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ESTIMATION OF SURFACE RUNOFF USING GEOSPATIAL TECHNOLOGY KOMBAI MICRO WATERSHED – A CASE STUDY

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ABSTRACT

Geospatial technology is being widely used for the assessment of natural resources. The present paper deals with the usage of geospatial technology for the estimation of surface runoff on a watershed basis. The Kombai micro watershed of Vaigai basin covers 64.08 Sq.Km. The assessment of surface runoff is much necessary before taking up any kind of conservation measures. The Soil Conservation Services (SCS) method has been employed to assess the surface runoff from the micro watershed. The remote sensing data products has been used to prepare the land use and soil layers. The GIS has been used to integrate the thematic layers to estimate the surface runoff based on CN values.

KEYWORDS : Surface water, Watershed, Geospatial technology,

I. INTRODUCTION

The sustainable development has been defined by the World Commission of Environment and Development in 1987 as "*development that meets the need of the present without compromising the ability of the feature generations to meet their needs"* (Pantulu 1996)

Water in its natural hydrological cycle is tapped for human activities from both the surface water and groundwater segments. The ultimate source for all the water is precipitation.

The surface and groundwater are in full form during the monsoon and post monsoon periods and goes on depleting with time due to over exploitation for multifaceted activities. In India the replenishment takes place only during the monsoon and after the monsoon period the stress on the water resources, both on surface and groundwater, is very high. The availability is very low and the demand is high. With the above in mind the sustainability of water resource in particular surface and groundwater has to be analysed on watershed basis using geospatial technology and suggest measures for replenishment.

METHODS OF ACHIEVING SUSTAINABILITY

The sustainability can be achieved by enforcing a strong and effective monitoring network. An integrated water management system on watershed basis is necessary to attain the sustainability.

Some of the scientific measures to ensure the sustainability are:

- Proper assessment of surface runoff on watershed basis
- Delineation of surplus and deficit watershed with respect to surface water.
- Inducing some artificial recharge measures in scientifically identified location.
- Geospatial technology such as, Remote sensing, Geographical Information System and Global Positioning system can be employed to achieve the above.

In the present paper a micro watershed has been taken up to estimate the surface water runoff, using geospatial technology. Kombai micro watershed lies in Vaigai basin. It lies between latitude of 9°43' – 9°53" and longitude of 77°12" – 77°18". Kombai micro watershed comprises of Uthamapalayam block of Theni district. The aerial extent of the watershed is 64.08 Sq.Km. Of which 46.65 Sq.Km in plains and 17.43 Sq.Km in hills (Figure-1)

The main objectives of the study is

- To assess surface water runoff from the micro watershed using SCS Method.

II. METHODOLOGY

To achieve the above objective the following methodology has been adopted.

- Demarcation of micro watershed from 1:50000 SOI topo sheet.
- Digitization of micro watershed boundary and other cultural features.
- Digitization of streams according to the stream order.
- Preparation of Land use and Soil map from IRS 1D digital satellite data Using ERDAS Image processing software.

- Collection and compilation of daily rainfall data.
- Calculation and integration of Land use, Soil map to obtain CN value use ArcGIS software.
- Estimation of surface runoff for daily, monthly and yearly runoff based on Soil Conservation Services (SCS) method.

The River Suthagangai odai originates from Kambam valley reserved forest area. The drainage pattern of the micro watershed is parallel to sub-parallel and dendritic. Based on Strahler method the drainage morphometric has been done. The drainage map and the stream order are presented in Figure -2

The micro watershed is formed of the Archean crystalline metamorphic complex. The rock types have experienced recurring tectonic and magmatic activities in the Precambrian period, which resulted in the complicated structure and geology. The rock types in the watershed include Granite, Charnockite Garnet biotite gneiss and recent alluvium.

Geomorphology map has been prepared from IRS 1D LISS III digital satellite data using ERDAS Image processing software by hybrid interpretation techniques. Geomorphologically the watershed is comprises of Structural hill, residual hill, linear ridges, shallow pediment, buried pediment, pediment inselberg, bazada, and valley fill. The lineaments act as conduits for groundwater movement. The lineament has been depicted from satellite data.

Slope is one of the important topographical features for determining the infiltration rate and runoff. Based on Ian Galbraith (1983) method, the slope has been prepared. The slope elucidates the slope variations in the micro watershed. The digital elevation model is presented in Figure - 5

The micro watershed is covered by four hydrologic soil group such as, A,B,C,D. The soil series includes Palaviduthi, Vylogam, Somayanur and Forest humic. The different soil series and the area of coverage by different soil series are presented in Figure-3

The land use map has been prepared form IRS 1D LISS III digital satellite data. The land use pattern of the micro watershed is presented in Figure-4. Nearly 25 percentage of the area is covered by dry forming.

The occurrence of ground water is restricted to weathered and fractured zone. Detailed geophysical survey and well inventory have been taken up in the micro watershed. The data reveals that the top soil varies from 4 to 8m weathering thickness varies from 7m to greater than 22m and the fractured zone varies from 8 to 18 m. The weathering thickness ranging from 7 to 12m is predominant in the micro watershed. The depth of the dug wells varies form 10 to 25m BGL and the depth of the bore wells varies from 40 to 120m.

Depth to water level data has been collected for pre and post monsoon seasons in selected wells. The pre monsoon water level varies from 5.5 m to 8.5 m and the post monsoon water level ranges from 3.5 m to 8.5 m. In some places, the water level depleted is below weathered zone.

Groundwater samples from selected number of wells have been collected and tested for physical and chemical quality of water. The quality parameters such as, total dissolved solids, SAR, and sodium percentage have been taken up for the analysis. The quality of groundwater in the study area is generally good.

The nearest raingauge station of the study area is Uthamapalayam. The normal annual rainfall in the micro watershed is 790 mm. The 50 years normal rainfall indicates that the major contribution of rainfall is during north east monsoon, which is 44 % of the total normal rainfall. Daily rainfall data collected from the above rain gauge station have been taken for the analysis and for runoff estimation.

Runoff is one of the most important hydrologic parameter used in most of the water resources applications. The predication of quantity and rate of runoff from the land to the streams is very difficult and it requires more time for ungauged watershed.

Rainfall, if it is not intercepted by vegetation of by artificial surfaces such as roofs or pavements, falls on the earth and either evaporates, infiltrates or lies in depression storage. When the loss arising in these ways are all provided for, there may remain a surplus that, obeying the gravitation laws, flows over the surface to the nearest stream channel. The streams coalesce into rivers and the rivers find their way down to sea.

Runoff may consist of surface runoff, subsurface runoff and groundwater runoff. Surface runoff is that part of runoff which travels over the ground surface and through channels into the basin outlet.

Subsurface runoff (Interflow) is that part of precipitation which infiltrates the surface soil and moves laterally through the upper soil horizons towards the streams.

Groundwater runoff is a portion of groundwater discharged into the streams.

The surface runoff assessment is very essential to quantify the water that flows out of the watershed. A portion of the surplus flow can be used for conservation with in the watershed.

The conventional methods of predication of runoff requires considerable amount of hydrological and meteorological data. The Remote sensing and GIS can help to a great extent in runoff assessment. Though there are number of methods are available to assess the runoff from a watershed, The Soil Conservation Services (SCS) method has been dealt elaborately, since it is reliable and more accurate than the other methods.

The most generally available data in India are the amounts measured by non-recording rain gauges and for such data, Rainfall-runoff relationship was developed.

Rainfall - runoff relationship, in general form, is given as

$$\ldots = (p-Ia)^2/((p-Ia) + S)$$

Where … = actual runoff, P = the rainfall S = potential retention and Ia = initial abstraction during the period between the period of beginning of rainfall and runoff in equivalent depth over the Catchment.

The effect of runoff is based on the antecedent soil moisture condition. The Soil Conservation Services has formulated three antecedent soil moisture conditions viz. AMC I, AMC II and AMC III before estimating runoff for a particular rainfall event the curve numbers have to be adjusted according to the season and total 5-day antecedent rainfall.

ANTECEDENT MOISTURE CONDITION (AMC)

AMC	5 days antecedent rainfall in cm	
	Dormant season	Growing season
I	Less than 1.25	Less than 3.5
II	1.25 to 2.75	3.5 to 5.25
III	Over 2.75	Over 5.25

CONDITION OF REGION

Black soil region AMC II and III $Ia = 0.1S$
Black soil region AMC I $Ia = 0.3S$
All other regions $Ia = 0.3S$

The S values are derived from the Curve Number (CN) values

$$CN = 25400/(254+S)$$
$$S = (25400/CN) - 254$$

Using the above equations developed are

$$\ldots=(P-0.3S)^2/(P+0.7S)$$ _.for all soil regions
$$\ldots=(P-0.1S)^2/(P+0.9S)$$ _.for black soil regions

Runoff curve number for hydrologic soil cover complex

The Land use pattern of the watershed and the hydrological soil group has to be considered to estimate the Curve number (CN value). The modified curve numbers for AMC-II are given below in Table - 1. The AMC I & AMC III have to be taken from the table for the runoff curve number AMC II.

Table-1. Modified curve numbers for AMC - II

Land use cover	Treatment of Practice	Hydrologic condition	Hydrologic soil group			
			A	B	C	D
Fallow	Straight row	-	77	86	91	94
Cultivated	Straight row	Poor	72	81	88	81
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Contoured and terraced	Poor	66	74	80	82
	Contoured and terraced	Good	62	71	78	81
Small Grain	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
	Contoured and terraced	Poor	61	72	79	82
	Contoured and terraced	Good	59	70	78	81
Closed seeded	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	83
	Contoured and terraced	Poor	63	73	80	83
	Contoured and terraced	Good	51	67	76	80
Pasture		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80

The land use / land cover map has been prepared from IRS 1C LISS III, digital satellite data has been prepared and the area of each land use unit has been calculated and presented in Figure -4

The soil map has been prepared from the satellite data and from the existing soil map of the micro watershed. The soil map and the area of each hydrological soil group is presented in Figure-3

The land use and soil map have been integrated using ArcGIS software and the integrated land use / soil attribute table has been used for the computation of total area weighted curve number of the micro watershed (for AMC II) and from the above table the curve numbers for AMC I and AMC III conditions have been computed. (Figure-5)

Table-2. Computation of Weighted curve number of Kombai watershed

Sl.No	Landuse	Soil Type	Area in Sq.Km	CN	% Area	% Area X CN	Weighted CN of Study Area
1	Built up land	A	0.76	96	1.19	113.86	AMC-II = 76.32 AMC-I = 57.64 AMC-III = 88.68
2	Dry farming	A	12.41	95	19.37	1839.81	
3		B	1.78	85	2.78	236.11	
4		C	0.35	91	0.55	49.70	
5		D	0.01	95	0.02	1.48	
6	Hills / Barren rocks	A	0.25	77	0.39	30.04	
7		B	0.18	86	0.28	24.16	
8		C	0.52	91	0.81	73.85	
9		D	1.04	93	1.62	150.94	
10	Irrigated farming	A	9.90	92	15.45	1421.35	
11		B	0.51	94	0.80	74.81	
12		C	0.06	95	0.09	8.90	
13	Land with scrub	A	1.31	33	2.04	67.46	
14		B	4.53	47	7.07	332.26	
15		C	0.52	64	0.81	51.94	
16	Less erosion	A	0.93	71	1.45	103.04	
17		B	3.74	80	5.84	466.92	
18		C	0.01	85	0.02	1.33	
19	Severe erosion	A	1.82	68	2.84	193.13	
20		B	5.86	71	9.14	649.28	
21		C	0.19	78	0.30	23.13	
22		D	0.04	84	0.06	5.24	

The daily rainfall data of Uthamapalayam rain gauge station has been collected for the year 1990 and 2004 and the weighted curve number of the micro watershed has been given as input for the calculation of daily runoff. The daily runoff of the micro watershed for the year 1990 and 2004 is presented as tables (Table 1&2). The monthly runoff is presented below.

Table-3. Monthly Runoff Estimation for the year 1990 & 2004

Month	1990			2004		
	Rainfall in mm	Runoff in mm	Runoff in MCM	Rainfall in mm	Runoff in mm	Runoff in MCM
January				102.40	70.52	4.52
February						
March				30.70	2.54	0.16
April						
May	170.00	84.85	5.44	36.00		
June	110.00	71.79	4.60			
July	20.00			42.80	2.30	0.15
August				75.80	26.65	1.71
September	230.00	29.27	1.88	184.60	66.27	4.25
October	158.00	2.75	0.18	127.60	21.81	1.40
November	130.00	14.56	0.93	84.60	2.62	0.17
December	4.00			14.60		
Total	822.00	203.22	13.02	699.10	192.71	12.35

The runoff estimation using SCS method reveals that there is sufficient runoff potential is available in the Kombai micro watershed. A portion of the runoff can be used for conservation measures in the micro watershed for sustainable groundwater development.

III. CONCLUSION

- As far as the Kombai micro watershed is concerned, the surface water runoff is considerably good and the groundwater resources is very less (Over exploited), which requires more attention to improve the groundwater resources.
- Conclusively, the integrated watershed approach is essential for assessing the surface runoff, groundwater potential and for identifying artificial recharge potential zones.

Fig .1 Kombai Watershed Base map

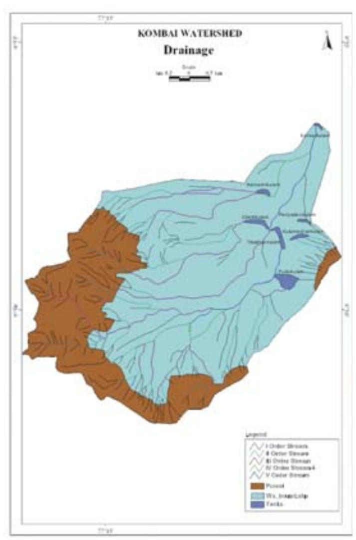

Fig .2 Kombai Watershed Drainage

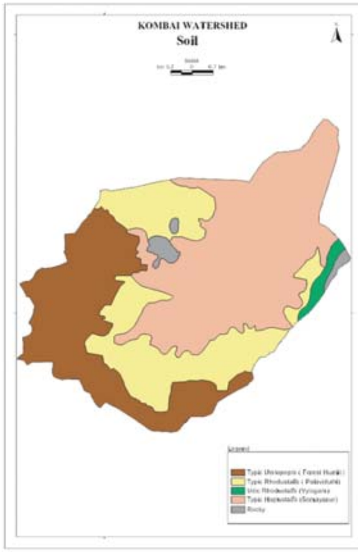

Fig .3 Kombai Watershed Soil

Table-4. Area Coverage

Soil	Area in Sq.Km	Area in Ha
Rocky	1.09	109
Typic Haplustalfs	27.96	2796
Typic Rhodustalfs	16.74	1674
Typic Urstopepts	17.43	1743
Udic Rhodustalfs	0.86	86
Total	**64.08**	**6408**

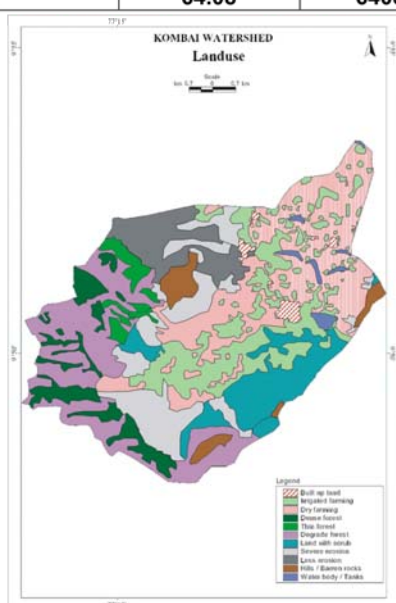

Fig .4 Kombai Watershed Landuse

Table-5. Area Covered for different landuse pattern

Land use	Area in Sq.Km	Area in Ha	Area %
Built up land	0.77	77	1.20
Degrade forest	10.92	1092	17.04
Dense forest	4.16	416	6.49
Dry farming	14.51	1451	22.64
Hills / Barren rocks	1.98	198	3.09
Irrigated farming	10.43	1043	16.28
Land with scrub	6.40	640	9.99
Less erosion	4.62	462	7.21
Severe erosion	7.92	792	12.36
Thin forest	1.72	172	2.68
Water body / Tanks	0.65	65	1.01
Total	**64.08**	**6408**	

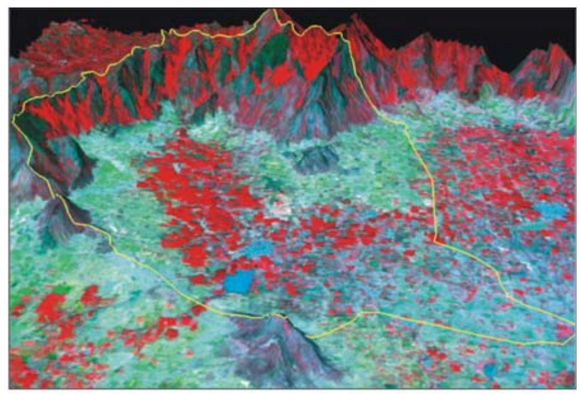

Fig .5 – Digital terrain model of Kombai micro watershed

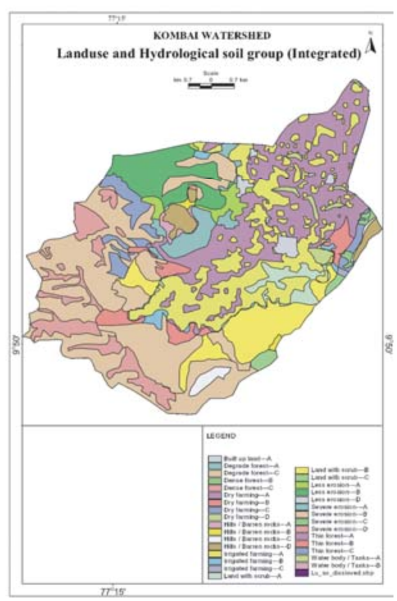

Fig . 6 Kombai Watershed Landuse and Hydrological soil group (Integrated)

Table-1. Kombai Watershed - Estimation of daily runoff for the year 1990

Kombai watershed - Estimation of daily runoff for the year 1990

Day-Month	01-Jan	02-Jan	03-Jan	04-Jan	05-Jan	06-Jan	07-Jan	08-Jan	09-Jan	10-Jan	11-Jan	12-Jan	13-Jan	14-Jan	15-Jan	16-Jan	17-Jan	18-Jan	19-Jan	20-Jan	21-Jan	22-Jan	23-Jan	24-Jan	25-Jan	26-Jan	27-Jan	28-Jan	29-Jan	30-Jan	31-Jan	Monthly Rainfall mm	Monthly Runoff mm
Rainfall in mm							81.40	14.40	6.60																								
5-Day Rainfall mm							81.40	95.80	102.40	102.40	102.40	21.00	6.60																				
CN	73.60	73.60	73.60	73.60	73.60	73.60	94.90	94.90	94.90	94.90	94.90	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60		
S	91.11	91.11	91.11	91.11	91.11	91.11	13.65	13.65	13.65	13.65	13.65	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11		
Daily Runoff mm							65.70	4.43	0.39																							102.40	70.52
Day-Month	01-Feb	02-Feb	03-Feb	04-Feb	05-Feb	06-Feb	07-Feb	08-Feb	09-Feb	10-Feb	11-Feb	12-Feb	13-Feb	14-Feb	15-Feb	16-Feb	17-Feb	18-Feb	19-Feb	20-Feb	21-Feb	22-Feb	23-Feb	24-Feb	25-Feb	26-Feb	27-Feb	28-Feb					
Rainfall in mm																																	
5-Day Rainfall mm																																	
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60					
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11					
Daily Runoff mm																																	
Day-Month	01-Mar	02-Mar	03-Mar	04-Mar	05-Mar	06-Mar	07-Mar	08-Mar	09-Mar	10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar		
Rainfall in mm											22.20					8.50																	
5-Day Rainfall mm											22.20	22.20	22.20	22.20	22.20	8.50	8.50	8.50	8.50	8.50													
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	87.25	87.25	87.25	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60		
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	37.12	37.12	37.12	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11		
Daily Runoff mm											2.54																					30.70	2.54
Day-Month	01-Apr	02-Apr	03-Apr	04-Apr	05-Apr	06-Apr	07-Apr	08-Apr	09-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr			
Rainfall in mm																																	
5-Day Rainfall mm																																	
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60			
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11			
Daily Runoff mm																																	
Day-Month	01-May	02-May	03-May	04-May	05-May	06-May	07-May	08-May	09-May	10-May	11-May	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May		
Rainfall in mm							6.00																	24.20	2.60		3.20						
5-Day Rainfall mm							6.00	6.00	6.00	6.00	6.00													24.20	26.80	26.80	30.00	30.00	5.80	3.20	3.20		
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60		
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11		
Daily Runoff mm																																36.00	
Day-Month	01-Jun	02-Jun	03-Jun	04-Jun	05-Jun	06-Jun	07-Jun	08-Jun	09-Jun	10-Jun	11-Jun	12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	17-Jun	18-Jun	19-Jun	20-Jun	21-Jun	22-Jun	23-Jun	24-Jun	25-Jun	26-Jun	27-Jun	28-Jun	29-Jun	30-Jun			
Rainfall in mm																																	
5-Day Rainfall mm																																	
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60			
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11			
Daily Runoff mm																																	
Day-Month	01-Jul	02-Jul	03-Jul	04-Jul	05-Jul	06-Jul	07-Jul	08-Jul	09-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul		
Rainfall in mm						8.00	6.60		21.60	5.60										1.00													
5-Day Rainfall mm						8.00	14.60	14.60	36.20	41.80	33.80	27.20	27.20	5.60						1.00	1.00	1.00	1.00	1.00									
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	87.25	87.25	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60		
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	37.12	37.12	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11		
Daily Runoff mm									2.30																							42.80	2.30
Day-Month	01-Aug	02-Aug	03-Aug	04-Aug	05-Aug	06-Aug	07-Aug	08-Aug	09-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug	26-Aug	27-Aug	28-Aug	29-Aug	30-Aug	31-Aug		
Rainfall in mm				2.00		1.00	3.20					2.00															47.20	20.40					
5-Day Rainfall mm				2.00	2.00	3.00	6.20	6.20	4.20	4.20	3.20	2.00	2.00	2.00	2.00	2.00											47.20	67.60	67.60	67.60	67.60		
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	87.25	94.90	94.90	94.90	94.90		
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	37.12	13.65	13.65	13.65	13.65		
Daily Runoff mm																											17.77	8.87				75.80	26.65
Day-Month	01-Sep	02-Sep	03-Sep	04-Sep	05-Sep	06-Sep	07-Sep	08-Sep	09-Sep	10-Sep	11-Sep	12-Sep	13-Sep	14-Sep	15-Sep	16-Sep	17-Sep	18-Sep	19-Sep	20-Sep	21-Sep	22-Sep	23-Sep	24-Sep	25-Sep	26-Sep	27-Sep	28-Sep	29-Sep	30-Sep			
Rainfall in mm						8.40		13.20	19.20	1.00						7.60	6.00	15.40					10.20	43.20		45.20	15.20						
5-Day Rainfall mm	20.40					8.40	8.40	21.60	40.80	41.80	33.40	33.40	20.20	1.00		7.60	13.60	29.00	29.00	29.00	21.40	15.40	10.20	53.40	53.40	98.60	113.80	103.60	60.40	60.40			
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	87.25	87.25	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	94.90	94.90	94.90	94.90	94.90	94.90	94.90			
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	37.12	37.12	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	13.65	13.65	13.65	13.65	13.65	13.65	13.65			
Daily Runoff mm									1.44															28.99		30.86	4.98					184.60	66.27
Day-Month	01-Oct	02-Oct	03-Oct	04-Oct	05-Oct	06-Oct	07-Oct	08-Oct	09-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct	21-Oct	22-Oct	23-Oct	24-Oct	25-Oct	26-Oct	27-Oct	28-Oct	29-Oct	30-Oct	31-Oct		
Rainfall in mm			4.60															14.40	5.00	8.60			15.20	20.40	11.20	5.20	27.40	15.60					
5-Day Rainfall mm	15.20		4.60	4.60	4.60	4.60	4.60											14.40	19.40	28.00	28.00	28.00	28.80	44.20	46.80	52.00	79.40	79.80	59.40	48.20	43.00		
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	87.25	87.25	87.25	94.90	94.90	94.90	87.25	87.25		
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	37.12	37.12	37.12	13.65	13.65	13.65	37.12	37.12		
Daily Runoff mm																								1.85	0.00		14.70	5.26				127.60	21.81
Day-Month	01-Nov	02-Nov	03-Nov	04-Nov	05-Nov	06-Nov	07-Nov	08-Nov	09-Nov	10-Nov	11-Nov	12-Nov	13-Nov	14-Nov	15-Nov	16-Nov	17-Nov	18-Nov	19-Nov	20-Nov	21-Nov	22-Nov	23-Nov	24-Nov	25-Nov	26-Nov	27-Nov	28-Nov	29-Nov	30-Nov			
Rainfall in mm	2.00	3.20		14.20								11.40							4.40							19.40	22.40	2.00	5.60				
5-Day Rainfall mm	17.60	5.20	5.20	19.40	19.40	17.40	14.20	14.20				11.40	11.40	11.40	11.40	11.40			4.40	4.40	4.40	4.40	4.40			19.40	41.80	43.80	49.40	49.40			
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	87.25	87.25	87.25	87.25			
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	37.12	37.12	37.12	37.12			
Daily Runoff mm																											2.62					84.60	2.62
Day-Month	01-Dec	02-Dec	03-Dec	04-Dec	05-Dec	06-Dec	07-Dec	08-Dec	09-Dec	10-Dec	11-Dec	12-Dec	13-Dec	14-Dec	15-Dec	16-Dec	17-Dec	18-Dec	19-Dec	20-Dec	21-Dec	22-Dec	23-Dec	24-Dec	25-Dec	26-Dec	27-Dec	28-Dec	29-Dec	30-Dec	31-Dec		
Rainfall in mm				2.00	6.20	5.40	1.00																										
5-Day Rainfall mm	30.00	7.60	5.60	2.00	8.20	13.60	14.60	14.60	12.60	6.40	1.00																						
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60		
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11		
Daily Runoff mm																																14.60	
Year Rainfall and Runoff in mm																																699.10	192.71

Table-2. Kombai Watershed - Estimation of daily for the year 2004

Kombai watershed - Estimation of daily runoff for the year 2004

Day-Month	01-Jan	02-Jan	03-Jan	04-Jan	05-Jan	06-Jan	07-Jan	08-Jan	09-Jan	10-Jan	11-Jan	12-Jan	13-Jan	14-Jan	15-Jan	16-Jan	17-Jan	18-Jan	19-Jan	20-Jan	21-Jan	22-Jan	23-Jan	24-Jan	25-Jan	26-Jan	27-Jan	28-Jan	29-Jan	30-Jan	31-Jan	Monthly Rainfall mm	Monthly Runoff mm
Rainfall in mm																																	
5-Day Rainfall mm																																	
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60		
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11		
Daily Runoff mm																																	
Day-Month	01-Feb	02-Feb	03-Feb	04-Feb	05-Feb	06-Feb	07-Feb	08-Feb	09-Feb	10-Feb	11-Feb	12-Feb	13-Feb	14-Feb	15-Feb	16-Feb	17-Feb	18-Feb	19-Feb	20-Feb	21-Feb	22-Feb	23-Feb	24-Feb	25-Feb	26-Feb	27-Feb	28-Feb	29-Feb				
Rainfall in mm																																	
5-Day Rainfall mm																																	
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.6				
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11				
Daily Runoff mm																																	
Day-Month	01-Mar	02-Mar	03-Mar	04-Mar	05-Mar	06-Mar	07-Mar	08-Mar	09-Mar	10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar		
Rainfall in mm																																	
5-Day Rainfall mm																																	
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60		
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11		
Daily Runoff mm																																	
Day-Month	01-Apr	02-Apr	03-Apr	04-Apr	05-Apr	06-Apr	07-Apr	08-Apr	09-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr			
Rainfall in mm																																	
5-Day Rainfall mm																																	
CN	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60	73.60			
S	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11	91.11			
Daily Runoff mm																																	
Day-Month	01-May	02-May	03-May	04-May	05-May	06-May	07-May	08-May	09-May	10-May	11-May	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May		
Rainfall in mm			6.00	60.00	29.00	13.00				5.00					22.00												31.00			4.00			
5-Day Rainfall mm			6.00	66.00	95.00	108.00	108.00	102.00	42.00	18.00	5.00	5.00	5.00	5.00	22.00	22.00	22.00	22.00	22.00								31.00	31.00	31.00	35.00	35.00		
CN	73.60	73.60	73.60	94.90	94.90	94.90	94.90	94.90	94.90	87.25	73.60	73.60	73.60	73.60	87.25	87.25	87.25	87.25	87.25	73.60	73.60	73.60	73.60	73.60	73.60	73.60	94.90	94.90	94.90	94.90	73.60		
S	91.11	91.11	91.11	13.65	13.65	13.65	13.65	13.65	13.65	37.12	91.11	91.11	91.11	91.11	37.12	37.12	37.12	37.12	37.12	91.11	91.11	91.11	91.11	91.11	91.11	91.11	13.65	13.65	13.65	13.65	91.11		
Daily Runoff mm				**44.93**	**16.09**	**3.52**									**2.46**												**17.85**					170.00	84.85
Day-Month	01-Jun	02-Jun	03-Jun	04-Jun	05-Jun	06-Jun	07-Jun	08-Jun	09-Jun	10-Jun	11-Jun	12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	17-Jun	18-Jun	19-Jun	20-Jun	21-Jun	22-Jun	23-Jun	24-Jun	25-Jun	26-Jun	27-Jun	28-Jun	29-Jun	30-Jun			
Rainfall in mm	79.00			31.00																													
5-Day Rainfall mm	83.00	83.00	83.00	110.00	110.00	31.00	31.00	31.00																									
CN	94.90	88.68	88.68	88.68	88.68	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30			
S	13.65	32.42	32.42	32.42	32.42	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90			
Daily Runoff mm	**63.36**			**8.43**																												110.00	71.79
Day-Month	01-Jul	02-Jul	03-Jul	04-Jul	05-Jul	06-Jul	07-Jul	08-Jul	09-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul		
Rainfall in mm									5.00		4.00	5.00							4.00	2.00													
5-Day Rainfall mm									5.00	5.00	9.00	14.00	14.00	9.00	9.00	5.00			4.00	6.00	6.00	6.00	6.00	2.00									
CN	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30		
S	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90		
Daily Runoff mm																																20.00	
Day-Month	01-Aug	02-Aug	03-Aug	04-Aug	05-Aug	06-Aug	07-Aug	08-Aug	09-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug	26-Aug	27-Aug	28-Aug	29-Aug	30-Aug	31-Aug		
Rainfall in mm																																	
5-Day Rainfall mm																																	
CN	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30		
S	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90		
Daily Runoff mm																																	
Day-Month	01-Sep	02-Sep	03-Sep	04-Sep	05-Sep	06-Sep	07-Sep	08-Sep	09-Sep	10-Sep	11-Sep	12-Sep	13-Sep	14-Sep	15-Sep	16-Sep	17-Sep	18-Sep	19-Sep	20-Sep	21-Sep	22-Sep	23-Sep	24-Sep	25-Sep	26-Sep	27-Sep	28-Sep	29-Sep	30-Sep			
Rainfall in mm		18.00			5.00			4.00	18.00					22.00	14.00	10.00		52.00	18.00	22.00					1.00	24.00	13.00	1.00	8.00				
5-Day Rainfall mm		18.00	18.00	18.00	23.00	23.00	5.00	9.00	27.00	22.00	22.00	22.00	18.00	22.00	36.00	46.00	46.00	98.00	94.00	102.00	92.00	92.00	40.00	22.00	1.00	25.00	38.00	39.00	47.00	46.00			
CN	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	87.25	87.25	87.25	88.68	88.68	88.68	88.68	88.68	87.25	76.30	76.30	76.30	87.25	87.25	87.25	87.25			
S	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	37.12	37.12	37.12	32.42	32.42	32.42	32.42	32.42	37.12	78.90	78.90	78.90	37.12	37.12	37.12	37.12			
Daily Runoff mm															**0.21**			**23.92**	**1.68**	**3.37**							**0.09**					230.00	29.27
Day-Month	01-Oct	02-Oct	03-Oct	04-Oct	05-Oct	06-Oct	07-Oct	08-Oct	09-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct	21-Oct	22-Oct	23-Oct	24-Oct	25-Oct	26-Oct	27-Oct	28-Oct	29-Oct	30-Oct	31-Oct		
Rainfall in mm		11.00									1.00	26.00					5.00		21.00	2.00	3.00	8.00	10.00		3.00	6.00	3.00	15.00	18.00	8.00	18.00		
5-Day Rainfall mm	22.00	20.00	19.00	11.00	11.00	11.00					1.00	27.00	27.00	27.00	27.00	26.00	5.00	5.00	26.00	28.00	31.00	34.00	44.00	23.00	24.00	27.00	22.00	27.00	45.00	50.00	62.00		
CN	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	87.25	76.30	76.30	76.30	76.30	76.30	87.25	87.25	88.68		
S	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	37.12	78.90	78.90	78.90	78.90	78.90	37.12	37.12	32.42		
Daily Runoff mm																													**1.07**		**1.68**	158.00	2.75
Day-Month	01-Nov	02-Nov	03-Nov	04-Nov	05-Nov	06-Nov	07-Nov	08-Nov	09-Nov	10-Nov	11-Nov	12-Nov	13-Nov	14-Nov	15-Nov	16-Nov	17-Nov	18-Nov	19-Nov	20-Nov	21-Nov	22-Nov	23-Nov	24-Nov	25-Nov	26-Nov	27-Nov	28-Nov	29-Nov	30-Nov			
Rainfall in mm	3.00					2.00	7.00	5.00		2.00	9.00	17.00	27.00		15.00	32.00					2.00						9.00						
5-Day Rainfall mm	62.00	47.00	29.00	21.00	3.00	2.00	9.00	14.00	14.00	16.00	23.00	33.00	55.00	55.00	68.00	91.00	74.00	47.00	47.00	32.00	2.00	2.00	2.00	2.00	2.00		9.00	9.00	9.00	9.00			
CN	88.68	87.25	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	87.25	87.25	88.68	88.68	88.68	87.25	87.25	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30			
S	32.42	37.12	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	37.12	37.12	32.42	32.42	32.42	37.12	37.12	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90			
Daily Runoff mm													**4.75**		**0.74**	**9.07**																130.00	14.56
Day-Month	01-Dec	02-Dec	03-Dec	04-Dec	05-Dec	06-Dec	07-Dec	08-Dec	09-Dec	10-Dec	11-Dec	12-Dec	13-Dec	14-Dec	15-Dec	16-Dec	17-Dec	18-Dec	19-Dec	20-Dec	21-Dec	22-Dec	23-Dec	24-Dec	25-Dec	26-Dec	27-Dec	28-Dec	29-Dec	30-Dec	31-Dec		
Rainfall in mm															2.00										2.00								
5-Day Rainfall mm	9.00														2.00	2.00	2.00	2.00	2.00						2.00	2.00	2.00	2.00	2.00				
CN	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30	76.30		
S	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90	78.90		
Daily Runoff mm																																4.00	
Year Rainfall and Runoff in mm																																822.00	203.21

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[3] CGWB, 1994 Manual on Artificial recharge of ground water

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