2.1 The Study Area

2.1.1 Location

Subtropical and tropical belt of south are vulnerable to disaster, as they are particularly exposed to extreme natural phenomena due to their geographical location. Storms, heavy rains, landslide are more frequent and severe in this belt. Hydro meteorological, seismic, volcanic and other natural events pose a permanent threat to people living in this region (Rao, 2010).

Being in the tropical belt as a gateway to North-East, the lone metropolitan of Guwahati and its surrounding is also lashed by the affect of cyclonic wave during the onset of monsoon, followed by heavy downpour and subsequent flooding, hill-slope sliding and emerging threat of urban flash flood etc. Kamrup Metropolitan district was created, bifurcating the old Kamrup district in December, 2002 vide notification no. GAG (B) 181/2002/28, dated 13th December, 2002. The district is bounded by Darrang and Kamrup (rural) district in North, state boundary of Meghalaya and parts of Kamrup (rural) district in South, Morigaon district in East and Kamrup rural district in West. The geographical extent of the district is latitudinal 25.43 -26.51 degree North and longitudinal 90.36 -92.12 degree.

The existing topography, unprecedented growth of population, shrinking waterlogged and swamp belt at the cost of expanding build-up zone, inability of the drainage to drain out the flood water etc. are some of the factors behind worsening of
the flood situation of the region. The focus of the research work is to unfold the flood vulnerability patterns of the new district, including rural and urban in relation to its vulnerable section of population, land-use and a strategy for its risk reduction model.

The sketch view of the study area is shown in reference to India-Assam and the district with shaded parts in figure 2.1

*A list of photograph is enclosed in page XXIII, and the photographs are enclosed in annexure XIII.*

![Diagram of study area](image-url)
2.1.2 Physiographic structure

The greater parts of the district of Kamrup Metro consist of wide plain, with steady east to west flow of the mighty Brahmaputra. South frontier is occupied by hills. East of Palasbari, isolated hills crop up above the alluvium, and at Guwahati reach down to the edge of the water. The plain falls roughly into three sections: 1) neighbourhood of Guwahati, overtopped only by a heavy flood, 2) western part, which is a belt of marshy tract, subjected to inundation during the rainy period, and 3) the densely populated central portion of the district.

Geomorphology of Kamrup Metro District is composed of three (3) major units namely: northern flood plain, gently sloping plain in the midst and piedmont plain towards southern Meghalaya (Soil Resource Atlas, Assam 1994).

Overall topography of the area varies from low-lying plain to undulating hillocks. The fringe area of Meghalaya is steep undulating converging to flat terrain towards the river Brahmaputra. The terrain is dotted with small hills to residual hillocks. The map of physiographic outlay of the newly created district is prepared from CARTOSAT2 data from NRSC, Hyderabad. The map is a clear representation of the physical character of the region, that sharply fall down from south to north. The elevation ranged between as low as 44 metre to-maximum of 701 meter. The south part is flanked by the Meghalaya plateau from where elevation falls southward. Blue shade occupies the major part of land area of the district, representing the low-lying belt, frequently affected by inundation and flooding during the monsoon. There are also intermittent hillocks that occupy the central north part. With ever expanding population that settled over the low-lying part of the district, exiting water bodies and the hill slope are coming under the threat of ecological imbalances, which ultimately
culminated into creation of certain hazards like issue of flash flood, urban water logging, flood in the periphery, landslide on the hill slopes etc. with disastrous affect.

The map of physical outlay of the new district as shown in figure 2.2, based on elevation differences speaks in itself about the vulnerability of the district towards various hazards. Rushing of water from Meghalaya plateau during monsoon towards the city and inability of the existing urban drainage to carry the additional water towards outlay are two major issues. In addition there is a continuous shrinking process of the exiting waterlogged and swamp zone, replaced by new built-up areas of settlement and other urban activities. Under such conditions urban places are continuously facing the issue of inundation of settlement zone during the monsoon, which expanded to new built-up areas. Field study has revealed some other facts like depleted urban drainage, the issue of backflow from the mighty Brahmaputra during the monsoon etc. that further aggravates the flood problem.

Figure: 2.2 Physiography of Kamrup Metropolitan District, Assam (elevation wise)
2.1.3 Relief and slope

The map of relief and slope zone of Kamrup metropolitan district is prepared on GIS platform on the basis of original NATMO, Kolkata map of the region. Based on information, the district can be divided into four (4) relief zone as below 50, 50-100, 100-300 and above 300 meter range. On the other hand major parts of the district have a land slope of less than 10 meter/ km. Out of the land slope zone, part of the western section (north part of Azara circle) falls below 50 meter relief, that approaching the bank of the mighty Brahmaputra. Rest of the central and eastern part also have a land slope of less than 10 meter/ km, with a relief ranged between 50-100 meter, that covers most part of the municipal ward under Guwahati Municipal Corporation, Chandrapur and part of Sonapur, which are falling under flood vulnerable zones.

Excluding this vast portion of flat land slope zone (less than 10 meter/ km), the southern part of the district has maintained an abruptly rising land slope of 300-600 meter/ km, with two distinctive relief zone of 100-300 and above 300 meter respectively, as we go towards the plateau of Meghalaya. The relation of relief and land slope is shown by figure 2.3
2.1.4 Geology

Kamrup Metro District lies in the northern fringe area of the Meghalaya Plateau. The isolated hills in the midst of alluvial plain are also known as inselberg comprising of mostly Precambrian gneissic rocks. It is dominated by scattered hillocks with intermittent plains, which are extended parts of Shillong Plateau that form the southern boundary of the district. The district is composed of recent alluvium in the central part and gneiss with old inliers of Achaean mid proterozoic era (NBSS & LUP).
2.1.5 Climate

Climate change studies become an important issue of research in all relevant disciplines. Indian Monsoon is known for its variations in time, place and amount. Some studies have found no significant change in annual rainfall, while many others have found a changing trend. Climate change should not be an international or national study, but to be percolated to regional and local level (IPCC, 2007). Such a local level study of rainfall trend was conducted by Ranganatha in Mysore city of Karnataka titled ‘Analytical Study of the Trend and Rhythm of Rainfall: A Pilot Study of Mysore, Karnataka’. Study of monthly and annual mean rainfall and rainy days was analyzed during 1971-2010, based on data of IMD, Pune. It was found that there is no substantial change in the annual rainfall trends, as the mean rainfall has remained stable. Seasonal change is more prominent, with wet season become wetter, while dry (winter) period has become drier (Ranganatha, 2014).

The climate of Kamrup metro, at local level doesn’t differ from rest of the districts of central Assam. Its principal character is cold and foggy winter, a moderately cool spring and a fairly temperate, but very humid summer. Climatically the region falls under subtropical monsoon, with semi dry summer and cold winter. It receives an annual rainfall of about 1500-2600 mm, with a high humidity of about 75%. Annual temperature ranged between 7-38.5 degree C.

The average temperature (daily minimum-maximum), rainfall and rainy days of 30 years database (1951-80) as measured by Regional Meteorological Centre, under IMD, Borjhar, Guwahati is shown in Table: 2.1, which is further illustrated separately by Figure: 2.4 & 2.5 respectively, indicating a general climatic character of the region. However as the Borjhar observation centre is located in the periphery
attached with the airport, the actual city picture is always have a chance of deviation from the data. A comparison of rainfall trend at Borjhar Airport (IMD) data with that of Chandmari Water Resource Department, located in the city centre is presented in chapter 3 for further illustration.

<table>
<thead>
<tr>
<th>Months</th>
<th>Average temperature (in °c)</th>
<th>Average Rainfall (in mm)</th>
<th>Average number of rainy days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily minimum</td>
<td>Daily maximum</td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>9.8</td>
<td>23.6</td>
<td>11.4</td>
</tr>
<tr>
<td>February</td>
<td>11.5</td>
<td>26.4</td>
<td>12.8</td>
</tr>
<tr>
<td>March</td>
<td>15.5</td>
<td>30.2</td>
<td>57.7</td>
</tr>
<tr>
<td>April</td>
<td>20.0</td>
<td>31.5</td>
<td>142.3</td>
</tr>
<tr>
<td>May</td>
<td>22.5</td>
<td>31.0</td>
<td>248.0</td>
</tr>
<tr>
<td>June</td>
<td>24.7</td>
<td>31.4</td>
<td>350.1</td>
</tr>
<tr>
<td>July</td>
<td>25.5</td>
<td>31.8</td>
<td>353.6</td>
</tr>
<tr>
<td>August</td>
<td>25.5</td>
<td>32.1</td>
<td>269.9</td>
</tr>
<tr>
<td>September</td>
<td>24.6</td>
<td>31.7</td>
<td>166.2</td>
</tr>
<tr>
<td>October</td>
<td>21.8</td>
<td>30.1</td>
<td>79.2</td>
</tr>
<tr>
<td>November</td>
<td>16.4</td>
<td>27.4</td>
<td>19.4</td>
</tr>
<tr>
<td>December</td>
<td>11.5</td>
<td>24.6</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Source: Regional Meteorological Centre, Guwahati-1951-1980
As shown in Figure: 2.4 during the winter season, the gap between minimum and maximum remains high. Minimum temperature is observed in the month of January 9.8°C, during which maximum remains more than double the minimum at 23.6°C. However with the advancing monsoon, during the summer season temperature continuously raised, that never falls below 30°C (March to September). The gap between minimum and maximum is also reduced considerably in this period.
As shown in Figure: 2.5 the rainfall trend of Kamrup Metro District in the observed time period have reflected a typical summer monsoon character. From the month of April with beginning of pre-monsoon phase till the month of August there is a continuous rise in rainfall, extended till the month of September. The rainfall trend is further supported by average number of rainy days during the same time period, represented by Figure: 2.6. Month of July, being the pick of the monsoon also have the highest number of average rainy days (16.8). All through, the four (4) month of May to August have the highest numbers of rainy days of a calendar year. Based on the thirty years average picture, a calendar year can be divided into 3 distinctive phase of number of rainy days as: pre-monsoon low rainy day’s phase (average 4 days/month), monsoon high rainy day’s phase, witnessing more than half of the month’s rain (15.3 days/month) and post-monsoon declining rainy day’s phase (4.4 days/month).
2.1.6 Soil

The soil of Kamrup Metro district can be broadly divided into three (3) types namely:

a) Very deep, well drained fine soils of Guwahati core that extended towards eastern parts of Chandrapur and Sonapur revenue circle. It is occurring on moderately sloping to moderately steep sloping side slopes of residual hills having clayey surface with moderate erosion hazard and slight stoniness.

b) Moderately deep, moderately well drained coarse loamy soil of western side towards Azara and polasbari (Kamrup rural) revenue circle. It is occurring on level to nearly level active floodplain and stable river islands having sandy surface with ground water table below one meter of the surface and very severe flood hazard.

c) Deep excessively drained fine soil towards south side piedmont plain of Meghalaya hill. It is occurring on moderately steep side slopes of hills having clayey surface with slight erosive hazards (NBSS & LUP, 1994).
The well drained fine soils of Guwahati core that extended towards eastern parts of Chandrapur and Sonapur revenue circle are mainly composed of old alluvium and red loamy soil, as shown in figure: 2.6. The type of red loamy soil is further distributed towards south along the border of Meghalaya plateau. The western part of Azara has mostly mixture of red sandy and young alluvium, as one go towards the bank of the mighty Brahmaputra (NATMO).

![Soil Map of Kamrup Metropolitan District, Assam](image)

**Figure: 2.7 Soils, Kamrup Metropolitan District, Assam**

### 2.1.7 Drainage

The main rivers that pass through the district of Kamrup Metropolitan are the mighty Brahmaputra and its tributary Kolong and distributaries’ Digaru. Digaru comes from the Meghalaya plateau and meet with river Kolong at a right angle near Chandrapur revenue circle, and finally meet the mighty Brahmaputra.
In urban morphology two main drainage are bahini that flows to Deepor bil and river Bharalu that meets mighty Brahmaputra. The shrinking water bodies with ever expanding settlement and urbanization process and depleted status of the outgoing channels of Bihini and Bharalu posing a serious threat, towards increasing urban flood hazard vulnerability in the region. Status of the urban drainage and its related issues like problems related to drainage are incorporated in chapter 4 in drainage part and in chapter 7 in vulnerability analysis respectively.

2.1.8 Forest

Department of Environment and Forest, Government of Assam have taken up major initiatives of social forestry throughout the state. According to recorded data of 31/12/2005, 17.68% of state area was under forest, that has gone up-to 24.58% in 2011. Forest survey of India (FSI) report has also reflected growing forest cover in the state after 2001. The trend has been evident in the study district of Kamrup Metropolitan, where more than 10% addition of forest is observed in between 1991-2011. The addition is primarily attributed to greater precision satellite imagery of IRS: LISSIII scanner, where further sub-types like scrub, grassland areas were included within forest category, which were earlier included as degraded wasteland. The detail report on the forest statistics and its possible reasons are explained in chapter: 4 (land-use, land-cover change).

With the typical climatic character of summer monsoon, the district of Kamrup Metropolitan, like rest of the state of Assam also bears a rich composition of forest. It is made up of tropical deciduous semi evergreen type of forest.
As shown in figure 2.8 the district is still occupied by as many as five (5) reserved forests in and around Guwahati city. They includes the Garbganga in west falling under Azara circle, Sila grant in North Guwahati circle, Fatasil within the municipal area of Guwahati, Amsangi in Chandrapur circle and Africola reserve forest in Sonapur circle. The forest in and around the district, especially on the hill slope have acted as a shield towards landslide. Apart from that the reserved forest also supports the biodiversity composition of a geographical area. However in last few years depleted forest in the vicinity of the city, especially near Jorabat area to expand the four lane highway has added fresh trouble in the name of rising landslide and related instability. The land-use, land-cover change of the district between 1991-2011 has been elaborately explained in chapter: 4, with related statistics and maps of the concerned decades.
2.1.9 Population

The earliest inhabitants of North East India were probably the Austric stock. They were the pre-Dravidian aborigines who are now represented by the Monkhmer khasis and Syntengs of Assam. The Dravidian came subsequently as invaders from the west.

After appearance of the Aryans in India, hordes of later Mongoloids poured through the north-east. They came in probably at a time when the Austric people had already been driven to the hills by the Dravidian conquerors. This later Mongoloids belonged to the Tibeto-Burman family of Indo-Chinese group and their representatives of present day are the Kachari, Koch, Mech, Rabha, Mikir, Lalung,
Garo, Naga, Kuki and Chutia. Of these tribes, people speaking Bodo (Boro) language seems to have occupied the plains of Assam for a very long time. During the time of Mahabharata and even before that, the Bodo tribes constituted the bulk of the population in Assam valley.

In the 2001 census, total population was 1062771, which has gone up-to 1260419 in 2011 census, maintaining a decadal growth rate of 18.95%. If we look at the urban and rural composition of the district, the 2001 census has revealed the fact that 80% of the resident population are urban dwellers, while only 20% forms the rural representation. Temporal changes are also noticeable in case of population density, which was 836/sq. km. in 2001 census, but has gone up-to 2010/sq. km. in 2011 census, more than double, within a span of a decade. Considering the geophysical background of the district, such rate of growth and expanded population density is a serious concern for kamrup metro district, in terms of increasing natural hazards and their intensity over the years.

The lone metropolitan of North East India, which is the last administrative bifurcation as a district (2003) originally belong to a low land surrounded by hillocks on all side. After shifting of the state capital to core of Guwahati, the region has witnessed unplanned economic activities, hap-hazard urban expansion and its follow up of population pull of all section of society, from all the corners of the state over the decades. As an urban pull, immediately surrounded by rural fringe, Kamrup Metro is bound to be affected by this unplanned growth. This has ultimately led to increasing hazard vulnerability and various related adaptation challenges over the decades (own observations).
From the demographic standpoint, as a vibrant urban pull, Kamrup metro district is continuously accommodating an ever-expanded population volume over the decades. Demographically, the new district has the distinction of the highest total urban population (1,044,832), highest total literacy (88.66%) and highest population density (2010 person/sq. km) of Assam. At the same time, on the other hand, it is also characterised by the status of being the lowest rural population (2.93%) and lowest total sex-ratio (922/ thousand male) of the state. (Source: Census, 2011, Assam).

The flood hazard vulnerability pattern is analysed in terms of their demographic pattern. For that, village-level population data are analysed in detail in chapter 5. The population data derived for analysis includes: village density trend, growth trend, growth of the vulnerable section of population (considering female and child under 06 years age group) of the vulnerable villages and wards as per need. The secondary data base is taken into consideration for 40 years observation (1971-2011).

Social vulnerability can be identified with the help of factors like: socioeconomic status, development, population density, age, race, gender, economic dependency, migration, growth etc. Children in the lower age group, female and special need population group etc. need special care during disaster, whereas socioeconomic status define ability to absorb loss and recover through insurance, safety etc. (Susan, C, 2009). In this study, 'vulnerable group' of population is identified by considering female and child (less than 06 years age group). In household-based case study, 'insurance mechanism' and response of both rural and urban people towards it is compared.
2.2 Methodology of the Study

Modelling the vulnerability of people will require the collection and analysis of data in quantitative and qualitative terms, with a combination of surveys of households, institutional analysis (local governments, insurance companies, voluntary organisations, businesses and employers), livelihood and welfare analysis (of income sources and employment patterns), and surveys of physical structures and infrastructure with the emphasis not only on property damage, but also the impact of floods on welfare and income earning opportunities (Parker, 2000).

In Indian context methodological emphasis on disaster related study incorporates themes like: zonation (in case of flood, flood risk area zonation), rainfall trend, land use change, population density, literacy trend, people’s occupation, and media usage (Rao, 2010). In view of the objectives being set for the study and wide scope of data generation, the research will encompass both primary and secondary source of data. The methodological steps are as follows:

(I) Base map of flood vulnerability

Base map of flood vulnerable zones of both rural and urban part of the study area is done by incorporating flood records of Flood Management Plan, Kamrup Metropolitan District, 2009 and GMDA report for rural and urban part respectively. In rural case most flood affected circles of Chandrapur, Sonapur and Azara are considered. The circle level village maps were taken from District Census Handbook.
1991, whereas for the urban case 60-ward old Municipal map is taken into consideration. The maps were developed in GIS platform using ArcGIS (ESRI® Arcmap™, version 9.3 (Ormsby et al., 2009)

(II) Circle-level vulnerability weight map

All the flood vulnerable villages of the three most flood affected circles are tried to be identified in terms their 'demographic vulnerability' by assigning weight on the basis of population density between 1971-2011 censuses. In assigning weight villages are ranged into three (3) population density groups as:

(a) Low density (below 500 person/ sq. km.) with weight index 1 (one)
(b) Moderate density (500-1000 person/ sq. km.) with weight index 2 (two)
(c) High density (above 1000 person/ sq. km.) with weight index 3 (three)

The assigned weight of a village in a particular census is thus added to the next successive census value to get a total weight index value of that particular village. If in case density data of a particular decade is not available, weight index is assigned based on the assigned value of the previous decade. Finally the given weight values are ranged to identify the vulnerability status as low, moderate and high of varied weight range. It is an indication of the fact that greater the population density more is the total weight, which is reflection of possibility of increasing number of population under flood vulnerability over a period of time.
(III) Ward-level vulnerability map

The 60-ward old Guwahati Municipal area map is developed on GIS platform to delineate the flood vulnerable and non vulnerable zones on it. The data of GMDA is taken for the map preparation.

(IV) Hill shade view and physiography

The basic information on hill shade view and physiography of the district is prepared on the basis of CARTOSAT-2 image of 2.5 meter resolution. The hill shade view is a black and white image of the district for interpretation of the location of the vulnerable places of the district as a whole. The physiographic map is an elevation based output of image, where elevation in color composition from lowest to highest value in metre is analyzed (lowest 44-to-highest 701 metre).

(V) Land-use/ land-cover change

For analysis of land-use/land-cover 1991-2011 data base was generated. It is compiled on the basis of concerned toposheet and satellite imagery of 1991 to 2011. For land use mapping toposheet nos. 78N/8, N/12, N/16, O/9, O/13 & 83B/4 are taken into consideration. For 1991 land-use, land-cover map IRS 1B, LISS II, dated, March, 1991 is taken for consideration. For 2011 land-use, land-cover map IRS 1D, LISS III, dated, January, 2011 is taken up.

The map is created by onscreen interpretation of satellite images as part of visual image interpretation. Various key interpretation elements like size, shape, shadow, tone, color, texture and pattern were identified for delineation of land-use
pattern. Classification follows the NRSC scheme of classification. After that the features were digitized in ArcGIS 9.3 version geo data base (Ormsby et al., 2009). 15 numbers of land-use types were identified in 1991 LISS II scanner image, which is added to 23 in 2011 with LISSIII greater precision scanner.

A census based village-wise land-use analysis is also made in the vulnerable villages to see the land-use trend in relation to population density and subsequent vulnerability pattern. To do that census data of land-use is categorized under 3 fundamental types as forest, agriculture and waste land.

The summary statistics generated by LISSII and LISSIII scanner image of each land-use classification were categorized in MS-excel format and converted to percentage value for its graphical presentation and comparative analysis of change during 1991-2011.

(VI) Map superimposition

The land-use/ land-cover map of 2011 based on LISS III scanner (23.5 metre resolution), image of hill shade view and physiography based on CARTOSAT-2 series data (2.5 metre resolution) are used as base map to create separate layers of the district. The map of flood vulnerable zones created in circle and ward level are superimposed on the base maps of land-use, hill shade view and physiography to see the location and pattern of flood vulnerability of the district. During superimposition the flood vulnerable sections are identified with stripe shade, for visual interpretation of the situation.
(VII) Other thematic maps

For all other need based thematic map interpretation such as relief and slope, forest, soil, etc. basic map information were derived on GIS platform from information of NATMO, Kolkata. Drainage map of the district is developed from IRSP6, LISSIII scanner image. In addition long section analysis of the main urban drainage system was done by using the original drainage survey map of Flood control department of Government of Assam.

(VIII) Demographic vulnerability analysis

Circle-level change of demographic statistics is made on the basis of census data. In addition vulnerable population growth with special thrust on female and child is calculated, using census statistics, at village and wards level.

(IX) Socioeconomic field survey

Situational assessment is undertaken based on primary and secondary data of case study area. A household level simple random sampling is conducted in 10 villages, and 07 municipal ward locations from among the flood vulnerable zones, which is documented with specific questionnaire. Questionnaire is designed in three parts to accommodate general profile, hazard identification and vulnerability assessment in terms of household level response. A total of 853 household (537 rural and 316 urban) is surveyed. The generated data is tabulated and analysed in terms of relevant statistical relations, using MS-Excel software. A model copy of questionnaire is annexed in appendix.
Rank analysis of vulnerability and coping capacity

Perception based rank analysis of flood vulnerability of the affected people is undertaken in a 10-point scale where value of 1 in the scale refers to the lowest and 10 to the highest of the rank. Accordingly value of all villages and ward locations were listed rank wise. In case of vulnerability ranking perception based rank value of the sample villages and ward locations were enlisted rank-wise to calculate the average vulnerability rank (AVR) of the concerned village or ward location. Finally a graphical representation of AVR is prepared for comparative analysis of the situation.

In addition coping capacity is analyzed by interpreting 4 parameters including People's self-preparation to fight with hazardous situation, people's view towards government assistance, training and awareness programme attended by the people and NGO functions in the affected locality. A correlation is tried to be established between vulnerability and coping capacity of the sample study villages using Karl Pearson's correlation, which is graphically presented for analysis.

For all other relevant analysis various carto-statistical models were developed as per need and relevance. The various sources of maps and images used in this research are given in Table: 2.2.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>MAPS/TOOLS</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RURAL &amp; URBAN FLOOD VULNERABILITY</td>
<td>BASED ON FLOOD MANAGEMENT PLAN, 2009 &amp; GMDA REPORT (Circle maps: District Census Handbook, Kamrup, 1991)</td>
</tr>
<tr>
<td>2</td>
<td>HILL SHADE VIEW AND PHYSIOGRAPHY</td>
<td>CARTOSAT-2 SERIES IMAGE OF 2.5 METRE RESOLUTION, ON WHICH FLOOD VULNERABLE LOCATIONS WERE SUPERIMPOSED (NRSC, HYDERABAD)</td>
</tr>
</tbody>
</table>
| 3      | LAND-USE, LAND-COVER MAP 1991-2011             | i) TOPOSHEET nos. 78N/8, N/12, N/16, O/9, O/13 & 83B/4  
| 4      | OTHER THEMATIC MAPS                              | NATMO MAPS, KOLKATA  
DIGITAL ELEVATION MODEL (DEM-ASTER)  
DRAINAGE: IRS-P6, LISS III, DECEMBER, 2011 |
| 5      | GIS PLATFORM                                    | ArcGIS (ESRI® Arcmap™, version 9.3 (Ormsby et al., 2009)) |
A total flow chart of methodological steps and processes followed during various stages of the research work is highlighted in figure 2.9.

**Figure: 2.9 Flow Chart of methodology**

Identification of flood vulnerable locations of the study area

- Rural Vulnerability status
- Urban Vulnerability status

Based on secondary data base

Assessment of Vulnerability Status of selected locations

Preparing of Questionnaire

Household survey for data collection of selected villages, using random sampling

Data Analysis

- Land-use & Land cover (1991-2011)
- Population structure (1971-2011)
- Statistical analysis of various parameters related to flood hazard vulnerability of the study area
- Correlation of vulnerability and coping mechanism

Formulation of a better management strategy