ESTIMATION OF RUNOFF FROM BEWAS BASIN USING SCS CURVE NUMBER MODEL

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ABSTRACT

Runoff is one of the most important hydrologic variables used in most of the water resources applications. Direct measurement of runoff provides excellent and timely data but it is limited in use to the exact location where it was collected. Conventional models for prediction of river discharge require considerable data for several hydro-meteorological parameters. Remote sensing technology can augment the conventional methods to a great extent in rainfall-runoff studies. The role of remote sensing in runoff calculation is generally to provide a source of input data or to aid estimation of equation coefficients and model parameters. Geographical Information System (GIS) provides efficient tools for data input into data base, retrieval of selected data items for further processing and software modules which can analyse/manipulate the retrieved data in order to generate desired information on specific form.

The United States Soil Conservation Service, SCS runoff curve number method is the most commonly used runoff model, which is based on a non-linear rainfall-runoff relation that includes a parameter called runoff curve number. This model involves relationship between landuse/land cover, hydrologic soil class (A,B,C and D) and runoff curve number of hydrologic soil cover complex, which is a function of soil type, land cover and antecedent moisture condition (AMC - I, II and III).

The Sagar city is facing acute shortage of municipal water supply especially during summer months, therefore,

the Public Health Engineering Department (Govt. of M.P.), Sagar has undertaken a project to augment the municipal water supply of the Sagar city by constructing a dam near Salaiya village in the Sagar block across Bewas river. The project envisages to construct a 1860 m long and 25.5 m high earthen dam to store 96 MCM water (gross). Therefore, a part of the Bewas river basin having outlet at dam site was selected for this study.

In the present study SCS curve number method is used to predict runoff volume at dam site resulting from the daily rainfall occurred in the Bewas basin. The ancillary data on landuse/land cover was interpreted from IRS 1B, LISS II imageries of the catchment area. ARC/INFO GIS package has been used as the core of the spatial database. The general relationships between the direct runoff and rainfall recorded at the four rain gauge stations in the Bewas catchment area were also developed for all the three antecedent moisture conditions.

The discharge measured by the Public Health Engineering Department, Sagar and the direct runoff volume estimated using SCS curve number method was compared and monthly correlation coefficient was calculated. In general good correlation was found between the measured and estimated runoff volumes. The seasonal correlation coefficient vary between 0.92 to 0.94.

1.0 INTRODUCTION

Runoff is one of the most important hydrologic variables used in most of the water resources applications. Direct measurement of runoff provides excellent and timely data but it is limited in use to the exact location where it was collected. Reliable prediction of quantity and rate of runoff from land surface into streams and rivers are difficult and time consuming to obtain for ungauged watersheds. However, this information is needed in dealing with many watershed development and management problems. Conventional models for prediction of river discharge require considerable data for several hydro-meteorological parameters. Collection of these data is expensive, time consuming and a difficult process, and the data are currently being used in hydrological research.

Remote sensing technology has emerged as an unique and extremely important tool in understanding, assessing and monitoring natural resources. The data obtained from the remote sensing platforms by virtue of their repetitive and synoptic coverage and computer aided analysis make significant contributions in understanding and monitoring the environmental processes (Balakrishnan, 1986). The main advantages of the satellite data and its interpretation over the conventional methods of surveying can be listed as follows.

- The capability of synoptic viewing of a comparatively larger area
- Monitoring capability due to repetitive coverage in relatively short time interval
- Relatively fast, accurate and economical for gross estimates compared to conventional methods
- Unbiased and near real time data availability
- Easy data handling and manipulation for computer aided classification

Remote sensing technology can augment the conventional methods to a great extent in rainfall-runoff studies. Runoff cannot be directly measured by remote sensing techniques. The role of remote sensing in runoff calculation is generally to provide a source of input data or to aid estimation of model parameters. There are two general areas where remote sensing has currently been

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used as input data for computing runoff. The first is based on producing input data based on various geomorphic descriptions of a basin for calculation of flood peak, annual runoff using empirical methods, such as Rational method. In the second approach, runoff models that are based on a landuse component (curve number method, etc.). There have been attempts (Ragan and Jackson, 1980) to estimate the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) runoff curve number using Landsat data. Experience has shown that satellite data can be interpreted to derive a number of thematic information in landuse, soil, vegetation, surface water, snow cover, stream network, landform, erosion intensity etc. which combined with conventionally measured climatic parameters (precipitation, temperature, evaporation etc.) and topographic parameters (height, contour, slope) should provide the necessary inputs to the models in practice for reliable and timely estimation of runoff.

Several empirical relations and mathematical models have been developed to study the rainfall-runoff relationship. Runoff relationships developed in one region, many times were not found satisfactory in other regions due to multiple dependence of the runoff process. In 1949 Sherman proposed plotting of runoff versus rainfall accounting antecedent moisture index. The effect of infiltration rate and antecedent moisture condition of the land cover soil complex on runoff is widely accepted. The United States Soil Conservation Service (SCS) has developed runoff curve number model, which is based on a non-linear rainfall-runoff relation that includes a parameter called runoff curve number. This model involves relationship between land cover, hydrologic soil class and curve number.

Geographical Information System (GIS) is a tool which facilitates generation of information required for a particular need of discipline. Input data to the system is georeferenced, in spatial as well as tabular form The system provides efficient tools for data input into data base, retrieval of selected data items for further processing and software modules which can analyse/manipulate the retrieved data in order to generate desired information on specific form

The GIS is a system for storing, retrieving and analysing geographically referenced data sets. In the GIS both spatial (for example; maps, satellite imagery) and non-spatial (for example; census data, field data) data source can be

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integrated and a set of spatially registered data layers can be analysed independently or in combination with a number of layers. Thus, one can stitch together bundles of data from a wide variety of sources and manipulate them to get quantitative information for resource management and planning.

The Sagar city is facing acute shortage of municipal water supply especially during summer months. Previously lake water was being supplied to the town from 1911 to 1958 without filtration, but now the quality of the lake water is so deteriorated that it is not being used for drinking or bathing purposes. The groundwater potential is poor since the city is located in rocky terrain. Therefore, exploitation of surface water resource becomes utmost important. Bewas river, a tributary to the Ken river flows in the south-east direction at about 10 km from the city. The Public Health Engineering Department, Govt. of MP. is constructing a dam near Salaiya village in the Sagar block across Bewas river to augment the municipal water supply to the Sagar city. The project envisages to construct a 1860 metres long and 25.5 metres high earthen dam to store 96 MCM water (gross). It has been designed to cater 10 lac's population anticipated by the end of 2046. Therefore, a part of the Bewas river basin having outlet at dam site was selected for this study. For operation of the reservoir, estimation of volume of runoff water resulting from the rainfall occurred in the upper catchment is essential.

In the present study SCS curve number method is used to predict the runoff volume at dam site from the daily rainfall occurred in the Bewas basin. The ancillary data on landuse/land cover was interpreted from IRS 1B, LISS II imageries of the catchment area. ARC/INFO GIS package has been used as the core of the spatial database. ARC/INFO is a modular, vector based package, and is versatile for creation, organisation, storage, retrieval, analysis, display, query and for making cartographic quality outputs in the form of maps and generation of statistical tabular reports.

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2.0 METHODOLOGY

The SCS (Soil Conservation Service) model developed by USDA (United States Department of Agriculture) computes direct runoff through an empirical equation that requires the rainfall and a watershed coefficient as inputs. The watershed coefficient is called the curve number (CN), which is an index that represents watershed's runoff potential for given soil-cover complex and AMC. This model involve relationship between land cover, hydrologic soil class and curve number.

SCS model enables the hydrologist to simulate various design alternatives and compare the results. The parameter defined by landuse allows the user to experiment with alternative form of land development and management and to assess the impact of the proposed changes on runoff. Hence, most planning agencies in watershed management use this method to estimate volume of the direct runoff water from a given storm

Basic data requirements of this model are:

1. Type of landuse/land cover such as bare soil, vegetation, impervious surface, agricultural lands etc. and hydrologic condition of such landuse.

2. The antecedent moisture condition (AMC) which is the index of the soil condition with respect to runoff potential before the storm The antecedent moisture conditions are based on the season and 5-day antecedent precipitation (SCS, 1984) and are defined as follows:

   AMC I: Dormant season antecedent soil moisture less than 12 mm Growing season antecedent soil moisture less than 36 mm
   AMC II: Dormant season antecedent soil moisture between 12 and 28 mm Growing season antecedent soil moisture between 36 and 53 mm
   AMC III: Dormant season antecedent soil moisture greater than 28 mm Growing season antecedent soil moisture greater than 53 mm

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3. Hydrologic soil group, hydrologically soils are assigned into four groups on the basis of intake of water on bare soil when thoroughly wetted. The hydrologic soil group classification can be based on texture of distributed soil.

Group	Minimum Infiltration Rate (in/hr)	Soil Texture
A	0.30 - 0.45	Sand, Loamy Sand or Sandy Loam
B	0.15 - 0.30	Silt Loam or Loam
C	0.05 - 0.15	Sandy Clay Loam
D	0 - 0.05	Clay Loam, Silty Clay Loam, Sandy Clay, Silty Clay or Clay

The method is based on an assumption of proportionality between retention and runoff in the following form:

$$\frac{P - Q}{S} = \frac{Q}{P} \qquad \ldots (2.1)$$

which states that the ratio of actual retention to potential retention is equal to the ratio of actual runoff to potential runoff. This assumption underscores the conceptual basis of the runoff curve number method. P, Q and S are expressed in the same units e.g. cm or inches.

For practical applications, Eq. 2.1 is improved by reducing the potential runoff by an amount equal to the initial abstraction. The initial abstraction consists of evaporation, interception, infiltration and surface storage, all of which occur before runoff begins.

Thus,

$$\frac{P - I_a - Q}{S} = \frac{Q}{P - I_a} \qquad \ldots (2.2)$$

where, I_a = initial abstraction.

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Solving for Q from Eq. 2.2 :

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \qquad \qquad \dots (2.3)$$

which is physically subject to the restriction that $P \geq I_a$ (i.e. the potential runoff minus the initial abstraction cannot be negative).

To simplify Eq. 2.3, initial abstraction is related to potential maximum retention. The following relationship between initial abstraction and potential maximum retention has been developed for Indian conditions (Handbook of Hydrology, 1972):

1. **For black soil region (Antecedent moisture condition I) and for all other regions:**

$$I_a = 0.3\, S \qquad \qquad \dots (2.4)$$

Therefore Eq. 2.3 reduces to

$$Q = \frac{(P - 0.3\, S)^2}{P + 0.7\, S}, \quad P \geq 0.3S \qquad \dots (2.5)$$

2. **For black soil region (Antecedent moisture condition II & III):**

$$I_a = 0.1\, S \qquad \qquad \dots (2.6)$$

Therefore Eq. 2.3 reduces to

$$Q = \frac{(P - 0.1\, S)^2}{P + 0.9\, S}, \quad P \geq 0.1S \qquad \dots (2.7)$$

Eq. 2.7 is used with the assumption that the cracks which are typical of black soil when dry, are filled. In practice, the Runoff Curve Number (CN) is used as a transformation of S, as follows:

$$S = \frac{25400}{CN} - 254$$

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where,

CN = runoff curve number of hydrologic soil cover complex. which is a function of soil type, land cover and antecedent moisture condition (AMC).

Q = actual direct runoff, mm

P = total storm rainfall, cm

S = potential maximum retention of water by the soil, cm

Some typical values of curve number used in India for various landuse classes defined in the Bewas catchment area are tabulated in Table 2.1 for all the three antecedent moisture conditions (Hand book of Hydrology, Ministry of Agriculture, 1972).

Table 2.1 Curve Numbers for Hydrologic Soil Group - C

Landuse (Cover)	Treatment	Hydrologic Condition	Runoff Curve Number		
			AMC I	AMC II	AMC III
Wasteland			75	88	95
Forest		Open	40	60	78
Shrub (pasture / range)		Good	55	74	88
Agriculture (Small Grain)	Straight row	Poor	69	84	93
		Good	67	83	93

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3.0 STUDY AREA

The Bewas river originates from the Vindhyan range near Siarmau village (Elevation 600 meters above MSL) in Silvani sub-division of Raisen district in Madhya Pradesh (MP.). The Bewas river flows for 20 km in Raisen district and 29 km in Sagar district upto the dam site. It further flows for 90 km in Chhattarpur and Damoh district before joining Sonar river near village Barkhera in Damoh district of MP., which is a tributary of the Ken river in the east Yamuna basin. The river basin is feather shaped with high banks. The basin upto the project site is 43 km long with average width of 11 km The catchment area upto the dam site is 507.12 Sq. km. The area was measured from 1:50,000 Survey Of India Toposheet.

3.1 LOCATION

The Bewas catchment is surrounded by the Narmada river basin in the south, Dhasan river basin in the west and Sonar river basin in the east. The Bewas river flows from SSW to NNE direction in the study area. The basin (Fig. 3.1) is having total geographical area of 507.12 Sq. km Out of which about one third part falls on Raisen district and the remaining two third fall on Sagar district. The study area lies between 23° 24' N and 23° 46' 13" N latitudes and 78° 31' E and 78° 47' 8" E longitudes. The proposed dam is located at 23° 43' 20" N latitude and 78° 45' 21" E longitude. Two major tributaries, Parkul river and Jamunia nala join the Bewas river at about 1.5 km Upstream of the dam site. The catchment area falls under SOI toposheet No. 55I/9, 10, 11 & 14 as shown in Fig. 3.2.

3.2 PHYSIOGRAPHY

The area falls under Bundelkhand plateau as per broad physiographical classification. The maximum area of the basin is covered by the Deccan trap. The small trap hillocks can be also observed in the area. The Deccan trap flows have covered pretrappean topography. The landscape is characterised by flat topped hills. The valleys have been filled up with black cotton soil having an average

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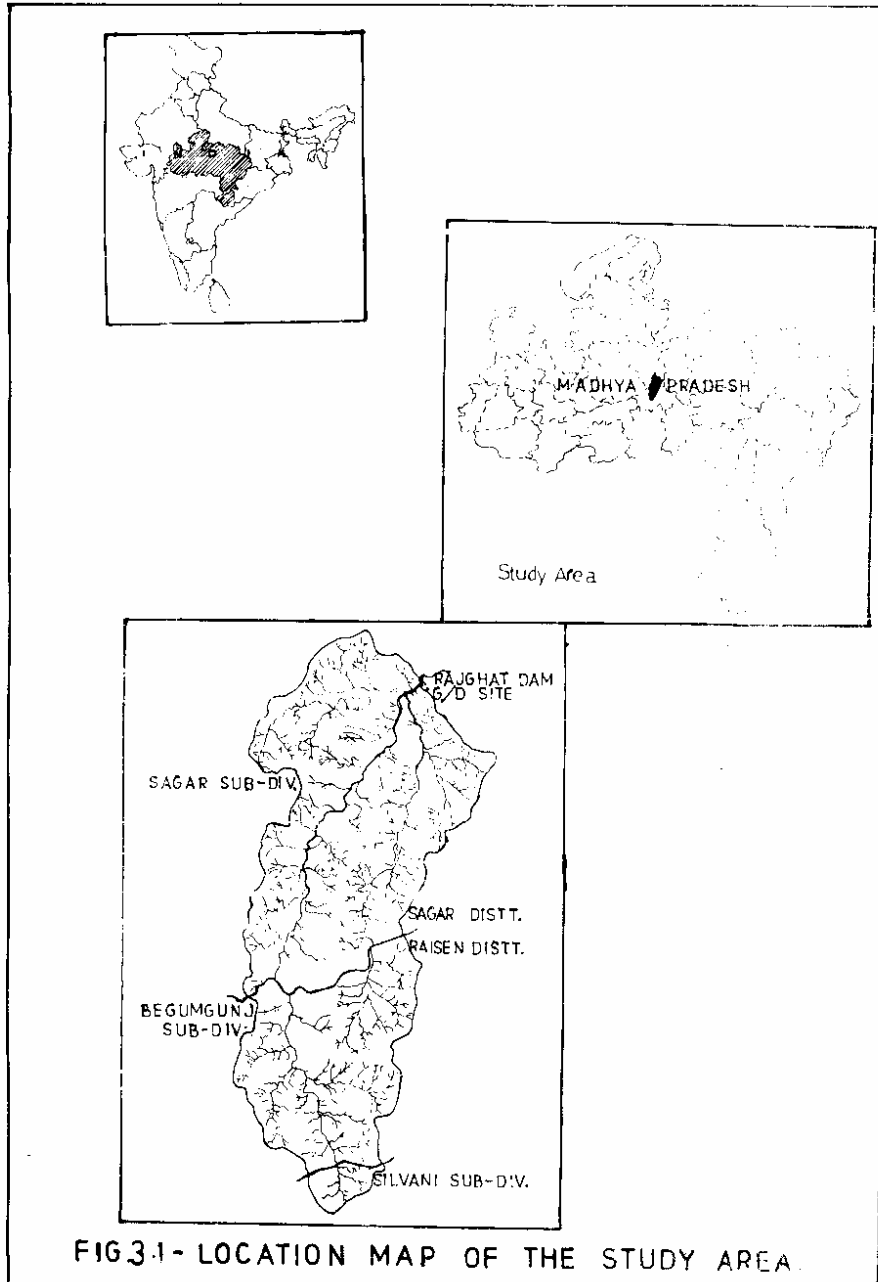
FIG.3.1- LOCATION MAP OF THE STUDY AREA

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$55\frac{1}{5}$

$55\frac{1}{9}$

$55\frac{1}{13}$

$55\frac{1}{6}$

$55\frac{1}{0}$

$55\frac{1}{14}$

BEWAS RIVER

$55\frac{1}{7}$

$55\frac{1}{11}$

$55\frac{1}{.15}$
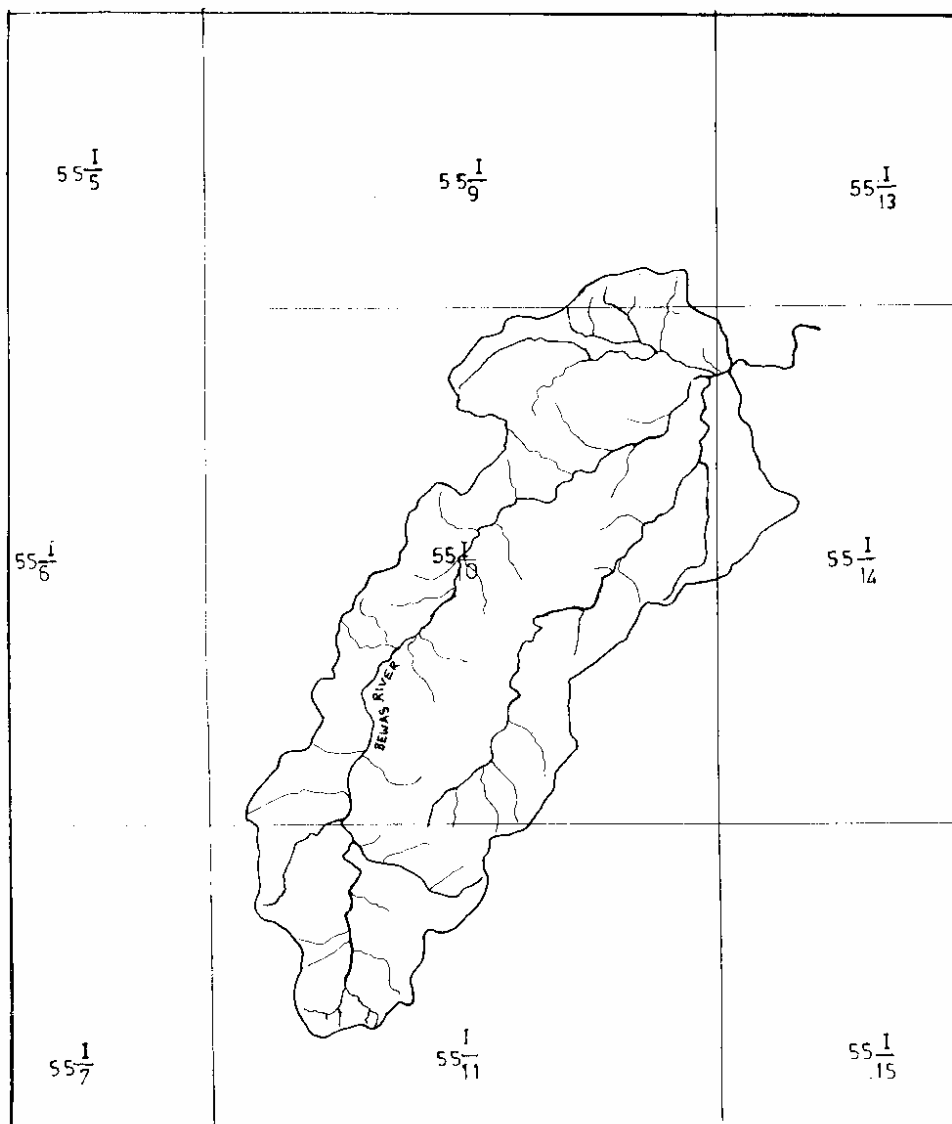
FIG. 3.2 :- S O I TOPOSHEET COVERAGE OF THE STUDY AREA.

thickness varying from 4 to 15 metres at places. The area attains a maximum height of 728 meters above MSL near village Khera in the south direction and the minimum height of 500 meters above MSL in the north direction near the dam site. The general slope of the catchment area is from south to north. Very small area is under irrigation however, the farmers are pumping water from the river Bewas and digging dug wells on limited scale for irrigation purposes.

3.3 GEOLOGY

The geology of the catchment area is characterised by Deccan Trap volcanic series. The Deccan trap, comprising of a number of thick layers of basalt, is formed by the volcanic eruption over Deccan plateau. Deccan traps are very finely grained black colour basalt formed by the consolidation of volcanic lava. Here, the meaning of trap is taken into consideration of ladder like slope. The catchment area is lying over 6th to 11th flow of this trap (Geohydrological Report, Govt. of MP.). The flows have been numbered from older to younger from 1 to 11 in the ascending order. In valleys mostly weathered basalt or clayey soil is found. The flows are separated from each other by redbole or intertrappean horizons but these horizons are not continuous. The basaltic country is also clearly marked by its flat plateau surface and steep slopes on all sides in the form of hills, plateau or ridges. Hillocks are often formed of basaltic exposures and the surrounding low lying areas consist of black cotton soil. At lower levels highly altered basalt is found and fresh exposures expected in the wells or nalla or river cuttings.

3.4 HYDROMETEOROLOGY

3.4.1 RAINFALL

No rain gauge station was located in the catchment area before the administrative approval for construction of a dam was granted to the P.H.E. Department in March, 1990. Now, there are four rain gauge stations installed in the catchment area to observe the daily rainfall data, i.e. three stations at Karaiya, Bilhera and Sultanganj villages and one near the dam site. Daily rainfall data during the month of June to October is being observed at these four stations since 1990. The average annual and monthly rainfall data for a period of 32 years

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(1965 to 1996) for Sagar observatory have been shown in Table 3.1. The average annual rainfall of Sagar was found to be 1204.69 mm It was also observed that about 92 percent of the total rainfall occur during the monsoon period i.e., during June to September. There are total 57 rainy days in a year having rainfall intensity more than 2.5 mm/day.

Table 3.1 Average Rainfall (mm) at Sagar (1965-1996)

MONTHS	January	February	March	April	May	June
AVE. OF 96 YRS.*	16.73	13.47	10.53	2.03	7.48	135.8

* 32 years include from 1965 to 1996.

July	August	September	October	November	December	Annual
348.41	452.79	169.47	22.18	13.25	12.52	1204.69

Source: Land Records & Settlement, Revenue Deptt., Govt. of MP.

3.4.2 TEMPERATURE AND EVAPORATION

The hottest month in the region is May and the coldest month is January. There is a small variation in the monthly value of maximum and minimum temperature during the period from November to February and also during July to September. The mean diurnal variation is of the order of 8 degree centigrade during July to September and 13 degree centigrade during November to February. The normal monthly and annual atmospheric temperature for 50 years are shown in Table 3.2.

The evaporation data at Sagar was not available, but the nearest Pan evaporation observatory is available at Raisen. The month-wise evaporation data for Raisen is given in the Table 3.3. The total pan evaporation losses during the year works out to be 1971 mm During the period from 1st February to 15th June the soil moisture zone is dry and no evaporation is likely to occur during the period. Thus the evaporation losses from the land surface are likely to occur during the period 15th June to end of January. The pan evaporation in this period is 908 mm

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Table 3.2 Normal Temperature at Sagar (Average of Yrs.1901 to 1950)

Month	Minimum	Maximum
January	11.3	24.7
February	13.2	26.9
March	18.3	32.6
April	23.2	37.6
May	26.5	40.4
June	25.7	36.9
July	23.3	29.8
August	22.6	28.6
September	21.9	30.1
October	19.1	31.1
November	14.7	27.8
December	11.8	24.9
Annual av.	19.3	30.9

Table 3.3 Pan Evaporation data for Raisen Observatory

Month	Pan-Evaporation (mm)
January	83
February	108
March	184
April	279
May	381
June	222
July	95
August	76
September	102
October	102
November	83
December	76
Annual total	1971

3.4.3 SOILS & VEGETATION

The soils of the area have been derived from Basaltic parent material and are classified under medium black soils under broad classification of Indian soils. The colour of the soil is determined due to the excessive presence of iron and lime. During the weathering of basalt, the iron constituents of the rock gets oxidised in red colour and due to continuous chemical processes and deposition, the soil is finally converted into black colour. Rainfall and climatic conditions played an important role in its formation. It is highly fertile and can be cultivated for years together without manuring. Alluvium is also found in the area along the streams and river banks. The area falls in the predominantly rabi tract of the state with wheat, gram and Jawar as the principal crops.

The Sagar region can be classified under Northern tropical dry deciduous forest. In this region trees like Teak, Sirus, Sal, Tendu, Bamboo, Eucalyptus etc. are found in abundant quantity.

4.0 DATA USED

The quantity of runoff water that comes into a reservoir due to the precipitation occurred in the upstream catchment area is most important factor in releasing water from the reservoir. If the total volume of runoff water coming into the dam is known simultaneously as the rainfall occur in the catchment area, increase in the level of water in the dam will be estimated well in advance for the operation of gates. In the present study a general relationship between the direct runoff and rainfall recorded at the four rain gauge stations in the Bewas catchment area was developed.

4.1 CATCHMENT AREA AND SUB-BASINS

The spatial data were mainly derived from remote sensing and other conventional sources. The data base were created on 1:50,000 scale and referenced with the Survey of India toposheet. The drainage map of the basin shown in the following Fig. 4.1 was prepared using SOI toposheet No. 55 1 / 9, 10, 11 & 14. The watershed line was marked on the basis of 20 m interval contour information available on the SOI toposheet. The Bewas catchment area upto the dam site was further divided into eight sub-basins (Fig. 4.2) according to the drainage system of the basin, to overcome the limitations of the SCS curve number method. The sub-basins are numbered from 1 to 8 in ascending order assigning No.1 to the sub-basin located in the most upstream and No.8 to the sub-basin at the outlet of the catchment area, i.e. near the dam site. The spatial distribution of the sub-basins are given in the Table 4.1.

4.2 RAINFALL AND DISCHARGE DATA

The rainfall and discharge data were collected from the Public Health Engineering Department, Govt. of MP., Sagar. Four rain gauge stations namely, Karaiya, Bilhera, Sultanganj and at Dam site were set-up in the basin to record the daily rainfall data in the basin since 1990. In this study four years rainfall data for the years 1993, 1994, 1995 and 1997 recorded at the four rain gauge

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FIG.4.1:- DRAINAGE MAP OF BEWAS BASIN UPTO
RAJGHAT DAM SITE.

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FIG. 4.2 :- MAP SHOWING SUB BASINS BOUNDARIES IN THE BEWAS BASIN.

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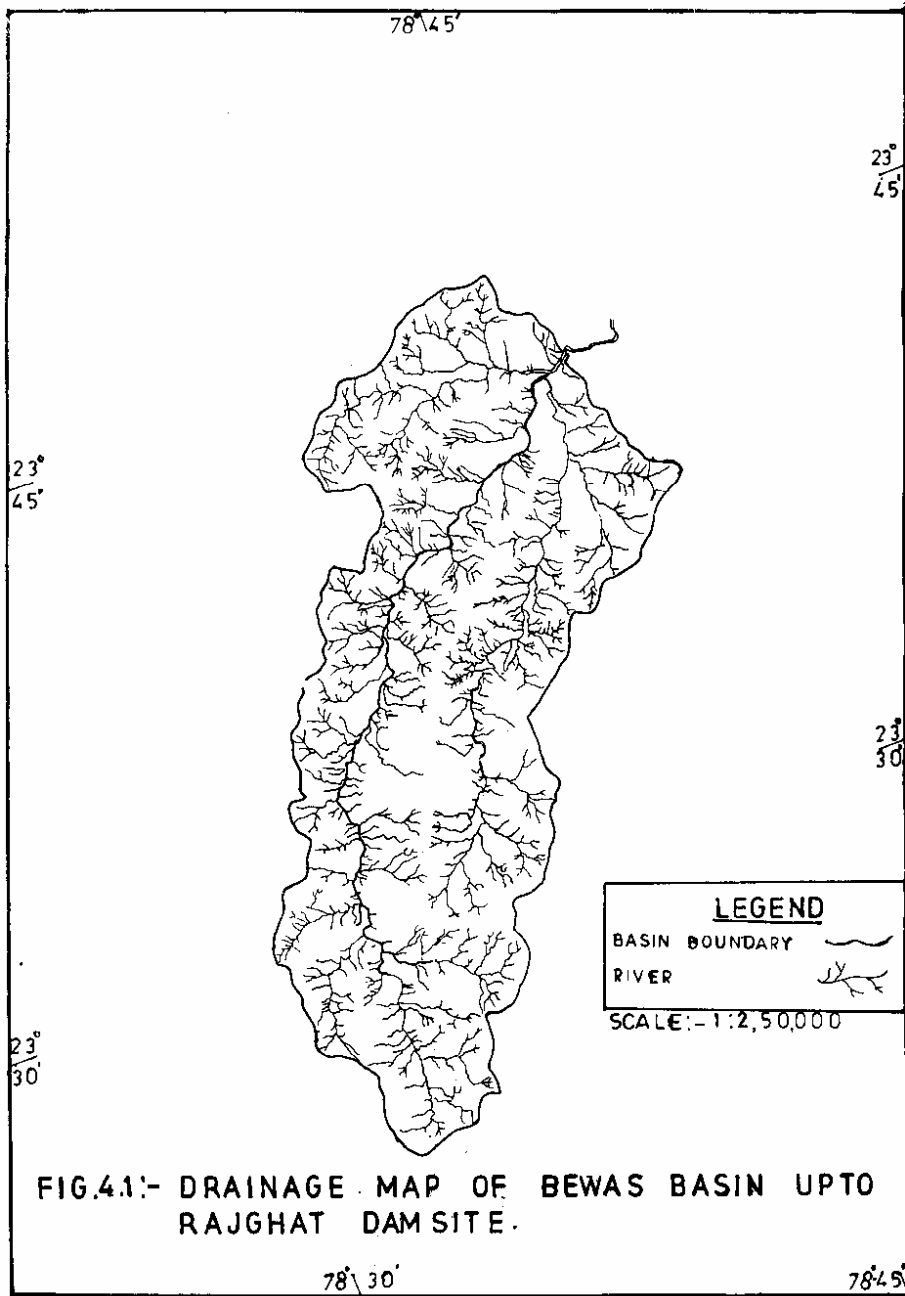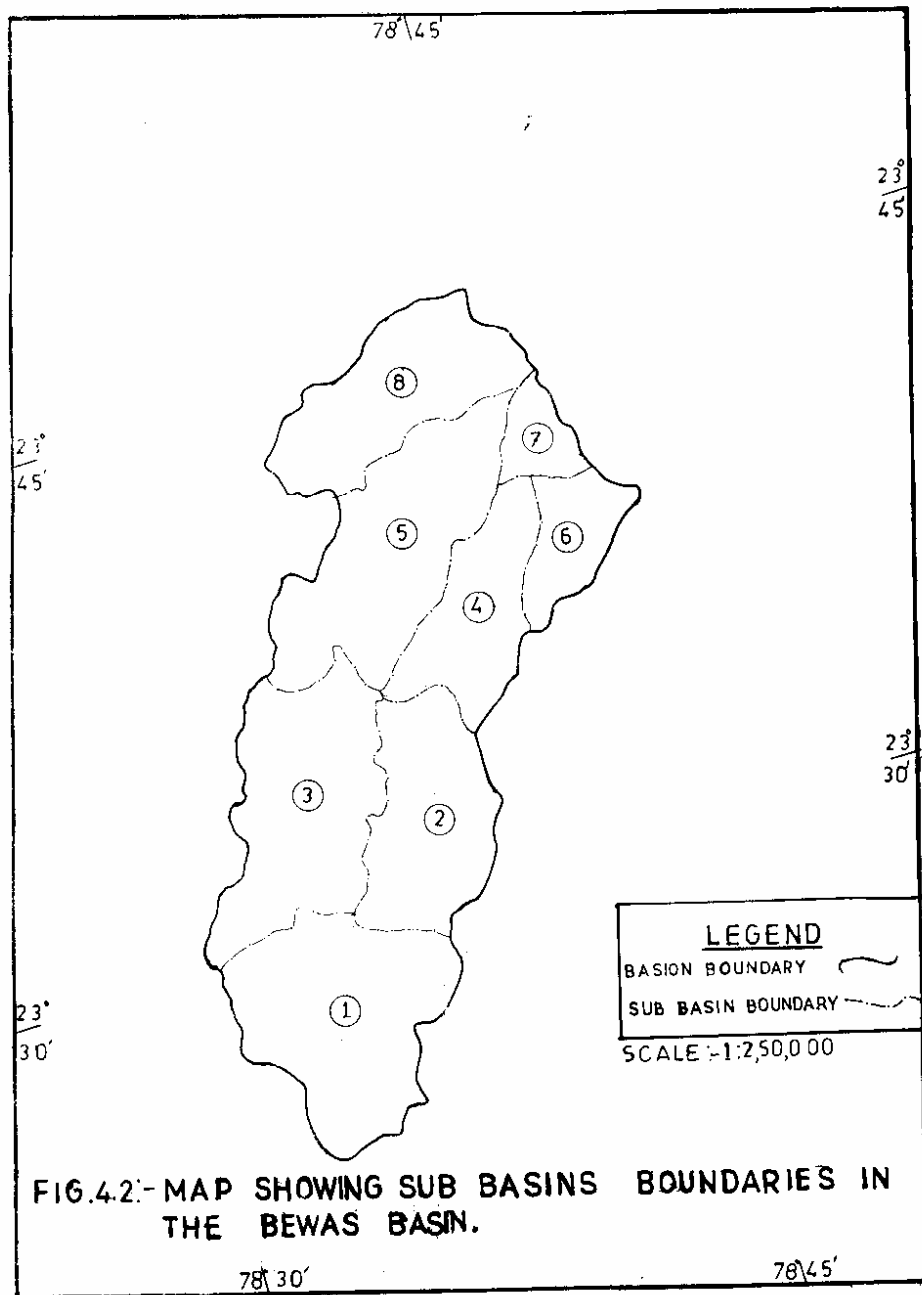
stations in the catchment area were used (Appendix-I) for prediction of direct runoff in the Bewas river at the proposed dam site.

Table 4.1 Spatial Distribution of Sub-Basins

Sub-Basin No.	Area (ha)	% of Basin Area
Sub-Basin 1	095.25	18.8
Sub-Basin 2	067.06	13.2
Sub-Basin 3	088.16	17.4
Sub-Basin 4	049.52	09.7
Sub-Basin 5	094.83	18.7
Sub-Basin 6	028.26	05.6
Sub-Basin 7	015.07	03.0
Sub-Basin 8	068.98	13.6
Total	507.12	100.0

Thiessen polygon method was followed to get weighted average rainfall in the eight sub-basins. The weights were calculated according to the Thiessen polygon area fall in each sub-basins as shown in Fig. 4.3. The average daily rainfalls for each sub-basins were thus estimated by multiplying the weights for each rain gauge stations given in the following Table 4.2 for all the eight sub-basins. The depth of flow in the Bewas river at the dam site is being recorded at every three hours during the monsoon period, i.e. from 15th June to 15th October every year since 1990, except for the year 1996 by the P.H.E. Deptt., Sagar. The cross-section of Bewas river at the dam site was surveyed and plotted by the P.H.E., Department. The water level in the river and the surface velocity of stream were measured simultaneously to get the rate of flow in the river. In this study the three hourly discharge data were summed-up to get daily discharge data, since the rainfall data was available on daily basis. The discharge data (Appendix-I) for the four years, i.e. 1993, 1994, 1995 and 1997 were also used for validation of the runoff model.

FIG.4.3:-MAP SHOWING RAINGAUGE STATIONS AND
THESSEN POLYGONS.

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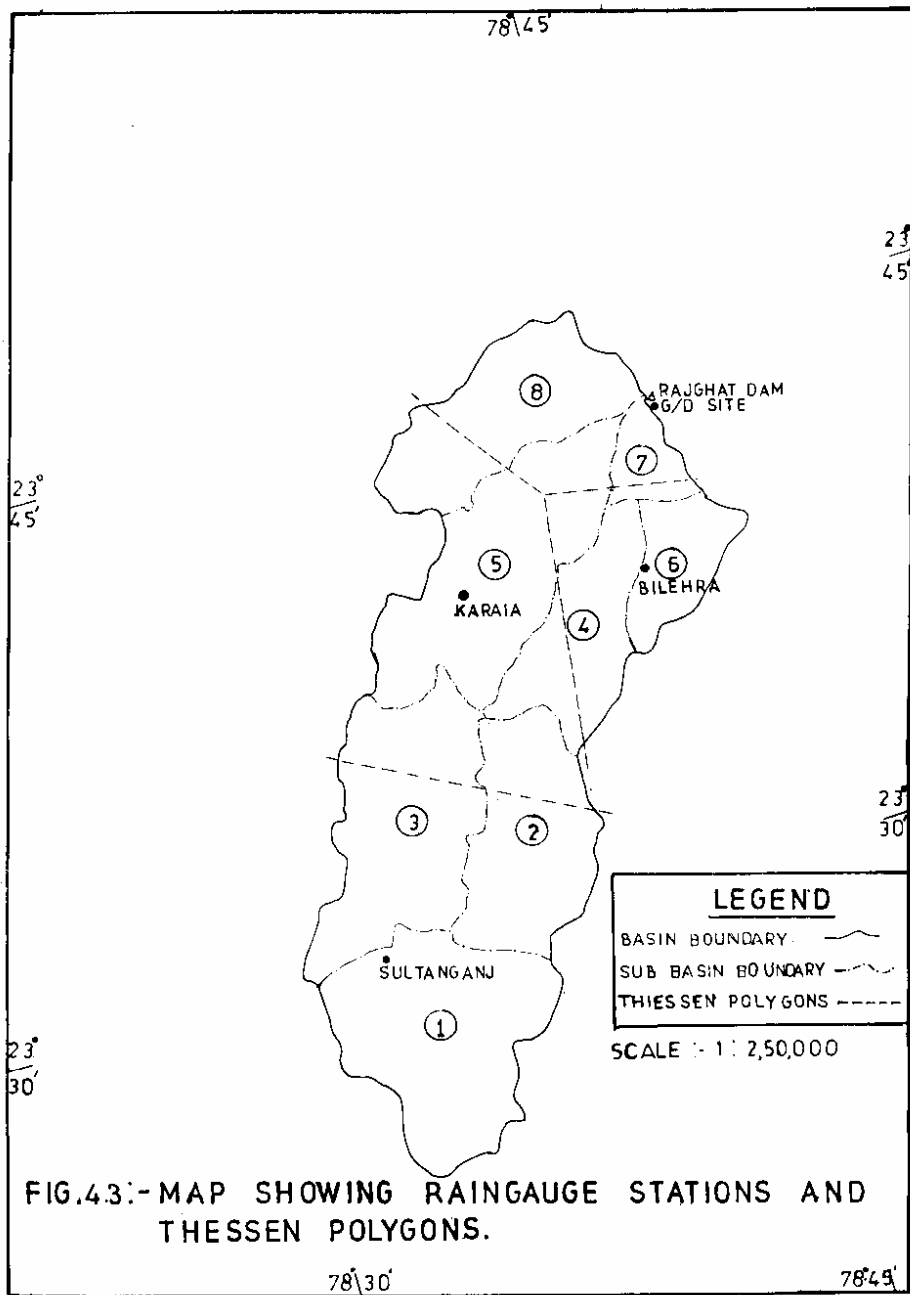
Table 4.2 Weights for Rainfall at Four Rain Gauge Stations

Sub-Basin No.	Weights for Rain Gauge Stations			
	Karaia	Sultanganj	Bilehra	Dam Site
Sub-Basin 1	0.000	1.000	0.000	0.000
Sub-Basin 2	0.286	0.714	0.000	0.000
Sub-Basin 3	0.270	0.730	0.000	0.000
Sub-Basin 4	0.363	0.000	0.637	0.000
Sub-Basin 5	0.764	0.000	0.099	0.137
Sub-Basin 6	0.000	0.000	1.000	0.000
Sub-Basin 7	0.000	0.000	0.298	0.702
Sub-Basin 8	0.377	0.000	0.000	0.623

4.3 LANDUSE AND HYDROLOGIC SOIL GROUP

The landuse/land cover map was prepared using IRS 1-B (Path 27-Row 51, sub-scene-B2, LISS-II data) imageries of both Kharif and Rabi season during the year 1992-93 (Fig. 4.4). Visual interpretation technique was followed to prepare the landuse/land cover map of the Bewas river basin using remote sensing data on 1:50,000 scale. Five landuse/land cover classes could be identified in the basin based on the colour, tone, texture, shape, size and association of the objects in the imagery. Spatial distribution of all the five landuse classes in the eight sub-basins is given in the following Table 4.3. The soil information was collected from the soil map of central India, published by the National Atlas & Thematic Mapping Organisation, Department of Science & Technology, GOI, Culcutta. The whole catchment area falls under shallow and medium black soil under broad classification of Indian soils. These soils fall under group-C of hydrologic soil group.

78\45'

23/45

23°
45'

23°
30'

23°
30'

LEGEND

BASIN BOUNDARY
SCRUB
FOREST
ROCKY/BARREN
GOOD CROP
POOR CROP
SUB BASIN BOUNDARY

SCALE :- 1:2,50,000

FIG 4.4 :-LANDUSE/LANDCOVER MAP OF
THE STUDY AREA.

78°45'

78°30'

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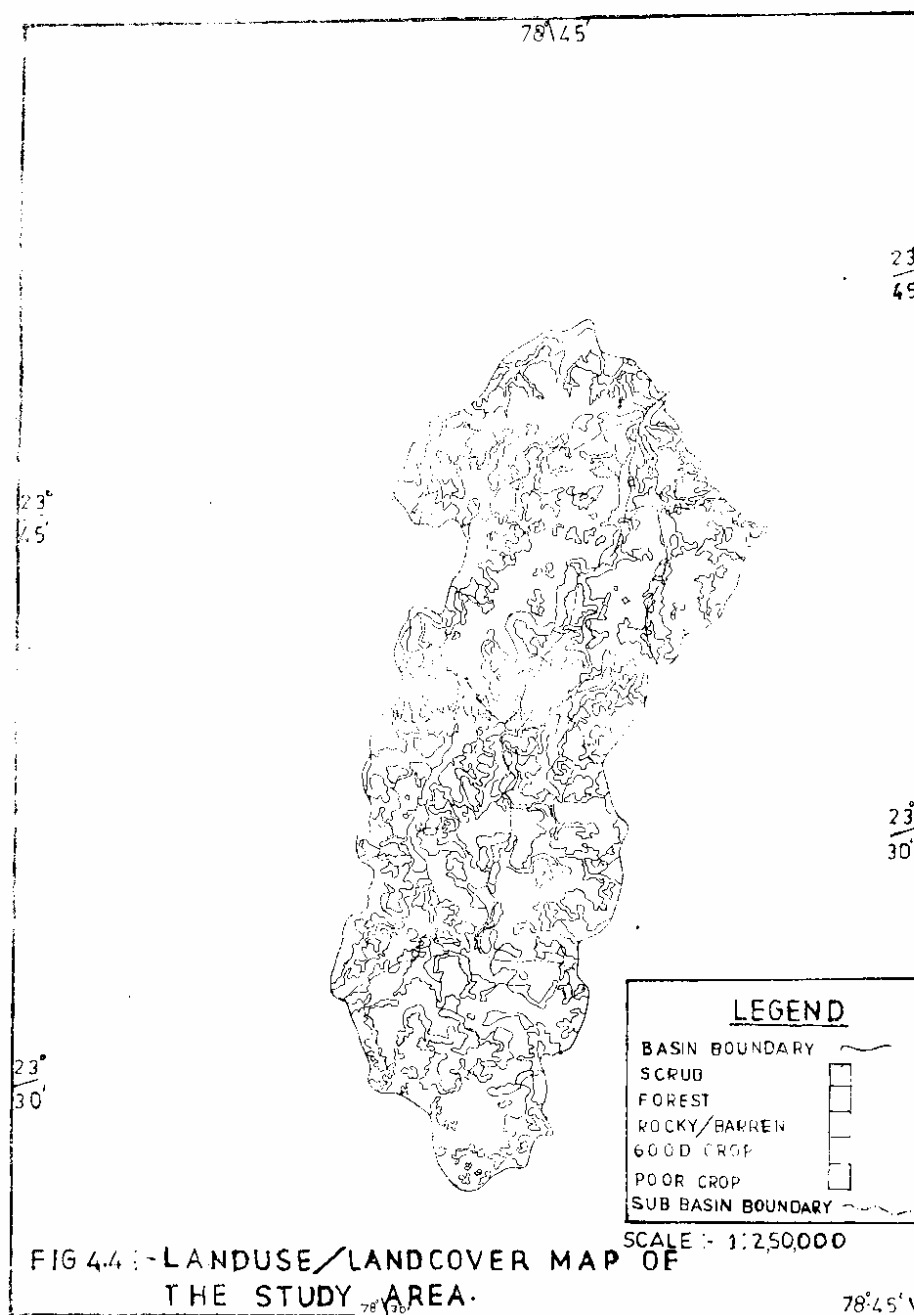
Table 4.3 Spatial Distribution of Landuse / Land Cover in Bewas Basin

Landuse Class	Sub-Basin-Wise Area (ha)								Total Area	% of Basin Area
	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8		
Wasteland	2.845	3.276	1.073	1.100	6.148	4.568	3.773	6.577	29.36	5.79
Shrub	8.474	6.105	14.127	9.108	14.002	4.545	4.160	18.689	79.21	15.62
Open forest	8.482	5.647	15.473	5.405	17.677	0.000	0.000	19.106	71.79	14.16
Good crop	63.740	38.353	35.189	26.935	50.279	19.145	7.133	23.494	264.268	52.11
Poor crop	11.710	13.674	22.289	6.971	6.726	0.000	0.000	1.122	62.492	12.32
Total	95.251	67.055	88.151	49.519	94.832	28.258	15.066	68.988	507.120	100.00

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4.4 DATABASE CREATION USING ARC/INFO GIS

In the present study, ARC/INFO GIS package has been used as the core of the spatial data base. A master template is created as a reference layer consisting of all the ticks, basin boundary, sub-basins boundaries etc. The tic maps and the basin boundary details from this master template have been used for all other map, to get the universal template.

The drainage map, Thiessen polygon map and the final interpreted map showing landuse/land cover of the basin were digitised and stored as coverage features in different layers, i.e. separate files. All the vectorised coverage data were processed for errors such as dangles, constituting the over-shoots or under-shoots and the label for polygons. The report of these errors were obtained and then a manual editing of these features were carried out in arc edit module. Finally the coverage is processed for topology creation.

The attribute codes for different categories are then verified and additional attributes such as features names, description etc., were included in the feature database. The spatial information and the area statistics were extracted from integration of different layers (maps) thus generated. Final maps were generated using the arc plot module. The symbols and colour palate available in the system were used to depict different categories.

5.0 RESULTS AND DISCUSSION

The most commonly used method to determine the rainfall excess (volume of runoff) is the SCS curve number procedure. In the present study, an attempt was made to estimate the runoff volume due to the rainfall occurred in the Bewas catchment area. Thus, the total volume of water flowing through the Bewas river at the proposed dam site during the monsoon period, i.e. 15th June to 15th October resulting from daily rainfall in the upstream catchment area was estimated using the SCS curve number method.

5.1 TIME OF CONCENTRATION

The time of concentration is the time a water particle takes to move from the most remote point in a watershed to the outlet. This longest flow path is called the hydraulic length. A commonly used time of concentration method is the following equation developed by Kirpich (1940):

$$t_c = 0.0195 \, L^{0.77} \, S^{-0.385} \qquad \qquad \ldots \ (5.1)$$

where L is the hydraulic length (maximum length) in m, S is the mean slope along the hydraulic length expressed as a fraction (m/m), and t_c is the time of concentration in minutes.

For Bewas basin, $L = 49000$ m and $S = 2.041 \times 10^{-3}$. Therefore,

$$t_c = 0.0195*(49000)^{0.77}*(0.002041)^{-0.385}$$
$$= 866 \text{ min} \approx 15 \text{ hours}$$

Since the time of concentration is less than 24 hours, therefore the average daily rainfall data computed for the eight sub-basins will contribute to the runoff water at the dam site on the same day.

5.2 Estimation of Runoff

In the present study Bewas river basin upto the proposed dam site was selected for estimation of water yield from the catchment area due to rainfall in the basin observed at the four rain gauge stations installed in the basin. This will be of help in operation of the reservoir if the real-time rainfall data is made available. The stored water will be utilised mainly for the municipal supply to the Sagar city by the Public Health Engineering Department, Sagar and the excess water will be used for other purposes. The total volume of water that come into the reservoir due to rainfall in the catchment area is being estimated by the P.H.E.D., Sagar by using conventional method of measuring surface velocity and depth of flow.

5.2.1 SCS Curve Number Method

The Bewas basin was divided into eight sub-basins such that the area of each sub-basin does not exceed 100 Sq. km Based on the spatial distribution of the sub-basins into the Thiessen polygons, weights were assigned to each rain gauge stations for the eight sub-basins. The average value of daily rainfall was calculated for all the eight sub-basins

The average value of curve number for all the sub-basins were calculated by assigning weights according to the area occupied by each landuse classes to the corresponding curve numbers given in the Table 2.1. Thus a single weighted average value of curve number was calculated for each sub-basins and for AMC I, II & III as given in the following Table 5.1. These weighted average curve number represents a variable index for the corresponding sub-basin and it is function of the landuse class, land cover soil complex and antecedent moisture condition.

Finally, the average daily rainfall and average curve number values were put in Eq. 2.5 in case of AMC-I and in Eq. 2.7 in case of AMC-II and AMC-III according to the 5-day antecedent soil moisture condition to get the depth of runoff contributed by each sub-basins. The mathematical calculations were carried-out using Microsoft Excel package to solve the equation 2.5 and 2.7 for various rainfall and curve numbers as input to these equations. The depth of

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runoff is then converted into volume of runoff and in Cu. Metre per Second (Cumecs) unit. The runoff volume thus obtained for each sub-basins were summed-up to get the total discharge at the dam site due to the rainfall occurred in the catchment area.

Table 5.1 Weighted Average Value of Runoff Curve Number

Sub-Basins in the Bewas Catchment	CN for Hydrologic Soil Group - C		
	Moisture Condition		
	AMC I	AMC II	AMC III
Sub-Basin - 1	64	81	92
Sub-Basin - 2	65	81	92
Sub-Basin - 3	63	79	91
Sub-Basin - 4	64	80	91
Sub-Basin - 5	63	79	91
Sub-Basin - 6	66	82	92
Sub-Basin - 7	66	81	92
Sub-Basin - 8	60	77	89

5.2.2 Observed Runoff

The Public Health Engineering department (P.H.E.D.), Sagar has estimated the total discharge (sum of the direct runoff and base flow) at the dam site by the conventional method. The cross-section of Bewas river was surveyed and a curve showing area verses depth was drawn. During the monsoon season, the surface velocity was measured by throwing a float in the river and the depth of flow at various points along the cross section were measured by the P.H.E. department. Knowing the depth of flow, cross section area was calculated using the Depth-area curve. By multiplying the average velocity and the area, total discharge in Cu. metre per second was estimated.

The total discharge was estimated at an interval of three hours and it was summed-up to get the daily discharge data. Fifteen hour time delay was also considered to get the daily runoff volume to avoid the time-lag between the observed and estimated runoff volume. Separate curves were drawn between the total daily discharge in Y-axis and the time (day) in the X-axis for the year 1993,

1994 1995 and 1997. Then, since the measured flow include both the direct runoff and the base flow, the base flow component was deducted from the total discharge to get the direct runoff volume.

The daily discharge data observed by the Public Health Engineering Department, Sagar at the dam site and the estimated runoff using the SCS curve number method for the year 1993, 1994, 1995 and 1996 were compared. The results are shown in two different ways, i.e. graphical presentation given in Fig. 5.1 to Fig. 5.4 and in tabular form given in the Table 5.3 to Table 5.6 in subsequent pages.

5.3 Comparison of Runoff

The discharge measured by the Public Health Engineering Department, Sagar and the direct runoff volume estimated using SCS curve number method were compared and month-wise correlation coefficient was calculated (Table 5.2) between observed and estimated daily runoff volume. In general good correlation was found. The intensity of the rainfall occurred during the month of June for the years 1995, 96 and during the month of October for the years 1993, 94 and 97 is quite less and does not produced any direct runoff, therefore no correlation was established. In the months of June, 1993 and September, 1994 the correlation is very poor. Since the rainfall occurred during these months are quite low, therefore the direct runoff volume estimated are very less than the observed discharge. This is because the actual initial abstractions in the catchment may be less than the assumed value. In general the correlation between the observed and predicted discharge is more than 0.92.

Table 5.2 Correlation Between Estimated and Observed Runoff

Year Period	Correlation Coefficient			
	1993	1994	1995	1997
15-30 June	0.202	0.993	*	*
01-31 July	0.992	0.943	0.952	0.924
01-31 August	0.968	0.950	0.852	0.971
01-30 September	0.856	0.749	0.973	0.918
01-15 October	*	*	0.938	*
Seasonal	0.936	0.926	0.939	0.941

* The value divided by zero. Hence, R cannot be calculated

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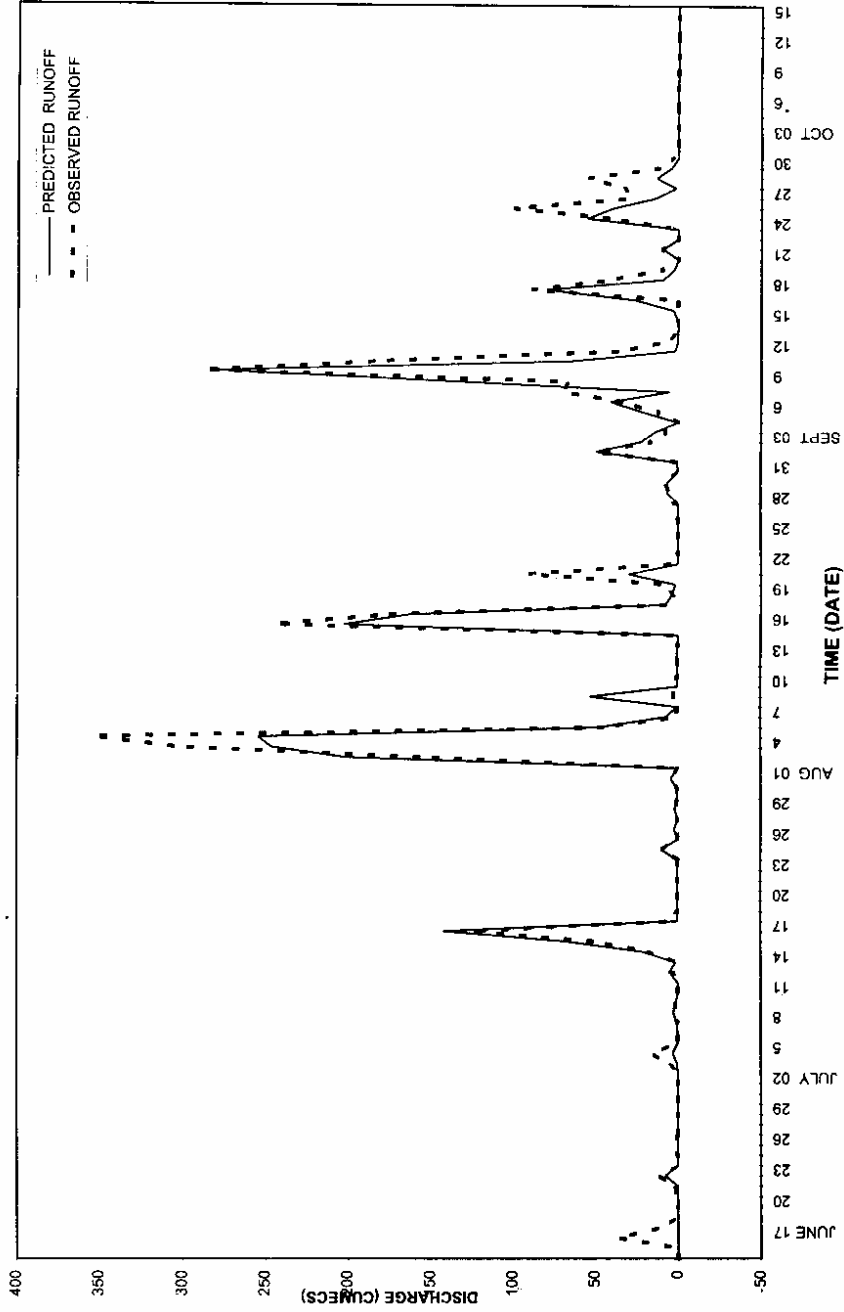
NIH, R C SAGAR

FIG. 5.1 PREDICTED AND OBSERVED RUNOFF DURING 1993

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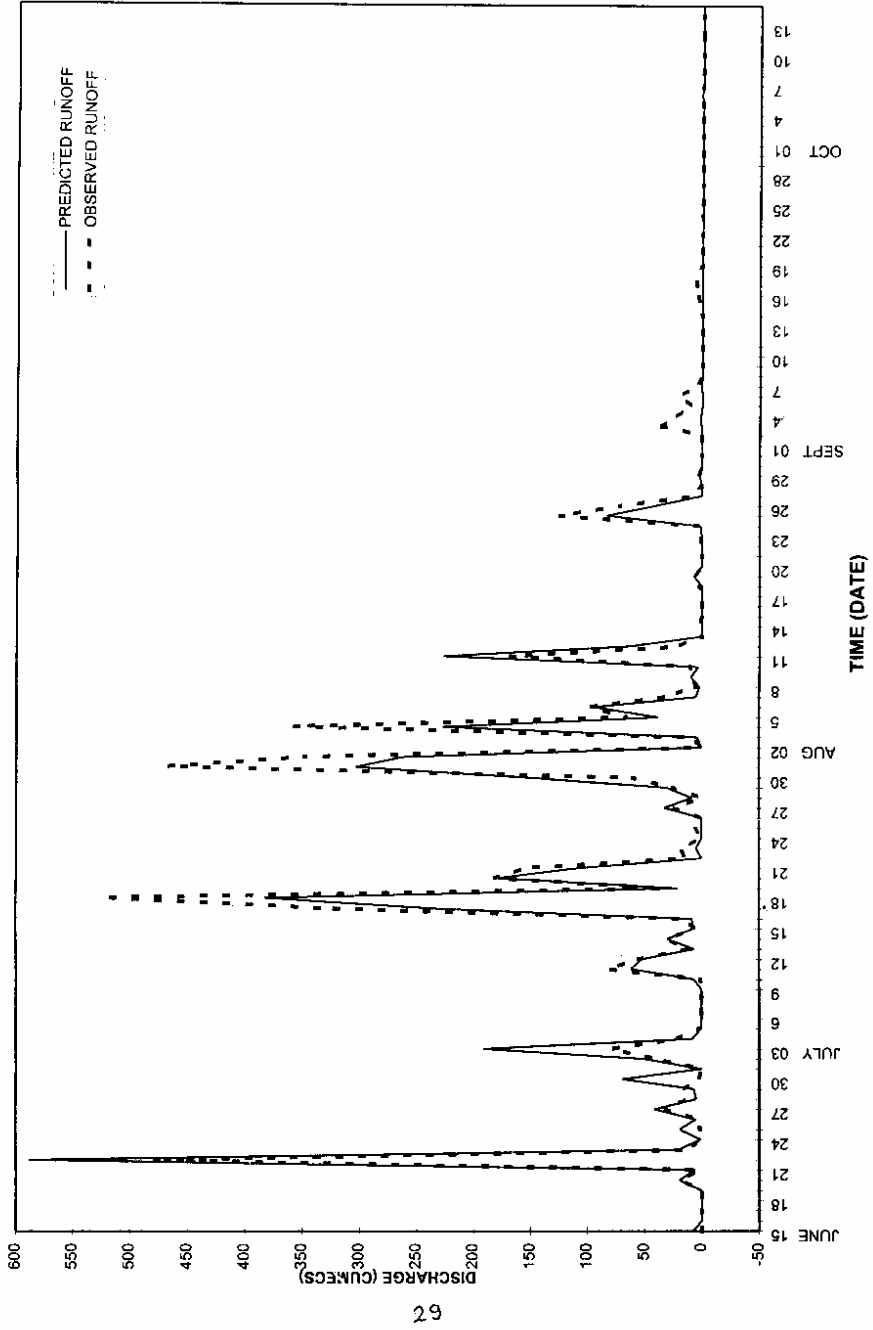
FIG.5.2 PREDICTED AND OBSERVED RUNOFF DURING 1994
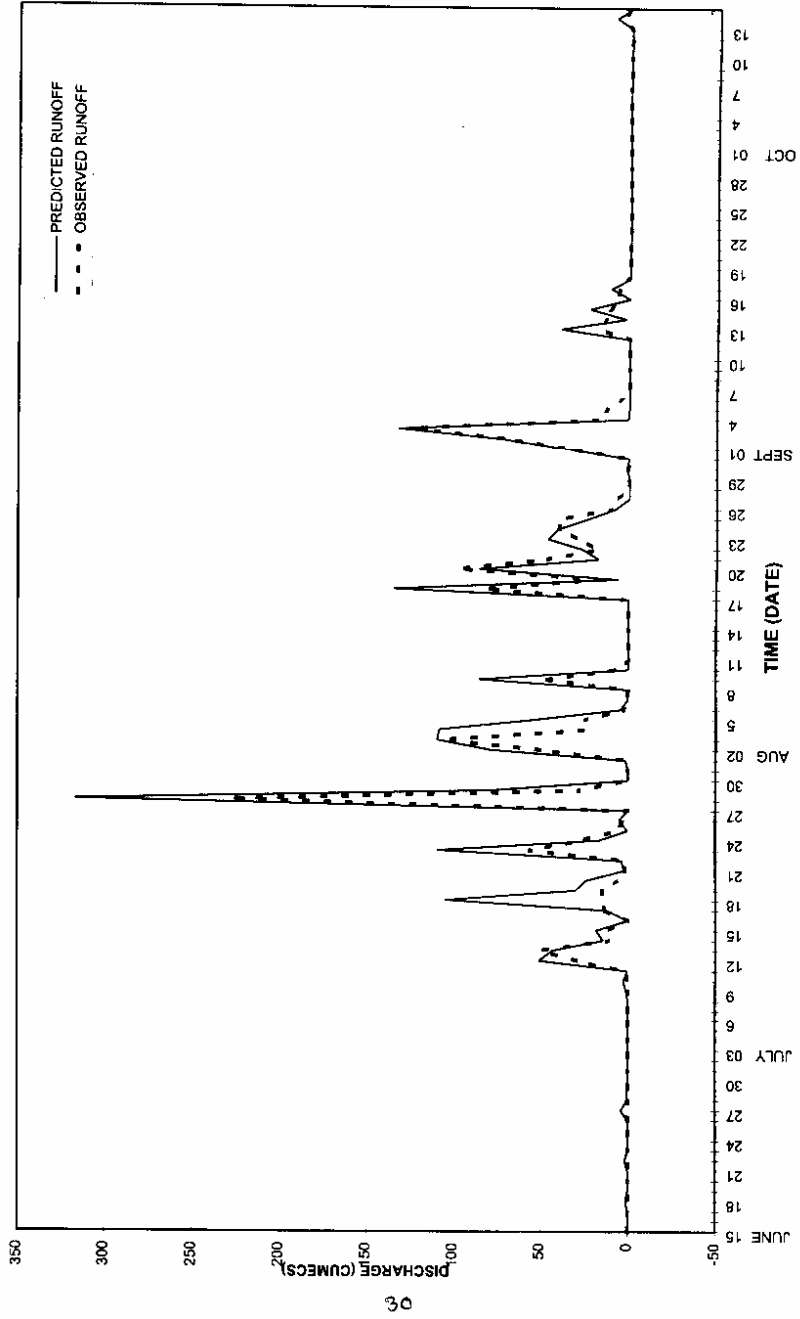
FIG. 5.3 PREDICTED AND OBSERVED RUNOFF DURING 1995
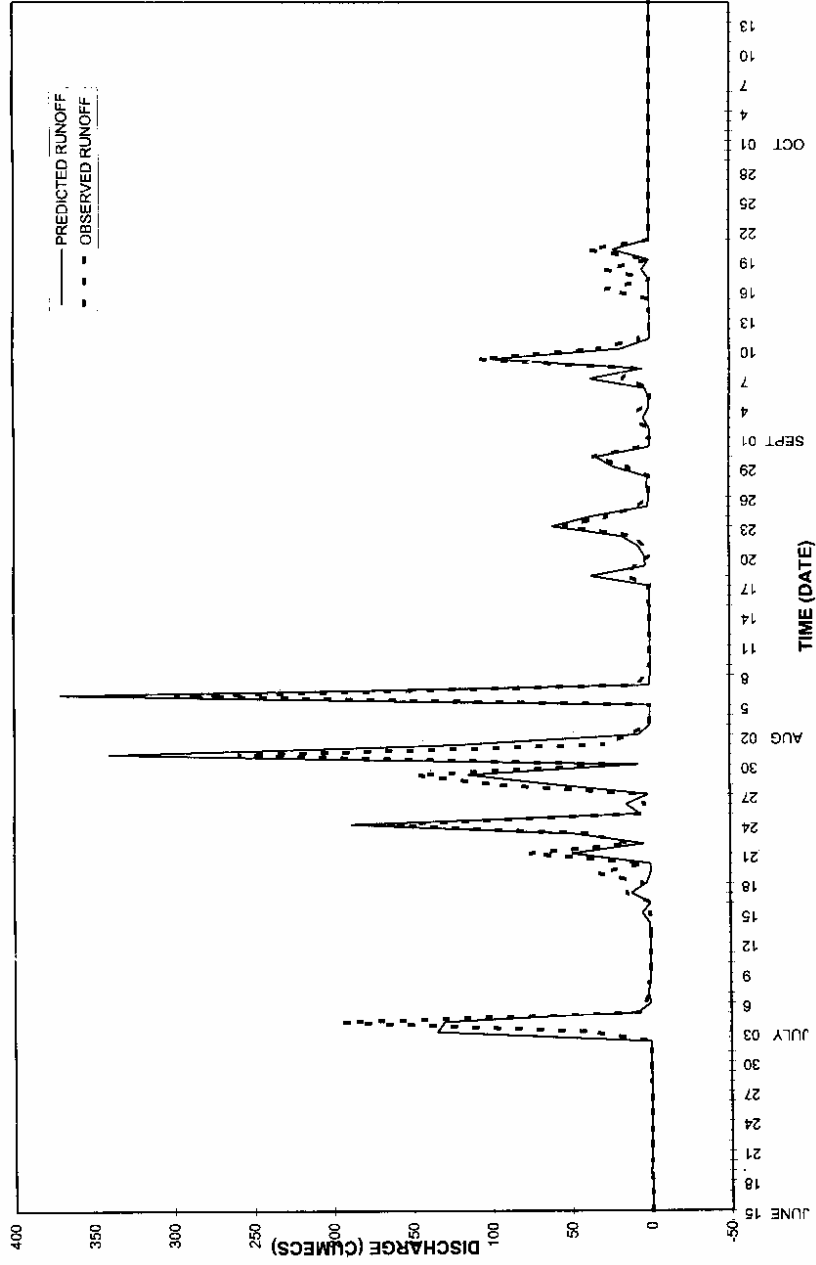
NIH, R C SAGAR

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NIH, R C SAGAR

PREDICTED RUNOFF
OBSERVED RUNOFF

FIG. 5.4 PREDICTED AND OBSERVED RUNOFF DURING 1997

DISCHARGE (CUMECS)

TIME (DATE)

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Table 5.3 Observed and Estimated Runoff During 1993

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1993, JUN 15	0.00	0.000	0.000	JUNE = 0.202
16	2.38	0.000	35.961	
17	1.65	0.000	9.987	
18	2.91	0.000	0.000	
19	0.00	0.000	0.000	
20	1.34	0.004	1.345	
21	0.00	0.000	1.638	
22	6.48	7.734	10.826	
23	0.00	0.000	0.000	
24	1.31	0.003	0.000	
25	0.32	0.000	1.652	
26	0.59	0.000	0.000	
27	0.00	0.000	0.000	
28	2.76	0.000	0.000	
29	0.72	0.000	0.000	
30	1.38	0.000	0.000	
1993, JUL 1	0.00	0.000	0.000	JULY = 0.992
2	0.04	0.000	0.000	
3	9.81	0.492	5.354	
4	12.08	3.145	15.579	
5	1.27	0.000	0.000	
6	1.90	0.000	0.000	
7	8.16	0.751	0.000	
8	9.70	2.680	2.449	
9	3.49	1.127	1.262	
10	0.51	0.000	0.000	
11	1.53	0.000	0.000	
12	9.65	5.114	3.221	
13	6.89	1.244	0.917	
14	24.18	20.895	17.372	
15	33.92	67.278	50.219	
16	39.46	142.279	125.219	
17	1.45	0.025	4.820	
18	0.00	0.000	0.000	
19	0.00	0.000	0.000	
20	0.00	0.000	0.000	
21	0.59	0.007	0.000	
22	0.82	0.000	0.000	
23	0.72	0.000	0.000	
24	10.00	9.950	9.360	
25	0.00	0.000	0.000	
26	3.58	2.132	0.000	

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Table 5.3 Observed and Estimated Runoff During 1993

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1993, JUL 27	0.61	0.000	0.000	
28	6.28	1.881	1.168	
29	3.32	0.253	0.469	
30	4.13	0.812	0.000	
31	7.59	4.134	3.396	
1993, AUG 1	3.70	0.207	0.000	AUG. = 0.968
2	54.78	201.619	152.463	
3	61.22	246.493	305.515	
4	63.33	254.613	352.931	
5	20.71	47.657	45.509	
6	6.12	7.515	0.920	
7	1.42	0.000	0.000	
8	21.66	53.162	2.526	
9	0.00	0.000	2.275	
10	0.00	0.000	0.000	
11	0.00	0.000	0.000	
12	2.25	0.653	0.000	
13	0.26	0.000	0.000	
14	1.45	0.014	0.000	
15	52.92	202.577	243.715	
16	46.24	162.277	174.281	
17	7.75	7.566	8.545	
18	6.61	3.621	2.649	
19	4.86	1.588	7.214	
20	14.59	29.802	90.119	
21	0.00	0.000	4.597	
22	0.00	0.000	0.000	
23	0.00	0.000	0.000	
24	0.00	0.000	0.000	
25	0.00	0.000	0.000	
26	0.00	0.000	0.000	
27	1.12	0.000	1.966	
28	9.47	6.555	4.566	
29	9.87	6.319	8.292	
30	0.88	0.000	1.562	
31	2.56	0.321	0.000	
1993, SEPT 1	20.35	49.433	48.628	SEPT. = 0.856
2	9.82	22.330	16.612	
3	7.89	14.235	7.537	
4	0.07	0.000	0.000	
5	14.23	21.248	11.722	
6	20.13	40.693	33.710	

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Table 5.3 Observed and Estimated Runoff During 1993

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1993, SEPT 7	5.55	5.014	69.474	
8	40.71	140.388	66.259	
9	68.19	281.233	286.754	
10	24.05	64.487	176.511	
11	4.74	1.728	33.530	
12	0.33	0.000	6.082	
13	0.00	0.000	0.000	
14	0.00	0.000	0.000	
15	4.69	2.847	0.000	
16	14.78	26.043	0.000	
17	28.60	79.691	88.219	
18	8.45	9.025	40.468	
19	5.75	2.304	9.453	
20	0.29	0.000	0.000	
21	6.20	9.104	9.020	
22	0.91	0.018	0.000	
23	0.89	0.000	0.000	
24	21.79	55.066	39.299	
25	18.73	39.845	99.119	
26	11.62	13.798	28.885	
27	3.17	1.593	32.588	
28	9.50	13.117	53.620	
29	4.37	4.182	11.989	
30	0.00	0.000	3.957	
1993, OCT 1	0.00	0.000	0.000	N.A.
2	0.00	0.000	0.000	
3	0.00	0.000	0.000	
4	0.00	0.000	0.000	
5	0.00	0.000	0.000	
6	0.00	0.000	0.000	
7	0.00	0.000	0.000	
8	0.00	0.000	0.000	
9	0.00	0.000	0.000	
10	0.00	0.000	0.000	
11	0.00	0.000	0.000	
12	0.00	0.000	0.000	
13	0.00	0.000	0.000	
14	0.00	0.000	0.000	
15	0.00	0.000	0.000	
Seasonal Total	973.05	2401.920	2885.296	0.938

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Table 5.4 Observed and Estimated Runoff During 1994

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1994, JUN 15	10.71	7.286	0.000	JUNE = 0.993
16	1.31	0.000	0.000	
17	2.31	0.000	0.000	
18	6.38	0.027	0.000	
19	1.37	0.000	0.000	
20	22.93	19.329	17.299	
21	6.53	5.750	2.299	
22	164.11	588.315	479.724	
23	23.11	20.566	10.637	
24	3.14	1.007	1.951	
25	12.46	19.346	1.105	
26	6.21	5.380	3.939	
27	18.89	41.529	31.102	
28	7.11	4.818	14.700	
29	5.99	6.814	14.248	
30	28.05	69.576	2.811	
1994, JUL 1	1.10	0.000	0.000	JULY = 0.943
2	23.60	50.540	40.727	
3	50.53	191.067	78.244	
4	7.73	8.070	21.639	
5	2.28	0.281	2.875	
6	0.31	0.000	0.000	
7	0.00	0.000	0.000	
8	0.00	0.000	0.000	
9	0.00	0.000	0.000	
10	8.26	6.792	1.203	
11	24.64	61.750	81.537	
12	22.15	52.447	54.357	
13	8.15	6.308	12.284	
14	14.97	29.980	29.454	
15	8.44	7.486	5.936	
16	9.06	8.394	16.864	
17	59.25	235.130	330.513	
18	86.66	383.039	522.979	
19	12.74	20.617	34.349	
20	49.11	179.540	180.639	
21	33.36	107.865	154.797	
22	1.51	0.000	14.452	
23	7.27	4.942	18.548	
24	0.00	0.000	0.000	
25	1.58	0.082	6.154	
26	1.48	0.009	1.621	

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Table 5.4 Observed and Estimated Runoff During 1994

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1994, JUL 27	16.38	32.497	23.709	
28	8.01	8.421	0.000	
29	13.50	30.562	24.932	
30	43.01	155.938	59.965	
31	72.24	303.571	466.850	
1994, AUG 1	64.12	262.165	348.101	AUG. = 0.950
2	0.00	0.000	0.000	
3	6.36	3.838	9.642	
4	57.88	227.257	356.741	
5	18.41	37.428	65.706	
6	31.49	93.924	96.642	
7	7.12	5.188	33.173	
8	3.84	1.980	5.356	
9	9.30	9.514	7.214	
10	5.60	2.982	10.601	
11	58.05	226.516	167.107	
12	24.40	63.755	21.298	
13	0.98	0.000	0.000	
14	1.23	0.030	1.181	
15	0.41	0.000	0.000	
16	0.60	0.000	0.000	
17	0.92	0.000	0.000	
18	1.42	0.004	2.122	
19	6.03	7.213	7.056	
20	0.00	0.000	0.000	
21	0.00	0.000	0.000	
22	0.00	0.000	0.000	
23	2.01	0.100	1.282	
24	4.54	1.037	3.670	
25	34.06	83.322	124.152	
26	18.37	40.989	71.392	
27	1.29	0.000	8.236	
28	0.00	0.000	0.000	
29	5.42	1.957	3.091	
30	2.36	0.402	0.000	
31	1.69	0.000	0.000	
1994, SEP 1	2.43	0.000	0.000	SEPT. = 0.749
2	5.40	0.072	0.312	
3	7.75	0.843	35.105	
4	7.19	1.144	21.999	
5	5.87	0.033	9.031	
6	4.71	0.016	19.987	

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Table 5.4 Observed and Estimated Runoff During 1994

Date	Average Rainfall (mm)	Runoff in Cumecs Predicted	Runoff in Cumecs Observed	Correlation Coefficient
1994, SEP 7	6.04	0.531	5.202	
8	0.00	0.000	0.000	
9	1.12	0.000	0.000	
10	0.00	0.000	0.000	
11	0.00	0.000	0.000	
12	0.00	0.000	0.000	
13	0.00	0.000	0.000	
14	0.00	0.000	0.000	
15	0.44	0.000	2.237	
16	2.79	0.000	3.969	
17	4.56	0.054	4.984	
18	7.50	0.597	5.154	
19	2.36	0.000	0.000	
20	4.64	0.002	0.000	
21	0.00	0.000	0.000	
22	0.00	0.000	0.000	
23	0.31	0.000	0.000	
24	0.41	0.000	0.000	
25	0.00	0.000	0.000	
26	0.00	0.000	0.000	
27	0.00	0.000	0.000	
28	0.00	0.000	0.000	
29	0.00	0.000	0.000	
30	0.00	0.000	0.000	
1994, OCT 1	0.00	0.000	0.000	N.A.
2	0.00	0.000	0.000	
3	0.00	0.000	0.000	
4	0.00	0.000	0.000	
5	0.00	0.000	0.000	
6	8.73	0.994	0.000	
7	0.60	0.000	0.000	
8	0.44	0.000	0.000	
9	0.00	0.000	0.000	
10	0.00	0.000	0.000	
11	0.00	0.000	0.000	
12	0.00	0.000	0.000	
13	0.47	0.000	0.000	
14	0.49	0.000	0.000	
15	0.00	0.000	0.000	
Seasonal Total	**1350.04**	**3748.960**	**4216.187**	**0.939**

Table 5.5 Observed and Estimated Runoff During 1995

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1995, JUN 15	0.51	0.000	0.000	N.A.
16	0.67	0.000	0.000	
17	3.23	0.000	0.000	
18	6.33	1.058	0.000	
19	0.22	0.000	0.000	
20	0.22	0.000	0.000	
21	7.16	0.000	0.000	
22	3.79	1.501	0.000	
23	0.00	0.000	0.000	
24	0.00	0.000	0.000	
25	0.00	0.000	0.000	
26	0.41	0.000	0.000	
27	14.33	3.739	0.000	
28	3.96	0.318	0.000	
29	1.61	0.065	0.000	
30	1.78	0.000	0.000	
1995, JUL 1	0.00	0.000	0.000	JULY = 0.952
2	0.00	0.000	0.000	
3	0.00	0.000	0.000	
4	0.00	0.000	0.000	
5	0.00	0.000	0.000	
6	0.00	0.000	0.000	
7	1.36	0.000	0.000	
8	0.00	0.000	0.000	
9	3.50	0.905	0.000	
10	7.72	2.458	0.000	
11	0.00	0.000	1.399	
12	33.61	50.800	29.307	
13	17.67	43.015	49.436	
14	12.75	13.942	10.807	
15	8.90	17.963	11.433	
16	0.51	0.000	0.000	
17	7.55	11.784	12.599	
18	35.06	104.560	14.694	
19	15.29	29.783	14.508	
20	14.04	24.039	6.736	
21	5.12	2.208	1.326	
22	6.29	3.450	1.762	
23	34.11	109.211	55.812	
24	12.24	16.653	27.184	
25	0.00	0.000	6.032	
26	5.97	4.887	2.371	

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Table 5.5 Observed and Estimated Runoff During 1995

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1995, JUL 27	0.00	0.000	0.000	
28	74.72	317.178	227.827	
29	28.14	78.320	27.839	
30	0.41	0.000	1.837	
31	0.00	0.000	0.000	
1995, AUG 1	5.00	1.538	1.011	AUG. = 0.852
2	27.39	78.571	49.167	
3	34.43	109.580	105.586	
4	34.03	108.469	24.069	
5	22.41	53.186	24.236	
6	6.94	4.592	2.721	
7	2.28	0.217	0.777	
8	0.00	0.000	0.000	
9	29.71	85.652	46.266	
10	1.36	0.052	7.474	
11	0.41	0.000	0.000	
12	0.29	0.000	0.000	
13	0.00	0.000	0.000	
14	0.51	0.000	0.000	
15	2.27	0.018	0.000	
16	0.72	0.000	0.000	
17	2.07	0.086	3.474	
18	36.46	134.821	82.334	
19	7.80	5.699	18.359	
20	30.43	85.734	97.367	
21	12.44	17.083	46.290	
22	14.98	26.761	17.400	
23	20.11	46.137	29.279	
24	19.17	40.365	40.087	
25	13.79	23.313	39.423	
26	8.09	7.715	10.200	
27	0.00	0.000	6.385	
28	0.00	0.000	0.000	
29	0.07	0.000	0.000	
30	3.65	1.431	0.762	
31	1.30	0.044	0.000	
1995, SEP 1	16.16	35.558	32.851	SEPT. = 0.973
2	26.46	73.186	70.184	
3	41.74	132.912	125.291	
4	2.25	0.653	16.141	
5	0.00	0.000	12.400	
6	0.00	0.000	5.505	

Table 5.5 Observed and Estimated Runoff During 1995

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1995, SEP 7	0.00	0.000	0.000	
8	0.00	0.000	0.000	
9	0.00	0.000	0.000	
10	0.00	0.000	0.000	
11	0.00	0.000	0.000	
12	0.51	0.000	0.000	
13	24.36	39.098	16.697	
14	7.43	1.996	13.332	
15	19.24	22.582	11.644	
16	0.00	0.000	6.543	
17	8.83	10.555	6.117	
18	1.88	0.065	1.120	
19	0.00	0.000	0.000	
20	0.00	0.000	0.000	
21	0.00	0.000	0.000	
22	0.00	0.000	0.000	
23	0.00	0.000	0.000	
24	0.00	0.000	0.000	
25	0.00	0.000	0.000	
26	0.00	0.000	0.000	
27	0.00	0.000	0.000	
28	0.00	0.000	0.000	
29	0.82	0.000	0.000	
30	0.00	0.000	0.000	
1995, OCT 1	0.00	0.000	0.000	OCT. = 0.938
2	0.00	0.000	0.000	
3	0.00	0.000	0.000	
4	0.00	0.000	0.000	
5	0.00	0.000	0.000	
6	0.00	0.000	0.000	
7	0.00	0.000	0.000	
8	0.00	0.000	0.000	
9	0.00	0.000	0.000	
10	0.00	0.000	0.000	
11	0.72	0.000	0.000	
12	0.31	0.000	0.000	
13	2.86	0.020	0.000	
14	13.45	8.563	3.958	
15	0.00	0.000	1.425	
Seasonal Total	**874.26**	**1994.088**	**1478.784**	**0.926**

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Table 5.6 Observed and Estimated Runoff During 1997

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1997, JUN 15	0.00	0.000	0.000	N.A.
16	0.00	0.000	0.000	
17	16.13	0.000	0.000	
18	0.00	0.000	0.000	
19	13.18	0.735	0.000	
20	0.00	0.000	0.000	
21	0.00	0.000	0.000	
22	0.00	0.000	0.000	
23	0.00	0.000	0.000	
24	0.00	0.000	0.000	
25	0.00	0.000	0.000	
26	0.00	0.000	0.000	
27	0.16	0.000	0.000	
28	3.02	0.000	0.000	
29	4.42	0.000	0.000	
30	3.99	0.000	0.000	
1997, JUL 1	0.00	0.000	0.000	JULY = 0.924
2	0.00	0.000	0.000	
3	58.07	134.703	38.840	
4	43.63	129.971	193.375	
5	8.23	8.325	7.875	
6	0.41	0.080	3.818	
7	4.32	1.818	1.154	
8	2.38	0.380	1.257	
9	0.72	0.000	0.316	
10	0.00	0.000	0.000	
11	0.00	0.000	0.000	
12	0.00	0.000	0.000	
13	0.00	0.000	0.000	
14	4.71	0.603	0.000	
15	6.64	4.999	0.307	
16	0.89	0.000	0.137	
17	13.72	11.819	14.410	
18	6.81	2.521	5.139	
19	1.64	0.004	32.221	
20	1.12	0.014	4.374	
21	25.45	49.459	75.115	
22	6.30	4.061	13.002	
23	22.99	47.147	39.682	
24	52.65	188.673	172.421	
25	7.69	6.007	4.496	
26	9.86	15.099	3.559	

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Table 5.6 Observed and Estimated Runoff During 1997

Date	Average Rainfall (mm)	Runoff in Cumecs Predicted	Runoff in Cumecs Observed	Correlation Coefficient
1997, JUL 27	3.07	1.003	6.622	
28	22.68	60.460	96.511	-
29	35.63	114.455	146.408	
30	8.15	7.053	17.339	
31	77.81	340.168	258.597	
1997, AUG 1	37.05	122.971	28.894	AUG. = 0.971
2	8.26	7.204	13.060	
3	0.00	0.000	0.000	
4	0.51	0.000	0.000	
5	0.00	0.000	0.000	
6	84.56	371.183	297.866	
7	1.19	0.115	8.757	
8	0.31	0.000	2.535	
9	0.00	0.000	0.000	
10	0.00	0.000	0.000	
11	1.26	0.013	0.000	
12	0.00	0.000	0.000	
13	1.57	0.071	0.000	
14	0.47	0.000	0.000	
15	1.45	0.000	0.000	
16	2.07	0.013	1.936	
17	0.13	0.000	0.000	
18	19.80	37.040	14.292	
19	5.72	2.553	8.569	
20	6.42	3.097	0.669	
21	8.55	6.694	3.060	
22	14.30	17.102	9.223	
23	24.12	60.855	53.026	
24	18.11	36.673	26.483	
25	3.93	1.072	6.326	
26	0.00	0.000	0.000	
27	1.19	1.430	0.368	
28	6.49	1.064	0.000	
29	13.13	22.577	13.496	
30	19.53	33.242	34.904	
31	0.77	0.000	5.612	
1997, SEP 1	0.00	0.000	0.000	SEPT. = 0.918
2	1.19	0.000	0.000	
3	6.49	3.851	15.985	
4	1.02	0.360	5.112	
5	1.03	0.005	0.000	
6	2.32	2.811	0.000	

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Table 5.6 Observed and Estimated Runoff During 1997

Date	Average Rainfall (mm)	Runoff in Cumecs		Correlation Coefficient
		Predicted	Observed	
1997, SEP 7	14.64	37.350	16.070	
8	6.94	4.347	8.172	
9	36.41	99.001	106.498	
10	9.47	17.738	32.225	
11	1.70	0.030	6.318	
12	1.78	0.004	0.000	
13	0.31	0.000	0.000	
14	0.00	0.000	0.000	
15	0.82	0.000	0.000	
16	4.93	0.052	26.429	
17	0.65	0.000	0.000	
18	7.34	4.429	26.475	
19	3.76	0.000	0.000	
20	22.95	22.887	36.836	
21	2.97	0.030	0.000	
22	0.00	0.000	0.000	
23	0.00	0.000	0.000	
24	0.00	0.000	0.000	
25	0.00	0.000	0.000	
26	0.00	0.000	0.000	
27	0.51	0.000	0.000	
28	2.16	0.000	0.000	
29	1.12	0.000	0.000	
30	0.13	0.000	0.000	
1997, OCT 1	0.72	0.000	0.000	N.A.
2	1.90	0.000	0.000	
3	1.25	0.000	0.000	
4	0.98	0.000	0.000	
5	1.09	0.000	0.000	
6	0.55	0.000	0.000	
7	0.44	0.000	0.000	
8	0.00	0.000	0.000	
9	0.00	0.000	0.000	
10	0.00	0.000	0.000	
11	0.00	0.000	0.000	
12	0.00	0.000	0.000	
13	0.00	0.000	0.000	
14	2.40	0.000	0.000	
15	0.31	0.000	0.000	
Seasonal Total	887.90	2116.328	1946.174	0.941

6.0 CONCLUSIONS

The conventional hydrological data are inadequate for purpose of design and operation of water resources systems. In such cases remote sensing data are of great value for the estimation of relevant hydrological data. Remote sensing data can serve as model input for the determination of river catchment characteristics, such as landuse/ land cover, geomorphology, slope, drainage etc. IRS-1B LISS-II data were used to generate landuse/land cover map of the catchment area.

The application of U.S.D.A., SCS curve number model is most commonly used for estimation of runoff from the catchment area. In the present study the SCS model was applied to estimate the runoff volume from the Bewas river basin falling in Sagar and Raisen districts of MP. The following conclusions may be drawn from the present study:

- The combination of remote sensing and SCS model makes the runoff estimate more accurate and fast

- Geographical Information System (GIS) arises as an efficient tool for the preparation of most of the input data (spatial and non-spatial) required by the SCS curve number model

- The runoff estimated from SCS curve number model are comparable with the observed runoff volume

- The analysis can be extended further to assess the impact of landuse changes after construction of the proposed dam on the rainfall-runoff relationship.

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Daily Rainfall (mm) Recorded in Bewas Basin

Year 1993	Rain Gauge Stations				Average * Rainfall
	Karaia	Sultanganj	Bilehra	Dam Site	
June, 15	0.000	0.000	0.000	0.000	0.00
16	0.000	0.000	0.000	18.200	2.38
17	0.000	0.000	0.000	12.600	1.65
18	0.000	0.000	0.000	22.200	2.91
19	0.000	0.000	0.000	0.000	0.00
20	0.000	0.000	0.000	10.250	1.34
21	0.000	0.000	0.000	0.000	0.00
22	0.000	0.000	0.000	49.500	6.48
23	0.000	0.000	0.000	0.000	0.00
24	0.000	0.000	0.000	10.000	1.31
25	0.000	0.000	0.000	2.450	0.32
26	0.000	0.000	0.000	4.500	0.59
27	0.000	0.000	0.000	0.000	0.00
28	0.000	6.750	0.000	0.000	2.76
29	0.000	1.750	0.000	0.000	0.72
30	0.000	0.000	9.500	0.000	1.38
July, 1	0.000	0.000	0.000	0.000	0.00
2	0.000	0.000	0.250	0.000	0.04
3	7.250	11.000	15.250	6.250	9.81
4	8.250	20.500	3.750	4.250	12.08
5	1.000	2.250	0.250	0.000	1.27
6	0.000	4.250	0.000	1.250	1.90
7	5.500	5.250	13.500	17.750	8.16
8	5.500	15.750	8.750	2.000	9.70
9	1.000	7.500	0.750	0.000	3.49
10	0.000	1.250	0.000	0.000	0.51
11	0.000	3.750	0.000	0.000	1.53
12	0.000	20.750	8.000	0.000	9.65
13	4.500	3.250	6.500	24.500	6.89
14	47.500	8.000	37.250	4.500	24.18
15	28.250	36.750	35.000	37.750	33.92
16	9.000	74.000	20.000	26.500	39.46
17	0.000	2.750	0.000	2.500	1.45
18	0.000	0.000	0.000	0.000	0.00
19	0.000	0.000	0.000	0.000	0.00
20	0.000	0.000	0.000	0.000	0.00
21	0.000	0.000	0.000	4.500	0.59
22	0.000	2.000	0.000	0.000	0.82
23	0.000	1.750	0.000	0.000	0.72
24	8.250	1.500	10.750	40.000	10.00
25	0.000	0.000	0.000	0.000	0.00
26	0.000	8.750	0.000	0.000	3.58

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Daily Rainfall (mm) Recorded in Bewas Basin

Year	Rain Gauge Stations				Average *
1993	Karaia	Sultanganj	Bilehra	Dam Site	Rainfall
July, 27	0.000	1.500	0.000	0.000	0.61
28	1.750	6.250	6.750	16.750	6.28
29	5.500	2.250	1.250	3.750	3.32
30	3.000	5.750	1.250	5.000	4.13
31	9.250	1.500	17.500	11.750	7.59
August, 1	3.250	3.500	4.750	4.250	3.70
2	66.000	25.000	88.000	84.500	54.78
3	55.000	84.750	25.000	43.250	61.22
4	72.250	54.750	42.750	92.000	63.33
5	29.000	11.000	32.500	18.250	20.71
6	0.750	13.500	0.000	2.750	6.12
7	1.000	2.250	1.250	0.000	1.42
8	11.750	32.750	18.750	14.200	21.66
9	0.000	0.000	0.000	0.000	0.00
10	0.000	0.000	0.000	0.000	0.00
11	0.000	0.000	0.000	0.000	0.00
12	0.000	5.500	0.000	0.000	2.25
13	0.000	0.000	0.000	2.000	0.26
14	0.000	2.750	0.000	2.500	1.45
15	26.250	86.500	37.500	29.500	52.92
16	48.500	53.000	46.500	19.750	46.24
17	0.000	12.000	4.000	17.250	7.75
18	5.250	7.000	7.250	8.000	6.61
19	8.250	3.000	1.750	6.000	4.86
20	9.750	25.500	3.500	4.500	14.59
21	0.000	0.000	0.000	0.000	0.00
22	0.000	0.000	0.000	0.000	0.00
23	0.000	0.000	0.000	0.000	0.00
24	0.000	0.000	0.000	0.000	0.00
25	0.000	0.000	0.000	0.000	0.00
26	0.000	0.000	0.000	0.000	0.00
27	0.000	2.750	0.000	0.000	1.12
28	6.500	3.500	14.000	30.250	9.47
29	8.000	10.000	13.250	10.250	9.87
30	1.750	0.000	0.000	2.500	0.88
31	0.000	6.250	0.000	0.000	2.56
September, 1	3.000	45.500	3.000	2.750	20.35
2	0.000	24.000	0.000	0.000	9.82
3	0.000	18.750	1.500	0.000	7.89
4	0.000	0.000	0.500	0.000	0.07
5	19.750	13.000	16.000	3.000	14.23
6	37.750	14.000	7.000	11.750	20.13

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Daily Rainfall (mm) Recorded in Bewas Basin

Year 1993	Rain Gauge Stations				Average * Rainfall
	Karaia	Sultanganj	Bilehra	Dam Site	
September, 7	1.500	2.250	26.000	3.000	5.55
8	53.500	17.000	53.750	69.950	40.71
9	52.750	78.500	64.500	77.500	68.18
10	16.750	38.000	12.000	11.500	24.05
11	3.750	2.750	8.250	9.500	4.74
12	0.000	0.000	0.000	2.500	0.33
13	0.000	0.000	0.000	0.000	0.00
14	0.000	0.000	0.000	0.000	0.00
15	6.500	1.250	12.500	2.500	4.69
16	21.000	7.500	24.250	12.250	14.78
17	37.000	21.250	16.750	44.750	28.60
18	8.500	4.000	19.750	9.750	8.45
19	6.750	5.250	5.250	5.500	5.75
20	0.000	0.000	2.000	0.000	0.29
21	1.500	0.000	9.000	33.750	6.20
22	1.000	0.750	2.000	0.000	0.91
23	0.000	1.250	1.000	1.750	0.89
24	8.250	38.250	11.000	15.000	21.79
25	19.750	26.250	4.000	9.250	18.73
26	12.500	10.500	16.000	8.250	11.62
27	3.750	0.000	11.000	3.000	3.17
28	1.750	10.250	29.000	4.250	9.50
29	0.000	10.500	0.500	0.000	4.37
30	0.000	0.000	0.000	0.000	0.00
October, 1	0.000	0.000	0.000	0.000	0.00
2	0.000	0.000	0.000	0.000	0.00
3	0.000	0.000	0.000	0.000	0.00
4	0.000	0.000	0.000	0.000	0.00
5	0.000	0.000	0.000	0.000	0.00
6	0.000	0.000	0.000	0.000	0.00
7	0.000	0.000	0.000	0.000	0.00
8	0.000	0.000	0.000	0.000	0.00
9	0.000	0.000	0.000	0.000	0.00
10	0.000	0.000	0.000	0.000	0.00
11	0.000	0.000	0.000	0.000	0.00
12	0.000	0.000	0.000	0.000	0.00
13	0.000	0.000	0.000	0.000	0.00
14	0.000	0.000	0.000	0.000	0.00
15	0.000	0.000	0.000	0.000	0.00
Seasonal Total					973.05

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Daily Rainfall (mm) Recorded in Bewas Basin

Year 1994	Rain Gauge Stations				Average * Rainfall
	Karaia	Sultanganj	Bilehra	Dam Site	
June, 15	2.500	2.750	37.400	25.750	10.71
16	0.500	1.000	4.000	1.250	1.31
17	0.000	5.250	0.000	1.250	2.31
18	0.000	11.250	1.000	12.500	6.38
19	0.000	2.250	2.000	1.250	1.37
20	11.000	23.250	28.750	44.250	22.93
21	2.250	14.250	0.000	0.000	6.53
22	157.000	166.250	174.250	164.500	164.11
23	25.500	25.250	18.000	16.500	23.11
24	10.000	0.000	0.000	0.000	3.14
25	18.000	5.750	5.000	28.500	12.46
26	16.000	0.250	7.500	0.000	6.21
27	33.000	6.750	16.500	25.750	18.89
28	13.250	4.250	2.500	6.500	7.11
29	5.000	0.750	3.500	27.500	5.99
30	27.500	23.500	31.000	40.500	28.05
July, 1	2.000	0.750	0.000	1.250	1.10
2	29.000	25.750	9.000	20.250	23.60
3	52.000	70.250	19.000	20.750	50.53
4	1.250	13.500	5.500	7.750	7.73
5	1.500	4.250	0.500	0.000	2.28
6	0.000	0.750	0.000	0.000	0.31
7	0.000	0.000	0.000	0.000	0.00
8	0.000	0.000	0.000	0.000	0.00
9	0.000	0.000	0.000	0.000	0.00
10	4.500	9.250	8.000	14.500	8.26
11	30.000	21.000	22.000	26.250	24.64
12	22.000	16.250	36.000	25.750	22.15
13	9.500	7.000	8.000	8.750	8.15
14	2.000	26.000	7.500	20.000	14.97
15	11.500	9.000	2.500	6.000	8.44
16	9.250	8.750	11.000	7.500	9.06
17	52.000	75.500	58.000	27.750	59.25
18	78.000	97.500	81.000	80.500	86.66
19	5.000	14.750	28.000	8.250	12.74
20	40.000	47.250	61.000	64.000	49.11
21	37.750	11.250	75.000	46.000	33.36
22	2.000	1.250	1.000	1.750	1.51
23	4.000	6.750	10.000	13.750	7.27
24	0.000	0.000	0.000	0.000	0.00
25	0.000	3.500	1.000	0.000	1.58
26	0.000	2.000	3.000	1.750	1.48

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Daily Rainfall (mm) Recorded in Bewas Basin

Year 1994	Rain Gauge Stations				Average * Rainfall
	Karaia	Sultanganj	Bilehra	Dam Site	
July, 27	14.000	18.250	0.000	34.500	16.38
28	2.000	12.250	13.000	3.750	8.01
29	3.500	28.000	0.000	7.250	13.50
30	20.000	71.500	11.000	45.000	43.01
31	75.000	75.500	79.000	48.500	72.24
August, 1	25.000	94.500	49.000	80.250	64.12
2	0.000	0.000	0.000	0.000	0.00
3	4.000	8.750	6.000	5.000	6.36
4	83.750	32.000	81.000	51.500	57.88
5	28.500	15.500	10.000	12.750	18.41
6	14.500	39.000	22.000	59.500	31.49
7	2.000	8.250	5.000	18.250	7.12
8	2.000	7.500	1.000	0.000	3.84
9	7.500	8.000	17.000	9.250	9.30
10	11.000	5.250	0.000	0.000	5.60
11	72.500	44.500	41.000	85.000	58.05
12	28.000	13.500	49.000	22.750	24.40
13	1.500	1.250	0.000	0.000	0.98
14	0.000	3.000	0.000	0.000	1.23
15	0.000	1.000	0.000	0.000	0.41
16	1.500	0.000	0.000	1.000	0.60
17	0.000	2.250	0.000	0.000	0.92
18	0.000	2.500	0.000	3.000	1.42
19	0.000	5.250	25.000	2.000	6.03
20	0.000	0.000	0.000	0.000	0.00
21	0.000	0.000	0.000	0.000	0.00
22	0.000	0.000	0.000	0.000	0.00
23	1.750	3.500	0.000	0.250	2.01
24	4.500	4.000	8.000	2.500	4.54
25	60.500	15.500	45.000	16.750	34.06
26	4.250	12.000	54.500	32.250	18.37
27	1.500	1.750	0.000	0.750	1.29
28	0.000	0.000	0.000	0.000	0.00
29	6.000	3.750	7.500	7.000	5.42
30	7.500	0.000	0.000	0.000	2.36
31	2.000	2.250	1.000	0.000	1.69
September, 1	3.500	3.250	0.000	0.000	2.43
2	2.000	7.000	5.000	9.000	5.40
3	7.500	7.750	9.000	7.000	7.75
4	11.000	4.500	9.000	4.500	7.19
5	8.000	6.250	1.000	5.000	5.87
6	7.500	5.000	1.000	1.250	4.71

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Daily Rainfall (mm) Recorded in Bewas Basin

Year	Rain Gauge Stations				Average *
1994	Karaia	Sultanganj	Bilehra	Dam Site	Rainfall
September, 7	7.000	5.500	8.000	3.300	6.04
8	0.000	0.000	0.000	0.000	0.00
9	0.000	2.750	0.000	0.000	1.12
10	0.000	0.000	0.000	0.000	0.00
11	0.000	0.000	0.000	0.000	0.00
12	0.000	0.000	0.000	0.000	0.00
13	0.000	0.000	0.000	0.000	0.00
14	0.000	0.000	0.000	0.000	0.00
15	0.000	0.000	3.000	0.000	0.44
16	4.000	3.750	0.000	0.000	2.79
17	11.000	2.000	2.000	0.000	4.56
18	15.750	6.250	0.000	0.000	7.50
19	7.500	0.000	0.000	0.000	2.36
20	9.250	4.250	0.000	0.000	4.64
21	0.000	0.000	0.000	0.000	0.00
22	0.000	0.000	0.000	0.000	0.00
23	0.000	0.750	0.000	0.000	0.31
24	0.000	1.000	0.000	0.000	0.41
25	0.000	0.000	0.000	0.000	0.00
26	0.000	0.000	0.000	0.000	0.00
27	0.000	0.000	0.000	0.000	0.00
28	0.000	0.000	0.000	0.000	0.00
29	0.000	0.000	0.000	0.000	0.00
30	0.000	0.000	0.000	0.000	0.00
October, 1	0.000	0.000	0.000	0.000	0.00
2	0.000	0.000	0.000	0.000	0.00
3	0.000	0.000	0.000	0.000	0.00
4	0.000	0.000	0.000	0.000	0.00
5	0.000	0.000	0.000	0.000	0.00
6	14.500	4.250	8.000	9.750	8.73
7	0.000	0.750	2.000	0.000	0.60
8	0.000	0.000	3.000	0.000	0.44
9	0.000	0.000	0.000	0.000	0.00
10	0.000	0.000	0.000	0.000	0.00
11	0.000	0.000	0.000	0.000	0.00
12	0.000	0.000	0.000	0.000	0.00
13	1.500	0.000	0.000	0.000	0.47
14	1.250	0.000	0.000	0.750	0.49
15	0.000	0.000	0.000	0.000	0.00
Seasonal Total					1350.04

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Daily Rainfall (mm) Recorded in Bewas Basin

Year 1995	Rain Gauge Stations				Average * Rainfall
	Karaia	Sultanganj	Bilehra	Dam Site	
June, 15	0.000	1.250	0.000	0.000	0.51
16	0.500	1.250	0.000	0.000	0.67
17	0.500	1.750	0.000	18.000	3.23
18	0.000	2.250	1.500	39.600	6.33
19	0.000	0.000	1.500	0.000	0.22
20	0.000	0.000	1.500	0.000	0.22
21	7.500	10.500	3.500	0.000	7.16
22	0.000	0.750	24.000	0.000	3.79
23	0.000	0.000	0.000	0.000	0.00
24	0.000	0.000	0.000	0.000	0.00
25	0.000	0.000	0.000	0.000	0.00
26	0.000	1.000	0.000	0.000	0.41
27	23.500	6.500	21.000	9.500	14.33
28	0.000	5.000	13.000	0.250	3.96
29	0.000	0.750	9.000	0.000	1.61
30	2.750	2.250	0.000	0.000	1.78
July, 1	0.000	0.000	0.000	0.000	0.00
2	0.000	0.000	0.000	0.000	0.00
3	0.000	0.000	0.000	0.000	0.00
4	0.000	0.000	0.000	0.000	0.00
5	0.000	0.000	0.000	0.000	0.00
6	0.000	0.000	0.000	0.000	0.00
7	0.000	3.250	0.000	0.250	1.36
8	0.000	0.000	0.000	0.000	0.00
9	0.000	0.000	2.000	24.500	3.50
10	0.000	17.250	3.000	1.750	7.72
11	0.000	0.000	0.000	0.000	0.00
12	59.250	29.500	4.000	18.000	33.61
13	0.000	42.500	2.000	0.000	17.67
14	23.250	3.750	15.000	13.250	12.75
15	0.000	21.250	1.000	0.500	8.90
16	0.000	1.250	0.000	0.000	0.51
17	0.000	17.000	3.000	1.250	7.55
18	41.750	30.750	31.000	37.250	35.06
19	7.750	25.250	12.000	6.000	15.29
20	13.000	17.750	17.000	1.750	14.04
21	4.000	5.250	10.000	2.000	5.12
22	6.000	4.250	6.000	13.750	6.29
23	37.250	13.750	48.000	75.000	34.11
24	13.750	11.250	15.000	8.750	12.24
25	0.000	0.000	0.000	0.000	0.00
26	5.000	3.500	18.000	2.750	5.97

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Daily Rainfall (mm) Recorded in Bewas Basin

Year	Rain Gauge Stations				Average *
1995	Karaia	Sultanganj	Bilehra	Dam Site	Rainfall
July, 27	0.000	0.000	0.000	0.000	0.00
28	70.750	60.250	114.000	86.500	74.72
29	36.500	19.000	42.000	21.500	28.14
30	0.000	0.000	1.000	2.000	0.41
31	0.000	0.000	0.000	0.000	0.00
August, 1	7.250	4.000	5.000	2.750	5.00
2	15.500	36.750	44.000	8.500	27.39
3	52.000	38.500	9.000	8.000	34.43
4	54.500	16.500	62.000	9.000	34.03
5	18.500	25.750	24.000	19.750	22.41
6	9.000	7.750	2.000	5.000	6.94
7	2.500	1.250	0.000	7.500	2.28
8	0.000	0.000	0.000	0.000	0.00
9	34.500	17.750	43.000	41.100	29.71
10	0.000	3.250	0.000	0.250	1.36
11	0.000	1.000	0.000	0.000	0.41
12	0.000	0.000	2.000	0.000	0.29
13	0.000	0.000	0.000	0.000	0.00
14	0.000	1.250	0.000	0.000	0.51
15	1.500	2.250	2.000	4.500	2.27
16	0.000	1.750	0.000	0.000	0.72
17	0.000	3.500	1.000	3.750	2.07
18	22.750	13.000	163.000	2.750	36.46
19	15.000	4.250	5.000	4.750	7.80
20	22.500	37.250	38.000	20.000	30.43
21	26.500	7.250	0.000	8.800	12.44
22	25.000	13.500	0.000	12.250	14.98
23	31.500	22.000	8.000	0.500	20.11
24	27.000	16.250	20.000	8.750	19.17
25	30.500	8.000	4.000	2.750	13.79
26	8.500	11.000	0.000	7.000	8.09
27	0.000	0.000	0.000	0.000	0.00
28	0.000	0.000	0.000	0.000	0.00
29	0.000	0.000	0.000	0.500	0.07
30	0.000	3.750	11.000	4.000	3.65
31	0.000	1.750	4.000	0.000	1.30
September, 1	3.500	21.500	40.000	3.600	16.16
2	9.000	30.250	63.000	16.200	26.46
3	37.250	33.750	64.000	53.160	41.74
4	0.000	5.500	0.000	0.000	2.25
5	0.000	0.000	0.000	0.000	0.00
6	0.000	0.000	0.000	0.000	0.00

Daily Rainfall (mm) Recorded in Bewas Basin

| Year | Rain Gauge Stations | | | | Average * |
1995	Karaia	Sultanganj	Bilehra	Dam Site	Rainfall
September, 7	0.000	0.000	0.000	0.000	0.00
8	0.000	0.000	0.000	0.000	0.00
9	0.000	0.000	0.000	0.000	0.00
10	0.000	0.000	0.000	0.000	0.00
11	0.000	0.000	0.000	0.000	0.00
12	0.000	1.250	0.000	0.000	0.51
13	11.000	33.250	38.000	13.710	24.36
14	12.000	8.250	2.000	0.000	7.43
15	17.000	17.250	35.000	13.500	19.24
16	0.000	0.000	0.000	0.000	0.00
17	4.000	12.500	17.000	0.000	8.83
18	0.000	0.000	0.000	14.330	1.88
19	0.000	0.000	0.000	0.000	0.00
20	0.000	0.000	0.000	0.000	0.00
21	0.000	0.000	0.000	0.000	0.00
22	0.000	0.000	0.000	0.000	0.00
23	0.000	0.000	0.000	0.000	0.00
24	0.000	0.000	0.000	0.000	0.00
25	0.000	0.000	0.000	0.000	0.00
26	0.000	0.000	0.000	0.000	0.00
27	0.000	0.000	0.000	0.000	0.00
28	0.000	0.000	0.000	0.000	0.00
29	0.000	2.000	0.000	0.000	0.82
30	0.000	0.000	0.000	0.000	0.00
October, 1	0.000	0.000	0.000	0.000	0.00
2	0.000	0.000	0.000	0.000	0.00
3	0.000	0.000	0.000	0.000	0.00
4	0.000	0.000	0.000	0.000	0.00
5	0.000	0.000	0.000	0.000	0.00
6	0.000	0.000	0.000	0.000	0.00
7	0.000	0.000	0.000	0.000	0.00
8	0.000	0.000	0.000	0.000	0.00
9	0.000	0.000	0.000	0.000	0.00
10	0.000	0.000	0.000	0.000	0.00
11	0.000	1.750	0.000	0.000	0.72
12	0.000	0.750	0.000	0.000	0.31
13	0.000	7.000	0.000	0.000	2.86
14	33.000	0.000	15.000	7.000	13.45
15	0.000	0.000	0.000	0.000	0.00
Seasonal Total					874.26

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Daily Rainfall (mm) Recorded in Bewas Basin

Year 1997	Rain Gauge Stations				Average * Rainfall
	Karaia	Sultanganj	Bilehra	Dam Site	
June, 15	0.000	0.000	0.000	0.000	0.00
16	0.000	0.000	0.000	0.000	0.00
17	18.000	12.500	37.000	0.000	16.13
18	0.000	0.000	0.000	0.000	0.00
19	5.500	16.250	18.000	16.750	13.18
20	0.000	0.000	0.000	0.000	0.00
21	0.000	0.000	0.000	0.000	0.00
22	0.000	0.000	0.000	0.000	0.00
23	0.000	0.000	0.000	0.000	0.00
24	0.000	0.000	0.000	0.000	0.00
25	0.000	0.000	0.000	0.000	0.00
26	0.000	0.000	0.000	0.000	0.00
27	0.000	0.000	0.000	1.250	0.16
28	8.000	1.250	0.000	0.000	3.02
29	2.000	3.250	2.500	16.000	4.42
30	0.000	9.750	0.000	0.000	3.99
July, 1	0.000	0.000	0.000	0.000	0.00
2	0.000	0.000	0.000	0.000	0.00
3	63.500	55.750	56.000	55.000	58.07
4	57.250	32.250	60.000	28.750	43.63
5	6.000	4.000	11.000	23.750	8.23
6	0.000	1.000	0.000	0.000	0.41
7	2.000	7.250	3.000	2.250	4.32
8	0.000	4.750	3.000	0.000	2.38
9	0.000	1.750	0.000	0.000	0.72
10	0.000	0.000	0.000	0.000	0.00
11	0.000	0.000	0.000	0.000	0.00
12	0.000	0.000	0.000	0.000	0.00
13	0.000	0.000	0.000	0.000	0.00
14	15.000	0.000	0.000	0.000	4.71
15	0.000	12.250	7.200	4.500	6.64
16	0.000	0.000	3.200	3.250	0.89
17	10.000	13.250	16.800	20.800	13.72
18	6.500	8.250	4.000	6.250	6.81
19	0.000	2.500	1.800	2.750	1.64
20	0.000	2.750	0.000	0.000	1.12
21	32.500	16.250	48.000	12.500	25.45
22	4.000	10.750	2.000	2.750	6.30
23	25.250	26.500	15.600	15.000	22.99
24	60.250	49.750	58.200	37.750	52.65
25	13.500	6.500	3.200	2.500	7.69
26	5.000	18.250	3.000	3.000	9.86

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Daily Rainfall (mm) Recorded in Bewas Basin

Year 1997	Rain Gauge Stations				Average * Rainfall
	Karaia	Sultanganj	Bilehra	Dam Site	
July, 27	1.500	6.000	1.000	0.000	3.07
28	0.000	39.000	22.000	27.000	22.68
29	35.000	46.750	22.000	17.750	35.63
30	9.000	10.000	5.600	3.250	8.15
31	63.250	118.000	58.000	9.750	77.81
August, 1	34.000	53.000	18.400	15.500	37.05
2	14.000	7.500	3.200	2.500	8.26
3	0.000	0.000	0.000	0.000	0.00
4	0.000	1.250	0.000	0.000	0.51
5	0.000	0.000	0.000	0.000	0.00
6	93.750	64.000	101.800	108.250	84.56
7	2.500	1.000	0.000	0.000	1.19
8	0.000	0.750	0.000	0.000	0.31
9	0.000	0.000	0.000	0.000	0.00
10	0.000	0.000	0.000	0.000	0.00
11	4.000	0.000	0.000	0.000	1.26
12	0.000	0.000	0.000	0.000	0.00
13	5.000	0.000	0.000	0.000	1.57
14	1.500	0.000	0.000	0.000	0.47
15	0.000	2.750	0.000	2.500	1.45
16	4.000	2.000	0.000	0.000	2.07
17	0.000	0.000	0.000	1.000	0.13
18	34.500	4.000	14.000	40.500	19.80
19	12.500	2.000	2.000	5.250	5.72
20	13.000	3.250	4.000	3.250	6.42
21	15.000	4.500	5.400	9.250	8.55
22	19.750	18.750	3.600	0.000	14.39
23	18.000	33.750	17.000	16.750	24.12
24	19.250	22.500	10.000	10.750	18.11
25	9.250	2.500	0.000	0.000	3.93
26	0.000	0.000	0.000	0.000	0.00
27	1.500	6.750	0.000	0.000	3.23
28	3.500	4.750	9.000	2.250	4.64
29	3.750	10.500	44.000	9.750	13.13
30	16.500	16.750	28.000	26.250	19.53
31	1.000	0.000	0.000	3.500	0.77
September, 1	0.000	0.000	0.000	0.000	0.00
2	1.500	1.750	0.000	0.000	1.19
3	5.250	10.000	5.200	0.000	6.49
4	0.000	0.000	7.000	0.000	1.02
5	2.000	0.000	2.800	0.000	1.03
6	0.000	0.000	16.000	0.000	2.32

Daily Rainfall (mm) Recorded in Bewas Basin

Year 1997	Rain Gauge Stations				Average * Rainfall
	Karaia	Sultanganj	Bilehra	Dam Site	
September, 7	3.000	6.000	73.000	5.000	14.64
8	6.000	7.250	14.000	0.500	6.94
9	27.250	43.250	10.000	66.500	36.41
10	5.500	2.500	40.000	7.000	9.47
11	1.500	3.000	0.000	0.000	1.70
12	2.000	2.500	0.000	1.000	1.78
13	0.000	0.750	0.000	0.000	0.31
14	0.000	0.000	0.000	0.000	0.00
15	0.000	2.000	0.000	0.000	0.82
16	5.000	7.500	0.000	2.250	4.93
17	0.000	1.500	0.000	0.250	0.65
18	6.500	4.000	23.000	2.500	7.34
19	4.500	5.750	0.000	0.000	3.76
20	26.000	23.500	2.000	37.250	22.95
21	0.000	7.250	0.000	0.000	2.97
22	0.000	0.000	0.000	0.000	0.00
23	0.000	0.000	0.000	0.000	0.00
24	0.000	0.000	0.000	0.000	0.00
25	0.000	0.000	0.000	0.000	0.00
26	0.000	0.000	0.000	0.000	0.00
27	0.000	1.250	0.000	0.000	0.51
28	1.750	2.250	0.000	5.250	2.16
29	0.000	2.750	0.000	0.000	1.12
30	0.000	0.000	0.000	1.000	0.13
October, 1	0.000	1.750	0.000	0.000	0.72
2	2.250	1.250	4.000	0.750	1.90
3	3.000	0.750	0.000	0.000	1.25
4	1.500	1.000	0.000	0.750	0.98
5	2.500	0.750	0.000	0.000	1.09
6	1.750	0.000	0.000	0.000	0.55
7	0.000	0.000	3.000	0.000	0.44
8	0.000	0.000	0.000	0.000	0.00
9	0.000	0.000	0.000	0.000	0.00
10	0.000	0.000	0.000	0.000	0.00
11	0.000	0.000	0.000	0.000	0.00
12	0.000	0.000	0.000	0.000	0.00
13	0.000	0.000	0.000	0.000	0.00
14	2.750	1.750	5.000	0.750	2.40
15	1.000	0.000	0.000	0.000	0.31
Seasonal Total					887.90

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