WATERLOGGED AREA MAPPING AND HYDROLOGICAL DATA ANALYSIS OF MOKAMA TAL AREA

GANGA PLAINS NORTH REGIONAL CENTRE
NATIONAL INSTITUTE OF HYDROLOGY
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ABSTRACT

The drainage problems of the agriculture land are basically associated with the stagnation of runoff and the rise of the water table. Generally the runoff stagnation is a result of intense rain, which produces excessive runoff for which the existing drainage capacity is not adequate or outlet conditions are not favourable. The rise of water table beyond a critical limit or surface ponding results in water logging conditions. Water logging in a low lying land of about 1062 sq. km. (Mokama Group of Tals) in the district Patna, Nalanda and Munger is caused due to excessive rainfall in the catchment, stagnation of water on land surface for long period, inadequate surface drainage, natural and artificial obstruction to surface outflow and poor topography.

A synoptic method of monitoring water logging problem across large area is a valuable tool for many research and management applications. In recent years, remote sensing data have been used for qualitative assessment of water logging and soil moisture conditions. Use of remotely sensed data with landuse, soil and topography information appears to be a useful technique for the delineation of the temporal and spatial extent of water logged area.

To delineate the area of submergence in Mokama group of Tals an attempt has been made to integrate remote sensing data, land use, contours, soil and other relevant information. IRS 1A LISS II data for the year 1989 (Pre & Post monsoon) were utilized to study the dead storage and extent of submergence (lean period in pre-monsoon) and live storage and monsoon submergence (peak flood period/post monsoon) information of
Mokama group of Tals corresponding to highest flood levels and other hydrological information (rainfall and runoff).

The study also utilizes the peak flood discharge series at sites to fit various distributions. This gives the values of floods at higher recurrence interval. Such information is useful in deciding any water resources structure in the basin for flood/ water management purpose. Further, an attempt has also been made to formulate a management model for water logging and drainage congestion problem of Mokama group of Tals. The model outlined in this study require various hydrological, topographical and land use data.
INTRODUCTION

The drainage problems over vast agricultural lands of the eastern region is of a magnitude that require immediate attention. The success of a Kharif crop in such areas is dependent primarily on chance. Submergence in flood affected areas of the region sometime continues for a long period and delays the Rabi sowing. The term drainage congestion used in general encompasses the three different types of situations each requiring different treatment viz.

i. Area remaining under water throughout the year; only the extremity may expand during the rainy season.

ii. Agricultural area remaining submerged in a manner that crop production is affected, due to absence of field drainage system/or its malfunctioning.

iii. Areas submerged due to unfavourable outfall conditions and deterioration in efficiency of natural streams and sluices.

The total area suffering from ill drained condition due to a combination of the above causative factors in the states of Andhara Pradesh, Orissa, West Bengal, Bihar and Eastern U.P. is estimated to be about 3.3 million hectares (Bhattacharya, 1992). Out of this, the state Bihar constitutes an area of nearly 0.9 million hectare. The flood prone area in Bihar is reported to be 6.46 million hectare out of the total flood prone area of 40 million hectare of the country. Almost all the river basins of North Bihar are flood prone. In central Bihar Sone, Punpun, Kiel-Harrohar, Badua and Chandan river basins are prone to flooding. There is practically no problem of flood in the region of South Bihar (Report
of the Second Bihar State Irrigation Commission, 1994). In Bihar considerable area remains surface waterlogged due to drainage congestion during monsoon. They get inundated with onset of monsoon by runoff from adjoining uplands or areas fed by spill from some rivers. They are classified (in agriculture terms) in three different classes (Table 1.1).

Table 1.1: Classification of waterlogged area

<table>
<thead>
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<th>Sl. No.</th>
<th>Classification</th>
<th>Depth of Submergence</th>
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<tr>
<td>1</td>
<td>Shallow</td>
<td>Where submergence for more than one month to a depth of 50 to 100 cm</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
<td>Submergence from a depth of 100 to 200 cm</td>
</tr>
<tr>
<td>3</td>
<td>Deep</td>
<td>Submergence more than 200 cm</td>
</tr>
</tbody>
</table>

In the state of Bihar, nearly 0.8 million hectare area is facing the problem of water logging and drainage congestion in North Bihar, and 0.1 million hectare in the Central Bihar. This, 0.1 million hectare of water logged area comes under Mokama group of Tal. A number of tributaries with their final destiny as Tal area contribute flows to the areas. These tributaries during monsoon period carry a considerable magnitude of flows. The Tal area are mainly spreaded (lengthwise) towards west to east. Most of the tributaries originate from South Bihar and flow toward northward direction. The northern side of the Tal area is blocked by the raised bank of the river Ganga flowing along direction of Tal area. During flood, the water level in the river Ganga exceeds the water level of Tal area. As a
result, natural drainage gets blocked and almost all the Talis in Mokama group of Talis get filled up with drainage waters from tributaries joining the Talis and create waterlogging. Due to this, land resources of Tal areas particularly during Kharif season get under utilized.

Efforts had been made by various individual experts and committees constituted by the Government to identify the major causes of waterlogging, and to find out possible solutions. To mention a few important names, Dr. K.L. Rao (1970-72), Dr. C.C. Patel (1976), Mokama Tal Technical-cum Development Committee (1988), and Second Bihar State Irrigation Committee (1994), etc. The Ganga Plains North Regional Centre, Patna of National Institute of Hydrology (Lohani & Jaiswal, 1995-96) has compiled all information of Tal area which include; hydrological features of the area, various remedial measures suggested by the experts and taken so far for management of Tal areas, and studies conducted by various organisations etc. These background information reveal that the main problems of the Tal areas are due to the congestion of hydrological factors which cause water logging and drainage problems to the area.

In the present study remote sensing technique and conventional methods have been applied to delineate surface water logged area in the Mokama group of Talis. For this purpose, pre-monsoon and post-monsoon FCC prints of remotely sensed data have been used and the interpretation was supported by ancillary data. Further, flood frequency analysis using annual peak discharge series (about 24 to 27 years) involving application of Normal Distribution, Two Parameter Lognormal Distribution, Three Parameter Lognormal Distribution, Pearson Type III Distribution, Log Pearson Type III Distribution and Extreme Value I Distribution at site is described and discussed.
Tal area being the final destiny of tributaries originating in the Tal basin, the management of Tal area can not be apprehended without coupling the regulation of tributary's water. Assuming the water logged area is a storage reservoir having inflow/ back water to/from various tributaries besides the effects of other hydrological factors, the problem can be visualized as an optimization problem, with objective of minimization of total water logged area under the constrains of translation of inflows in the upper reaches.

The study also addresses a formulation of optimization model supported by the all possible constraints. A strategy for solving the model has also been discussed. Solutions and outcomes of the model are being dealt separately under the work programme of 1997-98.
GEOGRAPHICAL FEATURES OF STUDY AREA

2.1 KiuL-Harohar River Basin

KiuL-Harohar, the major rivers of South Bihar are rainfed and carry very little discharge during non-monsoon period. The total catchment area of KiuL-Haborar river system is 17,223 Sq Km. It consists of a number of rivers like the Mohame, Dhanyan, Sukhmar, Barnar, Damar, Nagi, Nakti, Bajan, Ajan, Palgu etc. besides the river KiuL and Harohar. The river KiuL is the main river of the KiuL-Haborar river system and it originates at a latitude of 24° 23' N and longitude of 86° 10' E from an elevation of 605 m in Chotanagpur plateau. The river system is bounded by the Badua-Chandran system on the east, the Ganga on the north, the Chotanagpur plateau on the south and the Punpun river in the west. The upper catchment of the river system lies in Chotanagpur Plateau area which is characterised by low hills and slopes with depression and valleys. A number of small rivers in the river system bifurcate and rejoin each other a number of times during the course of flow and making it difficult to ascertain their exact length. Drainage pattern of the KiuL-Harohar river basin is shown in Figure 2.1. Brief description of a few important rivers is presented in the following paragraphs:

2.1.1 The River KiuL

The river KiuL is the main outfall channel of the KiuL-Haborar basin, rises in the hills of Chotanagpur Plateau. Bubuni, Sukhmar, Barnar, Dohara, Nagi, Nakti, Bajan, Ajan and Morwe are the important tributaries joining the river KiuL at right bank. The river Harohar is the biggest and one of the most important tributaries joining it on the right
bank. Initially the river Kosi flows in the North-West direction, then in East direction close
to the southern face of the Gidiheshwari Hills and then in North direction. After that it
flows in North-West direction up to Lakhisarai. It then turns in the North-East direction
and joins the river Ganga near Surajgarha in the Munger district.

2.1.2 The River Lilajan and Mohane (Falgu)

The river Falgu known as Mohane in the upper reach rises in the hills of Chatra
district at an elevation of 914 m. After traversing through hills and forests for about 64
km, it crosses the Grand Trunk Road and enters the plains of the Gaya district. After
traversing a length of 40 km it receives Lilajan. The river Lilajan is a major tributary of the
river Mohane. It also originates in the hills of Chatra district at latitude 24° 11' N and
longitude 84° 45' E at an elevation of 534 m. After traversing a distance of 85 km through
hills and forests, it crosses the Grand Trunk Road near Dobhi and travels a distance of about
29 km before joining the river Mohane. The combined river is known as the Falgu after
the confluence of the Lilajan and the Mohane and travels in North direction upto
Khizimadar where it again bifurcates into two channels. The right channel is again known as
the Mohane and the left channel is known as the Falgu. Further this Falgu river runs in
north direction where it is known as the Mahatmain and the Lokain. This is finally known
as the river Dhowa. Another right bifurcated channel from Ghoshi is known by local
names of the Jahwa and the Nona which again reunite with the Dhowa. Bifurcated right
branch of Mohane which is again known as Mohane joins the Bogahi river near Lalampur
and is again known as the Mohane in the down stream. The left branch of Mohane joins
the Jaha river taking off from Falgu. This right channel known as the Mohane flowing
further down for about 51 km joining the river Paimar. Paimar is another important river of the basin and it originates from the foot hills of Hazaribagh near Paharpur Railway Station. The combined river enters the Bhaktiarpur Tal and meets the river Dhowa near Bakhtiarpur. After this the combined river is again known as Mohane.

2.1.3 The River Panchane

The river Panchane is formed by a number of small streams namely Mangur, Dhadhar, Tilaya, Dhanarji and Khari. All these streams taking off from the Barakar valley in the hills of Kodarma range in Giridih/Hazaribagh district. The Panchane river bifurcates into a number of channels a few km upstream of Biharharif town known as the Goothana, the Charosa and the old Panchane. The Charosa again meets the old Panchane river after flowing about 26 km. Ultimately it joins the the river Mohane in the middle reach. The river Goothana after flowing in the North direction for about 29 km takes a turn in eastern direction and meets the two branches (the Jirain and the Kumbhari) of the river Sakri. The combined river below village Chhatpur is known as the Dhanayan. The river Dhanayan flowing in the east for about 16 km meets the river Mohane at Trimohani and the combined river is known as the river Harohar.

2.1.4 The River Sakri

It originates from the hills of Hazaribagh district at an elevation of 365 m near village Tisri. After flowing for about 64 km in the thick forest and hilly tracts of Hazaribagh district it enters the plains of Gaya district near village Dumri. The river Sakri crosses the Khul-Gaya section of the Eastern Railway near village Paura which is about 9.6 km east of Nawada town. After flowing further down for about 19 km in the North, it
bifurcates into two branches namely the *Jirain* and the *Kumbhari*. These two branches meet the river *Gothawa* and the combined river is known as *Dhanayan*.

### 2.1.5 The River Harohar

The river *Harohar* is the biggest and most important left bank tributary of the river *Kul*. It joins the river *Kul* downstream of Lakhisarai. In the tail reach, the river *Harohar* flowing for about 16 km below Trimohani in a serpentine course, is joined by the river *Tatt*. The river *Tatt* originates near Marui just on the east of Sakri valley. It traverses a distance of about 51 km before it meets the river *Harohar*.

### 2.2 Drainage Area

The *Kul-Harohar* river system drains an area of 17,223 Sq Km. Upper zone of the *Kul-Harohar* river basin lies in the Chotanagpur Plateau which is characterised by low Hills and slopes with depressions and valleys. In some areas there are hills from a series of ranges with general level gradually rising to an elevation of 600 m. The lower portion of the catchment lies in the Gangetic plains. This plain has been built-up in the process of land formation and the alluvial formation represents one continuous and conformable series whose accumulation is still going on. About 1062 Sq Km of total drainage area, lying in the lower zone of the river system is sacuer shaped and is a vast tract of low lying land.

*Kul-Harohar* river basin is drained by a number of important rivers. Area drained by these rivers is given in Table 2.1.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the River</th>
<th>Drainage Area (Sq Km)</th>
<th>% of Total Drainage Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Falgu</td>
<td>5,281</td>
<td>30.67</td>
</tr>
<tr>
<td>2.</td>
<td>Paimar</td>
<td>1,122</td>
<td>06.51</td>
</tr>
<tr>
<td>3.</td>
<td>Sakri</td>
<td>5,500</td>
<td>31.93</td>
</tr>
<tr>
<td>4.</td>
<td>Harohar</td>
<td>2,393</td>
<td>13.89</td>
</tr>
<tr>
<td>5.</td>
<td>Kisi</td>
<td>2,927</td>
<td>17.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>17,223</td>
<td>100.00</td>
</tr>
</tbody>
</table>

2.3 Geological Characteristics of the Basin

The upper zone of the river system is lying in Chotanagpur plateau while, the lower zone lies in the Gangetic plains. The entire Chotanagpur plateau area is characterised by low hills and slopes with depression and valleys. In some areas these hills form series of ranges. General level of the area gradually rises until eventually a height of 600 m is obtained. On this gradual rising surface there are rises like Parasnath which is at a level of 1260 m. Also, there are other rising to lesser heights. These are formed of Archean quartzites and schists.

The lower zone of the catchment lies in the Gangetic plains. It has semi undulation and microrelief and looks like a saucer shaped and shallow depression. It has a surficial cover of dense, poorly drained, unoxidised and humous rich clayey soil in the core or grading into progressively lighter soil towards peripheral part with progressive increase in silt fraction. Geomorphologically, the depression is divided into three substratas: Alluvial
uplands; older flood plain and; present flood plain of the Ganga on the northern side of Patna-Mokama road and The Ganga.

In Kuhl-Harohar basin the cropping sequence is widely governed by the three physiographic zones. These are given below (Table 2.2):

<table>
<thead>
<tr>
<th>St. No.</th>
<th>Part of the Kuhl-Harohar Basin</th>
<th>Physiographic Zone</th>
</tr>
</thead>
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<tr>
<td>1.</td>
<td>Southern Part</td>
<td>Old alluvium grey to greyish yellow soils with heavy texture.</td>
</tr>
<tr>
<td>2.</td>
<td>Middle Part</td>
<td>Tal area which remain under water for two to four months during Kharif and intensively cropped during Rabi.</td>
</tr>
<tr>
<td>3.</td>
<td>Extreme North Part</td>
<td>Alluvial zone up to the river Ganga.</td>
</tr>
</tbody>
</table>

2.4 Soil Characteristics

The lower zone (Mokama Tal) of the Kuhl-Harohar river basin generally suffers from drainage congestion for a period of two to four months. The soil of these Tals are grey to dark grey in colour, medium heavy to heavy in texture, slightly to moderately alkaline in reaction and of good fertility status.

The principal soil type in various districts of the river system are presented in Figure 2.2. The general data regarding the soil of the river system indicates that mainly alluvial, red and yellow, red sandy soils and deltaic alluvium occur in the river system. The upper zone of the basin is lying on the Chotanagpur Plateau. It has red, yellow, reddish yellow, greyish yellow type of soils. The yellow soils are medium textured, silty soil,
heaving practically no gravels. The pH value of the soil is strongly to moderately acidic. The red and yellow type of soil are moderately well drained. These are having good fertility and are less acidic. The reddish yellow soil resemble the yellow soil and are light textured.

The alluvium soil found in various districts can further be classified on the basis of colour and other properties. The grey and greyish yellow type which is found in the district of Patna, Gaya, Jahanabad, Nalanda, Munger, and Nawada remains greyish yellow to grey in colour, medium heavy in texture and neutral to slightly alkaline in reaction. These soils on drying crack heavily. Reddish soil and yellow type soils are found in the district of Patna, Gaya, Jahanabad, Nalanda, Munger and Nawada. These soils are somewhat poorly drained and show a tendency to crack during the dry months. The yellowish red and yellow type soil found at the foot hills separating the alluvial plain from the plateau region. These excessively drained to moderately drained, shallow to medium deep soil over the bed rocks and pebble. These are also strongly to moderately acidic and are of poor to moderate fertility. Calcareous alluvium soils are found in Munger and Jamui districts. There main characteristics is the high content of calcium carbonate. These soils are alkaline in nature. They are light coloured and their texture varies from sandy loam to loam.
FLOOD AND DRAINAGE CONGESTION PROBLEM

The Ganga sub-basin is a part of the main Brahmaputra-Meghna-Ganga river basin. It is the largest river basin in the country. A large part of this basin particularly the portions lying in the Eastern Uttar Pradesh and Bihar is flat in topography with poor drainage. Very high intensity of rainfall with poor drainage result flooding and drainage congestion almost every year in this region. The river Ganga flows from west to east in the central part of Bihar. The portion lying on the northern side of the left bank of the Ganga is known as North Bihar and that lying on the southern side as South Bihar. The State comprises alluvial plains of Indo-Gangetic basin in the north and Kaimur-Chotanagpur-Santhal Pargana plateau in the south. The alluvial plains is divided by the river Ganga flowing from west to east. The state, therefore, can be physiographically be divided into three regions. These are North Bihar, Central Bihar and South Bihar. Physiographical map of Bihar is shown in Figure 3.1. The North Bihar rivers are fed by the melting snows and glaciers of the great Himalayan range during spring and summer, and also from rains during monsoon and hence they are perennial. They carry significant flows during the dry weather due to snow melt and carry minimum flow during the winter. On the other hand, the peninsular rivers originate at much lower altitudes, flow through stable areas. Their flow is characterised by heavy discharges during monsoon followed by very low discharges during the rainless months. In order to give an idea of the problems of floods and drainage congestion in the Kosi-Harohar basin, the nature, characteristics and overall situation of these problems existing in the basin are being discussed in brief as follows:
Fig. 3.1: Physiographical Map of Bihar

Source: Second Bihar State Irrigation Commission
3.1 Flood Problem - Nature and Extent

In the State of Bihar, almost all the rivers carry heavy discharges during the monsoon months when their catchments receive intense and heavy rainfall. The floods occur almost every year in the various river basins in Bihar. Flood prone basins in Bihar with their respective flood prone areas in Lakh ha are indicated in the Table 3.1. Due to non favourable outfall conditions in monsoon season the North Bihar plains are affected by

Table 3.1 : Flood Prone Area Under Different Basins in Bihar

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of Basin</th>
<th>Flood Prone Area in Lakh ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ghaghara</td>
<td>2.53</td>
</tr>
<tr>
<td>2</td>
<td>Gandak</td>
<td>3.35</td>
</tr>
<tr>
<td>3</td>
<td>Burhi Gandak</td>
<td>8.21</td>
</tr>
<tr>
<td>4</td>
<td>Bagnati</td>
<td>4.44</td>
</tr>
<tr>
<td>5</td>
<td>Kaml-Balan</td>
<td>3.70</td>
</tr>
<tr>
<td>6</td>
<td>Kosi</td>
<td>10.15</td>
</tr>
<tr>
<td>7</td>
<td>Mahananda</td>
<td>5.15</td>
</tr>
<tr>
<td>8</td>
<td>Sone</td>
<td>3.70</td>
</tr>
<tr>
<td>9</td>
<td>Purpun</td>
<td>6.13</td>
</tr>
<tr>
<td>10</td>
<td>Kuli-Harohar</td>
<td>6.34</td>
</tr>
<tr>
<td>11</td>
<td>Badua</td>
<td>1.05</td>
</tr>
<tr>
<td>12</td>
<td>Chandan</td>
<td>1.13</td>
</tr>
<tr>
<td>13</td>
<td>Main Ganga Stem</td>
<td>12.92</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>68.80</td>
</tr>
</tbody>
</table>
acute problems of flood, waterlogging and drainage congestion due to very flat topography.
The southern Bihar is characterised by low hills and slopes in some parts and Ganges plain in the rest. Most of the rivers originating from South Bihar join the river Ganga. These rivers have steep slope in the upper reach and a very mild in lower reach. Many rivers like Karmamasa, Sone, Punpun, Kiul-Harochar, Badua-Chandani, Gumani etc. which originate from hilly region of South Bihar join the river Ganga. In comparison to North Bihar flood problems of Kiul-Harochar are not of very serious in nature. However, flash floods have been occurring during period of heavy rains in the catchment. The river Sakri experienced heavy flooding in 1896 and the river Kiul also experienced comparatively bigger flood in 1961. Besides this moderate flooding have been noticed in the year 1962, 1963, 1967, 1971 and in 1976, in the river Kiul. The river Falgu caused flooding in the year 1971 and severe flooding in the year 1986.

In the Kiul-Harochar river system, the bankful capacities of the rivers like the Kiul, the Harochar and the Punpun etc. are inadequate. Due to which they are unable to contain the flood discharges and as a result spilling takes place over their bank causing floods in the basin. Zamindari embankments are provided in places where spills causing floods in the basin. These embankments are generally of inadequate section and incapable of withstanding even medium floods. Rivers draining the Kiul-Harochar basin are non-perennial in nature. Due to spilling during monsoon season, sometimes flooding in lower reaches of these rivers takes place. Flood problem of the basin as identified is presented in Table 3.2.
### Table 3.2: Causes of Flooding in Kuhl-Harohar Basin

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>RIVER</th>
<th>CAUSES OF FLOODING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>KIJUL</td>
<td>• River spills near Lakhisarai and flooding takes place in nearby area.</td>
</tr>
</tbody>
</table>
| 2       | SAKRI  | • It carries lot of silt.  
          |        | • Flash flood in the river.  
          |        | • Zamindari embankment are existing below Sakri weir in which there are number of gaps and the flood water spills through these gaps. |
| 3       | FALGU  | • Occasional flash flood in the river. |
| 4       | PANCHANE | • Inadequate capacity of its several bifurcated channels. |

#### 3.2 Drainage Congestion Problem

The Kuhl-Harohar river system drains an area of 17,223 Sq Km. The upper catchment of the river system lies in Chotanagpur Plateau area which is characterised by low hills and steep slopes with depression and valleys. Flood peaks caused by heavy rains which pass off quickly and accumulates in the lower region where the terrain is flat. About 1062 Sq. Km. of this area, lying in the lower zone of the system is saucer shaped. It is commonly known as Mokama Group of Tal. The drainage problem in the Kuhl-Harohar basin is confined to Mokama group of Talas. It consists of seven Talas. Though the Mokama group of Talas is continuous, it is differently named in its different reaches from west to east as Fatuha Tal, Bakhtiarpur Tal, Barh Tal, More Tal, Mokama Tal, Barahiya Tal and
Singhad Tal. During monsoon months, the Tal gets filled up with water due to inflow of rivers entering the Tal and also due to obstruction in drainage caused by back water of Ganga entering the Tal. The maximum depth of submergence in the recent past was recorded in the year 1987 which varied from 3.86 m in Farukha to 5.76 m in More and Mokama Talas. Out of total Tal area 93 Sq Km area consists of high lands which are submerged only during high floods. 788 Sq Km area consists of very low lands where only Rabi crop is possible and in the remaining 181 Sq Km area it is possible to grow two crops. A Pie diagram (Fig 3.2) shows the percentage of Tal area under different topography. Due

Figure 3.2: Topographical Features of Tal Area
to the peculiar configuration, the flood water continues to accumulate and vast tract of this low lying land is subjected to flooding and waterlogging. The monsoon submergence of the Tal area hamper the optimum utilization of its land resources. The continued submergence of most of the Tal areas, from July to September, makes it impossible to grow any Kharif crop in a vast area. Rabi crop is grown almost in the entire Tal area when the accumulated water of the Tals gets drained out by its natural drainage through the Harohar and the Kiul into the Ganga by 15th October. The Rabi cultivation is also dependent on the availability of the residual moisture of the soil freed from submergence. As the Tal area do not get fully submerged every year, Kharif cultivation is practiced in peripheral areas of the Tal where depth of submergence is small. In some areas where irrigation facility has been created, even double crop, during both Kharif and Rabi season are being grown. In a very limited area hot weather crop is also grown. An average cropping pattern for the entire Mokarna Tal area is shown in Figure 3.3.

Various factors are responsible for frequent inundation of the Tal area. These can be broadly categorised as under:

(a) Ingress of Ganga Water in Tal

i. Inundation in the Tal area by back flow of Ganga water through the Balgudarghat bridge over the Harohar.

ii. Inundation caused by the back flow of Ganga water through the valley lines joining the Tal area to the Ganga across the high lands forming the right bank of the Ganga.
iii. Inundation caused by the back flow of Ganga water through the Punpun and spilling of this back flow over the right bank of the Punpun and flowing over the low country side into the Tal.

(b) Inundation Caused by the Catchment Runoff

Inundation caused by the north flowing rivers of Kział-Harohar basin which have an aggregate catchment of 13,340 Sq. Km. Inundation during monsoon period is caused by these numerous rivers which drain the runoff of this large catchment into the Tal area at their out falls.
(c) Inundation Caused by Rainfall in the Tal

Inundation is also caused by rainfall received by the Tal area itself during the monsoon period.

Due to proneness of the Tal area to frequent inundation the agricultural activities during the wet season is kept at a low. On the other hand, for the successful Rabi crop in major portion of the Tal which remain submerged in monsoon period, drainage of Tal by 15th October is very crucial. Any delay in drainage adversely affects the Rabi crop. Figure 3.4 shows the frequency in years in which different Tals were free from submergence by 15th of October in the period 1972 to 1991. It is obvious from the figure that the Rabi crop suffers irreparably due to delayed drainage of Tals.
Figure 3.4: Frequency in Years in which Tals were free from submergence by 15th October
DATA COLLECTION

To delineate water logged area in the Mokama Tal and for hydrological data analysis in the Kule-Harohan basin the following hydrological, remote sensing and ancillary data were collected.

4.1 Remote Sensing Data

The remote sensing data of IRS-1A satellite were collected from NRSA, Hyderabad. Satellite imageries of different dates have been used in the study. For delineation of waterlogged area scenes of different dates have been utilized. Details of the satellite remote sensing data used in the present study is given in Table 4.1.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Date</th>
<th>Satellite</th>
<th>Sensor</th>
<th>Format</th>
<th>Scene</th>
<th>Path/Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>09.04.89</td>
<td>IRS-1A</td>
<td>LISS-II</td>
<td>FCC</td>
<td>B1</td>
<td>22/50</td>
</tr>
<tr>
<td>2</td>
<td>07.12.89</td>
<td>IRS-1A</td>
<td>LISS-II</td>
<td>FCC</td>
<td>B1</td>
<td>22/50</td>
</tr>
<tr>
<td>3</td>
<td>08.04.89</td>
<td>IRS-1A</td>
<td>LISS-II</td>
<td>FCC</td>
<td>A1</td>
<td>21/50</td>
</tr>
<tr>
<td>4</td>
<td>14.11.89</td>
<td>IRS-1A</td>
<td>LISS-II</td>
<td>FCC</td>
<td>A1</td>
<td>21/50</td>
</tr>
<tr>
<td>5</td>
<td>08.04.89</td>
<td>IRS-1A</td>
<td>LISS-II</td>
<td>FCC</td>
<td>B1</td>
<td>21/50</td>
</tr>
<tr>
<td>6</td>
<td>14.11.89</td>
<td>IRS-1A</td>
<td>LISS-II</td>
<td>FCC</td>
<td>B1</td>
<td>21/50</td>
</tr>
</tbody>
</table>
4.2 Hydrological Data

Hydrological data collection of the basin includes the collection of Discharge and rainfall of various gauging station located in the vicinity of the basin.

4.3 Discharge Data

Peak discharge data of four gauge and discharge sites were collected from the report of Second Bihar State Irrigation Commission. These data were utilised in the present study. Period of data availability and catchment areas of these sites are given below:

Table 4.2: Discharge sites and availability of data

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of site</th>
<th>Name of river/tributary</th>
<th>Catchment area (Sq. Km.)</th>
<th>Nature of data available</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Gaya</td>
<td>Falgu</td>
<td>3171</td>
<td>Annual Peak Discharge</td>
<td>1960-90</td>
</tr>
<tr>
<td>2.</td>
<td>Kadarganj</td>
<td>Sakri</td>
<td>1590</td>
<td>Annual Peak Discharge</td>
<td>1962-91</td>
</tr>
<tr>
<td>3.</td>
<td>Lakhisarai</td>
<td>Kiul</td>
<td>2619</td>
<td>Annual Peak Discharge</td>
<td>1963-90</td>
</tr>
<tr>
<td>4.</td>
<td>Mankathia</td>
<td>Harohar</td>
<td>14177</td>
<td>Annual Peak Discharge</td>
<td>1962-91</td>
</tr>
</tbody>
</table>

4.4 Rainfall Data

Average annual monsoon rainfall data from 1974 to 1989 of the catchment areas of the rivers entering the Mokama group of Tals is available in the report of Second Bihar State Irrigation Commission. These annual averages were computed from the rainfall data of sixty five blocks falling in the Kiul-Harohar basin.
4.5 Ancillary Data

Ancillary data includes the collection of following information and maps of the basin.

i. Topographical features

ii. Landuse information

iii. Soil map

iv. Geological information

v. Toposheets of the scale 1:50,000 and 1:2,50,000
METHODOLOGY

In the present study, water logged area map of the Mokama Tal was prepared using remote sensing technique. Peak discharge data of four rivers in the Kaul-Harobar system were used to carry out flood frequency analysis. Further, a management model for the water logged area has been developed. Various methods/techniques used in the study are described below.

5.1 Remote Sensing Approach for Inundated Area Mapping

Remote sensing technique facilitate in efficient monitoring of water logged and flood inundated area due to its repetitive synoptic coverage. It allows to visualise the things and the phenomenon in their entirety over the time and near real time measurement. Remote sensing data either in the digital format or in the imagery form can be quickly analysed on a computer or visually, as the case may be, to provide reliable estimate of waterlogged area. The interpretation of remote sensing data and acquisition of useful information in the present study was based on the basic image interpretation elements like site, shape, shadow, tone/colour, texture, pattern, size and association. A tentative classification scheme was drawn based upon knowledge and experience of the study area.

Two basic approaches have been used for water logged area mapping - dynamic and static.

5.1.1 Dynamic Approach

The dynamic or actual or direct approach uses the historical evidence to map the extent of waterlogging and drainage congestion or flood inundation mainly caused by
monsoon rainfall. An inundated area-frequency relationship can be developed by observing the evidence of events. This approach is highly agreeable to remote sensing wherein the successful application utilises the changes influenced by additional water that include increased soil moisture, vegetation moisture stress and standing water. All of this result in characteristically reduced reflectivity that lasts up to two weeks after the events and thereby reducing the need for obtaining satellite observations at the time of peak inundation.

5.1.2 Static Approach

The static approach utilises the indicators of water logging or inundation which can be identified using in-situ observations or by remote sensing techniques. The indicators broadly include meteorologic, physiographic, geomorphic and topographic features. Remotely sensed data based delineation of surface waterlogging or flood inundation area using static approach involves identification of indicators through their multispectral response and the spatial response pattern.

In the present study, the waterlogged areas from IRS-1A LISS IV False Colour Composites had been transferred on to the base map by optical processing the two scenes of different dates i.e. before and after monsoon. The delineated map can be confirmed with the help of ancillary data such as drainage map, contour map, submergence level and percentage submergence data. The extent of waterlogging can be depicted by two colour temporal composites. Post-monsoon IRS LISS II scene was superimposed on a pre-monsoon scene to prepare a composite water logged area scene. Further, the area frequency analysis of the historical data have also been done.
5.2 Flood Frequency Analysis

Following methods were used in the study to fit the annual peak discharge series and to carry out flood frequency analysis.

i. Normal distribution
ii. Two parameter Log normal distribution
iii. Three parameter Log normal distribution
iv. Pearson type III distribution
v. Log Pearson type III distribution
vi. Extreme Value I or Gumble distribution

5.2.1 Normal Distribution

Probability density function (PDF) of the normal distribution is given by

\[
f(x) = \frac{1}{\sigma \sqrt{2\pi}} \exp \left[ -\frac{(x - \mu)^2}{2\sigma^2} \right]; \quad -\infty < x < \infty \quad \text{(5.1)}
\]

where,

\(\mu\) is the location parameter, and \(\sigma\) is the scale parameter. The density of normal distribution is continuous \(-\infty < x < +\infty\) and tends to zero as \(x\) tends to \(\pm \infty\). It has a symmetrical bell shape and as a result the mean, median and mode are equal.

By integrating the equation (5.1), we can write the Cumulative Density Function (CDF) as:

\[
F(x) = \int_{-\infty}^{x} f(x) \, dx = \frac{1}{\sigma \sqrt{2\pi}} \int_{-\infty}^{x} \exp \left[ -\frac{(x - \mu)^2}{2\sigma^2} \right] \, dx \quad \text{(5.2)}
\]
in eq. (5.2) if \( Z = \frac{X - \mu}{\sigma} \); where z is called the reduced variate or standardized variate, then equation (5.2) reduces to

\[
F(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} \exp\left[ -\frac{z^2}{2} \right] \, dz
\]

\[\text{(5.3)}\]

The PDF and CDF of normal distribution corresponding to standardized variate z can be calculated from the standard tables.

5.2.2 Two Parameter Lognormal Distribution

If \( Y = \ln(x) \) follows normal distribution then X follows log normal distribution. Assuming that the mean and variance of Y are \( \mu_Y \) and \( \sigma_Y^2 \) respectively, the PDF of X can be written as:

\[
f(x) = \frac{1}{\sigma_Y \sqrt{2\pi x}} \exp\left[ -\frac{1}{2} \left( \frac{\ln(x) - \mu_Y}{\sigma_Y} \right)^2 \right]
\]

\[\text{(5.4)}\]

In relation to the variable X, \( \mu_Y \) controls the scale so it is called the scale parameter, while \( \sigma_Y \) controls the skewness and hence it may be regarded as a shape parameter.

5.2.3 Three Parameter Lognormal Distribution

If the variable X has a lower bound \( X_0 \), different from zero, and the variable \( Z = X - X_0 \) follows a lognormal distribution with two parameters then X is lognormally distributed with three parameters. Its PDF can be written as
\[ f(x) = \frac{1}{\sqrt{2\pi}(x-x_0)\sigma_y} \exp \left[ -\frac{1}{2} \left( \frac{\log_e(x-x_0) - \mu_y}{\sigma_y} \right)^2 \right] \] ....(5.5)

In equation (5.5) \( \mu_y, \sigma_y \) and \( x_0 \) are called the scale (mean of \( \ln(x-x_0) \)) the shape (Standard deviation of \( \ln(x-x_0) \)), and the location parameters, respectively. Parameter \( x_0 \) is estimated by trial and error.

The cumulative density function (CDF) of the three parameter lognormal distribution is given by

\[ F(x) = \int_{x_0}^{x} \frac{1}{(x-x_0)\sigma_y \sqrt{2\pi}} \exp \left[ -\frac{1}{2} \left( \frac{\ln(x-x_0) - \mu_y}{\sigma_y} \right)^2 \right] dx \] ....(5.6)

The three parameter lognormal PDF can be applied to positive or negative valued events provided \( (X-x_0) > 0 \), while the two parameter lognormal distribution should always be applied to positive valued events.

5.2.4 Pearson Type III Distribution

Pearson type III distribution is a three parameter distribution. This is also known as Gamma distribution with three parameters. The PDF of the distribution is given by

\[ f(x) = \frac{(x-x_0)^{y-1}e^{-(x-x_0)/\beta}}{\beta^y \Gamma(y)} \] .......(5.7)

\[ F(x) = \int_{x_0}^{x} \frac{(x-x_0)^{y-1}e^{-(x-x_0)/\beta}}{\beta^y \Gamma(y)} dx \] .......(5.8)
Where,

\[ x_0 = \text{Location parameter} \]
\[ \beta = \text{Scale parameter} \]
\[ \gamma = \text{Shape parameter} \]

5.2.5 Log Pearson Type III distribution

The probability density function of log Pearson type III distribution is given by

\[
f(x) = \frac{1}{|\beta| \cdot \lambda} \cdot x \left[ \frac{\log_e x - y_0}{\beta} \right]^{\gamma - 1} \exp \left[ -\frac{\log_e x - y_0}{\beta} \right] \]

\[ \ldots \ldots(5.9) \]

Where,

\[ y_0 = \text{Location parameter} \]
\[ \beta = \text{Scale parameter} \]
\[ \gamma = \text{Shape parameter} \]

5.2.6 EV I Distribution or Gumble Distribution

The probability density function of EV I distribution function is given by

\[
f(x) = \frac{1}{\alpha} \exp \left[ \frac{x - u}{\alpha} - e^{(x - u) / \alpha} \right]
\]

\[ \ldots \ldots(5.10) \]

Where,

\[ u = \text{Location parameter} \]
\[ \alpha = \text{Shape parameter} \]

The cumulative density function of the EV I distribution is given by
\[ F(x) = e^{-e^{-\frac{(x-\mu)}{\alpha}}} \]  \hspace{0.5cm} \text{......(5.11)}

The parameter of the distribution can be estimated from the following equations using methods of moments.

\[ \mu = u + 0.5772\alpha \]  \hspace{0.5cm} \text{......(5.12)}

\[ \sigma^2 = \left( \frac{\pi^2 \alpha^2}{6} \right) \]  \hspace{0.5cm} \text{......(5.13)}

5.3 Evaluation Criteria for Selecting a Suitable Frequency Method

Evaluation criteria used in the present study for selecting an appropriate frequency analysis are:

i. Average of the relative deviations between computed and observed values of annual maximum discharge peak (ADF)

ii. Efficiency (EFF)

iii. Standard Error (SE)

5.3.1 Computation of ADF Values

The following relationship is used for computation of ADF values.

\[ ADF = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{QO_i - QC_i}{QO_i} \right) \]  \hspace{0.5cm} \text{......(5.14)}

5.3.2 Computation of EFF Values

EFF values are computed using the relations:

\[ \text{EFF} = \frac{(IV - MV)}{IV} \]  \hspace{0.5cm} \text{......(5.15)}
where,
\[ IV = \sum_{i=1}^{n} (QO_i - \overline{Q})^2 \quad \ldots \ldots (5.16) \]
\[ MV = \sum_{i=1}^{n} (QO_i - QC_i)^2 \quad \ldots \ldots (5.17) \]

\( \overline{Q} \) = Mean of the observed peak discharge series, \( QO_i \)

\( QO_i \) = \( i \)th value of the computed peak discharge series

\( n \) = Sample size

5.3.3 Computation of SE Values

SE values are computed, in non dimensional form using the following relationships:

\[ SE = \left( \frac{1}{n} \sum_{i=1}^{n} (QRO_i - QRC_i) \right)^2 \quad \ldots \ldots (5.18) \]

where,

\[ QRO_i = \frac{QO_i}{\overline{Q}} \quad \ldots \ldots (5.19) \]

\[ QRC_i = \frac{QC_i}{\overline{QC}} \quad \ldots \ldots (5.20) \]

5.4 Outline of Optimization Model for the Waterlogged Area

For the formulation of the management model it is considered that water logged area serve as a storage reservoir having inflows/back water flow to/from various tributaries and outflow to/from the river Ganga (A schematic of the conceptualization is given in Fig 5.1. The objective function, which minimizes the total surface water logged area under the
FIG. 5.1: Schematic Representation of the Conceptualization of Mokama Tal Area
constraints of check over inflows (translation of inflow hydrographs) from different tributaries, and considering minimum crop water requirement in the upper reaches and in the Tal area, assumes that the back water flow from the river Ganga is completely checked.

The objective function to be minimized to obtain the optimum level of area free from surface water logging is thus:

$$\text{Min } f(I) = \text{Min } \sum_{j=1}^{n} \left[ I_j - \sum_{k=1}^{m_j} S_{jk} \right]$$

$$\ldots (5.21)$$

Where,

- $f(I) = \text{Total inflow into the Tal area from various tributaries}$
- $I_j = \text{Total inflow into the Tal area from jth tributary with no check dam}$
- $S_{jk} = \text{Storage capacity of kth check dam on jth river}$
- $m_j = \text{Maximum possible number of check dams on jth river}$
- $j = 1 \text{ to } n = \text{Number of rivers}$
- $k = 1 \text{ to } m_j = \text{Number of check dams on jth river}$

The above objective function can be solved under the following constraints:

### 5.4.1 Inflow into the Tal area

Total storage in all check dams in a tributary cannot be more than the total runoff contribution of that tributary to the Tal area.

$$I_1 - \sum_{j=1}^{n} \sum_{k=1}^{m_j} S_{jk} \geq 0$$

$$\ldots (5.22)$$

$$I_2 - \sum_{j=1}^{n} \sum_{k=1}^{m_j} S_{jk} \geq 0$$

$$\ldots (5.23)$$
\[ I_n \geq \sum_{j=1k=1}^{n} \sum_{j=1k=1}^{m} S_{jk} \geq 0 \]  \hspace{1cm} \text{(5.24)}

where, \( I_1 \), \( I_2 \), \( I_3 \), \ldots, \( I_n \) are inflows into the Tal area from tributary numbering 1, 2, 3, \ldots, and \( n \).

5.4.2 Storage in Tal Area

\[ \sum_{j=1}^{n} I_j - \sum_{j=1k=1}^{n} m_j \geq V_1 \]  \hspace{1cm} \text{(5.25)}

\[ \sum_{j=1}^{n} I_j - \sum_{j=1k=1}^{n} m_j \leq V_2 \]  \hspace{1cm} \text{(5.26)}

where,

\( V_1 \) = Minimum required storage volume in Tal area for successful Rabi and Kharif cropping.

\( V_2 \) = Maximum storage in the Tal.

5.4.3 Maximum Storage Constraints in Check Dams

\[ S_{11} \leq S_{m11} \]  \hspace{1cm} \text{(5.27)}

\[ S_{12} \leq S_{m12} \]  \hspace{1cm} \text{(5.28)}

\[ S_{1k} \leq S_{m1k} \]  \hspace{1cm} \text{(5.29)}

\[ S_{2k} \leq S_{m2k} \]  \hspace{1cm} \text{(5.30)}
\[ S_{jk} \leq S_{mj} \]  \hspace{1cm} (5.31)

where,

\[ S_{jk} = \text{Storage in the } k\text{th check dam on } j\text{th river} \]
\[ S_{mj} = \text{Maximum storage in the } k\text{th check dam on } j\text{th river} \]

5.4.4 Water Requirement in the Catchment

Storage in the check dams should be sufficient to fulfill water requirement of the command area of each check dam. It is considered that the 30% of cultivable land in the command require irrigation during Kharif cultivation, 70% during Rabi cultivation and 80% during hot weather.

\[ 0.3A_j \cdot WR_{\text{Kharif}-k} + 0.7A_j \cdot WR_{\text{Rabi}-k} + 0.8A_j \cdot WR_{\text{HW}-k} \leq S_{jk} \] \hspace{1cm} (5.32)

where,

\( j = 1 \text{ to } n = \text{Number of rivers} \)
\( k = 1 \text{ to } m_j = \text{number of check dams on } j\text{th river} \)
\( A_j = \text{Cultivable area in the command of } k\text{th check dam on } j\text{th river} \)
\( WR_{\text{Kharif}-k} = \text{Water requirement from } k\text{th check dam for irrigation of Kharif crop} \)
\( WR_{\text{Rabi}-k} = \text{Water requirement from } k\text{th check dam for irrigation of Rabi crop} \)
\( WR_{\text{HW}-k} = \text{Water requirement from } k\text{th check dam for irrigation of Hot weather crop} \)
RESULTS AND DISCUSSION

The drainage problems of the Mokama Group of Tal is associated with the stagnation of runoff and ingress of the Ganga water by backflow. Stagnation of runoff in the area is caused by intense rain during monsoon period, resulting into excessive runoff for which drainage conditions are not favourable due to high water levels in the Ganga. Waterlogging problem arise in the area due to excessive rainfall, stagnation of water on land surface for long periods, inadequate surface drainage conditions during monsoon period and poor topography. The present study was carried out in order to delineate waterlogged area in the Mokama Group of Tal using the satellite remote sensing technique. Further, the historical discharge data of various sites have been analysed for flood frequency analysis.

6.1 Waterlogged Area Mapping

The waterlogged areas was delineated based upon the sharp contrast between water spread and the adjacent areas on the satellite data. It was also possible to delineate the areas where the water had receded. The post-monsoon scenes of the IRS LISS II data were used to delineate the standing water areas and wet areas during monsoon. While, pre-monsoon scenes were used to delineate the permanent water logged/wet areas. These areas were demarcated as water logged areas during monsoon season. The standing water areas appeared as dark blue depending upon the depth of water, while the wet areas appeared as dark grey to light grey in colour/tone on the imagery.

Remote sensing technique in integration with ancillary data such as soil map, contour map, rainfall in the catchment, runoff in to the Tal, submergence level and control structures etc. has been used to delineate the water logged areas. Historic data (Table 6.1) regarding frequency and extent of submergence in different Talas from year 1972 to 1991
Table 6.1: Extent of submergence in different years in Mokama Tal area.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Name of Tal</th>
<th>Year in which more than 50% submerged</th>
<th>Year in which more than 75% submerged</th>
<th>Year in which 100% submerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fatiha Tal</td>
<td>1972,73,76,78,88,89</td>
<td>1972,73,76,78,89</td>
<td>1973,76,78,89</td>
</tr>
<tr>
<td>2</td>
<td>Bakhtarpur Tal</td>
<td>1976,78,83,86,87</td>
<td>1976,78</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Barh Tal</td>
<td>1973,76,78,87,90</td>
<td>1976,78</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>More Tal</td>
<td>1973,74,76,78,80,87,89,90</td>
<td>1973,74,76,78,80</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Mokama Tal</td>
<td>1973,76,78,80,82,83,84,85,87,89,90</td>
<td>1973,76,78,80,82,83,84,87,90</td>
<td>1973,76,78,80,82,87,90</td>
</tr>
<tr>
<td>6</td>
<td>Barahiya Tal</td>
<td>1973,74,75,76,78,80,82,83,84,85,87,88,89</td>
<td>1973,74,75,76,78,80,82,83,84,87,90</td>
<td>1987</td>
</tr>
<tr>
<td>7</td>
<td>Singhaul Tal</td>
<td>1973,74,75,76,77,78,79,80,82,83,84,85,87,88,89</td>
<td>1973,74,75,76,78,80,82,83,84,85,87</td>
<td>1983,84,85,87</td>
</tr>
</tbody>
</table>

were used in this study. Submergence frequency and extent of submergence of various Talas is shown in Figure 6.1 to 6.7. Contour map at the interval of one foot was taken from the Report of Mokama Tal drainage Scheme, Water Resources Department Government of Bihar. The contour map of the Tal area is shown in Figure 6.8. A surface plot of theses contours was prepared to indicate the low lying areas susceptible to submergence. 3-D surface plot with contour map is presented in Figure 6.9. Water logged area map so delineated was further supported by the historic submergence data and surface plot to assess water logging in the Tal area. The water logged area map developed by pre-monsoon and post-monsoon remote sensing data for the year 1989 and ancillary data is shown in Figure 6.10. It was observed that due to moderate to low rainfall in the basin the submergence in the More Tal, Mokama Tal, Barahiya Tal and Singhaul Tal was between 50 to 75%. While, Bakhtarpur Tal and Barh Tal got submergence below 50%. Fatiha Tal
Fig 6.1: Frequency of Submergence in Fatuha Tal

Fig 6.2: Frequency of Submergence in Bakhtiarpur Tal
Fig 8.3: Frequency of Submergence in Barh Tal

Fig 8.4: Frequency of Submergence Morh Tal
Fig 6.6: Frequency of Submergence in Mokama Tal

Fig 6.8: Frequency of Submergence in Barahiya Tal

Fig 6.7: Frequency of Submergence in Singhual Tal
Fig 6.8: Contour Map of Mokama Tal Area
Fig 6.9: 3D Surface Plot of Mokama Tal Area
Fig. 6.10: Water logged Area Map Delineated from Remote Sensing Data
is the exception with 100% submergence. This may be due to inundation caused by the Ganga by back flow through the Punpun.

6.2 Flood Frequency Analysis

The statistical parameters of original and log transformed series of the historical flood records of four gauging sites are given in Table 6.2. It is observed from the table that the mean maximum flood of the gauging sites vary from 565.57 cusec to 967.41 cusec.

Table 6.2 : Sample statistics of the original and logs of the data

<table>
<thead>
<tr>
<th>NAME OF SITE</th>
<th>ORIGINAL DATA</th>
<th>LOGS OF DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MEAN (Cusec)</td>
<td>SD (Cusec)</td>
</tr>
<tr>
<td>GAYA</td>
<td>745.08</td>
<td>799.98</td>
</tr>
<tr>
<td>KADARGANJ</td>
<td>565.57</td>
<td>629.62</td>
</tr>
<tr>
<td>LAKHISARAI</td>
<td>628.40</td>
<td>409.55</td>
</tr>
<tr>
<td>MANIKATHA</td>
<td>967.41</td>
<td>536.48</td>
</tr>
</tbody>
</table>

Data series computed through various distribution methods and actual data series is plotted on the probability paper by Weibull plotting position formula. These plots are shown in Figures 6.11 to 6.14. The flood estimates for different recurrence intervals obtained by different methods are given in Table 6.3 to Table 6.6. The descriptive abilities of different methods have been evaluated by computing ADF, EFF and SE values. These values are given in Table 6.7 to 6.9. It can be seen that the values of ADF, EFF and
Fig. 6.11: Graphical Comparison of Distribution Fits at Gya Site
Fig 6.12: Graphical Comparison of Distribution Fits at Kindanaj Site
Fig. 6.13: Graphical Comparison of Distribution Fits at Lakhnunar Site
Fig. 6.14: Graphical Comparison of Distribution Fits at Manchester Site
SE computed from different methods are quite comparable. It is, therefore, difficult to identify a suitable method based on the computed values of ADF, EFF and SE.

Table 6.3: Flood estimates at Gaya site for different return periods

<table>
<thead>
<tr>
<th>RETURN PERIOD (YEAR)</th>
<th>DISTRIBUTION METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>2</td>
<td>628.4125</td>
</tr>
<tr>
<td>3</td>
<td>805.0131</td>
</tr>
<tr>
<td>5</td>
<td>973.3410</td>
</tr>
<tr>
<td>10</td>
<td>1153.3410</td>
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<tr>
<td>25</td>
<td>1345.5610</td>
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<tr>
<td>50</td>
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<tr>
<td>100</td>
<td>1581.3420</td>
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<td>200</td>
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</tbody>
</table>

Table 6.4: Flood estimates at Kadarganj site for different return periods

<table>
<thead>
<tr>
<th>RETURN PERIOD (YEAR)</th>
<th>DISTRIBUTION METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
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<tr>
<td>5</td>
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<td>10</td>
<td>1372.5880</td>
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<tr>
<td>25</td>
<td>1668.1000</td>
</tr>
<tr>
<td>50</td>
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<tr>
<td>100</td>
<td>2030.5810</td>
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<tr>
<td>200</td>
<td>2187.6410</td>
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### Table 6.5: Flood estimates at Lakhisarai site for different return periods

<table>
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<th>RETURN PERIOD (YEAR)</th>
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<th></th>
<th></th>
<th></th>
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<th></th>
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</thead>
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<td>3 Parameter Log Normal</td>
<td>Pearson Type III</td>
<td>Log Pearson Type III</td>
<td>Extreme Value Type I</td>
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</tr>
<tr>
<td>2</td>
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<td>758.2972</td>
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<tr>
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<tr>
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<td>2438.1260</td>
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<td>3054.6810</td>
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### Table 6.6: Flood estimates at Mankatha site for different return periods

<table>
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<th>RETURN PERIOD (YEAR)</th>
<th>DISTRIBUTION METHOD</th>
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<th></th>
<th></th>
<th></th>
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</tr>
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<tbody>
<tr>
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<td>3 Parameter Log Normal</td>
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<td>Log Pearson Type III</td>
<td>Extreme Value Type I</td>
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<tr>
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<tr>
<td>3</td>
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<td>1057.6960</td>
<td>1162.2320</td>
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<td>1166.3250</td>
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<tr>
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<td>1308.0350</td>
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<td>1449.4140</td>
<td>1403.8310</td>
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<tr>
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<td>1673.1960</td>
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<td>1741.7830</td>
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<td>2197.8840</td>
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</tr>
<tr>
<td>100</td>
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<td>2799.9980</td>
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</tr>
<tr>
<td>200</td>
<td>2349.5050</td>
<td>3211.7810</td>
<td>2588.8780</td>
<td>2701.0890</td>
<td>2682.7770</td>
<td>3113.2870</td>
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### Table 6.7: ADF values for different stations

<table>
<thead>
<tr>
<th>STATION</th>
<th>METHOD</th>
<th>Normal</th>
<th>2 Parameter Log Normal</th>
<th>3 Parameter Log Normal</th>
<th>Pearson Type III</th>
<th>Log Pearson Type III</th>
<th>Extreme Value Type I</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAYA</td>
<td></td>
<td>0.9718</td>
<td>0.1050</td>
<td>0.3298</td>
<td>0.2925</td>
<td>0.1005</td>
<td>0.6868</td>
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<tr>
<td>KADARGANJ</td>
<td></td>
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<td>0.2544</td>
<td>0.6770</td>
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<td>0.1590</td>
<td>1.1646</td>
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<tr>
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<td></td>
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<td>0.0692</td>
<td>0.1418</td>
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<tr>
<td>MANKATHA</td>
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<td>0.1744</td>
<td>0.0972</td>
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</table>

### Table 6.8: EFF values for different stations

<table>
<thead>
<tr>
<th>STATION</th>
<th>METHOD</th>
<th>Normal</th>
<th>2 Parameter Log Normal</th>
<th>3 Parameter Log Normal</th>
<th>Pearson Type III</th>
<th>Log Pearson Type III</th>
<th>Extreme Value Type I</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAYA</td>
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<td>0.8667</td>
<td>0.8682</td>
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<td>0.9544</td>
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### Table 6.9: SE values for different stations

<table>
<thead>
<tr>
<th>STATION</th>
<th>METHOD</th>
<th>Normal</th>
<th>2 Parameter Log Normal</th>
<th>3 Parameter Log Normal</th>
<th>Pearson Type III</th>
<th>Log Pearson Type III</th>
<th>Extreme Value Type I</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAYA</td>
<td></td>
<td>0.6082</td>
<td>0.3282</td>
<td>0.3602</td>
<td>0.2815</td>
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<td>0.4557</td>
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<td>KADARGANJ</td>
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<td>0.3161</td>
<td>0.3496</td>
<td>0.2393</td>
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<td>0.4200</td>
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<tr>
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<td>0.1176</td>
<td>0.1053</td>
<td>0.1255</td>
</tr>
<tr>
<td>MANKATHA</td>
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<td>0.1161</td>
<td>0.1128</td>
<td>0.1012</td>
<td>0.1148</td>
</tr>
</tbody>
</table>
6.3 Management Model

The formulation of management model developed in the study require various hydrological, topographical and land use data for the upper zone of Kiul-Harohar basin and the Tal area. At present sufficient database is not available to solve the model for the actual field condition. An effort would be necessary for the contour surveying the total Tal land. It can help in developing an area capacity curve which would be the input to the model. Further, data, such as, inflow data of various rivers meeting the Tal area and rainfall of the basin is required to compute total contribution of the catchment to the tal area. Information concerning evaporation and seepage from the Tal area are other data needed for evaluating the model response. Such information and other related data can help in to estimate the input data of the model. The estimation of model’s response and evaluation of required input data form another study, and are being dealt separately under the work programme of 1997-'98.
CONCLUSIONS

The Mokama Group of Tal is having a very unique problem of surface water logging during the monsoon season. Though the Tal area is continuous from Fatuha to Lakhisarai, it is differently named in its different reaches. These are namely Fatuha Tal, Bakhtiarpur Tal, Barh Tal, More Tal, Mokama Tal, Barahiya Tal and Singhaur Tal. Remotely sensed data and historical discharge, rainfall and other related data of Mokama Tal area and Kiul-Harohar basin have been analysed. An attempt has also been made to formulate a management model for the entire Tal area so as to minimize the total water logged area in an optimal manner. From the study following conclusions are drawn:

1. Historical submergence data for a period of 20 years from 1972 to 1991 indicates that submergence above 50 per cent and up to 75 per cent in case of Fatuha, Bakhtiarpur, Barh and More Tal has occurred only in 25 to 40% of years. While in lower Tal of Mokama, Barahiya and Singhaur the frequency is 55 to 80% of years.

2. Remote sensing satellite scenes obtained during pre-monsoon and post-monsoon time were valuable to understand the problem of water logging and drainage congestion before the commencement of rainy season, during the rainy season and after the monsoon.

3. The remotely sensed information were integrated with the conventional ground survey data and ancillary data such as contour maps, soil maps, drainage map, submergence data, rainfall data and river discharge data. The water logged area map so prepared defines the area susceptible for waterlogging and drainage congestion.

4. The visual interpretation of IRS 1A LISS II FCC prints gives a reasonably accurate assessment and it is often possible to delineate different stages of soil moisture. The water logged area map so developed almost matches with the historical submergence data. The remote sensing data when collected and analysed in a continuous fashion can help in planning the optimum landuse strategy for the area.
5. The flood frequency analysis at site indicate that the superiority of one method over the other could not be established. The analysis provides the estimate of floods at higher recurrence interval. These can be considered as a base information while deciding a water resources structure in the basin for optimal minimization of inflows into the Tal area.

6. The management model developed in the study requires a hand full of data such as inflow of various tributaries contributing to the Tal area, area capacity curve of the Tal area, inflow/back flow to/from the river Ganga, rainfall in the basin, evaporation data, seepage from Tal area etc. An optimum land use planning with reduced area of submergence can be decided when the objective function of minimization of total water logged area is solved under various related constraints.
REFERENCES


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R. JHA
R.K. JAISWAL

ASSISTANCE: A.K. SIVADAS
ATM PRAKASH