Wadi Hadramout, the following methods were used:

1) SCS curve number for loss factor.

2) SCS unit hydrograph.

3) Muskingum-cung for channel routing.

These methods assisted in finding the Hydrological Parameters to accomplish the simulation of rainfalls, its impact on the study area and to represent it in graph.

Those Parameters are shown in the following table:

Table 5-1 The parameters used with HEC-HMS

Name of parameter	**Description**
1. Total precipitation	In Simulation Process and using the amount of rainfalls depth.
2. Curve Number (CN)	It is a Hydrological Parameter used to predict the rainfall infiltration.
3. Maximum retention (s)	It represents the maximum quantity that can be stored in the Catchments.
4. Initial abstraction (Ia)	It represents of the largest quantity to rainwater which is absorbable both at the Surface depressions.
5. Time lag (TL)	It represents the mid-period between the excess of rainwater and the peak discharge.

Continue …..

6. Duration of effective rainfall (Tr)	It is the time interval to the effect of the rain on the catchment in terms of the start and finish of the rain.
7. Slope	Slope is a very important factor in determining the velocity of runoff inside the Catchments.
8. Infiltration rate (f)	It represents the maximum limit of water average that can be absorbed by soil.
9. Total direct runoff	The maximum quantity that was formed while rainfalls.
10. Peak discharge	It is the maximum discharge during rainfalls.
11. Time of peak discharge	It represents the start time in the runoff is the beginning of the rainfall time of impact in the catchment until the peak discharge.
12. Spillway length	The effective crest length.
13. Spillway head	The head over the spillway crest.

Continue …..

14. Area of catchment	The Area of catchment of Wadi Hadramout and Sub-Catchments.
15. Bottom width	It represents the width of catchment at area place of water harvesting.
16. Length of reach	The length of the channel reach is the distance along a stream channel between two points of junction.
17. Inflow	It represents the rainfall flow inside the catchment.
18. Outflow	It represents the flow out in the catchment stream and during the creating of runoff occur place inside the catchment.

5.1.5 Comparison between scenarios

There are two scenarios. The first scenario is to consider Wadi Hadramout as one catchment. The second scenario is to consider it as several sub-catchments. The outputs in the scenarios are given in Table 5-2.

Table 5-2 Compare is on between Outlets for main Catchment and Outlet for main Sub-Catchments.

Name	Peak outflow (m^3/s)
Outlet for main Catchment	12519.902
Outlet for main sub-catchments	14236.251
Difference between peak flows	1716.349

From Table 5-2 it is shown that the flood obtained from the first scenario is 12519.902 m^3/s whereas the peak flood outflow in the second scenario is 14236.251m^3/s which is greater than the first scenario by 1716.349 m^3/s.

The reason for that is the first scenario uses an average value for all properties for the whole catchment which will give an approximate value.

As a conclusion in order to select flood values, large catchments should be divided into several sub-catchments to give more accurate result.

The flood hydrographs for the first scenario and the second scenario are given in appendix (A, D).

5.1.6 The flood mitigation.

In order to mitigate the flood risk it should be controlled by a control system.

In Hadramout catchment the control system is in favor of dam construction to store flood water and accordingly reduce the flood peak.

The dam should be designed to be capable of storing the amount of water to reduce the flood risk.

In our case two scenarios were selected. The first scenario is to build one dam at the outlet of the biggest subcatchment. One dam is not enough for the reduction needed. It was found that another sub-catchment is suitable in Hadramout Catchment.

Sub-Catchments (D, G) were selected for this purpose and analyzed depending on the routing model of Muskingum method. The series of flood control simulations performed in HEC-HMS provided several insights regarding the operation of the reservoirs under different conditions. Appropriate results of Storage Capacity of the reservoir were obtained.

As a flood control project routing procedure were seen in order to find maximum outflow from the main catchment outlet.

The purpose of determining this step is to prevent any outflow from the main catchment greater than the outlet channel capacity.

The use Dam-1 will reduce 5155.57 m^3/s and dam-2 will reduce the rest of flow.

The final results of the last process are given in Tables (5-3, 5-4).

Table 5-3 Results reservoir-1

Reservoir-1 for subcatchment (D)	
Peak inflow(m^3/s)	5155.512
Peak outflow(m^3/s)	0.0
Peak storage(m^3)	402661516

Table 5-4 Results reservoir-2

Reservoir-2 for subcatchment (G).	
Peak inflow(m^3/s)	4549.109
Peak outflow(m^3/s)	0.0
Peak storage(m^3)	333301967

5.1.6.1 Result of catchment main outlet after mitigation

The flood inflow at the reservoir inlet was routed using HEC HMS which gave a final hydrograph at the outlet of the main catchment.

As a comparison between the resulted hydrographs of the main catchment for flood peaks without dam and with dam shows a reduction in the different results for the main peak flow which gave a safer flood as shown in Table 5-5.

The flood hydrograph for main outlet catchment after mitigation as appendix (E)

Table 5-5 Results of the main catchment for flood peaks without dam and with dam.

Name	Peak outflow (m^3/s)	Total outflow (mm)
Catchment without reservoir	14236.251	43.483
Catchment with reservoir	5525.748	19.077
Difference between peak flows	8710.503	24.406

CHAPTER 6

Conclusions & Recommendation

6.1 Conclusions

The aim of this research is a comprehensive study to analyze the risks resulted by floods at Wadi Hadramout Catchment. The first task of this research was to use a probability analysis for rainfall depths. It is recommended for flood mitigation a designed storm not less than 50 years return period.

Geographical Information Systems (GIS) was used to get a sufficient result to describe the topography and the nature of land cover. It is considered an important part to complete the simulation.

WMS Model was used to make delineation for the catchment and to divide the catchment to 8 Sub-Catchments.

HEC-HMS was used to design runoff model which depends on rainfall excess, lands use, and soil type. A Simulation Scenario was developed to get the flood Hydrograph as shown in appendix (A).

It was found that two dams at two sub-catchments outlet are essential to reduce the flood flow and cause the flood mitigation needed.

This reduction of the peak flow at the outlet of the main catchment became 5525.748m^3/s instead of flood peak 14241.378 m^3/s with the dams construction.

This value was found to be less than outlet channel which can carry 5797.338 m^3/s. Accordingly the Wadi Hadramout urban area will be safe against any flood hazard.

6.2 Future Recommendations

The results of this study lead to the following recommendations:

1- Limitation of the human different activities in using the lands in watercourses to reduce environmental impacts of the flood hazard.

2- Use the necessary facilities to decrease the damages arising from floods and runoffs nearby the main watercourses.

3- It is possible to control or mitigate the floods effectively by establishing hydraulic structures to control the rainwater amount, to limit the runoff.

4- The amount of water stored can be used for agricultural development processes and different uses as well.

5- For the decision maker they should select the dam construction on subcatchment (D) as a first priority and postpone the construction of second dam afterward due to urgent reasons.

   - This first priority of construction of the first dam can mitigate flood resulted from rainfall 54 mm such as that occurred in October 2008.which my happen again. The peak discharge and flood hydrograph for 54 mm are given in appendix. (F)

   - The construction of the second dam will help together with the first dam to mitigate the flood which will occur for 75mm rainfall of probable rainfall for 50 years return period given by the probability analysis for Hadramout Wadi.

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Appendix A – Results of Catchment Wadi Hadramout

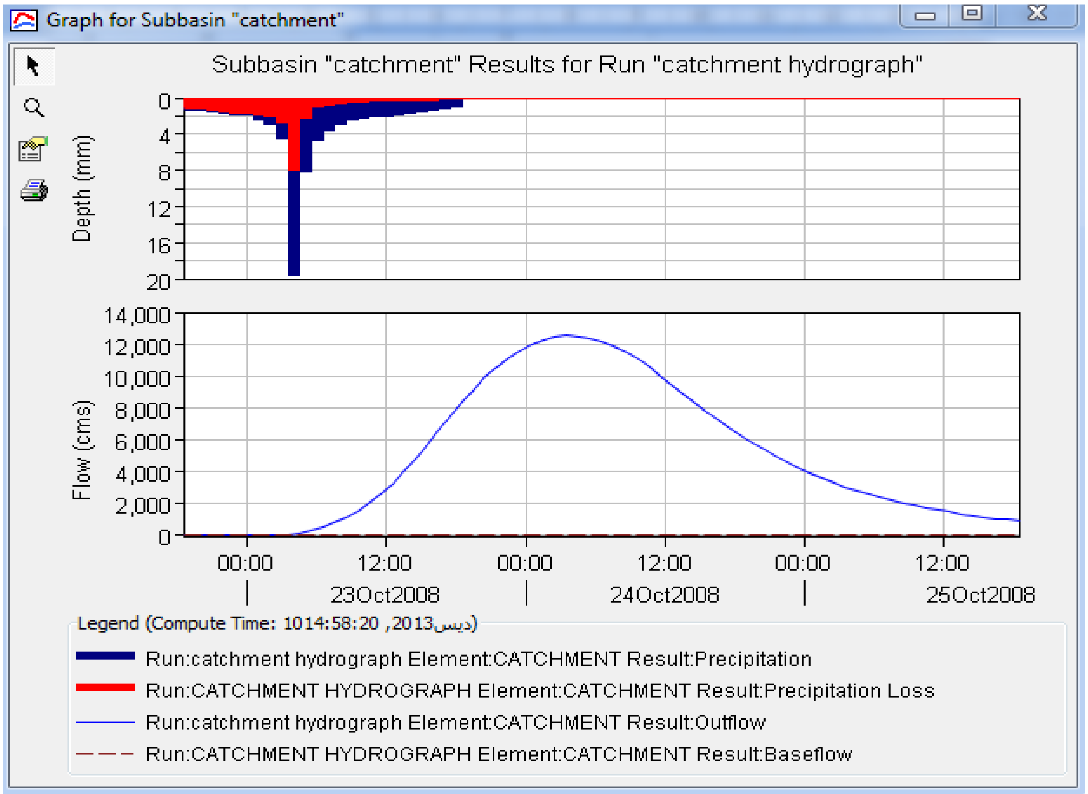

Figure A.1—Global for catchment

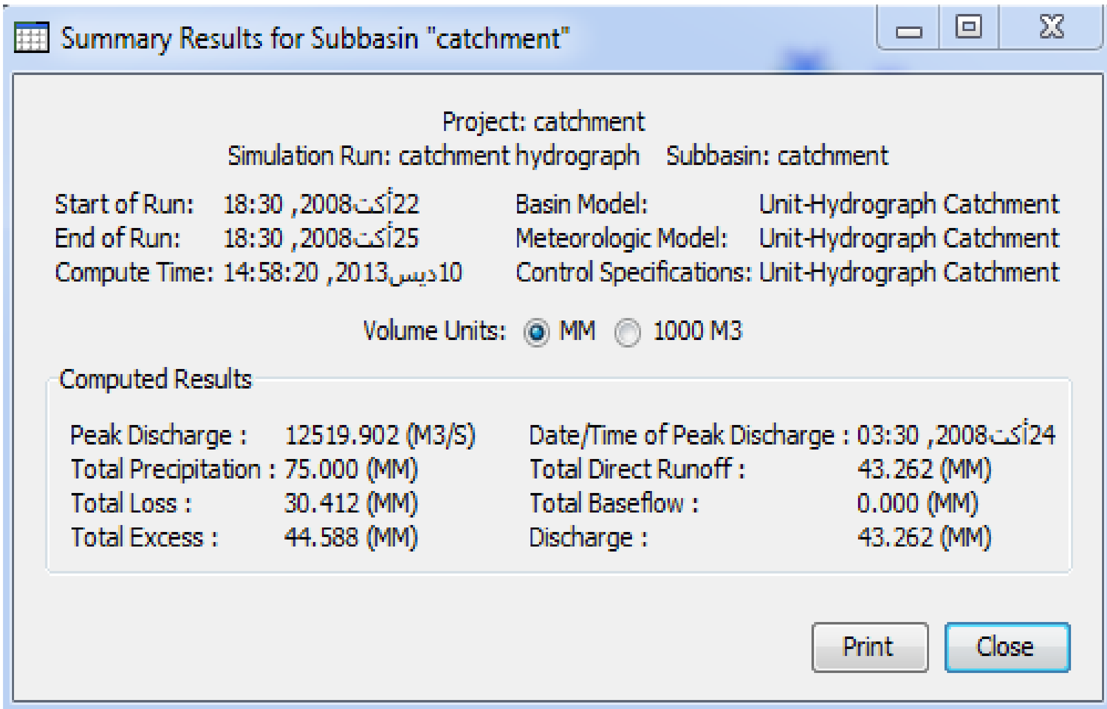

Figure A.2—Summary results Catchment.

Appendix B - Results analysis for subcatchment.

Subcatchment (A)

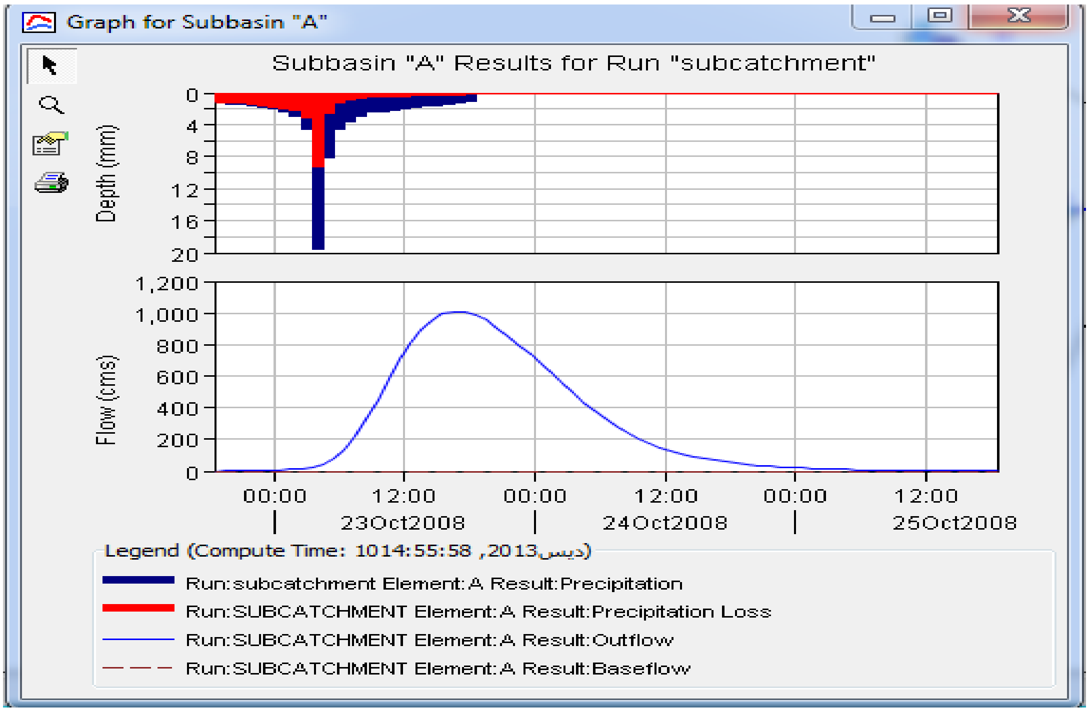

Figure B.1—Global for Subcatchment (A).

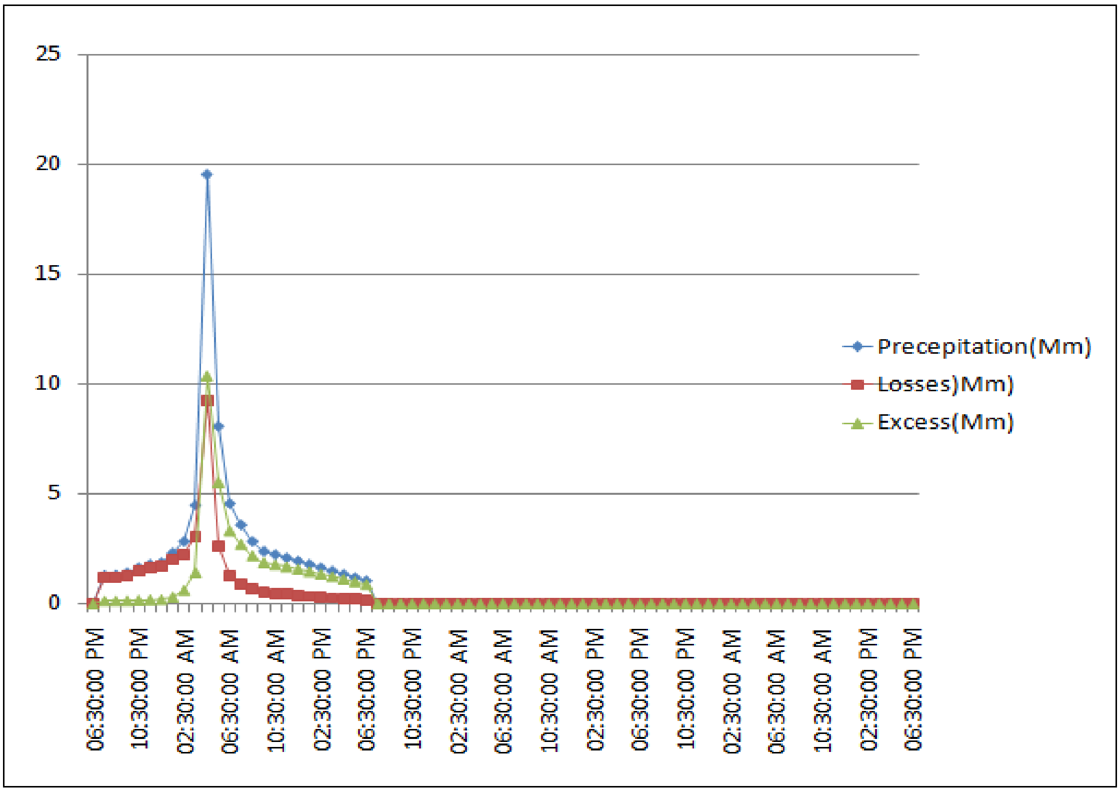

Figure B.2—Effect event rainfall for Subcatchment (A)

Subcatchment(B)

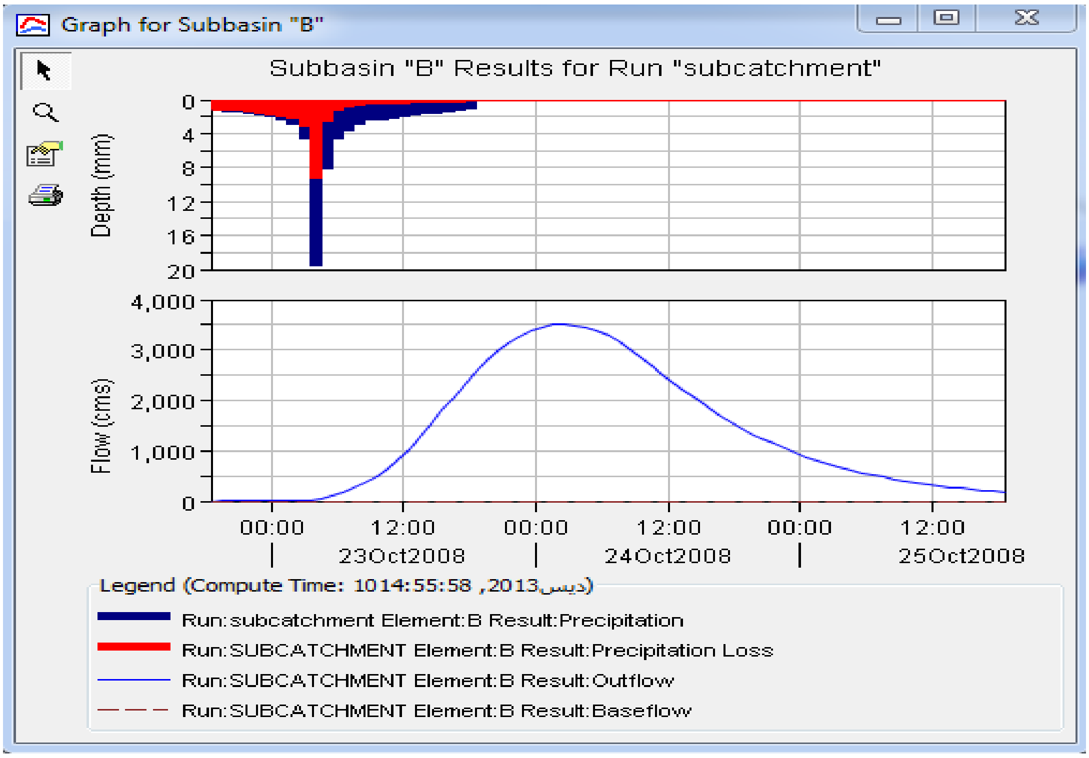

Figure B.3—Global for Subcatchment (B).

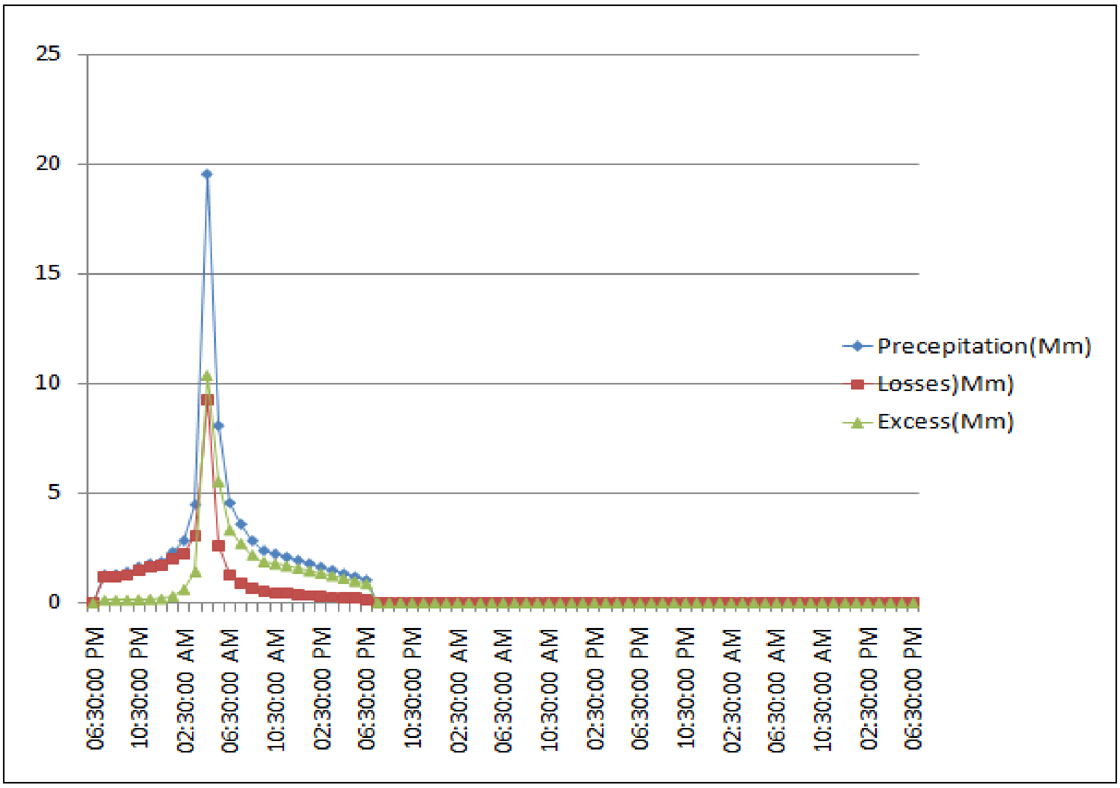

Figure B.4—Effect event rainfall for Subcatchment (B)

Subcatchment(C)

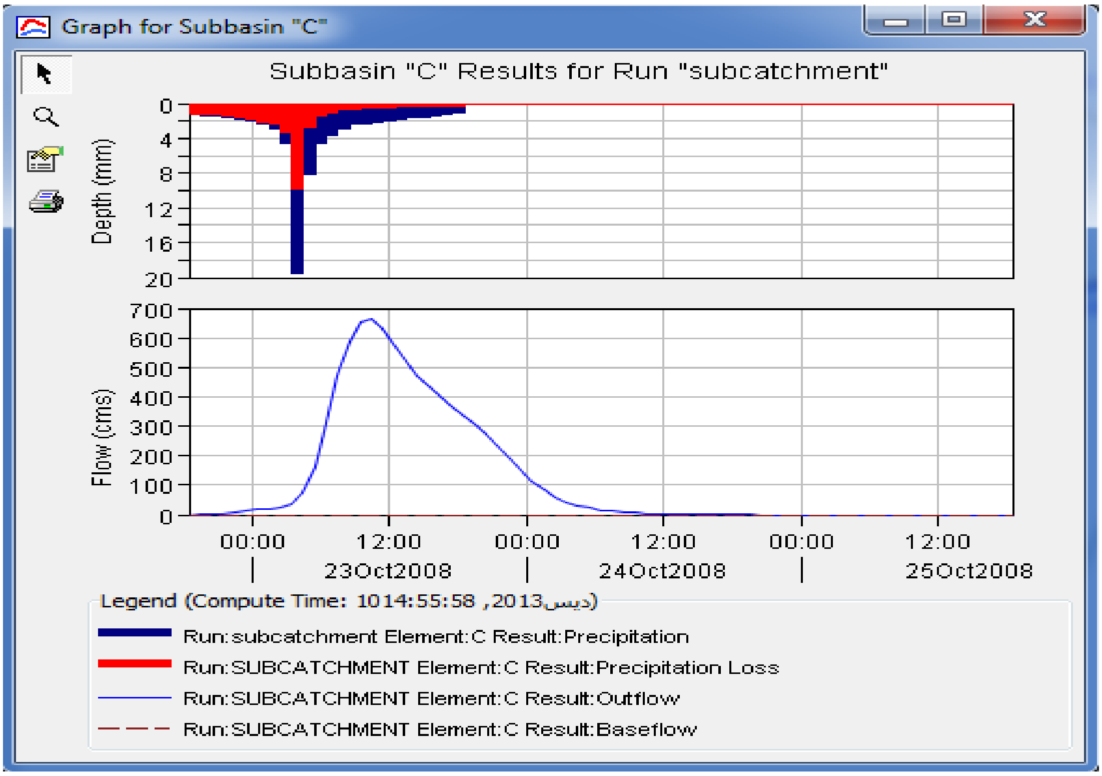

Figure B.5—Global for Subcatchment (C).

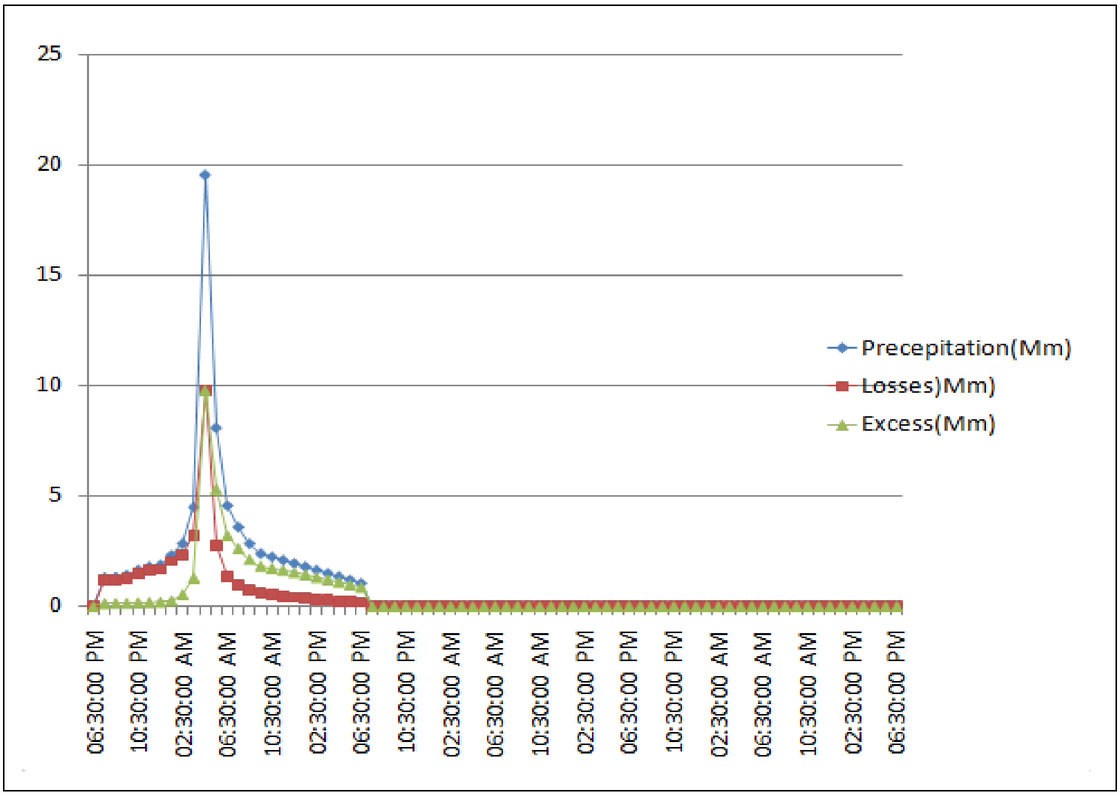

Figure B.6—Effect event rainfall for Subcatchment (C)

Subcatchment(D)

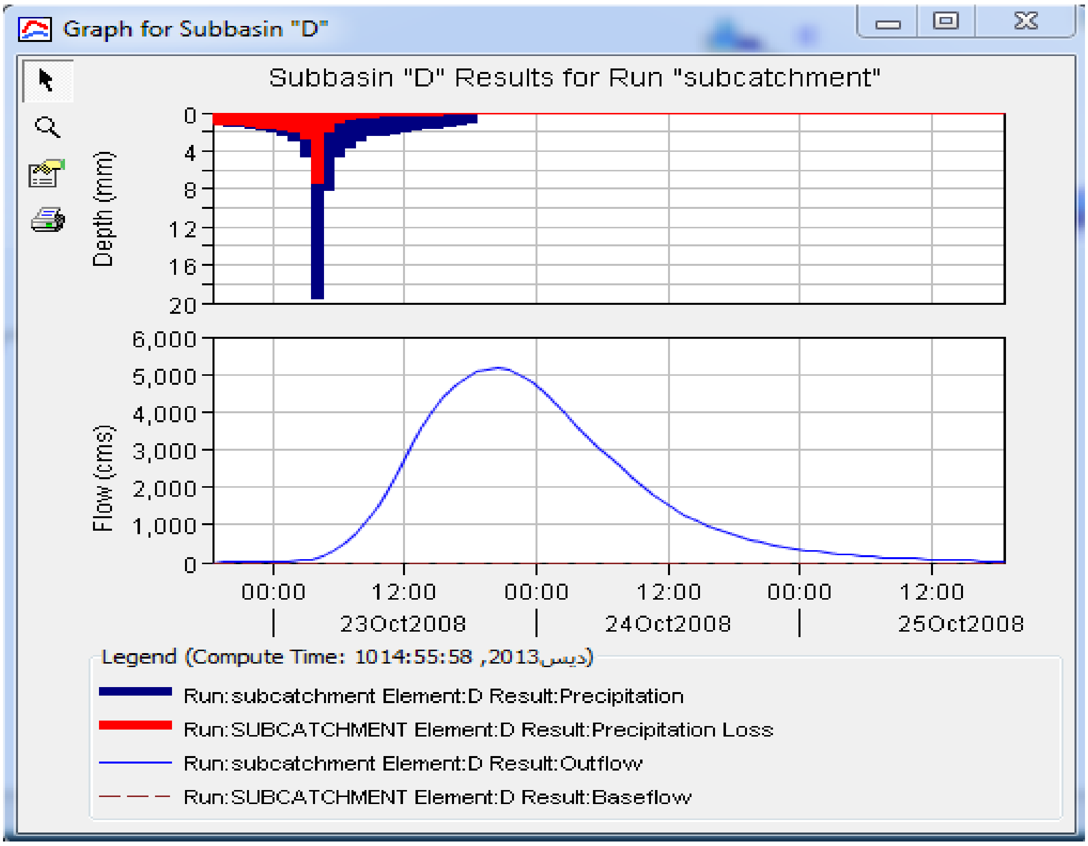

Figure B.7—Global for Subcatchment (D).

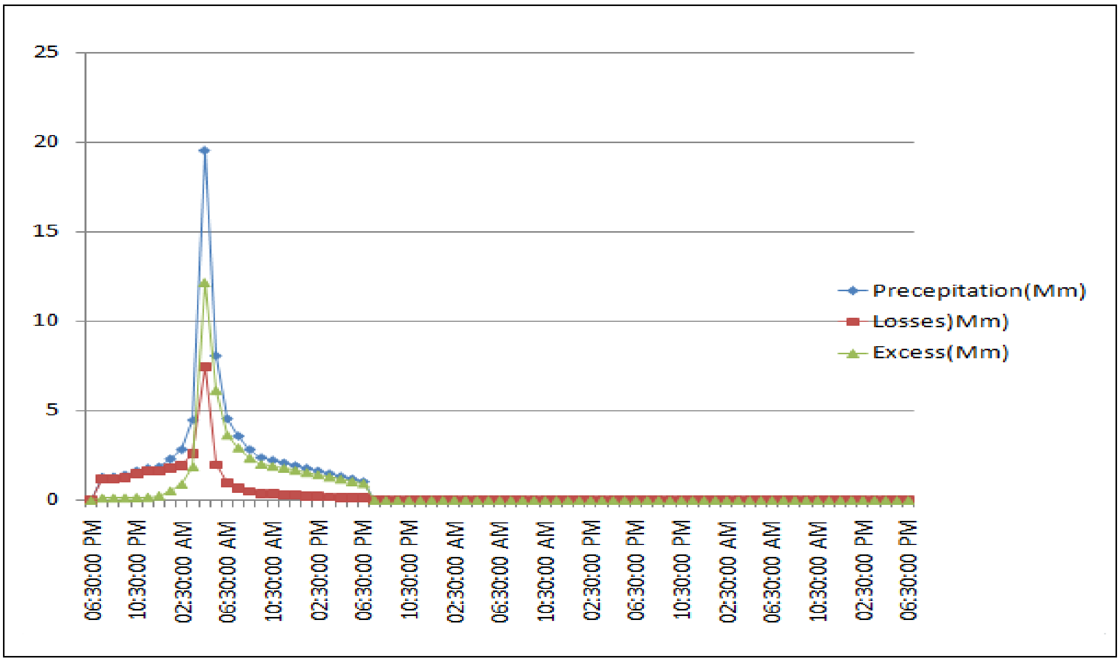

Figure B.8—Effect event rainfall for Subcatchment (D)

Subcatchment(E)

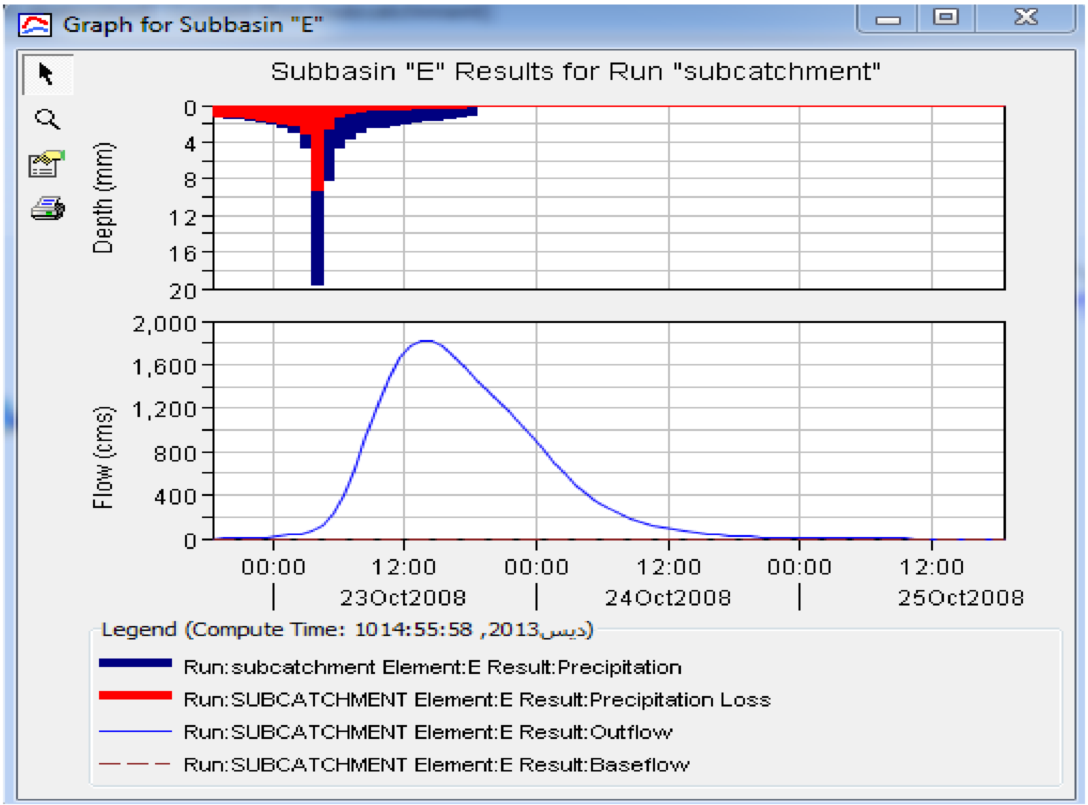

Figure B.9—Global for Subcatchment (E).

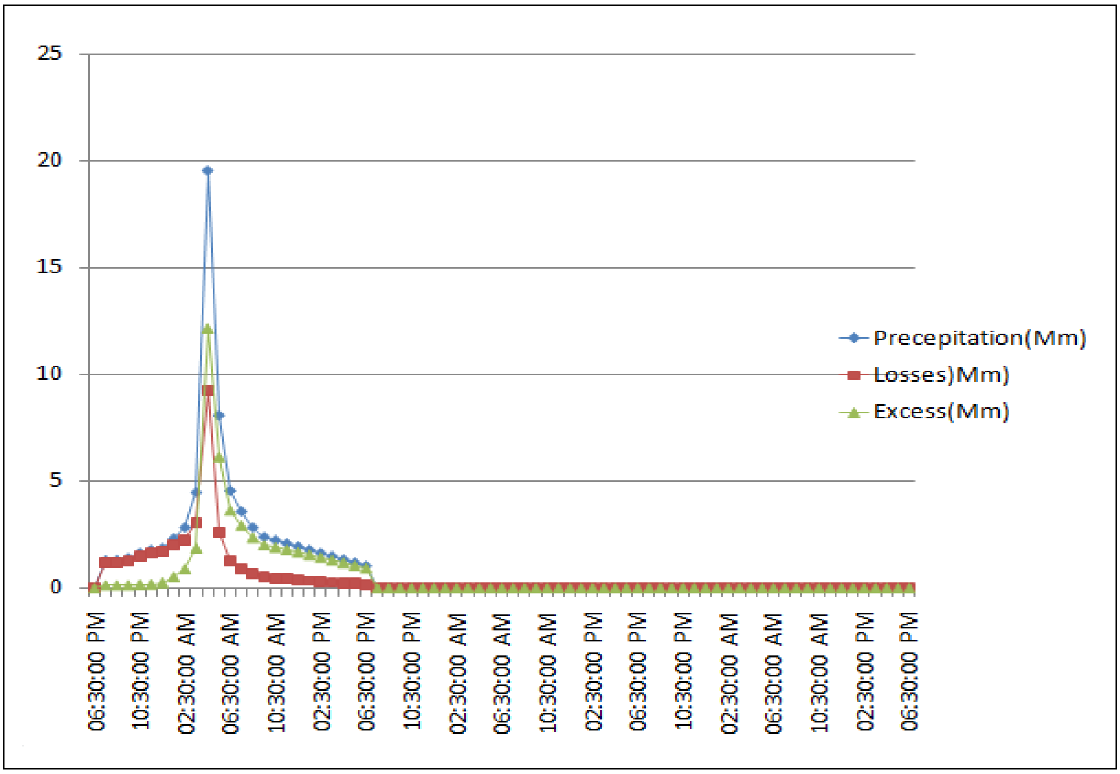

Figure B.10—Effect event rainfall for Subcatchment (E)

Subcatchment(F)

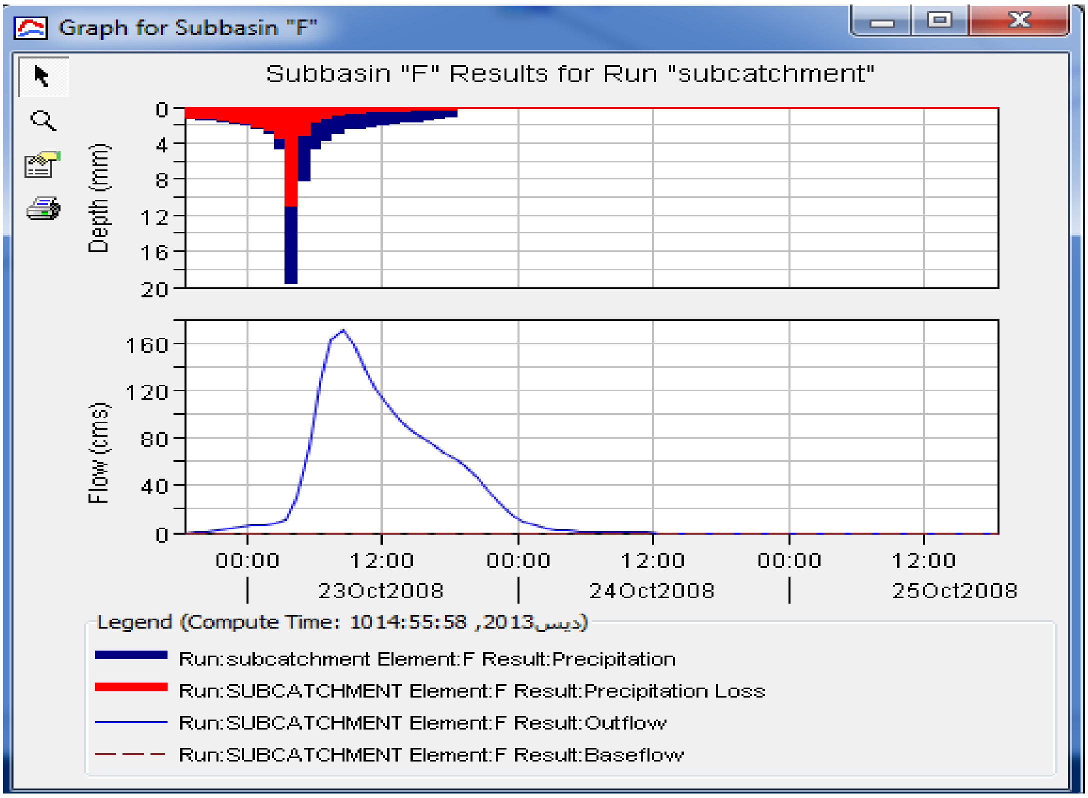

Figure B.11—Global for Subcatchment (F).

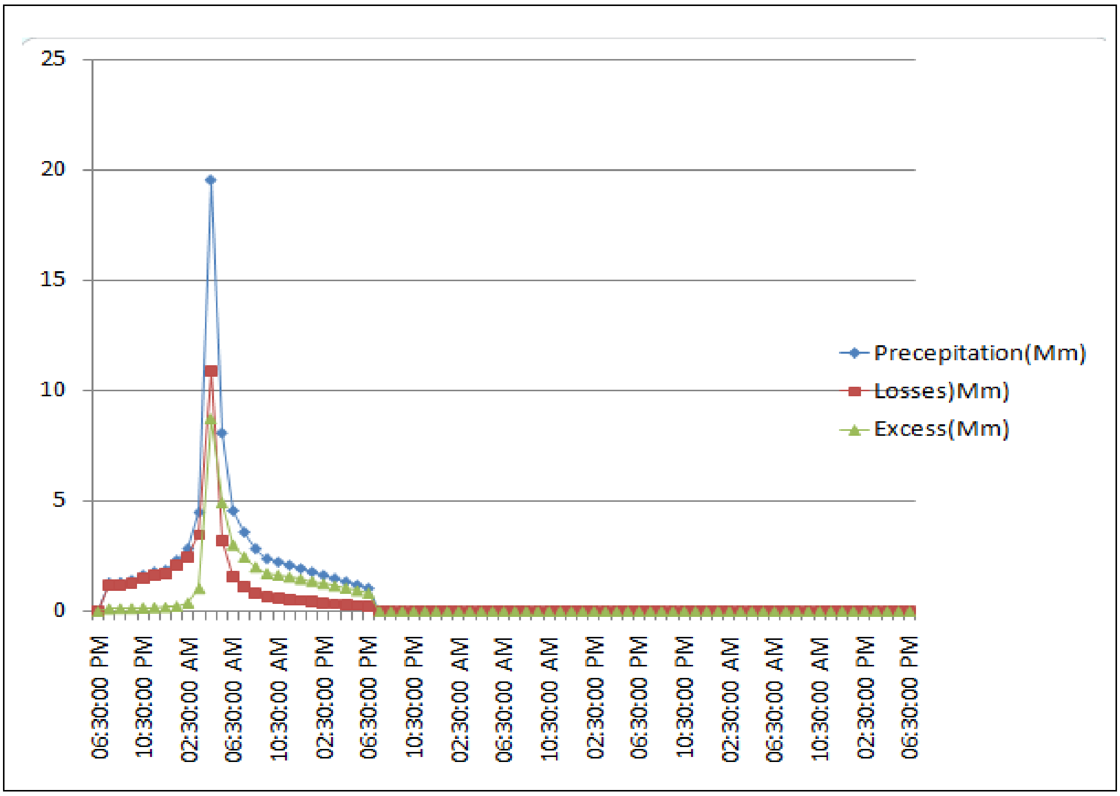

Figure B.12—Effect event rainfall for Subcatchment (F)

Subcatchment (G)

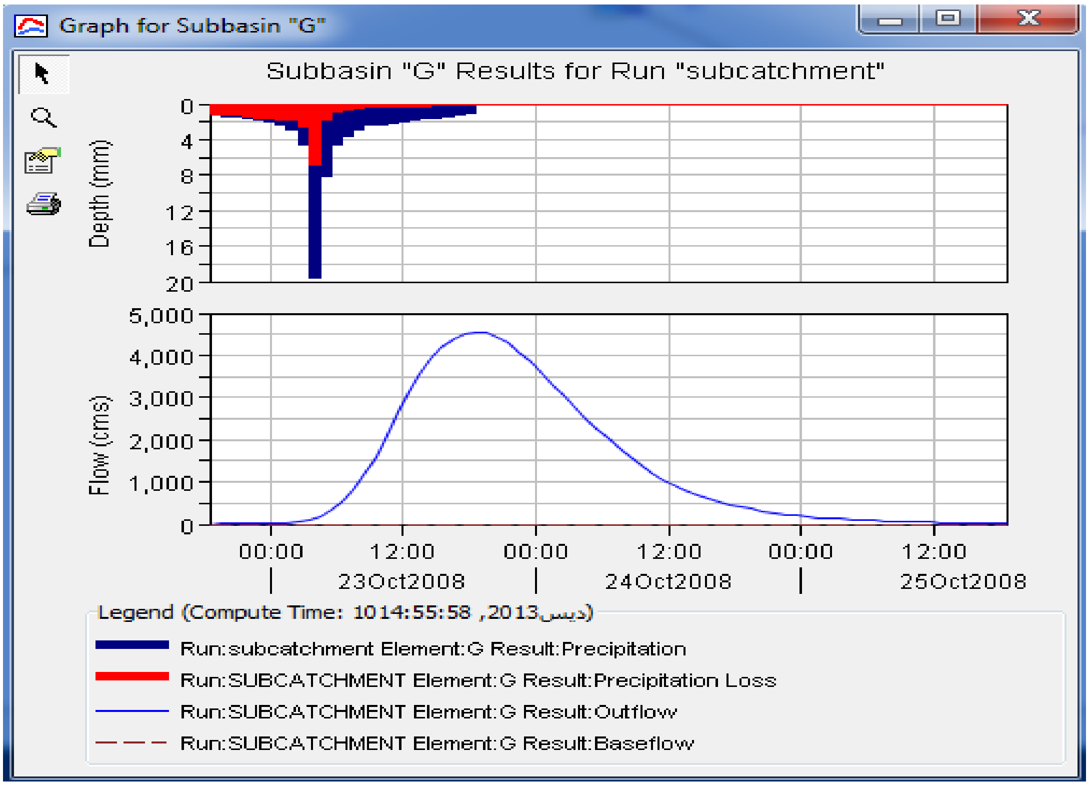

Figure B.13—Global for Subcatchment (G).

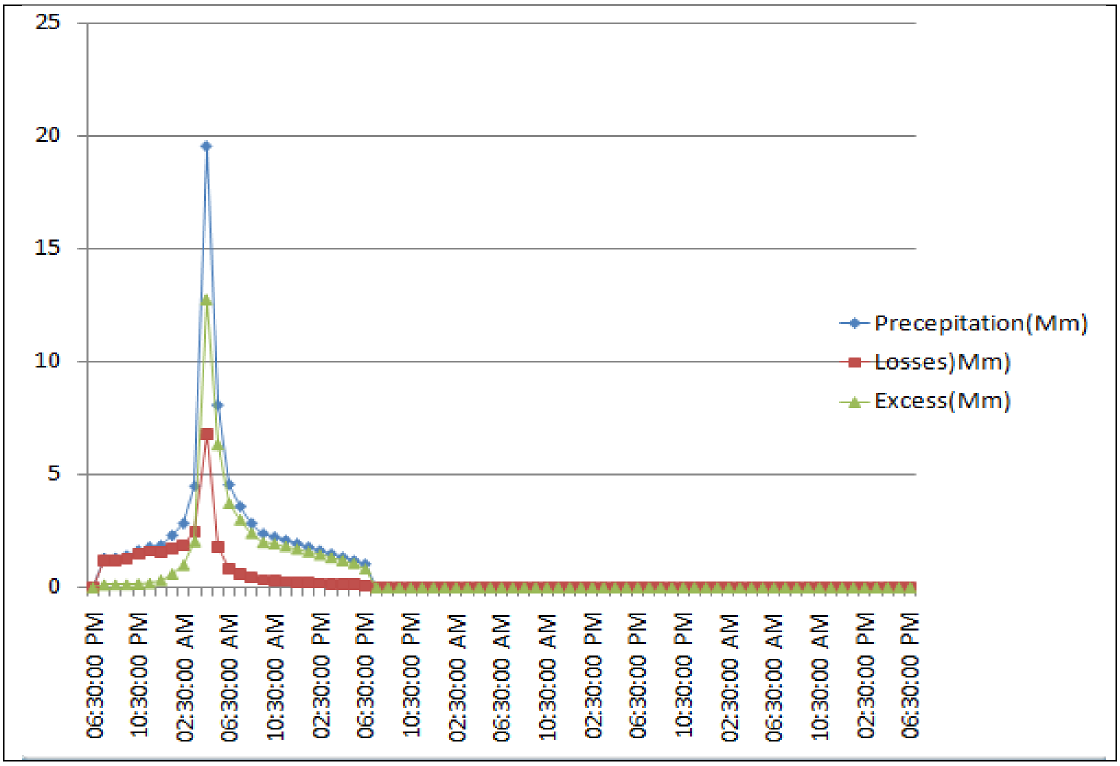

Figure B.14—Effect event rainfall for Subcatchment (G)

Subcatchment(H)

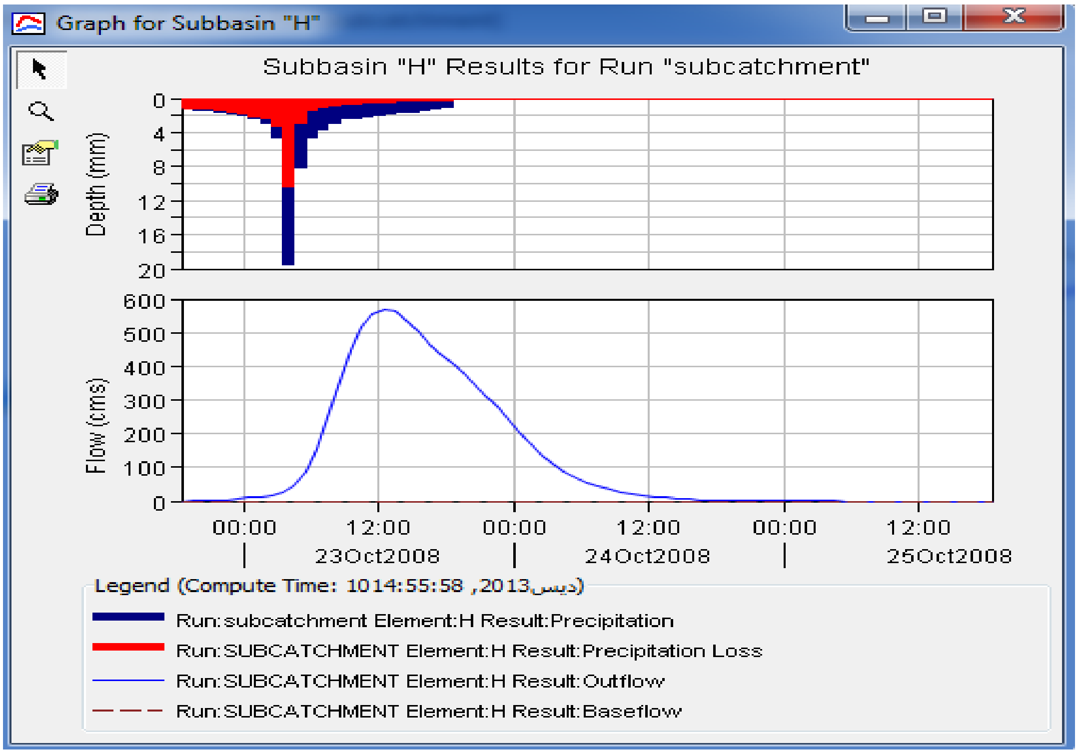

Figure B.15—Global for Subcatchment (H).

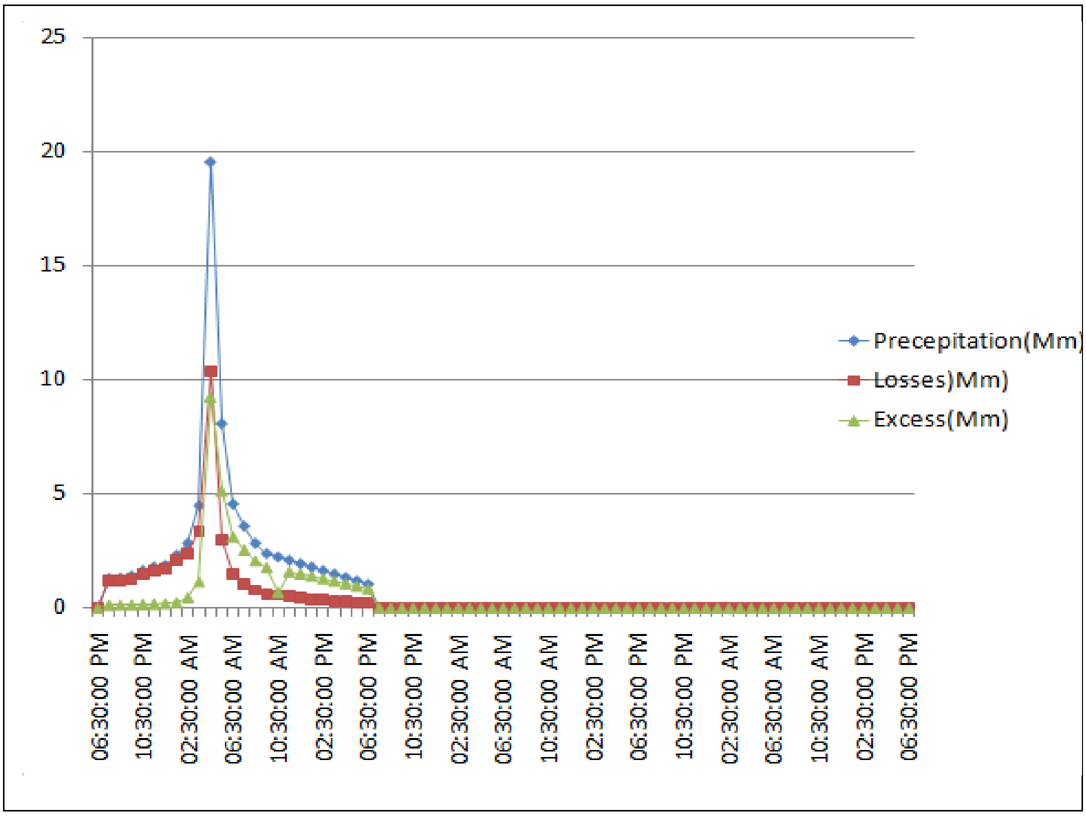

Figure B.16—Effect event rainfall for Subcatchment (H)

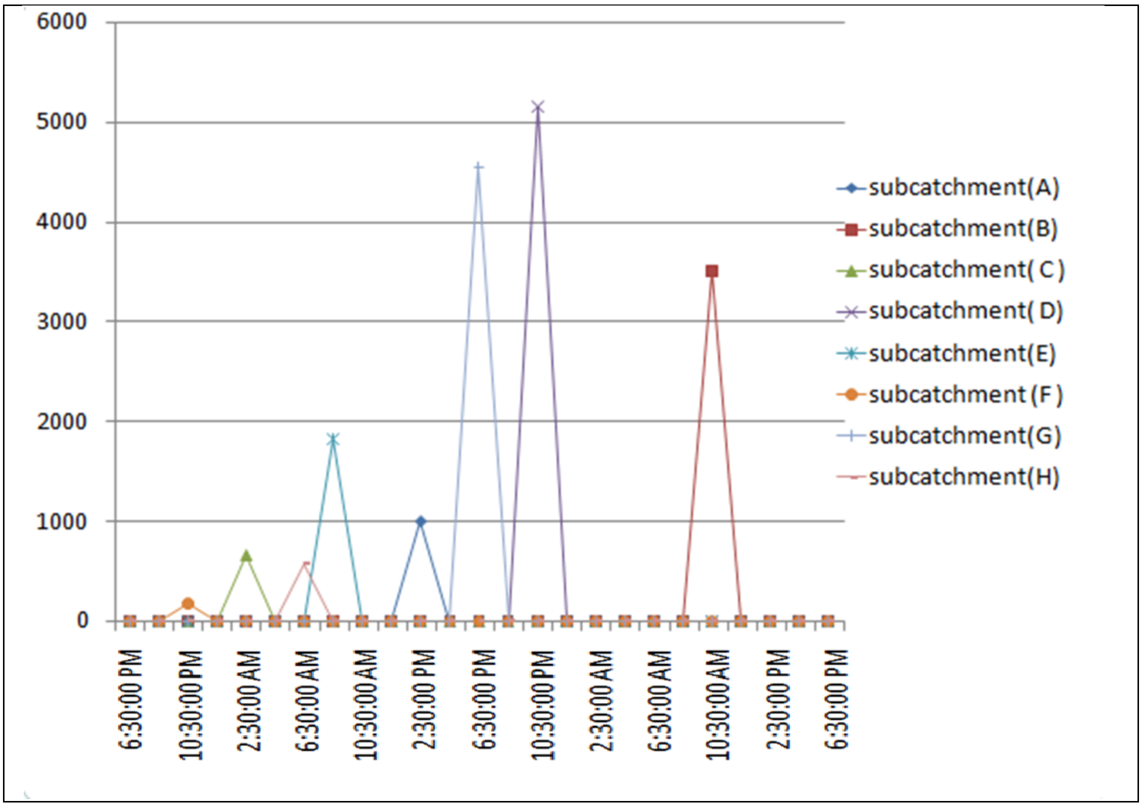

Figure B.17—comparison of flow hydrographs for Subcatchment

Appendix C - Results of reaches.

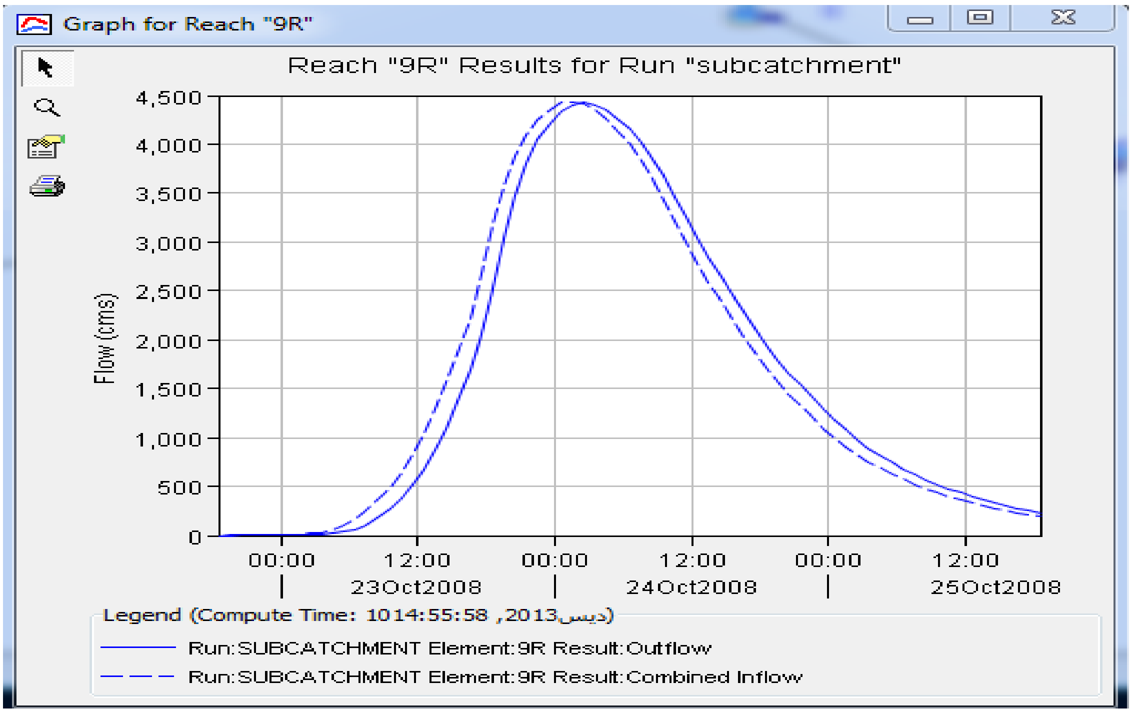

Figure C.1—Result of 9R

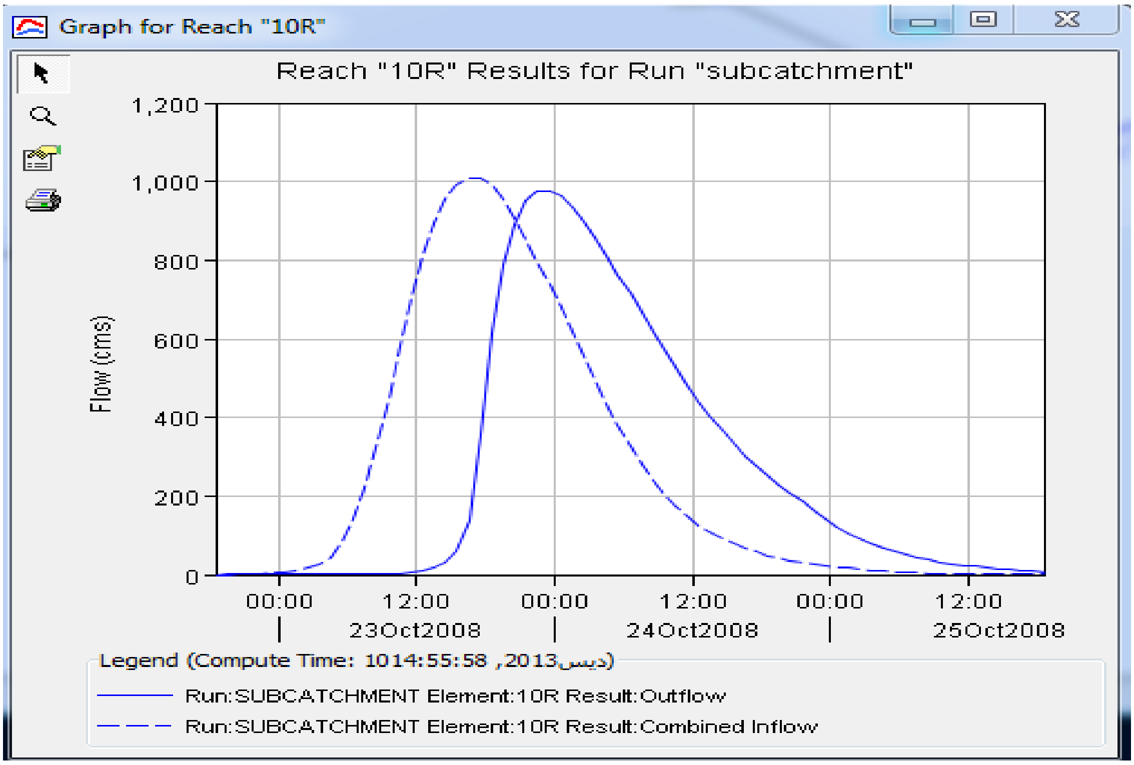

Figure C.2—Result of 10R

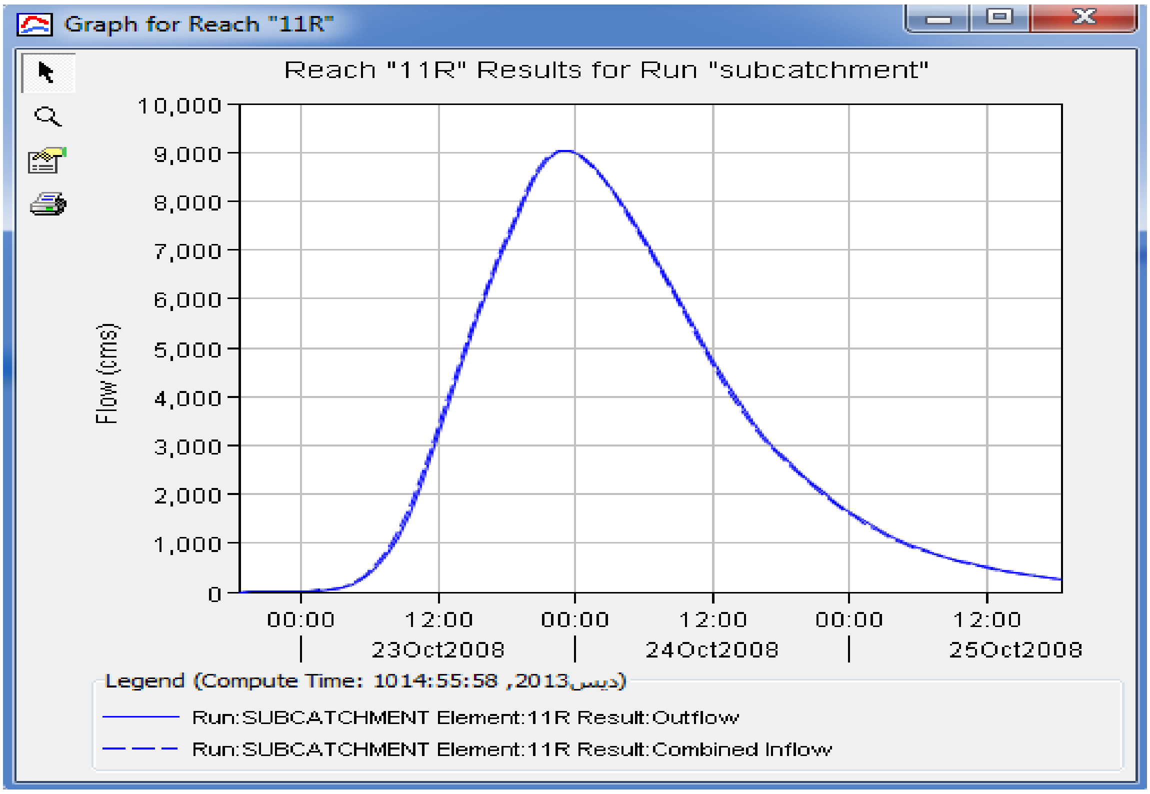

Figure C.3—Result of 11R

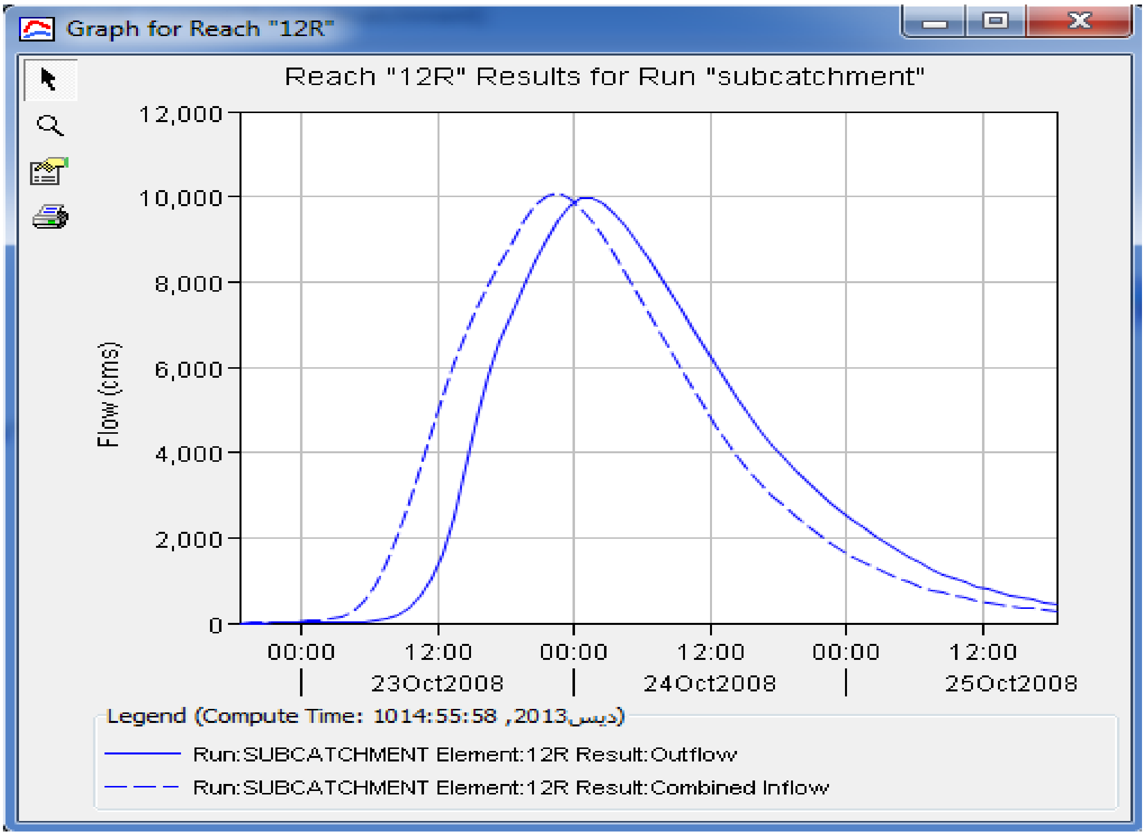

Figure C.4—Result of 12R

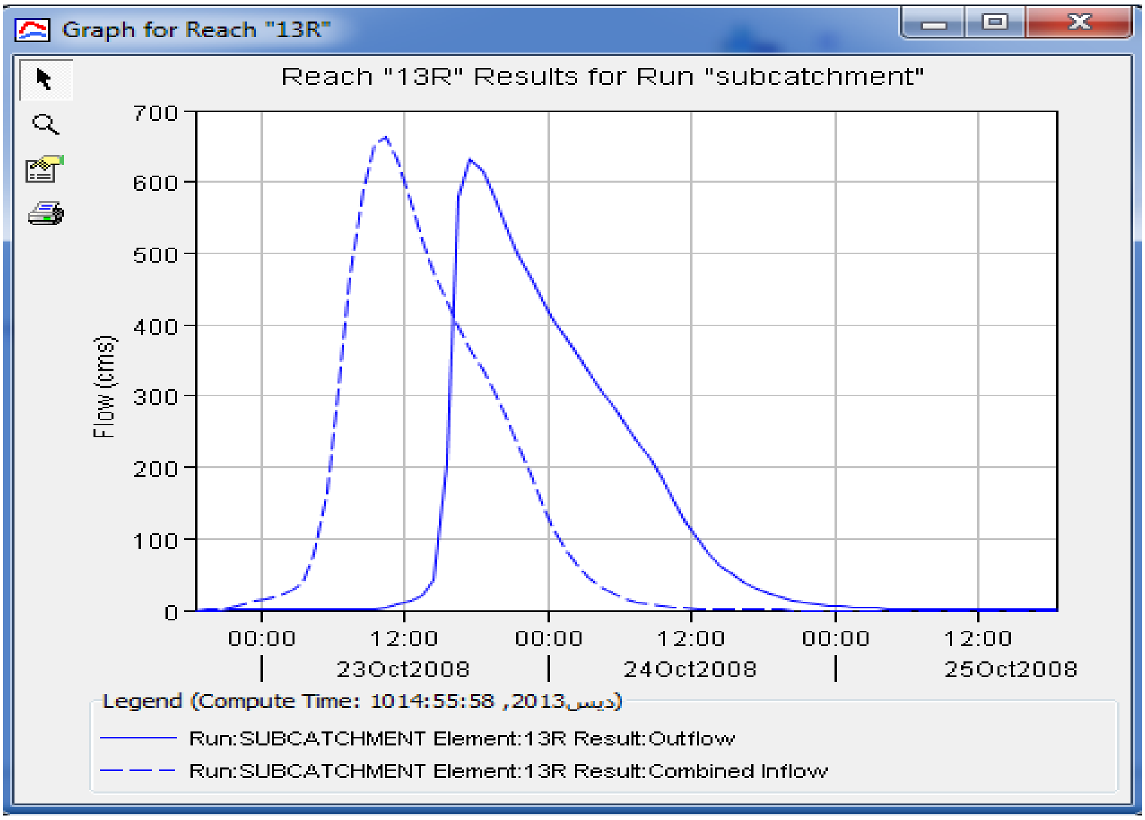

Figure C.5—Result of 13R

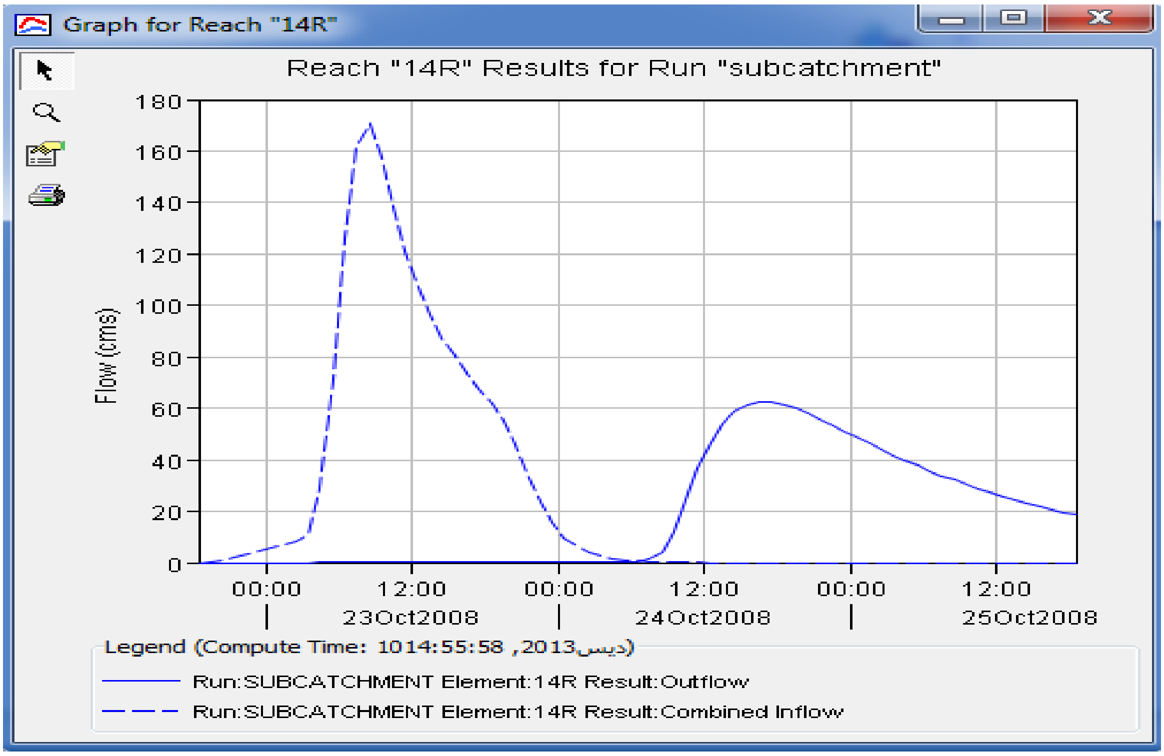

Figure C.6—Result of 14R

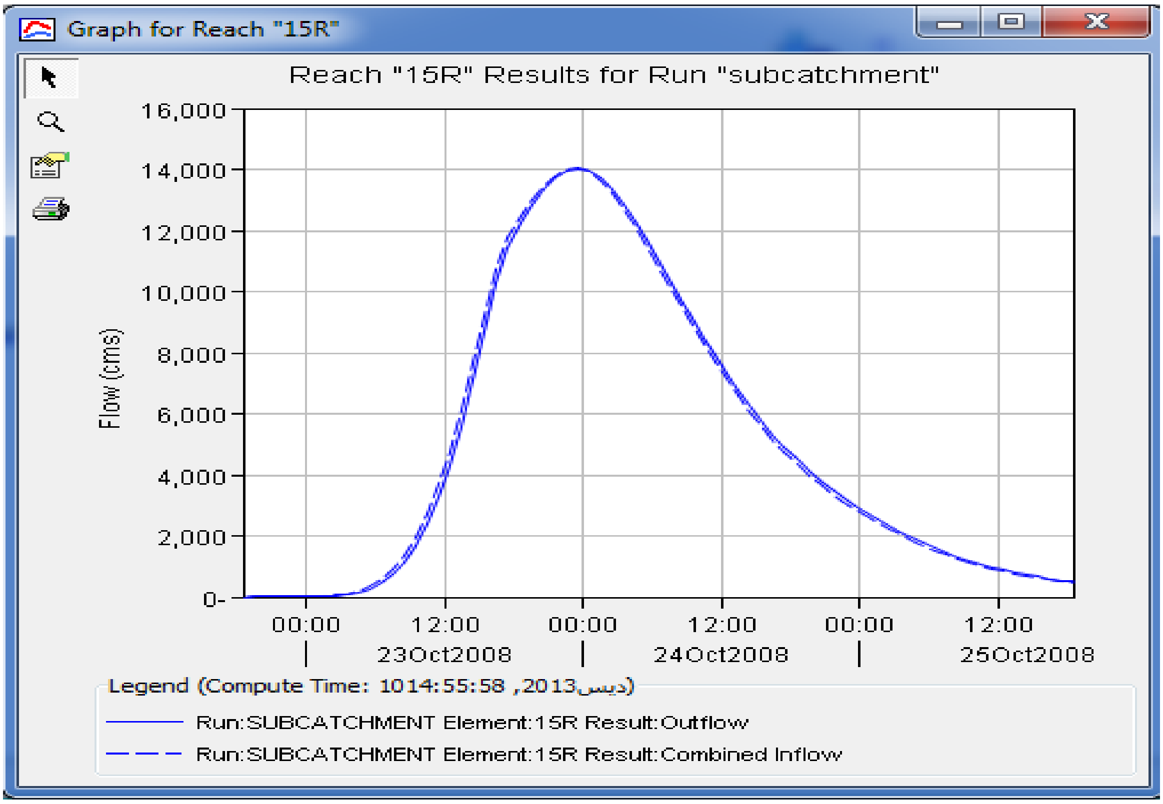

Figure C.7—Result of 15R

Appendix D -Result of outlet main for sub-catchments

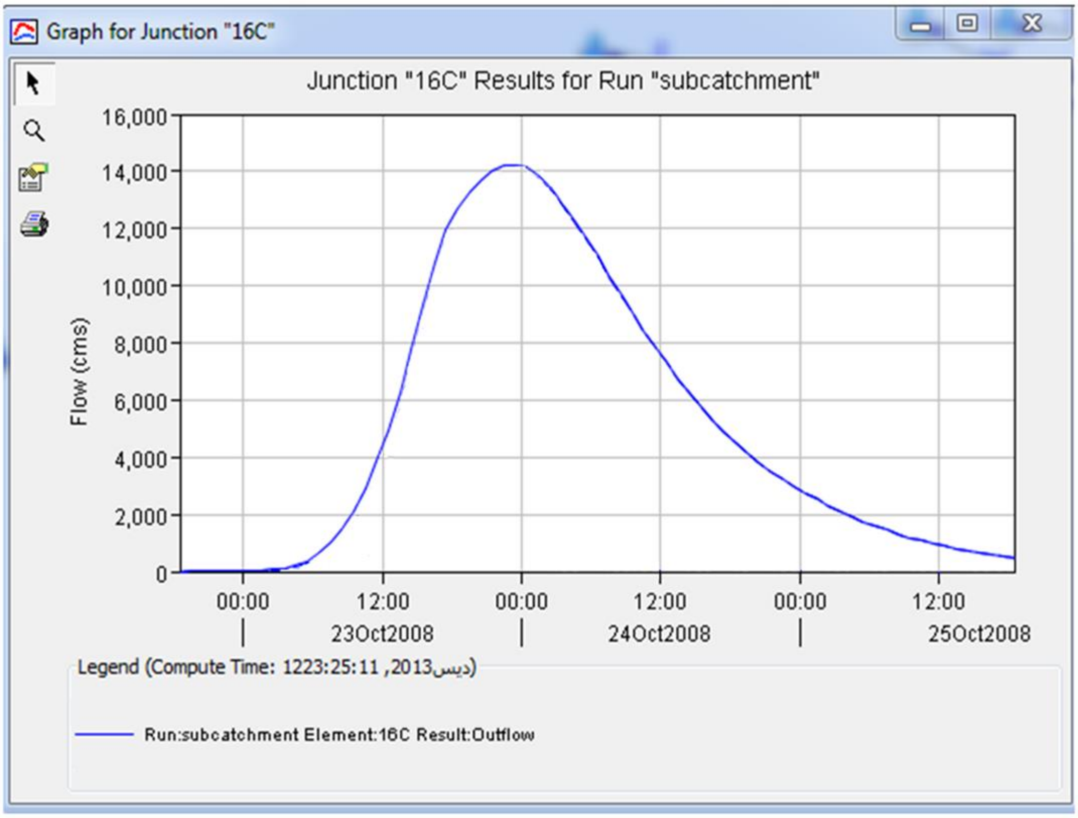

Figure D.1—Graph for junction "16c"

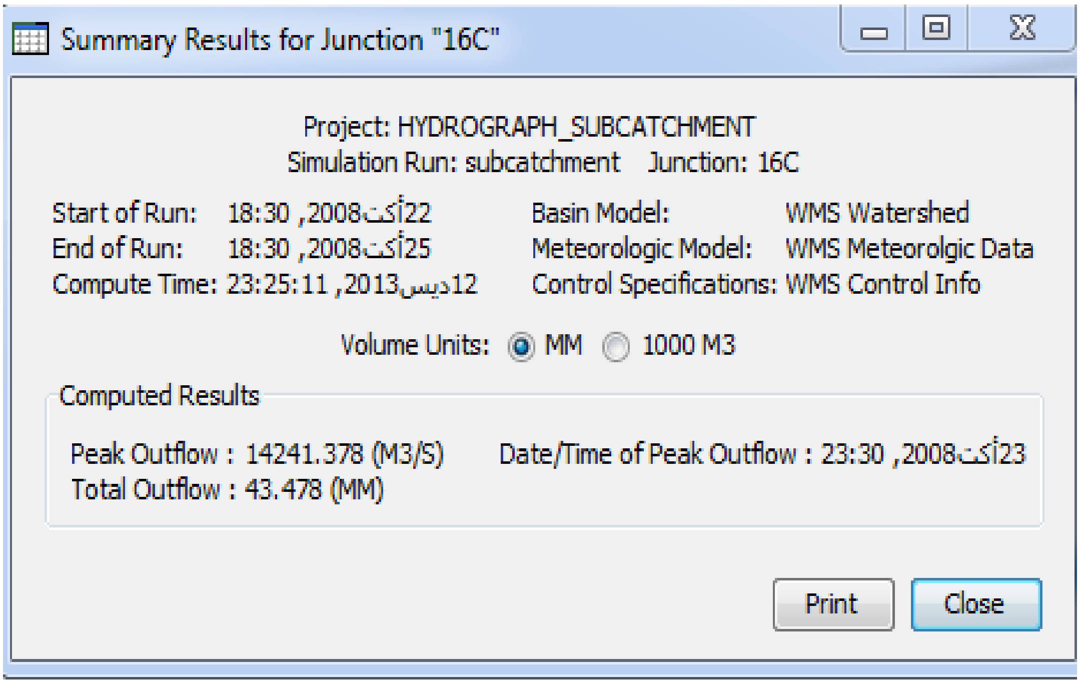

Figure D.2—Global summary Junction "16c".

Appendix E -Result of main outlet catchment for after mitigation

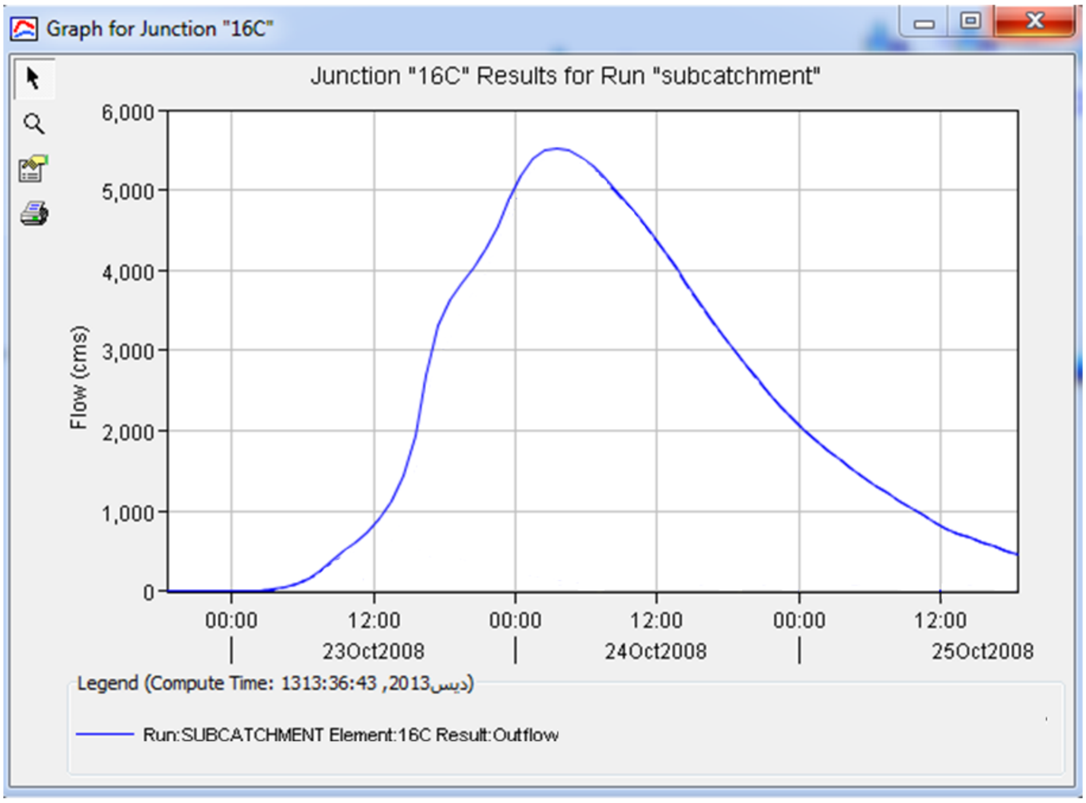

Figure E.1—Graph for junction for catchment after mitigation

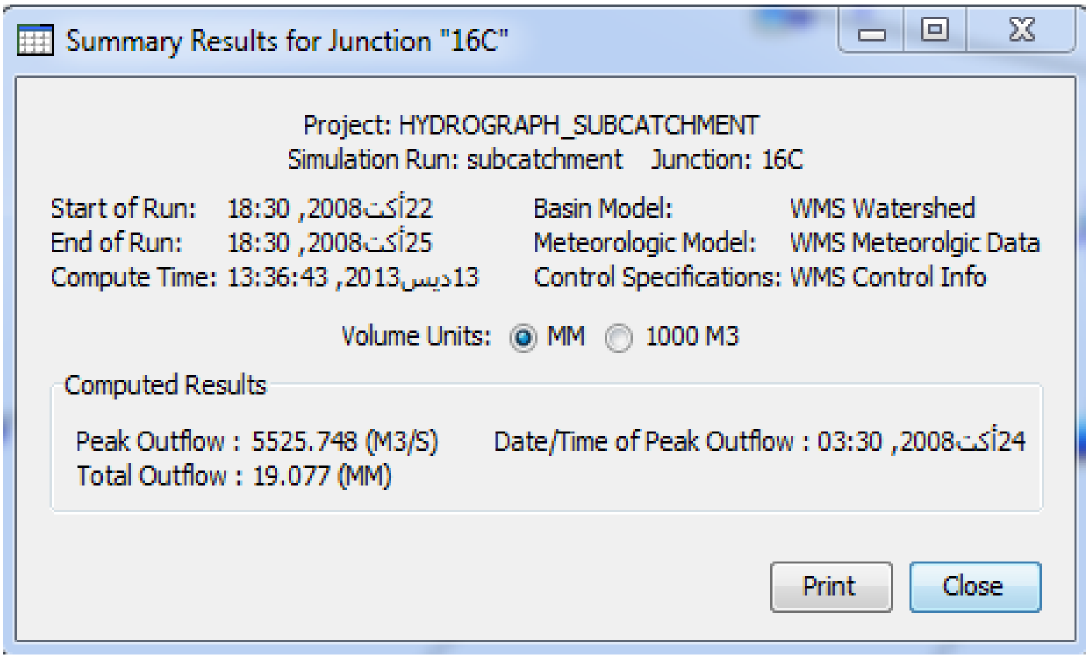

Figure E.2—Global summary Junction for catchment after mitigation

Appendix F – Results of Catchment Wadi Hadramout at 54 mm

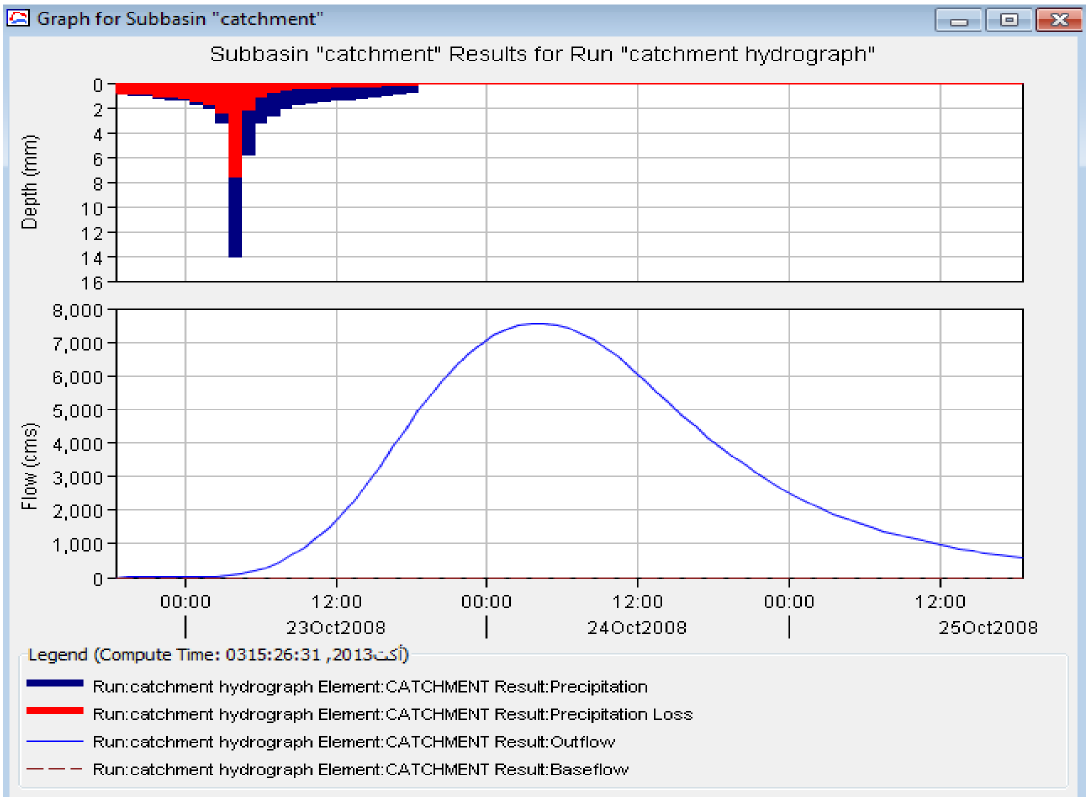

Figure F.1—Global for catchment

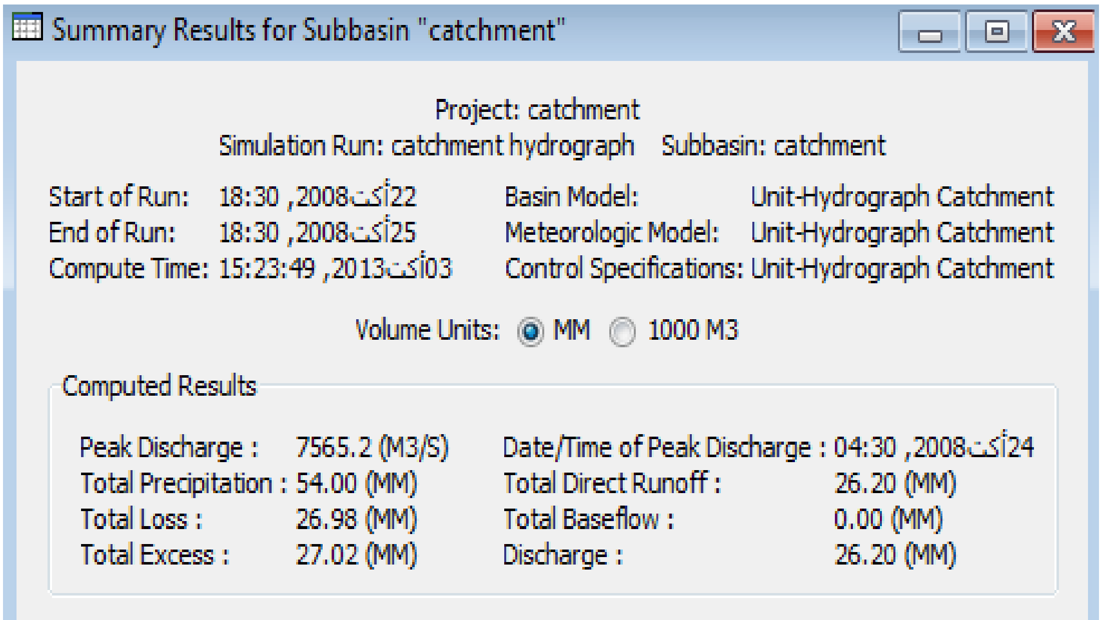

Figure F.2—Summary results Catchment.