CATCHMENT RESPONSE MODELLING OF A TYPICAL RIVER BASIN IN ODISHA USING SCS-CN METHOD

A

DISSERTATION

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BY

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CERTIFICATE

This is to certify that the Dissertation entitled **—** **"***Catchment Response Modelling of a Typical river basin in Odisha using S.C.S-CN method"* *submitted by* **BIMOSH SAHOO** *to the* **National Institute of Technology, Rourkela***, in partial fulfillment of the requirements for the award of Master of Technology in Civil Engineering with specialization in Water Resources Engineering is a record of bona fide research work carried out by him under my supervision and guidance during the academic session 2012-13. To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.*

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ABSTRACT

Estimation of discharge normal and peak and/or hydrograph is often used for small to medium sized gauged and un-gauged catchments for the design of hydraulic structures. Hydrological modeling is the tool which simulates the catchment behaviour by solving the equations that govern the physical processes occurring within the catchment hydrologic models are usually used to simulate the catchment response for a given input. This paper discusses the applicability of the curve number procedure developed by the US **Soil Conservation Service (SCS)** to estimate runoff from the available information onantecedent soil moisture condition of the catchment.The proposed area is located in geographical latitude **19^0 – 23'** N and **83^0 – 21' – 45"E** longitudes. The study area is marked from the Survey of India **Topo-sheets** and the **Digital Elevation Model (DEM) i**s generated. SCS-CN method is used to calculate runoff from the rainfall and then the results are compared with the observed data Based on the soil classification, the given area falls under the soil; groups **B, C and D** with soil moisture condition of **AMC-II**. Standard error estimate are computed between the observed and computed values.In addition to knowing the total runoff,it is equally important to know the peak runoff,as it is the peak runoff which may act as a precursor to a flood. The peak rate of runoff is a function of the average rainfall rate during the time of concentration. An empirical relationship has been tried to establish between peak runoff (**Q_p**) and catchment coefficient **(C)**,rainfall **(P)** ,catchment area in the form of a power function. The empirical relationships are generally applicable for a particular region where the relationships are developed taking into account the effect of data of that region.In all other area it can give approximate values

Keywords: *Watershed, topo-sheets, Land use and land cover, soil classification, curve numbers, Runoff, Rainfall runoff modeling, DEM ,AMC, standard error of estimate , peak runoff ,time of concentration*

CHAPTER 1
INTRODUCTION

1.1 General

Water is one of the most important natural resource.Life cannot be imagined on earth without water.71% of the total Earth's surface is covered with water, and is mandatory for all known forms of life. On earth, Oceans have the major share of the total water i.e. 96.5%, 1.7% present in form of groundwater, 1.7% in glaciers and the ice caps of Antarctica and Greenland, a very small fraction in other large water bodies, and 0.001% in the air as vapor, clouds, and precipitation. Freshwater percentage is only 2.5, and ut of it 98.8% is in form of ice and groundwater. So, less than 0.3% of all freshwater is in rivers, lakes, and the atmosphere (Gleick, 1993; CIA-The world fact book, 2008). Water on earth is not stagnant. It continuously moves from one place to another or one form to other. The continuous movement of water on, above and under the surface of the Earth can be explained through a cycle known as hydrologic cycle. The various aspects of water related to the earth can be explained in terms of this cycle (Chow *et al.*, 1988; Subramanya, 2008). It is a continuous recirculating cycle which means that there is neither a beginning nor an end or apause. Hydrologic cycle is a very vast and complex cycle in which a large number of paths arethere with varying time scale. The various processes involved in this cycle are evaporation,interception, transpiration, surface runoff, infiltration and percolation. Figure 1.1 shows aschematic diagram of hydrologic cycle.

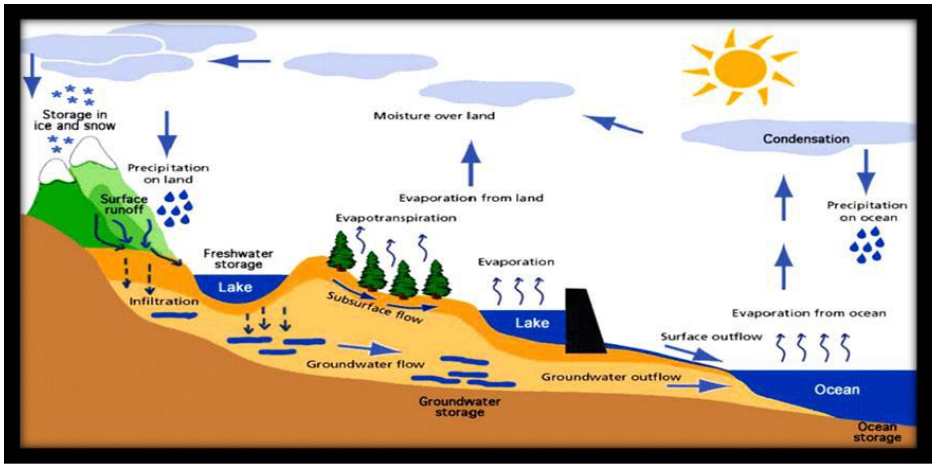

Figure 1.1: The Hydrologic cycle

Water is taken for granted because of abundance, but the problem with water is, it is not always present in theproper place, at the proper time and of the proper quality. INDIA has only 4% of the world's freshwater with 16% of world's population and 10% of its cattle. In the total geographical area of 329Mha,47% is cultivated, 23% forest,7% non-agricultural use area,23% waste land. So the use of available water should be done efficiently to meet the people's needs. In order to have accurate idea of available water runoff is to be computed. Hydrological modeling is a powerful technique of hydrologic system investigation for both the research hydrologists and the practicing water resources engineers involved in the planning and development of integrated approach for management of water resources.

1.2 Hydrology of drainage basins

Drainage basins are local open systems. A drainage basin is an area of land drained by a river and its tributaries (river system). It includes water found in the water table and surface run-off. There is an imaginary line separating drainage basins called a watershed. Usually, this is a ridge of high land. The red line in Figure 1.2 shows the watershed for a river basin. Any precipitation that falls on the other side of the watershed will flow into a river in the adjacent river basin.

The drainage basin hydrological cycle may be defined as a single river basin bounded by its own watershed and the sea. The drainage basin hydrological cycle is an open system. This means it has inputs and outputs. Energy from the sun and precipitation (including rain and snow) enter the system and water leaves it.

Figure:1.2 The drainage basin

1.3 Hydrological modeling for basins & its importance

Hydrologic models are symbolic or mathematical representation of known or assumed functions expressing the various components of a hydrologic cycle**.** A rainfall-runoff model is a mathematical model describing the rainfall - runoff relations of a catchment area, drainage basin or watershed. More precisely, it produces the surface runoff hydrograph as a response to a rainfall hydrograph as input. A rainfall runoff model can be really helpful to the present work in the case of calculating discharge from a basin. The transformation of rainfall into runoff over a catchment is known to be very complex hydrological phenomenon, as this process is highly nonlinear, time- varying and spatially distributed. Over the years researchers have developed many models to simulate this process.

The importance of hydrological modeling in a catchment is:

- To understand the spatial rainfall distribution over the catchment.
- To get information about catchment characteristics such as slope, soil type, land use, underlying geology.
- Surface-groundwater interactions, water allocation, wetlands modeling, etc. can be better understood through hydrological modeling.
- Accurate stream flow forecasts are an important component of watershed planning and sustainable water resource management *(Brooks et al., 2003)*

There are several approaches to estimate runoff in watersheds. Examples are the University of British Columbia Watershed Model (UBCWM), Artificial Neural Network **(ANN),** SCS Curve Number **(SCS-CN)** method and Geomorphological Instantaneous Unit Hydrograph **(GIUH)***(Beckerset al., 2009).Nathan and McMahon (1990a, b***)** calibrated the **SFB** model on 168 catchments, 250 km2 in area, in south-eastern mainland Australia.

1.4 Objectives of the study

The specific objectives of the present study are:

I. Delineation and development of Digital Elevation Model, and extraction of data of the study area for hydrological analysis

II. Studying the soil and climate properties of the catchment area for assigning Hydrological Soil Groups (H.S.G).

III. Development of SCS-CN model for runoff estimation of the basin.Error analysis and correlation statistics for obtaining most suitable model for runoff simulation in catchments.

IV. Establish an empirical model relatingpeak runoff (**Q_p**) with catchment coefficient (**C)** ,time of peak (**t_p**),rainfall **(P)**catchment area(**A**) in the form of a power function.

1.5 Thesis outline

Chapter 01 Introduces the work related to hydrology of ungauged basins, importance of hydrological modeling in ungauged basins and objectives of the present work.

Chapter 02 Focuses about the previous research works related to hydrological modeling indifferent ungauged basins around the globe by many researchers and hydrologists.

Chapter 03 Describes about the geographical location of the study area, its characteristics, available hydrological data and time observed discharge.

Chapter 04 Covers the use of hydrological software as a tool to delineate different maps, about the hydrological models used in the study, and the input parameters required for these models as well as empirical relation between catchment parameters

Chapter 05 Incorporates the results obtained from the present research work and analysis about the same.

Chapter 06 Provides the summary, important conclusions derived from hydrological modeling of the basin

CHAPTER 2
REVIEW OF LITERATURE

In the present chapter literature survey has been done for various aspect of the present work. These are as follows:

2.1 Hydrologic System and Catchment area

A hydrologic system is defined as a structure or volume in a space, surrounded by a boundary that receives water and other inputs, operates on these parameters internally, and produces themas outputs (Chow *et al*., 1988).A **catchment area** or **watershed** is an extent or an area of land where surface water from rain and melting snow or ice converges to a single point at a lower elevation, usually the exit of the basin, where the waters join another water body, such as a river, lake, reservoir, estuary, wetland, sea, or ocean. Drainage basins drain into other drainage basins in a hierarchical pattern, with smaller **sub-drainage basins** combining into larger drainage basins.The drainage basin includes both the streams and rivers that convey the water as well as the land surfaces from which water drains into those channels, and is separated from adjacent basins by a drainage divide.

Accurate drainage boundaries are essential for accurate modeling studies. Through the ILWIS, catchment boundaries may be determined fairly accurately. When delineating watersheds from a topographic map, drainage divides are located by analyzing the contour lines. Arrows representing the flow directions are drawn perpendicular to each contour, in the direction of the steepest descent. The location of a divide is taken to be where flow directions diverge, or where the arrows point in opposite directions. Manually locating these is a difficult process, and slight errors are unavoidable. The extent of these errors is dependent upon the worker, and different workers will likely present different results. On the contrary, watersheds and catchments determined through the use of raster data will produce consistent results.

2.2Digital Elevation Modelling

A Digital Elevation Model (DEM) is a digital cartographic/geographic dataset of elevations in xyz coordinates. The terrain elevations for ground positions are sampled at regularly spaced horizontal intervals. DEMs are derived from hypsographic data (contour lines) and/or photogrammetric methods using USGS 7.5-minute, 15-minute, 2-arc-second (30- by 60-minute), and 1-degree (1:250,000-scale) topographic quadrangle maps.

This elevation information is represented incomputers as elevation data in a digital format.This format is usually called digital elevationmodels (DEM). Thus a DEM is a computerized representation of the Earths relief. Differentformats exists, among the most usual aretriangulated irregular networks (TIN),tagged image file format(TIFF) regulargrids, contour lines and scattered data points. ADEM is usually described either by a wire framemodel or an image matrix in which the value ofeach pixel is associated with a specific topographicheight.

2.2.1 DEM and Geographical information systems

DEMs can be used together with other spatialdata, image data in geographic informationsystems (GIS), for instance. A GIS is aninformation system designed to acquire, store, process and display data referenced by spatial orgeographical coordinates. In a sense, a GIS may bethought of as a higher-order map, being both adatabase system with specific capabilities forspatially referenced data as well as a set ofoperations for processing and analyzing the data.

The DEM provides a basic spatial referencesystem to the GIS spatial data set. Images or vectorinformation can automatically be draped over andintegrated with the DEM for more advancedanalysis.Terrain analysis based on digital elevation models is being increasingly used in hydrology (e.g. Wilson and Gallant, 2000).

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2.2.2Catchment Delineation

Hydrologic processes are fundamentally different on hillslopes and in channels. In channels flow is concentrated. The drainage area, A, (e.g. in m2) contributing to each point in a channel may be quantified. On hillslopes flow is dispersed. The "area" draining to a point is zero because the width of a flow path to a point disappears. On hill slopes flow and drainage area need to be characterized per unit width (e.g. m3/s/m = m2/s for flow). The specific catchment area, a, is defined as the upslope drainage area per unit contour width, b, (a = A/b) (Moore et al., 1991) and has units of length (e.g. m2/m = m). The differences between processes on hillslopes and in channels make it important to properly map the physical extent of channels in a watershed. Model elements in hydrologic and water quality models are sometimes delineated based on area draining directly to a channel segment with hillslope or overland flow length a parameter used to quantify for example hydrologic response time or erosion and sediment delivery (e.g. hillslope length in the USLE methodology

Wischmeyer and Smith, 1978). The correct scale associated with the terrain needs to be identified, so that model input parameters are estimated correctly.

1 Area defining concentrated contributing area at P

2.Specific catchment Flow path originating area is A/b at divide with dispersed contributing area A

Mapping channel networks from digital elevation models follows the now well rehearsed procedure (e.g. Wilson and Gallant, 2000; Tarboton and Ames, 2001) of filling pits, computing flow direction and then computing the contributing area draining to each grid cell. The earliest method (O'Callaghan and Mark, 1984) for delineating drainage networks used a support area threshold applied to the grid of drainage areas. Channels and channel start points are mapped as those grid cells where the support area threshold is exceeded. This procedure has been widely

used and is implemented in Arc Hydro (Maidment, 2002)

2.2.3 Delineation Method

Identify ridge lines from topo sheet. Water will travel perpendicular to the elevation contours which is the direction that maximize slopecontours.Watershed boundary is delineated by drawing lines perpendicular to the elevation contour lines for landperpendicular to the elevation contour lines for land that drains to outlet.

Step 1: Choose the point of the watershed outlet. This is generally our point of interest for designing a structure or monitoring location.

Step 2: Delineate the watershed boundary by drawing perpendicular lines across the elevation contour lines for perpendicular land that drains to the point of interest.

Note -A watershed boundary always runs perpendicular to the contour linesto the contour lines.

.“Arrows” that point upstream are valleys.

.“Arrows” that point downstream are hills.

2.3 Hydrological modeling

Hydrologic models are symbolic or mathematical representation of known or assumed functions

expressing the various components of a hydrologic cycle (Beven*et al.*, 1979).Ground water, rainfall and runoff are the major components of a water system in any given area.Complexity of these subsystems and their interactions depend on many factors such asgeological, hydrological, environmental and geographical characteristics of the area (Cheng *etal*., 2001). Hydrological modeling can be defined as a powerful technique of hydrologic system

investigation for both the hydrologists and the practicing water resources engineers involved in the planning and development of integrated approach for water resources management (Schultz,

1993; Seth, 2008).regardless of the user. The accuracy of these results will also only be a function of the accuracy and resolution of the raster data.

2.4 Peak Discharge estimation for catchments

2.4.1Rational Method

Among the various types of empirical relations rational formula is the most used method for calculating peak discharge of small catchments ,also considered as a representative of all other empirical relations. Rational formula by definition means a formula whose units are numerically consistent .The peak discharge in the original F.P.S unit is given by:

$$Q_p = CIA \qquad \text{(i)}$$

In S.I units $$Q_p = 0.278CIA \qquad \text{(ii)}$$

Where Q_p is peak discharge is in cumec, C is the runoff coefficient i.e ratio between runoff and rainfall,A is the catchment area in km^2 and I is the intensity in rainfall mm/h duration of which should be equal to the time of concentration of the concerned basin.

Runoff Coefficient C-Runoff coefficient represents cumulative effect of watershed losses viz (i) initial losses,(ii) depression storage (iii) nature of the soil (iv) surface slope (v) degree of saturation, (vi) rainfall intensity,(vii) geology of the catchment (viii) geohydrological characteristics of the basin.The value of C varies from 0.05to 0.95.The composite /weighted value of C can also be computed .For this the whole area is to be divided into sub areasA_1,A_2,….A_n with the runoff coefficients **C_1,C_2,…C_n**.Thenthe weighted is computed as $C_w=\sum(C_iA_i)/A_i$.

The intensity of rainfall at a place,any of the formulaes can be used depending upon the suitability.

$$I=(K.T^a)/(t_c+b)^n \qquad \text{(iii)}$$

where I is the intensity of the rainfall(cm/h),T is the return period(years),tc is time of concentration of the watershed in (h),K ,a ,b, and n are constants. For different places the constants are different.

2.4.2Empirical Relations :

Various equations relating catchment area, river bed-slope and return periods to the flood peak discharge area available.The following formulaes holds good for regions where investigation has been carried out.and sufficient care has been taken elsewhere.

Dicken'sformulae(1865): Dicken's proposed the following form of catchment flood peak realation for the regions of Central and North India catchments..

$$Qp=CA^{3/4} \qquad (iv)$$

where A is the catchment area in sqkm,Qp is the maximum flood discharge (cumec) and C catchment runoff coefficient depending on the location of the placeThe range of C is given following table.Formountaineous regions the value of C is in the range of 14-28.for flood peaks C varies between **25 and 28.**

Sl no	Area Description	Value of C
1	For flat ,sandy or cultivated plains of north India	2.8-6.0
2	Undulating area with hard soil for north Indian hills	11.0-14.0
3	Undulating country for central India region	14.0-28.0
4	Catchments covered with precipitous hills as of Odisha Andhra	22.0-28.0
5	Western ghat regions of India	20.0-40

Table2.4 –Dicken's Coefficient for various regions of India

Ryve'sFormula(1884): Ryve modified Dicken's equation to suite the catchments of Tamil Nadu.The relation is as follows

$$\mathbf{Qp=CA^{2/3}} \qquad \textbf{(v)}$$

Where Qp is the peak discharge in cumec and A is the area in km^2.Ryve suggested following values:

- C=6.8 for areas within 75 km from the coast
- C=8.5 from 75 to 175 km from the coast
- C=10.2 for a limited areas near the hills

Inglis Formulae (1940):Inglis gave a following relation between catchment area and peak discharge.

$$\mathbf{Q_p=(124A)/sqrt(A+10.4)} \qquad \textbf{(vi)}$$

The concerned area is a drought prone area with highly uneven rainfall. There are periods of zero mm rainfall as well as periods of over 200m rainfall in a day. As a result the runoff is also very highAregression relation between peak discharge with rainfall ,catchment area and time of concentration can be developed for the region under consideration .The peak discharge may be obtained from the runoff depth computed by S.C.S–CN method from daily rainfall records in the two stations of Kalyansinghpur and Rayagada(Jkpur) by the following formulae :

$$\mathbf{Q_p=(0.0208AQ_d)/t_p} \qquad \textbf{(vii)}$$

Where tp is the time to peak (h) .which may be obtained from the time of concentration,A is the catchment area in consideration (ha),Qd is the runoff in cm.Qp obtained from other hydrological data

CHAPTER 3
STUDY AREA AND DATA COLLECTION

3.1 The study area

The study area for the present work is a catchment area of the proposed Lower Nagavali Irrigation project across the river Nagavali. The proposed project is located near village Bheja in Kalyansinghpur block of Rayagada district in the state of Odisha.The river Nagavali originates from the hilly area of Eastern Ghats near village Bijapur in Kalahandi district at an elevation of about 1000m. The total basin area of Nagavali is 9275 sq. km. The catchment area lying within Orissa is 4500 sq. km. The river Nagavali in the upper reaches is known as Badanadi. Sananadi, a tributary of Nagavali, joins near Kalyanasinghpur. The geographic co-ordinates of the river are north latitudes **18^0 -10' to 19^0- 44'** and east longitudes of **82^0-53' to 84^0-05'**.The proposed area is located in geographical latitude **19^0 – 23'** N and **83^0 – 21' – 45"E** longitudes. The catchment area intercepted upto proposed dam site is 1176.84 sq. km. After accounting for the projects lying in the upstream, the free catchment for the project works out to be 681.84 sq. km. It envisages construction of Earth Dam with Central Concrete spillway across river Nagavali in Nagavali Basin..

Figure3.1(a) map of Rayagada (Odisha)

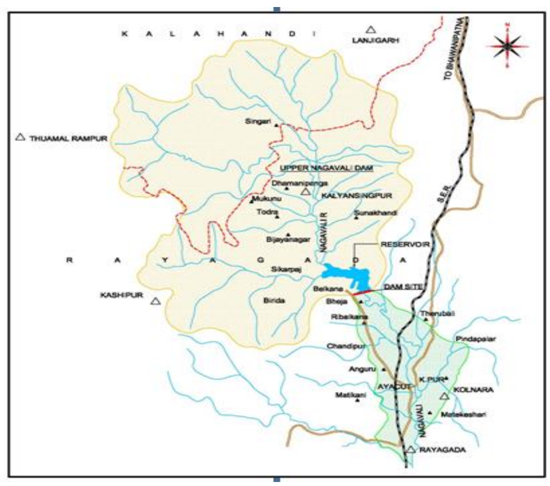


Figure:3.1(b) map of lower Nagavalli catchment area

3.1.1 Topography

The catchment area is continuously sloping and has natural valleys. So water logging is not anticipated after introduction of irrigation in the area.

3.1.2 Area wise distribution,land use and land cover

Catchment land cover is largely forested. More than 60% of the area is covered with dense forest.Alluvial plains are around 9.0%.While moderate development is primarily located in the stream valleys. Barren lands are present in patches. Now days the forest cover is gradually decreasing due to rapid extension of mineareas around the basin.The soil of this catchment comes under the red soil group. It is of laterite origin. Red soils andalluvial so the predominant soil types in the district.the entire district comes under North Eastern Ghats agro climatic zone

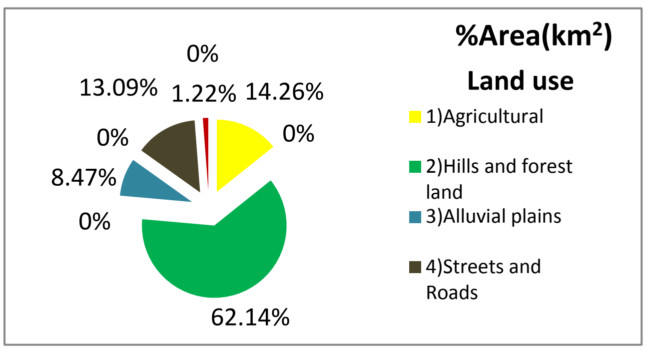


Figure3.1(c) :area distribution pie chart

3.1.3Drainage

A network of natural field drains is in existence, which are adequate for drainage works. All the natural drains are leading to the river. The main canals run in contour and minors, sub-minors run in ridges in a sloped ayacut towards the river. The area as observed from the GWL is free from drainage congestion. Taking into account this fact and the land topography & sandy nature of soil texture which is free draining, it is expected that providing irrigation facility by the project will not lead to drainage congestion.The alluvial deposits in the flood plains of the Vamsadhara&Nagavalli form the repository of groundwater in the district.

3.1.4 Existing Agriculture pattern:

The cultivated area of the district is 30% of the total geographical area. The total irrigated area of the district from all sources is only 322.51 sq.km. Which comes to 19.3 % if the net cultivates area. No uniform cropping pattern is followed in the district. Shifting or Podu cultivation is practiced on high hill slopes.The entire area of proposed command area depends solely on rainfall. Therefore, crop diversification or cash crop is impossible to introduce in the command area at present. The local people are adopting the cropping pattern according to the distribution of rainfall and availability of soil moisture as they depend upon rain only. Kharif paddy is the principal crop of the area. Generally local varieties of paddy of different duration with low yield are cultivated. Besides, paddy, maize, pulses and vegetables are also grown in the up lands. Local varieties of seeds are generally used by farmers.

3.1.5 Ground water

The present proposal aims at utilization of surface water resources of the Nagavali river. The ground water observation in the ayacut shows the ground water table is much below the NSL. It is expected that small addition brought by irrigation water will not create any problem of water logging as the ground slope is steep enough for drainage and the soil is free draining.

3.2 Data collection & analysis

3.2.1 The climate of the zone is tropical with three prominent seasons, namely, Summer (March – May), Rainy (June to October), and Winter (November to February).

I. **Temperature:** The area belongs to tropical climatic zone. The average temperature in summer is 30 to 40 degree Celsius, and in winter it is 20 to 24 degree Celsius.

II. **Relative Humidity:** Relative Humidity is minimum in march and maximum in the month of August.

III. **Rainfall:** Rainfall in the basin is mainly from south west monsoon, which occurs during the period from June to October. About 80% of the precipitation is available from these months. The average rainfall in the catchment is about 1300 mm.For the present study both monthly rainfall and daily rainfall has been taken into consideration. There are two rain gauge stations, namely Rayagada and Kalyanasinghpur influencing the catchment area. The rainfall data of the above two stations have been found to be consistent. The monthly rainfall data for these stations (Rayagada and Kalyanasinghpur) .The rainfall data from two sites, namely Rayagada and Kalyanasinghpur, have been considered for the period 1969-2010. Further, a weighted average has been considered for the two sites, with Rayagada contributing 94% to the weighted average, and Kalyanasinghpur contributing 6%. From the observed data it is clearly evident that the average annual rainfall data in Kalyansinghpur(1490.3 mm) is higher than that in Rayagada(1315.8 mm).

CHAPTER 4
METHODOLOGY

The chapter describes about the use of ILWIS for delineation of topographic maps for catchment area and subsequently creation of a Digital Elevation model.

4.1 Development of maps

The toposheet, maps 65/M series in which the study area comes, was collected and scanned. The scanned map wasimported to ILWIS software. Boundary of the basin was drawn using this software to create a base map or segment mapThe major flow lines and minor flow lines of the river Nagavalli were drawn over the boundary map as a layer map, which was then added to the segment map, contours with an interval of 100 m were also digitized.The two maps obtained were now converted to a raster map and both the raster maps were crossed to generate the Digital Elevation Model.(D.E.M) of the catchment Flow direction map was drawn taking DEM of the basin as input. It gives a clear idea about thedirection of flow with in the catchment. The catchment parameters like area, perimeter were extracted from DEM, also the flow parameters like flow length ,slope ,time of concentration were found out from the DEM.

4.2 Use of ILWIS

In ILWIS, the TIN structure is not used. DEMs are always in the form of raster maps,with a value domain. Each pixel in the raster map contains the altitude of the centerof the pixel. Using a large pixel size will therefore result in more general DEMs (asmoother topography). Especially when the mapped changes in topography occur atdistances smaller than the pixel size, the slope angles derived from the DEM maylead to an underestimation of the actual slope angles in the field. The accuracy of a D.E.M depends very much on the detail of the contour lines, that were used for theinterpolation, and the scale of the original topographic map from which the contourlines were digitized. The larger the scale of the map, and the smaller the contourinterval, the more accurate the DEM will be the creation of a Digital Elevation Model from a segment map is done with theContour interpolation operation. This operation works in two steps:

- **Segment to raster conversion**. First the segment map is converted to raster, using a geo-reference in which the pixel size, the number of lines and columns, and the minimum and maximum X and Y coordinates of the map are defined. It is important to make sure that the pixel size is not too large, in relation to the maximum spacing of the contour lines. Otherwise it may happen that two contour lines may have to be located in the same pixel, which is of course not possible.. The input segmentmap should be a value map. The raster map resulting from the segment to raster conversion will contain values for those pixels covered by a contour line. All other pixels in the map remain undefined
- **Contour interpolation**. A linear interpolation is made between the pixels with altitude values, to obtain the elevations of the undefined values in between the rasterized contour lines. The output of the contour interpolation is a raster map in which every pixel has a value. The operation calculates, for each undefined pixel in between two rasterized segments (outcome of the first step), the shortest distance towards the two nearest isolines.

4.2.1Data extracted from DEM:

(a) Length of travel –It is the maximum length travelled by a drop of water to reach the outlet orthe point of consideration in the channel from the furthest point of catchment.It was measured directly from the map with the help of a string and ruler .The length obtained was multiplied by the scale of the map which in this case was 1 cm=2.5km to get the actual distance

(b) Time of concentration - It is defined as the time needed for water to flow from the most remote point in a watershed to the watershed outlet. It is a function of the topography, geology, and land use within the watershed.It can be estimated using the Kirpich's (1940) formulae:

$$t_c=0.0003233L^{0.77}S^{-0.385} \quad \text{(i)}$$

where t_c is the time of concentration in(h),L is the maximum length of travel in(m),S is the slope of the channel given by H/L ratio and is the elevation difference between the remote point in the channel and the outlet point

Time of concentration is useful in predicting flow rates that would result from hypothetical storms, which are based on statistically derived return periods. For many (often economic) reasons, it is important for engineers and hydrologists to be able to accurately predict the response of a watershed to a given rain event.

4.2.1(c)Time to peak-It is the time lapse between the starting of the rising limb and to the peak of the hydrograph P. It is represented in days for large basins and in hours for small basins. Factors like distribution of rainfall over the basin, duration of storm, travel time of water in the channel and other catchment characteristics govern the time to peak .

$$t_p =0.6\ t_c+t_c^{1/2} \quad \text{(ii)}$$

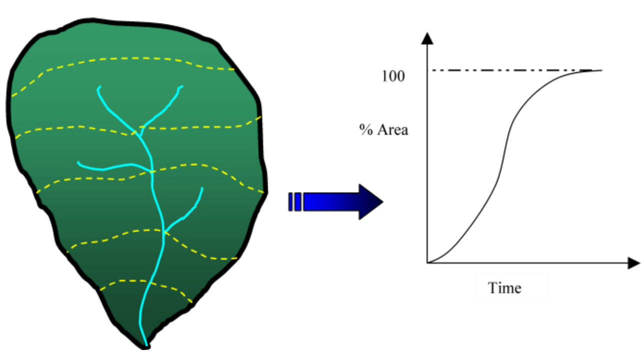


Figure 4.2.(a):length of travel and time to peak

4.3 Rainfall-Runoff modeling

4.3.1 SCS-CN Model

SCS-CN method developed by soil conservation services (SCS) of USA in 1969.rainfall runoff technique, is a well-knownmethod, widely used to estimate runoff, and thus,water recharge, stream flow, infiltration, soil moisturecontent, and landfill leachate production, from precipitation.

Such modern environmental applicationsneed accurate results to evaluate critical water problems.The method is summarized by using curve numbersto represent a single parameter relation betweenrainfall depth and runoff depth. The single parameter relation is S; the transform of S is CN (Clopper,1980).

It is simple can predict accurately, and a stable conceptual method for estimation of direct runoff depth,based on rainfall. The single parameterrelation is S; the transform of S is CN (Clopper,1980).

Water balance equation of the rainfall in a known interval of time is the basis of this method, which can be expressed as

$$\mathbf{P = I_a + F + Q} \qquad \mathbf{(1)}$$

Where P=total precipitation

I_a= initial abstraction

F=cumulative infiltration excluding I_a

Q=direct surface runoff

The first concept is that the ratio of actual amount of direct runoff (Q) to maximum amount of potential runoff (=P-I_a) is equal to the ratio of actual infiltration (F) to the potential maximum retention (or infiltration), S. The proportionality concept can be represented as

$$Q / (P-I_a) = F/S \quad (2)$$

The second concept is that the amount of initial abstraction (I_a) is some fraction of the potential maximum retention(S).Thus **$I_a = \lambda S$** **(3)**

Combining equation (3) and (4)

$$Q= (P-\lambda S)^2/P+ (1-\lambda) S \quad (4)$$

Where P= Daily Rainfall

Q=Daily Runoff from the catchment.

The parameter S represents the potential maximum retention. It depends up on the soil vegetation-land use complex of the catchment and also up on the antecedent soil moisture content in the catchment just before the starting of the rainfall event. For convenience in practical application the soil conservation service of USA has expressed S (in mm) in terms of dimension less parameter *CN* (Curve number) as

$$CN(cm) =2540/(S+25.4) \quad (5)$$

4.3.2 Initial Abstraction Ratio Adjustment

The relationship $I_a= 0.2* S$ was derived from the study of many small, experimental watersheds . Since the history and documentation of this relationship are relatively obscure, more recent analysis used model fitting methods to determine the ratio with hundreds of rainfall-runoff data from numerous U.S. watersheds. In the model fitting done by Hawkins et al. (2002) found that the ratio of I_a to S varies from storm to storm and watershed to watershed and that the assumption of **Ia/S=0.2** is usually high. More than 90 percent of **Ia/S** ratios were less than 0.2. Based on this study, use of **Ia/S** ratios of 0.05 rather than the commonly used value of 0.20 would seem more appropriate especially where the areas having low values of rainfall

The SCS method uses only three factors tomodify S: season of year and **antecedent moisture condition**which together, provide a rough measure of theexpected value of soil moisture; the

hydrologic soilcover(H.S.G)complex which reflects the effects of vegetation;and land use which represents some, but not all, ofthe watershed influences on infiltration and overlandflow (Martin, 1979; Montgomery, 1980; Clopper,1980).

4.4 Soils

To determine the value of CN, the hydrological soil classification is adopted here. Soils are categorized in to four classes A, B, C, D based up on their infiltration and other characteristics. Effective depth of soil, average clay content, infiltration characteristics and permeability; these are some of the important soil characteristics that influence hydrological classification of soils.

1) Group A (Low runoff potential)

k_{sat}> =0.3in/hr Example - Deep sand, deep loess and aggregated silt.

2) Group B (Moderately low runoff potential)

.**k_{sat}< 0.3in/hr** Example -Shallow loess, sandy loam, red loamy soil, red sandy loam and red sandy soil.

3) Group C (Moderately high runoff potential)

.**0.04<k_{sat}<0.15 in/hr** Example-Clayey loam, shallow sandy loam, soil usually high in clay, mixed redand black soil.

4) Group D (High runoff potential)

k_{sat}<0.04in/hr. Example -Heavy plastic clays, certain saline soils and deep black soils, where k_{sat} is the average hydraulic conductivity.

Hydrologic Soil Group	Soil Type	Character
Group A	sand, loamy sand, sand loam	low runoff potential, high infltration rates
Group B	silt loam, loam	moderate infiltration rates
Group C	sandy clay loam	low infiltration rates
Group D	clay loam, silty clay loam, sandy clay, silty clay, clay	high runoff potential very low infiltration rates

Table:4.4: Different hydrological soil groups

4.4.1Hydrological Soil Groups

On the basis of the landcover, the cultivation treatment, the hydrologic conditionof the soil, and the hydrologic soil group of theparticular soil-the actual runoff curve number to usein determining daily runoff from precipitation. Landuse, cover treatment, and hydrologic condition can bedetermined based on the following summaries:

Fallow>-Land is kept as bare as possible to conservemoisture for use by a succeeding crop. Highestpotential for

runoff exists in this category.

Row crop-Any field crop (maize, sorghum, soybeans,sugar beets, tomatoes, tulips) planted in rows

far enough apart so that most of the soil surface isexposed to rainfall impact throughout the growingseason.

Row crops are planted either in ***straight rows*** or onthe ***contour.*** or***contoured and terraced,*** and they arein either

Poor or ***good rotation.*** These land treatmentsand hydrologic conditions are discussed later.

Small grain-(wheat, oats, barley, flax, etc.) isplanted in rows close enough that the soil surface is not exposed except during planting and shortly thereafter.Land treatments and hydrologic conditions arethe

same as for row crops.

Close-seeded legumes or rotation meadow-(alfalfa,sweet clover, timothy, etc., and combinations) eitherare planted in close rows or broadcast. The landtreatments and hydrologic conditions are the same asfor row crops except if seed is broadcast.

Rotations-are planned sequences of crops, whosepurpose is to maintain soil fertility, or reduce erosion,or provide an annual supply of a particular crop.Rotations range from "poor" to "good" in proportionto the amount of dense vegetation in therotation,

Poor rotations-generally are one-crop land usessuch as continuous corn (maize), or continuous wheat, or combinations of row crops, small grains,and fallow.

Good rotcctions-generally contain alfalfa or otherclose-seeded legume or grass to improve andincrease infiltration.

Cover treatments

Straight-row-fields are farmed in straight rowseither up and down the hill or across the slope. Whereland slopes are less than 2%, farming across the slopein straight rows is equivalent to contouring andshould be so considered.

Contoured-fields are farmed as closely as possibleon the contours.

Terraced-refers to systems containing open-endlevel or graded terraces, grassed waterway outlets,

and contour furrows between the terraces.

Grassland (natiue pasture or range)

Hydrologic condition is based on the vegetativecondition:

Poor-is used if the area is grazed heavily, has nomulch. or has plant cover on less than one-half of thearea.

Fair-represents land not grazed heavily, withplant cover on one-half to three-quarters of theGood-indicates a

lightly grazed area that hasplant cover on more than three-quarters of the area.

Meadow-A field on which grass is grown continuously,protected from grazing, and generally mowed forhay.

Drained meadows have low watertables and littleor no surface runoff except during storms having highrainfall intensities.

Undrainedmeadows have highwatertables and may be so wet as to be the equivalentof water surfaces.

Woods and forests-Woods-usually are small isolated groves of treesbeing raised for farm or ranch use.

Hydrologic condition is based on the vegetation:

Poor-is used in areas grazed heavily or burnedregularly. Litter, small trees, and brush are destroyed.

Fair-indicates fields grazed but not burned. Theremay be some litter but these woods are not protected.

4.4.2 Antecedent moisture condition (AMC)

The second step is to determine the five-day antecedent moisture condition**(AMC)** of the particular soil from the daily precipitation record. This provides a measure of soil wetness. In this situation, the precipitation totals that will shift the soil from one antecedent moisture class to another, vary with the season of the year**.**

AMC-I: Soils are dry but not to wilting point.

AMC-II: Average condition

AMC-III: Sufficient rainfall has occurred within the immediate last 5 days. Saturated soil condition prevails.

The limits of these three AMC classes, based on total rainfall magnitude in the previous 5 days are given in Appendix –I. This depends up on two seasons 1) growing season 2) Dormant season.

The variation of **CN**under AMC-II, called **CNII**. The conversion of **CNII**to other two AMC conditions can be made through the use of following equations.

For AMC-I: **CNI = CNII**/ (2.281-0.01281CNII)

For AMC-III: **CNIII = CNII**/ (0.427+0.00573CNII)

Above two equations are applicable in the **CNII**, range of 55 to 95 which covers most of thepractical range.

CHAPTER 5

RESULT AND DISCUSSION

This chapter describes the results obtained from rainfall-runoff modeling using SCS-CN model,

model.

5.1 SCS-CN Model

The data required to model through SCS-CN model were downloaded from various sources and maps were delineated using ILWIS.

Digital elevation model (DEM) of the Lower Ngavalli basin was drawn. Flow direction map, flow accumulation map and Land use/land cover map of the basin was also drawn by ILWIS. Figure 5.1 shows the polygon map of the basin.So the slope in the basin is high having very hilly topography. Figure

5.2 and 5.3 shows the flow direction and contour lines of the basin. It helps in marking

the best possible places where measurements, sampling can be done in the stream. Digital Elevation Model of the basin (Figure 5.4) shows that more than 60% area of the catchment iscovered with dense forest.It shows the large difference in elevation in the topography of the basin

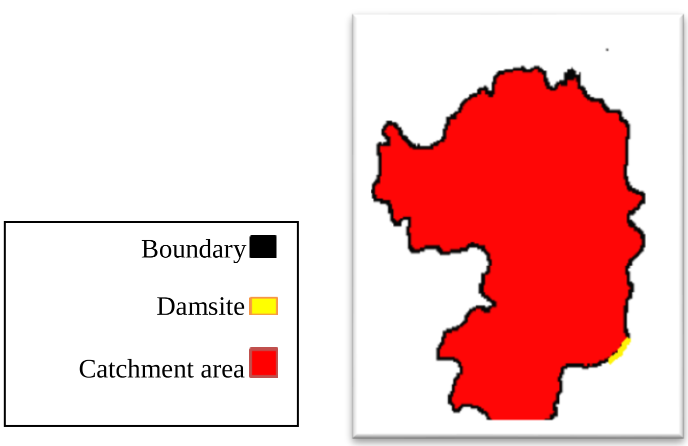
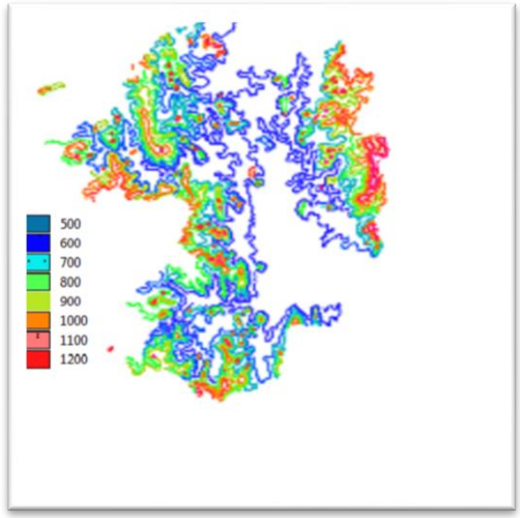


Figure 5.1(a): catchment boundary map (polygon) obtained by catchment delineation method



Major flowline **Minor flowline**

Figure 5.1(b): contour map of the catchment **Figure 5.1(c): flowlines of the catchment**

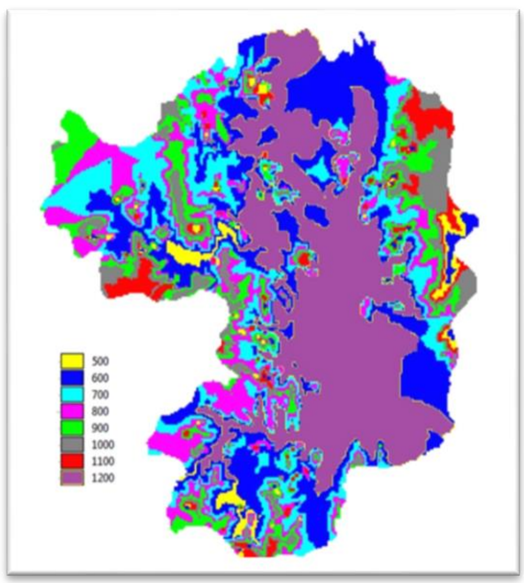


Figure 5.1(d): D.E.M of the catchment

Length of travel was measured directly from the map with the help of a string and ruler .The length obtained was multiplied by the scale of the map which in this case was 1 cm=2.5km to get the actual distance

So total length of travel is **19.8*2.5=49.5km**

$tc=0.0003233L^{0.77}S^{-0.385}$

or t_c=9.6 hrs

where t_c is the time of concentration in(h),L is the maximum length of travel in(m),S is the slope of the channel given by H/L ratio and is the elevation difference between the remote point in the channel and the outlet point

$t_p = 0.6\ t_c + t_c^{1/2}$

or t_p=8.934hrs

wher t_p is the time to peak in hrs .

Note that that t_p is lesser than the t_c ,it is because t_p represents the time at the peak discharge whearas t_c represents the total time taken by water to flowfrom inlet to outlet.The whole catchment area is divided into 5 different land use type depending upon the soil type , agricultural pattern, forest cover etc. These were further bracketed into different hydrological soil groups (HSG) based upon their infiltration rates.Individual areas were found out using AUTOCAD and then multiplied with appropriate scale to get the original area.

5.2 Weighted CN& Potential Maximum Retention

Land Use	% area	Area(km^2)	Cover Treatment	Hydrologic condition	HSG	Curve Number(AMC-II)	Svalue-(2540/CN)-25.4))
1)Agricultural and wasteland	14.26%	167.7					
a) Fallow Row Crops		110.682	Contoured	Good	C	82	5.57
b)Fallow row crops	-	57.01	Bare Soil	-	C	91	2.51
2)Hills and forest land	62.14%	730.79					
a)				Poor	C	77	7.58
b)				Fair	C	73	9.39
3)Alluvial plains	8.47%	99.64			B	76	8.02
4)Streets and Roads	13.09%	163.57					
a)Paved Curbs		102.25			D	98	0.51
b)Dirt		61.32			D	89	3.13
5)Residential area	1.22%	14.34					
a)1/8 acre		6.45			B	90	2.82
b)1/4 acre		5.01			B	83	5.2
c)1/3 acre		2.86			B	81	5.95

Table 5.2 Weighted CN computation of different land use types & s-value

Table 5.2 is a representation of the Hydrological Soil Group (H.S.G) and the corresponding Curve Number values, based on the cover treatment nnd hydrological condition of that particular area.Subsequently the S-value or the potential maximum retention was also computed **Contured cover treatment** indicate that fields are farmed as closely as possible on the contours. So the soil class was taken as Group B ,C andD depending upon the cover type, cover treatment,soil type and infiltration capacity . **Bare cover treatment** means land has a high runoff potential**.**The values of CN for AMC-II condition were selected from the tables given by S.C.S (TR-55). The value of CN is lower for soils with high infiltration. A **poor** condition refers to heavily grazed pastures with almost no vegetation.A **good** condition refers to lightly grazed with 75% or more land covered with plants.

.If the area consisits of patches of land then a **composite curve number (CN)** for the watershed can be obtained by weighing them in proportion of the area. The following calculation of the concerned catchment area illustrates the fact.

WeightedCNValue:

CNw=(A1CN1+A2CN2+A3CN3+A4CN4+A5CN5+A6CN6+A7CN7+A8CN8+A9CN9A+A10CN10+A11CN11)/(A1+A2+….A11) = 91891.61/1176.04=78.13

S value (in cm)= (2540/CNw)-25.4)) =7.10

A value of CN is for a given AMC condition depending upon the land use pattern.If the area consists of patches of land used , then a composite curve number (CN_w) for the watershed is obtained by weighing them in proportion of the area .For example ,for a watershed of 100 km^2 ,if the soil of 70 sqkm (70%) of the area has CN of 60 and 30 sq.km(30 %) has CN 80,the weighted CN is (0.7*60)+(0.3*80)=66

5.2.1Computed run off depth value of land use areas in monsoon season

	MONTH		JUN		JUL		AUG		SEPT		OCT	
	Avg Monthly Rainfall in (cm) (P)		16.83		30.49		26.7		20.48		12.73	
Land Use	S Value(cm)	CN	Qd (cm	%	Qd (cm)	%	Qd (cm)	%	Qd (cm)	%	Qd (cm)	%
1)Agricultural and waste land												
a) Fallow Row Crops contoured	5.57	82	12.38	73.58%	25.51	83.66%	21.82	81.72%	15.84	77.32%	8.6	67.58%
b) Fallow Row Crops bare	2.51	91	14.52	86.29%	28.05	91.98%	24.28	90.94%	**18.12**	88.48%	10.51	82.57%
2)Hills and forest land												
a)Poor	7.58	77	11.26	66.92%	24.06	78.90%	20.44	76.54%	14.6	71.27%	7.65	60.12%
b)Fair	9.39	73	10.39	61.76%	22.87	75.00%	19.32	72.34%	13.62	66.50%	6.94	54.54%
3)Alluvial plains	8.02	76	11.04	65.60%	23.76	77.92%	20.15	75.48%	14.35	70.06%	7.47	58.68%
4)Streets & Roads												
a)Paved Curbs	0.51	98	16.31	96.91%	29.96	98.27%	26.17	98.03%	19.96	97.45%	**12.21**	95.95%
b)Dirt	3.13	89	14.04	83.41%	27.5	90.18%	23.74	88.93%	17.61	85.99%	**10.07**	79.08%
5)Residential area												
a)1/8 acre	2.82	90	14.28	84.83%	27.77	91.07%	24.01	89.92%	17.86	87.22%	**10.29**	80.79%
b)1/4 acre	5.2	83	12.61	74.94%	25.79	84.60%	22.09	82.75%	16.08	78.53%	**8.8**	69.13%
c)1/3 acre	5.95	81	12.16	72.24%	25.22	82.72%	21.55	80.70%	15.59	76.11%	8.41	66.05%

Table 5.2(b) Runoff depth values

$$Q_d=(P-(I_a))^2/(P-I_a+S)) \text{ (i)}, \quad I_a=0.2S \text{ (ii)}$$

Runoff depth percent =(Qd/P) (ii) Qd-Runoff depth(cm),P-rainfall(cm)

Table 5.2(b) is a representation of runoffs depth **'Q_d'** calculated using S.C.S Curve Number formulae given in equation (i) for the different land use areas of the concerned catchment.In the equation I_a is the initial losses consisting of interception, depression storage and infiltration.Subsequently the **runoff depth %**using equation (ii) has also been calculated..It is clearly evident from the table that higher the value of curve number, lower is the maximum potential retention and higher are the values of runoff depth and runoff depth percent. This is because higher vaues of curve number corresponds to higher runoff and low infiltration.

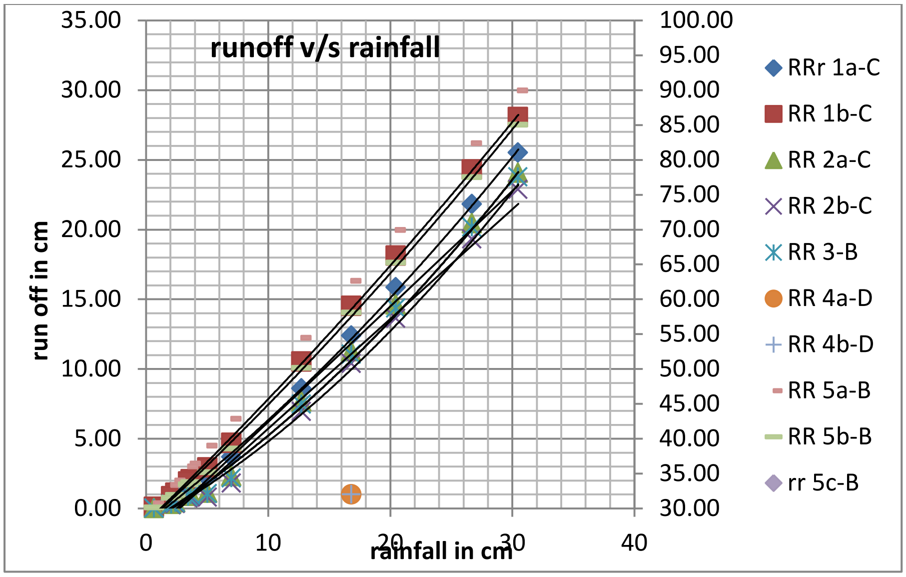


Figure 5.2.(a): Computed CN graph

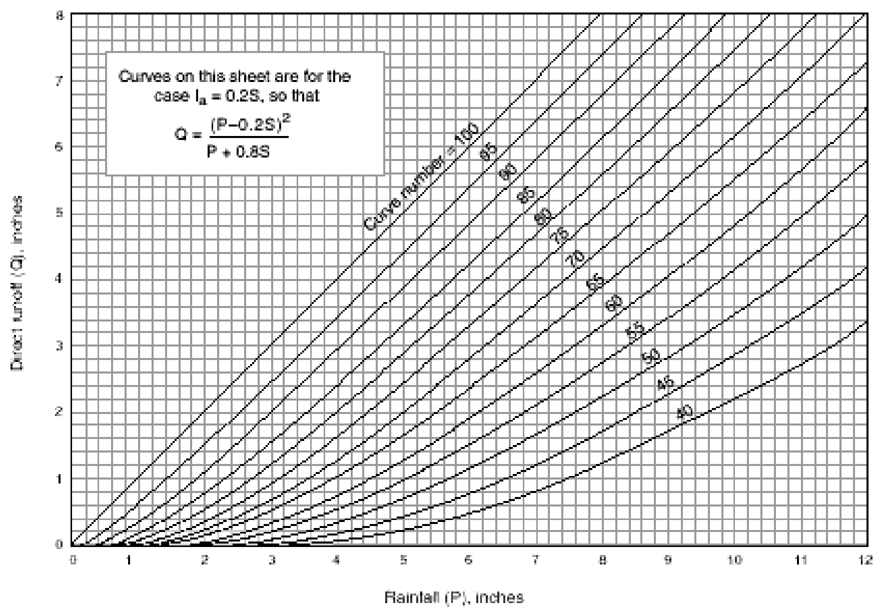


Figure 5.2(b): Actual CN graph

The curve number graph shows a relationship between rainfall and runoff supported by a index value from zero to 100.It generally takes into account the percent runoff from a given amount of rainfall.two different rainfall values can have same curve number if the percent runoff is similar .Different rainfall values having similar percentage runoff values when plotted on the graph follow a somewhat linear path.On joining the points of the path and measuring with the index a value of Curve Number is obtained .Itgenerally has a range from 30 to 100; lower numbers indicate low runoff potential while larger numbers are for increasing runoff potential.

5.3Standard Error of estimate

The standard error of estimate is the standard deviation of the prediction errors. It is computed like any other standard deviation - the square root of the error sum of squares divided by the degrees of freedom. It is given by the equation:

$$\mathbf{sqrt((\sum (y_{oi}-y_{ei})^2)/N-2)} \qquad \text{(i)}$$

y_{oi}-observeddata,y_{ei}-estimated data,

N- no of pairs of data points

It measures the spread of points around the fitted curve. The minimum value is 0,higher the value of error more spread out the points will be,lower the value more closely fitted the points will be. Similar formulas are used when the standard error of the estimate is computed from a sample rather than a population. The only difference is that the denominator is **N-2** rather than **N.** The reason **N-2** is used rather than **N-1** is that two parameters (the slope and the intercept) were estimated in order to estimate the sum of squares. Formulas for a sample comparable to the ones for a population are shown below.In the following sections the runoff depth using S.C.S-CN method as well standard error estimate between observed and computed value of runoff from the monthly as well as daily rainfall values for the months June to October for a period from 1977-78 to2001-02has been computed for different initial abstraction values, i.e **I_a=0.2S, I_a=0.05S, I_a=0.3S**

5.3.1 Monthly Rainfall values

I_a=0.2S JUNE

YEAR	JUN	Qd	Q obs	Mean	Q obs	Q obs	(II-I)	(II-I)^2
		(cm) **(I)**	**(cumec)**	(cumec)	(m)	(cm) **(II)**		
1977-78	12.52	**8.828**	94.84	3.06	**0.007**	0.674	-8.154	66.48
1978-79	20.91	**16.881**	30.88	1.00	**0.002**	0.219	-16.662	277.61
1979-80	14.59	**10.785**	135.23	4.36	**0.010**	0.961	-9.824	96.51
1980-81	7.97	**4.673**	394.10	12.71	**0.028**	2.800	-1.873	3.51
1981-82	7.78	**4.507**	45.52	1.47	**0.003**	0.323	-4.184	17.50
1982-83	9.17	**5.741**	91.08	2.94	**0.006**	0.647	-5.093	25.94
1983-84	34.5	**30.244**	18.13	0.58	**0.001**	0.129	-30.116	906.95
1984-85	7.91	**4.621**	757.36	24.43	**0.054**	5.381	0.760	0.58
1985-86	17.93	**13.990**	121.36	3.91	**0.009**	0.862	-13.127	172.33
1986-87	13.49	**9.741**	506.27	16.33	**0.036**	3.597	-6.144	37.75
1987-88	15.22	**11.386**	86.73	2.80	**0.006**	0.616	-10.769	115.98
1988-89	36.15	**31.878**	82.33	2.66	**0.006**	0.585	-31.293	979.22
1989-90	8.31	**4.973**	1698.08	54.78	**0.121**	12.065	7.092	50.29
1990-91	20.22	**16.209**	1172.19	37.81	**0.083**	8.328	-7.881	62.11
1991-92	14.46	**10.661**	283.85	9.16	**0.020**	2.017	-8.644	74.73
1992-93	13.06	**9.335**	484.81	15.64	**0.034**	3.445	-5.891	34.70
1993-94	29.12	**24.931**	26.49	0.85	**0.002**	0.188	-24.743	612.21
1994-95	11.63	**7.996**	1496.87	48.29	**0.106**	10.635	2.639	6.97
1995-96	33.28	**29.038**	-47.09	-1.52	**-0.003**	-0.335	-29.372	862.73
1996-97	10.35	**6.813**	92.19	2.97	**0.007**	0.655	-6.158	37.92
1997-98	15.99	**12.122**	-3.98	-0.13	**0.000**	-0.028	-12.151	147.64
1998-99	18.84	**14.870**	374.61	12.08	**0.027**	2.662	-12.208	149.05
1999-00	14.15	**10.367**	182.00	5.87	**0.013**	1.293	-9.073	82.33
2000-01	19.61	**15.617**	170.56	5.50	**0.012**	1.212	-14.405	207.50
2001-02	29.14	**24.951**	902.09	29.10	**0.064**	6.409	-18.542	343.79
							SUM	**4006.99**

Table.5.3(a)

Qd(cm)	**(P-(0.2*7.1)) ^{2}/(P+(0.80*7.1))**
Mean(cumec)	**Q obs(cumec)/31**
Q obs(cm)	**(Qobs m^3/sec*3600*24*30)/(1176.84*10^6)**

I_a=0.2S JULY

YEAR	JULY	Qd (cm)	Q obs	Mean	Q obs(m)	Qobs(cm)	(II-I)	(II-I)^2
		I	(cumec)	(cumec)		II		
1977-78	30.83	23.691	1100.74	35.51	0.078	7.82	-15.870	251.86
1978-79	12.92	7.110	892.31	28.78	0.063	6.34	-0.771	0.59
1979-80	21.1	14.462	186.17	6.01	0.013	1.32	-13.140	172.65
1980-81	16.01	9.814	894.26	28.85	0.064	6.35	-3.461	11.98
1981-82	34.54	27.273	103.12	3.33	0.007	0.73	-26.541	704.41
1982-83	19.56	13.037	1255.97	40.52	0.089	8.92	-4.114	16.92
1983-84	29.48	22.394	455.44	14.69	0.032	3.24	-19.158	367.02
1984-85	34.6	27.331	1203.56	38.82	0.086	8.55	-18.780	352.70
1985-86	19.47	12.954	835.11	26.94	0.059	5.93	-7.021	49.29
1986-87	10.03	4.719	2135.18	68.88	0.152	15.17	10.451	109.23
1987-88	40.07	32.652	433.78	13.99	0.031	3.08	-29.570	874.38
1988-89	46.58	39.025	1421.35	45.85	0.101	10.10	-28.926	836.72
1989-90	27.3	20.309	1946.98	62.81	0.138	13.83	-6.475	41.93
1990-91	56.35	48.643	4801.32	154.88	0.341	34.11	-14.530	211.12
1991-92	46.3	38.750	2724.40	87.88	0.194	19.36	-19.393	376.10
1992-93	54.96	47.271	2084.33	67.24	0.148	14.81	-32.462	1053.81
1993-94	27.77	20.757	1004.68	32.41	0.071	7.14	-13.619	185.47
1994-95	12.49	6.744	3406.60	109.89	0.242	24.20	17.459	304.82
1995-96	47.39	39.820	697.69	22.51	0.050	4.96	-34.863	1215.42
1996-97	35.07	27.787	197.05	6.36	0.014	1.40	-26.387	696.28
1997-98	57.01	49.294	226.18	7.30	0.016	1.61	-47.687	2274.06
1998-99	64.82	57.015	473.61	15.28	0.034	3.36	-53.650	2878.33
1999-00	19.27	12.770	472.54	15.24	0.034	3.36	-9.413	88.61
2000-01	31.67	24.500	516.75	16.67	0.037	3.67	-20.828	433.81
2001-02	35.06	27.777	1820.39	58.72	0.129	12.93	-14.844	220.34
							SUM	**13727.87**

Table 5.3(b)

I_a=0.2S AUGUST

YEAR	AUGUST	Qd (cm)	Qobs(cumec)	Mean	Q obs in (m)	Q obs in (cm)	(II-I)	(II-I)^2
1977-78	24.29	19.093	1307.15	42.17	0.09	9.29	-9.806	96.16
1978-79	13.44	8.733	290.11	9.36	0.02	2.06	-6.672	44.51
1979-80	10.2	5.794	511.94	16.51	0.04	3.64	-2.157	4.65
1980-81	19.4	14.365	580.7	18.73	0.04	4.13	-10.240	104.85
1981-82	131.5	125.708	1265.45	40.82	0.09	8.99	-116.717	13622.90
1982-83	27.47	22.195	2841.22	91.65	0.20	20.19	-2.009	4.04
1983-84	20.73	15.645	808.72	26.09	0.06	5.75	-9.899	97.99
1984-85	16.04	11.165	2161.47	69.72	0.15	15.36	4.192	17.57
1985-86	21.09	15.992	2493.18	80.43	0.18	17.71	1.722	2.96
1986-87	13.99	9.243	1296.85	41.83	0.09	9.21	-0.029	0.00
1987-88	28.84	23.537	623.43	20.11	0.04	4.43	-19.107	365.09
1988-89	36.6	31.171	1284.08	41.42	0.09	9.12	-22.048	486.13
1989-90	38.71	33.255	2907.44	93.79	0.21	20.66	-12.598	158.72
1990-91	45.2	39.680	2792.242	90.07	0.20	19.84	-19.841	393.67
1991-92	20.51	15.433	8197.98	264.45	0.58	58.25	42.813	1832.94
1992-93	15.35	10.515	2988.41	96.40	0.21	21.23	10.717	114.86
1993-94	20.56	15.481	1130.54	36.47	0.08	8.03	-7.449	55.48
1994-95	30.02	24.694	3501.81	112.96	0.25	24.88	0.186	0.03
1995-96	48.69	43.141	521.02	16.81	0.04	3.70	-39.439	1555.46
1996-97	24.04	18.850	677.3	21.85	0.05	4.81	-14.038	197.06
1997-98	40.32	34.847	1011.05	32.61	0.07	7.18	-27.664	765.29
1998-99	39.71	34.244	982.61	31.70	0.07	6.98	-27.263	743.26
1999-00	33.62	28.233	756.14	24.39	0.05	5.37	-22.861	522.63
2000-01	30.13	24.802	781.731	25.22	0.06	5.55	-19.248	370.48
2001-02	19.84	14.788	1936.418	62.47	0.14	13.76	-1.030	1.06
							SUM	**20866.25**

Table5.3(c)

I_a=0.2S SEPTEMBER

YEAR	SEPT	Qd	Q obs	Mean	Q obs	Q obs	(II-I)	(II-I)^2
		(cm)	(cumec)	(cumec)	(m)	(cm)		
1977-78	11.2	5.666	1959.08	65.30	0.144	14.38	8.717	75.979
1978-79	10.63	5.201	1106.32	36.88	0.081	8.12	2.922	8.535
1979-80	18.88	12.413	196.19	6.54	0.014	1.44	-10.972	120.388
1980-81	18.54	12.101	668.52	22.28	0.049	4.91	-7.193	51.743
1981-82	7.55	2.840	1739.34	57.98	0.128	12.77	9.929	98.593
1982-83	27.02	20.042	1215.51	40.52	0.089	8.92	-11.118	123.602
1983-84	7.75	2.984	1942.31	64.74	0.143	14.26	11.276	127.155
1984-85	9.46	4.270	1040.57	34.69	0.076	7.64	3.370	11.357
1985-86	13.98	8.024	567.76	18.93	0.042	4.17	-3.856	14.867
1986-87	15.59	9.440	703.28	23.44	0.052	5.16	-4.277	18.290
1987-88	26.1	19.166	618.79	20.63	0.045	4.54	-14.623	213.839
1988-89	29.75	22.653	1767.79	58.93	0.130	12.98	-9.674	93.591
1989-90	14.67	8.627	1415.00	47.17	0.104	10.39	1.761	3.102
1990-91	22.46	15.731	4463.42	148.78	0.328	32.77	17.038	290.282
1991-92	17.41	11.073	2035.58	67.85	0.149	14.94	3.871	14.988
1992-93	34.91	27.632	2302.90	76.76	0.169	16.91	-10.725	115.020
1993-94	32.35	25.156	1777.50	59.25	0.130	13.05	-12.106	146.547
1994-95	14.89	8.821	3490.14	116.34	0.256	25.62	16.803	282.337
1995-96	17.35	11.019	583.72	19.46	0.043	4.29	-6.733	45.339
1996-97	31.36	24.201	307.17	10.24	0.023	2.26	-21.946	481.619
1997-98	43.35	35.858	531.03	17.70	0.039	3.90	-31.959	1021.409
1998-99	42.04	34.576	622.61	20.75	0.046	4.57	-30.005	900.322
1999-00	16.1	9.895	1367.27	45.58	0.100	10.04	0.144	0.021
2000-01	17.03	10.730	335.17	11.17	0.025	2.46	-8.269	68.377
2001-02	12.61	6.846	787.70	26.26	0.058	5.78	-1.063	1.130
							SUM	4328.43

Table 5.3(d)

I_a=0.2S OCTOBER

YEAR	OCT	Qd (cm)	Q obs	Mean	Qobs(m)	Qobs (cm)	(II-I)	(II-I)^2
			(cumec)	(cumec)				
1977-78	1.68	0.009	658.48	21.241	0.048	4.834	4.825	23.282
1978-79	3.5	0.471	135.426	4.369	0.010	0.994	0.523	0.273
1979-80	11.03	5.527	172.101	5.552	0.013	1.264	-4.263	18.175
1980-81	2.35	0.108	312.7	10.087	0.023	2.296	2.188	4.788
1981-82	11.32	5.765	833.452	26.886	0.061	6.119	0.354	0.125
1982-83	10.34	4.967	264.502	8.532	0.019	1.942	-3.025	9.149
1983-84	20.14	13.572	1036.574	33.438	0.076	7.610	-5.962	35.547
1984-85	15.68	9.520	1694.32	54.655	0.124	12.439	2.919	8.522
1985-86	14.37	8.364	944.57	30.470	0.069	6.935	-1.429	2.043
1986-87	13.06	7.230	821.48	26.499	0.060	6.031	-1.199	1.437
1987-88	10.48	5.079	225.187	7.264	0.017	1.653	-3.426	11.739
1988-89	2.82	0.231	535.832	17.285	0.039	3.934	3.703	13.715
1989-90	14.35	8.347	861.024	27.775	0.063	6.321	-2.025	4.102
1990-91	14.87	8.803	2916.715	94.088	0.214	21.414	12.611	159.027
1991-92	12.19	6.491	921.68	29.732	0.068	6.767	0.276	0.076
1992-93	8.26	3.356	689.57	22.244	0.051	5.063	1.706	2.912
1993-94	17.87	11.491	733.43	23.659	0.054	5.385	-6.106	37.282
1994-95	30.2	23.085	1135.19	36.619	0.083	8.334	-14.751	217.584
1995-96	12.7	6.923	673.88	21.738	0.049	4.947	-1.975	3.902
1996-97	6.7	2.252	162.74	5.250	0.012	1.195	-1.057	1.117
1997-98	25.01	18.133	139.83	4.511	0.010	1.027	-17.106	292.614
1998-99	25.4	18.502	574.61	18.536	0.042	4.219	-14.283	204.014
1999-00	7.08	2.511	739.136	23.843	0.054	5.427	2.916	8.502
2000-01	3.49	0.467	-53.021	-1.710	-0.004	-0.389	-0.857	0.734
2001-02	9.31	4.153	478.357	15.431	0.035	3.512	-0.641	0.411
							SUM	**1061.073**

Table 5.3(e)

5.3.2 Standard Error Estimate table for Ia=0.2S JUNE-OCTOBER

MONTH	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Square of error	**$\sum$((yoi-yei)^2**	**$\sum$((yoi-yei)^2**	**$\sum$((yoi-yei)^2**	**$\sum$((yoi-yei)^2**	**$\sum$((yoi-yei)^2**
SUM	**$\sum$=4006.99**	**$\sum$=13727.87**	**$\sum$=20866.25**	**$\sum$=4328.43**	**$\sum$=1061.073**
Std error of estimate sqrt((sum(yoi-yei)^2)/N-2)	**12.63**	**23.43**	**28.49**	**13.16**	**6.51**

Table:5.3(f)

Average error= (12.63+23.43 +28.49+13.16+6.51)/5=16.81

Figure 5.3 (a),(b),(c),(d),(e) are the tabulation of the computed data of runoff depth Q_d obtained by using S.C.S-CN method for different months. The formulae is **Q_d(cm) =(P-(0.2*S)) ^{2}/(P-I_a+S)),**whereP is the rainfall in cm, S is the potential maximum retention in(cm**) ,** the value of S computed in **section 5.2** is taken as **7.1**,I_a is taken as 0.2S.The observed data of discharge(cumec) is taken and by deducting the baseflowvalues,it is converted to appropriate discharge depth(cm)taking time of concentration into account. Observed and computed values are compared and error is calculated by using standard error of estimate.

Table 5.3(f).is a representation of the standard error estimate of the catchment for the monthly rainfall in the period 1977-78 TO 2000-01.Only the monsoon period that is June to October has been considered**.**It can be seen thatthe error values increase from June to August and then starts decreasing in the month of September and October. The reason behind is that,in the months of June –August the rainfall value increase and so does the runoff depth, therefore the difference between observed and computed discharge values are very high ,so the error is also high.

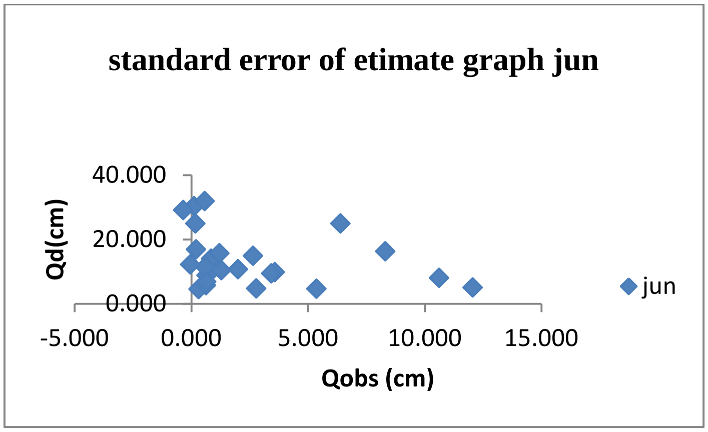


Figure : 5.3(a)

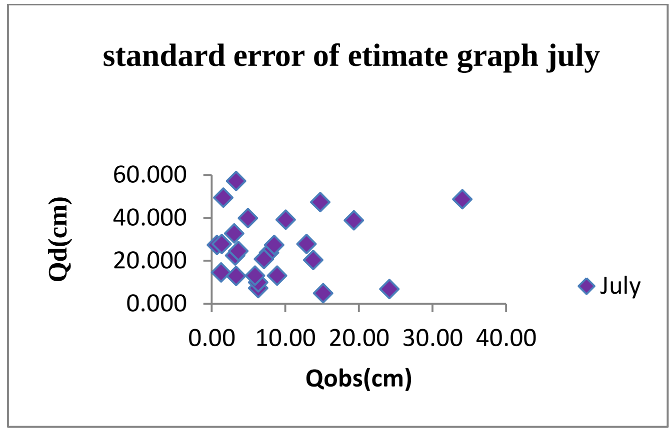


Figure : 5.3(b)

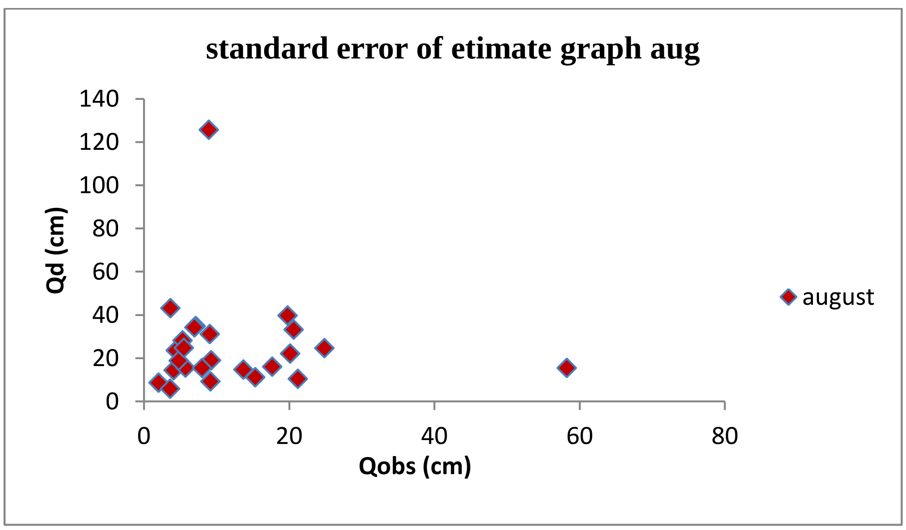


Figure : 5.3(c)

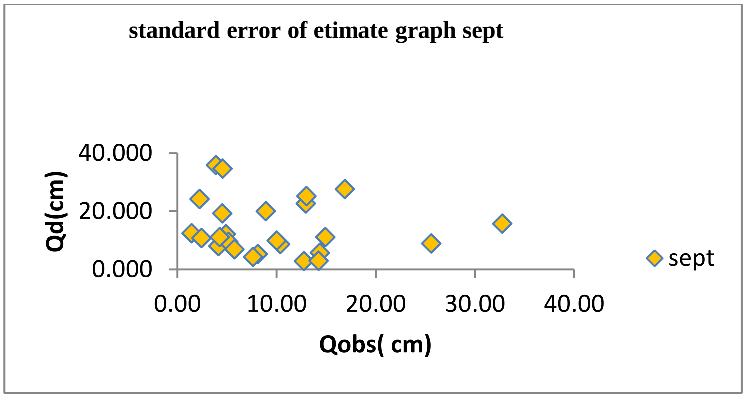


Figure : 5.3(d)

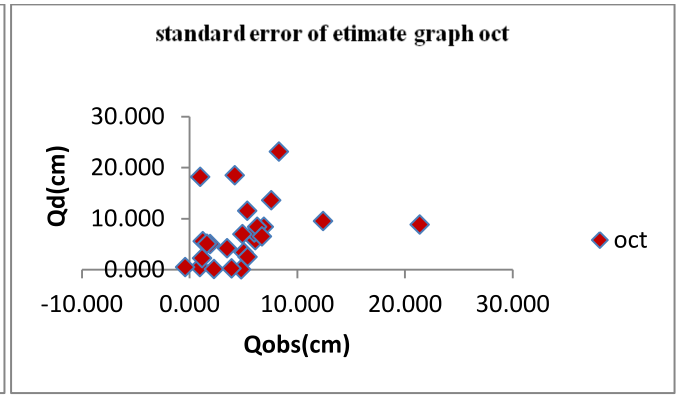


Figure : 5.3(e)

Graphs in figure 5.3(a),(b),(c),(d),(e) represents the distribution of points around the the straight line.Higher the value of standard estimate error more dispersed the points are from the straight lineas in case of July and August, whearas lower is the error value more closely placed the points area around the straight line as in case of October.

5.3.3 Standard Error Estimate table for Ia=0.05S JUNE-OCTOBER

MONTH	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Square of error	∑((yoi-yei)^2	∑((yoi-yei)^2	∑((yoi-yei)^2	∑((yoi-yei)^2	∑((yoi-yei)^2
SUM	∑=5372.34	∑=14660.07	∑=21557.80	∑=4590.17	∑=1184.14
Std error of estimate sqrt((sum(yoi-yei)^2)/N-2)	14.66	24.22	29.36	13.55	6.88

Table:5.3(g)

Average error=(14.66+24.22+29.36+13.55+6.88)/5 = 17.73

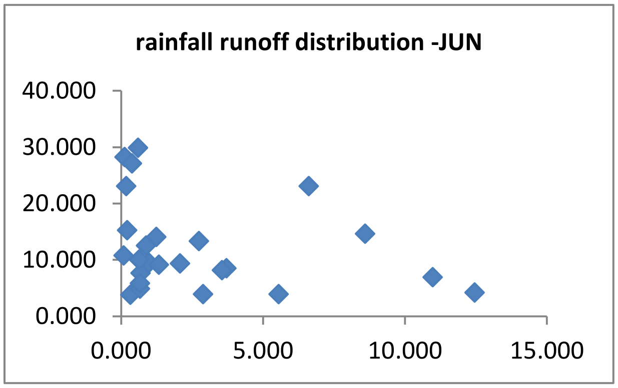


Figure:5.3(g)

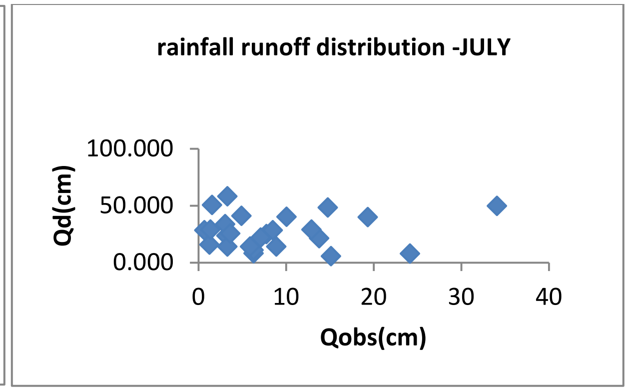


Figure:5.3(h)

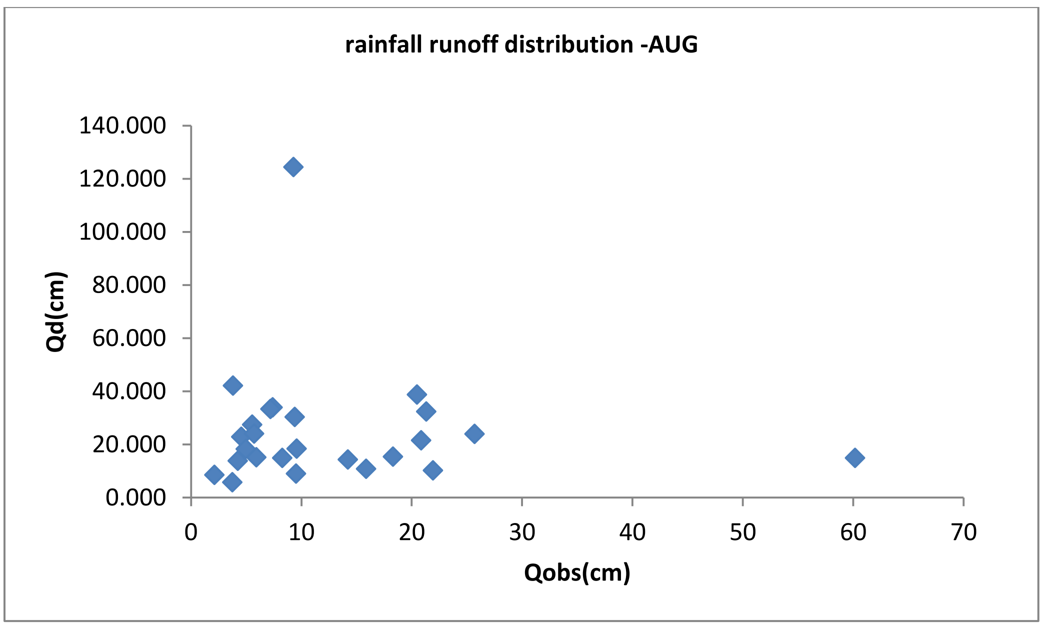


Figure:5.3(i)

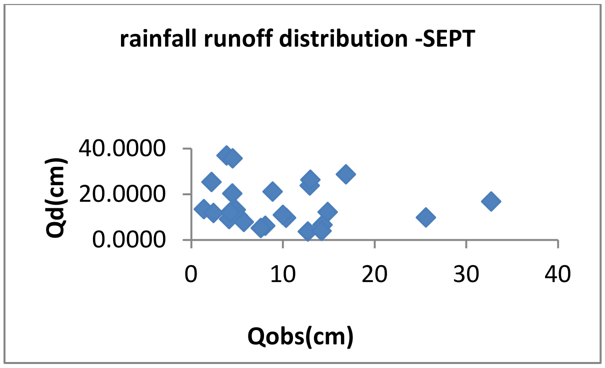


Figure:5.3(i)

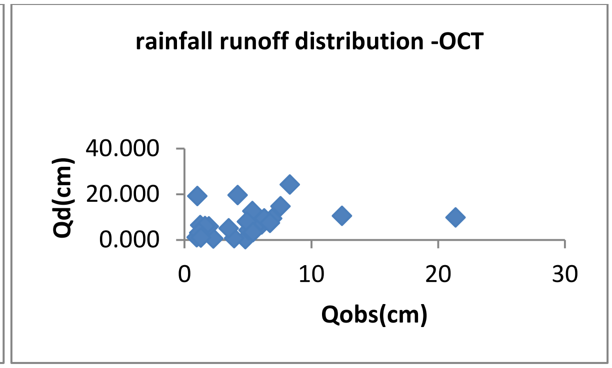


Figure:5.3(j)

5.3.4 Standard Error Estimate table for Ia=0.3*S JUNE-OCTOBER

MONTH	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Square of error	$\sum((yoi-yei)^2$	$\sum((yoi-yei)^2$	$\sum((yoi-yei)^2$	$\sum((yoi-yei)^2$	$\sum((yoi-yei)^2$
SUM	∑=3639.97	∑=13134.81	∑= 19454.96	∑=4115.89	∑=994.45
Std error of estimate $sqrt((sum(yoi-yei)^2)/N-2)$	12.07	22.92	27.89	12.83	6.30

Table5.3(h)

Average error=(12.07+22.92+27.89+12.83+6.30)/5=13.36

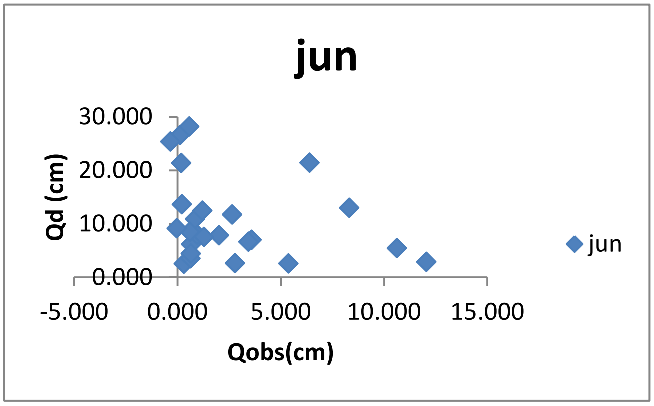


Figure5.3(k)

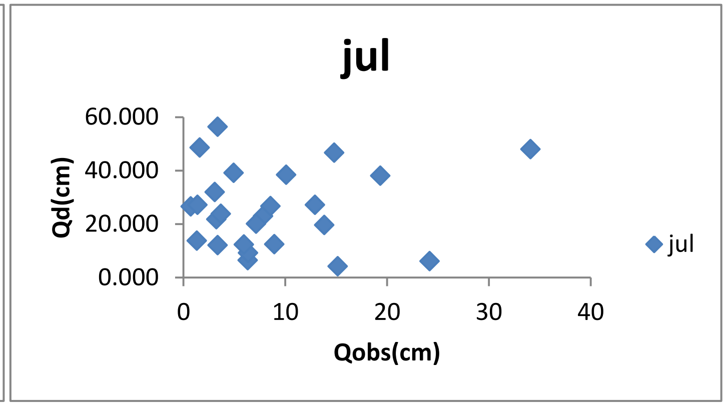


Figure5.3(l)

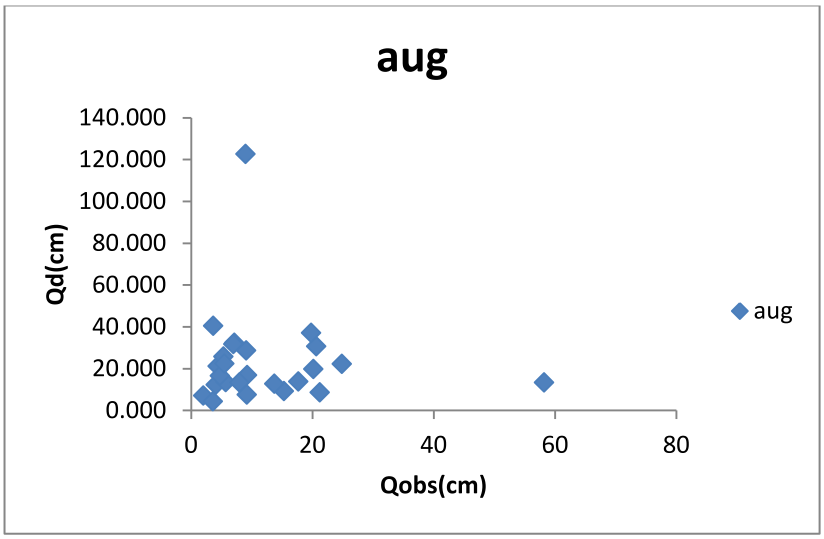


Figure5.3(m)

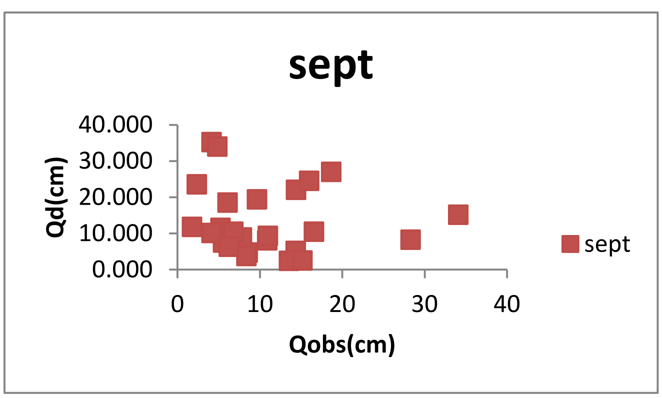


Figure5.3(o)

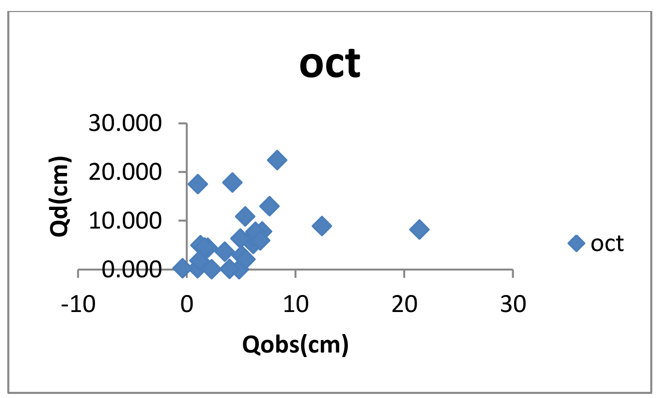


Figure 5.3(n)

5.3.5 Baseflow DeductionsForMonthly Rainfall

JUN			JUL			AUG		
q obs	baseflow deduction	qobs - baseflow	q obs	baseflow deduction	qobs - baseflow	q obs	baseflow deduction	qobs - baseflow
94.838	0	94.838	1100.74	0	1100.74	1307.15	0	1307.15
88.879	58	30.879	950.31	58	892.31	348.11	58	290.11
182.232	47	135.232	233.17	47	186.17	558.94	47	511.94
440.74	46.64	394.1	940.90	46.64	894.26	627.34	46.64	580.7
151.25	105.73	45.52	208.85	105.73	103.12	1371.18	105.73	1265.45
195.309	104.23	91.079	1360.20	104.23	1255.97	2945.45	104.23	2841.22
143.21	125.08	18.13	580.52	125.08	455.44	933.8	125.08	808.72
859.59	102.23	757.36	1305.79	102.23	1203.56	2263.7	102.23	2161.47
309.36	188	121.36	1023.11	188	835.11	2681.18	188	2493.18
872.56	366.29	506.27	2501.47	366.29	2135.18	1663.14	366.29	1296.85
297.42	210.69	86.73	644.47	210.69	433.78	834.12	210.69	623.43
276.571	194.24	82.331	1615.59	194.24	1421.35	1478.32	194.24	1284.08
1769.008	70.93	1698.078	2017.91	70.93	1946.98	2978.37	70.93	2907.44
1355.512	183.318	1172.194	4984.64	183.318	4801.32	2975.56	183.318	2792.242
507.25	223.4	283.85	2947.80	223.4	2724.40	8421.38	223.4	8197.98
725.88	241.07	484.81	2325.40	241.07	2084.33	3229.48	241.07	2988.41
429.64	403.15	26.49	1407.83	403.15	1004.68	1533.69	403.15	1130.54

OCT			SEPT		
q obs	Baseflow deduction	qobs - baseflow	q obs	baseflow deduction	qobs - baseflow
658.48	0	658.48	1959.08	0	1959.08
193.426	58	135.426	1164.32	58	1106.32
219.101	47	172.101	243.189	47	196.189
359.34	46.64	312.7	715.16	46.64	668.52
939.182	105.73	833.452	1845.066	105.73	1739.336
368.732	104.23	264.502	1319.743	104.23	1215.513
1161.654	125.08	1036.574	2067.387	125.08	1942.307
1796.55	102.23	1694.32	1142.798	102.23	1040.568
1187.77	366.29	821.48	755.76	188	567.76
435.877	210.69	225.187	1069.57	366.29	703.28
730.072	194.24	535.832	829.48	210.69	618.79
931.954	70.93	861.024	1962.026	194.24	1767.786
3100.033	183.318	2916.715	1485.934	70.93	1415.004
1145.08	223.4	921.68	4646.739	183.318	4463.421
930.64	241.07	689.57	2258.98	223.4	2035.58
1136.58	403.15	733.43	2543.97	241.07	2302.9
1016.09	342.21	673.88	2180.65	403.15	1777.5
177.54	14.8	162.74	3859.84	369.7	3490.14

Table5.3 (i)

Section 5.3.5 shows baseflow deductions table from observed monthly discharge values has been done .For each year the monsoon period i.e June-October ,the baseflow deductions has been done from the previous year dry season i.e April and May.The lower of the two values has been considered as base flow level .

5.4 Daily Rainfall Analysis

In this section the daily rainfall of Kalyansinghpur and Jkpurbetween the period 2004 -2009 has been analysed. Daily Rainfall values were taken and the runoff depth was calculated using S.C.S-CN method. The corresponding observed discharge values were then compared with computed values and error was found out.The calculations are shown in the following tables i.e **5.4(a)(b),(c),(d)(e).**

Station Name: **JK Pur**
Station Code: **N4**

2004											
MONTH	**DATE**	**RAINFALL**	**RAINFALL**	**Qd**	**Q obs**	**baseflow**	**Q'obs**	**Q'obs**	**Q'obs**	**(II-I)**	**(II-I)^2**
		(mm)	(cm)	(cm)	cumec	cumec	cumec	(m)	(cm)		
JUN	6/13/2004	45.8	4.58	1.58	146.843	7.434	139.41	0.010888	1.09	-0.49	0.24
	6/14/2004	71.6	7.16	3.33	200.848	7.434	193.41	0.015106	1.51	-1.82	3.31
JUL	7/5/2004	44	4.4	1.47	48.22	7.434	40.79	0.003186	0.32	-1.15	1.32
	7/25/2004	82.2	8.22	4.13	146.843	7.434	139.41	0.010888	1.09	-3.04	9.27
AUG	8/4/2004	62.8	6.28	2.70	146.843	7.434	139.41	0.010888	1.09	-1.61	2.58
	8/21/2004	74.2	7.42	3.52	288.61	7.434	281.18	0.021961	2.20	-1.33	1.76
SEPT	9/9/2004	19.4	1.94	0.29	48.22	7.434	40.79	0.003186	0.32	0.03	0.001
OCT	10/4/2004	38.4	3.84	1.15	91.16	7.434	83.73	0.006539	0.65	-0.49	0.24
	10/5/2004	112	11.2	6.55	200.848	7.434	193.41	0.015106	1.51	-5.04	25.44

Table:5.4

eff area (sq.km)=1106.229

Q'_{obs}(cumec)=Q_{obs}-baseflow

(Qobs m^3/sec *3600*24*30)/(1106.229*10^6)

Q_d(cm)=$(P-(0.2*7.1))^2/(P+(0.80*7.1))$

5.4(a)

YEAR	2005										
MONTH	DATE	RAINFALL	RAINFALL	**Qd**	Q obs	baseflow	Q'obs	**Q'obs**	**Q'obs**	(II-I)	(II-I)^2
		(mm)	(cm)	(cm)	cumec	cumec	cumec	(m)	(cm)		
JUN	6/21/2005	29.8	2.98	0.71	54.392	14.814	39.58	0.003091	0.31	-0.40	0.16
	6/27/2005	15.2	1.52	0.16	54.392	14.814	39.58	0.003091	0.31	0.14	0.02
								0	0.00		
JUL	7/8/2005	26.8	2.68	0.57	595.66	14.814	580.85	0.045366	4.54	3.96	15.71
	7/25/2005	14.6	1.46	0.15	91.16	14.814	76.35	0.005963	0.60	0.45	0.20
								0	0.00		
AUG	8/5/2005	18.2	1.82	0.25	123.14	14.814	108.33	0.008461	0.85	0.60	0.35
	8/19/2005	17.8	1.78	0.24	106.72	14.814	91.91	0.007178	0.72	0.48	0.23
								0	0.00		
SEPT	9/13/2005	45.6	4.56	1.56	595.66	14.814	580.85	0.045366	4.54	2.97	8.84
	9/18/2005	15.6	1.56	0.17	146.843	14.814	132.03	0.010312	1.03	0.86	0.73
	9/19/2005	82.4	8.24	4.15	390.098	14.814	375.28	0.029311	2.93	-1.22	1.48
oct	10/22/2005	36.4	3.64	1.04	123.14	14.814	108.33	0.008461	0.85	-0.19	0.04
	10/31/2005	42.2	4.22	1.36	288.61	14.814	273.80	0.021384	2.14	0.78	0.60

Table:5.4(a)

5.4(b)

MONTH	DATE	RAINFALL	RAINFALL	**Qd**	Q obs	baseflow	Q'obs	**Q'obs**	**Q'obs**	(II-I)	(II-I)^2
		(mm)	(cm)	(cm)	cumec	cumec	cumec	(m)	(cm)		
JUN	6/19/2006	19.2	1.92	**0.28**	26.334	18.789	7.55	0.000589	0.06	-0.22	0.050
	6/23/2006	17.1	1.71	**0.22**	35.196	18.789	16.41	0.001281	0.13	-0.09	0.008
	6/27/2006	16.6	1.66	**0.20**	54.392	18.789	35.60	0.002781	0.28	0.08	0.006
	6/28/2006	93.8	9.38	**5.05**	146.843	18.789	128.05	0.010001	1.00	-4.05	16.411
	6/29/2006	65.8	6.58	**2.91**	200.848	18.789	182.06	0.014219	1.42	-1.49	2.209
JUL	7/2/2006	34.6	3.46	**0.94**	91.16	18.789	72.37	0.005652	0.57	-0.38	0.144
	7/3/2006	253	25.3	**19.42**	3989.286	18.789	3970.50	0.310108	31.01	11.59	134.391
	7/4/2006	105.8	10.58	**6.03**	1199.08	18.789	1180.29	0.092184	9.22	3.18	10.136
	7/30/2006	31	3.1	**0.77**	91.16	18.789	72.37	0.005652	0.57	-0.20	0.040
AUG	8/1/2006	32	3.2	**0.81**	200.348	18.789	181.56	0.01418	1.42	0.60	0.365
	8/2/2006	35	3.5	**0.97**	315.172	18.789	296.38	0.023148	2.31	1.35	1.821
	8/3/2006	102.4	10.24	**5.75**	1675.513	18.789	1656.72	0.129395	12.94	7.19	51.647
	8/17/2006	56.8	5.68	**2.28**	888.767	18.789	869.98	0.067948	6.79	4.51	20.364
	8/22/2006	53	5.3	**2.03**	2322.807	18.789	2304.02	0.179951	18.00	15.96	254.880
	8/23/2006	17	1.7	**0.21**	532.968	18.789	514.18	0.040159	4.02	3.80	14.453
SEPT	9/4/2006	11.4	1.14	**0.08**	146.843	18.789	128.05	0.010001	1.00	0.92	0.850
	9/5/2006	16.4	1.64	**0.20**	146.843	18.789	128.05	0.010001	1.00	0.80	0.645
	9/18/2006	15.4	1.54	**0.17**	146.843	18.789	128.05	0.010001	1.00	0.83	0.690
	9/20/2006	17.6	1.76	**0.23**	146.843	18.789	128.05	0.010001	1.00	0.77	0.590
	9/30/2006	139	13.9	**8.89**	200.848	18.789	182.06	0.014219	1.42	-7.46	55.723
OCT	10/28/2006	8	0.8	**0.03**	77.96	18.789	59.17	0.004621	0.46	0.44	0.190
	10/29/2006	4.2	0.42	**0.00**	77.96	18.789	59.17	0.004621	0.46	0.46	0.213

Table:5.4(b)

5.4(c)

2007											
MONTH	DATE	RAINFALL	RAINFALL	**Qd**	Q obs	baseflow	Q'obs	**Q'obs**	**Q'obs**	(II-I)	(II-I)^2
		(mm)	(cm)	(cm)	cumec	cumec	cumec	(m)	(cm)		
JUN	6/23/2007	37	3.7	1.07	96.8	18.789	78.01	0.006093	0.61	-0.46	0.213391
	6/27/2007	26.6	2.66	0.56	135.243	18.789	116.45	0.009095	0.91	0.34	0.118768
	6/29/2007	45	4.5	1.53	227.478	18.789	208.69	0.016299	1.63	0.10	0.010413
JUL	7/7/2007	12.8	1.28	0.11	123.14	18.789	104.35	0.00815	0.82	0.71	0.501822
	7/13/2007	15.4	1.54	0.17	227.478	18.789	208.69	0.016299	1.63	1.46	2.132873
	7/16/2007	12.6	1.26	0.10	333.35	18.789	314.56	0.024568	2.46	2.35	5.543694
	7/23/2007	21	2.1	0.34	36.09	18.789	17.30	0.001351	0.14	-0.21	0.043739
AUG	8/6/2007	49	4.9	1.77	427.8	18.789	409.01	0.031945	3.19	1.42	2.018123
	8/7/2007	93.4	9.34	5.02	897.435	18.789	878.65	0.068625	6.86	1.84	3.398575
	8/12/2007	41.2	4.12	1.30	743.478	18.789	724.69	0.0566	5.66	4.36	18.96931
	8/13/2007	26.6	2.66	0.56	914.736	18.789	895.95	0.069976	7.00	6.43	41.37975
	8/27/2007	27.2	2.72	0.59	364.18	18.789	345.39	0.026976	2.70	2.11	4.438073
	8/29/2007	38	3.8	1.13	485.92	18.789	467.13	0.036484	3.65	2.52	6.365396
SEPT	9/3/2007	32.4	3.24	0.83	120.39	18.789	101.60	0.007935	0.79	-0.04	0.001603
	9/15/2007	21.2	2.12	0.35	92.16	18.789	73.37	0.005731	0.57	0.22	0.049126
	9/17/2007	26.4	2.64	0.56	108.4	18.789	89.61	0.006999	0.70	0.14	0.020607
	9/23/2007	33.6	3.36	0.89	130.86	18.789	112.07	0.008753	0.88	-0.02	0.000335
	9/24/2007	23.4	2.34	0.43	108.4	18.789	89.61	0.006999	0.70	0.27	0.070853
	9/27/2007	19.8	1.98	0.30	120.39	18.789	101.60	0.007935	0.79	0.49	0.240968
OCT	10/20/2007	24.6	2.46	0.48	28.5	18.789	9.71		0.000758	-0.48	0.230989

Table:5.4(c)

5.4(d)

2008											
MONTH	DATE	RAINFALL	RAINFALL	**Qd**	Q obs	baseflow	Q'obs	**Q'obs**	**Q'obs**	(II-I)	(II-I)^2
		(mm)	(cm)	(cm)	cumec	cumec	cumec	(m)	(cm)		
JUN	6/9/2008	17.6	1.76	0.23	4.218	3.466	0.75	5.87E-05	0.01	-0.23	0.051
	6/11/2008	23.4	2.34	0.43	28.189	3.466	24.72	0.001931	0.19	-0.24	0.058
JUL	7/27/2008	24.8	2.48	0.49	24.455	3.466	20.99	0.001639	0.16	-0.33	0.106
	7/28/2008	28	2.8	0.63	28.189	3.466	24.72	0.001931	0.19	-0.43	0.188
	7/31/2008	20.6	2.06	0.33	35.484	3.466	32.02	0.002501	0.25	-0.08	0.006
							0.00				
AUG	8/4/2008	23	2.3	0.42	22.983	3.466	19.52	0.001524	0.15	-0.27	0.071
	8/8/2008	30.6	3.06	0.75	258.01	3.466	254.54	0.019881	1.99	1.24	1.542
	8/10/2008	21.4	2.14	0.36	211.488	3.466	208.02	0.016247	1.62	1.27	1.603
	8/17/2008	29.4	2.94	0.69	49.947	3.466	46.48	0.00363	0.36	-0.33	0.107
	8/25/2008	24.6	2.46	0.48	49.947	3.466	46.48	0.00363	0.36	-0.12	0.014
SEPT	9/12/2008	36.8	3.68	1.06	153.299	3.466	149.83	0.011702	1.17	0.11	0.012
	9/13/2008	20.4	2.04	0.32	112.47	3.466	109.00	0.008514	0.85	0.53	0.279
	9/14/2008	21.2	2.12	0.35	122.86	3.466	119.39	0.009325	0.93	0.58	0.338
	9/15/2008	27.4	2.74	0.60	153.299	3.466	149.83	0.011702	1.17	0.57	0.326
	9/16/2008	45.8	4.58	1.58	430.343	3.466	426.88	0.03334	3.33	1.76	3.090
	9/17/2008	27	2.7	0.58	363.7	3.466	360.23	0.028135	2.81	2.23	4.979
	9/18/2008	31.2	3.12	0.77	363.7	3.466	360.23	0.028135	2.81	2.04	4.156
	9/23/2008	43.2	4.32	1.42	153.299	3.466	149.83	0.011702	1.17	-0.25	0.063
OCT	10/2/2008	37.8	3.78	1.11	41.545	3.466	38.08	0.002974	0.30	-0.82	0.668

Table:5.4(d)

5.4(e)

YEAR	2009										
MONTH	DATE	RAINFALL	RAINFALL	**Qd**	Q obs	baseflow	Q'obs	**Q'obs**	**Q'obs**	(II-I)	(II-I)^2
		(mm)	(cm)	(cm)	cumec	cumec	cumec	(m)	(cm)		
JUN	6/6/2009	25.2	2.52	**0.51**	9.001	6.052	2.95	0.00023	0.02	-0.48	0.233
	6/20/2009	25.2	2.52	**0.51**	9.863	6.052	3.81	0.000298	0.03	-0.48	0.227
	6/25/2009	38.2	3.82	**1.14**	10.483	6.052	4.43	0.000346	0.03	-1.10	1.214
	6/30/2009	32.4	3.24	**0.83**	10.207	6.052	4.16	0.000325	0.03	-0.80	0.642
											0.000
JUL	7/2/2009	46	4.6	**1.59**	34.187	6.052	28.14	0.002197	0.22	-1.37	1.873
	7/3/2009	39.2	3.92	**1.19**	69.759	6.052	63.71	0.004976	0.50	-0.69	0.482
	7/12/2009	36.8	3.68	**1.06**	80.05	6.052	74.00	0.005779	0.58	-0.48	0.233
	7/13/2009	24	2.4	**0.46**	226.81	6.052	220.76	0.017242	1.72	1.27	1.605
	7/14/2009	75.2	7.52	**3.60**	363.7	6.052	357.65	0.027933	2.79	-0.81	0.649
	7/15/2009	24.2	2.42	**0.47**	258.01	6.052	251.96	0.019679	1.97	1.50	2.258
	7/19/2009	45.2	4.52	**1.54**	363.7	6.052	357.65	0.027933	2.79	1.25	1.571
	7/20/2009	39.4	3.94	**1.20**	160	6.052	153.95	0.012024	1.20	0.00	0.000
	7/27/2009	28	2.8	**0.63**	59.496	6.052	53.44	0.004174	0.42	-0.21	0.044
	7/28/2009	21	2.1	**0.34**	258.01	6.052	251.96	0.019679	1.97	1.62	2.636
AUG	8/15/2009	56	5.6	**2.23**	122.86	6.052	116.81	0.009123	0.91	-1.32	1.732
	8/20/2009	26.6	2.66	**0.56**	122.86	6.052	116.81	0.009123	0.91	0.35	0.121
	8/25/2009	20.2	2.02	**0.32**	112.86	6.052	106.81	0.008342	0.83	0.52	0.268
	8/26/2009	24.8	2.48	**0.49**	112.86	6.052	106.81	0.008342	0.83	0.34	0.119
SEPT	9/1/2009	15.8	1.58	**0.18**	122.86	6.052	116.81	0.009123	0.91	0.73	0.536
	9/21/2009	11.2	1.12	**0.07**	59.496	6.052	53.44	0.004174	0.42	0.34	0.118
OCT	10/2/2009	34.2	3.42	**0.92**	53.65	6.052	47.60	0.003718	0.37	-0.55	0.305
	10/3/2009	11.8	1.18	**0.09**	49.95	6.052	43.90	0.003429	0.34	0.26	0.066

Table:5.4(e)

5.4.1(a) Standard error estimateJkpur

YEAR	2004	2005	2006	2007	2008	2009
SQUARE OF ERRORS	$\sum((yoi-yei)^2$	$\sum((yoi-yei)^2$	$\sum((yoi-yei)^2$	$\sum((yoi-yei)^2$	$\sum((yoi-yei)^2$	$\sum((yoi-yei)^2$
SUM	∑=46.02	∑=31.30	∑=565.827	∑=85.74	∑=27.023	∑=16.930
Std error of estimate sqrt((sum(yoi-yei)^2)/N-2)	1.88	1.138	5.070	2.07	1.08	0.877

Table:5.4(f)

Average error=(1.88+1.138+5.070+2.07+1.08+0.877)/5=2.42

5.4.1(b) Standard error estimate Kalyansinghpur

YEAR	2004	2005	2006	2007	2008	2009
SQUARE OF ERRORS	∑((yoi-yei)^2	∑((yoi-yei)^2	∑((yoi-yei)^2	∑((yoi-yei)^2	∑((yoi-yei)^2	∑((yoi-yei)^2
SUM	∑=116.523	∑=55.984	∑=455.723	∑=149.475	∑=29.744	∑=61.572
Std error of estimate sqrt((sum(yoi-yei)^2)/N)	**2.31**	**1.163**	**4.551**	**2.606**	**1.126**	**1.167**

Table:5.4(g)

Average error=(2.31+1.163+4.551+6.606+1.126+1.167)/6=2.82

The standard error estimate of Jkpur and Kalyansinghpur in section 5.4.1(a) and(b) show that the error values are within 5.0 .As compared to the monthly values 1.e 17.42, 13.36 the error in daily values are far less i.e 2.82,2.42.This is due to the reason that the difference between observed and computed data in monthly discharge values is very high, whearas the difference between observed and computed data in daily discharge values is less so less error is generated.

5.5.1Peak discharge values Jkpur

2001	P(mm)	P(cm)	Qd(cm)	Qd (m^3/sec)	A(km^2)	A(ha)	Qp=(0.0208*A*Qd)/tp
jun	56.8	5.68	2.2821	292.195	1106.229	110622.9	587.7671
jul	64.4	6.44	2.808	359.560	1106.229	110622.9	723.275
aug	48.8	4.88	1.7613	225.515	1106.229	110622.9	453.6351
sep	25.6	2.56	0.522	66.900	1106.229	110622.9	134.5746
oct	29.6	2.96	0.699	89.526	1106.229	110622.9	180.087
2002							
jun	27.2	2.72	0.590	75.661	1106.229	110622.9	152.1963
jul	58	5.8	2.363	302.591	1106.229	110622.9	608.6779
aug	54	5.4	2.095	268.321	1106.229	110622.9	539.7433
sep	26.2	2.62	0.547	70.1390	1106.229	110622.9	141.0883
oct	46.4	4.64	1.612	206.490	1106.229	110622.9	415.3661
2003							
JUN	16.4	1.64	0.196	25.213	1106.229	110622.9	50.71841
JUL	100.4	10.04	5.588	715.499	1106.229	110622.9	1439.264
AUG	39.2	3.92	1.191	152.577	1106.229	110622.9	306.9168
SEPT	81.2	8.12	4.0561	519.337	1106.229	110622.9	1044.673
OCT	89.06	8.906	4.671	598.167	1106.229	110622.9	1203.245
2004							
JUN	71.6	7.16	3.330	426.399	1106.229	110622.9	857.7243
JUL	82.2	8.22	4.133	529.239	1106.229	110622.9	1064.592
AUG	74.2	7.42	3.523	451.168	1106.229	110622.9	907.5492
OCT	112	11.2	6.554	839.164	1106.229	110622.9	1688.022
2005							
JUN	29.8	2.98	0.708	90.719	1106.229	110622.9	182.4868
JUL	26.8	2.68	0.573	73.433	1106.229	110622.9	147.7158
AUG	18.2	1.82	0.250	32.083	1106.229	110622.9	64.53723
SEPT	45.6	4.56	1.564	200.259	1106.229	110622.9	402.8319
OCT	42.2	4.22	1.362	174.430	1106.229	110622.9	350.8753
2006							
JUN	93.8	9.38	5.0512	646.734	1106.229	110622.9	1300.94
JUL	253	25.3	19.418	2486.211	1106.229	110622.9	5001.142
AUG	102.4	10.24	5.752	736.578	1106.229	110622.9	1481.666
SEPT	139	13.9	8.886	1137.822	1106.229	110622.9	2288.788
2007							
JUN	37	3.7	1.071	137.156	1106.229	110622.9	275.8965
SEPT	32.4	3.24	0.833	106.727	1106.229	110622.9	214.6871
OCT	24.6	2.46	0.481	61.632	1106.229	110622.9	123.9775
2008							
JUN	23.4	2.34	0.4337067	55.529	1106.229	110622.9	111.7014
JUL	28	2.8	0.6262991	80.188	1106.229	110622.9	161.3037
AUG	30.6	3.06	0.7462545	95.547	1106.229	110622.9	192.1982

Table 5.5

The peak discharge values on the Jkpur site were calculated from the daily peak rainfall values from 2001-2008.The runoff depth(Q_d) using S.CS-CN method explained in previous sections was first calculated .The area of the site in sqkm obtained through plainimeter was conveted into hectare and then put into the following formulae of peak discharge .The time of concentration was also taken into account.Similarly the discharge values will be computed for Kalyansinghpur in section **5.5.4**

$$\mathbf{Qp=(0.0208*A*Qd)/tp} \qquad \mathbf{(1)}$$

5.5.2 Relationship of Qp with the catchment parameters

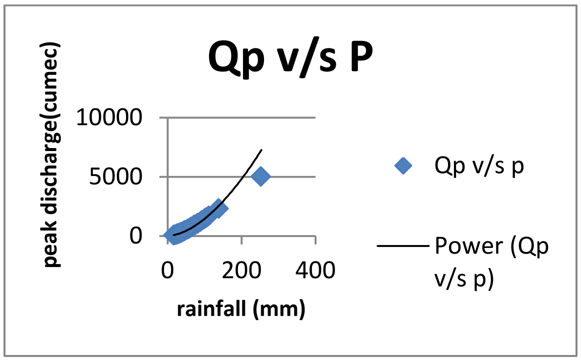


Figure 5.5(a)

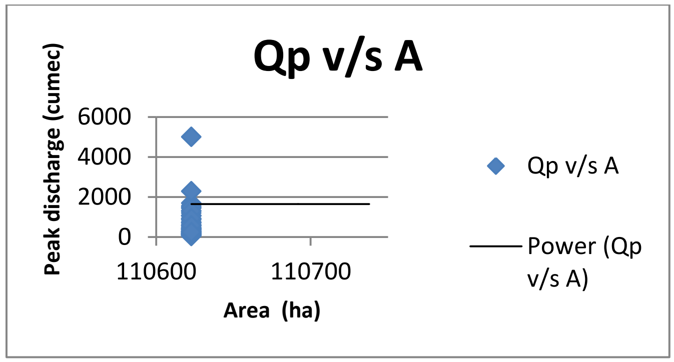


Figure 5.5(b)

Two equations of power function generated are :

$$\text{Qp v/s P - } \mathbf{y = 0.517x^{1.725}} \qquad \text{(i)}$$

x being the independent variable i.e rainfall(mm), y being the dependant variable i.e peak discharge(cumec).

$$\text{Qp v/s A -}\mathbf{y = 11.9x^{0..502}} \qquad \text{(ii)}$$

x being the independent variable i.e area(ha), y being the dependant variable i.e peak discharge(cumec).

Multiplying equations (i) and (ii) we get:

$$\mathbf{Qp^2=(0.516P^{1.726})*(11.9A^{0.502})}$$

$$\text{or}\mathbf{Qp=sqrt((0.51611.9)(P^{1.726}A^{0.502}))}$$

$$\mathbf{Qp =2.472P^{0.863}\ A^{0.251}} \qquad \text{(iii)}$$

Single parameter optimization will be used here ,so the exponents of rainfall and catchment area i.e**x** and **y** respectively and the catchment coefficient **c** will be optimized separately. Following tables shows the optimization of the variables.

jkpur, Qp =peak discharge, area=1106.229sqkm

$t_p=0.6*t_c + (t_c)^{1/2}$

t_p= time to peak (h) and t_c is the time of concentration in (h)

5.6 Optimization

There are various optimization options: Single parameter optimization, Multiple parameter optimization. These options are used to get the optimized values of different hydrologic and hydraulic parameters.For the present study the rainfall intensity and catchment area were used for simulation of flow. Records of observed flows were used to obtain the peak discharge and then compared with the simulated flow as it wasrequired for calibration and validation of the model

5.6.1(a) Jkpur site : for y values

Qp(cumec)	P(mm)			Qp =2.472*P ^ 0.863*A^ y					
		y	0.251	0.281	0.311	0.341	0.5217	**0.5307**	**0.5308**
587.767073	56.8	Qp	22.8667649	32.39814	45.9024037	65.03554435	530.3634	**588.8005**	**589.4847**
		y	0.251	0.281	0.311	0.341	0.5264	**0.5388**	**0.539**
723.275005	64.4	Qp	25.4841772	36.106548	51.1565583	72.47974713	624.2313	**720.9236**	**722.6001**
		y	0.251	0.266	0.281	0.296	0.486	**0.496**	**0.499**
453.63508	48.8	Qp	20.0589603	23.876249	28.4199801	33.82839909	390.4579	**438.5435**	**454.0924**
		y	0.251	0.266	0.281	0.381	0.633	0.6332	**0.6335**
180.086991	29.6	Qp	13.0294733	15.509026	18.4604469	58.96940071	1100.717	1103.277	**1107.127**
		y	0.251	0.301	0.351	0.451	0.531	**0.532**	**0.5321**
608.677893	58	Qp	23.2830822	41.613354	74.3746568	237.5797816	601.6128	**608.6406**	**609.3479**
		y	0.251	0.281	0.311	0.511	0.5652	**0.5653**	**0.5654**
1439.26356	100.4	Qp	37.3850793	52.96801	75.0462523	765.7694155	1437.058	**1438.728**	**1440.4**
		y	0.251	0.281	0.381	0.481	0.501	**0.502**	
306.916781	39.2	Qp	16.6038189	23.524659	75.1463418	240.0448248	302.8093	**306.3466**	
		y	0.251	0.301	0.351	0.451	0.5531	0.5533	**0.5534**
1044.67315	81.2	Qp	31.1278386	55.634119	99.4336701	317.6274102	1039.668	1042.085	**1043.296**
		y	0.251	0.266	0.366	0.466	0.546	0.556	**0.559**
1203.24523	89.06	Qp	33.7115153	40.126931	128.180055	409.4538491	1036.842	1164.531	**1205.82**
		y	0.251	0.301	0.351	0.401	0.543	0.545	**0.546**
857.724256	71.6	Qp	27.9249273	49.909625	89.2024031	159.429545	829.4588	848.9507	**858.8678**
		y	0.251	0.301	0.401	0.501	0.551	0.553	**0.554**
1064.5919	82.2	Qp	31.4583899	56.224907	179.602859	573.7170423	1025.392	1049.489	**1061.748**
		y	0.251	0.301	0.401	0.501	0.531	0.537	**0.538**
694.162908	62.8	Qp	24.9368323	44.569066	142.369854	454.7812435	644.3442	690.8456	**698.9157**
		y	0.251	0.301	0.381	0.481	0.543	0.547	**0.5481**
907.549203	74.2	Qp	28.7978909	51.469854	130.334844	416.3370319	855.3886	896.0636	**907.5844**
		y	0.251	0.301	0.351	0.401	0.411	0.511	**0.571**
1688.0219	112	Qp	41.0660354	73.396446	131.179896	234.4550182	263.3286	841.1675	**1688.547**
		y	0.251	0.301	0.401	0.501	0.511	**0.514**	

Figure 5.6.(a)

yavg =0.549

5.6.1(b) for x values

Qp(cumec)	P(mm)		Qp =2.472*P ^ x*A^ 0.251							
		x	0.863	1.463	2.464	2.664	2.704	2.724	2.73	**2.733**
587.767073	56.8	Qp	22.8667649	64.83562886	368.9066	522.1389	559.7061	579.4914	585.5622	**588.6215**
		x	0.863	1.863	2.463	2.643	2.657	**2.659**	**2.66**	
723.275005	64.4	Qp	25.4841772	164.1181011	501.7507	701.5966	720.1316	**722.8191**	**724.1666**	
		x	0.863	1.863	2.163	2.463	2.563	2.623	2.643	**2.873**
453.63508	48.8	Qp	20.0589603	97.88772626	157.4904	253.3846	296.9081	326.5332	337.0511	**485.3246**
		x	0.863	1.863	2.163	2.863	3.063	3.263	**3.283**	
180.086991	29.6	Qp	13.0294733	38.56724086	53.40797	114.159	141.8302	176.2085	**180.0747**	
		x	0.863	1.263	1.363	1.463	**1.473**	**1.474**		
608.677893	58	Qp	23.2830822	420.0133816	500.7327	596.9648	**607.5514**	**608.6203**		
		x	0.863	1.863	2.263	2.363	2.393	2.423	2.433	**2.446**
1439.26356	100.4	Qp	37.3850793	375.3461965	944.3337	1189.32	1274.532	1365.85	1397.72	**1440.266**
		x	0.863	0.563	0.263	0.163	0.133	**0.123**		
306.916781	39.2	Qp	28.1228576	74.31451145	196.3757	271.4934	299.1993	**309.0493**		
		x	0.863	1.163	1.363	1.393	1.423	1.433	1.435	**1.437**
1044.67315	81.2	Qp	314.017952	588.6013925	894.8134	952.8382	1014.626	1036.099	1040.448	**1044.816**
		x	0.863	1.163	1.363	1.413	1.433	1.436	1.439	**1.441**
1203.24523	89.06	Qp	340.234441	655.6666314	1015.359	1132.671	1183.307	1191.095	1198.935	**1204.19**
		x	0.863	1.863	2.163	2.463	2.563	2.583	**2.603**	
857.724256	71.6	Qp	27.9124245	199.8529594	360.7319	651.116	792.7745	824.6088	**857.7213**	
		x	0.863	1.863	2.063	2.263	2.463	2.493	2.523	**2.535**
1064.5919	82.2	Qp	31.4443051	258.472188	393.902	600.292	914.8227	974.5027	1038.076	**1064.652**
		x	0.863	1.863	2.063	2.263	2.463	2.563	2.663	**2.673**
694.162908	62.8	Qp	24.9256674	156.5331913	226.0468	326.4302	471.392	566.4717	680.7288	**693.352**
		x	0.863	1.863	2.263	2.463	2.563	2.583	2.584	**2.585**
907.549203	74.2	Qp	28.7849973	213.5846801	476.1367	710.9064	868.666	904.1925	906.0065	**907.8241**
		x	0.863	1.863	2.163	2.363	2.383	2.395	2.398	**2.401**
1688.0219	112	Qp	41.0660354	459.939596	949.4371	1539.252	1615.452	1662.971	1675.068	**1687.253**
		x	0.863	1.863	2.163	2.363	2.563	2.763	2.803	**2.883**
402.831905	45.6	Qp	18.9101199	86.23014672	135.9404	184.1372	249.4219	337.8528	358.9931	**405.3249**
		x	0.863	1.863	2.163	2.463	2.493	2.523	2.526	**2.534**
1068.585	82.4	Qp	31.5103195	259.6450328	488.8304	920.3147	980.4245	1044.46	1051.09	**1068.974**
		x	0.863	1.863	2.163	2.463	2.473	2.474	**2.475**	
1300.93957	93.8	Qp	35.2386022	330.5380884	646.9673	1266.319	1294.987	1297.889	**1300.797**	
		x	0.863	1.863	2.163	2.463	2.523	2.583	2.643	**2.647**
748.98638	65.8	Qp	25.9499526	170.7506883	300.4901	528.808	592.0952	662.9566	742.2986	**747.9138**
		x	0.863	1.863	2.063	2.093	2.123	2.125	2.127	**2.132**

xavg= 2.26 **Table 5.6(b)**

So the exponents obtained after optimization of both the x and y is **xavg=2.26,y avg=0.549**.

Putting the values in the equation (iii),we get :

5.6.1(c) for C values **Qp =2.472*P$^{2.26}$*A$^{0.549}$** (iv)

Qp(cumec)	P(mm)	Qp =2.472*P ^ 2.26*A^ 0.549								
		c	2.472	1.972	1.472	0.972	0.272	0.178	**0.176**	
587.767073	56.8	Qp	8239.49669	6572.932	4906.367	3239.802	906.6113	593.2971	**586.6308**	
		c	2.472	1.972	1.472	0.972	0.272	0.182	**0.163**	
723.2750054	64.4	Qp	10943.48143	8729.994	6516.507	4303.019	1204.137	805.7094	**721.5969**	
		c	2.472	1.972	1.472	0.972	0.272	0.202	**0.192**	
453.6350802	48.8	Qp	5846.584658	4664.023	3481.461	2298.9	643.3135	477.7549	**454.1037**	
		c	2.472	1.972	1.472	0.972	0.272	0.243	**0.2372**	
180.086991	29.6	Qp	1888.829304	1506.785	1124.74	742.695	207.8324	185.6738	**181.242**	
		c	2.472	1.972	1.472	0.972	0.243	0.183	**0.174**	
608.6778932	58	Qp	8638.149386	6890.951	5143.752	3396.554	849.1385	639.4747	**608.0251**	
		c	2.472	1.972	1.472	0.972	0.202	0.132	**0.11**	
1439.263563	100.4	Qp	32327.25223	25788.57	19249.88	12711.2	2641.628	1726.212	**1438.51**	
		c	2.472	1.972	1.472	0.672	0.302	0.232	**0.14**	
1044.67315	81.2	Qp	18478.64282	14741.05	11003.46	5023.32	2257.504	1734.242	**1046.525**	
		c	2.472	1.972	1.472	0.672	0.372	0.172	**0.149**	
907.549203	74.2	Qp	15072.53395	12023.88	8975.231	4097.388	2268.197	1048.736	**908.4982**	
		c	2.472	1.972	1.472	0.672	0.372	0.155	0.12	**0.109**
1688.021898	112	Qp	38221.36352	30490.51	22759.65	10390.27	5751.759	2396.566	1855.406	**1685.327**
		c	2.472	1.972	1.472	0.672	0.372	0.292	0.212	**0.198**
402.8319047	45.6	Qp	5015.728143	4001.22	2986.712	1363.499	754.794	592.4727	430.1514	**401.7452**
		c	2.472	1.972	1.472	0.672	0.372	0.072	0.0514	**0.0513**
5001.141781	253	Qp	241060.3722	192302.2	143544	65530.97	36276.08	7021.176	5012.339	**5002.588**
		c	2.472	1.972	1.472	0.672	0.372	0.172	0.118	**0.114**
1554.231892	105.8	Qp	33605.55358	26808.31	20011.07	9135.49	5057.146	2338.25	1604.149	**1549.771**
		c	2.472	1.972	1.472	0.672	0.372	0.172	**0.1186**	
1481.665683	102.4	Qp	30939.25366	24681.31	18423.37	8410.671	4655.907	2152.731	**1484.383**	
		c	2.472	1.972	1.472	0.672	0.372	0.172	**0.091**	
2288.787947	139	Qp	62271.15105	49675.85	37080.56	16928.08	9370.901	4332.782	**2292.344**	
		c	2.472	1.972	1.472	0.672	0.372	0.172	**0.1258**	
1292.639801	93.4	Qp	25354.6363	20226.27	15097.91	6892.522	3815.504	1764.158	**1290.297**	
		c	2.472	1.472	0.472	0.272	0.172	**0.147**		

cavg=0.145 **Table:5.6(c)**

So, final equation after optimization comes out to be:

$$Qp=0.145(P^{2.26})(A^{0.549}) \qquad \textbf{(v)}$$

In above section the equation of peak discharge that was generated by graphical method was optimized by single parameter optimization method which involved method of trials.The exponents x and y of rainfall and catchment area were optimized from their initial values. The average of optimized values for the different peak dischargewas found out as :**xavg= 2.26,y avg= 0.549.**The values were then put in the initial equation i.e**Qp =2.472*P**$^{2.26}$***A**$^{0.549}$andthe optimized value of the catchment coefficient **(c)**was found out as **cavg=0.145**

5.6.2Kalyansinghpur peak discharge

2001	Qd(cm)	Qd (m^3/sec)	A(km^2)	A(ha)	Qp=(0.0208*A*Qd)/tp	P(cm)	P(mm)
jun	13.13	1147.32	754.75	75475	2307.894	18.6	186
jul	5.07	442.66	754.75	75475	890.430	9.4	94
	3.21	280.63	754.75	75475	564.502	7	70
aug	2.94	256.54	754.75	75475	516.052	6.62	66.2
sep	2.50	218.41	754.75	75475	439.348	6	60
2002							
jun	3.07	267.89	754.75	75475	538.874	6.8	68
sep	1.84	160.48	754.75	75475	322.804	5	50
oct	-		754.75	75475		1.2	12
2003							
JUN	1.24	108.01	754.75	75475	217.275	4	40
JUL	1.83	159.86	754.75	75475	321.567	5	50
	2.22	193.93	754.75	75475	390.098	5.6	56
AUG	6.74	588.79	754.75	75475	1184.371	11.42	114.2
SEPT	4.67	407.84	754.75	75475	820.383	8.902	89.02
	2.92	255.42	754.75	75475	513.783	6.602	66.02
OCT	2.64	230.67	754.75	75475	464.000	6.202	62.02
2004							
JUN	10.44	911.72	754.75	75475	1833.979	15.64	156.4
JUL	4.13	361.09	754.75	75475	726.342	8.22	82.2
AUG	5.56	485.58	754.75	75475	976.779	10.004	100.04
SEPT	3.07	268.14	754.75	75475	539.384	6.804	68.04
OCT	3.21	280.76	754.75	75475	564.760	7.002	70.02
2005							
JUN	3.10	270.43	754.75	75475	543.977	6.84	68.4
JUL	2.24	195.84	754.75	75475	393.934	5.62	56.2
	1.43	125.14	754.75	75475	251.734	4.34	43.4
AUG	7.39	645.78	754.75	75475	1299.015	12.1845	121.845
SEPT	5.07	442.94	754.75	75475	890.997	9.404	94.04
	3.44	300.25	754.75	75475	603.976	7.304	73.04
OCT	1.24	108.21	754.75	75475	217.671	4.004	40.04
2006							
JUN	5.00	437.03	754.75	75475	879.104	9.32	93.2
JUL	19.17	1674.69	754.75	75475	3368.717	25.04	250.4
	6.92	604.36	754.75	75475	1215.700	11.63	116.3
AUG	3.92	342.24	754.75	75475	688.427	7.94	79.4
	5.07	442.66	754.75	75475	890.430	9.4	94
	5.34	466.73	754.75	75475	938.858	9.74	97.4
SEPT	1.85	161.58	754.75	75475	325.036	19	190
OCT	13.50	1179.56	754.75	75475	2372.752	2.3	190
2007							
JUN	4.29	374.68	754.75	75475	753.680	8.42	84.2
	3.90	340.90	754.75	75475	685.735	7.92	79.2
JUL	4.62	403.54	754.75	75475	811.741	8.84	88.4
	1.98	172.80	754.75	75475	347.595	5.22	52.2
AUG	8.82	770.15	754.75	75475	1549.189	13.82	138.2
	10.69	933.75	754.75	75475	1878.292	15.92	159.2
	14.47	1263.77	754.75	75475	2542.141	20.04	200.4
SEPT	2.24	195.84	754.75	75475	393.934	5.62	56.2
	1.85	161.58	754.75	75475	325.036	5.02	50.2
2008							
JUN	1.36	119.01	754.75	75475	239.393	4.22	42.2
JUL	1.42	124.12	754.75	75475	249.664	4.32	43.2
AUG	4.15	362.44	754.75	75475	729.067	8.24	82.4
	4.13	361.09	754.75	75475	726.342	8.22	82.2
SEPT	4.54	396.63	754.75	75475	797.839	8.74	87.4

Table 5.6(d)

Following graphs represent variation of peak discharge with rainfall and area.

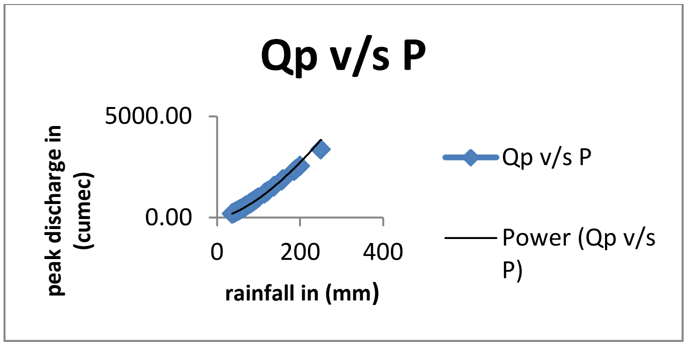


Figure:5.6(a)

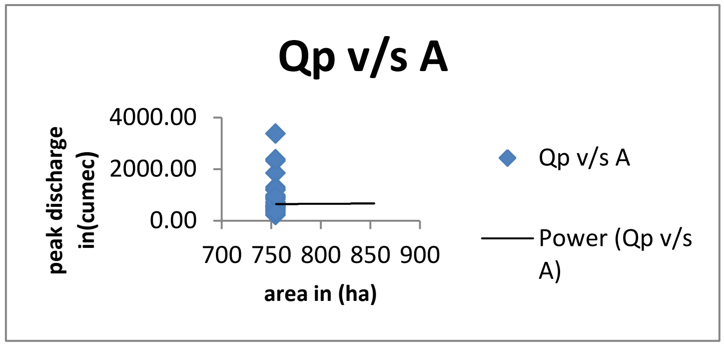


Figure:5.6(b)

Two equations of power function generated are :

Qp v/s P (i)

x being the independent variable i.e rainfall(mm), y being the dependant variable i.e peak discharge(cumec).

Qp v/s A (ii)

x being the independent variable i.e area(ha), y being the dependant variable i.e peak discharge(cumec).

Multiplying equations (i) and (ii) we get:

$$\mathbf{Qp^2 = 7.78(A^{0.476})(P^{1.522})}$$

$$\text{or}\,\mathbf{Qp = 2.79(A^{0.238})(P^{0.776})}$$

$$\mathbf{Qp = 2.79 * P^{0.776} * A^{0.238}} \quad \text{(iii)}$$

5.6.3(a)Kalyansinghpur site :x values

Qp(cumec)	P(mm)	**Qp =2.79*P ^{x} *A $^{0.238}$**								
		x	0.776	1.776	1.876	1.976	2.006	2.036	**2.0362**	
2307.89	186	Qp	57.97155684	1078.27096	1444.3725	1934.775132	2112.10685	2305.692	**2307.04**	
		x	0.776	1.776	2.076	2.176	2.23	**2.232**		
890.43	94	Qp	34.13658978	320.883944	628.47259	786.3196492	887.4584571	**891.4445**		
		x	0.776	1.776	2.076	2.176	2.276	2.306	**2.336**	
564.50	70	Qp	27.15619996	190.0934	340.79754	414.0056366	502.9398616	533.174	**565.2258**	
		x	0.776	1.776	2.276	2.376	2.386	**2.396**		
439.35	60	Qp	24.09452057	144.567123	354.11569	423.6042316	431.2626054	**439.0594**		
		x	0.776	1.776	2.076	2.376	**2.476**			
322.80	50	Qp	20.91575964	104.578798	169.48632	274.6791212	**322.643299**			
		x	0.776	1.776	2.276	2.376	2.476	2.576	**2.586**	
217.27	40	Qp	17.59022814	70.3609126	140.72183	161.646929	185.6835615	213.2944	**216.2719**	
		x	0.776	1.776	2.076	2.106	2.136	2.166	**2.17**	
1184.37	114.2	Qp	39.70286212	453.406685	941.42939	1012.786103	1089.551384	1172.135	**1183.609**	
		x	0.776	1.776	2.076	2.176	2.236	2.246	2.249	**2.25**
820.38	89.02	Qp	32.72467097	291.315021	561.31824	698.4863358	796.3925158	813.9956	819.352	**821.1453**
		x	0.776	1.776	2.076	2.079	**2.081**			
1833.98	156.4	Qp	50.68083124	792.749562	1808.9381	1823.923304	**1833.982371**			
		x	0.776	1.776	2.076	2.176	**2.276**			
726.34	82.2	Qp	30.76192077	252.862989	475.71496	587.2648316	**724.9719034**			
		x	0.776	1.776	2.076	2.106	2.136	2.166	2.207	**2.208**
976.78	100.04	Qp	35.9267788	360.704859	720.56325	772.1899021	827.5154853	886.805	974.7634	**977.0144**
		x	0.776	1.776	2.076	2.106	2.136	2.146	2.148	**2.151**
1299.01	121.845	Qp	41.73834405	508.373031	1076.1596	1159.968266	1250.30373	1281.953	1288.378	**1298.076**
		x	0.776	1.776	1.876	1.936	1.956	**1.966**		
3368.72	250.4	Qp	73.01517908	1828.30008	2522.9632	3060.757844	3264.387135	**3371.227**		
		x	0.776	1.776	2.076	2.106	2.136	2.156	2.159	**2.165**
1215.70	116.3	Qp	40.26825198	468.31977	977.72429	1052.40717	1132.794651	1189.769	1198.559	**1216.334**
		x	0.776	1.776	2.076	2.176	2.276	2.286	**2.289**	
688.43	79.4	Qp	29.94564203	237.768398	442.69058	544.6058877	669.9839245	684.0102	**688.2751**	
		x	0.776	1.776	1.876	**1.926**				
325.04	50.2	Qp	20.98065312	237.768398	292.50694	**324.4346316**				
		x	0.776	1.776	1.976	1.996	2.016	2.026	**2.031**	
2372.75	190	Qp	58.93668618	1119.79704	2017.8554	2140.25296	2270.074856	2337.91	**2372.583**	
		x	0.776	1.776	2.076	2.086	2.096	2.106	**2.116**	
1549.19	138.2	Qp	46.03701539	636.231553	1398.8386	1436.060367	1474.272542	1513.502	**1553.774**	
		x	0.776	1.776	1.976	1.996	2.036	2.076	**2.077**	
1878.29	159.2	Qp	51.37841899	817.94443	1422.697	1503.665632	1679.689456	1876.319	**1881.519**	
		x	0.776	1.776	1.876	1.976	2.006	2.016	**2.018**	

xavg=2.29

Table:5.6(e)

5.6.3(b) Kalyansinghpur site: y values

Qp(cumec)	P(mm)		Qp=2.79*(P^0.776)*(A^y)							
		y	0.238	0.338	0.438	0.538	0.558	0.561	0.564	**0.566**
2307.89	186	Qp	57.97155684	178.235938	547.99373	1684.829275	2109.171831	2181.451	2256.206	**2307.461**
		y	0.238	0.338	0.438	0.478	0.518	0.528	**0.5285**	
890.43	94	Qp	34.13658978	104.954351	322.68647	505.6999172	792.510468	886.7129	**891.7065**	
		y	0.238	0.338	0.438	0.478	0.498	**0.508**		
564.50	70	Qp	27.15619996	83.4928547	256.70222	402.292325	503.6140174	**563.4765**		
		y	0.238	0.338	0.438	0.478	0.488	0.493	0.495	**0.497**
439.35	60	Qp	24.09452057	74.0795953	227.76077	356.9365638	399.3641435	422.4332	432.0298	**441.8443**
		y	0.238	0.338	0.438	0.458	0.46	**0.462**		
217.27	40	Qp	17.59022814	54.0818805	166.27697	208.1556286	212.8843644	**217.7205**		
		y	0.238	0.338	0.438	0.538	0.54	0.5403		
1184.37	114.2	Qp	39.70286212	122.068084	375.30335	1153.885596	1180.098772	1184.082		
		y	0.238	0.338	0.438	0.468	0.498	0.499	0.5	**0.525**
820.38	89.02	Qp	32.72467097	100.613348	309.33988	433.2813608	606.8817816	613.7364	620.6685	**821.8731**
		y	0.238	0.338	0.538	0.548	0.554	0.557	0.5572	**0.5576**
1833.98	156.4	Qp	50.67580262	155.804841	1472.7925	1647.857313	1762.732543	1823.139	1827.239	**1835.467**
		y	0.238	0.338	0.438	0.478	0.518	0.5184	0.5188	**0.5194**
726.34	82.2	Qp	30.76192077	94.5787917	290.78639	455.7075234	714.164607	717.3803	720.6105	**725.483**
		y	0.238	0.338	0.438	0.478	0.518	0.521	0.525	**0.532**
976.78	100.04	Qp	35.9267788	110.45836	339.60878	532.2198022	834.0712549	862.6538	902.2934	**976.0957**
		y	0.238	0.338	0.438	0.468	**0.469**			
251.73	43.4	Qp	18.73979989	57.6162862	177.14364	248.1187971	**250.921266**			
		y	0.238	0.338	0.438	0.478	0.518	0.528	0.531	**0.544**
1299.01	121.845	Qp	41.73834405	128.326257	394.54436	618.3124109	968.9917705	1084.172	1121.325	**1297.606**
		y	0.238	0.338	0.438	0.538	0.568	0.578	**0.579**	
3368.72	250.4	Qp	73.01517908	224.488174	690.19813	2122.042566	2972.269499	3325.571	**3363.133**	
		y	0.238	0.338	0.438	0.538	0.541	0.5412	0.5413	**0.5414**
1215.70	116.3	Qp	40.26825198	123.806398	380.64787	1170.31754	1210.422877	1213.145	1214.508	**1215.873**
		y	0.238	0.338	0.438	0.538	0.548	0.558	0.561	**0.567**
2372.75	190	Qp	58.93668618	181.203268	557.11691	1712.878861	1916.481719	2144.286	2217.768	**2372.373**
		y	0.238	0.338	0.438	0.538	0.548	0.551	**0.5511**	
1549.19	138.2	Qp	46.03701539	141.542699	435.17885	1337.975302	1497.014917	1548.316	**1550.056**	
		y	0.238	0.338	0.438	0.538	0.548	0.558	0.5581	**0.5585**
1878.29	159.2	Qp	51.37841899	157.965064	485.67009	1493.212692	1670.704736	1869.295	1871.395	**1879.822**

yavg=0.55 7

Table:5.6(f)

5.6.3(c) Kalyansinghpur site: C values

Qp(cumec)	P(mm)		Qp=c*(A^0.625)*(P^2.29)					
		c	2.7	2.2	0.7	0.2	0.1	**0.049**
2307.89	186	Qp	174291.720	103632.915	32974.10	9421.17408	4710.58704	**2308.188**
		c	2.7	2.2	0.7	0.2	0.16	**0.124**
890.43	94	Qp	36522.0292	21715.8012	6909.5731	1974.163741	987.0818705	**888.3737**
		c	2.7	2.2	0.7	0.2	0.12	**0.11**
564.50	70	Qp	18593.73454	11055.7341	3517.7336	1005.066732	603.0400392	552.7867
		c	2.7	2.2	0.7	0.2	0.14	**0.125**
439.35	60	Qp	13063.46777	7767.46732	2471.4669	706.1333929	494.29337	**441.333**
		c	3.7	2.2	0.7	0.2	**0.15**	
217.27	40	Qp	5161.898907	3069.23719	976.57547	279.0215625	**209.2661719**	
		c		2.2	0.7	0.2	0.14	**0.115**
820.38	89.02	Qp	32225.17095	19160.9125	6096.654	1741.901133	870.9505663	**827.403**
		c	2.7	2.2	0.7	0.2	0.1	**0.95792**
1833.98	156.4	Qp	117191.0025	69681.1366	22171.271	6334.648782	3167.324391	**1834.514**
		c	2.7	2.2	0.7	0.2	**0.1**	
726.34	82.2	Qp	26862.63288	15972.3763	5082.1197	1452.03421	**726.017105**	
		c	2.7	2.2	0.7	0.2	0.1	**0.085**
976.78	100.04	Qp	42468.04971	25251.2728	8034.4959	2295.570255	1147.785127	**975.6174**
		c	2.7	2.2	0.7	0.2	**0.15**	
251.73	43.4	Qp	6222.194682	3699.68332	1177.172	336.3348477	**252.2511357**	
		c	2.7	2.2	0.7	0.2	0.17	**0.131**
1299.01	121.845	Qp	66103.49241	39304.7793	12506.066	3573.161752	1786.580876	**1268.472**
		c	2.7	2.2	0.7	0.2	0.15	**0.136**
3368.72	250.4	Qp	344321.9569	204731.974	65141.992	18611.99767	9305.998835	**3350.16**
		c	2.7	2.2	0.7	0.2	0.1	**0.076**
1215.70	116.3	Qp	59466.12801	35358.2383	11250.349	3214.385298	1607.192649	**1221.466**
		c	2.7	2.2	0.7	0.2	0.1	**0.05**
2372.75	190	Qp	182994.4258	108807.496	34620.567	9891.590584	4945.795292	**2472.898**
		c	2.7	2.2	0.7	0.2	0.1	**0.07**
1549.19	138.2	Qp	88278.61955	52489.99	16701.36	4771.817273	2385.908636	**1670.136**
		c	3.7	2.2	0.7	0.2	0.1	**0.057**
1878.29	159.2	Qp	122051.109	72570.9297	23090.75	6597.357243	3298.678621	**1880.247**
		c	2.7	2.2	0.7	0.2	0.1	**0.046**

c avg=0.129 **Table:5.6(g)**

So, final equation after optimization comes out to be:

$$\mathbf{Qp=0.129(P^{2.29})\ (A^{0.557})} \qquad \textbf{(iv)}$$

In above section(5.6.2)the equation of peak discharge that was generated by graphical method was optimized by single parameter optimization method which involved method of trials.The exponents x and y of rainfall and catchment area were optimized from their initial values. The average of optimized values for the different peak dischargewas found out as :**xavg= 2.29,y avg= 0.557.**The values were then put in the initial equation i.e **$Qp = 2.79*P^{2.29}*A^{0.557}$**andthe optimized value of the catchment coefficient **(c)**was found out as **cavg=0.129.**

CHAPTER 6
CONCLUSIONS

The present work can be summarized in the following way:

The concerned study area for the present work is a gauged drainage basin Lower Nagavalli in Rayagada district-Odisha. After obtaining the D.E.M and extracting data from the model, SCS-CN model was used .

The model used its own set of parameters as their input and discharge in the form of runoff depth was predicted. The values were then validated with the observed discharges. The process was followed for both monthly and daily rainfall analysis.Standard error of estimate was also computed to understand the correlation between observed and computed values. The runoff values obtained by the S.C.S curve number method were used to compute the peak discharge and an empirical relationship was established between peak discharge with rainfall intensity and catchment area in the form of a power function and runoff coefficient C was estimated.

- ❖ The present work on SCS CN justifies the principle theories that both the curve number (CN) and hydrological soil group(H.S.G) play a major role in determining the runoff potential in an area. Higher values of Curve Number and H.S.G with low infiltration value for a given AMC type gives higher values of runoff.
- ❖ A comparison between error estimate values for same set of rainfall values between different initial abstraction values :i.eIa=0.2S .0.05S and 0.3S reveals that the error values are lower for Ia=0.2S and Ia=0.3S than that of Ia=0.05S.This is due to the reason that higher abstraction looses results in lower runoff values and thus higher errors.
- ❖ Daily rainfall analysis for runoff computation using SCS-CN method gives greater accuracy than monthly analysis

- The maps delineated using ILWIS shows that the basin has a hilly topography; Morethan 60% of the basin is covered with forests. Elevation of the basin varies from 251 m mean sea level to 1500 m mean sea level.

- The SCS-CN model facilitates runoff estimation and improves the accuracy of estimated data. Fairly comparable values are found between observed and computed values indicating a fair correlation. Proper calibration of data is highly important for S.C.S-CN method. It is highly essential to assign Curve Number based on H.S.G, land cover and A.M.C conditions judiciously,because chances of errors are very high.
- .Use of landsat and land cover maps along with temperature information is important as it Curve number values are dependant on it.
- Standard estimate of errors shows that lower the value of error, more closed spaced the points will be ,whereas higher the value of error, more dispersed the points will be.

- The runoff coefficient obtained from the empirical model was found to be in the range of **0.129-0.145** for the whole catchment site.The variables x and y were in2.26-2.29 and 0.549-0.557 respectively

CHAPTER 7
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APPENDIX-I

Table 1: AMC for determining the value of CN (Source: Engineering Hydrology)

Antecedent condition	Description	Growing Season 5 day Antecedent Rainfall	Dormant Season 5day Antecedent Rainfall
Dry AMC -I	An optimum condition where soils are dry but not to the wilting point and when satisfactory plowing and cultivation takes place.	Less than 1.4 in or 35mm	Less than 0.05 in or 12 mm
Average AMC-II	Average case	1.4.in to 2 in. Or 35 to 53mm	0.5 in. to 1 in. 12 to 28mm
Wet AMC-III	Heavy or light rainfall has occurred for 5 days previous to a given storm	Over 2 in. or 53 mm	Over 1 in. or 28 mm

Table 2: Runoff Curve numbers for hydrologic soil cover complexes under AMCII (Source: Engineering Hydrology)

APPENDIX-II

Land Use Descrition	Treatment	Hydrologic condition	Hydrologic Soil Group			
			A	B	C	D
Fallow	Straight row	-	77	86	91	94
Row crop	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Cont.& terraced	Poor	66	74	80	82
	Cont.& terraced	Good	62	71	78	81
Small grains	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Cont.& terraced	Poor	61	72	83	82
	Cont.& terraced	Good	59	70	78	81
Close-seeded Legumes or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	81
	Cont.& terraced	Poor	63	73	80	83
	Cont.& terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	26	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Forests		-	56	75	86	91
Farmsteads		-	59	74	82	86
Roads (dirt)		-	72	82	87	89
(hard surface)			74	84	90	92
Commercial & business Area		-	89	92	94	95
		-	81	88	91	93
Industrial Area		-	77	85	90	92
Residental Area		-	57	71	86	86

)

APPENDIX-II

Table 3: Runoff Curve numbers for hydrologic soil cover complexes under AMCII (Source: Engineering Hydrology

Cover description: Cover type and hydrologic condition	Average percent impervious area [2]	Curve numbers for hydrologic soil group: A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.
2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.