CHAPTER II

PHYSIOGRAPHY AND DRAINAGE

PHYSIOGRAPHY:

The area under investigation is a part of the north eastern sub-divisions of the Aligarh and Etah districts, comprising all the stretches between the Ganga and the left bank of the Kali rivers. The latter forms the boundary on the west and south dividing the area from the rest of the Aligarh and Etah districts.

The physical feature of the area presents a great diversity of appearances. From the low valleys of the Ganges which lies between the present active channel and the upland margins, the level rises sharply to the high sandy uplands which crown the old flood bank of the river Ganga and then descends gradually into a depression drained by the Nim and Chhoiya rivers beyond which it rises again to the bank of the Kali-river. Along the right bank of Kali-river is another sandy belt rising from the low valley of the Kali river and this is followed by a belt of loam soil which sinks gradually into the broad central depression further west. Physiographically, the Ganga Kali sub-basin can broadly be divided into the following three distinct physiographic units (Fig. 2 b).

- The low valley of the Ganga
- Eastern upland between the low valley of the Ganga and the Nim river
- Nim-kali interfluves
Plate 1. - A view of the Lower Ganga Canal.
(1) The low valley of the river Ganga

It lies between the right bank of the river Ganga and uplands margins. It extends in north west to south east direction parallel to the old bank of the river Ganga. It is 1.6 km wide in north which gradually increases due south where it attains a maximum width of about 16 kilometre, which further south reduces to about 7 kilometre near Soron. The soil of this physiographic unit is recent alluvium comprising fine through medium to coarse sand. Geomorphologically, this tract consist of numerous point bar deposits with enechelon distribution, aligned parallel or sub parallel to the old high bank. They are usually separated by the intervening low land which once form the parts of the erstwhile channels. Each point bar deposit consists of coarsest material at bottom and the finest at the top thus it represents a fining upward sequences.

The lower Ganga canal which is 73.17 m wide and 37 km long with a discharge of 8500 cusec traverses through the eastern margin of the study area (Plate I). The canal flows mainly through the low valleys of Ganga upto Sikandarpur village thereafter traverses along the upland and crosses the kali river near Kasganj through an aquiduct. This canal is a feeder channel out of which Farrukhabad distributary has been taken out which irrigates south eastern part of the study area.

The construction of the lower Ganga canal has greatly benefitted the low valley of Ganga by means of protective embankments
Plate 2a - sand dunes in the low valley of the Ganga.

Plate 2b - Low valleys of the Ganga high land in the background.
which run at right angles to the canal as far as the old channels.

The soil of this valley throughout the area is sandy, differing from the soil of upland. In that they contain a large admixture of vegetable matters. Along the edge of the Ganga are found rich soft loam on which sugarcane is cultivated without irrigation. Similar but less valuable soil is met with along the edge of the old channel of the Ganga. Between the above two, the level lies higher and the quality of soil deteriorates from north to south, being very sandy just above the old channel. South of the old channels, there is always a considerable stretch of very poor soil, either wind blown sand or waste land.

The sub-soil throughout this tract is sand of the Ganges. The surface is everywhere uneven. The crests of the vertical or lateral point bar deposits which are generally aligned enechelon almost sub-parallel to upland margins form the topographic highs while the intervening lows represents the old channels, are mostly found as marshy tracts full of weeds (Plate-II). The point bar deposit are covered with thick forest and form the natural habitat for wild animals.

Eastern Upland:

The low valleys of the Ganga is followed by eastern upland (area between upland margin and the Nim) river which extends in
northwest to southeast direction (Fig. 2b). The eastern flank of this upland slopes towards the Ganga while the western flank tapers towards the Nim-Chholya depression— a mini watershed bounded by the Nim and Chholya rivers. This upland commences with the belt of high undulating ground above the steep upland margins facing the low flood plains of the river Ganga. The soil of this tract is almost sandy. The ravines are comparatively low and seldom extensive. The sandy tract extends inland as far as the valley of the Nim river. The central portion of this upland is occupied by loam soil and waste land with numerous patches of salt efflorescence. This tract is thickly populated and there are numerous mango grooves. The crest of this upland is traversed by the Anupshahar branch of the Upper Ganga canal and its various distributaries.

**Nim-Kali Interfluve:**

The Nim-Kali interfluves forms basically the part of eastern upland which has been dissected by perennial stream called Nim hence present physiographic unit is named after Nim-Kali interfluves.

This physiographic unit has further been divided into

(a) Nim - Chholya Depression

(b) Atrauli upland

The Nim - Kali interfluves from the largest physiographic unit of the study area which extends for about 50 km in length from Atrauli in North to Kasganj in south.
Plate 3 - View of confluence of Nim and Kali rivers.
(n) **Nim - Chholya Depression**

The eastern upland is followed by a mini watershed called Nim-chholya depression.

This low land appears to have been carved out of the upland through continuous erosion with the passage of time. The Nim enters the area in the north and traverses due south-east and joins the Kali river at Barhari in Etah district (Plate - III). It is a perennial stream but Chholya is a drainage channel which joins it at Rumami which remains dry except during the rainy season. There is a belt of low land along the Nim comprising fair quality loam but the soil is apt to deteriorate after heavy floods especially in southern reaches owing to saturation and appearance of salts. The country west of river is a fine stretch of good loam soil extending to sandy ridge which overlooks the valley of Kali river.

(b) **Atrauli upland** :

It is a part of Nim - Kali Interflues. It lies west of Nim-Chhoiya rivers. This part is a stretch of good loam soil which extends westward upto the low flood plain of the Kali river. Almost universally the soil on the immediate margin of the Kali river is a good loam, well raised and not too stiff. This portion is the best and least uncertain portion of the valley. Through the central parts of the Atrauli upland there runs a depression in which soil stiffens into clay and at places there is good deal of waste land, particularly south east of Atrauli.
GEOMORPHOLOGY OF THE AREA

An attempt has been made to identify different geomorphic elements of the Ganga-Kali Sub-basin in parts of Aligarh-Etah districts. For the above purpose, remote sensing data product of LANDSAT TM F.OC bands 2,3,4 pertaining to 145 path and 041 row and 146 path and 041 row were used.

There are two well defined planation (T₂, T₁ surfaces) which have developed in response to changing climate and sea level fluctuations during late quaternary (Singh, 1987). On these regional planation surface a number of relict drainages, abandoned channels and meander scars are present in contrast to present day active channels (T₀ surface) forming a distinct geomorphic element in the area. T₁ surface from the flood plain of the river about 2-5 m higher than the active channels and represents deposits of past phase of the Ganga.

From the active channel through flood plain to the adjacent uplands, in all three geomorphic surfaces are identified where each one has its own distinctive fluvial geomorphic characters.

T₀ Surface:

The braided stream character and fine sand size of the active channel of the present day Ganga river is T₀ - surface. Here the channel is braided type: a channel which is divided into several
Plate 4a - A view of marshy tract at $T_1$ surface.

Plate 4b - Bushes in the low valley of the Ganga.
channels which successively meet and re-divided. Generally the braiding is low and at bankful stage channel is slightly sinuous. This surface is made up of a few active channels and channel bars (Fig. III).

\[ T_1 \text{ Surface} : \]

This surface is located about 5-10 m above the TO-surface and restricted within the river valley. The lower ganga canal form the limiting line of this surface. It shows extensive vegetation and number of marshy tracts (Plate - IV). Near surface sediments are silty sand; but below few metres, thick sand deposits are present. In the imagery, this surface shows many meander scars and a very prominent meander scroll close to Sikandarpur village (Fig. 3). Meander scrolls are defined as depression and rises on the convex side of bends formed as channel migrated laterally down the valley and toward the concave bank (Leopold, 1964). Presence of these geomorphic features implies that when the Ganga river was flowing at \( T_1 \) surface it was highly sinuous in character. The age of the \( T_1 \) surface, abandoned meandering channel is conceptually inferred to be around 20-30 ka, the last inter glacial (Ghosh and Singh, 1988)

\[ T_2 \text{ Surface} : \]

This surface is an upland surface, it is 5-10 m above the \( T_1 \) surface. Major part of this surface shows silty clay, very often
interclated with the calcareous concretions of varying sizes. There are many abandoned drainage and abandoned channels which have given rise to numerous lakes and marshy lands spread here and there all over the area (Fig. 3).

Down to the 10 metres depth below this surface no major sand bodies are encountered during the water well drillings. Age of this surface may be last interglacial (120 ka) upon which tens of metres of sediment have accreted ever since; the age of abandoned drainages is 5-10 ka (Singh, 1987; Ghosh and Singh, 1988). The study shows that the $T_1$ surface appears in contrast to the braided stream characters of the present day Ganga river To. It is argued that $T_1$ surface is an older surface and formed by palaeo-Ganga river during 25-30 ka. This palaeo Ganga-River of $T_1$ surface phase was a highly meandering type, which carried somewhat coarser grained sediment load. It implies that the paleo-Ganga River of 25-30 ka period was carrying more water and less sediment load to distinctive meanders (Singh, 1990).

Mukherji (1963) pointed out from his study of the Ganga-Yamuna interfluves that the paleo-Ganga river was characterised by 8-15 km wide broad river valley as compared to the present day 3-10 km narrow flood plain. This means that in earlier phase the Ganga river was much larger and carrying very higher discharges. This is further substantiated through the study of the satellite imagery data which show tight meandering of high amplitude demanding a higher water budget during their active phase.
Around 18 ka years back during the last sea-level low stand, the Ganga river cut itself into its $T_1$ surface as a result of base level adjustment due to fall in sea level, later due to rise in sea level, the Ganga river has aggraded to develop the $T_0$ surface and this tendency is still continuing. During last 25000 years the Ganga river underwent a distinct change from meandering type to the present day braided type consequent to the decrease in water budget and increase in sediment load (Singh, 1990).

Further, the decrease in the discharge may be attributed to a meteorological and other factors as well. One of the most important factor leading to fall in discharge was the construction of the two feeder canals, one at Hardwar and other at Narora which were constructed in 1879 led to great decrease in discharge amounting to about 11876 cusec. The diversion of such a huge discharge of the Ganga water through these two canals is bound to have its impact on the river behaviour, what happened before 1879 and what factor controlled the fall in discharge are very little known yet the metamorphosis of the drainage from meandering to braided is very well distinct.

**DRAINAGE**:

The study area under investigation is drained by the Ganga, Nim, Chhhoiya and the Kali rivers. The right bank of the Ganga forms the eastern most hydroboundary. However, the Ganga merely touches the study area in the east and directly drains low of valleys
Plate 5 — Old channels of the river Ganga.
and a small portion of uplands from which the surface water is carried down by small streams which flow through the few ravines of small magnitude and finally join the Ganga river.

The Old Ganga:

The left over channels of the Ganges are known as the old Ganga. It flows through the low valleys of the Ganga adjacent to the high bank of the upland margins (Plate - V). The flow in the old Ganga channel is slightly sluggish due to the blockade at many places by sand spills and weeds.

The floods in this low valley of the Ganga are common and of long continuance, while the lands in its neighbourhood are liable to water logging.

The Kali River:

The kali river which forms the western hydroboundary of the area is the only tributary of the Ganga which traverses the area. It rises in Muzaffar Nagar district and passes through Meerut and Bulandshahar, before entering Aligarh district on the northern border close to the Atrauli-Road railway station, then it takes devious but south easterly course, along the southern and western border of Aligarh district passing into Etah near Barhari and forms the southern boundary of the area. The valley through which it flows is deep and about 0.5 kilometer in width from crest to crest and
Plate 6a  - Steep left bank of the river Kali.

Plate 6b  - Hard pan exposed on the left bank of river Kali.
though stream floods readily, its inundations however, long continued never extend outside the valley. The river is not navigable but of perennial nature and its volume is increased by the surplus water from the Ganga canal. Northern portion of Etah district drains into the Kali river, which is capable of dealing considerable volume of water. It flows mainly through the upland and is characterized by meandering deep channels and highly ravinous banks and finally joins the river Ganga south of Farrukhabad town.

The Nim and Chholya Rivers:

The chholya being an ephemeral stream, of more importance, however, is only the Nim which traverses through the middle of the Ganga-Kali upland. The stream rises in Bulandshahr district enters the area at Chakathal, flows in southerly or south-easterly direction past the villages of Bijauli, Bhikampur and Gangiri. At a place Rumamal, it is joined on its right bank by a small drainage channel called Chholya, which has its source north of Atrauli, close to the district border, and during the rains carries off good deal of water from the low ground in the vicinity. It is dry during the hot weather, but the Nim is perennial, and is utilized for irrigation.

CLIMATE AND RAINFALL:

The Ganga-Kali sub-basin falls under the sub-tropical climatic zone and is characterized by hot summer and chilly winter.
The temperature starts rising by the middle of March, April, May and June are the hottest months of the year. During June the temperature often rises to 45°C while during winter season mercury touches 4°C. December and January are the coldest months of the year.

Rainfall:

The hot spell is followed by the onsets of monsoon which breaks around the 2nd week of June every year. The area receives rainfall mainly from the south west monsoon during the months of June to September. However, heavy precipitation takes place in the month of July and August and monsoon recedes in September. The average annual rainfall for the Ganga-Kali sub-basin is 754.12 mm.

Areal Distribution of Rainfall:

A Perusal of Isohyetal map (fig. 4) of the study area shows that the intensity of rainfall decreases from east to west and on an average the eastern part of the area receives slightly more rainfall which gradually decreases in the west proximal to the bank of river Yamuna.

Departures:

The departure and cumulative departures from the annual rainfall are given in (Appendix IA & B) and are shown in (figure
 departures show wide variations from the mean, indicating the erratic nature of the rainfall whereas cumulative departures ends around the mean annual rainfall indicating a cumulative compensating effect, as far as the quantum of excess and deficit rainfall over a longer period is concerned.

Variability of Rainfall:

The available annual rainfall data of Atrauli and Kasganj rain-gauge stations for the period 1901 to 1989 have been statistically analysed and results are tabulated (table 1).

The table shows that the highest rainfall at Atrauli rain-gauge station is 1402 mm (1983) where as lowest 307.3 mm (1987) and at Kasganj the highest rainfall 1227 mm (1960) while lowest 208 mm is recorded in 1918, showing a very wide range of variation.

The mean annual rainfall for Atrauli and Kasganj and 755 mm and 753 mm respectively. The average mean annual rainfall for the entire Ganga-Kali sub-basin is 745.12 mm. The standard deviation at Atrauli is 250.53 and at Kasganj it is 225.43 mm.

The coefficient of variation in the basin varies from 29.93 to 33.18%, minimum and maximum being at Kasganj and Atrauli respectively. This suggests that occurrence of rainfall varies mildly, all over this basin. The average coefficient of variation in the entire basin is 31.5% which is considerably high and indicates a significant variability of rainfall with time.
Table 1: Results of statistical analysis of annual rainfall at Atrauli and Kasganj raingauge stations.

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<tr>
<td>Atrauli</td>
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<tr>
<td>Highest rainfall (1983)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>1402 mm</td>
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<tr>
<td>Lowest rainfall (1987)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>307.3 mm</td>
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<tr>
<td>Mean</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>755.06 mm</td>
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<tr>
<td>Standard deviation</td>
<td>...</td>
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<td>...</td>
<td>247.4</td>
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<tr>
<td>Coefficient of variation</td>
<td>...</td>
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<td>...</td>
<td>33.18%</td>
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<tr>
<td>Kasganj</td>
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<tr>
<td>Highest rainfall (1960)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>1227.7 mm</td>
</tr>
<tr>
<td>Lowest rainfall (1918)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>208.00 mm</td>
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<tr>
<td>Mean</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>753.19 mm</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>225.43</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>29.93%</td>
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</table>

DROUGHT ANALYSIS

Rainfall varies in space and time. Droughts and floods are the consequences of this variability.

In general drought refers to large and prolonged lack of rainfall affecting agriculture, domestic water supplies and other water dependent economic activities. But with the developing techniques of operational management of our water resources, a
DEPARTURE OF ANNUAL RAINFALL FROM MEAN RAINFALL
(KASGANJ)

FIG. 5-b
drought condition has to be viewed from 3 different angle (Upadhya et al., 1989).

(a) Meteorological :

When the actual rainfall is less than the normal (long term climatological mean) by 25% or more over an area.

(b) Hydrological :

When there is marked depletion of surface water and consequent drying up of lakes, reservoirs and rivers. It may also result in recession of glacier due to insufficient regeneration of seasonal snow cover.

(c) Agricultural :

When soil moisture is inadequate to support healthy growth of crops. Water table goes deeper and ground water is unable to meet the demand. The study area forms a part of the central Ganga plain which is basically an agricultural tract, hence the computations are mainly based on agricultural definition of drought. The computation takes into account the negative departure of rainfall from the mean.

The classification of drought based on the percentage of the negative departure of rainfall from its mean are as follows.
DEPARTURE FROM MEAN ANNUAL RAINFALL AND CUMULATIVE DEPARTURE

ATRAULI

FIG. 6-a
The analysis for drought occurrence in the basin shows that the area in general has been experiencing droughts of varying intensity over the period (1901-1989). The table below shows the year and frequency of occurrence of droughts in the basin.

**Table 2a: Result of Drought Analysis at Atrauli**

<table>
<thead>
<tr>
<th>Types of Drought</th>
<th>Years</th>
<th>Frequency of occurrence</th>
</tr>
</thead>
</table>
DEPARTURE FROM MEAN ANNUAL RAINFALL AND CUMULATIVE DEPARTURE
(KASGANJ)

FIG. 6-b
<table>
<thead>
<tr>
<th>Type of drought</th>
<th>Years</th>
<th>Frequency of occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe drought (50 - 75%)</td>
<td>1901, 1941, 1979, 1987</td>
<td>4.49%</td>
</tr>
</tbody>
</table>

**Table 2b: Result of Drought Analysis at Kasganj**
Normal drought 1902, 1907, 1912.
(25 - 25%) 1913, 1923, 1928.
1932, 1935, 1938,
1941, 1944, 1947,
1966, 1984, 1986,
1987.

Severe drought 1905, 1918
(50 - 75%) 2.24%

SOIL TYPE OF THE AREA

The soil survey of the area was carried out by the department of Agriculture, Government of Uttar Pradesh in the year 1953. In all, three types of soils have been reported pertaining to three distinct physiographic units of the basin (fig. 7) which are as under:

1. Sandy loam
2. Sandy loam to loam
3. Loam to clay loam
1. Sandy Loam:

The low valley of the Ganga is underlain by sandy to silty loam, which this tract receives year after year because of overflowing of the Ganga during flood season.

Generally, the deposit is of silty nature with varying colour from light grey to ash grey. The soil is immature and has sandy to silty loam texture.

Consequent to shallow groundwater level salt efflorescence appears to be common feature of the entire tract which are locally called as usar (wasteland). Generally, the soils are alkaline in reaction with a pH usually above 8. The soil profile consists of numerous immature stratified layers of younger soils which deposited over one another during the flood periods of the river Ganga. Those soils have fewer reserves of lime, magnesia and iron. The presence of lime saves the soil from becoming completely salinized.

2. Sandy Loam to Loam Soil:

This soil type covers the major portion of the upland tract. The soil varies in colour from light brown to dark brown and the texture of the soil is sandy to good quality loam. Generally, the surface soil to a depth of 20 to 25 cm is well drained soil and contains loose loam that can easily be ploughed and cultivated. The soils are more leached than the other soil of the area. The percentage of lime content is low and magnesia is every
where more than the lime. The calcareous nodules occur almost everywhere in the sub-soil. The pH ranges between 6.2 to 6.8

3. Loam to Clay Loam :

A small portion of the area between Charrah and the left bank of the Kali river are covered by this soil. This is a sticky and generally clayey loam to loam in texture. The colour varies from grey to dark grey tending to black when moist. The tract is underlain by thick pan of calc concretions occurring in mild cases in the form of nodules which at places cement together forming a stiff impermeable belt in the bottom layers. The percentage of clay decreases with the increase in depth which shows an ideal example of water logged soils where the impermeable sub-soil horizon does not allow the translocation of even the finest clay particles. Due to poor drainage, the soluble sodium salts are deposited on the surface in the form of salt efflorescence (reh). The pH value of the soil ranges from 7 to 9. Iron and Alumina remain stationary and magnesia is little in the entire profile (Agrawala, et al. 1953).

Land use pattern in the Ganga-kali Sub-basin

The statistics pertaining to the land use pattern in the Ganga-kali sub-basin is given in (Table 3).
Table 3: Land use pattern in Ganga-kali Sub-basin (In hectares)

<table>
<thead>
<tr>
<th>Area</th>
<th>Forest</th>
<th>Cultivable waste land</th>
<th>Present fallow land</th>
<th>Cultivable land</th>
<th>Barren land</th>
<th>Land under pasture</th>
<th>Land under non cultivated land</th>
<th>Land under miscellaneous use</th>
<th>Land under traces and grooves</th>
<th>Net area sown more than once</th>
<th>Area sown</th>
<th>Total Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>134000</td>
<td>127</td>
<td>60.81</td>
<td>34.27</td>
<td>58.52</td>
<td>143.57</td>
<td>5.85</td>
<td>3.90</td>
<td>104250</td>
<td>81728</td>
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</tbody>
</table>

The perusal of table show that out of total area of 134000 hectares, 77% of the area is under cultivation of which 78% is sown more than once. Only 0.09% of the total area is covered by the forest. Rest of the area is covered by the barren and uncultivable land.

Wheat, peanut, potato, groundnut and sugarcane are the major winter crops. Maize, millet, and rice are the important crops which is cultivated during the summer.

With the advent of the high yielding varities of wheat and paddy the crop pattern is gradually changing. The wheat dominates the winter crops and paddy and millet as the summer crops. Beside it groundnut, potato and sugarcane being cash crops have started attracting the farmers in the area.
Water Use Pattern in the Area

Groundwater, is an important source of water supply which is basically a renewable resource, but the volume of water may vary greatly from place to place depending on the climate, regional hydrogeology and rate of groundwater use for agriculture, domestic and industrial purposes. The use of groundwater has escalated significantly worldwide since 1960 (Fletcher, 1986).

Out of the total water resources of the Ganga-kali sub-basin, 19.8% is derived from the surface water source and 80.2% from the groundwater source (figure 8a). The Anupshaher branch of the upper Ganga canal and Farukhabad distributary of the lower Ganga canal supply the surface water for irrigations mainly for Ganga-Nim interfluves known as the eastern upland and also the area lying west and south-east of Kasganj town.

Administratively, the study area is divided into various integrated developmental blocks and accordingly the water use pattern are furnished as below and shown in (figure 9).

Table 4: Contribution of surface and groundwater for irrigation in different blocks (Anon, 1987)

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Percent area irrigated by surface water</th>
<th>Percent area irrigated by the Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrauli</td>
<td>5.0%</td>
<td>95%</td>
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<tr>
<td>Bihauli</td>
<td>35.17%</td>
<td>64.83%</td>
</tr>
<tr>
<td>Gangiri</td>
<td>26.84%</td>
<td>73.16%</td>
</tr>
<tr>
<td>Kasganj</td>
<td>12.10%</td>
<td>87.90%</td>
</tr>
<tr>
<td>Average</td>
<td>19.80</td>
<td>80.20</td>
</tr>
</tbody>
</table>
Estimates of groundwater use of the Kali basin show that out of the total groundwater withdrawn i.e. 169 M.C.M. 85% is used for irrigation purpose and remaining 15% is used for domestic purpose (figure 8b). Water used for rural supply also includes water for livestocks.