CHAPTER - III

HYDROMETEOROLOGY

Hydrometeorology is defined as the study of atmospheric processes which affect the water resources of the earth and are the interest to the hydraulic engineers. (Reddy, 1986 p. 12). Taking a broader view of hydrometeorology, the World Meteorological Organisation seems of concerned with the study of atmospheric and land phases of hydrological cycle with the emphasis in their relationship involved. (WMO, 1970).

Hydrometeorological data are required to determine the water balance of a basin for developing and managing its water resources. The most important hydrometeorological elements are precipitation particularly rainfall, evaporation, transpiration, Solar radiation, air temperature, humidity, soil moisture, water levels, stream discharge, water quality, etc. The study of hydrogeology necessitates the collection of data, temperature, radiation, humidity, evapotranspiration, wind velocity and rainfall.

3.1 TEMPERATURE

The temperature data taken by the meteorological observatory located at Nowgaon have been collected for the year 1962-1992. The monthly average maximum and minimum temperature are given in Table 3.1.
### TABLE - 3.1

MONTHLY AVERAGE MAXIMUM AND MINIMUM TEMPERATURE IN DEGREE CELSIUS AT NOWGOAN STATION (Year 1962 - 1992)

<table>
<thead>
<tr>
<th>Month</th>
<th>Maximum Average Temperature in Degree Celsius</th>
<th>Minimum Average Temperature in Degree Celsius</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>22.20</td>
<td>6.17</td>
</tr>
<tr>
<td>February</td>
<td>26.53</td>
<td>9.25</td>
</tr>
<tr>
<td>March</td>
<td>32.43</td>
<td>14.55</td>
</tr>
<tr>
<td>April</td>
<td>37.79</td>
<td>20.09</td>
</tr>
<tr>
<td>May</td>
<td>41.09</td>
<td>33.71</td>
</tr>
<tr>
<td>June</td>
<td>38.90</td>
<td>27.19</td>
</tr>
<tr>
<td>July</td>
<td>31.44</td>
<td>23.67</td>
</tr>
<tr>
<td>August</td>
<td>30.54</td>
<td>23.78</td>
</tr>
<tr>
<td>September</td>
<td>30.43</td>
<td>22.59</td>
</tr>
<tr>
<td>October</td>
<td>31.93</td>
<td>17.10</td>
</tr>
<tr>
<td>November</td>
<td>29.58</td>
<td>10.02</td>
</tr>
<tr>
<td>December</td>
<td>24.32</td>
<td>7.10</td>
</tr>
</tbody>
</table>

**Source:** I.M.D. Climatological Tables of observatory in India.

The collected temperature data have been used for preparing the different temperature curves from the Nowgoan observatory.

#### 3.2 ANNUAL AVERAGE MAXIMUM AND MINIMUM TEMPERATURE

The annual average of maximum and minimum temperature curves have been shown in fig. 3.1. It shows that highest average maximum temperature is 30.49°C in the year 1966.
FIG. 3.1: RELATIONSHIP OF ANNUAL RAINFALL, TEMPERATURE, HUMIDITY OF CHHATARPUR, NOWGOAN STATIONS, M.P.

INDEX
○ RAINFALL IN CM
△ MAXIMUM HUMIDITY IN %
▲ MINIMUM HUMIDITY IN %
■ MAXIMUM TEMPERATURE IN °C
● MINIMUM TEMPERATURE IN °C

YEARS
and the lowest average maximum temperature is 31.51°C in the year 1971. The highest average minimum temperature is 18.51°C in the year 1973. Whereas the Lowest average minimum annual temperature is 16.47°C in the year 1988. (Appendix - 3).

3.3 MONTHLY AVERAGE MAXIMUM AND MINIMUM TEMPERATURE

The monthly average of maximum and minimum temperature curves have been plotted and shown in fig. 3.2. It indicates that the monthly average maximum temperature rises up to 41.09°C in May and fall down to 22.20°C in January. Therefore, May is the hottest month and January is the coldest month.

Both the mean, maximum and minimum temperature rise rapidly from February onwards till May. The increase in maximum temperature in the period from January to May is 18.89°C. From June onwards, both the maximum and minimum temperature start falling, the former very rapidly while the latter lowers slowly. From the beginning of June to the end of July, the maximum temperature fall by about 7.46°C whereas the minimum temperature falls only by about 4.60°C from June to September (rainy season). During August and September there is no appreciable fall in maximum temperature. In October, a slight rise in the maximum temperature is experienced due to much reduced cloudiness. The night temperature start falling rapidly after September while the temperature followed this trend after October and both attain lowest value by December.
FIG. 32: RELATIONSHIP OF HYDROMETEOROLOGICAL PARAMETERS OF UPPER URMI RIVER BASIN.
The fall in minimum temperature and maximum temperature is 10.0°C and 7.61°C respectively during these periods. (Appendix-2)

3.4 MONTHLY TEMPERATURE RAINFALL RELATIONSHIP

The temperature and rainfall relationship is shown in fig. 3.2. It shows that during the rainy season for the month of June to September, the temperature is low and the rainfall is maximum. During the period from February to May the rainfall is minimum but the temperature is slightly higher than in the preceding season, whereas during winter season from October to January, the temperature is lower and the rainfall is slightly higher.

3.5 HUMIDITY

The humidity plays a complementary role in total climatic pattern of an area along with its rainfall and temperature. The mean monthly relative humidity percentages for 30 years (1962-1992) for Nowgoan station have been collected and presented in Table 3.2. These data have been plotted and shown in fig.3.2.

The Table 3.2 shows that the relative humidity recorded at 8.30 A.M. is generally high during the period June to October. It is 56.0 percent in June, rising to a little more than 77.0 percent in August. It is 39.0 percent in June rising to a little more than 69.0 percent in August. It becomes clear from the Table and figure that the month of August has the maximum humidity percentage.
From September onwards, the percentage of humidity gradually decreased till November and then from December to January, it gradually increase. From February onwards, it goes on decreasing till the month of May. The month of April has the lowest percentage of humidity.

**TABLE - 3.2**

**MEAN MONTHLY RELATIVE HUMIDITY IN PERCENTAGE OF NOWGOAN STATION (M.P.).**

<table>
<thead>
<tr>
<th>Month</th>
<th>Humidity percentage</th>
<th>Humidity percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at 8:30 Am</td>
<td>at 5:30 Pm.</td>
</tr>
<tr>
<td>January</td>
<td>79.0</td>
<td>38.0</td>
</tr>
<tr>
<td>February</td>
<td>66.0</td>
<td>28.0</td>
</tr>
<tr>
<td>March</td>
<td>57.0</td>
<td>20.0</td>
</tr>
<tr>
<td>April</td>
<td>30.0</td>
<td>11.0</td>
</tr>
<tr>
<td>May</td>
<td>31.0</td>
<td>19.0</td>
</tr>
<tr>
<td>June</td>
<td>74.0</td>
<td>39.0</td>
</tr>
<tr>
<td>July</td>
<td>74.0</td>
<td>63.0</td>
</tr>
<tr>
<td>August</td>
<td>77.0</td>
<td>69.0</td>
</tr>
<tr>
<td>September</td>
<td>75.0</td>
<td>59.0</td>
</tr>
<tr>
<td>October</td>
<td>66.0</td>
<td>43.0</td>
</tr>
<tr>
<td>November</td>
<td>61.0</td>
<td>39.0</td>
</tr>
<tr>
<td>December</td>
<td>72.0</td>
<td>40.0</td>
</tr>
</tbody>
</table>

**Source:** India Meteorological Department, Govt. of India, Nagpur.
3.6 WIND VELOCITY

The horizontal component of the air movement parallel to the earth's surface is generally referred to as air currents (Reddy 1986 P.35). The wind velocity is measured by "anemometer" and the wind direction is usually measured by "Wind Wane". Wind velocity is indirectly affect the intensity of rainfall. Whenever, the wind velocity is high, there is less chance of heavy rainfall but whenever, it is low or stationary the rainfall will be high.

The seasonal variation of atmospheric pressure takes place in a systematic manner with a maximum in the winter (January) and a minimum in Monsoon season (July). Mean wind velocity and direction of the Nowgoan observatory station is given in Table 3.3.

TABLE - 3.3
MEAN WIND VELOCITY (KM/HRS.) AND PREDOMINANT WIND DIRECTION OF NOWGOAN STATION M.P.

<table>
<thead>
<tr>
<th>Month</th>
<th>Wind velocity km./hrs.</th>
<th>Predominant direction Morning</th>
<th>Predominant direction Evening</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2.7</td>
<td>ENE</td>
<td>ENE</td>
</tr>
<tr>
<td>February</td>
<td>4.0</td>
<td>ENE</td>
<td>WNW</td>
</tr>
<tr>
<td>March</td>
<td>4.2</td>
<td>WNW</td>
<td>WNW</td>
</tr>
<tr>
<td>April</td>
<td>4.7</td>
<td>WSW</td>
<td>WNW</td>
</tr>
<tr>
<td>May</td>
<td>6.0</td>
<td>WNW</td>
<td>WNW</td>
</tr>
<tr>
<td>June</td>
<td>8.2</td>
<td>WSW</td>
<td>WSW</td>
</tr>
<tr>
<td>July</td>
<td>7.1</td>
<td>WSW</td>
<td>WSW</td>
</tr>
<tr>
<td>August</td>
<td>3.9</td>
<td>WSW</td>
<td>WSW</td>
</tr>
<tr>
<td>September</td>
<td>4.4</td>
<td>WSW</td>
<td>WNW</td>
</tr>
<tr>
<td>October</td>
<td>2.9</td>
<td>WSW</td>
<td>NNE</td>
</tr>
<tr>
<td>November</td>
<td>2.1</td>
<td>ENE</td>
<td>NNE</td>
</tr>
<tr>
<td>December</td>
<td>2.1</td>
<td>ENE</td>
<td>NNE</td>
</tr>
</tbody>
</table>

Source: India Meteroroligical Department, Govt. of India, Nagpur.

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3.7 **EVAPORATION LOSSES**

Evaporation and evapotranspiration is one of the hydrologic cycle. Evaporation from the water area is the process under which a portion of water near its surface is changed into the gaseous state or water vapour and its distributed in atmosphere. (Sharma, 1979; Penman, 1956).

The evaporation losses have been computed for Upper Urmil river basin from the standard curve prepared by I.M.D., Nagpur and presented in Table 3.4.

**TABLE - 3.4**

MONTHLY EVAPORATION LOSSES AT CHHATARPUR STATION, M.P.

<table>
<thead>
<tr>
<th>Month</th>
<th>Evaporation losses in cm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>7.62</td>
</tr>
<tr>
<td>February</td>
<td>8.89</td>
</tr>
<tr>
<td>March</td>
<td>16.51</td>
</tr>
<tr>
<td>April</td>
<td>20.32</td>
</tr>
<tr>
<td>May</td>
<td>25.40</td>
</tr>
<tr>
<td>June</td>
<td>20.32</td>
</tr>
<tr>
<td>July</td>
<td>17.78</td>
</tr>
<tr>
<td>August</td>
<td>16.51</td>
</tr>
<tr>
<td>September</td>
<td>14.60</td>
</tr>
<tr>
<td>October</td>
<td>9.52</td>
</tr>
<tr>
<td>November</td>
<td>6.35</td>
</tr>
<tr>
<td>December</td>
<td>6.35</td>
</tr>
</tbody>
</table>

(Source: India Meteorological Department, Govt. of India, Nagpur.)
A glance at the Table 3.4 brings out the fact that the evaporation losses for Upper Urmil river basin go on increasing from the month of January to the month of May. From the month of June, the evaporation losses gradually decrease till the month of December.

3.8 RAINFALL

Rainfall is described as the total liquid product of precipitation or condensation from the atmosphere as received and measured at a raingauge station. Among the several meteorological factors, it is considered as of most importance specially for agricultural activity, besides providing water to the growing crops. Rain brings out a favourable change in the climate surrounding the plants thereby promoting active vegetation growth. Apart from the quantity of rainfall, its time distribution also plays an important role in the cropping pattern of particular region.

The method of analysis and which aspects of rainfall are to be analysed depend upon the purpose of analysis. If data are available for a longer period, one can estimate the long term mean rainfall and variability in rainfall for a given location. If the observed rainfall at a site in any year is less than its mean annual rainfall then it is called a deficient year or dry year and in the converse, it is called a surplus or wet year. A rainy day is defined as the day on which 2.5 mm. or more of rainfall is recorded (Sharma, 1979, p.40; Subramanyam & Venkatesh, 1983).
3.8:1 MEAN ANNUAL RAINFALL

The rainfall data available 1901 to 1991 of Chhatarpur raingauge station have been collected from the office of The Collector, Chhatarpur headquarter and presented in Appendix-4. These data have been shown in the form of curve for Chhatarpur station (fig.3.3). The result inferred from these data is given in the Table 3.5.

**TABLE - 3.5**
PATTERN OF RAINFALL VARIATION IN UPPER URMIL RIVER BASIN

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Items</th>
<th>Chhatarpur raingauge station</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Period of rainfall recorded</td>
<td>1901-1991</td>
</tr>
<tr>
<td>2.</td>
<td>Number of years</td>
<td>91</td>
</tr>
<tr>
<td>3.</td>
<td>Average rainfall in mm.</td>
<td>1067.66 mm.</td>
</tr>
<tr>
<td>4.</td>
<td>maximum rainfall in mm. and year</td>
<td>1633.82 mm. (In year 1971)</td>
</tr>
<tr>
<td>5.</td>
<td>Minimum rainfall in mm. and year</td>
<td>195.10 mm. (In year 1948)</td>
</tr>
<tr>
<td>6.</td>
<td>Number of years above average rainfall</td>
<td>49</td>
</tr>
<tr>
<td>7.</td>
<td>Number of year above 1½ times average rainfall</td>
<td>02</td>
</tr>
<tr>
<td>8.</td>
<td>Number of year below average rainfall</td>
<td>42</td>
</tr>
<tr>
<td>9.</td>
<td>Number of year below half average rainfall</td>
<td>05</td>
</tr>
<tr>
<td>10.</td>
<td>Average number of rainy days</td>
<td>Not available</td>
</tr>
</tbody>
</table>

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FIG. 3.3: ANNUAL RAINFALL AT CHHATARPUR RAINGAUGE STATION
FROM 1901 – 1991

SCALE. HORIZONTAL 1 CM = 1 YEAR, VERTICAL 1 CM = M.M.

ANNUAL RAINFALL IN M.M.

0 200 400 600 800 1000 1200 1400 1600 1800


YEARS

AVERAGE RAINFALL
A glance at the Table 3.5 makes clear that the average annual rainfall at Chhatarpur station is 1067.66 mm. It is of particular interest to note that in span of 91 years from 1901 to 1991 neither the maxima reaches twice the mean nor the minima is reduced to half. Further, about 53.84 percent of number of years have average rainfall and 46.15 percent years have rainfall below the average. Out of 91 years, 42 years have rainfall below the average. 49 years have rainfall above the average. The number of years below half average is 05. The maximum rainfall is 1633.82 mm. in the year 1971. The lowest recorded rainfall is 195.10 mm. in the year 1948.

3.8:2 MEAN MONTHLY RAINFALL

From the rainfall data collected from 1901 to 1991, the average rainfall of each month has been calculated and these are given in the Table 3.6.

TABLE - 3.6
MONTHLY AVERAGE RAINFALL IN MILLIMETRES

<table>
<thead>
<tr>
<th>Month</th>
<th>Monthly average rainfall in mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>21.65</td>
</tr>
<tr>
<td>February</td>
<td>13.64</td>
</tr>
<tr>
<td>March</td>
<td>6.04</td>
</tr>
<tr>
<td>April</td>
<td>3.25</td>
</tr>
<tr>
<td>May</td>
<td>5.02</td>
</tr>
<tr>
<td>June</td>
<td>97.92</td>
</tr>
<tr>
<td>July</td>
<td>429.24</td>
</tr>
<tr>
<td>August</td>
<td>349.07</td>
</tr>
<tr>
<td>September</td>
<td>177.40</td>
</tr>
<tr>
<td>October</td>
<td>32.84</td>
</tr>
<tr>
<td>November</td>
<td>12.86</td>
</tr>
<tr>
<td>December</td>
<td>6.32</td>
</tr>
</tbody>
</table>
A glance at the Table 3.6 shows that July and August are the principal rainy months during the rainy season together making about sixty percent of the annual rainfall and they are followed by September and June in decreasing order together making about twenty-five percent of the annual rainfall. Thus, the rainy season extending from June to September receive about ninety percent of the annual rainfall. Much of the rainfall during the month of June is lost due to intense evaporation and only small part of it goes to contribute to the building up of the soil moisture zone water requirements. A little of it goes as runoff. During the month of July, a part of the rainfall is utilized for saturating the soil moisture zones in the study area. The rest of it goes mostly as runoff and evapotranspiration losses and a very little goes towards the ground water increments. In the month of August, the ground water increment to the ground water bodies takes place and by this time the soil moisture zone water requirements are met by the rainfall. September is another month when ground water increment is possible due to infiltration in the study area to the upper aquifer bodies. A glance at the same table also reveals the fact that the rainfall in other month is more or less scanty and is just enough to meet a small part of the soil moisture zone water requirements.
3.8.3 RESIDUAL MASS CURVE

The residual mass curve have been prepared for Chhatarpur raingauge station by taking the cumulative departures of rainfall from the average annual rainfall. The part of curve, which are above the base line (1067.66 mm.), representing the average annual rainfall for the number of years under consideration, indicate better periods of recharge and infiltration conditions to the ground water bodies and vice-versa. The part of curve, which are above the base line (1067.66 mm.), representing the average annual rainfall for the number of years under consideration, indicate better periods of recharge and infiltration conditions to the ground water bodies and vice-versa.

Broadly any residual mass curve can be divided into parts depending on the curve which lie above or below the base line or graze the base line. Each part has its own significance with respect to annual ground water increment to ground water bodies of an area.

For preparation of residual mass curve for Chhatarpur raingauge station, the average annual rainfall for 91 years (1901-1991) have been considered. These are given in Appendix-4. The average annual rainfall for Chhatarpur raingauge station for a period of 91 years (1901-1991) is 1067.66 mm. This average annual rainfall value is taken as zero base line.

The residual mass curve prepared from the data of Chhatarpur raingauge station shown in fig. 3.4.
FIG. 3.4: RESIDUAL MASS CURVE OF RAINFALL FOR CHHATARPUR RAIN GAUGE STATION FROM 1901 - 1991

SCALE: HORIZONTAL 1 cm = 1 YEAR, VERTICAL 1 cm = 100 M.M.

BASE LINE

YEAR

YEAR

YEAR

YEAR

YEAR

YEAR

YEAR

YEAR

YEAR

YEAR

YEAR

YEAR

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A glance at the residual mass curve of Chhatarpur station reveals that it can be divided into three major segments or cycles. From 1901 to 1981, the curve is well below the base line, except for the 1901, 1904, 1906, 1910 and 1911 years. Which too are only slightly above the base line. From the year 1982 to 1987, the curve is prominently above the base line. After the year 1988 to 1991, the curve is again well below the base line. The first and third parts of the curve are below the base line and indicates a period of ground water drought conditions, whereas the second part of curve including 1901, 1904, 1906, 1910 and 1911 years, which is well above the base line indicates a good period for the ground water increment due to rainfall.

3.8:4 RAINFALL DEPENDABILITY

It is workout by the following formula:

\[
\text{Percentage dependability} = \frac{M}{n+1} \times 100
\]

Where, \( M \) = Cumulative frequency of rainfall.
\( n \) = Number of years of rainfall records.

Using the above formula, the rainfall data for 91 years (1901 to 1991) for Chhatarpur raingauge station have been arranged in descending order (Appendix-6). Their frequency is noted and the value of \( M \) is determined. From the value \( M \) and \( n \), the percentage dependability is plotted on abscissa and rainfall in mm. is plotted on the ordinate. This curve is shown in fig.3.5.
FIG. 3.5: RAINFALL DEPENDABILITY OF CHHATARPUR RAINGAUGE STATION.

INDEX
THE 50% DEPENDABILITY WILL BE 1125 mm
THE 75% DEPENDABILITY WILL BE 865 mm
THE 90% DEPENDABILITY WILL BE 665 mm
VERTICAL SCALE 2 cm = 100 mm
HORIZONTAL SCALE 2 cm = 10 %
This fig. reveals that the 50 percentage dependability of rainfall works out at 1125 mm.; 75 percentage at 865 mm. and 90 percentage at 665 mm. respectively.

3.8:5  ISOHYETAL MAP

Isohyetal map has been prepared by plotting the depth of rainfall at location of various raingauges and plotting of Isohyets by the isopleth interpolation method. (Kulkarni et al., 1994).

Isohyetal map is prepared on a horizontal scale of one centimetre equal to eight kilometres with ten millimetre isohyet interval. It is shown in fig.3.6. From the study of isohyetal map it reveals that upper Urmil river basin has a uniform spacing of isohyets indicate that, there is not much variation in the rainfall in the distribution over the study area.

3.9  CORRELATION OF CLIMATOLOGICAL DATA

An attempt has been made to bring out inter-relationship among the annual average rainfall, temperature, humidity and evaporation losses for Nowgoan station except rainfall for Chhatarpur station and shown in fig.3.1. Similarly, for the same station the relationship of monthly average rainfall, temperature, humidity and evaporation losses are also show in fig.3.2. These figures clearly reveal the fact that at the beginning of the rainy season, the temperature and evaporation losses are higher as compared with their respective values in other rainy months.
The month of August is the wettest month, as a consequence of which the humidity percentage and the rainfall are at the maximum. Due to these conditions, the evaporation losses and the temperatures are considerably lowered. During the month of September, the percentage of humidity and rainfall decrease with a consequent slight increase in temperature and evaporation loss. During the winter season, from the month of October to the month of January, the evaporation losses, rainfall and temperature gradually decrease whereas, the percentage humidity increase. In the summer season, from the month of February to the month of May, the temperature and evaporation losses increases and the rainfall, percentage humidity decreases.