CHAPTER-III

HYDROLOGY OF THE GREATER IMPHAL AREA
3.1 INTRODUCTION

This chapter mainly deals with hydrology of the Greater Imphal Area. It encompasses analysis of the trends of temperature, rainfall and run-off of the area. Based on these hydrological data, a water-balance study is also carried out to comprehend the availability of water resources during various months of a year. The excess water that flows as run-off through the pervious and impervious layers without any beneficial use can be harvested using suitable water harvesting techniques to augment the availability of surface water storage during lean period of the year in the study area.

3.2 ANALYSIS OF ANNUAL TREND OF RAINFALL

There has been a global concern over the rapid changes of annual precipitation during 1901-2005. The precipitation has increased in eastern parts of north and south America, northern Europe and central Asia and decreased in the Sahel, Mediterranean, southern Africa and parts of southern Asia (Panchauri, 2007), as shown in Fig.3.1. The annual rainfall at all-India level also shows some interesting changes. Increasing trends in the monsoon seasonal rainfall have been recorded along the west and east coast of India, and NW India (an increase of over 10%-12% of normal levels over the past 100 years,), whereas a decreasing trend has been observed over eastern Madhya Pradesh, NE India, and some parts of Gujarat and Kerala (a decrease of close to 6%-8% of normal levels over the past 100 years) (Ghosh, 2008). For instance, Mumbai received a record breaking 94.4 cm of rain in a twenty four hour period on 26th July 2005 which broke the record of earlier rainfall recorded by Cherrapunji, the world’s wettest place. Cherrapunji recorded around 84 cm on 12th July 1910, while Mumbai’s own highest recorded rainfall was around 58 cm on 5th July 1974. Barmer, one of the India’s driest districts in Rajasthan, received 75 cm of
rainfall in August 2006, which was five times the district’s average annual rainfall (Mahapatra, 2008). These trends indicate that there is shift in the rainfall patterns in and around the Indian subcontinent.

**Precipitation (rain & snow) is variable - but there is evidence for systematic change**

Precipitation has increased in eastern parts of North and South America, northern Europe and northern and central Asia – and decreased in the Sahel, Mediterranean, southern Africa and parts of southern Asia.

*Fig.3.1 Global trends of annual precipitation (1901-2005, after Panchauri 2007)*

In view of the foregoing changes in the patterns of rainfall, globally and in India in particular the analysis of hydrological data of the study area is carried out to evaluate run-off rate with the precipitation for the designs of hydraulic structures, drainage system, and water-supply schemes. The available rainfall records of the past 50 years (1957-2007) with the exceptions of 1998 and 1999 have been analysed for determining the current trend of rainfall in the GIA. Using arithmetic mean method, the average monthly and yearly rainfalls of the area are determined.

When the rainfall measured at various stations in a catchment shows little variation, the average precipitation over the catchment area is taken as the arithmetic mean of the station values. Thus if \( P_1, P_2, P_3, \ldots P_n \) are the rainfall values in a given
period in \( N \) stations within a catchment, then the value of the mean precipitation over the catchment by the arithmetic-mean method is:

\[
P_{\text{mean}} = \frac{P_1 + P_2 + \ldots + P_i + \ldots + P_n}{N}
\]

The distribution of the mean monthly rainfall is shown in Table A-II (3.1) and Fig. 3.2. It shows that about 59\% of the precipitation (rainfall) occurs in the monsoon period (June-September). The average annual rainfall of the area has been computed as shown in Table A-II (3.1) and Fig. 3.3 and is found to be about 1441 mm. The highest monthly rainfall of about 255.51 mm occurs in June. In the dry or non-monsoon period, it is observed that some appreciable amount of rainfall is recorded in the months of April and October during various years.

It may be mentioned that according to Indian Meteorological Department (IMD) classification, annual rainfall of more than 20\% from normal value (LTM) present flood condition and annual rainfall of less than 20\% from normal value (LTM) indicates drought over an area (Das, 2003). From the Fig.3.2, it is observed that there were floods in 1966, 1976, 1983, 1991, 1993, 2000 and 2004 and droughts in 1972, 1978, 1979, 1981, 1984, 1992 and 2006. It is thus inferred from the analysis of rainfall data that a decline in annual rainfall now continues to prevail in the GIA and is 28.28\%. Under these circumstances, the status of surface water resources in the GIA will be subjected to stress during the coming years. In order to meet the future requirements of water in the study area, we have to find out a suitable water storage structure.
3.3 ANALYSIS OF ANNUAL TREND OF TEMPERATURES

Monitoring and analysis of atmospheric temperatures on a global and regional scale have acquired special importance in the last few decades, due to clear indications of global warming in the post-industrial era. The significant increase in mean annual global surface air temperature during the past century, predominantly over the Northern hemisphere, is probably the most widely quoted aspect of
contemporary climate change (Rupa Kumar et al., 1992). The rate of warming averaged over the last 50 years is nearly twice that of the last 100 years. The average global temperature went up by about 0.74°C during 1906-2005. Hingane et al., (1985) have prepared, for the first time an all-India mean series of seasonal and annual surface air temperature for long-term trend studies, using data of the period 1901-82 from a network of 73 stations. The analyses indicate a significant warming of 0.4°C per hundred years in mean annual temperature of the country as a whole. The all-India mean annual surface-air temperature variation during the period 1901-2000, based on fixed network of well distributed 31 stations over the country, shows a rise of 0.4°C in winter, 0.2°C in pre-monsoon and 0.5°C in post-monsoon periods during the last 100 years. These changes could affect the availability of water resources by altering the timing and magnitude of the runoff.

According to Wladimir Koppen, (the world-renowned climatologist') classification of climates, Manipur falls under the category of ‘Caw’. It stands for sub-tropical monsoon; hot and wet summer, mild and dry winter. The name sub-tropical is given because Manipur lies outside the tropics, i.e., it borders the Tropic of Cancer on the north. The capital letter ‘C’ indicates that the average temperature of the coldest month should be in between −3°C and 18°C. The small letter ‘w’ denotes that the wettest summer month should have at least ten times the precipitation of the driest winter month. Finally, the small letter ‘a’ indicates that the average temperature of the warmest month should be more than 22°C (Shyamsundar, 1996).

The annual temperature distributions (both maximum and minimum) over a period of 48 years have been analysed to determine the trend of temperature variations in the GIA. Arithmetic mean method is also used for the estimation of mean temperature. From the analysis of data, it is found that the hottest month is June with mean maximum temperature of about 29.09°C (>22°C). The coldest month is
January having mean minimum temperature of 4.16°C (-3°C and 18°C). Thus, Manipur enjoys a sub-tropical monsoon type of climate.

The analysis of temperature data of the GIA as shown in Table A-II (3.2) indicates rise of 0.57°C in winter, 0.1°C in pre-monsoon and 0.5°C in post-monsoon periods respectively during 1957-2007 as shown in Figs. 3.4, 3.5 and 3.6. It shows that the GIA is also following the current trend of increase in temperature at par with other areas of the country.

Fig. 3.4 Changing trends of winter temperature (1957-2007) in the GIA

Fig. 3.5 Changing trends of pre-monsoon temperature (1957-2007) in the GIA
Fig. 3.6 Changing trends of post-monsoon temperature (1957-2007) in the GIA

Fig. 3.7 Characteristics of mean maximum temperature in the GIA
Fig. 3.8 Characteristics of mean minimum temperature in the GIA

Fig. 3.7 reveals that in the entire area, there is an increasing trend of mean annual maximum temperature is evident, and is 0.15°C with respect to LTM. On the other hand, Fig. 3.8 exhibits that the mean annual minimum temperature of the GIA has increased to 0.87°C with respect to LTM and then the trend is on the rise. Table A-1 (3.1) and Fig. 3.9 depict of mean monthly maximum, minimum and average temperatures of the study area. It reflects that differences between these three parameters are less in monsoon season (June-September) as compared to other months of a year. This indicates that the entire area is expected to experience an extreme climate in the coming years.
3.4 POTENTIAL EVAPOTRANSPIRATION (PET)

GRID first produced average monthly temperature surfaces by a nearest-neighbour interpolation of data from 1834 climate stations, altitude-adjusted to standardized values representing sea-level temperatures. Then, using a table of average day length and a description of how to calculate, Thornthwaite PET, a 'C' program was written by the GRID-Nairobi analysts to produce an initial estimate of PET.

As the results of this global PET estimation did not match normally obtained values, it was necessary to make an adjustment, as the Thornthwaite method is known to systematically underestimate PET in more arid regions and different seasons. Thus, the UEA/CRU provided an empirical adjustment factor using detailed data sets for Europe and Sudan, where Penman estimates were available for the same time period, 1951 to 1980. The resulting model yielded a calibration of Penman PET using Thornthwaite PET, with precipitation in the equation as an additional variable:
Where $\text{PET} (P) = \text{Penman PET}; \text{PET} (T) = \text{Thornthwaite PET}; \text{and PRECIP} = \text{mean annual precipitation in mm. (UEA/CRU, 1990).}$

While Penman and Thornthwaite PETs remain comparable in humid areas, the above formula allows for greater adjustments in dry and semi-arid regions, where the underestimation of Thornthwaite PET is the highest. The Mean Annual Potential Evapotranspiration (PET) data set shows PET for the period 1951-1980, classified into eight categories as shown in Fig.3.10.

**Mean Annual Potential Evapotranspiration**

from UNEP/GRID and UEA/CRU

<table>
<thead>
<tr>
<th>GRID-Code value</th>
<th>Mean Annual PET (in mm.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(Non-land areas)</td>
</tr>
<tr>
<td>2</td>
<td>0 - 400</td>
</tr>
<tr>
<td>3</td>
<td>400 - 800</td>
</tr>
<tr>
<td>4</td>
<td>800 - 1200</td>
</tr>
<tr>
<td>5</td>
<td>1200 - 1600</td>
</tr>
<tr>
<td>6</td>
<td>1600 - 2000</td>
</tr>
<tr>
<td>7</td>
<td>2000 - 2400</td>
</tr>
<tr>
<td>8</td>
<td>2400 - 2800</td>
</tr>
<tr>
<td>9</td>
<td>&gt; 2800</td>
</tr>
</tbody>
</table>

**Fig. 3.10 Mean annual potential evapotranspiration map of the world**

The determination of potential evapotranspiration of a region depends on number of factors such as temperature, rainfall, relative humidity, wind speed,
sunshine duration, solar radiation, etc. In the absence of reliable field observations, the PET values have been estimated for GIA using Blaney-Criddle equation (Li, 2000):

\[ ET = K_c \times K_t \times (t \times p/100) \]

\( K_c = \) Monthly growth stage coefficient = Crop coefficient

\( K_t = \) Climatic coefficient = 0.0173 \( t - 0.314 \)

\( t = \) Mean monthly temperature °F

\( P = \) Percentage of daylight hours

Using the above equation, it is estimated that the total annual PET value for the GIA is 118.17 cm as shown in Table A-II (3.3), that is, within the limit of potential evapotranspiration of the area (800-1200 cm) as shown in Fig. 3.10. It is also less than the annual average rainfall value of 144.1 cm and it shows that the GIA is not a drought prone area.

The climatic water balance i.e. the graph of monthly average rainfall with monthly average PET and time is generated as depicted in Fig. 3.11. From the graph, it is clear that the scarcity of water in the GIA is during the period of November to March. Thus, the water scarcity period of GIA can be compensated from the monsoon season with proper water harvesting structure.
3.5 ESTIMATION OF RUNOFF

Runoff is a direct indicator of water availability. It is one of the most important hydrological variables used in many water resources applications, viz., design of irrigation scheme, irrigation structures, etc. (Beven, 1998). Prediction of watershed runoff resulting from precipitation events is of great interest to hydrologists. The nonlinear response of a watershed to rainfall events makes the problem very complicated. The observed run-off depends on geomorphological factors, viz., topography, vegetation, soil type, etc. and climatic factors, such as precipitation, temperature, etc. (Anmala et al., 2000).

The runoff of the GIA for 49 years period has been computed using "SCS runoff curve number" for composite area, agricultural area, forest area, settlement area and grassland area as depicted in Tables A-II (3.4, 3.5, 3.6, 3.7, 3.8) and Fig.3.12. The Curve number method (SCS, 1972), also known as the Hydrologic Soil Cover Complex Method, is a versatile and widely used procedure for runoff estimation (Rao et al., 1996; Sharma et al., 2001; Chandramahon and Durbude, 2001; Sharma and Kumar, 2002). The SCS method with initial abstraction consideration is given below:
\[ Q = \frac{(P - 0.3S)^2}{(P + 0.7S)} \]

\[ S = \frac{25400}{CN} - 254 \]

Where,

- \( Q \) = Runoff depth, mm
- \( P \) = Rainfall, mm
- \( S \) = Maximum recharge capacity of watershed after 5 days rainfall antecedent
- \( I_a = 0.3 \) S (initial abstraction of rainfall by soil and vegetation, mm)
- \( CN \) = Curve number, \( CN \) is found out from the table.

\[ CN = \frac{\sum (CN_i \times A_i)}{A} \]

Where

- \( CN \) = Weighted curve number
- \( CN_i \) = Curve number 1 to any no. \( N \)
- \( A_i \) = Area with curve number \( CN_i \)
- \( A \) = Total area of the watershed

The assumed Curve numbers for different categories are as below:

- Settlement: 84; Agricultural area: 77.5 (Non monsoon) & 80.5 (Monsoon);
- Forest area: 79; Grassland area: 80
Run-off of the catchment area is converted into Cumece in accordance to the types of area and velocity of flow. While analyzing the rainfall data (1957-2007), it is observed that the mean monthly run-off of the GIA is very high in June, July and August as compared to other months of the year due to the influence of south-west monsoon (June-September). It is also found that major contribution of run-off in these months is from the composite layer. Pervious layer of soil that allows water to percolate to the ground water table, whereas impervious layer does not permit water to percolate to the underlying soil strata. Usually impervious layer gives large contribution to run-off but its contribution in the GIA is less due to less area coverage as compared to other areas such as agricultural area, forest area, grassland area, etc.

3.6 CORRELATION BETWEEN RAINFALL AND RUNOFF

A proper understanding and modeling of rainfall-runoff relationship at watershed scales is important for water management studies, safe yield computations, and design of flood control structures. The response of a watershed to precipitation is complicated by various hydrologieologic components that are distributed within it in a
heterogeneous manner. One of the most common methods is to correlate runoff, \( y \) with rainfall, \( x \).

A correlation coefficient of 0.60 between rainfall and runoff has been computed from analysis of annual rainfall records of 49 years period as depicted in Table A-I (3.2). It is because of the following factors: Greater Imphal is composed of pervious (9328.32 Ha) and impervious area (4105.037 Ha); loss of water is high in pervious area as compared to impervious (area), and lack of detailed field observations. The value indicates a good correlation between rainfall and runoff for clayey type of soil of the GIA as depicted in Fig.3.13. The regression equation between rainfall and runoff has been found to be

Linear Fit: \( y = 21.068786 + 1.3356976 \times \)

Where,

\[
y = \text{Runoff} \\
\text{And } x = \text{Rainfall}
\]

![Rainfall/Runoff](image)

*Fig. 3.13 Correlation between rainfall and runoff of the GIA*
3.7 ASSESSMENT OF SOIL WATER BALANCE

Constructing a water balance is one of the first tasks in understanding the water regime of a specific area. In simple terms, a water balance is a budgeting exercise that assesses the proportion of rainfall that becomes stream flow (or runoff), evapotranspiration, and drainage (or groundwater recharge). Figure 3.14 represents a simple 'box' model representation of a water balance, which could be expressed in the form of Equation 1 (Thorntwaite et al., 1955; 1957).

Eq 1 \[ P = ET + RO + dSW + D \] where dSW is the change in soil water over the time step.

**Thorntwaite-Mather soil water balance model**

Model Description

![Diagram](image)

*Fig.3.14 Simple 'box' model representation of a water balance*
CHAPTER III
HYDROLOGY OF THE GREATER IMPHAL AREA

Water is stored in the soil reservoir until the soil water content \( SW \) exceeds the available water capacity \( AWC \), at which point the excess goes into storage \( S \). The monthly streamflow is a simple linear function of \( S \). Determining the soil water budget requires keeping track of the accumulated potential water loss \( APWL \) and the amount of water in the soil \( SW \).

Notation:

\[
AWC = \text{Available Water Capacity} \quad [\text{depth}]
\]

\[
= (\text{Field capacity-Wilting point}) \times (\text{Soil depth})
\]

\[
SW = \text{Available Soil Water (i.e., above wilting pt.)} \quad [\text{depth}]
\]

\[
APWL = \text{Accumulated Potential Water Loss (negative)} \quad [\text{depth}]
\]

\[
\square P = \text{Net Precipitation; } P - PET \quad [\text{depth}]
\]

\[
P = \text{Precipitation} \quad [\text{depth}]
\]

\[
PET = \text{Potential Evapotranspiration} \quad [\text{depth}]
\]

\[
AET = \text{Actual Evapotranspiration} \quad [\text{depth}]
\]

Equations:

Calculations to determine \( SW \) and \( APWL \) are made for each time step using monthly precipitation \( P \) and potential evapotranspiration \( PET \). Excess water, i.e., net precipitation (\( IP \)) in excess of the soil’s water holding capacity \( AWC \) leaves the soil and is stored in the watershed and eventually released to the river.
Table 3.1  Calculations to determine SW and APWL

<table>
<thead>
<tr>
<th>Situation in the Watershed</th>
<th>SW</th>
<th>APWL</th>
<th>Excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil is drying</td>
<td>$\Delta P &lt; 0$</td>
<td>$AWC \exp\left(\frac{APWL_t}{AWC}\right)$</td>
<td>$= 0$</td>
</tr>
<tr>
<td></td>
<td>$SW_{t-1} + \Delta P$</td>
<td>$APWL_{t-1} + \Delta P$</td>
<td></td>
</tr>
<tr>
<td>Soil is wetting</td>
<td>$\Delta P &gt; 0$ but</td>
<td>$AWC \ln\left(\frac{SW_t}{AWC}\right)$</td>
<td>$= 0$</td>
</tr>
<tr>
<td></td>
<td>$SW_{t-1} + \Delta P \leq AWC$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil is wetting</td>
<td>$\Delta P &gt; 0$ but</td>
<td></td>
<td>$= SW_{t-1} + \Delta P$</td>
</tr>
<tr>
<td>above capacity</td>
<td>$SW_{t-1} + \Delta P &gt; AWC$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$AWC$</td>
<td></td>
<td>$= 0$</td>
</tr>
</tbody>
</table>

When $P > PET$, $AET = PET$

When $P < PET$, $AET = dSW + P$

**MODEL OUTPUT**

![Monthly Average Soil Water Balance](image)

*Fig. 3.15 Monthly average soil water balance of the GLA*

- Water deficit = Nov. to Mar.
- Soil moisture utilization = Nov. to Feb.
- Soil moisture recharge = Apr. to May
- Water surplus = June to Augt.
From the Fig.3.15, it is interpreted that there is availability of surplus quantity of water in June, July and August in the GIA. However, it flows as run-off to river without any utilization and is one of the main factors for the scarcity of water during lean season. After the monsoon season, the scarcity of water mainly takes place during the months of November to March with little activity of soil moisture utilization from November to February due to unavailability of sufficient quantity of water. It is because of this reason that double cropping is not possible in the GIA. The soil moisture recharge takes place alone in the months of April to May. This cycle is repeated every year from the last many years and actions are needed to conserve the precious water resource.

3.8 ASSESSMENT OF SURFACE WATER RESOURCES

The Greater Imphal Area is mainly made up of impervious area and pervious area. The impervious area is mainly located in the Municipal area and the pervious area is found predominantly in the non-Municipal area. In addition to this, the GIA possess a number of water bodies in the forms of lakes, tanks, ponds, wetlands, etc. These areas possesses reasonable quantum of water resources and contribute significant amount to total surface water resources of the basin. The annual surface water surplus of the basin has occurs in June-August and is estimated as below:

\[
\text{Water availability} = \{\text{Excess water from "Thornwaite-Mather soil water balance"} + \text{Interception (including water bodies)} + \text{Average runoff}\}
\]

\[
= (13.79+2.21+25.63) \text{ Cmec}
\]

\[
= 41.63 \text{ Cmec}
\]

\[
= \frac{41.63 \times 1000 \times 60 \times 60 \times 24}{10^6} \text{ MLD}
\]

\[
= 3596.83 \text{ MLD}
\]

From the Fig.3.15, the total quantity of water available during the water surplus period (June-August) is estimated as the sum of “Excess water from
Thornwaite-Mather soil water-balance + Interception (including water bodies) + Average runoff”. The estimated surface water availability is 41.63 Cumeecs that can be effectively harvested for its usage during lean season.

3.9 WATER REQUIREMENT OF THE GIA IN 2007

Demands for water in the GIA are growing rapidly in owing to an increasing population and the rising standards of living. Water is used for agriculture, domestic, industrial and commercial purposes. Agricultural water requirement, which constitutes the majority of the total water demand, is satisfied mainly through rainfall, diversions of water from dams and rivers. Domestic and minor industrial water requirements of the area are met mainly from Imphal water supply.

(i) Agricultural demand

Irrigated agriculture consumes the bulk of the available water supplies. Despite the loss of agricultural land to urbanization, the cropping pattern in the GIA is typically of an underdeveloped agricultural economy with about nine-tenths of the total cultivated area under cereals, mainly rice. The growth of employment in this sector reduced significantly in the GIA. The employment in this sector is mainly outside the municipal area. There are small patches of agricultural land in the Municipal area where small number of agricultural workers are concentrated.

Agricultural water demand for the study area is modeled as the total surface area under irrigation multiplied by the demand per unit area (Downs et al., 2000). Lacking data on crops and crop-dependent demand, we assumed that average annual irrigation demand for paddy crop, i.e., 1200mm/hectare (± 20%). This is a reasonable assumption because during city growth, competition exists between land area for agriculture and area for settlement. We estimated the error in unit demand to be
± 20% and the error in area values to be ± 10%. An empirical estimation of annual
requirement of water in the GIA is as follows:

Total area of agricultural land in the GIA = 3725.741 ha.

Annual irrigation water demand of paddy crop (base period = 120 days)

= 1200 mm/ hectare

∴ Annual requirement of water

\[
\frac{3725.741 \times 10^4 \times 1.20 \times 10^3}{120 \times 10^6} = 372.57 \text{ MLD}
\]

(ii) Domestic demand

Greater Imphal draws its water supply mainly from surface reservoirs and
rivers, which are recharged annually by monsoonal and post-monsoonal rainfall. The
municipal and non-municipal areas of the GIA lack sufficient water supplies to meet
the current water demand. The annual per capita water use varies from one location to
another because of differences in social, economic, and climatological factors, viz.,
size of the family, level of income and education of the family, value and size of the
house, price and availability of water, and average temperature and precipitation. In
town, the affluent sections of the population can afford and are provided with house
connections. However, for the economically weaker sections in urban and rural
fringes, stand posts are provided at strategic locations.

We modeled domestic water demand for a population as the total number of
people withdrawing water multiplied by the demand rate per person. Table A-1 (3.3)
shows the estimation of domestic water demand of the GIA for 2007 and Table 3.2
derpicts the projected domestic water demand of the area in 2007. It may be noted that
the water shortage has already started to make its impact on the lives of the people
residing in the area. It is, therefore, necessary to augment Imphal water supply system
to meet the requirements of the town in years of low rainfall and also to strengthen and improve the existing water distribution system.

Table 3.2: Annual domestic water demand of the GIA in 2007

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Area</th>
<th>Population</th>
<th>Domestic water demand (MDL)</th>
<th>Daily water demand (MDL)</th>
<th>Annual water demand (MDL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Municipal area</td>
<td>2,65,332</td>
<td>36.88</td>
<td>38.9</td>
<td>14198.5</td>
</tr>
<tr>
<td>2</td>
<td>Non-municipal area</td>
<td>2,59,067</td>
<td>22.02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ii) Industrial and commercial demand

Industrial and commercial demand includes the quantity of water, which is supplied to offices, factories, industries, hostels, hospitals, etc. It is mainly met through Imphal water supply. The extent of industrial and commercial water consumption is usually an insignificant fraction of actual intake. This quantity will vary considerably with the nature of the City and with the number and types of industries establishments present in it. On an average, a provision of 20 to 25 % of the total water consumption is generally made in the design for these uses. For the GIA, it is assumed that 20 % of the total water supply is used for industrial and commercial purposes in the municipal and non-municipal areas. Table A-I (3.4) displays the estimation of industrial and commercial water demand of the GIA for 2007 and Table 3.3 shows the estimated industrial and commercial water demand of the GIA for 2007.
Table 3.3: Annual industrial and commercial water demand of the GIA for 2007

<table>
<thead>
<tr>
<th>SL No.</th>
<th>Area</th>
<th>Population</th>
<th>Industrial and commercial water demand (MLD)</th>
<th>Total demand (MLD)</th>
<th>Annual demand water (MLD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Municipal area</td>
<td>2,65,332</td>
<td>7.96</td>
<td>12.26</td>
<td>4474.9</td>
</tr>
<tr>
<td>2.</td>
<td>Non-municipal area</td>
<td>2,59,067</td>
<td>4.66</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.10 IMBALANCE BETWEEN SUPPLY AND DEMAND OF WATER

The total water requirement of the Greater Imphal Area is the sum of the quantity of water for agriculture (372.57 MLD), domestic (14198.5 MLD), and industrial and commercial (4474.9 MLD) purposes. It is estimated that the total water requirement of the GIA is 19045.97 MLD for 2007, while the available surface water resources is 3596.83 MLD. Hence, the quantity of water required for agriculture can be met through rainwater harvesting such as installation of check dams along the course of river. The remaining quantity of water (3596.83-372.77 = 3224.06 MLD) can supply 22.70% of the annual domestic water requirement of the GIA. This is a clear indication that the future agricultural water and a part of potable water requirement of the GIA can be meet from the available surface water resources through the adoption of water harvesting techniques and systematic management.