CS(AR) 9/97-98

# ESTIMATION OF RUNOFF FROM BEWAS BASIN USING SCS CURVE NUMBER MODEL


NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667
1997-98

# CONTENTS

# LIST OF TABLES

## LIST OF FIGURES

# 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 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 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.

## 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

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:

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

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,

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

where, $I_a$ = initial abstraction.

Solving for Q from Eq. 2.2 :

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

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:**

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

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 ):**

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

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:

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

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 |

# 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

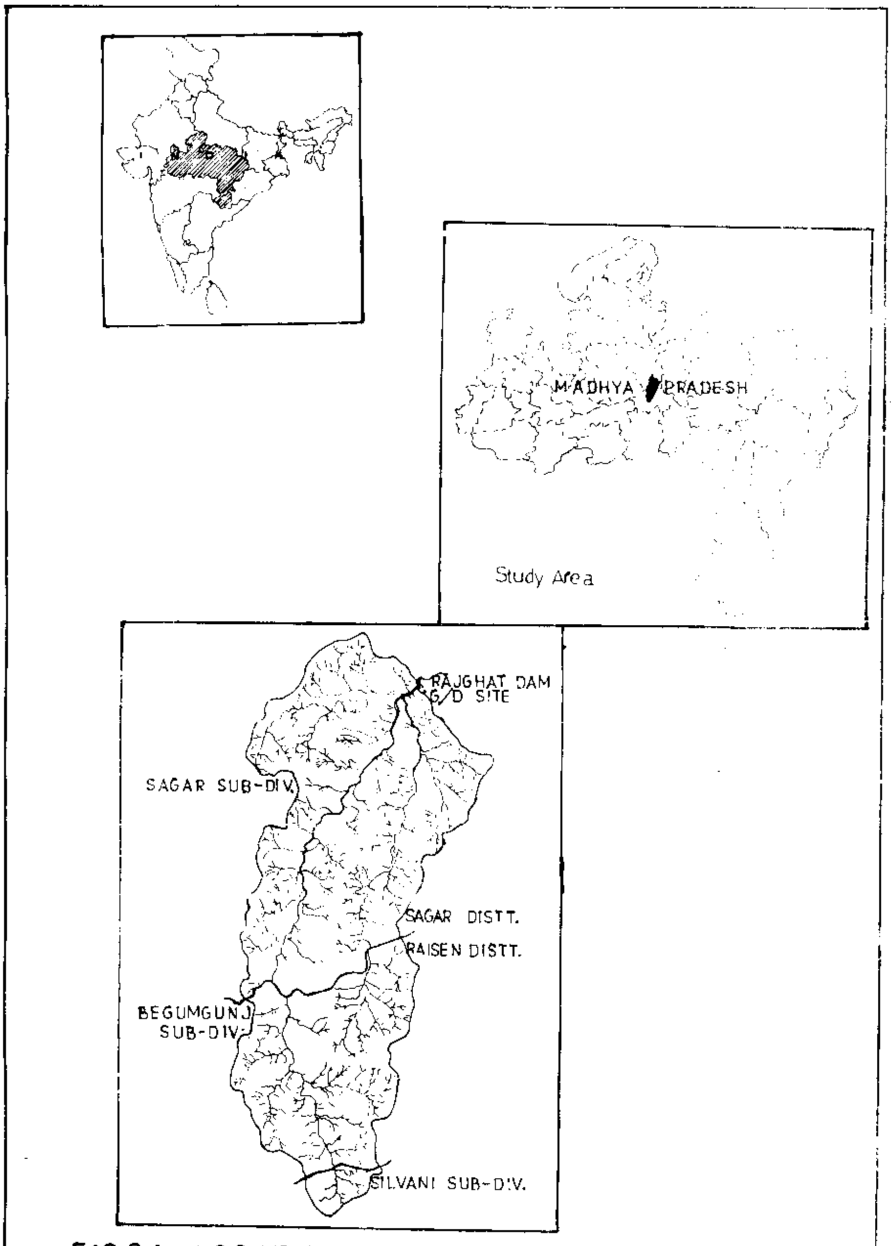


FIG.3.1 - LOCATION MAP OF THE STUDY AREA

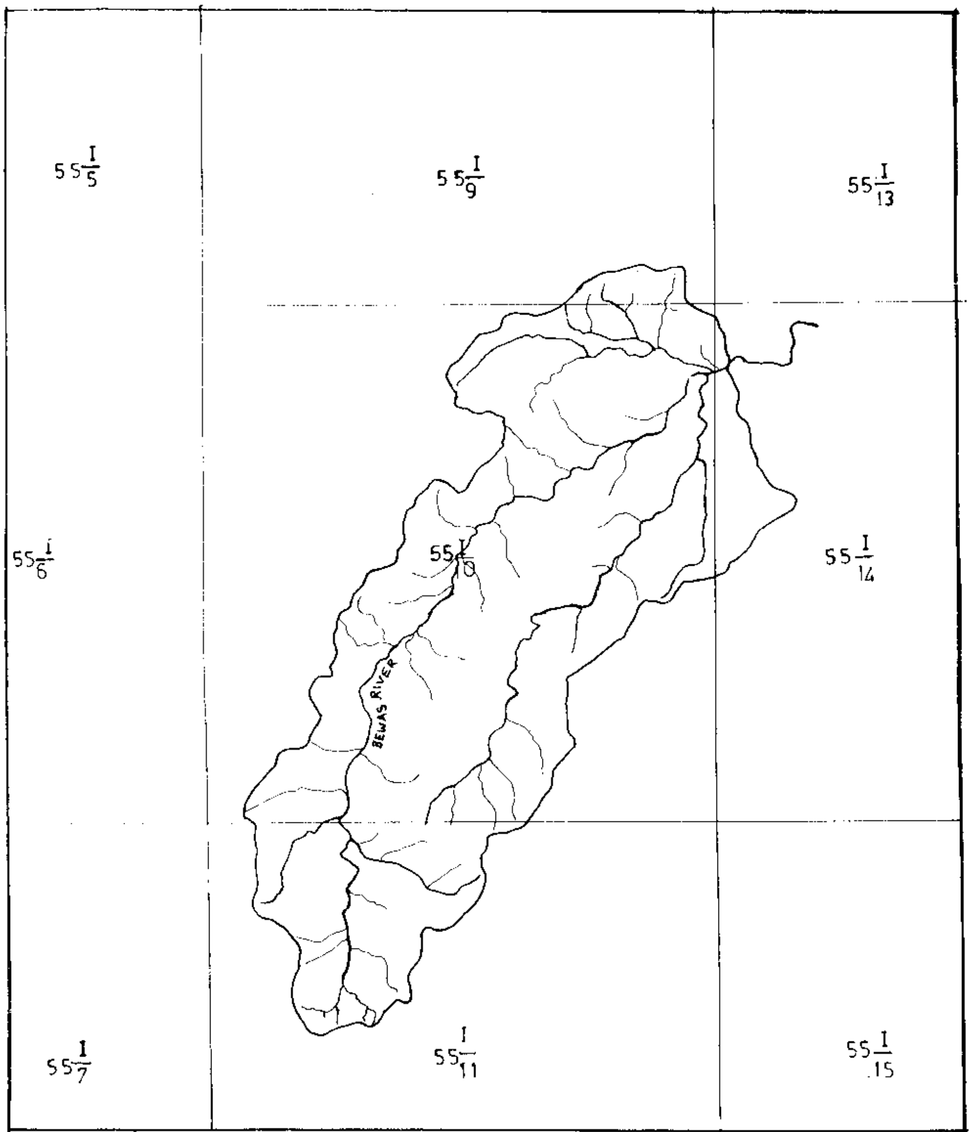


FIG. 3.2 :- S O I TOPOSHEET COVERAGE OF THE STUDY AREA.

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 $6^{th}$ to $11^{th}$ 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

(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 1$^{st}$ February to 15$^{th}$ 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 15$^{th}$ June to end of January. The pan evaporation in this period is 908 mm

**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 I / 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

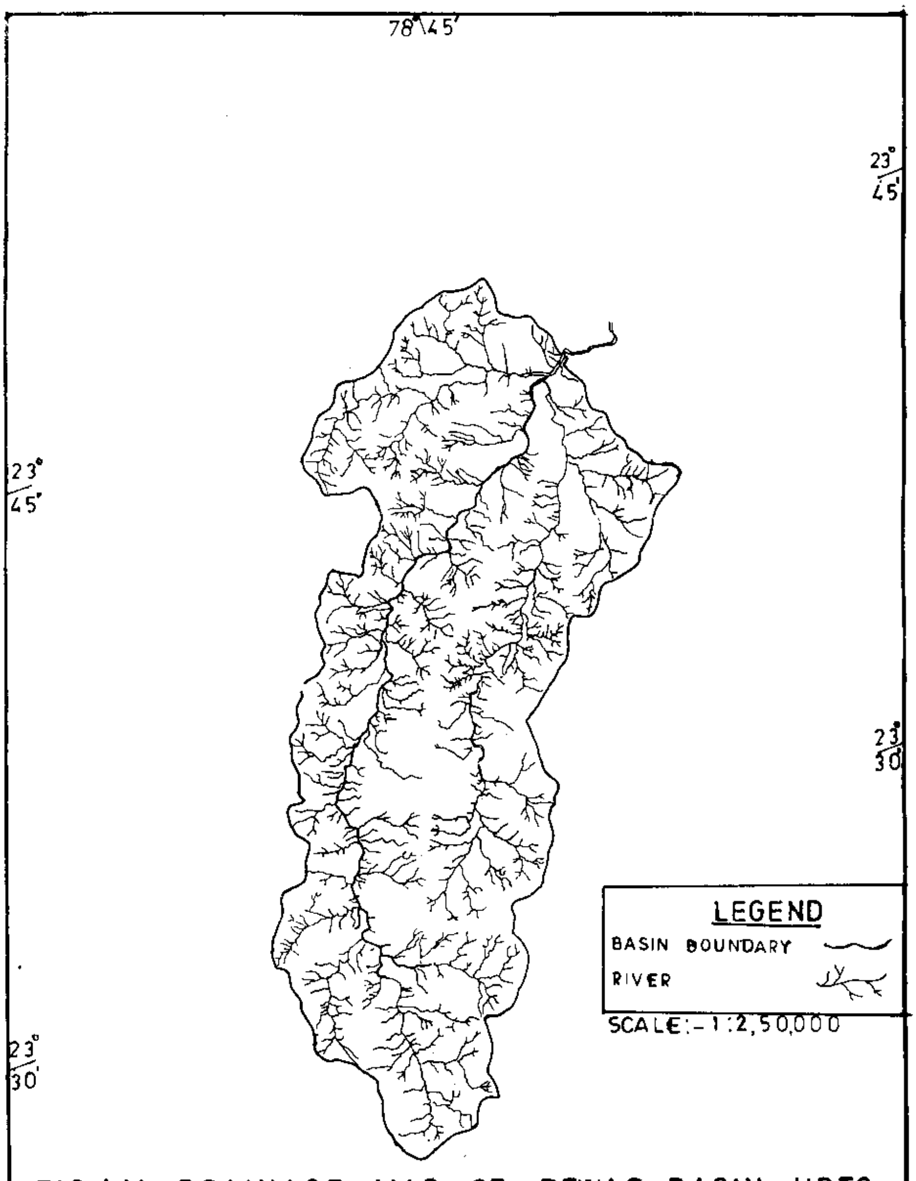


FIG.4.1:- DRAINAGE MAP OF BEWAS BASIN UPTO RAJGHAT DAM SITE.

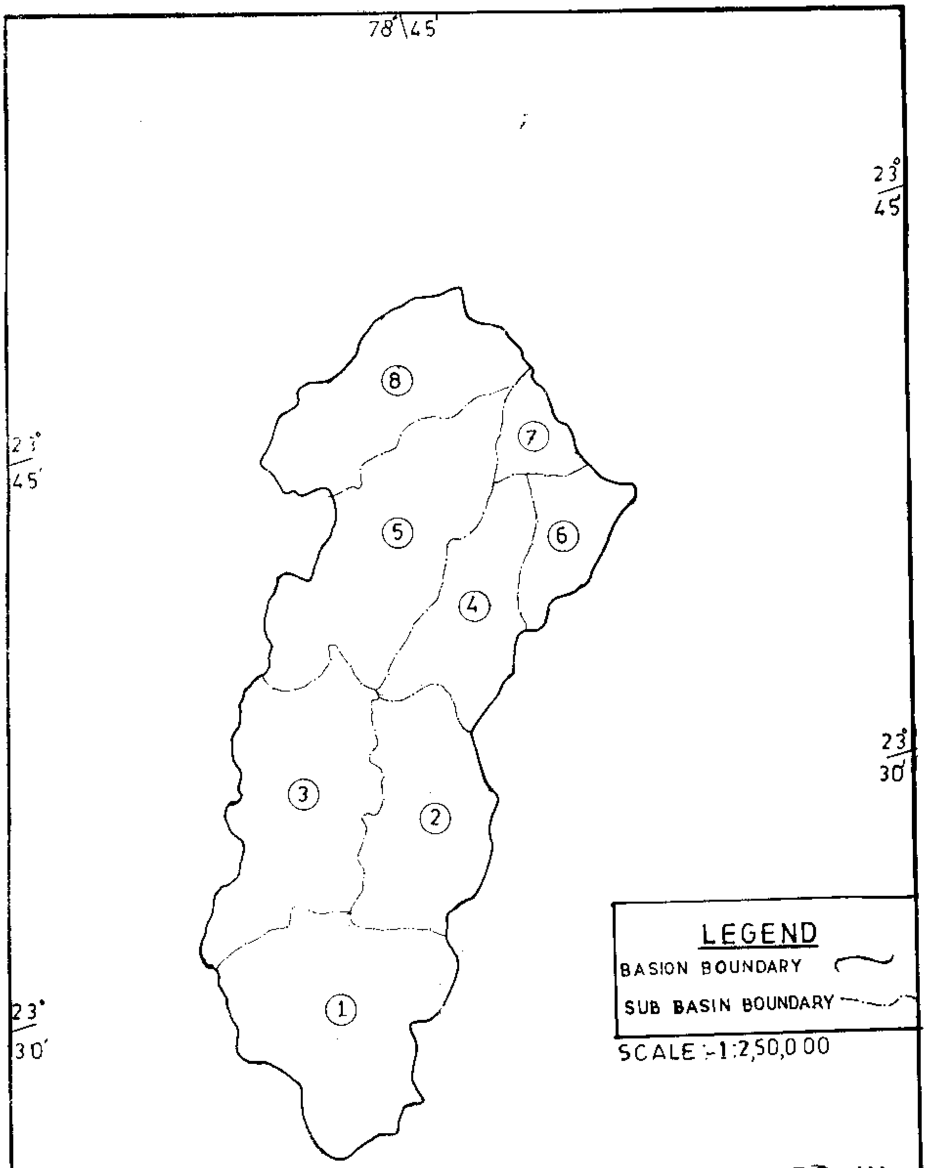


FIG.4.2:- MAP SHOWING SUB BASINS BOUNDARIES IN THE BEWAS BASIN.

78°30' 78°45'

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 15$^{th}$ June to 15$^{th}$ 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.

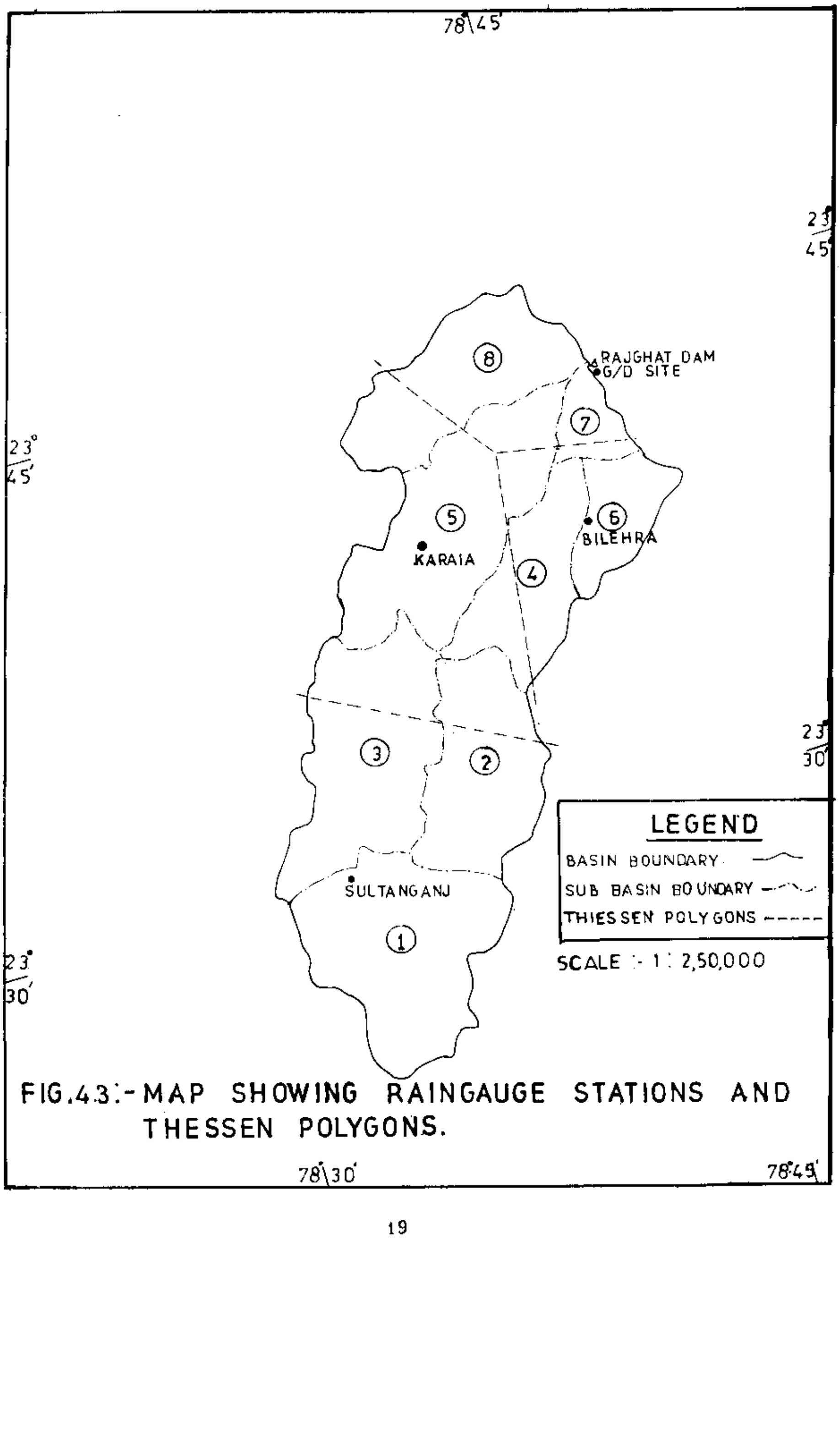


FIG.4.3 :- MAP SHOWING RAINGAUGE STATIONS AND THESSEN POLYGONS.

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.

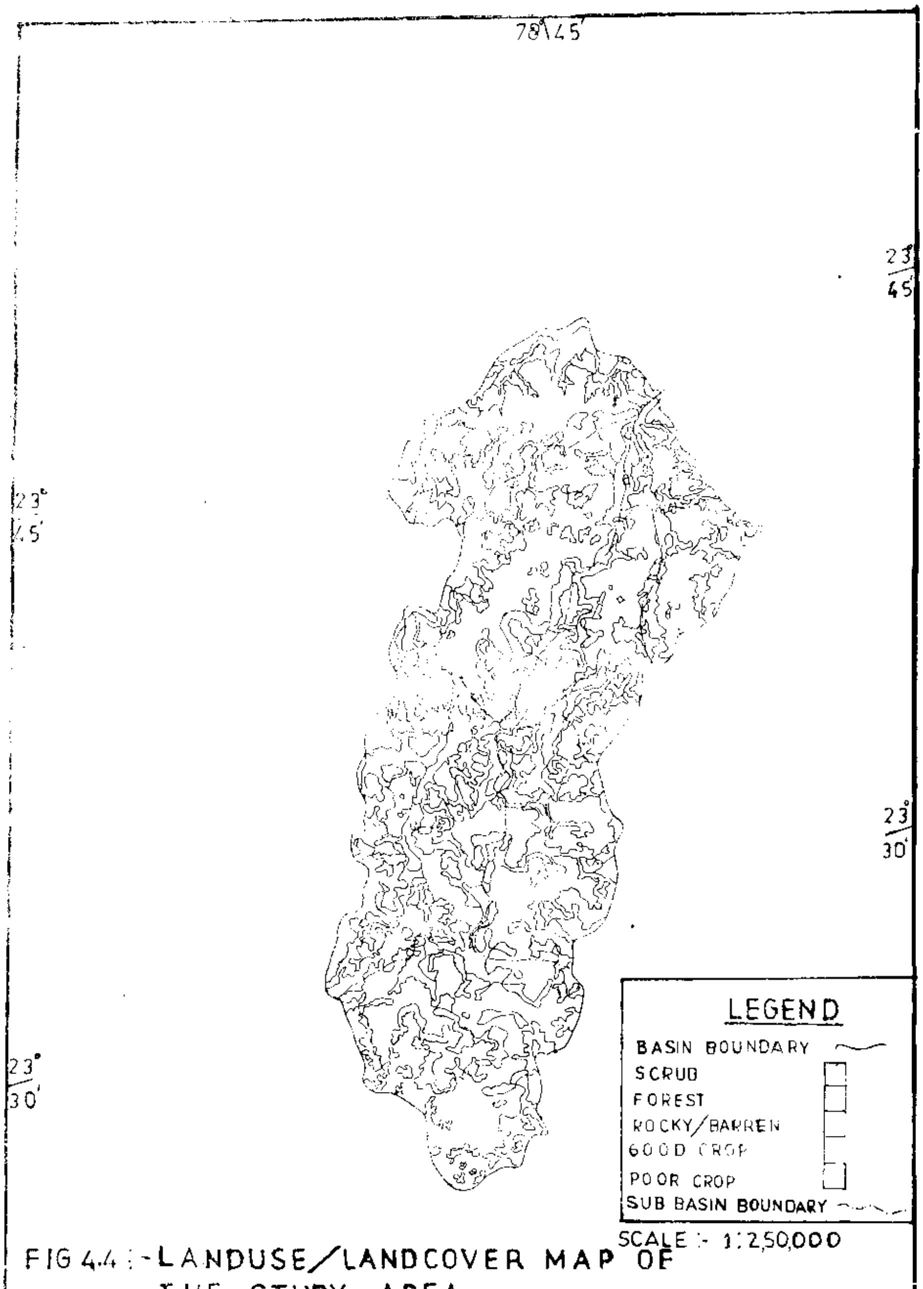


FIG 4.4 :- LANDUSE/LANDCOVER MAP OF THE STUDY AREA.

**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** |

## 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):

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

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,

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

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 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

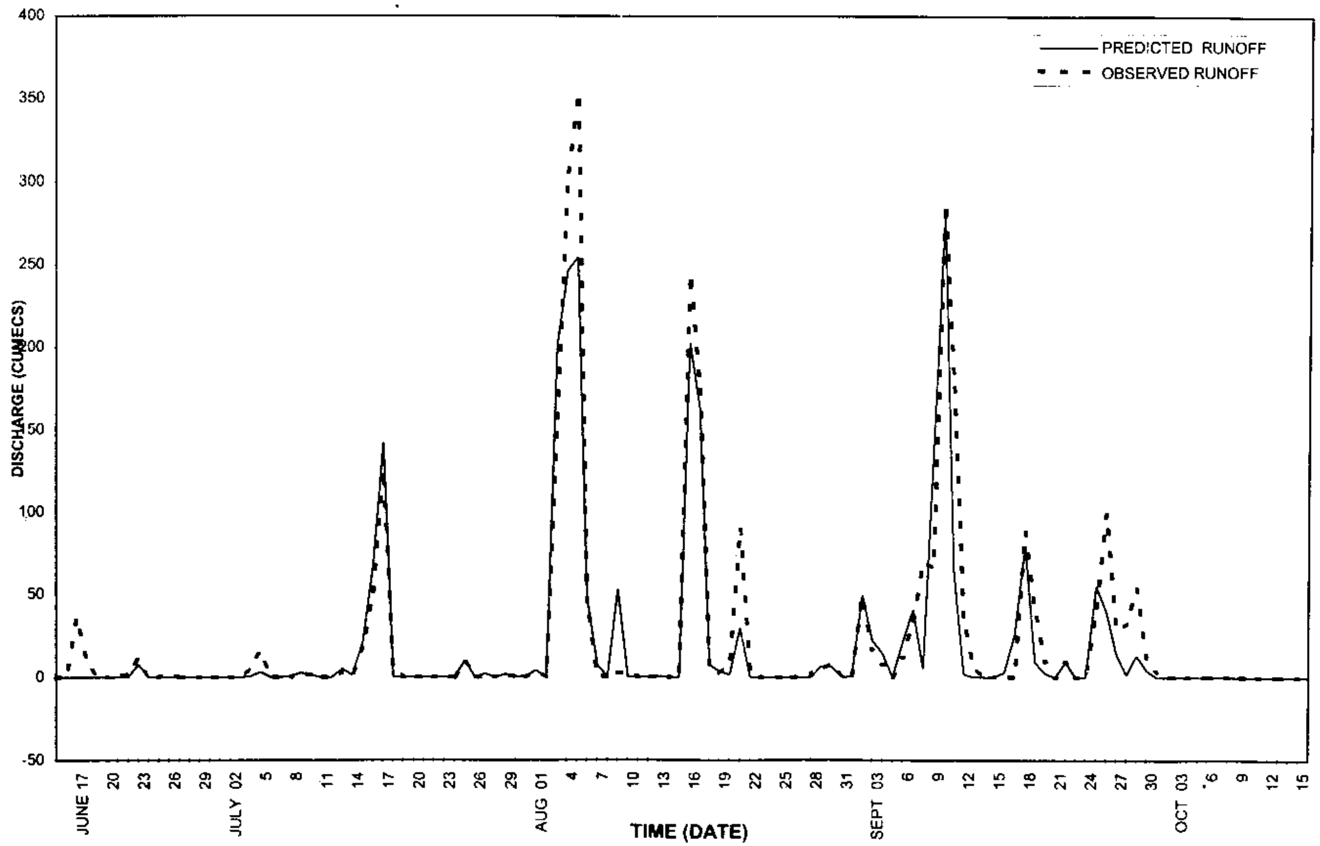


FIG.5.1 PREDICTED AND OBSERVED RUNOFF DURING 1993

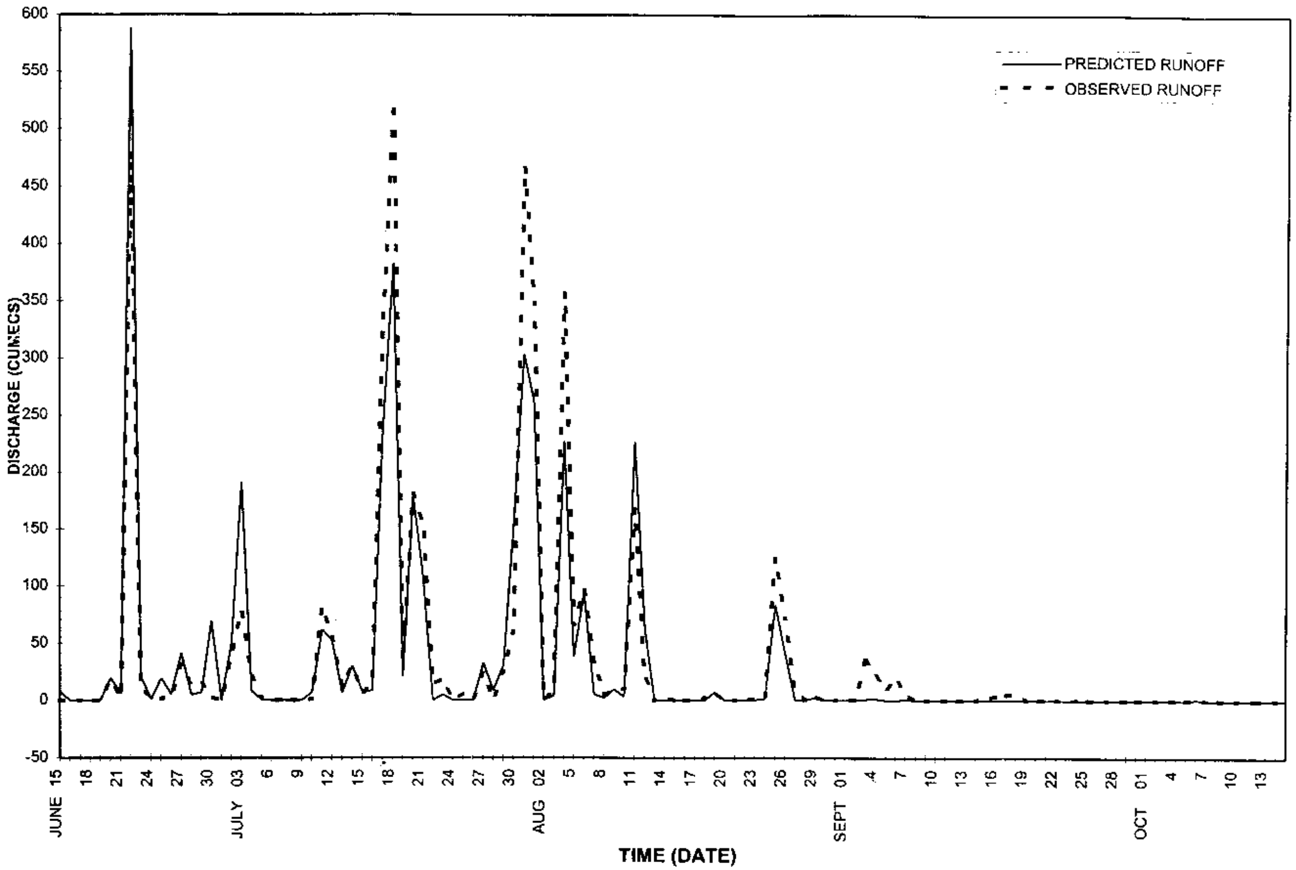


FIG.5.2 PREDICTED AND OBSERVED RUNOFF DURING 1994

NIH, R C SAGAR

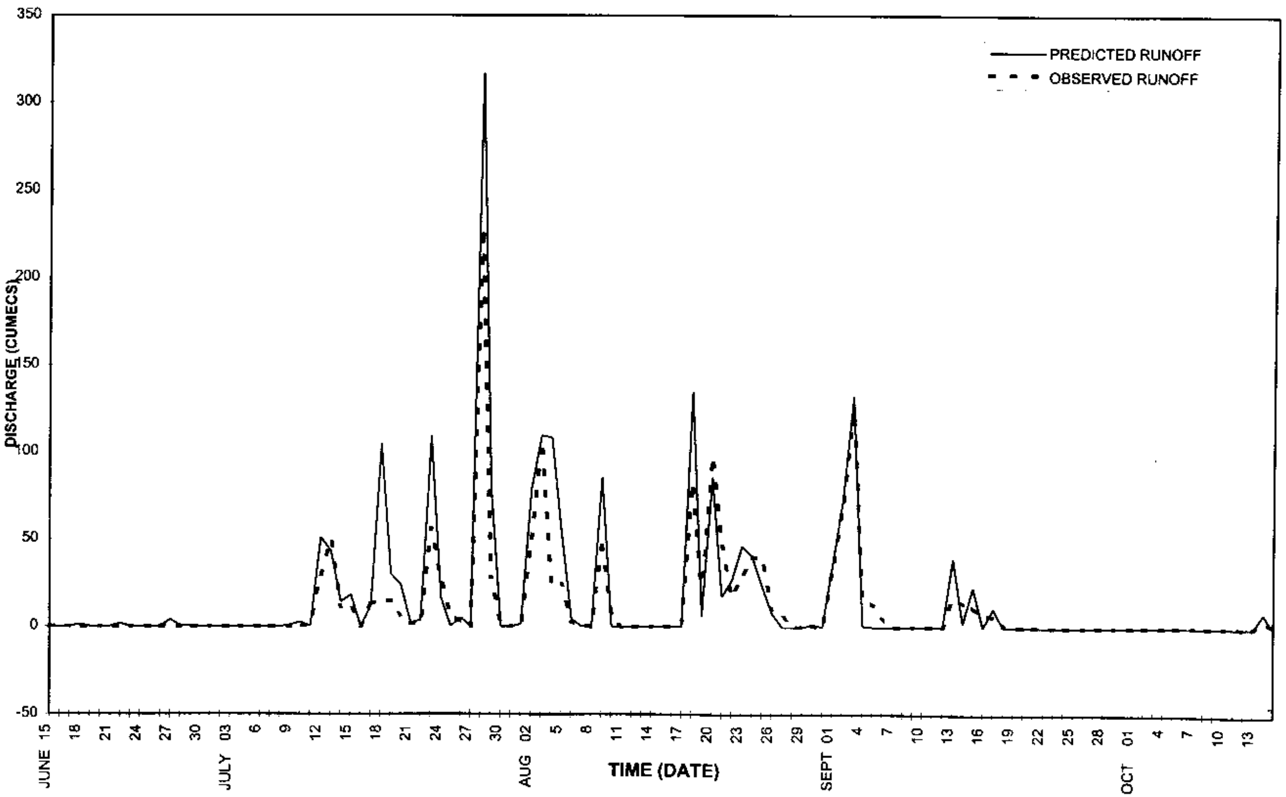


FIG.5.3 PREDICTED AND OBSERVED RUNOFF DURING 1995

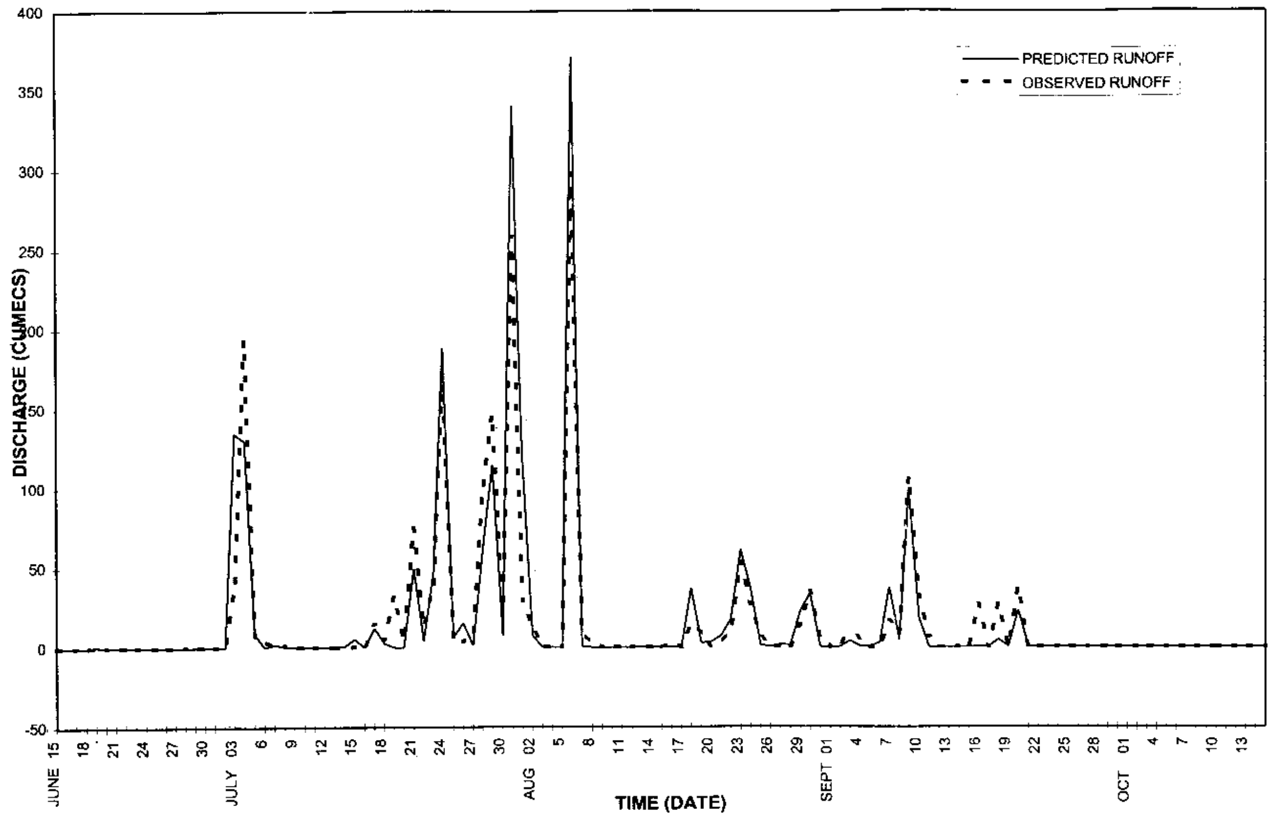


FIG.5.4 PREDICTED AND OBSERVED RUNOFF DURING 1997

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 | |

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 | |

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** |

**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 | |

**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 | |

**Table 5.4 Observed and Estimated Runoff During 1994**

| Date | Average Rainfall (mm) | Runoff in Cumecs | | Correlation Coefficient |
|---|---|---|---|---|
| | | Predicted | Observed | |
| 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 | |

**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** |

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 | |

Table 5.6 Observed and Estimated Runoff During 1997

| Date | Average Rainfall (mm) | Runoff in Cumecs | | Correlation Coefficient |
|---|---|---|---|---|
| | | Predicted | Observed | |
| 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 | |

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.

# 7.0 REFERENCES


1. Balakrishnan P (1986). Issues in water resources development and management and the role of remote sensing; *ISRO Publication*, ISRO, Bangalore.

2. Burrough, P A (1987). Principles of GIS for land resources assessment; *Clarendon Press*, Oxford.

3. Chatterjee, C, Jha, R, Lohani, A K and Jaiswal R K (1997). Determination of SCS curve number and landuse changes for Hamidnagar sub-basin of Punpun basin; CS(AR) 14/96-97, *National Institute of Hydrology*, Roorkee.

4. Geohydrological Report of Begumganj Block District Raisen (1976). *Directorate of Tube Wells and Ground Water Surveys*, Bhopal, Madhya Pradesh.

5. Geohydrological Report of Sagar and Jaisinagar Block District Sagar (1988). *Ground Water Survey, Irrigation Department*, Bhopal, Madhya Pradesh.

6. Handbook of Hydrology (1972). Soil Conservation Department, *Ministry of Agriculture*, New Delhi.

7. Kirpich, P Z (1940). Time of concentration of small agricultural watersheds, *Civil Eng.* 10:362.

8. Krishnan V S (1970). Sagar District; *District Gazetteers Department*, Bhopal, Madhya Pradesh.

9. Kumar, P, Tiwari, K N and Pal, D K (1991). Establishing SCS runoff curve number from IRS digital data base, *Photonirvachak, J. of the Indian Society of Remote Sensing*, 19 (4):245-251.

10. Ragan R M and Jackson T J (1980). Runoff synthesis using Landsat and SCS model; *Journal of the Hydraulics Division*, ASCE, 106(HY 5):667-678.

11. Soil Conservation Service (1972). National Engineering Handbook, Section 4, Hydrology, SCS, *U.S. Department of Agriculture*, Washington, D.C.

12. Soil Conservation Service (1984). Engineering field Manual, *U.S. Department of Agriculture*, Washington, D.C.

13. Ward, A D and Elliot, W J (1995). Environmental Hydrology, *CRC, Lewis Publishers*, Boca Raton, Florida.

**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 |

**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 |

**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** |

**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 |

**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 |

**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** |

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 |

**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** |

**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 |

**Daily Rainfall (mm) Recorded in Bewas Basin**

| Year | Rain Gauge Stations | | | | Average * |
|---|---|---|---|---|---|
| 1997 | Karaia | Sultanganj | Bilehra | Dam Site | Rainfall |
| 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** |

| | | |
|---|---|---|
| DIRECTOR | : | DR. S. M. SETH |
| HEAD | : | DR. BHISHM KUMAR |
| STUDY GROUP | : | TEJRAM NAYAK |
| | | R. K. JAISWAL |