Chapter II

Study area
STUDY AREA

The Imphal valley, which is also known as Manipur valley, where the present study was conducted, lies in the middle of the state of Manipur, which is a state of India. Manipur lies in the north-eastern part of India. The study area falls in parts of Imphal valley, also known as Manipur valley. The Imphal valley in the central part of the north-east Indian state of Manipur. Manipur and the region around it forms a part of the larger north-eastern Himalayan (NE Himalayan) region.

Manipur is bounded by the other Indian states, Nagaland in the north, Mizoram in the south-west, Assam in the west and another country, Myanmar in the east and south-east. The valley is a flat plain valley which is surrounded on all sides by the Manipur Hills. Geographically, the valley occupies 10% of the total area of the state but supports 61.54 percent of the state's total population of 22,93,896 persons (Statistical Abstract of Manipur, 2007). The area forms a part of the larger north-east Himalayan (NE Himalayan) region.

The area is chosen because few scientific geoenvironmental studies were carried out in the north-east India in general and in Manipur in particular due to logistical problems and uneasy access as compared to other much studied intermontane valleys in the central and western Himalayan regions. Even though, the state is considered industrially virgin area, since 1961, the population of the state is growing at the rate greater than all-India decadal growth percentage. The ever growing population and its attendant anthropogenic activities like unplanned growth in urban settlements and huge accumulation of solid wastes in the absence of proper landfill sites, encroachment on the scattered wetlands for habitation and agricultural activities, shifting agricultural practices in the higher reaches in the surrounding hills, deforestation along with the impacts felt from the external factors like global warming and climatic change phenomenon are
exerting pressure on the geoenvironment of the study area. The impacts of these natural and anthropogenic activities are manifested in the form of deterioration of quality of water resources, deteriorating health conditions, increase incidences of water- and vector-borne communicable diseases, increasing frequency and intensity of the occurrence of flood hazards in the study area and landslides and soil degradation and loss etc. in the mountains and hilly regions. Ignorance about the stresses on the geoenvironment is no less hazardous while planning for mitigation and improvement of the geoenvironment conditions. This geoenvironmental appraisal study will supplement the previously existing scattered and insufficient informations and data, and will provide an integrated picture for the various geoenvironmental parameters and their impacts in the study area. The findings of this study will be a useful part, not only in the quest for awareness but also planning for mitigation, correction, conservation and management for sustainable development of the study area.

2.1-Location

The Imphal valley lies in the central part of Manipur (see fig.2.1). The study area in parts of Imphal valley is bounded by 24°16’N and 25°02’N latitudes and 93°41’E and 94°09’E longitudes, and covers an area of about 1800sq.kms. This valley is an elongated, oval shaped, intermontane valley with elevation ranging from 746m to 850m above the mean sea level (msl) with an average elevation of about 780m above the msl. This valley tapers toward south. Imphal, the capital of Manipur is connected by three National Highways (NH-39, NH-53 and NH-153) and also state highways and district roads. Also, there are air services operating on daily basis connecting Imphal with other places in India like Guwahati, Kolkata and New Delhi.
Fig. 2.1: Location map of the study area
2.2 – Geology

Some early workers like Mallet (1876), Oldham (1883) Evans (1932), and Brunnschweiler (1966), Anonymous (1974) Acharya et al. (1986) have described the geology of the north-east on the regional basis. GSI or any other organization is yet to provide a standard stratigraphic succession of Manipur other than the adoption of the generalized sequence of Assam with minor modifications here and there. Ibotombi (1993) compiled and established a stratigraphic succession of Manipur by modifying the earlier data as well as incorporating later emerged data. The geological map of Manipur is given in Fig. 2.2 and the stratigraphic succession is given in following table 2.1.

Fig. 2.2 Geological map of Manipur (Brunnschweiler, 1966 and Ibotombi, 1993, 1998)
Table-2.1: Stratigraphic succession of Manipur.

<table>
<thead>
<tr>
<th>Lithounits and age</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluviums (Quaternary-Holocene Pleistocene (?))</td>
<td>Dark grey to black clay, sill and sandy deposits of fluvio-lacustrine origin. Mainly fluvial alluviums in the Barak valley area of western plains. Clay, sand, gravel, pebble, boulder deposits of the foothills and old river terraces</td>
</tr>
<tr>
<td>Stratigraphic break</td>
<td>Mottled clay, molted sandy clay, sandy shale, clayey shale and sandstone.</td>
</tr>
<tr>
<td>Tipams (Miocene)</td>
<td>Greenish to blue, moderate to coarse ferruginous sandstone with sandy shale, clay. Often brown to orange due to weathering. Molasse type of deposits. Shale, sandy shale, siltstone, ferruginous sandstone, massive to false-bedded ferruginous sandstones.</td>
</tr>
<tr>
<td>Sumas (Miocene to Upper Oligocene)</td>
<td>Alternation of sandstones and shale with more argillaceous horizons in the middle and minor conglomerates. Transitional characters from flysch to molasse sediment</td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Disangs (Eocene to Upper Cretaceous)</td>
<td>Dark grey black, splintery shales and intercalations of shales, siltstones and sandstones showing occasionally rhythmite characters.</td>
</tr>
<tr>
<td>Unconformity (partly)</td>
<td></td>
</tr>
<tr>
<td>Ohpiolite Melange Zone (Lower Eocene to Upper Cretaceous)</td>
<td>Basic and ultrabasic intrusive and extrusive of peridotite, gabbro, serpentinite composition. Associated sediments are mainly pelagic such as cherts, limestones, shales etc.</td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Metamorphic Complex (Pre Mesozoic or Older)</td>
<td>Low to medium grade metamorphic rocks of various compositions - phyllitic schists, quartzites, micaceous quartzites, quartz-chlorite-mica shists, marble.</td>
</tr>
<tr>
<td>(?) Unconformity</td>
<td></td>
</tr>
<tr>
<td>Basement Complex</td>
<td>Unseen</td>
</tr>
</tbody>
</table>
The Imphal valley which lies in the central part of the state has a distinct geologic nature as it occurs within the surrounding hilly region (see fig.2.3). It is oval shaped valley encircled by the hills of Manipur on all sides with only narrow inlet and outlet of Imphal River in its northern and southern sides. It has a fresh water lake, the Loktak Lake, the largest in the north-east India, in the southern part of the valley. Small hillocks do occur rising above the flat alluviums of the valley.

The major central part of the state is occupied by Disang and Barail sediments. They constitute the principal flysch sediments of the region. The Disangs is a monotonous sequence of dark grey to splinterly shales with some intercalations of siltstone. Barails on the other hand, are mainly arenaceous sediments with minor to thick interbands of shales. The contact between the two lithounits is gradational as well as tectonic. (Ibotombi, 1998).

The Imphal valley lies within the Disang-Barail Flysch Basin. This valley was originated as a result of the tectonic and structural evolution of the Indo-Myanmar Range. The valley does not contain any lithounit except the Quarternary Alluvium Deposits, 40-50m thick, of fluviolacustrine origin (Ibotombi, 1993). After the deposition of the Tipams which might have completed by the end of Miocene or Early Pleistocene, erosion, denudation started in the region and the post-Tipam period is represented only by a sequence of alluviums of varying thickness. The largest occurrence of alluviums is of the Imphal valley. The sediments of the deposits are derived from the surrounding Disangs and Barails and mainly contain dark-grey to black clay, silt and sandy deposits. Clay, sand, gravel, pebble and boulder deposits are found in the foothills of the old river terraces. These are thought to be Older alluviums (Oldham, 1883). The age of these alluviums is assigned to be Recent.

Tectonically the valley is bounded by two large and prominent structural and tectonic lineaments, one on the eastern side, the Thoubal-Kodam Thrust fault and the other
on the western side, a faulted anticline axis marked by high angle reverse fault. The western tectonic element serves as a structural contact between the Disangs and the Barails at places and runs close and parallel to the contact of the lithounits. The tectonic sketch of the Imphal valley is given in fig.2.4. Almost all the hillocks within the valley are composed mainly of Disangs. Some outcrops of the Barails occur as cappings in the form of outliers mainly on the eastern part of the valley.

Godwin-Austen (1873) opined that valley was evolved due to the gradual fill-up old lake, the Loktak Lake. But Oldham (1883) pushed for fluvial-filling in the evolution of the valley. Ibotombi (1993) concluded that the valley was originated as a result of structural and tectonic evolution of the IMR and the present landscape is the result of continuous erosional processes since then.

The Manipur Hills stretch between the Naga-Patkai Hill in the north and north-east and the Chin Hills in the south. The Manipur Hills forms a part of the Indo-Myanmar Range (IMR). The structural and tectonic pattern of the region is transitional between the NE-SW trending pattern of Naga- Patkoi Hills and N-S trend of Mizoram and Chin Hills. The rock of the state is predominantly made up of Tertiary and Cretaceous sediments with minor igneous and metamorphic rocks. The rock formations are mainly flysch sediments of Tertiary age and constitute about 70% of the total area of the state.
Fig. 2.3: Geological Map of Imphal valley and catchment area (after Dinachandra, 2001).
Fig. 2.4: Geological sketch of Imphal valley (after Ibotombi, 1993).
2.3- Geomorphology

The Imphal valley, enclosed by Manipur Eastern Hills and Western Hills, is also one of the Himalayan midlands like the valley of Kashmir and Kathmandu valley in the Himalayas. It is an intermontane basin, about 60-65 km. long and 30-35 km. broad having an area of 1800 sq. km. The valley is a high level flood plain with an average elevation of about 780 meters above msl. The 900 meters contour forms its outer limits. It is a lacustrine plain-site of an ancient lake, which was subsequently filled up and uplifted to its present position, the remnant of which occupies as the present day Loktak Lake, in the south-east corner of the valley (Singh, 1982). The flat-land topography of the Imphal valley which is formed by the alluvial deposits after the Tertiary period is occasionally broken by hills and mounds which rise above this flat surface. These include the Langol, Heingang, Nongmaiijing Ching, Langthabal and Waithou etc. The scenic beauty of Loktak Lake, which is the largest fresh water lake in the north-east India, also features a series of islands which rise above the water level. Sendra, Ithing, Thanga and Karang are the most important among them. The geomorphological map of the Imphal valley is given in fig.2.5.

The Manipur Hills, which enclose the Imphal valley, consist of a series of parallel ranges extending between the Naga Hills in the north and Mizo and Chin Hills in the south. Having a general slope towards the south, these hills extend from north-east to south-west direction. These hills broadly fall into two groups-the Manipur Eastern Hills and the Manipur Western Hills, which differ in their layout, structure and relief.

The Manipur Eastern hills having the important hill ranges of Nupithel (Mapithel), Chingai, Malain, Angoching and Yomadung forms a compact and continuous chain along the Indo-Myanmar frontier for about 200 km., attains an average height of about 1,500 meters. The breadth ranges from 50 km in the north to about 30
km. in the south. Khayangbung (2,833 m.), Shiroi (2,568 m.) and Kachubung (2,498 m.) are the important peaks. Formed of the Disang shales, Ukhrul limestones and the serpentinites, the Manipur Eastern hills contain a number of important minerals like limestone, chromite, talc, nickel and copper ores (Laiba, 1992).

The Manipur Western hills, with the number of parallel ranges— Uningthou, Koubru, Khoupum, and Haobi, spreads over the entire western part, running north to south for about 180 km. with a breadth of 50 km. in the north and 70 km. in the south. The hills are generally higher in north and west and lower towards the south. Important peaks of this hill ranges are Tenipu (2,994 m.), Koubru (2,652 m.), Leikot (2,831 m.), Tamphaba (2,664 m.), and Iso (2,460 m.). Small valleys are also found running parallel with ridges from north to south, these hills are composed of compact sandstones, shales and clays of the Barail series, but their western slopes are covered with sandstones, shales, mudstones and conglomerates of the Surma series.
Fig. 2.5: Geomorphological map of Imphal valley and catchment area (after Dinachandra, 2001).
2.4 – Drainage

The Imphal valley is traversed by important rivers of the state of Manipur like Imphal River also known as Manipur River, Irl River, Thoubal River, Wangjing River etc. The Imphal River flows from north to south and is joined by its tributaries, the Irl River, Thoubal River, and Sekmai River at different places. Other rivers, Nambul, Nambol, Khuga and Sekmai also drain the valley. These rivers along with other smaller rivers and streams form the Imphal River system. This river system has a catchment area of 6,322 sq. kms. and embraces 28.4 per cent area of the state. The drainage map of the study area along with the catchment is given in fig.2.6. The Irl River is the largest on the Central plain and meets the Imphal River at Lilong. The Thoubal River also meets with Imphal River at Irong. It merges near the Loktak Lake and further flows down in the name of Manipur River. After crossing the Manipur border, it joins with Chindwin River of Myanmar and finally meets with Irrawady River to merge in the Bay of Bengal. These rivers carry a good amount of silt, which has raised their beds considerably. Discharging maximum quantity of water during the monsoon months, they frequently inundate the lands along their banks.

The Imphal River system along with Loktak Lake and other associated lakes and private and community ponds of varying sizes dotting the valley landscape provide the main sources of surface water for used in domestic and municipal purposes.

Other important lakes in the Imphal valley are Phumlenpat, Kharungpat, Ikoppat and Waithoupat. There are also number of marshes and swamps in the vicinity of the lakes and along the inter-reverine tracts.
Fig. 2.6: Drainage map of the Imphal valley and catchment area (after Dinachandra, 2001).
3.1.1 Materials and Methods

The characteristics of the satellite data and the data set sources used for the study is given in tables 3.1a & b. The various modules like Hydrological and Geological modules of Geomatica were used for making calculations and cartographic outputs. Landsat ETM+ (Enhanced Thematic Mapper plus) and SRTM-DEM (Shuttle Radar Topography Mission-Digital Elevation Model) data were used for various Geological, Structural and Geomorphic analyses. A subset of valley region of a Landsat ETM+ of October, 2000 was acquired from Global Land Cover Facility (GCLF), University of Maryland, USA website, http://glcf.umiacs.umd.edu/index.shtml This Landsat data is made available under the National Aeronautics and Space Administration, NASA sponsored Multi-resolution Seamless Image Database (MrSID) maintained by NASA at http://zulu.ssc.nasa.gov/mrsid and the University of Maryland Global Land Cover facility web sites. The Landsat ETM+ has 6 reflective wavelength bands of 30 meters spatial resolution, 1 thermal band of 60 meters resolution and a panchromatic band of 15 meters resolution. The 3-arc SRTM-DEM data on 90 meter spatial resolution for Manipur region was also downloaded from website http://srtm.cgiar.org/ The Shuttle Radar Topography Mission is an international research effort that obtained digital elevation models on a near-global scale from 56 °S to 60 °N, to generate the most complete high-resolution digital topographic database of Earth to date. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during the 11-day mission in February 2000. The Landsat ETM+ and SRTM-DEM are already geometrically corrected. The SRTM-DEM has many voids (data gaps). These voids were removed using the Preprocessing techniques that include the sink removal with the help of SAGA 2.0. The generation of FCC, ratioing pseudo images and principal component analysis were processed using the Geomatica 9.1.0. The enhanced featured in various images were compared with geological...
and the portrayal of geologic units and structures on a map or other display media in their correct spatial relationship with one another. Landsat images covering large areas with multispectral data have been effectively used in geological science. Lithological mapping has been successfully carried using multispectral optical Remote Sensing data in arid and semiarid areas (Sarkar and Kanungo, 2002; Yalcin et al., 2002, Yalcin, 2005). Different spatial informations such as land cover, hydrology and Digital Elevation Model (DEM) integrated in a GIS allows interpretation and analysis of geomorphologic features more precisely and conveniently.

In the present work, the geological, topographic and structural characteristics of the study area have been evaluated using the digital image processing techniques such as Band Ratioing, Principal Component Analysis (PCA) and generation of False Color Composites (FCC). The aim of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between the features on the land (Rigol and Chica-Olmo, 1998; Sabins, 2000). Specifically, Landsat ETM+ Band 5 (TM5) has been used in the delineation of geological discontinuities. Besides, FCC has also been generated using band ratio images of TM1/TM4, TM1/TM5 and TM1/TM7, which have helped in the identification of geological features. These band ratios are used in this qualitative study of the geology of the study area because the spectral variance is widest in ETM bands 5 and 7 and narrowest in bands 3 and 7. The color composite of TM4, TM5 and TM7 are considered informative. These bands i.e. band 4, band 5 and band 7 contain geological informations particularly, the band 7, and are useful for geological studies. Lithological units can be distinguished by their different contrast and color tones (Reis et al.2007).

Nevertheless, the results of a digital image analysis always require a thorough ground check in selected areas in order to evaluate the accuracy of the interpreted map.
3.1 Geological-Geomorphological studies:

In geological studies covering large areas, recognizing the discontinuities and determining the relationship between them is very important. Remote Sensing and Geographical Information System (GIS) techniques are used for this purpose in various studies. Remote sensing is the technique of obtaining information about objects through the analysis of the data collected by special instruments that are not in physical contact with the objects of investigation (Campbell, 1996; Lilles and Keifer, 2000). GIS is a powerful set of tools for collecting, storing, retrieving, analyzing, integrating and displaying spatial data from the real world for a particular set of purposes (Heywood, 1998; Yomtalioglu, 2000; Longley et al., 2001). It is possible to obtain data about an area at a faster rate by using Remote Sensing and then storing the data and analyzing those using statistical and mathematical criteria with the help of GIS. So, there is a close link between Remote Sensing and GIS technologies. In contrast, to the conventional methods of time consuming geological fieldwork with its expensive and complex logistics, Remote Sensing techniques offer efficient, faster and low cost applications to supplement the preliminary geologic-geomorphologic investigations. As a result of the technological developments there have been some radical changes in the technology of preparation of geological and geomorphological maps through time.

The satellite images are a unique resource for geological, geomorphological, global changes research and applications in agriculture, forestry, regional planning, education and national security (Goward et al., 2001; Reis, 2003). Geological mapping involves the identification of landforms, rock types, and geological structures (folds, faults, fractures)