Technical Report and Atlas on

REMOTE SENSING AND GIS BASED INPUTS FOR HAZARD RISK VULNERABILITY ASSESSMENT OF GUWAHATI CITY, SILCHAR, DIBRUGARH TOWNS AND DHEMAJI DISTRICT, ASSAM

Volume II

SILCHAR TOWN

2014

North Eastern Space Applications Centre
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Web: http// nesac.gov.in

Assam State Disaster Management Authority
Government of Assam, Assam Sachivalaya
Dispur – 781006, Guwahati, Assam
http// sdmassam.nic.in

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Volume-I
Contains entire details of Guwahati city in 1:10,000 scale

Volume-II
Contains entire details of Silchar Town in 1:10,000 scale

Volume-III
Contains entire details of Dibrugarh Town in 1:10,000 scale

Volume-IV
Contains entire details of Dhemaji District in 1:25,000 scale

North Eastern Space Applications Centre (NESAC)

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12	Abstract	The study was taken up for ASDMA, Govt of Assam to conduct Multi-Hazard Vulnerability and Risk Assessment studies for Guwahati city, Silchar, Dibrugarh towns and Dhemaji district, Assam on 1:10,000 scale for the city/towns and on 1:25,000 scale for the district. The state of Assam is susceptible to number of natural hazards, for example, Flood, Landslide, Earthquake as well as it also has threat from manmade hazard like Industry. With increasing population growth, societal exposures to various hazards are increasing. Hence it has been called to analyze potential hazards and to assess related vulnerability and risks. The findings on flood risk study of Dhemaji district along with detailed on hazard are compiled in this volume.
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भारत सरकार, अन्तरिक्ष विभाग
उमियम - 793103, मेघालय
दूरभाष : 0364-2570140, 2570012, 2570141
फैक्स : 0364-2570139

NORTH EASTERN SPACE APPLICATIONS CENTRE
Government of India, Department of Space
Umiam - 793103, Meghalaya
Tele : 0364-2570140, 2570012, 2570141
Fax : 0364-2570139

Dr. S. Sudhakar
Director

Date: 12th June, 2013

Preface

Natural catastrophes such as earthquakes, landslides, flood, cyclone, drought etc, have always caused a major problem in many developed and developing countries. Though, by itself any of the natural catastrophes does not considered as a disaster until destruction in terms of damage to population and property is encountered. However, in recent years, the growth of population and the diffusion of haphazard development over hazardous areas have sharpened the impact of natural catastrophes or hazards worldwide. In addition, manmade hazard mainly due to accidental failure of industries is a growing threat to any of the community. The State of Assam is vulnerable to various natural hazards and already witnessed many disastrous incidences other than the recurring problem of flood during rainy season. Many of the important cities/towns in real times are susceptible to such hazards.

Urban flash floods present greater runoff volumes and flow velocities, resulting in higher flow peaks and water stages resulting in disruption of social systems and significant economic losses. Hydrologic and hydraulic simulation tools integrated with closed contour ground survey inputs provide a viable solution to understand the movement of flood waters in intricate urban environments. The city of Guwahati is experiencing perpetual flash floods and landslide-related disaster during monsoon season causing threat to the population dwelling in low lying areas add on the hills and the intensity of such incidences are increasing day by day. The state also has number of medium to large scale industrial set up primarily related to natural gas and oil sector other than various small scale industries. However, most of the natural and manmade catastrophic events are intrinsically complex phenomenon caused by a large set of factors many of which are still unidentified.

Seismic hazard can induce high scale disaster on existing natural conditions and man-made structures with varying relative motion of different magnitudes, and can be analyzed deterministically or probabilistically. Seismic hazard assessment is taken up in the project area of interests to address this disaster.

With the technological advancement, losses caused by a disastrous event can be avoided or minimize if timely measures are taken even if it cannot be prevented. The Hazard Zonation Maps are one of the important inputs for such pre-disaster planning. In this regard North Eastern Space Applications Centre (NESAC) has taken up an initiative to address the multi hazard zonation, vulnerability and risk assessment for Guwahati City, Dibrugarh and Silchar Towns in 1: 10,000 scale and Dhemaji district in 1: 25,000 scale. This study has been proposed by Assam State Disaster Management Authority (ASDMA) under the Revenue and disaster management department, Government of Assam to address different hazards and to assess both social and physical vulnerability and associated risks.

Findings of the project are presented in four different atlases of which Volume II is for Silchar Town, Volume I is for the Guwahati city, Volume III is for Dibrugarh Town and Volume IV is for Dhemaji District. It is expected that the study will strengthen ASDMA the ways and means of extending similar approach to entire Assam towards minimizing the damage caused by natural and manmade (industrial-mainly petrochemicals) hazards to the population and property. It is further expected that this technical report and atlas would serve as reference for disaster management and other concerned officials for developmental planning not only for Assam but also to the North Eastern Region in general.

(S. Sudhakar)

Acknowledgements

The project titled "Remote Sensing and GIS Based Input for Hazard Risk Vulnerability Assessment of Guwahati city, Silchar, Dibrugarh towns and Dhemaji district, Assam." has been carried out by NESAC team under the guidance of external advisory committee. Members of the committee are from various Organizations like Indian Meteorological Department (IMD), Geological Survey of India (GSI), National Remote Sensing Centre (NRSC), Regional Remote Sensing Centre (RRSC), Space Applications Centre (SAC), and Institutes. The entire project team is thankful for their constant encouragement and support to carry out the study. The project team extends their sincere gratitude to Assam State Disaster Management Authority, Guwahati, for providing the opportunity to carry out the study. The entire project team indebted to Prof. S Sengupta, Dr. P. K. Guha, Prof. J.R Kayal, Er. C.R.Deka, Er. Murali Mohan, Dr. Ashok Baruah, Head, Chemical Engineering Division, Assam Engineering College, Guwahati, for their valuable guidance and suggestion. Thanks are due to Shri P. K Saikia, Managing Director, Assam Industrial Infrastructure Development Corporation Ltd. (AIIDC), Govt. of Assam for his keen interest and support. The project team is also extremely grateful to members of HRVA Technical Sub-Committee and special thanks are due to Prof. Chandan Mahanta, Dept. of Civil Engineering, IIT, Guwahati.

The project team also extend thanks to locals of Silchar town who have supported during DGPS/RTK/ETS survey work, preparation of social and building inventory surveys, ground reconciliation and database collection of flood inundation. Special appreciation and thanks to Shri Joydeep Dey, Sr. Depot Manager, Ramnagar Dopot, Silchar for sharing the valuable information.

The project team is indebted to the Water Resources Department - Silchar Division, Govt of Assam, Silchar Municipal Board (SMB), and especially to Mr Arijit Kumar Endow, Consulting Engineer, GMDA, for his heartful cooperation in providing valuable data/statistics regarding ground flood database, and without whose information and guidance, the flood hazard zonation exercise would have been difficult. The project team also expresses its thankfulness to the Mr. Shamin Ahmed Laskar, District Project Officer, District Disaster Management Authority - Cachar, for his indispensable coordination during the ground survey work and flood database collection. The meteorological data provided by the Regional Meteorological Centre (RMC), IMD, Guwahati, as well as AWS (Automated Weather Station) data access from IMD and MOSDAC (Meteorological & Oceanographic Satellite Data Archival Centre), SAC is also acknowledged. The project team also owe a depth of gratitude to Dr. S Sudhakar, Director NESAC, for his constructive suggestions, continuous guidance and encouragement. The project team extremely thankful to each and every individual who have contributed directly or indirectly in completion of the work successfully.

Project Team

Project Management

Overall Guidance

Dr. S. Sudhakar, Director, NESAC

External Experts

Dr. S. Sengupta,Former Head, Regional Remote Sensing Advisor, Dept of Science & Technology; Govt. of West Bengal

Dr. P. K. Guha, Geologist (Retd), Geological Survey of India, Kolkata

Prof. J.R Kayal, Former Dy.Director General (Geophy) of Geological Survey of India, Ex visiting Professor, University of Tokyo, Japan; CSIR Emeritus Scientist, Jadavpur University, Kolkata; Guest faculty UNESCO.

Er. C.R.Deka (Retd), Former Chief Inspector of Factories, Govt of Assam.

Er. Murali Mohan, Scientist and Head of Aerial Survey and Photogrammetry Division (Retd.), NRSC, Hyderabad

Er. S. Ahmed, Former Director Dept of Urban Affairs, Govt of Meghalaya; Assistant Professor Meghalaya Administrative Training Institute.

Project Team from NESAC

Shri M. Somorjit Singh

Mrs Jenita Mary Nongkynrih

Shri Victor Saikhom

Shri Romeji Singh

Mrs. Rekha Bharali Gogoi

Sangeeta Sarmah

Executive Summary

The State of Assam is susceptible to various natural hazards like flood both riverine and flash/urban floods, landslide and related phenomenon, earthquake etc. In addition, about 30 Major Accident Hazard Industries are reported from Assam with probable threats mostly associated to industrial facilities handling petro-chemical products. In recent years, relative vulnerability of population and infrastructure has increased due to unplanned development of settlements in hazardous areas because of population growth and influx. North Eastern Space Applications Centre (NESAC), Umiam, Meghalaya, had taken up the project "Hazard, Vulnerability and Risk Assessment of Guwahati city, Silchar, Dibrugarh towns and Dhemaji district, Assam" on request from Assam State Disaster Management Authority (ASDMA) under the Revenue and Disaster Management department, Government of Assam. As per the Disaster Management Act, 2005, one of the measures necessary for managing disaster is the preparedness to deal with any of them which means the measures that enable rapid and effective response in disaster situation. Hazard analysis along with vulnerability and risk assessment (HRVA) are one of the efforts of preparedness for mitigating disasters. The outputs generated from HRVA is considered as one of the important inputs required for taking necessary mitigation measures there by to reduce risk of the society at large.

The project has the following broad objectives: to prepare GIS based multi hazard maps for Guwahati city, Silchar & Dibrugarh towns (1:10,000 scale) and for Dhemaji district (1:25,000 scale), and arrive at vulnerability and risk assessment maps for probable multi hazards for the areas under study.

Broadly, the work was carried out in 3 major phases: assessment of frequency-magnitude- damages related to past hazardous events for each study areas; preparation of hazard zonation maps for probable hazards; assessment of physical and social vulnerability and risk for each hazard. An integrated approach, using space technology in conjunction with field based survey is followed to address the objectives. Findings of the project were compiled in four different atlas volumes for the four study areas and this volume (Volume II) contains entire details of Silchar town in 1:10,000 scale.

Silchar Town, the headquarter of Cachar District is situated in the south-eastern portion in the state of Assam. It is the second largest town of the state after Guwahati in terms of population and municipal area. The municipal area falls between 92˚46'16.9" E to 92˚49'33.4" E longitudes and 24˚47'47" N to 24˚50'52.5" N latitude. The town is having 28 numbers of wards within an area covering 15.75 sq. km. The town is facing congestion and anthropogenic stress due to rapid urbanization. Depending upon the terrain conditions and considering the historic hazardous/disaster events, it was decided to address following hazards for preparation of hazard zonation maps and also to assess vulnerability and risk associated to each hazard as:

- Urban Flood Hazard
- Industrial Hazard
- Seismic scenario.

Hazard zonation maps are prepared considering available historical records, frequency of each hazards, various resource/thematic maps in spatial domain, and sophisticated models for assessing nature, their probable impact to the study areas. Cartosat I stereo data, high resolution QuickBird Multispectral and Panchromatic Imagery acquired on 13th March. 2011 were used for generation of various resource/thematic maps in 1:10,000 scale in UTM projection and WGS84 datum. In addition, data from various ground surveys carried out during 2011-2012 are integrated for deriving hazard zonation, vulnerability and risk maps. Ground survey comprised of DGPS (Differential Global Positioning System) and ETS (Electronic Total Station)/Real Time Kinematic (RTK) surveys for generation of hybrid DEM of 1 m spatial resolution and reconciliation to be used for urban flash flood hazard zonation; population and building survey used for vulnerability and risk assessment.

Urban flooding is one of the most recurrent hydro-meteorological disasters presently in the globe. Silchar town experiences recurrent flood inundation and frequent water logging during the rainy season and it has become a public grievance. Flooding is typically caused by short duration, locally centered, and high intensity summertime convective storms. Two-dimensional flood routing programs can efficiently simulate these complex urban flood environments with accuracy and detail. The objective of the project is to arrive at flood hazard zones (FHZ) in Silchar urbane. Hydro-meteorological, spatial and ancillary database was collected and processed to aid the hydrological and hydraulic modelling platform. Extensive ground reconciliation survey using DGPS and ETS (Electronic Total Station)/Real Time Kinematic (RTK) surveying techniques was carried out to obtain Z-flood points, which was also used to derive a hybrid Digital Elevation Model (DEM) of 1m spatial resolution and stature Base Flood Elevation (BFE) points for integration in the modelling process. Flood and Storm events have been identified and analyzed from the hourly rainfall data and IDF (Intensity−Duration−Frequency) analysis. Quasi-distributed hydrological modelling for Silchar urban catchment was adopted to generate flood hydrographs for selected event dates when flood inundation has actually occurred. Flood inundation simulation was carried out using the derived flood hydrographs as boundary conditions with water levels, incorporating parameters as drainage nodes, congestion points, etc. The simulated flood inundation layers were extracted and schematized using scale of flood discharges from hydrographs and ground-based flood database. GIS spatial analysis and overlay/union/intersection areas, etc was applied for integration of the (i) Simulated flood inundation layers, (ii) Base Flood Elevation & Z-Flood point layers, and (iii) ground database of actual flooding. The generation of the final flood hazard layers has been done using the coupling of the hydraulic model-derived layers with BFE / Z-Flood points, and was checked with ground records. The major finding from the project study is that the root cause of urban flash flooding experienced in Silchar town is local storm water congestion in the event of flash storm events, and the flat topography with an average elevation which is very close to the HFL of Barak river aggravates the flooding duration. The incapacity of the prevailing drainage system which has been suffocated with solid waste has choked the conveyance capacity of the storm water drainage system.

Industrial disasters however low in frequency but it may have a great potential to damage the environment. The damage may be either immediate or long term in nature. The present study was carried out with the estimation of areas of short duration probable accidental threats of key hazards such as toxicity, flammability, thermal radiation, over pressure etc. Industrial hazard map was prepared considering various physical, chemical and atmospheric parameters using Aerial Locations of Hazardous Atmosphere (ALOHA) software (NOAA, U.S. Environmental Protection Agency, 2007) and depicted as various levels of threat zones. In Silchar town, within the study area there is no identified MAH units so far by Chief Inspector of Factories, Govt. of Assam. However, in the North Western corner of boundary with a radial distance of 0.5 km. Ramnagar IOCL storage facility was located as one of the identified MAH unit and it has considered for the analysis since it is very near/closed to study area.

Hazard zonation maps as well as vulnerability and risk assessment maps are prepared for various conditions ,e.g, Toxic Dispersion, Thermal Radiation in case of a flash fire, Vapour Cloud Explosion (Congested), Boiling liquid expanding vapour explosion (BLEVE).

The state of Assam falls under Zone V of Seismic Zonation Map and the state has already experienced one great earth quake in the year 1950. In an area, intensity of damage due to earthquake also depends on site characteristics, usually represented by Predominant Frequency. In this project, site characterization assessment is done using empirical method from available subsurface data .

Vulnerability and risk was assessed for infrastructure and population through socio-economic survey using the samples of buildings derived from high resolution data along with physical survey of population characteristics and their pattern and temporal distribution. The use of space technology, especially the high resolution satellite data of Worldview coupled with Cartosat-I have made it possible to identifying buildings types in the study area. Though the collection of economic status data from the field was not possible, but this was inferred indirectly from the building types extracted out from the satellite data. However, education as a parameter was not used in the calculation of Vulnerability in the study. During the survey, temporal data on population occupying the buildings was collected on two-hourly interval. Statistical method was used in the study. Temporal data was represented in four intervals during the day, i.e., Morning, Day, Evening and Night. The risk assessment, which combines information on the nature of hazard with information on vulnerability of the targets, will help to clarify decision making for disaster management and the development of mitigation strategies.

To assure the quality of the data base generated under the project, an advisory committee was constituted taking experts from various Organizations like GSI, NRSC, RRSC, SAC, IIT Guwahati, and NIT Silchar.

Table of Contents

List of Figures

List of tables

1 PROJECT BACKGROUND

1.1 Background

Natural hazards like, floods/flash floods, landslides, forest fire, earthquake, cyclone, and thunderstorm etc, have always constituted a major threat to the society, hence both developed and developing countries are concerned about their systematic management. In addition, safety measures, emergency preparedness and response (during and after) for Major Accident Hazard (MAH) industrial sites are also becoming an integral part for the decision makers. The State of Assam, India with its relatively immature topography, fragile geologic base and active tectonics is vulnerable to various natural hazards like earthquake, flood, landslide etc. Some major industrial installations especially of petrochemical products also make the state vulnerable to industrial hazard. In recent years, the growth of population with unplanned development of settlements in steep slopes and other hazardous areas have increased their relative vulnerability towards natural hazards. However, prediction of hazards in space and time is a very difficult task. In recent times, in spite of these constraints several sound, hazard investigations have been carried out and some of them constitute a reliable starting point for evaluating future hazards, social and physical vulnerability towards them and aimed to assess risk within an area.

A project has been proposed to address different hazards and to assess both social and physical vulnerability and associated risks by Assam State Disaster Management Authority (ASDMA) under the Revenue and disaster management department, Government of Assam for Guwahati city, Dibrugarh and Silchar townships along with the flood prone district of Dhemaji to NESAC.

Findings of the project are presented in four different atlases of which volume II is for the Silchar Town.

1.2 Project Objectives

The project has following objectives formulated by ASDMA.

(i) To identify and acquire relevant data sources such as historical and scientific data related to hazards, government records, hazard maps, satellite imageries, research documents and publications for conducting hazard assessment.

(ii) To assemble database for various hazards in order to assess their frequency, geographical distribution and magnitude, and present them statistically and analytically.

(iii) To provide adequate scientific analysis in respect of causation, frequency and magnitude for each hazard while establishing their probabilistic estimates.

iv) To conduct an assessment of some of physical vulnerability which includes housing, critical infrastructure, lifelines and essential facilities such as, schools, hospitals, in structural terms, present their vulnerability to hazards.

(v) To conduct a detailed assessment of some of social patterns of vulnerability, which include vulnerabilities, associated with gender, weaker sections, disability, widow hood and other social handicaps.

(vi) To present an economic analysis of some of the impact of past disasters and assess their impact in statistical and analytical terms.

(vii) To prepare GIS based hazard maps on 1:10,000 scale for Guwahati city, Silchar & Dibrugarh towns and 1:25,000 scale for Dhemaji district and the area likely to be affected.

(viii) To represent different types of vulnerabilities on GIS maps, and prepare a composite vulnerability and potential multi hazard map for the city/town/district.

(ix) To prepare an atlas, showing both hazards and vulnerability together for the city/town/ district.

(x) To provide broad recommendations for integrating the concerns of hazard and vulnerability reduction in the development strategy.

1.3 Study Area

Silchar Town, the head-quarter of Cachar District is situated in the south-eastern portion in the state of Assam. It is the second largest town of the state after Guwahati in terms of population and municipal area. The municipal area falls between 92˚46'16.9" E to 92˚49'33.4" E longitudes and 24˚47'47" N to 24˚50'52.5" N latitude. The town is having 28 numbers of wards within an area covering 15.75 sq. km (approx). The location map of the study area is shown in Fig 1.1. The major portion of town area lies on the left (southern) bank of Barak River (also known as Surma River) with an average elevation of 22 meters above the MSL. The climate is tropical by nature and summer is hot, humid and mixed with heavy rainfall and thunderstorms. Winter generally starts towards the end of November and lasts till February. It is well connected with every means of transportation such as roads, rails and air with other places. The town has a population of around 172,710 (males - 86,812 and females - 85,897) with an average literacy rate of 91.74% and high density in the core area of commercial facilities.

1.4 Hazards addressed

Depending upon the terrain conditions and considering the historic hazardous/ disaster events of the study areas, it has been decided to address following hazards for preparation of Hazard Zonation Maps and also to assess vulnerability and risk associated to each hazard.

- o Urban Flash Flood Hazard, and
- o Industrial Hazard
- o Seismic Hazard

there by incorporating the suggestions and recommendations of the two Committees.

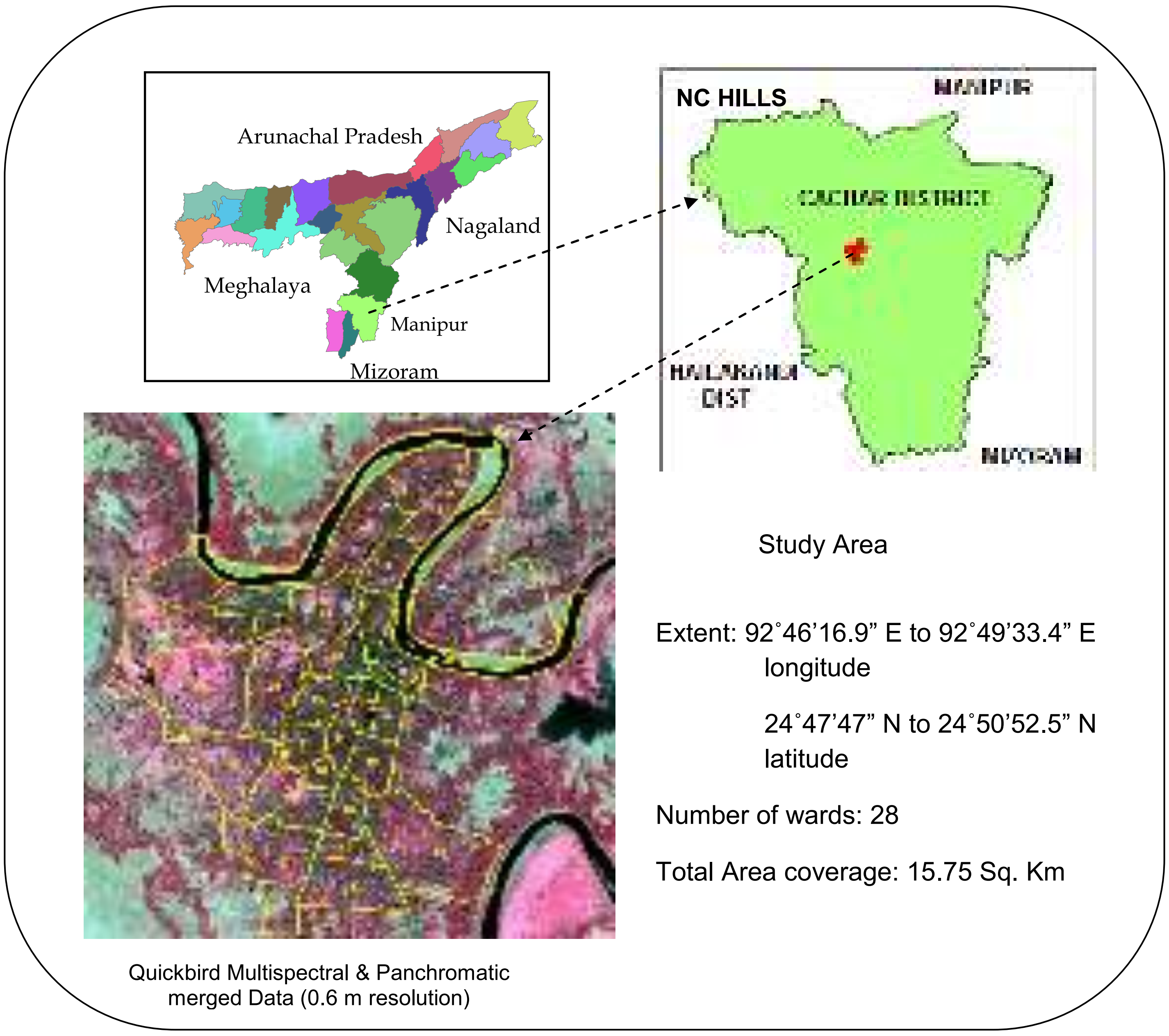


Figure.1.1 Location Map of the study area, Silchar Town

1.5 Methodology

As the nature of work is unique involving multi hazard component along with vulnerability and risk assessment so the overall methodology followed to carry out the study was divided in three main phases (Fig 1.2). These are:

1. Collection of baseline data and historic hazardous/ disaster events under hazard scenario development phase.
2. Preparation of Flood, Industrial Zonation maps and report on Seismic scenario of the study area.
3. Assessment of physical and social vulnerability and preparation of risk maps using standard analysis techniques

It may be noted here that the methodology as well as questionnaire and format used for survey were finalized after several presentations made to the HRVA Technical Sub- committee constituted by ASDMA as well as to the external advisory committee constituted by NESAC and

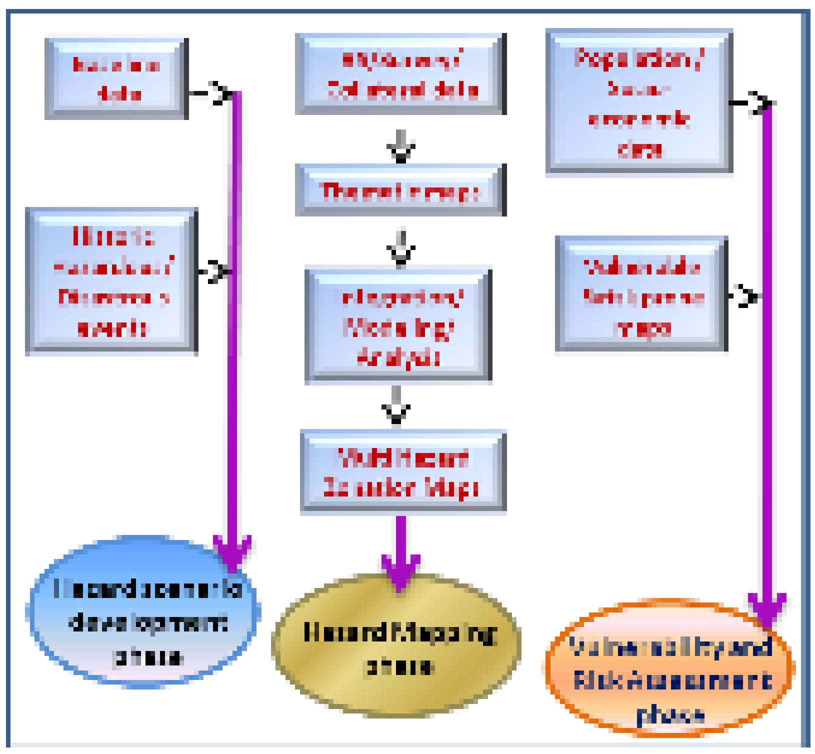


Figure 1.2 Overall methodology of the project

Hazard means the probability of occurrences of a potentially damaging phenomenon within a specific period of time and within a given area (Varnes, 1984) which can be natural or man-made. However, the zonation maps prepared under this project are in true sense susceptibility maps in absence of temporal component as it is difficult to predict when a hazardous phenomenon is likely to occur. Vulnerability is defined as the exposure to risk and an inability to avoid or absorb potential harm (Pelling, 2003).

Risk Analysis deals with the use of available information to estimate the risk caused by hazards to individuals or populations, property or the environment, from hazards. Risk is often represented by,

Risk = Hazard x Vulnerability

However, a potentially damaging phenomenon (Hazard), such as earthquake, landslide or flood by itself is not considered a disaster when it occurs in uninhabited areas or not in close proximity to any infrastructure. It is called a Disaster when it occurs in a densely populated area, close to infrastructures and results in a large destruction in terms of loss of life and damage to property. The methodology adopted for the study is presented in figure 1.3.

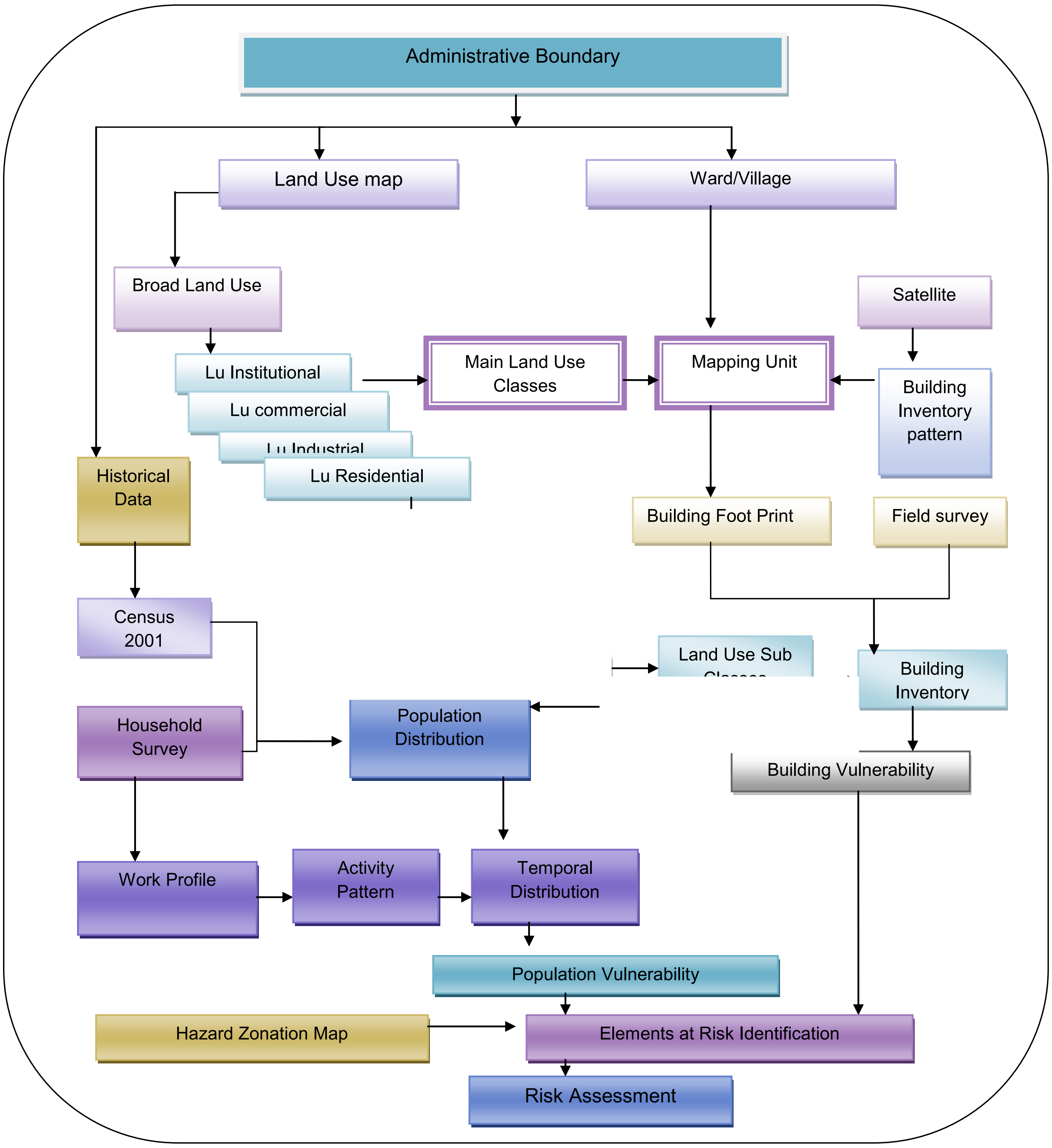


Figure: 1.3 Methodology flowcharts for Vulnerability & Risk Assessment

The aspect of vulnerability assessment was based on population vulnerability and building vulnerability. The methodology adopted for the vulnerability assessment is discussed as follows:

(i) Database preparation- This is the first step was preparation of the administrative map for the study area based on the information collected from the concerned Urban Department. A buffer of one kilometre was created for analysis. Overlaying this administrative boundary on the high resolution image, a land-use map was generated with broad categories as Built up and Non-built up. In the built up category, the sub-classes included were

Residential, Institutional, Commercial and Industrial. From the built up map, mapping units were generated based on the homogeneity of the usage. The main purpose for generating of mapping unit is to add the information collected in the field as attribute data. Overlaying the urban development area and municipal boundary on the satellite data, mapping units was delineated. A mapping unit is defined by homogeneity in the building in the building characteristics and bounded by road network. Each mapping unit has a unique ID assigned to each of them (Figure 1.4). It may be noted here that the refinement of the classes was also done after field survey. Once the mapping units were ready, a grid of .5x.5 sq. km overlaid for the distribution of sample points.

(ii) Sampling Design

In planning a socio-economic survey and building inventory, a range of methodological issues have been considered. In this case, the parameters considered were for mainly two objectives, the population characteristics

Figure1.4: Mapping unit overlaid on satellite image

and the building characteristics, wherein the list of attributes of interest are being incorporated. Stratified sampling was used while designing the sample size for the survey. Strata were taken for each municipal ward of urban areas and village in case of a district.

(iii) Determining Sample size using Stratified Sampling with proportional allocation

For deciding the number of samples to take for observations, the household data of different wards in the urban areas (Guwahati, Silchar and Dibrugarh) and villages in Dhemaji District were taken into consideration. For each study area the sample size was calculated using Stratified sampling:

$$n_h = (N_h / N) * n$$

Where,

n_h is the sample of each strata

N_h is the total number of sample in each stratum *h*

N is the total population in the whole study area

n is determined sample size.

The distribution of these sample points were considered accordingly in each mapping units for carrying out socio-economic survey and building inventory. The derived sample size for the town is 2854.

(iv) Design of questionnaire- The design of the questionnaire for making a building inventory and temporal population details per hour of a building is the major key for vulnerability assessment. The structure of the questionnaire was broadly composed of three major sections such as: identification number, structural condition and temporal population details of the buildings. The first section (i.e. identification data) includes the general building and plot information collected from field survey. The second section (i.e., structural condition) describes the general information about building material, wall material, no. of floors, airtight condition etc. The third section deals with the population details per building for every two hours interval (Annexure I).

(v) Determining the Temporal Distribution of population inside Buildings- The information about the number of people inside the buildings at different time periods is important for vulnerability assessment. Population within the buildings were taken for different time periods of a day i.e. Morning (6 AM to 10 AM), (10 AM to 6 PM), evening (6 PM to 10 PM) and night (10 PM to 6 AM). The people within the particular building in different time period depends on the different use type of that building. The temporal distribution of op population was prepared for each mapping unit in the study area. However, during the survey, temporal data on population occupying the buildings was collected on two-hourly bases. Statistical method was used in the study. Temporal data was converted to the four periods of the day, i.e., morning, day, evening and night. This was done by averaging out the presence of persons residing in the buildings.

(vi) Determining Population Vulnerability**-** For population vulnerability assessment the following indicators were used. Indicator to be used in this study will Composition of Population and Age wise population

- Population Density- household & persons
- Daily Activities pattern
- Population Distribution including the vulnerable groups (female, children 0-14 years and elders-above 60 years
- Temporal Distribution

Persons over 60 and those under the age of 14 years were considered more vulnerable. Females were considered more vulnerable than males. Dense to highly dense populated areas will be more vulnerable than lesser dense areas. Densely populated housing units are considered to be more vulnerable. In average house occupancy, larger households were considered more vulnerable than smaller households.

In this study, each indicator was measured on a 0 to 9 ordinal scale based on their frequency and contribution to population vulnerability. For example, if the presence of vulnerable population in a particular mapping unit, then it was measured in the following manner:

- 0-20 percent of the total population in a ward/village, the score is 1
- 20-30 percent of the total population in a ward/village, the score is 3
- 30-40 percent of the total population in a ward/village, the score is 5
- 40-50 percent of the total population in a ward/village, the score is 7

In the mapping unit, based on the samples collected from the field survey, interpolation technique was used for deriving the vale for the whole mapping unit. The method adopted in this study is the Kringing method. In Kriging method, it weights the surrounding measured values to derive a prediction for an unmeasured location. The general formula for interpolators is formed as a weighted sum of the data:

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

where:
$Z(s_i)$ = the measured value at the i^{th} location.
λ_i = an unknown weight for the measured value at the i^{th} location.
s_0 = the prediction location.
N = the number of measured values.

In this method, the weights are based not only on the distance between the measured points and the prediction location but also on the overall spatial arrangement of the measured points. To use the spatial arrangement in the weights, the spatial autocorrelation was quantified. Thus, in this method, the weight, λ_i, depends on the measured points, the distance to the prediction location, and the spatial relationships among the measured values around the prediction location. Though the collection of economic status data from the field was not possible, but this was inferred indirectly from the building types extracted out from the satellite data.

Determining Building vulnerability- for assessing building vulnerability, several parameters were taken into consideration and weightages and ranks were assigned to them based on the type of hazard as well as the condition of the buildings. The whole area based on the degree of vulnerability, was categorized into high, medium and low vulnerable zones at the level of mapping units, which are consisting of groups of buildings, bounded by streets, or by particular types of land use (e.g. water body, agriculture land etc.). Based on the use of the buildings of the area, there will be five classes namely i) Residential, ii) Commercial, iii) Institutional. iv) Public building and v) Mixed uses. The category “institutional” refers to the buildings used mainly for school, office etc. Further sub classification of buildings, e.g., institutional buildings to school, office etc was restricted due to mapping scale as identification of individual buildings were beyond the scope of the study. The category “Public Buildings” includes temples, mosques, community halls, clubs, lodge, restaurants etc. Mixed category represents the buildings used for more than one activity. Buildings which are used for commercial purpose on the ground floor while other floors are used for other activities such as residential will be identified as “mixed use type”. As per the proposal the data for vulnerability assessment was collected on one time basis. Change is evitable. The database on vulnerability needs to be updated periodically to revise the vulnerability assessment.

Risk Assessment

Risk assessment in its broad definition is a structured procedure that evaluates qualitatively and/or quantitatively the level of risk imposed by the hazard sources. According to Westen (2011) the qualitative approach is based on the experience of the experts and the risk areas are categorized with terms as ‘very high’, ‘high’, ‘moderate’, ‘low’ and ‘very low’ risk. The number of qualitative classes varies but generally three or five classes are accepted which should have a direct line with practical indications (e.g. in very high risk areas: ‘immediate physical and no-physical remedial measures are required and no more infrastructure development must be allowed in this area’).

In case of risk assessment for Silchar Town, risk was calculated by combining results of individual hazard and vulnerability assessment (physical and social). A semi-qualitative approach was adopted based on the relative ranking and weights assignments by given criteria. Risk index: Very High, High, Medium, Low and Very Low, was prepared. The number of qualitative classes varies but generally three or five classes are accepted which should have a direct line with practical indications (e.g. in very high risk areas: ‘immediate physical and no-physical remedial measures are required and no more infrastructure development must be allowed in this area’).

In the study, Risk was expressed as follows:

Risk = Hazards * Vulnerability of elements at risk

For this purpose a risk matrix (Figure 1.5) was prepared, from which each possible combination of hazard and vulnerability was identified in terms of different levels of risk. In the matrix, values are assigned to different categories of vulnerability and hazard to get the combined results (risk) in value and then categorised them into different classes.

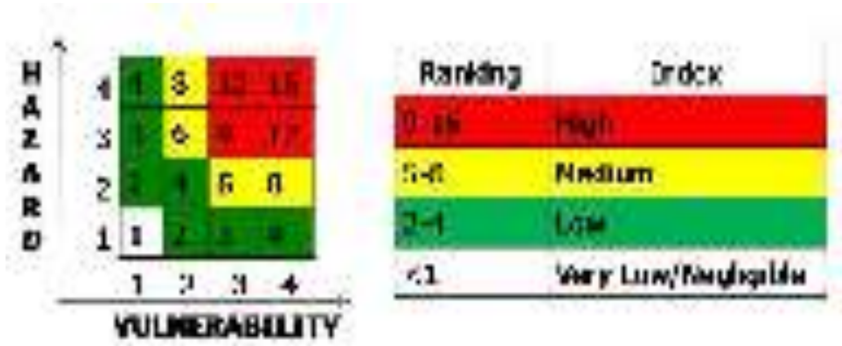


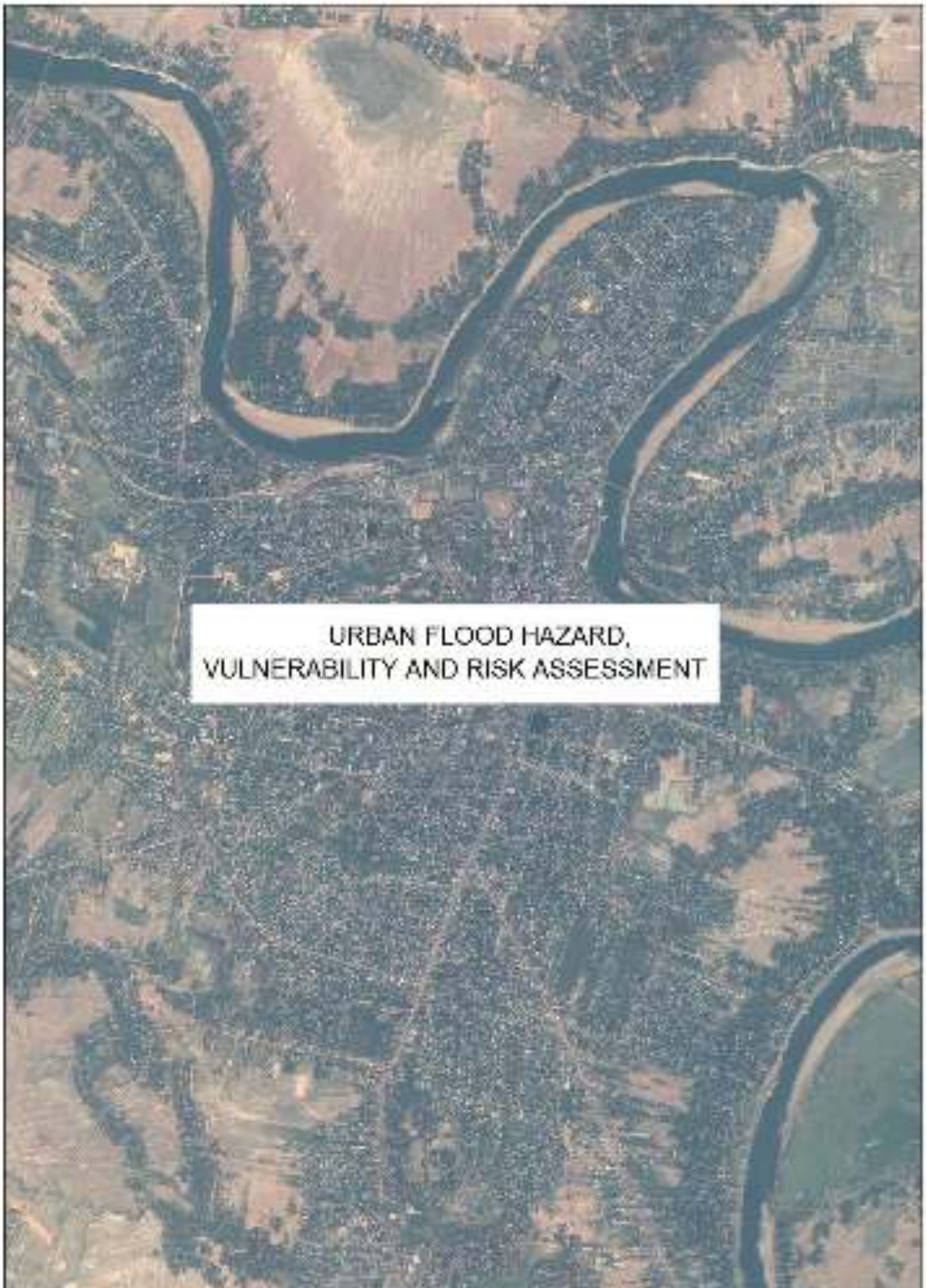
Figure1. 5: Risk Matrix

1.6 Data used

Various satellite data used for Silchar Town HRVA exercise are

I. QuickBird Multispectral Imagery acquired on 13th March. 2011 (4 band, 2.4m spatial resolution)
II. QuickBird Panchromatic Imagery acquired on 13th March. 2011 (single band, 0.6m spatial resolution)
III. IRS P5 Cartosat-I acquired on 27th Feb. 2011. (single band, 2.5m spatial resolution)

The baseline database was built mainly on Cartosat I imagery. Details of theme/hazard specific primary/derived databases and their sources are discussed in respective sections.


URBAN FLOOD HAZARD,
VULNERABILITY AND RISK ASSESSMENT

2. Urban Flood Hazard Zonation

2.1 Introduction

Urban flood is one of the most recurrent hydro-meteorological disasters presently in the globe. A sizeable portion of the world population suffers from flood every year. India is one of the worst flood-affected countries, being second in the world after Bangladesh and accounts for one fifth of global death count due to floods. The historic town of Silchar in South Assam is affected by urban flash flooding frequently, and it has become an imperative to address this hydrologic disaster.

Conveyance of floodwaters in wash corridors and arroyo floodplains that were once predominantly overland sheet flow or flow in rills and gullies, are now redirected by houses, fences, small buildings, streets, and other obstructions to flow. In many of these cases, flood containment within the historic mapped floodplain is questionable due to loss of storage and flow path obstruction, and there is a need to quantify the discharge that has been diverted from the floodplain. Traditional one-dimensional backwater models are inadequate to predict the unconfined flow behaviour in such urban environments and if used, require too many assumptions regarding flow diversions and potential confinement. Advances in the computational speed of computers has facilitated the reality of using two-dimensional flood routing programs to efficiently simulate these complex urban flood environments with accuracy and detail.

Flood hazard mapping and flood inundation modelling are the vital components in flood mitigation measures and land use planning, and are prerequisites for the flood insurance schemes. As flood itself cannot be prevented but the damages due to flood can be mitigated with proper planning and preparedness in community level. For that it is very important to identify the degree of hazard associated with various portions of a flood plain. Hence flood hazard zonation is an important component of overall flood management strategy.

Scenario

Silchar town experiences urban flooding and severe water logging in the occurrence of storm events and particularly during the rainy season, it has become a public and socio-economic woe. Silchar is inundated frequently due to excessive rainfall and flooding by the Barak River and its flashy flowing tributaries. In the last three decades, Silchar and the Barak Valley have been ravaged by three major floods in 1986, followed by 1991 and in 2004. Floods in Silchar and Cachar district are inevitable, considering the topography and the intricate river system. The objective of flood mitigation is to control changes in the volume of run-off, peak stage of the flood, time of rise and duration of floodwaters, and location of flooding. The major localities of Silchar which are partially or frequently affected by flash floods are Central Road, Sadarghat, Padmanagar road, Tarapur, Malugram, Janiganj, Park Road, Itkhola, Ambikapatty, Shillong patty, Marwari patty, Hospital Road, College Road,Shib Colony, Vivekananda Road, National Highway, Bilpar, Premtala, Nazirpatty, Madhurband, Sonai Road, Public School Road, Rangirkhari, Das Colony, Link Road, Kalibari Chor, etc. Rangikhari is one of the major drainage flowing in and around Silchar town. A view of the Silchar Town is shown in fig. 2.1 when the Barak River is in full flow.

Figure 2.1 Silchar town and its environs with Barak River at full flow

2.2 Objectives

Major objectives of the project study are:

(a) Urban Flood Hazard map of flood affected wards of the cities/town in 1:10,000 scale with classification scheme of low hazard, moderate hazard, high hazard and very high hazard areas.

(b) Vulnerability and Risk Assessment for urban flood hazard in Silchar town and greater region

2.3 Database

Apart from the various satellite data as described in section I, following data bases were used for the study

2.3.1 Hydro-Meteorological Data

(a) Rainfall data (hourly, daily) 1995 - 2012 (source: IMD, AWS_ISRO, etc)

(b) Daily discharge and water level data of rivers and major sewer-storm / drainage channels (source: WRD, Govt of Assam, CWC, SMB, etc)

(c) Sewer and drainage layout map and plans of Silchar (Source: SMB, etc)

(d) Cross-section and Longitudinal profiles of rivers and major drainage / sewer channels (ground survey)

2.3.2 Spatial and Ancillary Data

(a) Municipal Sewer-Storm / Drainage system map from respective departments for Silchar
(b) Flood Inundation reports/maps
(c) Municipal Sewer-Storm / Drainage system map from respective departments for Silchar
(d) Municipal Wards and Town Layout.

2.4 Methodology and Formulation

In the face of growing incidents of floods, and especially in inhabited areas, a need was felt to apply the latest flow computational methods to the problem of urban flooding in a more accurate form.

a) Creation of base maps in 1:10,000 scale for Silchar. The base map essentially contain layers such as district, city/town, revenue circle/block/taluk, municipal ward, All major and semi major roads, Bridges, Culverts, Major rivers and tributaries, major canals, sewerage and storm water drainages, cluster of households, other public facilities and infrastructure from both ortho-rectified satellite images and other collateral maps and information.

b) Collection of detailed information on major sewerage / storm water drains along with related hydro-met datasets, cross section, embankment breach history, inundation history etc. This component comprises extensive field survey work using precise surveying techniques to get Z-flood points, which will be used to derive Base Flood Elevation (BFE) points.

c) Generation of flood hazard index (Very high, high, medium, low, very low) in municipal ward/revenue circle/block level based on weightages assigned to various factors contributing to potential hazard scenarios by integrated analysis in GIS.

Urban floodplain areas have significant effects on inundation flows. Shallow-water models account for the reduction in storage and in the exchange sections due to presence of buildings and other structures on the floodplains, and are most appropriate to analyse such problems (Soares-Frazão et al. 2008, Sole & Zuccaro 2005).

The integration applied to the study of flood events and hazards is the use of geospatial procedures that provides a broad range of tools for determining area affected by floods and for forecasting areas that are likely to be flooded due to high water level in a river (Sharma, 1999). A scheme of progressive weightage has been adopted for the variable ‘flood-prone’ zones. Detail workflow is given in Fig 2.2.

2.4.1 Ground Reconciliation Survey (ETS/RTK/DGPS)

To address the urban flooding hazard extensive ground survey was necessitated and carried out in selected Z-Flood zones of Silchar urban catchment. These ground survey was directed to provide vital inputs in the flood hazard zonation in structuring of Base Flood Elevations (BFE) and structuring of a hybrid DEM of 1 m spatial resolution. It is of great advantage to apply the RTK GPS technology along with ETS to the ground surveying of the Z-Flood markings, as it was able to achieve fast position fix with a high accuracy, high efficiency and high productivity in comparison with the traditional time-consuming and labour-intensive surveying practice (Xiao et al., 2006). The Z-flood points derived from this survey for the respective project AOI are presented in figure 2.1.

2.4.2 Hybrid Digital Elevation Model

The DEM was a fundamental dataset used for development of the urban catchment hydrological model (HEC-HMS platform) and the hydraulic flood inundation simulation model (HEC-RAS/SWMM/ISIS platforms). This dataset was a vital input in the hydrological-hydraulic model build-up, and flood hazard layer generation. Thereby, a Hybrid DEM of 1 m spatial resolution was developed using Z-flood points from RTK/ETS survey and CARTOSAT-I stereo dataset.

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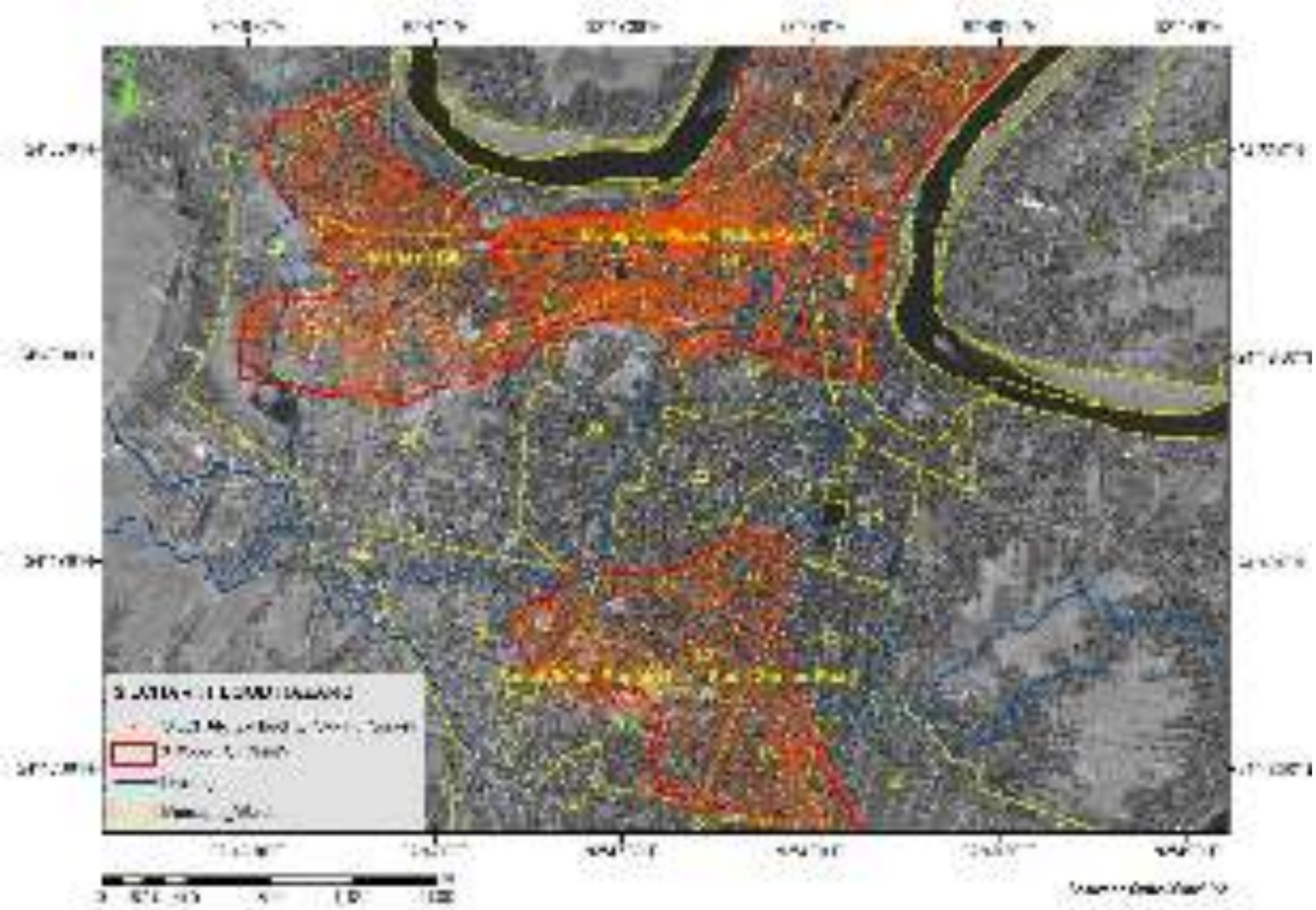


Figure 2.2 Z-Flood ground survey for Silchar Town using DGPS, ETS/RTK

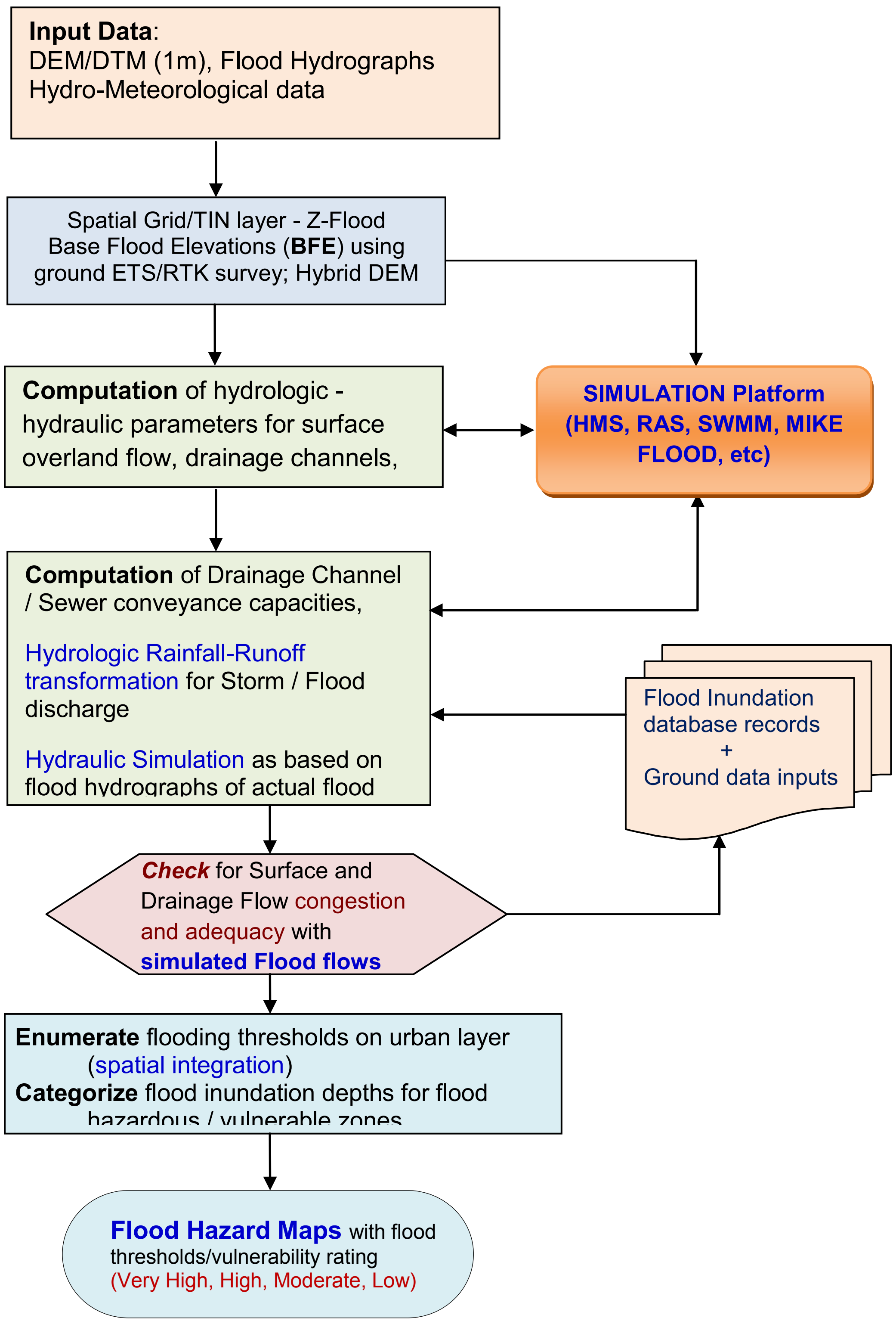


Figure 2.3 Methodology followed in the Urban FHZ

2.5 Hydrologic-Hydraulic Analysis & Modelling

2.5.1 Hydro-Meteorological Data Analysis

Silchar region is generally characterized by hot humid summer with heavy sudden storms. The rainfall data analysis showed that there are storms and surges in the annual intensity-duration-frequency (IDF) trend for the last 5 years (Fig 2.3a). Rainfall peaks of 124 mm and 44 mm were recorded on 3rd June, 27th June and 14th July in 2012 at Silchar (source: AWS_ISRO069) as shown in Fig. 2.3b.

It was observed that the storm rainfall pattern and intensity has a bearing with the induced surface overland flow and drainage discharge capacities (over that it was already conveying prior to the storm event). These extreme storm events were used to generate 1 to 3 hourly flood hydrographs using distributed/quasi-distributed hydrological modelling techniques.

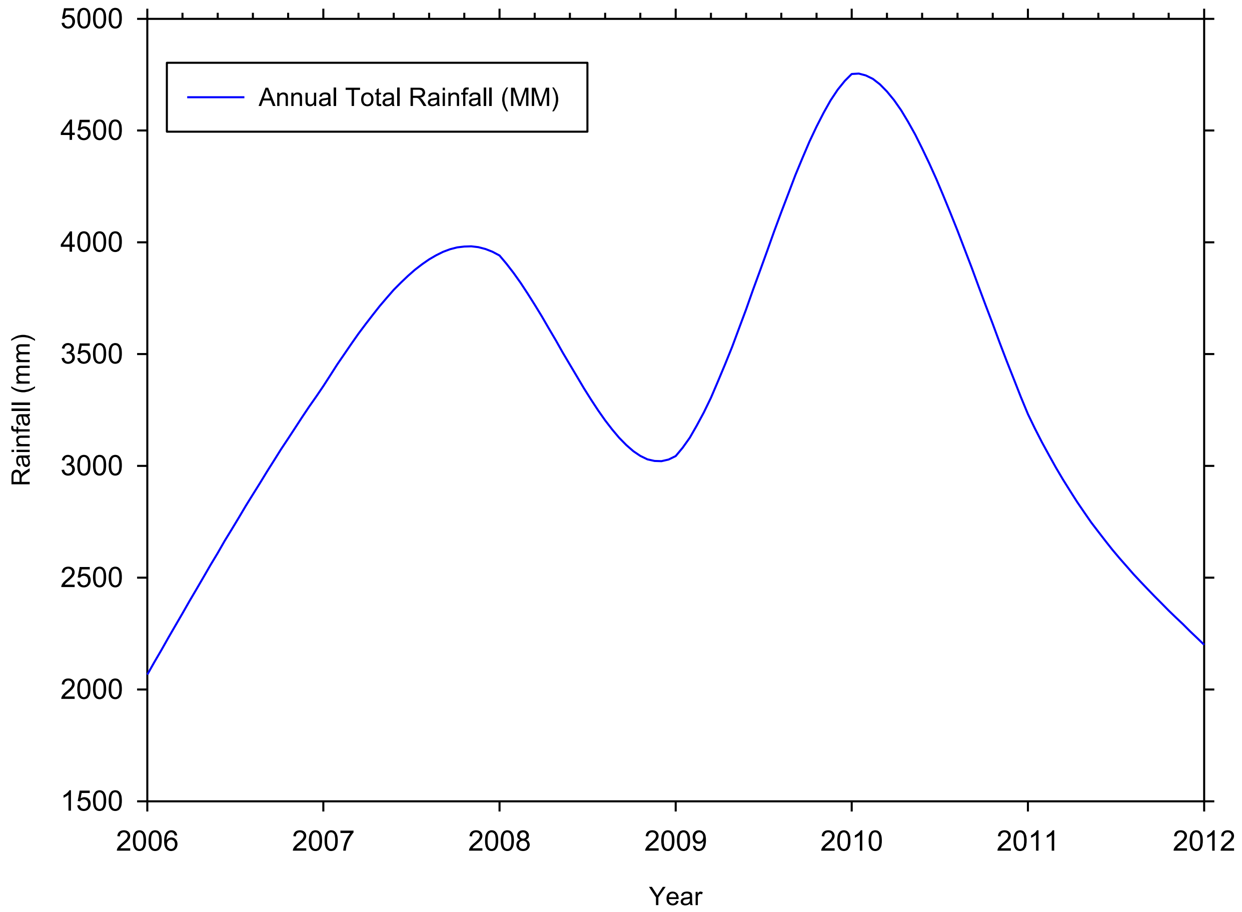


Figure 2.4a Rainfall distribution in Silchar town (2006-12)

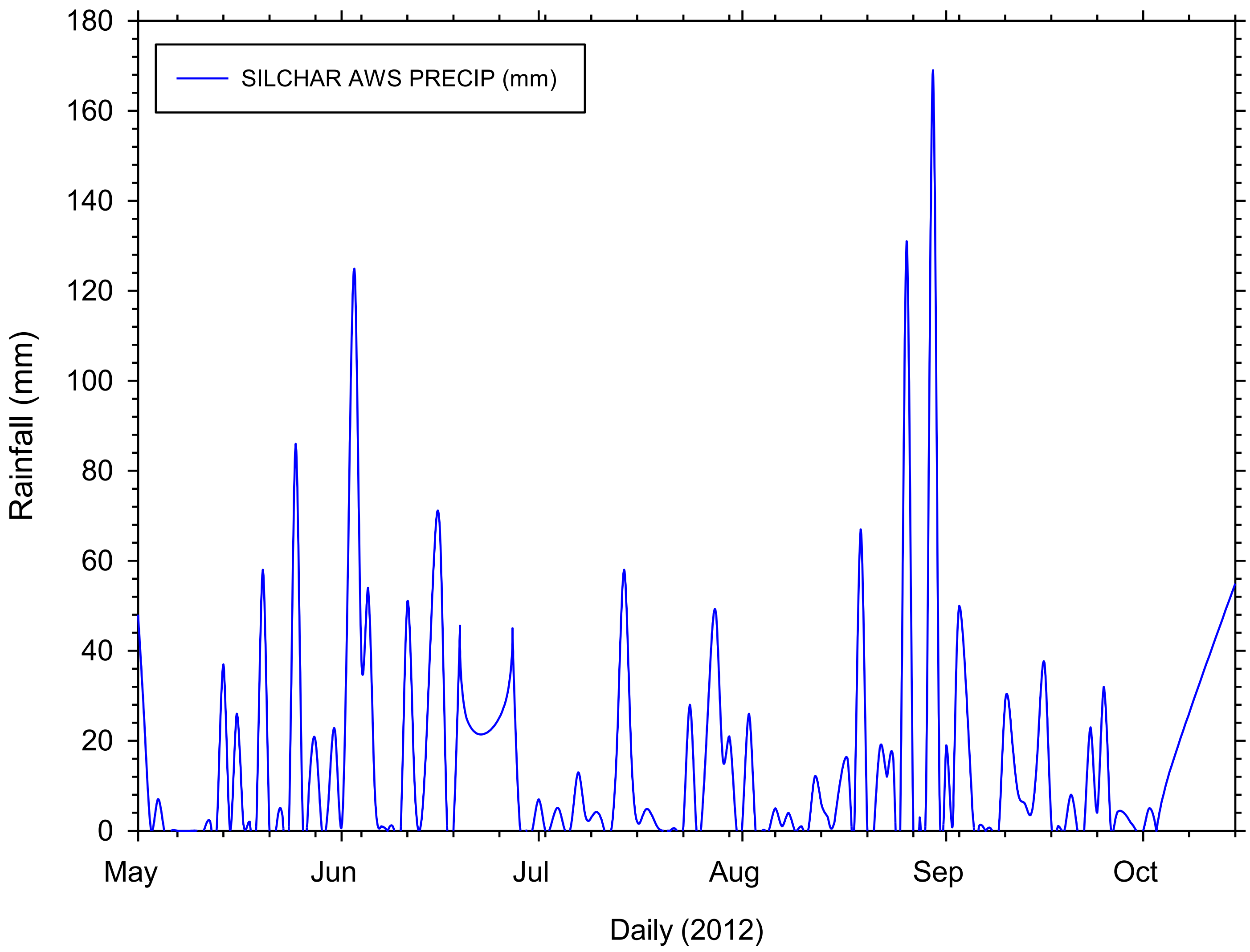


Figure 2.4b Daily rainfall in Silchar town in 2012

2.5.2 Hydrological Modelling and Flood Hydrographs

Flood and Storm events have been identified and analyzed from the hourly rainfall data and Intensity-Duration-Frequency (IDF) techniques. A quasi-distributed hydrological model was developed in HEC-HMS environment for Silchar urban catchment and model runs were carried out for the particular event dates when actual flood inundation has taken place in parts and parcels of Silchar town. The urban catchment hydrologic model developed and adopted is shown in Fig. 2.4. The magnitude and scale of storms were converted to flood runoff based on the hybrid DEM and drainage system to derive flood hydrographs at drainage reaches, junctions and outlets for selected storm events which have actually caused flash floods. Most dataset adopted were of that of the recent period year 2010-2012 as it has been understood from ground reconciliation that flooding regime is highly dynamic in Silchar region and was not the same as it used to take place before the last 5 years or so. The generated flood hydrographs for some of the selected extreme events are presented in Figs. 2.5a to 2.5c. These flood hydrographs formed the boundary conditions of the urban flood inundation simulation. It may be noted that spatial resolution of rainfall data used in the hydrological model was assumed in the range of 5 km effective radius of the rain gauge station(s) wherever available.

2.5.3 Urban Flood Simulation and Coupling with Ground Inputs

Flood inundation hydraulic simulation was carried out for Silchar urban catchment using the derived flood hydrographs of actual flood events especially that of last year 2012. Base flood elevations were established with Z-flood points using a hybrid DEM of 1m spatial resolution derived from close contour ground RTK/ETS survey as shown in Fig 2.6. The hydraulic model platform was used to simulate the urban flooding conditions with the Z-flood points (Figs. 2.7a and 2.7b). The major drainage channels as Rangikhari, etc were adopted as pilot channels. Drainage nodes and congestion points were identified and statured based on the drainage gradient and confluences as shown in Fig. 2.8. These nodes/points were used as junctions in during the hydraulic model simulation. The simulated flood layers were extracted in spatial database format for further GIS post-processing. Some of the layers are presented in figures 2.9a to 2.9c The simulated flood inundation layers were further schematized using scale of flood discharges from hydrographs and ground-based flood extents and depths. GIS spatial analysis and overlay/union/intersection areas, etc was done for integration of the (i) Simulated flood inundation layers, (ii) Base Flood Elevation & Z-Flood point layers, and (iii) ground database of actual flooding (ground reconciliation, database from various sources).

The generation of the final flood hazard layers has been done using the coupling of the hydraulic model-derived layers with BFE / Z-Flood points, and was checked with ground records. The layers were overlaid on the Z-flood points derived from the ground and the weightage scheme applied to derive the final flood hazard layer in four respective categories as very high, high, moderate and low in 1:10,000 scale overlaid on the urban spatial layer using high resolution imagery. The flood hazard layers are presented in Figs. 2.10a to 2.10b. A statistical representation of flood hazard zonation of Silchar town and greater region is presented in Fig. 2.11. The flood hazard statistics ward-wise with area and percentage distribution is presented in Table 2.2. Flood hazard. statistics vulnerability and risk assessment was carried out for Silchar urbane and reported in the following section 2.6.

2.6 Vulnerability and Risk Assessment for Flood Hazard

For population vulnerability assessment real time scenario was calculated to show the temporal distribution of population. The main objective to assess vulnerability of population is to get a fair estimate of the population who might get affected if an event happened. Preparedness and mitigation plan can be prepared in advance based on the result of population vulnerability. Population vulnerability of a particular place also changes in different time periods in a day. Thus it plays a significant role in risk assessment for any type of hazard. In this study, population vulnerability assessment has been carried for different time periods. Population within the buildings for the study area were estimated for different time periods of a day i.e. morning, day, evening and night (Fig 2.12). Temporal population distribution during morning and day time is similar and the same way the distribution is similar for evening and night time period. Therefore, temporal distribution of morning and night time only has been considered. People within a particular building in different period depend on the different use type of that building. From the figures it can be interpreted that the buildings are more vulnerable during morning time and night time in residential areas, whereas in commercial, institutions, and other building use are having concentration during the day time. Vulnerable population occupying the buildings have also been identified. This group includes children below the age of 14 years, females and elders above the age of 60 years. In the study area, it is observed that there is a considerable vulnerable population in the very high vulnerable zones (Fig 2.13). It may be noted here, that population characteristics and population vulnerability assessment for all the hazards is considered as same.

For building vulnerability assessment for Silchar Town several parameter were taken into consideration and weightages and ranks were assigned to them based on the type of hazard as well as condition of the building. Characteristics of buildings (Fig 2.14) found in the city are described as follows:

Building Structure Type

In Silchar town, most of the buildings are rural structures and Assam type houses in timber frame (2.71 sq. km.). Reinforced concrete building are spread out in a linear pattern especially in the commercial areas (1.67 sq. km.) and Brick Masonry Wall building of large blocks and prefabricated type, half timbered structures are also spread out in the town (.53 sq. km.).

Building Roof Material Type:

Building roof materials in Silchar town were classified into concrete, tiles or asbestos, tin-sheets and thatched. Tin-sheet roof is predominant in the area (2.83 sq. km.). Cement-roofs cover an area of 1.49 sq. km.

Building Height:

Height of buildings is mainly determined by the number of floors. Generally there is a predominance of buildings having one floor (3.5 sq. km.).

Building Age:

The buildings within Silchar town have been constructed in several time periods. Buildings found within the area are mostly older than 15 years but few buildings are there which have come up recently.

Building Walls:

The city is dominated by buildings having concrete walls. In some areas, buildings are of rural structure with wooden or bamboo mixes with mud, sand or lime.

Vulnerability assessment related to flood hazard was based on the parameters namely, building wall material, distance from river/stream/drains, number of floors, return period of floods, protecting walls and water tanks (Table 2.1). For flood hazard, wall material of the building will be assumed to be the most important factor. In case of a flood event if the building wall material is concrete then there will be less chance for buildings to be washed away. Therefore, the maximum weightage 10 is assigned to the wall material of the building. Again, distance of a building far away from river/stream/drains will also affect the vulnerability of the building.

Table 2.1: Flooding transect - scoring of the components

Sl.No.	Land use	Score
1	Building material	10
2	No. Of floors	8
3	Distance to river/stream/drain	6
4	Return Period	5
5	Protecting wall	3
6	Presence of water tank/pond/well	2

Weightage assigned to this indicator is 8. However, this aspect will be taken into account in risk assessment, where the vulnerability and hazard factors are combined. The number of floors of a building is also an important parameter for building vulnerability assessment in case of flood hazard. Thus the number of floors is considered to the next important factor and assigned a weightage of 6. The return period of floods, presence of protecting wall and water tank are the three parameters which will be considered in flood vulnerability assessment. The assigned weightages are 5, 3 and 2 respectively.

The building vulnerability assessment in case of flood hazard was calculated using the following formula:

Flood Vulnerability Vulnerability = [0.29(Rank of wall material) + 0.23* (Distance to river/stream/drain) + .14 * (Rank of Return Period of floods) + .08*(Rank of protecting walls) + 0.05* (Presence of watertank).*

Using the above mentioned calculation, each mapping unit was assigned by a certain degree of vulnerability in terms of high, medium and low. For flood, the vulnerability value ranges from 1 to 10. The vulnerability index was prepared based on this range where value 1 to 3 represents low category, 4 to 6 represents medium category and 7 to 10 represents high category. Building Vulnerability map for flood hazard in Silchar town was prepared on the basis of characteristics of the buildings (Fig 2.15). Localities falling under different Vulnerability zones are presented in Table 2.3. A risk map for the study area was prepared combining the results of building vulnerability and Flood hazard zonation map. By multiplying the value of hazard map of a mapping unit with the vulnerability value of the respective mapping unit, a flood risk map for Silchar was prepared (Fig 2.16) and the table of localities in different risk zone is given in table 2.4. Vulnerable population under flood hazard risk is given in Table 2.5. It may be noted that there are certain parcels which have been classed as low to medium flood vulnerable zones, which were classes under high to very high flood hazard. The hierarchical application of building/structure type and socio-economic attributes in the model block has taken these zones as categorically not highly susceptible to flood hazard depending on the building conditions.

2.7 Limitations

The hydrologic model has been based on hybrid DEM of 1 m spatial resolution which has hydromorphometric parameters which may not precisely reflect the urban hydrologic system as in the ground due to the intricate drainage system. The hydraulic model simulation has been based on flood hydrographs of selected storm events, and the entire range of hydraulic data could not be incorporated during the model analysis. Due to the lack of reliable and high resolution rainfall data (available in coarse grid of 0.5º x 0.5 º only and interpolated), storm intensity and Intensity-Duration Frequency (IDF) analysis could not be done for an extensive period. Thus a base period of 5 years (2006-11) was mainly used for the hydrologic flood hydrograph model derivation. Dearth of ground drainage discharge data was another shortcoming in the model calibration, based on which sensitivity parameters for flood routing may not have been appropriately defined.

2.8 Conclusions

The generation of flood hazard layers has been done using the coupling of the hydraulic model derived layers and that based on base flood elevation with Z-Flood points. Silchar urbane region has a major land cover of depressions and low-lying areas, with its northern periphery banked by the Barak river which makes the region vulnerable to floods. Ward No 9 covering Mahutpura, Padma Nagar, parts of Fatak Bazar, etc was found to have the highest distribution of "very high" flood hazard zone (FHZ) among the wards in Silchar municipal area with almost 92 % area under the category. Under the "high" FHZ category, ward no 2 covering Ghariala, Shibbari Road, etc was found to have the highest distribution with 90 %. Under "moderate" and "low" FHZ, ward no 6 (Municipal Office, Court Road, etc) with 95 % and ward no 28 (E&D Colony, Kalain Road, parts of Ambicapur, etc) with 28 % of their respective ward areas, were found to have the highest distribution in their respective FHZ categories. It should be noted that the percentage area distribution of FHZ presented ward-wise in Table 2.2 may not exactly match the locations of flood zones as flood inundation layers are not scaled by administrative or sub-watershed boundaries.

It has been found that parcels of Tarapur, Sonai Road, T.V. Centre, Vivekananda Road, Link Road, Bilpar, Kalibari, Ithkola, Malugram, Ghoriala, Rongpur, and Kathat Road suffer from perpetual flooding and were classed as high to very high flood hazard zones. Some remaining pockets in Silchar town though defined by a flatter topography are classed as low FHZ due to the interlocking urban barriers. Further, the major finding from the project study is that the root cause of urban flash flooding experienced in Silchar town is local storm water congestion in the event of sudden storm events, and the flat topography with an average elevation which is very close to the HFL of Barak river aggravates the flooding duration. The incapacity of the prevailing drainage system which has been suffocated with solid waste has choked the conveyance capacity of the storm water drainage system. It may also be noted that the flood flows of the Barak River also do create havoc in supplementing the urban flooding woes in Silchar town as a result of the hydraulic model results and ground reconciliation checks.

Flood vulnerability and risk were assessed for the town and the area was divided into various levels of vulnerability and risk zones. In the vulnerable zones, ward no 3,7,9,10,17,21,22,25 are falling under high category. Ward no 6, 17, 22, 24, 28 are falling under medium vulnerable zones.

Risk was estimated taking hazard and vulnerability into consideration and various risk zones like very high, high, medium and low were categorised. Ward no 2,3,4,9,19,22,23 are falling in very high risk zone. Ward no 16, 17, 18,19,22,28 falls under high risk zone. Medium risk category includes ward no 6,10,11,24. Approximately 3331 no of persons are likely to be affected very highly by flood hazard in this town.

2.9 Recommendations, Implementation and Future Scope

Incorporation of minor drainage hydraulic data as cross-section and storm flow data can further enhance the model simulation and calibration, which will further improve the results and may also admit the use of more complex urban flood simulation models with rigorous schemes. t is thereby suggested that related departments/agencies/bodies should initiate regular gauging of storm discharge in the major and minor drainage channels of Silchar region, besides Barak river, so that a sound hydraulic database can be established to support robust database requirements for urban flood inundation modelling. More detailed topographical information in the form of sub-metre Digital Elevation Models may be developed for the entire metropolitan area using the the same or enhanced ground survey techniques (as LiDAR). It may be noted that sensitivity parameters for the flood routing were subjectively assumed in certain cases where data was not available and defined during the flood routing exercise.

Towards the mitigation aspect, the project study has found that, the natural drainage system to the major drainage i.e. the Barak river as well as to the inland wetlands needs to be hydraulically tuned to assure efficient storm water passage. Besides municipal bodies should take up measures to flush the choked drainage system and control the solid waste dump which has considerably led to the storm water congestion in the low lying pockets Thereby, a compliant regulation with hydraulic imperatives to restore the natural flow is recommended to restore the natural flow and dealing with the recurrent urban flash flood hazard in Silchar town and greater region.

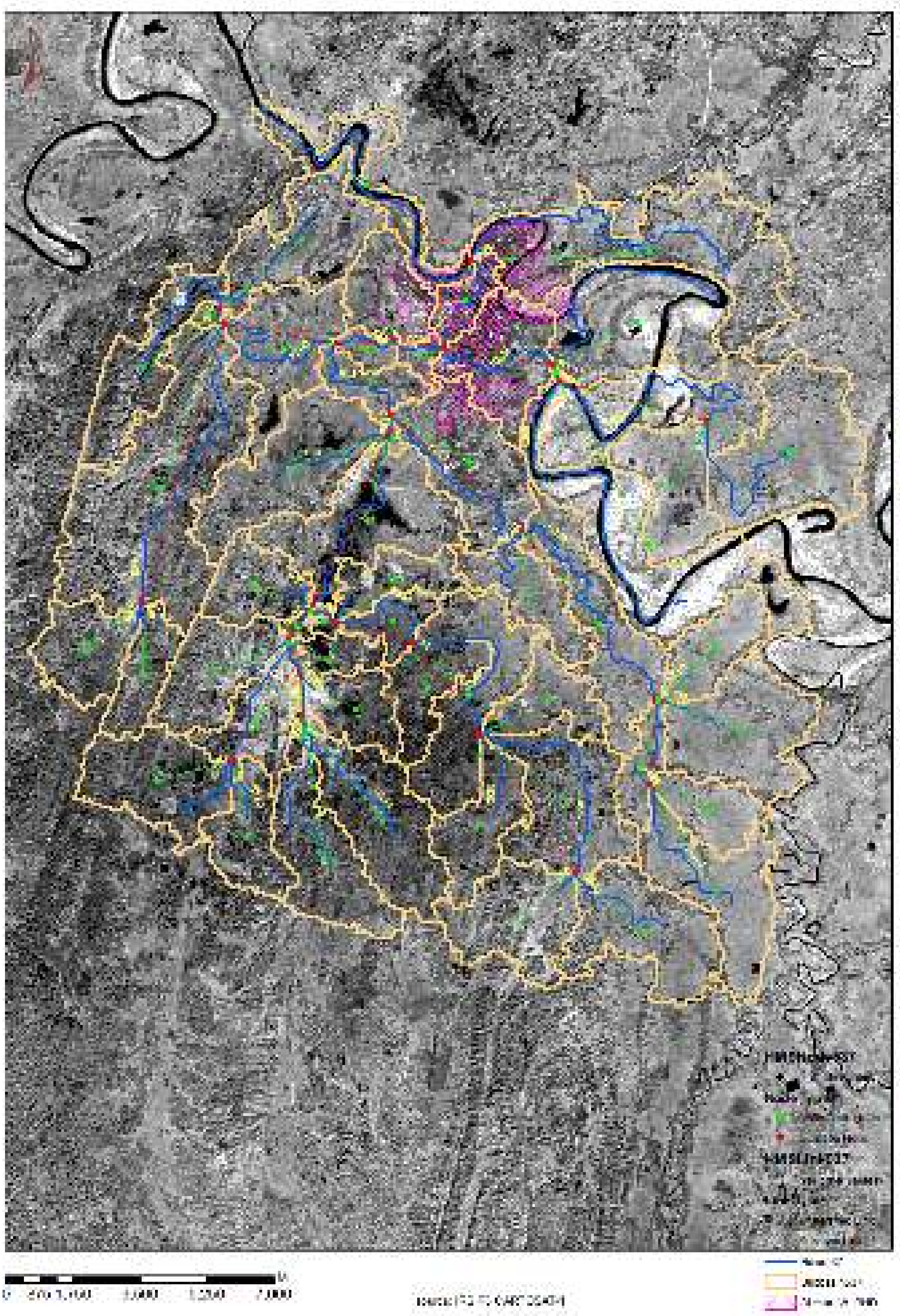


Figure 2.5 Urban Catchment and Sub-catchments ascribing Silchar town

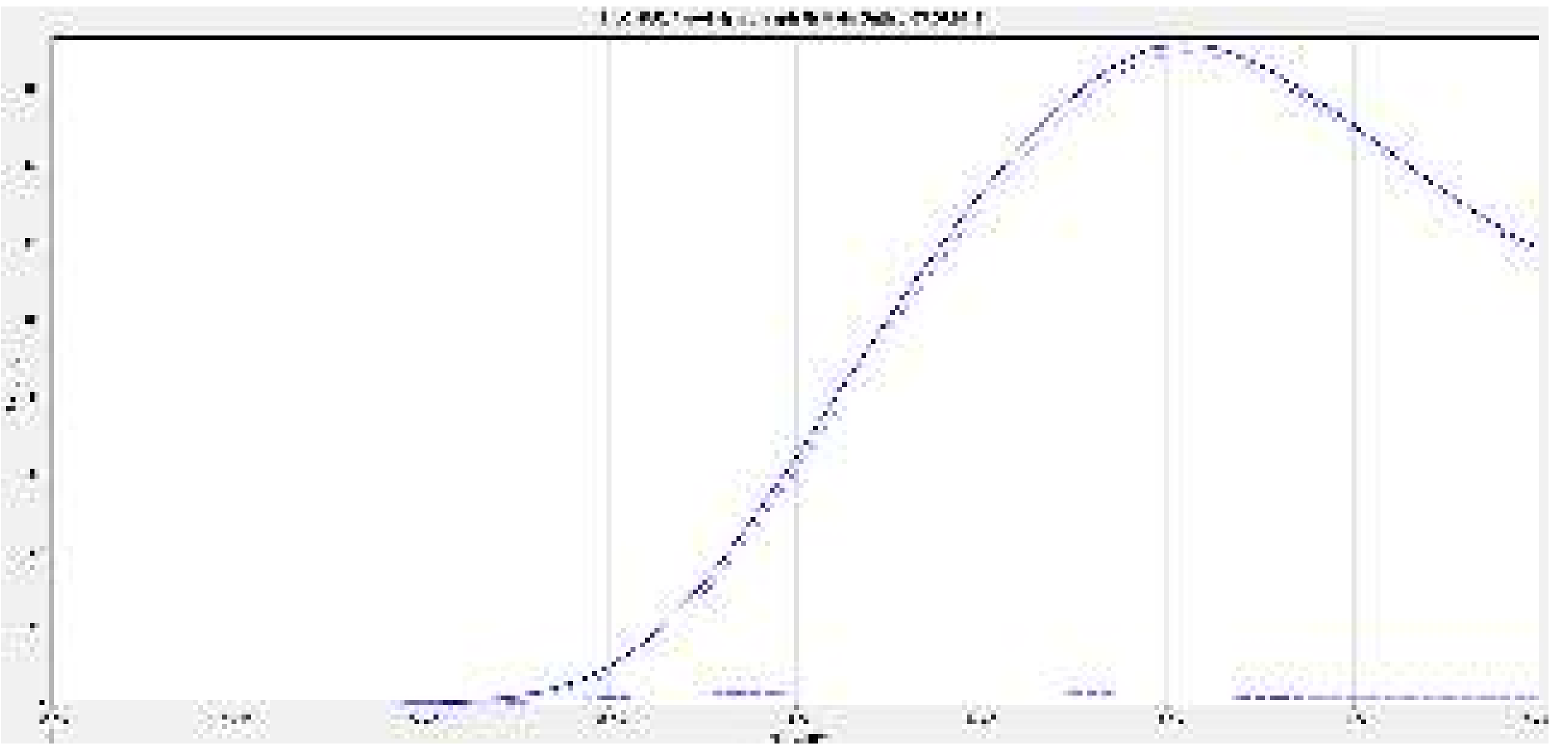


Figure 2.5a Flood hydrograph of storm event on 03.06.2012

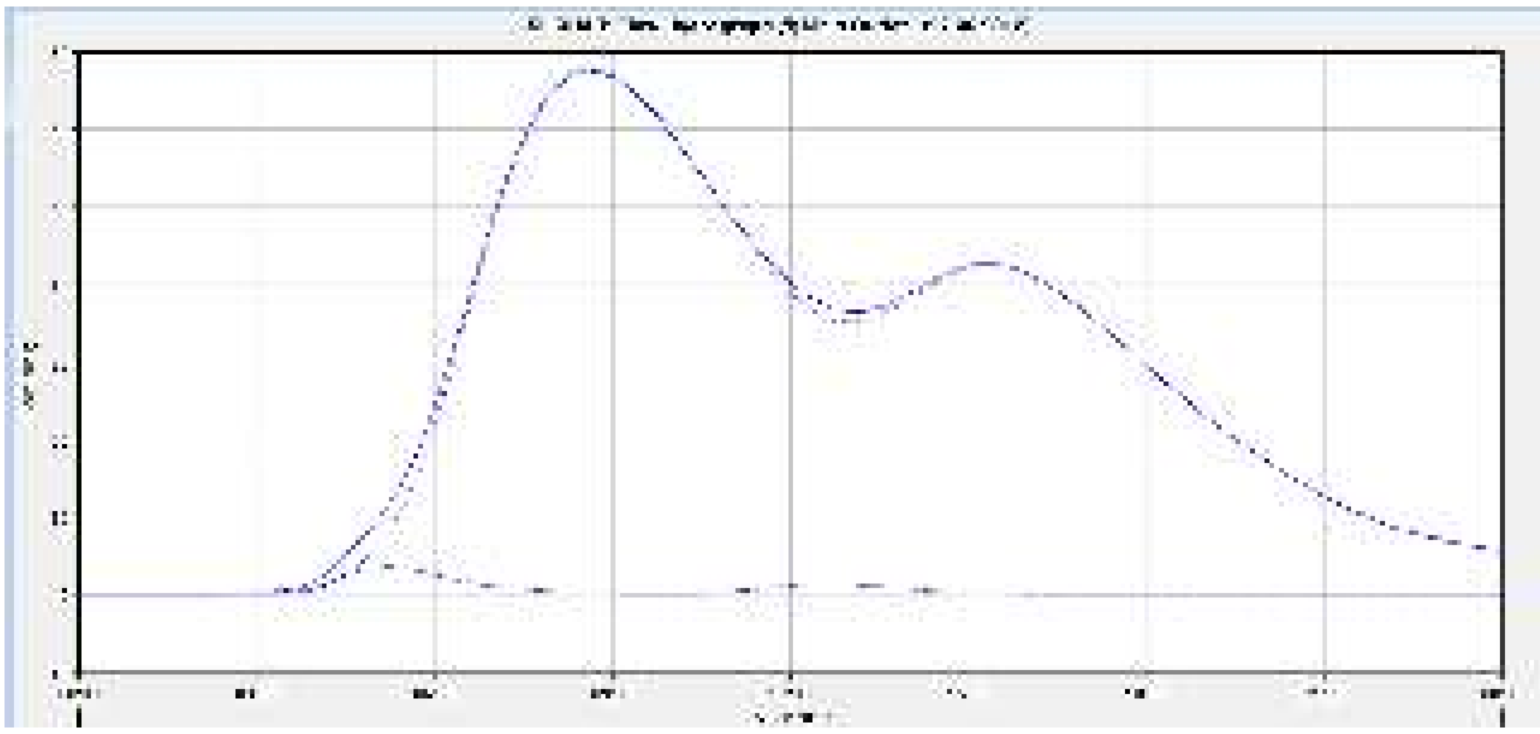


Figure 2.5b Flood hydrograph of storm event on 27.06.2012

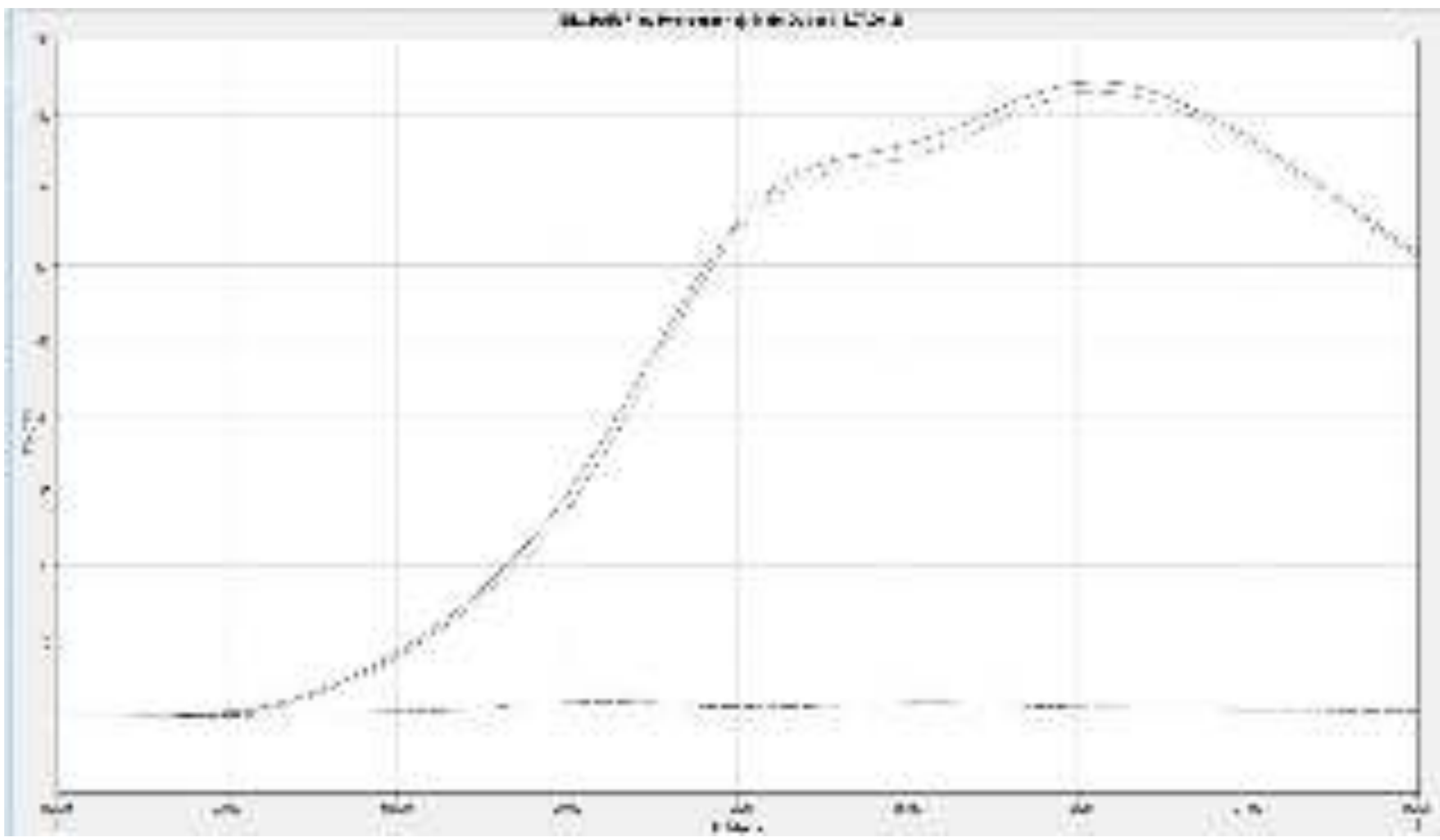


Figure 2.5c Flood hydrograph of storm event on 14.07.2012

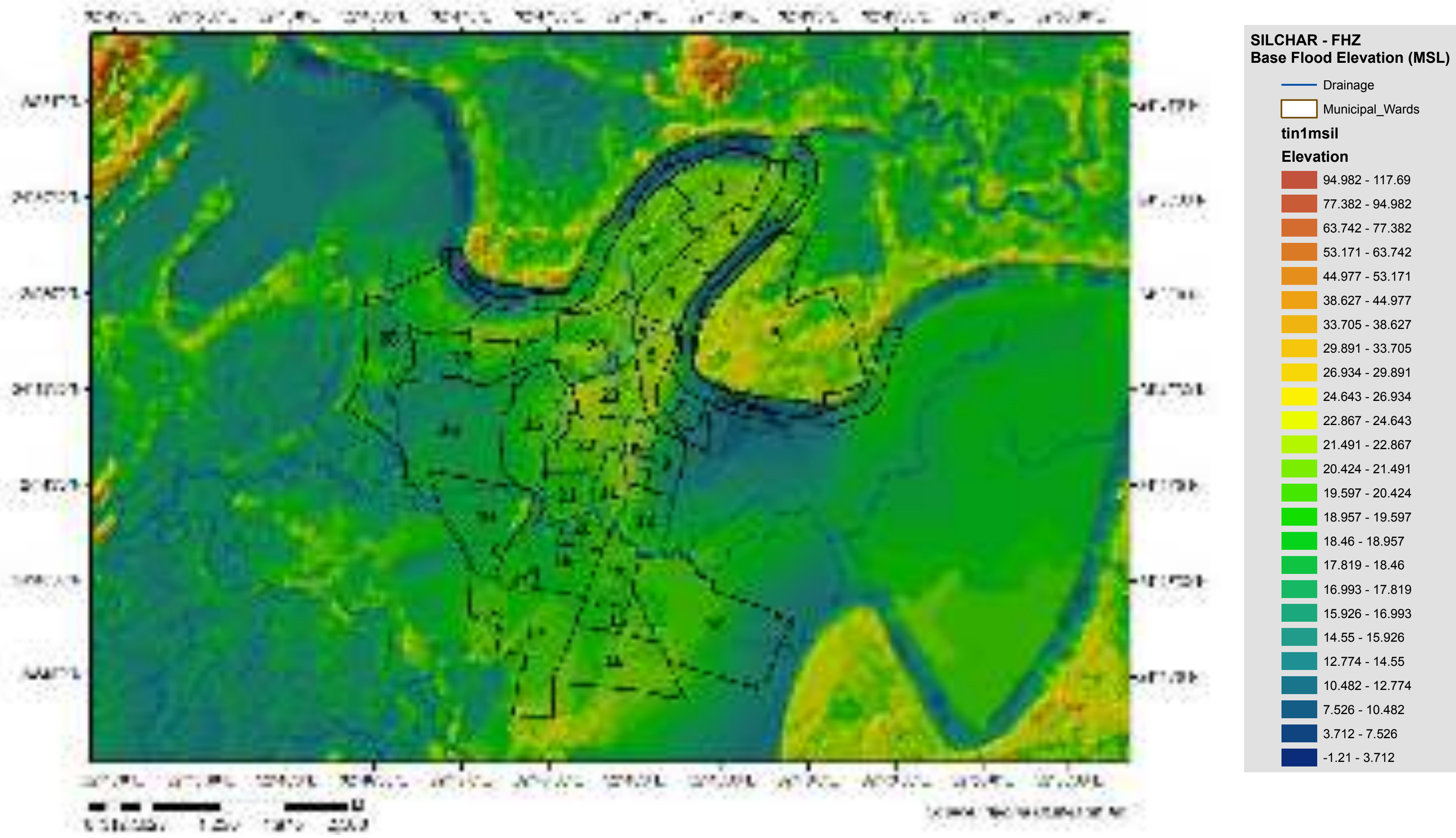


Figure 2.6 Base Flood Elevation of Silchar and adjoining areas

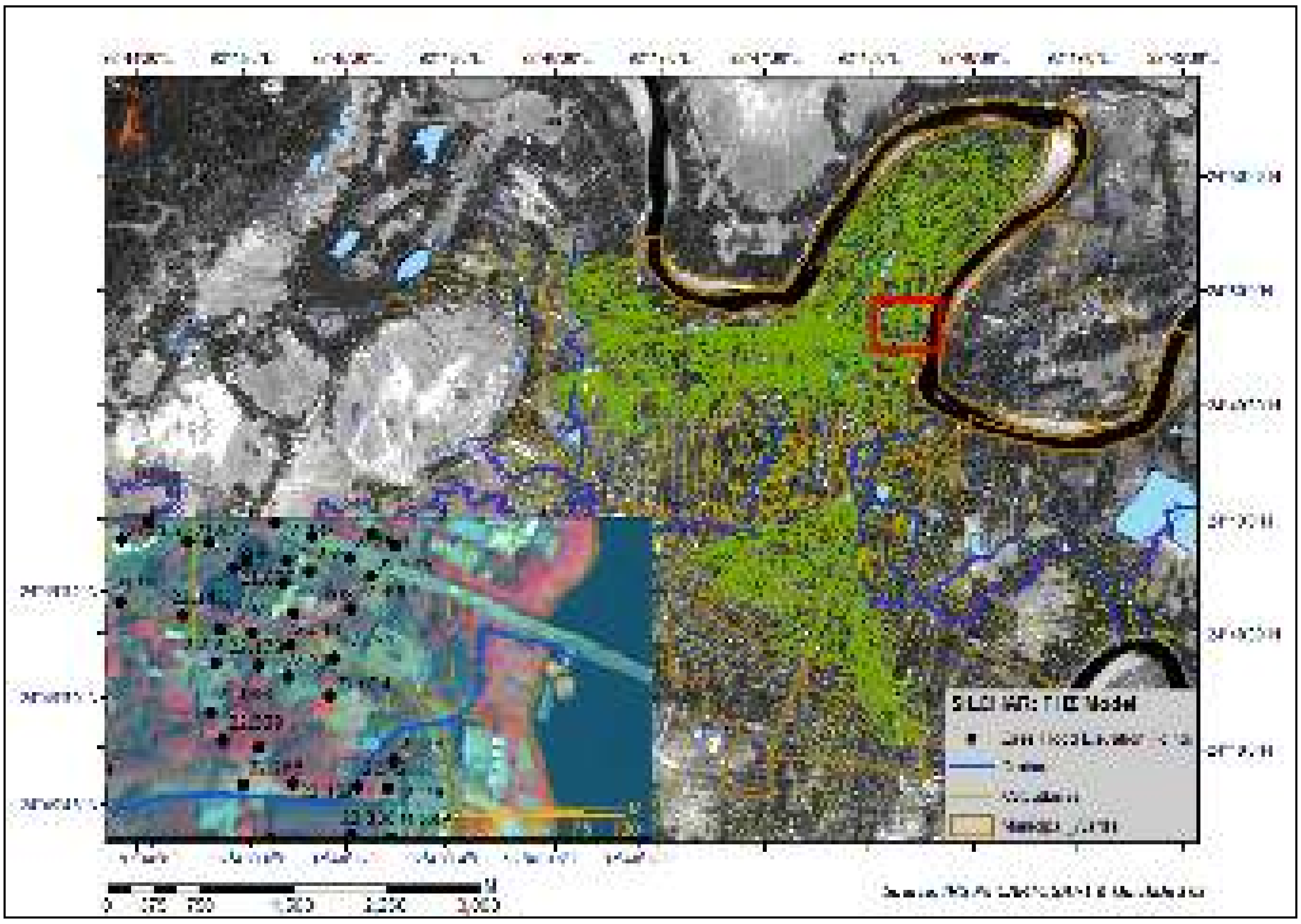


Figure.2.7a Hydraulic model platform with Z-Flood points

Figure 2.7b Z-Flood points in a parcel of Silchar

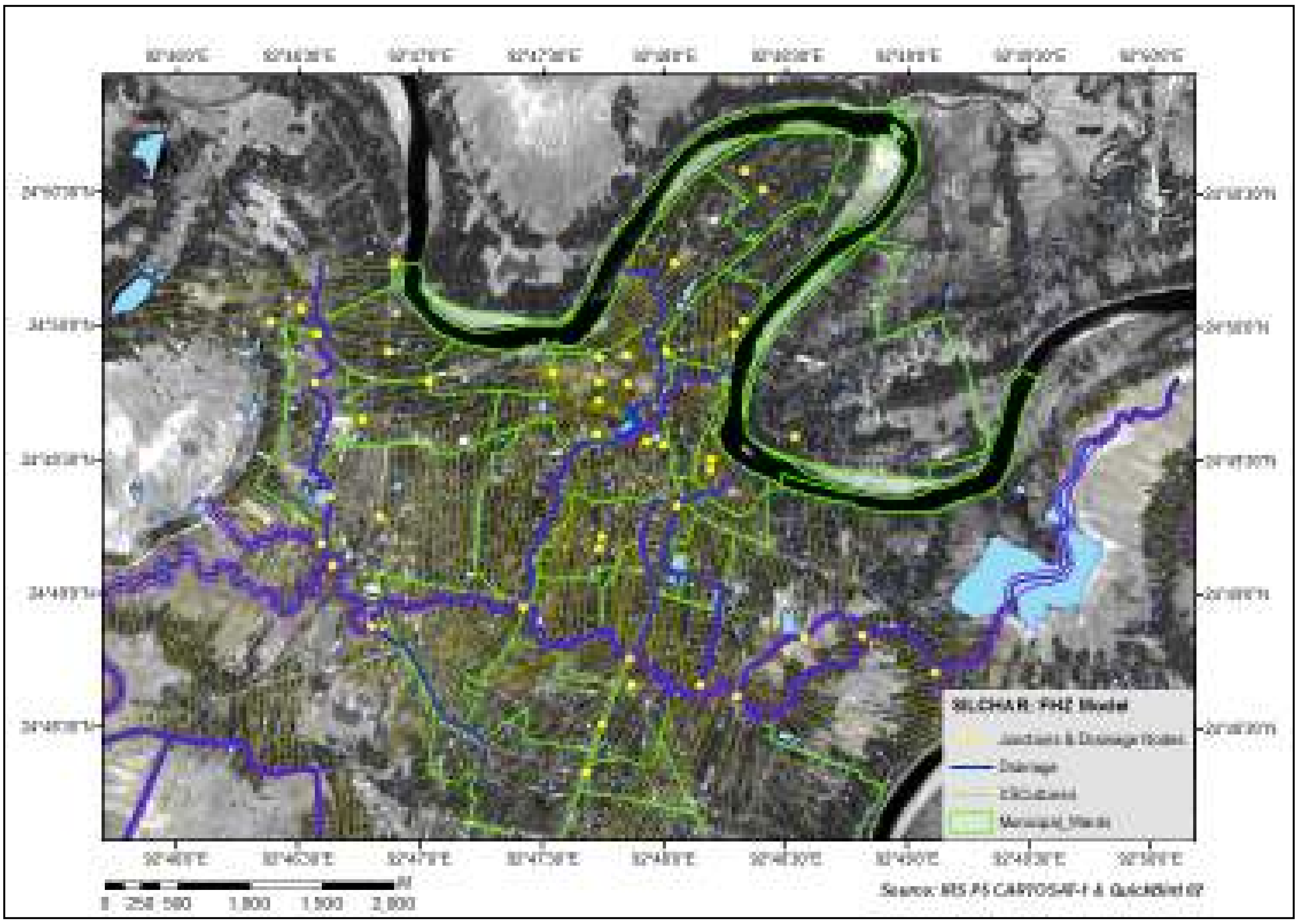


Figure 2.8 Drainage Junctions and Congestion Nodes in and around Silchar Town

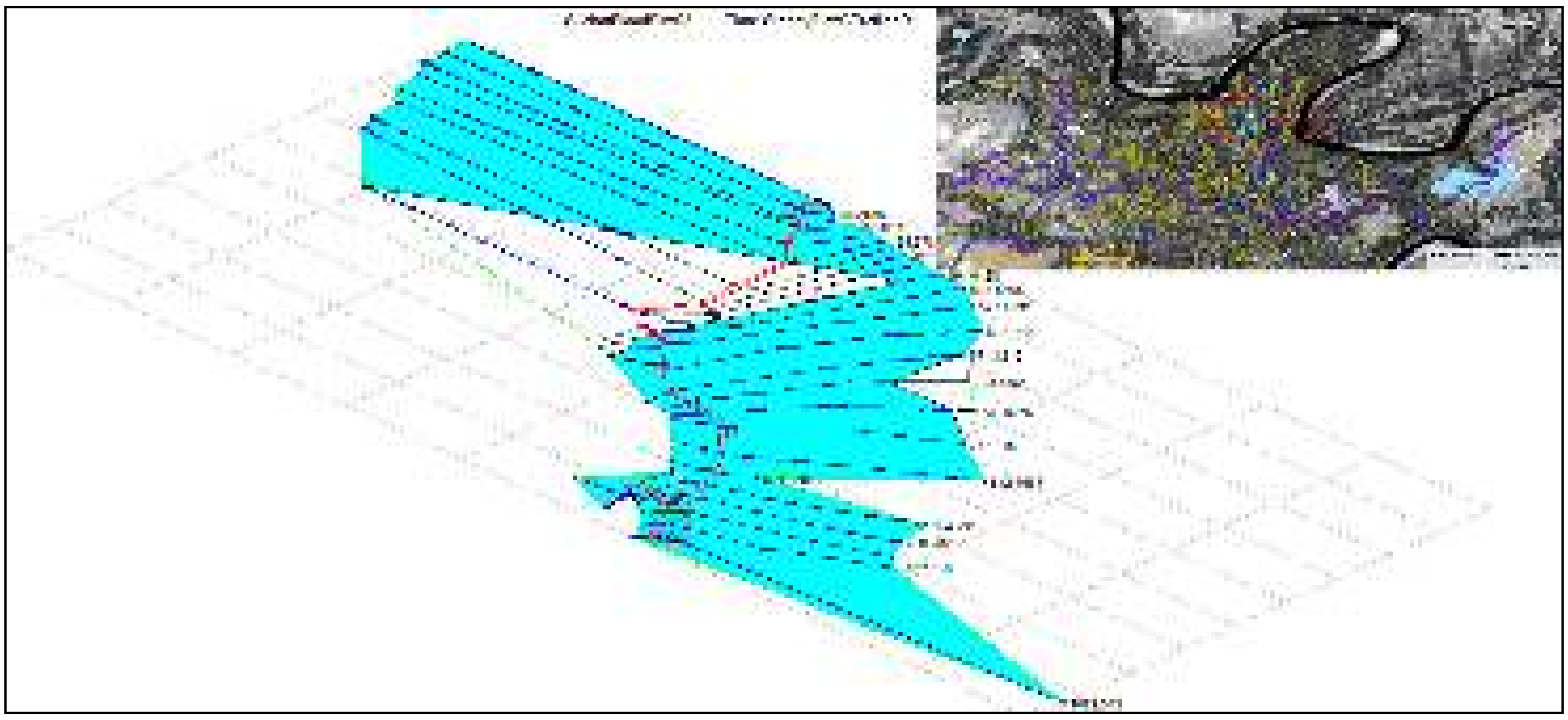


Figure 2.9a Flood inundation simulation 1

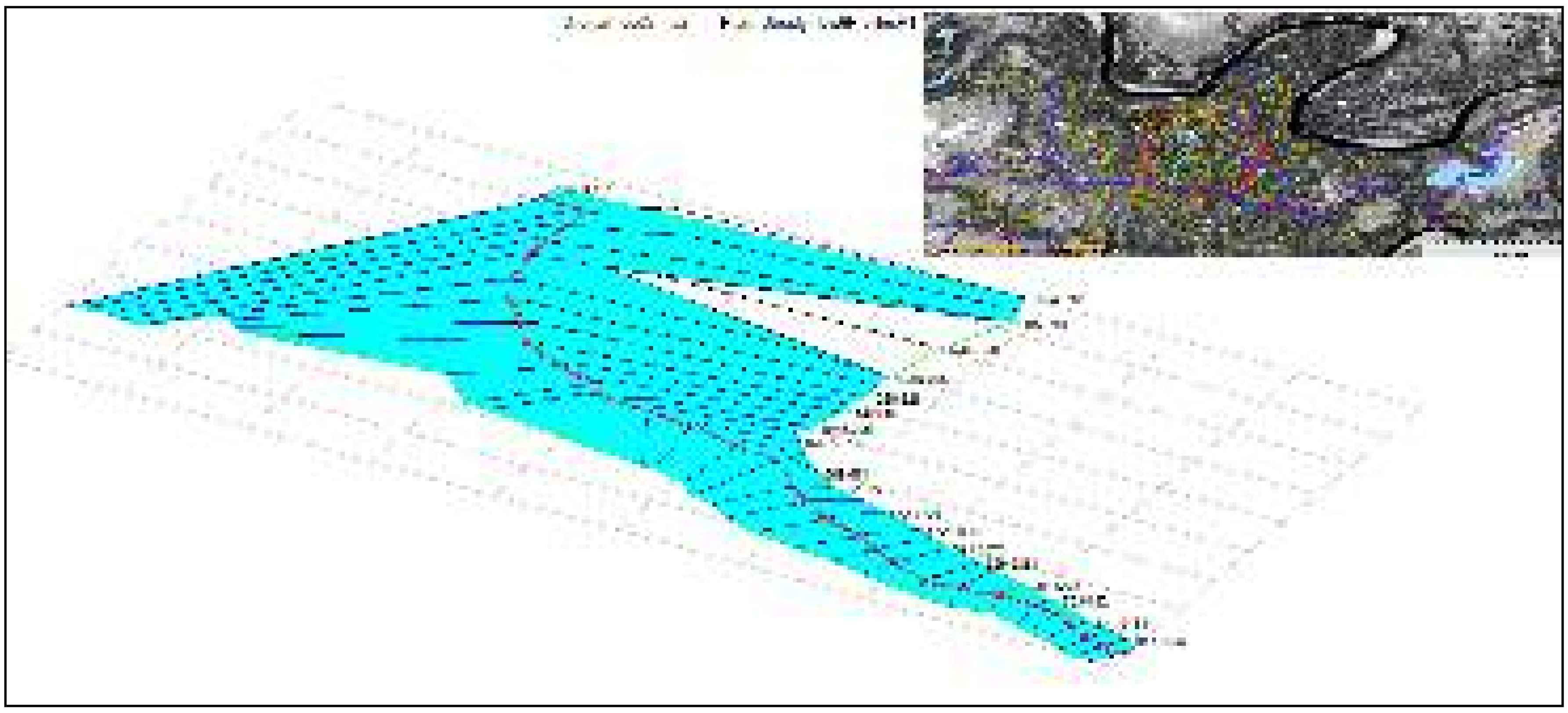


Figure 2.9b Flood inundation simulation 2

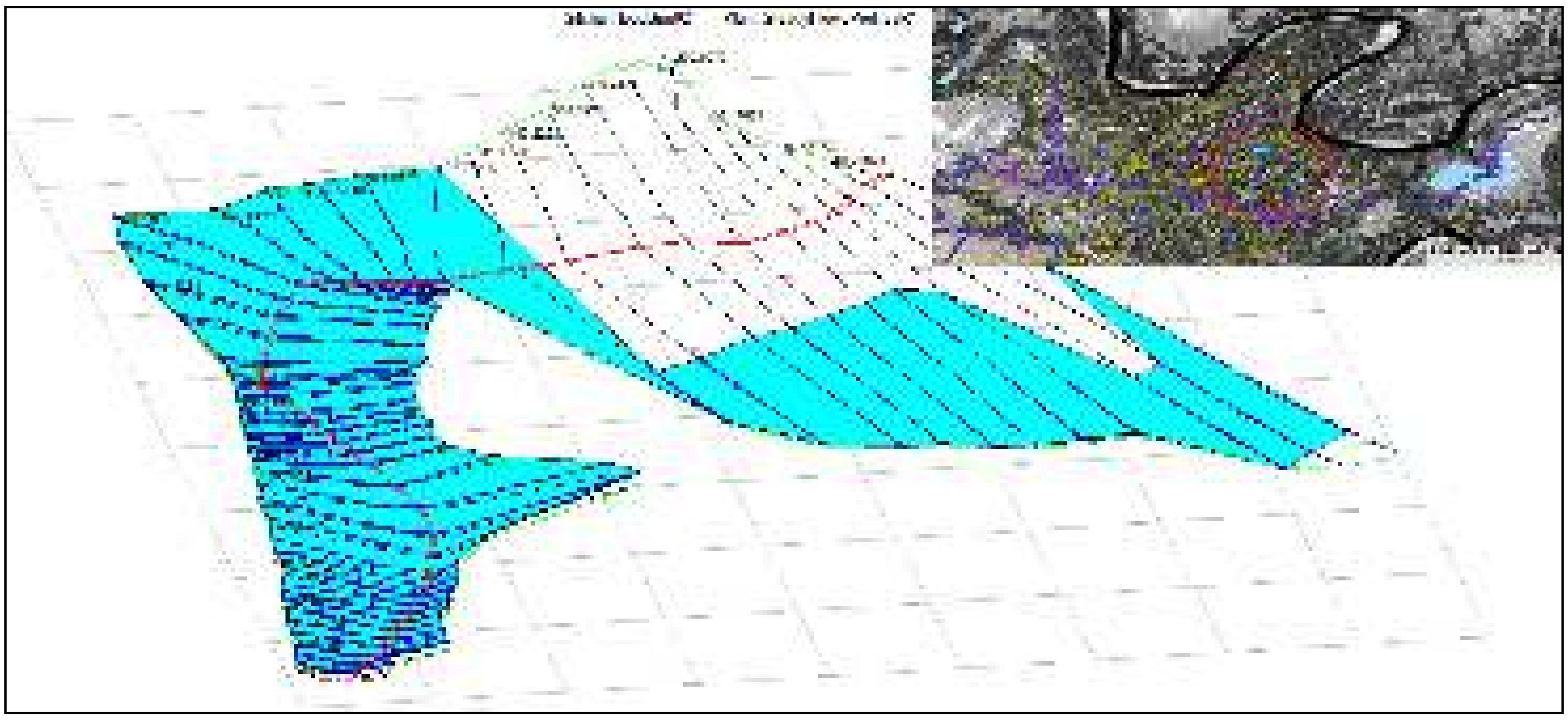


Figure 2.9c Flood inundation simulation 3

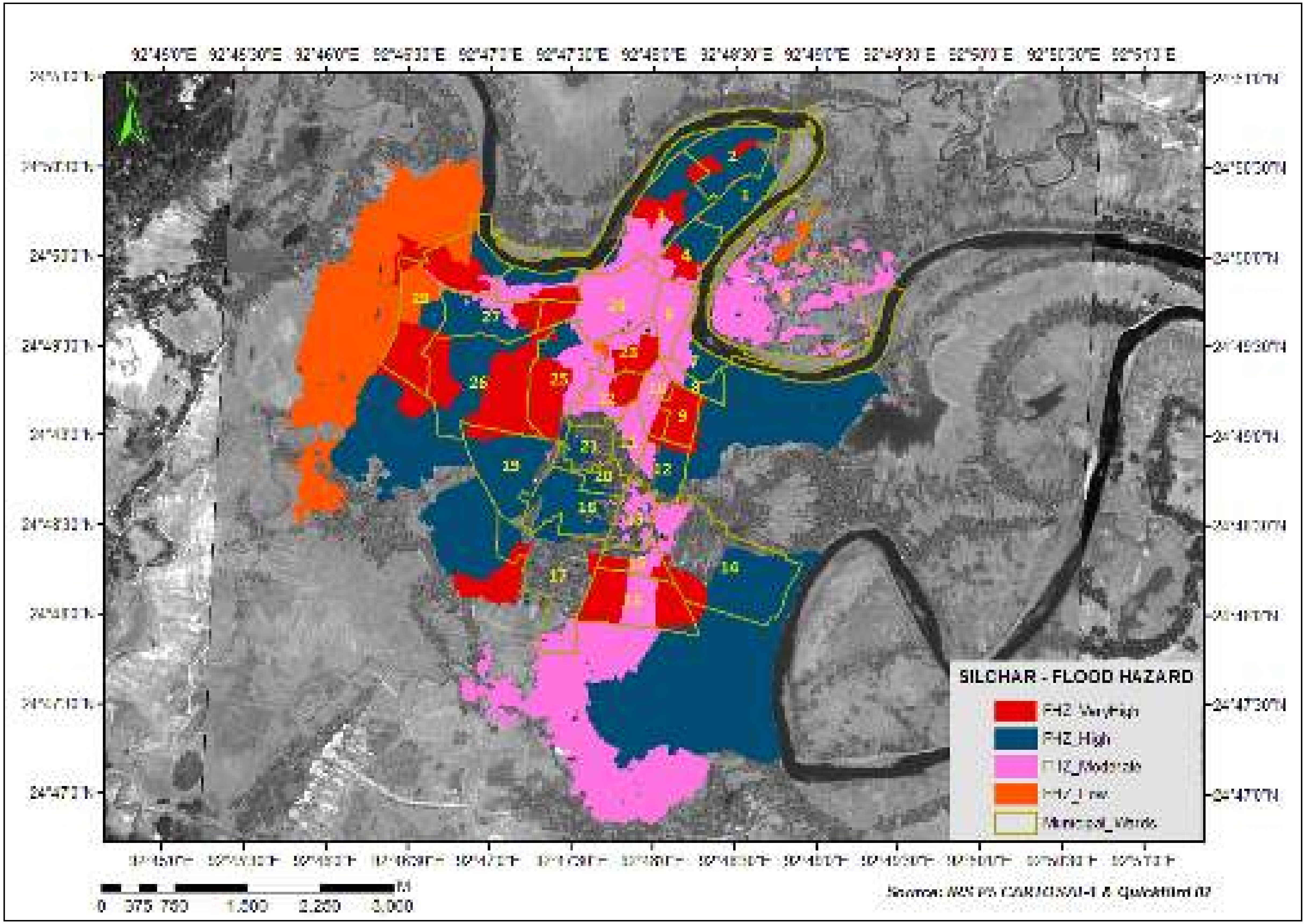


Figure 2.10a Flood Hazard Zonation of Silchar Town and greater region

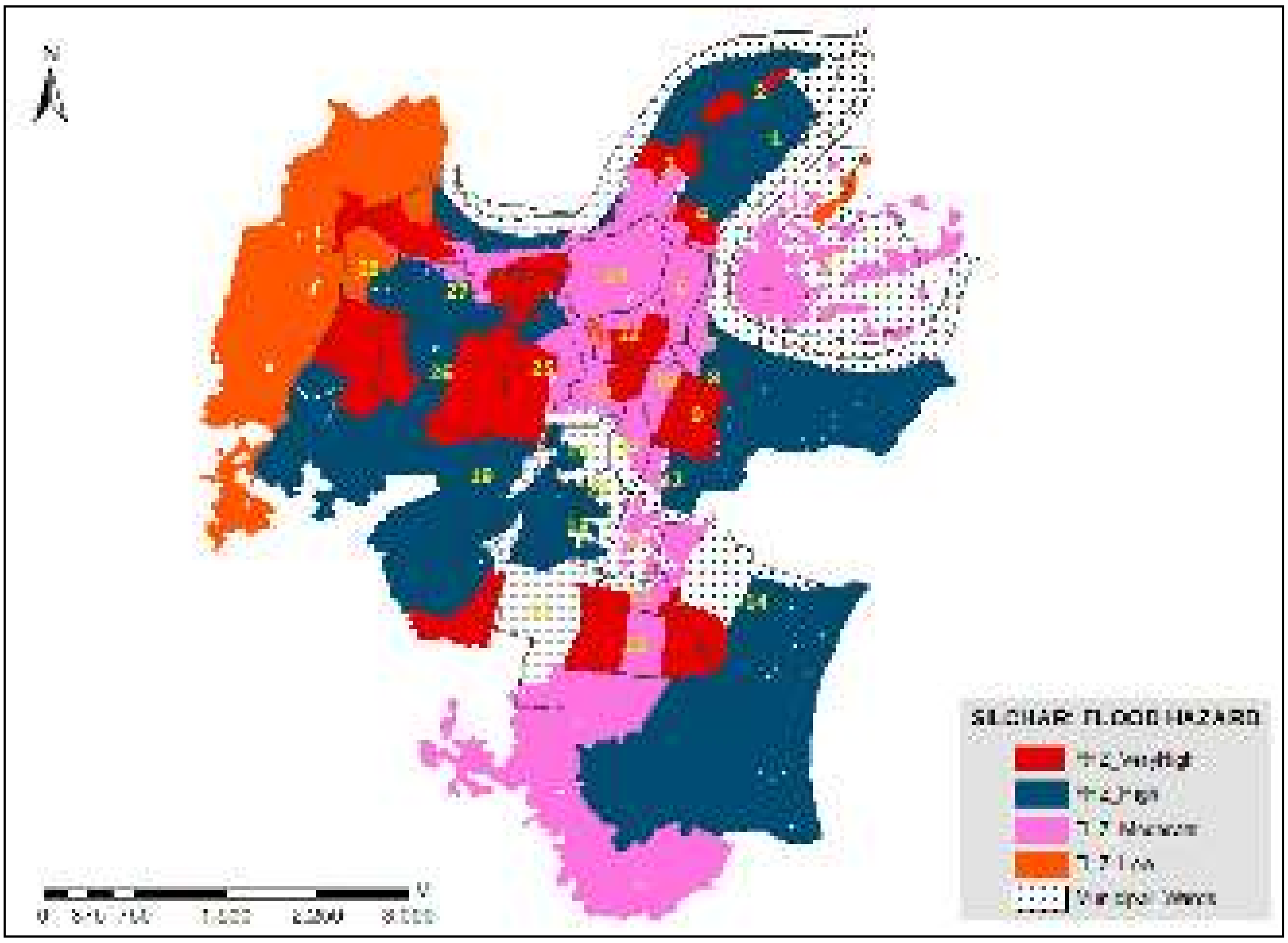


Figure 2.10b Flood Hazard Zonation of Silchar Town and greater region

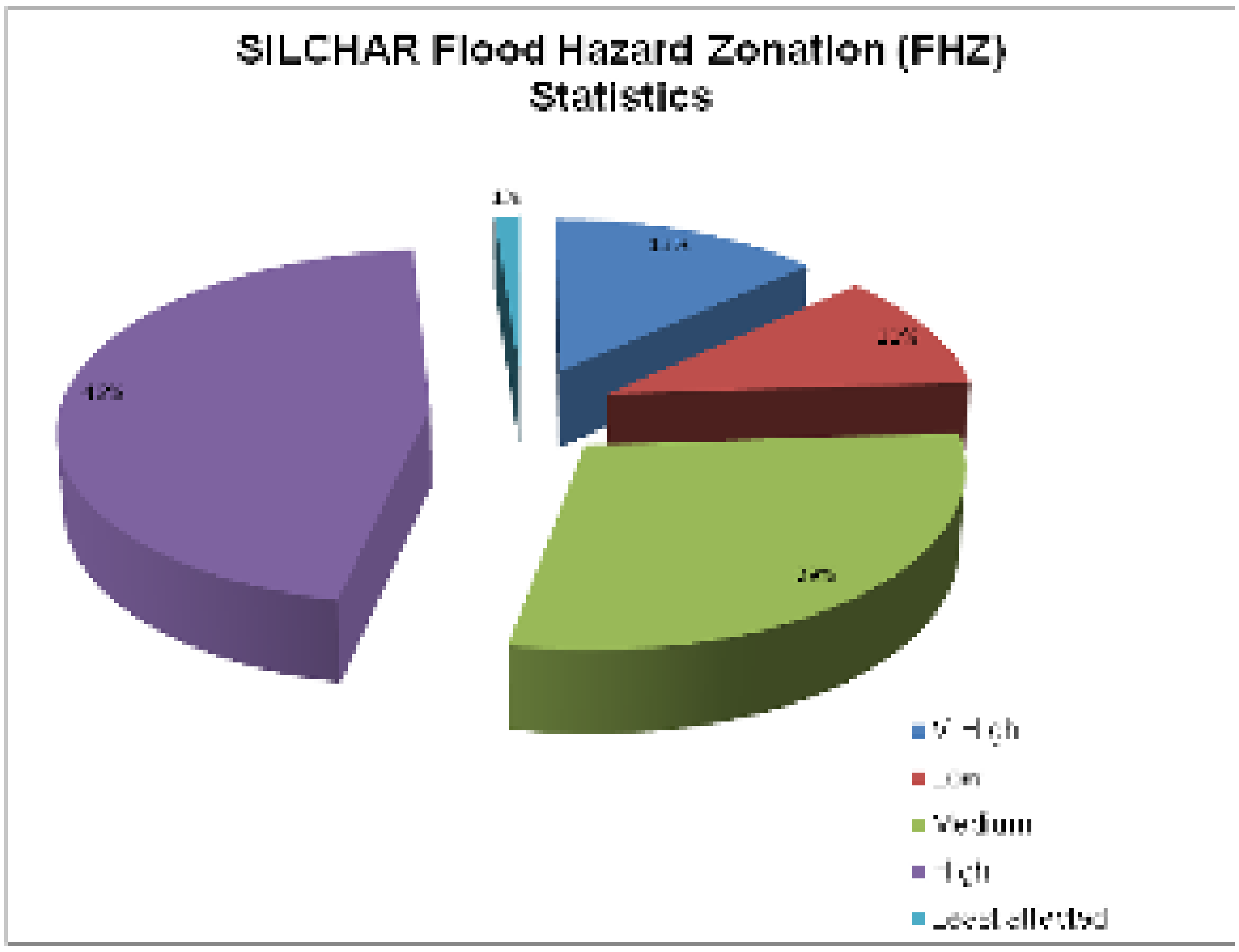


Figure 2.11 Flood Hazard Zonation statistics of Silchar Town and greater region

Table 2.2 Flood Hazard Zonation Statistics (ward-wise) of Silchar town

WARD NO.	WARD / LOCATION	WARD Area (sq.m)	FLOOD HAZARD ZONES (area in sq.m)				FLOOD HAZARD ZONES (% of ward area)			
			Very High	High	Moderate	Low	Very high	High	Moderate	Low
1	Mallugram	342388.27	—	244792.51	1019.59	—	—	71.50	0.30	—
2	Ghariala	431410.73	50961.47	384714.93	168.39	—	11.81	89.18	0.04	—
3	Ithkola	653645.05	158068.75	278588.67	220627.00	—	24.18	42.62	33.75	—
4	Natun Patty, Daccai Patty	291729.90	78585.50	140977.49	60405.10	—	26.94	48.32	20.71	—
5	Rongpur	1691034.13	—	1071.38	588567.53	37199.31	—	0.06	34.81	2.20
6	DC Office, Municipal Office	218356.65	636.97	—	206804.67	—	0.29	—	94.71	—
7	Kalibari	194274.70	—	94971.76	83186.93	—	—	48.89	42.82	—
8	Fatak Bazar	119223.85	826.64	76983.36	41396.74	—	0.69	64.57	34.72	—
9	Mahutpara	182592.09	167984.59	5664.47	4656.58	—	91.98	3.10	2.55	—
10	Radhamohan Rd	173080.46	54383.29	—	117625.57	—	31.42	—	67.96	—
11	Civil Hospital, Sunil Sarkar Rd, Desha	187647.48	589.16	—	108332.42	—	0.31	—	57.73	—
12	Lochan Bairag Rd	274035.10	31129.51	144911.84	50430.16	—	11.36	52.88	18.40	—
13	Sonai Rd, Bidhan Sarani	254992.57	—	—	88062.11	—	—	—	34.54	—
14	Muktaram Rd	1145038.25	93926.10	511838.74	105228.59	—	8.20	44.70	9.19	—
15	Rangikhari, Rabindra Sarani	188515.14	75239.57	—	63479.05	—	39.91	—	33.67	—
16	Link Road	563781.75	365456.65	25426.59	171809.41	—	64.82	4.51	30.47	—
17	Ambicapur, Khatal Rd, H.K. Rd	806622.78	52984.72	124581.90	90159.38	—	6.57	15.44	11.18	—
18	Kanakpur, Rangirkhari	476437.67	—	340547.97	514.10	—	—	71.48	0.11	—
19	Chengkori Rd, Satsang Ashram	584032.99	52599.25	471632.13	1242.01	—	9.01	80.75	0.21	—
20	Tarani Rd	162831.14	—	60711.89	1427.23	—	—	37.29	0.88	—
21	College Rd	216858.18	—	53705.18	4016.66	—	—	24.77	1.85	—
22	Jail Rd	294235.36	96002.58	—	143692.92	—	32.63	—	48.84	—
23	Nazira Patty, Shillong Patty, Gopalganj	289403.43	138614.43	—	127083.72	20407.91	47.90	—	43.91	7.05
24	Police Grounds, Gandhi Bagh Rd	610574.12	83465.00	864.14	517209.63	—	13.67	0.14	84.71	—
25	Tarapur, Jhalupara	597932.61	284270.93	100045.90	191438.15	1154.87	47.54	16.73	32.02	0.19
26	Uttar Krishnapur, Vivekananda Rd	1034517.57	619812.63	411137.44	—	—	59.91	39.74	—	—
27	Tarapur, Railway Stn, TV Centre	421279.83	80423.04	259421.80	77815.76	3117.99	19.09	61.58	18.47	0.74
28	Industrial Area, E&D Colony, Malini Beel	907668.25	457831.24	151393.82	37225.89	256520.40	50.44	16.68	4.10	28.26
*	Railway Stn, Trunk Rd	264630.45	62516.99	90984.23	114032.38	—	23.62	34.38	43.09	—

(NB. *Flood hazard zonation area and percentage distribution within each ward area may not exactly scale with FHZ layers as given in Figs. 2.10a or 2.10b due to averaging out in layer splitting*)

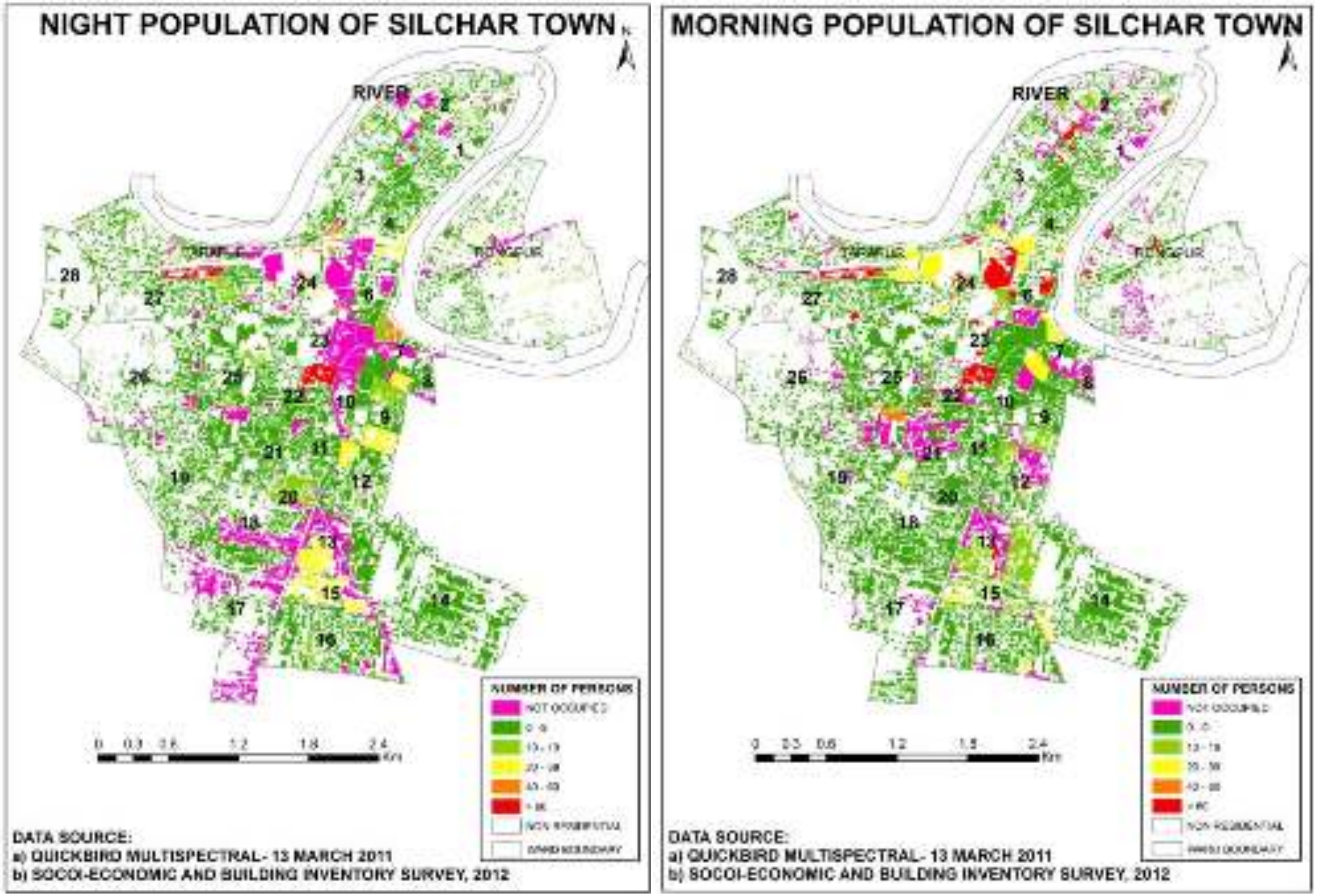


Figure 2.12 Temporal Distribution of Population in Silchar town

Note: Temporal population distribution of Silchar Town during morning and day time is similar and the same way the distribution is similar for evening and night time period. Therefore, temporal distribution of morning and night time only has been considered.

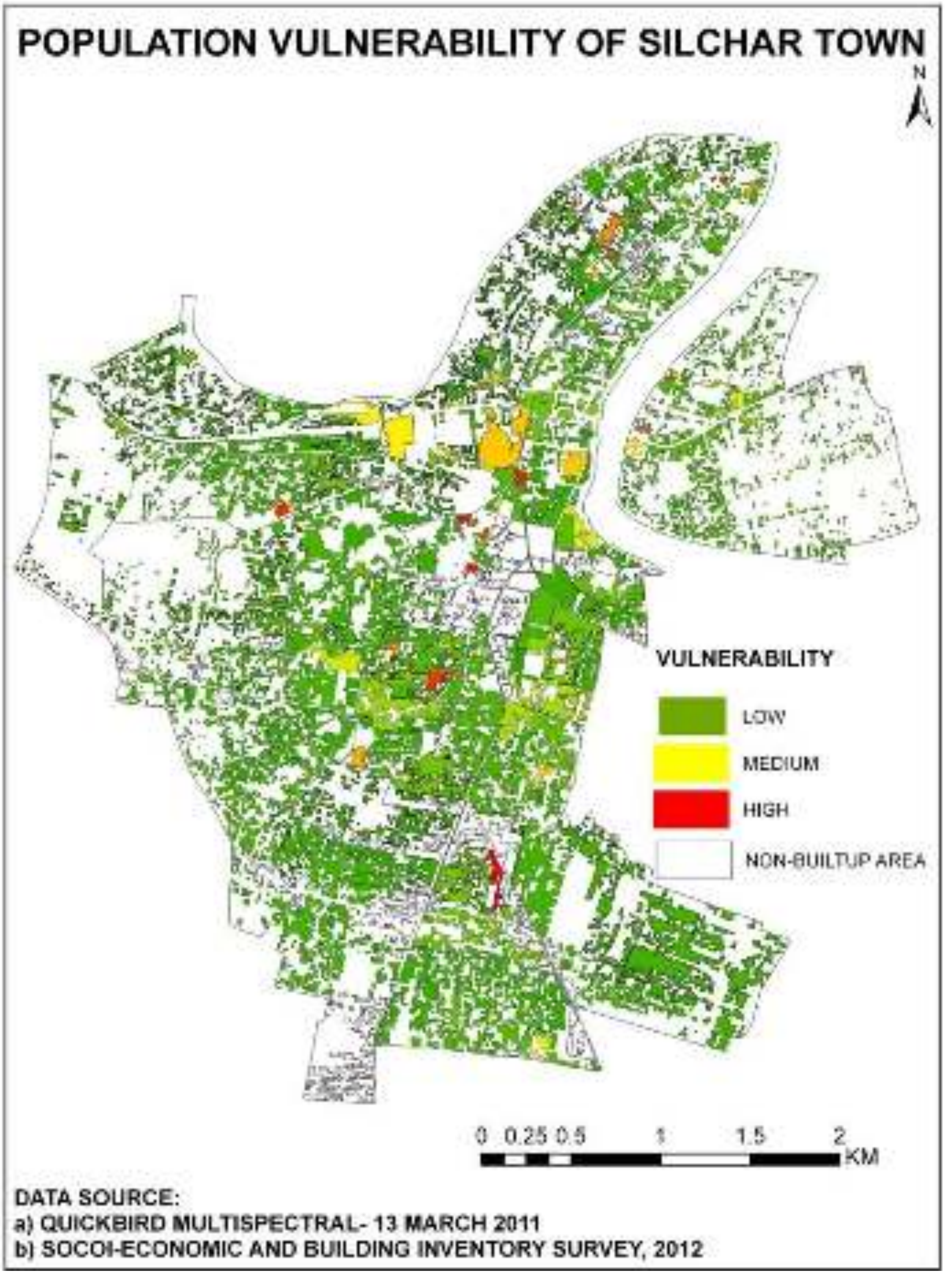


Figure 2.13 Population Vulnerability of Silchar Town

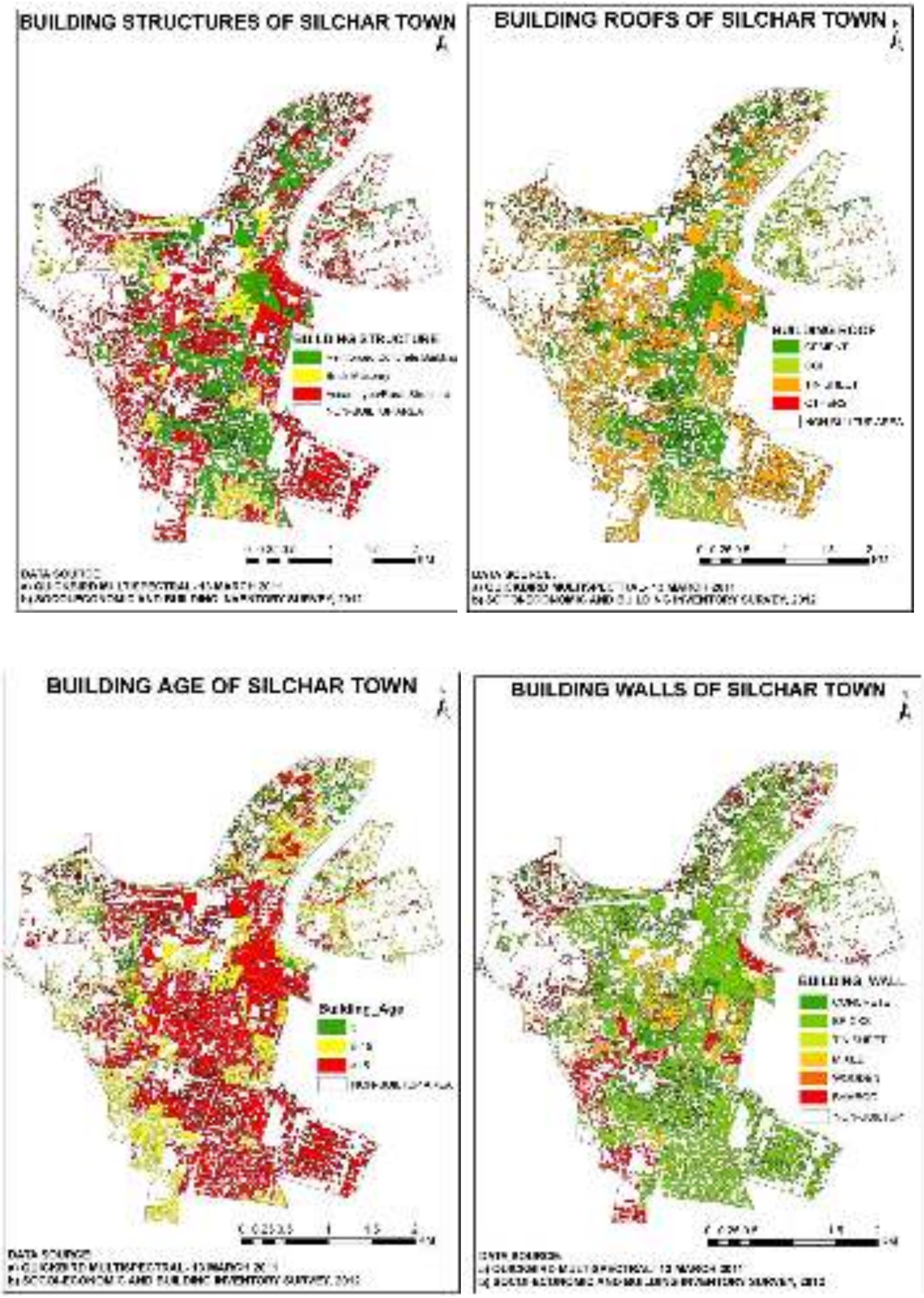


Figure 2.14 Building Characteristics in Silchar Town

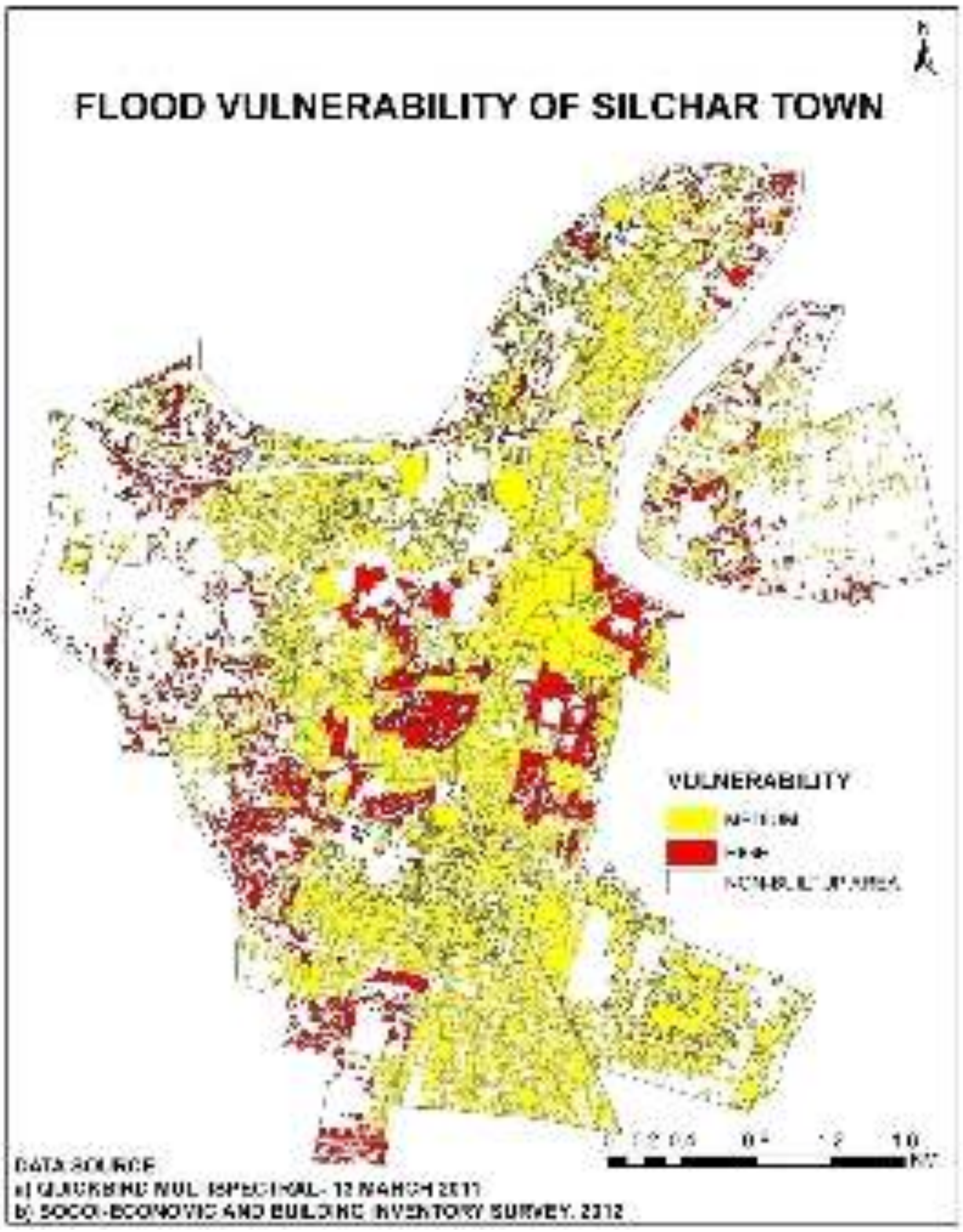


Figure 2.15 Vulnerability assessments for Flood Hazard in Silchar

Table 2.3 Localities in different Building Vulnerability zones for Flood Hazard

Sl. No.	High Vulnerability Zone	Medium Vulnerability Zone	Low Vulnerability Zone
1	Ambikapatty (Ward no 22)	Tarapur, PWD road, Park road, Trunk Road(Ward no 24)	No area is falling under this zone.
2	Bilpar (Ward no 9)	Janiganj, Court road, Central road, sadarghat Road(Ward no 6)	
3	Bilpar, Fatak bazaar (Ward no 10)	Mashim pur, Ramnagar(Ward no 28)	
4	R.K Mission Road, Vivekananda Road, Ambikaptty (Ward no 25)	Tarapur Chandmari road(Ward no 27)	
5	Chengkuri Road, Panchayat Road (Ward no 19)	Central Road(Ward no 23)	
6	Vivekananda Road(lane no 16, 17, 23,28), ashram road,Tarapur road (Ward no 26)	Vivekananda Road Lane no. 7, 13, Ambikapatty(Ward no 25)	
7	Second Link Road, Rangirkhari, Chengkuri road(Ward no 17)	Vivekananda Road lane no 19, 23,26,Ashram Road(Ward no 26)	
8	Mashimpur, Ramnagar,Itkhola Kalibari road(Ward no 28)	Ambikapatty(Ward no 22)	
9	Ramnagar, Tarapur maluni beel(Ward no 27)	Fatak Bazar, Bilpar (Ward no 10)	
10	Shillong patty Road, Central Road(Ward no 23)	Ambikapatty(Ward no 11)	
11	Tarapur, Itkhola road(Ward no 3)	Rangirkhari (Ward no 20)	
12	Ward no 2(north)	Ambikapatty, panchayat Road(Ward no 21)	

13	Ward no 1 (north)	Sonai Road, K.C road, Bidhan Sarans (Ward no 13)	
14	Janiganj, Water works road(Ward no 7)	Second Link Road (Ward no 16)	
15	Ambikaptty, Panchayat road(Ward no 21)	Rabindra sarani, !st Link Road, Sonai Road (Ward no 15)	
16	Sadhanghat (Ward no 4)	Mahaprabhu Road, Ramkrishna Road, ShyamSundar Road, Muktaram Road, Rammohan Road(Ward no 14)	
17		Panchayat Road, Bankim Lane, Rangirkhari, Happy Valley Road(Ward no 18)	
18		Bankim Sarani, Ramkrishna lane, mahatma lane(Ward no 17)	
19		Ward no 2(west)	
20		Itkhola Road, trunk Road (Ward no 3)	
21		Malugram Road, Natun Patty, Sadhanghat,(Ward no 4)	
22		Malugram Road, Joy kumar Road (Ward no 1)	

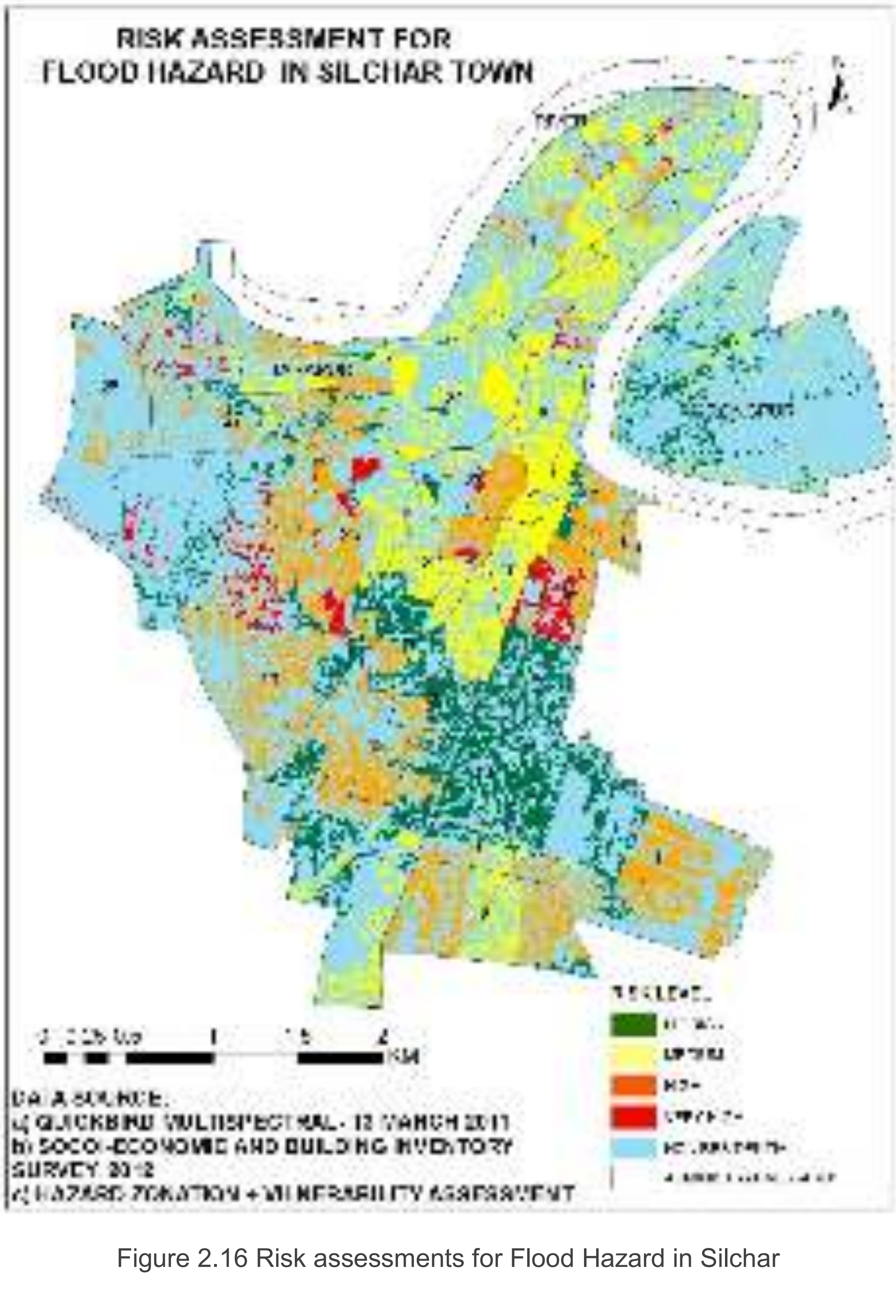


Figure 2.16 Risk assessments for Flood Hazard in Silchar

Table 2.4 Localities in different Risk zones for Flood Hazard

Sl.No	Very High zone	High Risk Zone	Medium Risk Zone	Low Risk Zone
1	Bilpar(Ward no 9)	Ramnagar, Mashimpur Ward no 28	Trunk Road, Circuit house, Cachar College, S.P Office (Ward no 24)	No area is falling under this zone.
2	Vivekananda Road, Ambikapatty , R.K Mission Road (Ward no 25)	Chengkuri Road, Panchayat Road, Ashram Road Ward no 19	Central Road, D.C office (Ward no 6)	
3	Vivekananda Road, Anandamayee lane, Rabindranagar lane,Satsang Ashram (Ward no 26)	Second Link Road (Ward no 16)	Fatak Bazaar (Ward no 10)	
4	Ramnagar,Mashimpur(Ward no 28)	Ward no 14(east)	Ambikapatty (Ward no 11)	
5	Ambikapatty(Ward no 22)	1st link Road(Ward no 15)	Ambikapatty (Ward no 22)	
6	Shillong patty road (Ward no 23)	Chengkuri Road, Bhakatpur (Ward no 17)	Jhalupara, Ambikapatty. M.C. (Ward no 25)	
7	Ward no 2	Rangirkhari, Panchayat Road, K.C Road,Bankim Road,Happy valley Road (Ward no 18)	Itkhola (Ward no 3)	
8	Ward no 3	Ambikapatty (Ward no 21)	Ward no 2(south, west and east)	
	Daccai patty, Sadhanghat (Ward no 4)	Vivekananda road lane 1, 2, 7, 12, 13 (Ward no 25)	Malugram Road(Ward no 1)	
	Ashram Road (Ward no 19)	Vivekananda road lane 17,19,23,26,28, ashram road, Tarapur Ward no 26(east)	Nutan Patty, Dacai patty, Malugram Road (Ward no 4)	
		Fatak Bazar (Ward no 8)	Fatak Bazar (Ward no 7)	
		Janiganj (Ward no 7)	Shillong patty road, Central Road (Ward no 23)	
		Shillong patty road, Central Road (Ward no 23)	Rangirkhari, Second link road (Ward no 17)	
		Itkhola (Ward no 3)	Second Link Road (Ward no 16)	
		Ward no 2(centre)	1st link road (Ward no 15)	
		Nutan patty, Malugram Road (Ward no 4)		
		Tarapur Malini beel, Ramnagar, Tarapur chandmari road,Kalimoha Road(Ward 27)		
		Tarapur, Kalibari road (Ward no 24)		
		Ambikapatty Ward no 22 (north east)		
		Rangirkhari (Ward no 20)		

Table 2.5 Number of Persons likely to be affected during flood in different risk Zones

WARDS	LOCALITIES	LOW RISK	MEDIUM RISK	HIGH RISK	VERY HIGH RISK
WARD NO.1	Malugram Road, Itakola Malluram, Itakola Gonaila, Itakola Malluram High School	0	1706	206	1
WARD NO.2	Itakola Road, Itakola Rrya Patty, Itakola Kalibari Road, Itakola Khasia Patty, Itakola	0	1864	733	96
WARD NO.3	Itakola Rerman Road, Rahaman Patty, Daccai Patty, Bani Para, Khasai Patty	0	3680	1823	55

WARD NO.4	Natun patty, daccai patty	0	1609	286	82
WARD NO.5	Rongpur Part 3, Rongpur Part-4 Kadamtala, Rongpur Part-4 Rajpath Road, Rongpur Part-5, Rongpur Kalyan Sarani, Rongpur Angarjur, Rongpur Koratigram Navali, Rongpur Koratigram, Rongpur Gongapara	0	439	0	0
WARD NO.6	Central Road, Ukil Patty, D.c Office, Municipal Office Court, Post office	0	1706	0	0
WARD NO.7	Sadarghat Road, Janiganj Mahavir Magh, Janiganj Kalinari Char, Kalibari Road	0	1411	1889	0
WARD NO.8	Fatak bazar	0	361	724	0
WARD NO.9	Bilpar	0	0	1421	1408
WARD NO.10	Radhamahab Road	0	1973	976	223
WARD NO.11	Ambikapatty, Sunil Sarkar Road, Arun Chanda Road, Desha, Bandhu Road	0	1709	54	0
WARD NO.14	Kanakpur Road, Radha Madrab, College Road, Ramchandran Road, Rammohan Road, Ramsundar Road, Ramakrishna Road,Mahaprbhu Lane, Kali Krishna Road, Mukta ram Road	0	17	1860	0
WARD NO.15	Rabindra Sarant, 1st Link Road	0	262	406	0
WARD NO.16	2nd Link Road	0	840	1957	0
WARD NO.17	Kathal Bagan Road, Mahatma lane, Udayachal Lane, Ekdalia Lane, Rmakrishna Lane, Bankimsarani	0	806	796	0
WARD NO.18	Bankim Lane, Sahati Lane, Indrani Lane, Sundari Mohan Lane, M. M. Park B B D Lane, K C Road (W), Panchayet Road, Srimaa Lane, Happy Valley Road.	0	0	2298	0
WARD NO.19	Cheng Kuri Road, M. A. Lane.	0	0	2209	60
WARD NO.20	Tarani Road, Bhola Giri lane, Rangirkhari	0	0	721	0
WARD NO.21	College Road, Ambikapatty	0	280	471	0
WARD NO.22	Ambikapatty	0	1528	812	138
WARD NO.23		0	527	644	48
WARD NO.24	Trunk Road, PWD Road, Park Road, Tarapur-24,	0	3118	586	0
WARD NO.25	R. K. mission Road, Bishnupur Sil-3, Vivekanand Road Lane 1-3-7-12,	0	1165	1875	554
WARD NO.26	Tarapur T V Centre, Vivekanand Road, Chandmari Malini Road, Ashram Road, Sishu Mandir Area	0	0	978	406
WARD NO.27	Tarapur Gunomoi Road, Tarapur Maluni Hills, Tarapur Malini Beel, Tarapur Mohon Lane	0	185	1632	0
WARD NO.28	Itakola Manipur Para, Itakola Ghat, Itakola Swami Road, Ramnagar	0	105	749	260

INDUSTRIAL HAZARD, VULNERABILITY AND RISK ASSESSMENT

3. INDUSTRIAL HAZARD ZONATION

3.1 Introduction

Industrialization is an emerging large scale global phenomenon since it plays a significant key role in the development of a country or region. India is also considered as one of the fastest developing countries in terms of industrial and technological sector. These have led with the increased in frequency and severity of accidental disasters related to industry. Industries that are processing, manufacturing, refining and storing chemical and petrochemical products are the major sources of industrial hazard that can have a significant effect to the surroundings. It may be recalled the Bhopal gas incident (1984), one of the worst industrial disaster in the global history (NDMA, 2007). Another tragic incident occurred at Hindustan Petroleum Corporation Limited (HPCL) at Vishakhapatnam, 1997. Vapour Cloud Explosion and Fire occurred at Indian Oil Corporation at Sitapur, Jaipur in October, 2009 may also be mentioned as major incident.

In India there are about 1666 Major Accident Hazard Units (MAH) which are handling a large number of chemicals as raw materials, in processing, products, and wastes, with flammable, explosive, toxic properties (NDMA, 2007). These may have an adverse impact on both the community and the environment if any accident occurred in these units. At the same time microclimatic conditions of that area such as wind speed and direction, measurement height, atmospheric stability, cloud cover, relative humidity, etc., also plays an important role in affecting the dispersion pattern of the toxic gas clouds.

3.2 Scope

In Assam, thirty (30) MAH units were identified by Chief of Factories, Govt. of Assam and the entire units are handling mostly petrochemicals except two or three units. It is well known fact that hazardous materials pose a threat to public safety and environment. Chemical disasters, though low in frequency, have the potential to cause significant or long term damage. In today's scenario most of the industrial sites are in densely populated areas. Relocation of these sites or sensitive neighborhood like residential areas, important infrastructural setup is rarely possible. It may be noted that time is a critical factor in the first moments of an accident. A mismanaged response due to lack of preplanning can contribute to raise in fatalities and injuries as well as an increase in damage to property and the environment. The purpose of this study is to provide comprehensive ideas about potentially hazardous units/facilities (MAH) as well as their probable hazardous consequences in terms of spatial coverage. At the same time the information highlighted will be an additional aid to give focus on district level offsite emergency preparedness, response planning (during and after), mock drill, improved safety measures etc,.

3.3 Objectives

The study has been taken up with the following objectives:

- Preparation of industrial hazard / threat zonation maps on 1: 10,000 for Silchar town that may be generated by different hazardous units/ installation.
- Assessment of vulnerability & risk of different key hazards such as toxic release, fire, explosion, etc of Silchar town.

3.4 Methodology

In order to meet the objective of the study a methodology has been designed through integrated approach using the strength of remotely sensed data and GIS. It involves satellite data preparation, pre-field interpretation, field data collection, analysis and preparation of final hazard/threat zonation maps. However, major part of the data used in the analysis was collected through field survey. The broad approach is shown in the flowchart (figure.3.1) Vulnerability is defined as the exposure to risk and an inability to avoid or absorb potential harm (Pelling, 2003). Risk Analysis deals with the use of available information to estimate the risk caused by hazards to individuals or populations, property or the environment, from hazards.

3.5 Hazard, Vulnerability & Risk Assessment

Hazard analysis is a primarily the most important step and overall procedure for evaluating the hazards, consequences, vulnerabilities, probabilities and risk associated with the presence of hazardous material within any given locality or jurisdiction. The present study has been carried out for MAH units identified by chief of factories to estimate the areas of probable threats of key hazards such as toxicity, flammability, thermal radiation and over pressure near a short duration chemical release using ALOHA (Aerial Locations of Hazardous Atmosphere) software developed by National Oceanic and Atmospheric Administration (NOAA) and U.S. Environmental Protection Agency (EPA). Each key hazards or threat zones show an overhead view of the regions in the atmosphere with specific Level of Concerned (LOC) i.e. a threshold value of a hazard above which a threat to people or property may exist. The type of the LOC is depending on the scenario. For toxic gas dispersion scenarios, an LOC is a threshold concentration of the gas at ground level above

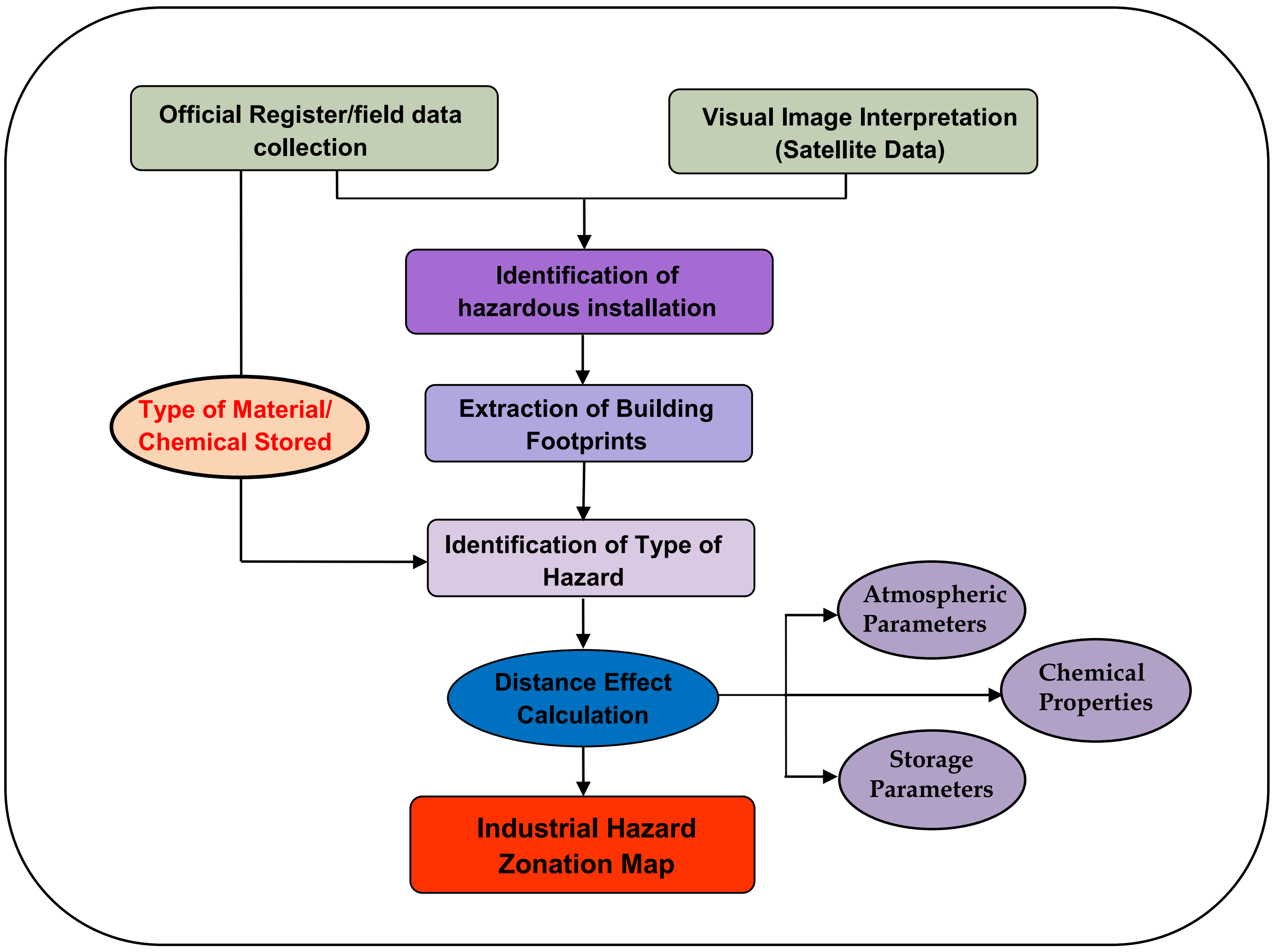


Figure 3.1 Methodology Flowchart for Hazard Analysis

which a hazard is believed to exist. Each LOC estimates a threat zone where the hazard is predicted to exceed that LOC at some time after a release begins. Toxic LOC also referred as exposure limits, exposure guidelines, or toxic endpoints and expressed by an exposure guidelines designed to help the emergency responders known as Acute Exposure Guideline Levels (AEGLs). AEGLs estimate the concentrations in terms of ppm or percentage at which most people including sensitive individuals such as old, sick, or very young people will begin to experience health effects if they are exposed to a toxic chemical for a specific length of time (duration). Toxic Level of Concern such as Protective Action Criteria (PACs) defined by U. S Department of Energy is also used when AEGLs and ERPGs are not available. A flammable Level of Concern (LOC) is a threshold concentration of a fuel in the air above which a flammability hazard may exist. It is the prediction of flammable area i.e. part of a flammable vapour cloud where the concentration is in the flammable range between Lower and Upper Explosive limits (LEL & UEL) which is also known as Lower and Upper Flammability limits. It is expressed in terms of percentage. A thermal radiation Level of Concern (LOC) is a threshold level of thermal radiation (heat) above which a hazard may exist. This radiation may be from pool fire, jet fire, or Boiling Liquid Expanding Vapour Explosion (BLEVE) and expressed in terms of kilowatts per square meter. An overpressure Level of Concern (LOC) is a threshold level of pressure from a blast wave, usually the pressure above which a hazard may exist and expressed in terms of pounds per square inch (psi). Each hazard/threat zone is shown in different colours such as red, orange and yellow. The red zone represents the worst hazard and the orange and yellow zones represent areas of decreasing hazards. An uncertainty dashed line also known as confidence line enclosed each hazard zones if there is a change under atmospheric stability of A, B and C. Vulnerability Assessment includes database preparation- the collection of information on socio-economic and buildings of different use/type, field survey, design of questionnaire for building inventory, ancillary data, etc. Risk assessment in its broad definition is a structured procedure that evaluates qualitatively and/or quantitatively the level of risk imposed by the hazard sources. In this project work risk assessment was done for buildings and population for fire, explosion and toxic release hazard separately. Risk for the study area was calculated by combining results of hazard and vulnerability assessment and are categorized into 'very high', 'high', 'moderate', 'low' and 'very low' risk.

In Silchar town, inside the municipal boundary there are no identified MAH units so far in the government record. However, in the North West corner of boundary with a radial distance of 0.5 km. Ramnagar IOCL storage facility (figure. 3) was located as one of the identified MAH unit and it has considered for the analysis since it is very near/closed to

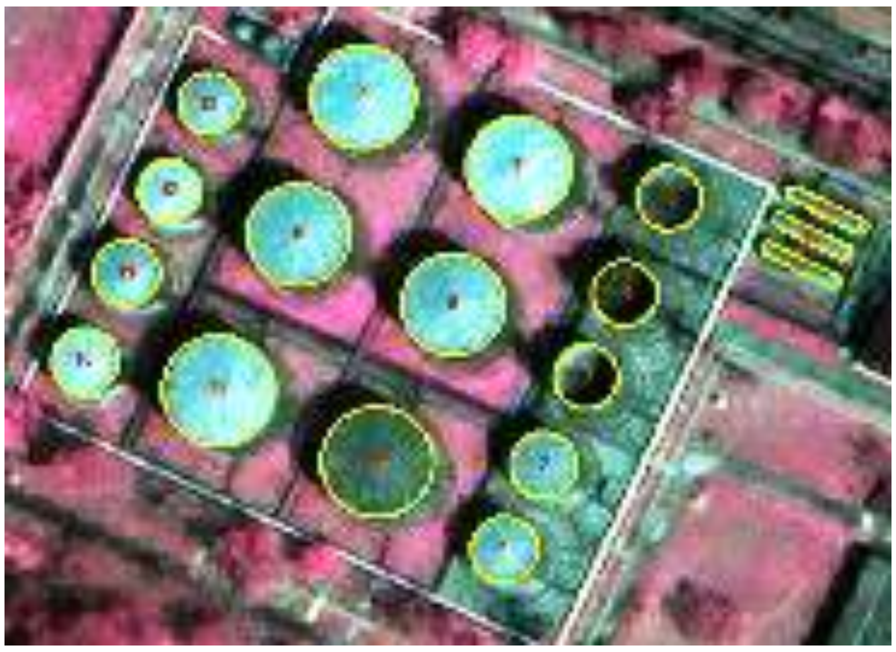


Figure 3.2 Ramnagar Storage facility, Silchar

municipal area. In this facility, the analysis of thirteen storage tanks of various petrochemical products such as motor spirit, high speed diesel and superior kerosene oil has been carried out. For this purpose 3rd September, 2009, 15.30 hours were chosen. At this time the air temperature recorded was 36.49° C and the prevalent wind speed and direction was 0.89 meters/second from 358.99° true north. The relative humidity was 50%, cloud cover 3 tenths with atmospheric stability class B. The resultant hazard map for selected storage tank of various products analyzed using the parameters mentioned is given in figure 3.3 to 3. 6. And also the overall scenario for each analyzed tank is given from table no. 3.1 to 3.13.

3.5.1 Vulnerability Assessment for Industrial Hazard

Building vulnerability for Industrial hazard was assessed for four different industrial hazards - Pool Fire, Vapour Cloud Explosion (VCE), Boiling Liquid Expanding Vapour Explosion (BLEVE) and Toxic Release in Silchar town.

3.5.1.1 Building Vulnerability for Pool Fire

A pool fire hazard vulnerability assessment for the detailed study areas was base on certain parameters, such as; building construction type characterized by the type of wall material and roof material. Weightages was assigned to different parameters/themes depending on the severity observed in the local conditions. The weightages of the themes were having value from 1 (low) to 10 (high), based on the construction material. Roof material was considered to be the most important parameter for the fire hazard because once a building is gutted by fire will easily spread to the neighbouring buildings if they have same type of roof material. Thus maximum weightage 10 was assigned to the roof material. Buildings materials (i.e. wall material) is another important parameter and thus assigned with the weightage of 3. It is also to mention here that other factors were not taken into account, such as space between individual buildings, or the distance to water bodies. The building vulnerability assessment in case of pool fire hazard was calculated using the following formula:

Pool Fire Vulnerability = {0.77 (Rank of Roof Material) + 0.23* (Rank of Building Material)*

Based on the weightages and ranks for different parameters, buildings in the mapping unit were identified by a certain degree of vulnerability in terms of high, medium and low. The vulnerability value for pool fire ranges from 2 to 15. Based on this range vulnerability index was considered where value 2 to 4 represents low, 5 to 9 represents medium and 10 to 15 represents the high category.

Building Vulnerability map for pool fire hazard in Silchar town was prepared on the basis of characteristics of the buildings (Figure 3.8).

3.5.1.2 Building Vulnerability for VCE

The building vulnerability assessment for the Vapour Cloud Explosion hazard was prepared based on certain parameters, such as; building material (wall material), roof material and number of stories of buildings. Weightages was assigned to different parameters/themes depending on the effect of vapour cloud explosion and severity observed in the local condition. Roof material was considered to be the most important parameter for vapour cloud explosion because the roof collapse might be one of the most direct effects of the explosion. Thus maximum weightage 10 was assigned to roof material. Building material, the next important parameter, was given weightage value of 6. The third important parameter taken into consideration was number of stories of a particular building. In case of an explosion event there is a chance of taller buildings will get much more effected which make leads to more vulnerable. Thus for vulnerability assessment of building this parameter was assigned to a weightage of 5. The building vulnerability assessment in case of vapour cloud explosion was calculated using the following formula:

VCE Vulnerability = {0.43* *(Rank of Roof Material) + 0.35* (Rank of Building Material) + 0.22* (Rank of No. of stories).*

After calculating the total weight value, buildings were classified in a degree of vulnerability in terms of high, medium and low. For VCE the vulnerability value ranges from 2 to 13. The vulnerability index was prepared based on this range where value 2 to 3 represents low category, 4 to 9 represents medium category while 10-15 represents high category.

Building Vulnerability map for Vapour Cloud Explosion hazard in Silchar town was prepared on the basis of characteristics of the buildings (Figure 3.9).

3.5.1.3 Building Vulnerability for BLEVE

Boiling Liquid Expanding Vapour Explosion is a consequence of explosion results from fireballs or from flame jets. Thus it is much more hazardous with respect to population as well as for buildings. For BLEVE, building vulnerability was assessed based on certain parameters, such as building construction type (wall material), roof material and number of stories. Weightages was assigned to different parameters depending on the severity observed in the local condition. The number of stories of a building is the prime important factor for the BLEVE hazard because if in between a building and the source of BLEVE a taller building would be there then it might be protect the smaller one though it depends on also the direction from which the BLEVE comes. Thus this parameter was assigned with a weightage of 10. Roof material and building material were assumed to be the next most important parameters because of their strength to withstand the explosion. Thus a weightage of 8 was assigned to both roof materials as well to building material. The building vulnerability assessment in case of boiling vapour cloud explosion was calculated using the following formula:

BLEVE Vulnerability = {0.38 (Rank of 'number of Stories') + 0.26* (Rank of 'Roof Material') + 0.26* (Rank of Building Material')}*

Using the above mentioned weightages and ranks to the different parameters each individual building were assigned by a certain degree of vulnerability in terms of high, medium and low. For BLEVE the vulnerability value ranges from 2 to 11. The vulnerability index was prepared based on this range where value 2 to 3 represent low category, 4 to 6 represent medium category and 7 to 11 represents high categories.

Building Vulnerability map for BLEVE hazard in Silchar town was prepared on the basis of characteristics of the buildings (Figure 3.7).

3.5.1.4 Building Vulnerability for Toxic Release

Also an assessment was made for the vulnerability related to toxic release hazard based on the same parameters above mentioned. For toxic release hazard, the air tight condition of the building was considered to be the most important factor. In case of a toxic release event if the building is air tight then there will be less chance for people to inhale the toxic gas which is harmful for their health. Therefore, the maximum weightage 10 was assigned to the air tight condition of the building. But if a building is far away from the source of toxic release in that case there will be less probability for the people might be affected though the building is not at all air tight. However, this aspect will be taken into account in risk assessment, where the vulnerability and hazard factors are combined. The height of a building is also an important parameter for building vulnerability assessment in case of toxic release. Normally toxic gas is heavier than air. So it will float over the surface. So in toxic release event the short building are much more vulnerability than the tall buildings. Thus the number of stories was considered to the next important factor and assigned a weightage of 8. The air tight condition of a building mainly depends on roof material. These two parameters are thus assigned with a weightage of 2. For building vulnerability assessment in case of toxic release, the formula used was as follows:

TR Vulnerability = [0.46(Rank of Air Tight Condition) + 0.36* (Rank of No. of stories) + 0.09* (Rank of Building Material) + 0.09* (Rank of Roof Material).*

Using the above mentioned query each individual building was assigned by a certain degree of vulnerability in terms of high, medium and low. For toxic release the vulnerability value ranges from 1 to 10. The vulnerability index was prepared based on this range where value 1 to 3 represents low category, 4 to 6 represents medium category and 7 to 10 represents high category.

Building Vulnerability map for toxic release hazard in Silchar town was prepared on the basis of characteristics of the buildings (Figure 3.10).

3.5.2 Risk Assessment for Industrial Hazard.

In Sichar town, risk assessment for industrial hazards was carried out for the following:

3.5.2.1 Risk Assessment for Pool Fire

Risk map for pool fire hazard in Silchar town was prepared on the basis of vulnerability and hazard map (Figure 3.12).

3.5.2.2 Risk Assessment for VCE

Risk map for VCE hazard in Silchar town was prepared on the basis of vulnerability and hazard map (Figure 3.11). The study area was categories in to high, medium, low and no risk based on the number of scenarios from where there might be a chance to get affected.

3.5.2.3 Risk Assessment for BLEVE

Risk map for BLEVE hazard in Silchar town was prepared on the basis of vulnerability and hazard map (Figure 3.13).

3.5.2.4 Risk Assessment for Toxic Release

Risk map for toxic release hazard in Silchar town was prepared on the basis of vulnerability and hazard map (Figure 3.14).

3.6 Results and Discussion

The purpose of this project is to provide a comprehensive idea about potentially hazardous units/facilities (MAH) within or at the periphery of the study area as well as their probable hazardous consequences in terms of spatial coverage using very high resolution remotely sensed data, Areal Locations of Hazardous Atmosphere (ALOHA) and ArcGIS software and extensive field surveys. Hazard zonation (such as toxicity, flammability, thermal radiation, overpressure (blast force)) for each and every tank storing different chemical/petrochemical products of various facilities were generated by using the ALOHA software. In the process it has been analyzed the atmospheric data collected by Automatic Weather Station (AWS) for last three years and considered a particular time of a day of a month of the year where the highest daily maximum temperature was recorded and also the current atmospheric conditions such as wind speed, direction, humidity, cloud cover etc. at that time. At the same time data collected through extensive field surveys such as type of chemical, quantities, storage conditions (vertical or horizontal tank, sphere and their numbers) for each units were also incorporated in the analysis. The final hazard zonation map does generated using ALOHA shows an overhead view of the regions predicting specific levels of concern (LOC) of various key hazards mentioned above for different chemical or products. And again it was imported in GIS and overlaid on satellite data for further assessment of vulnerability and associated frisk.

In Silchar Town, Ward no 26 and 28 is very much vulnerable to all the four industrial hazards like BLEVE, Pool Fire, Vapour Cloud and Toxic Release. From The Risk point of view also Ward no 28 is highly affected by these hazards. Areas under different Vulnerability Zones for BLEVE, Pool Fire, Toxic Release and Vapour Cloud are in table 3.14, 3.15, 3.16, 3.17 respectively.

Areas under different Risk zones are presented in table 3.18 for BLEVE, 3.19 for Vapour Cloud, 3.20 for Toxic Release and 3.21 for Pool Fire. Numbers of persons likely to be affected are presented in Table 3.22 for BLEVE, Table 3.23 for Pool Fire, Table3.24 for Toxic Release and table 3.25 for Vapour Cloud.

3.7 Limitations

The chemical database of ALOHA doesn't contain complex hydrocarbon mixtures e.g. petroleum products. The predictions are not more than one hour after the release begins or for a distance of more than 10 km from the released points i.e. it truncates threat/hazard zones that are longer than 10 km. It doesn't include the byproducts of combustion (e. g., smoke) or chemical reactions, hazardous fragments (e.g., flying debris from the container and the surrounding area if a chemical release involves an explosion) and sharing of data due to security reasons.

3.8 Conclusion and Recommendation

3.8.1 Conclusion

The study was carried out giving emphasis to those MAH units identified by the Chief of Factories, Government of Assam which is falling within the boundary of the four study area such as Guwahati City, Townships of Silchar and Dibrugarh as well as Dhemaji District. However, Dibrugarh Town and Dhemaji District has been excluded since there are no identified MAH units within the study area or at the periphery in the government record as well as through field verification. In the entire process of the study an attempt has been made to estimate the areas near a short-duration of chemical release and their probable threats of various key hazards such as-toxicity, flammability, thermal radiation, over pressure etc. to provide first hand ideas for emergency responders as well as further assessment of vulnerability and associated risk. The generation of entire hazard/threat zones of various chemicals for different MAH units located at different places has been carried out by setting a constant time of a particular day of a month of the year and prevailing local atmospheric condition at that time to have the maximum extent in terms of spatial coverage. At the same time very high resolution remotely sensed data has played a significant role in the identification of various storage facilities, in delineation of individual tanks, interpretation of various existing natural and man-made features etc. It may be noted that if any accident happened in any of the MAH units the extent of the hazard/threat zones may not be same as analyzed above due to various reasons.

Vulnerability of Industrial hazards like BLEVE, Vapour Cloud, Toxic release, Pool Fire was studied in this work. According to vulnerability the town was divided into High, medium, low zone. Ward no 2, 24, 25, 26 are mostly affected by BLEVE hazard. For Pool Fire hazard ward no 1, 2, 3, 7, 26, 28 are mostly affected. Almost all the wards are vulnerable for Toxic release hazard. In case of Vapour cloud, small portion of the wards 1, 2, 3, 26 are highly vulnerable.

Risk for these hazards also estimated for the Silchar town. In Silchar town, the risk of industry is more on the population of in ward 28 and 27. Maximum effect on the population is mostly if BLEVE takes place. Approximately 1249 no of persons are likely to be affected by BLEVE and 15 are by Vapour cloud in the study area.

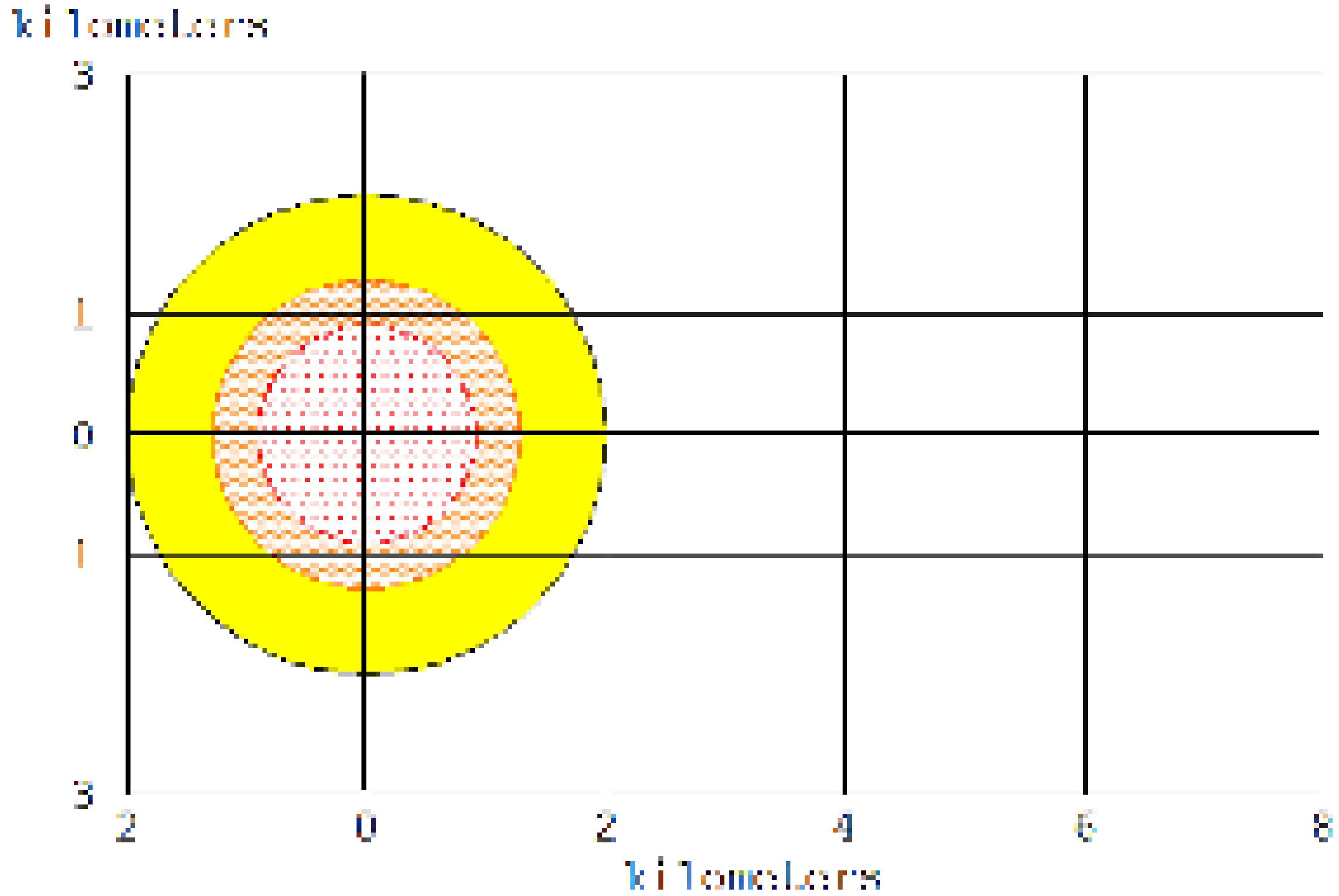
In Silchar town, the effect of industry on the population is mostly in ward 28 and 27. Maximum effect on the population is mostly if BLEVE takes place.

3.8.2 Recommendation

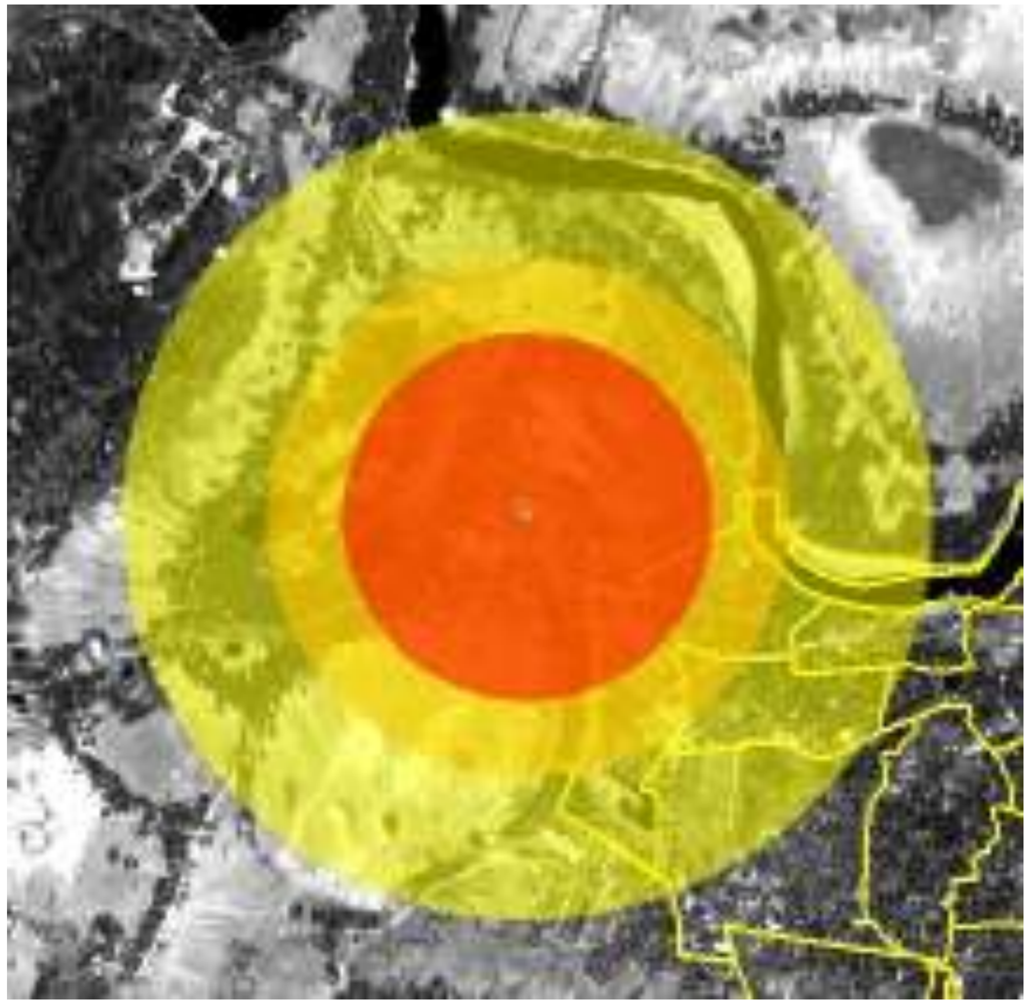
It may be mentioned that such type of studies i.e. the aerial extent estimation of possible threat zones from hazards like toxicity, fire, explosion the following points may be taken into consideration for emergency preparedness, during and after as well as future planning.

a. The output may be considered an important input for emergency preparedness, personnel for first emergency responders, improving the existing safety measures, trial mock drill etc. It may also provide an idea of direction to start evacuation of general public during emergency.
b. First responders must take the necessary precautions to protect themselves and others from the overpressure and hazardous fragments if a boiling liquid expanding vapour pressure is likely to occur since it is generally associated with high pressure explosion.
c. It can be used for the industrial planners, decision makers as a guide map in the process of site selection and installation of any storage facilities handling flammable products like LPG, motor spirit, diesel etc. along with the very high resolution remotely sensed data where it plays a significant role in providing the real time and past information of the earth's surface.
d. In addition it can be used as an essential parameter in carrying out of environmental impact assessment for such type of installation.
e. The areas under risk zones should be avoided for future urban development. Mitigation measures like retrofitting of buildings, in case of weak structures can be carried out.
f. GIS for its functional capability of data capturing, input, manipulation, transformation, combination, query, analysis of multiple data in different formats provides an interface for integration and bring into a detail single output map which enables the planners or decision makers to visualize them spatially.

Figure 3.3 Thermal radiation (heat) from BLEVE -Tank no. 1- Superior Kerosene Oil (SKO) Vertical Tank, Ramnagar Storage, Silchar



Threat/hazard zones modelled by Areal Locations of Hazardous Atmosphere (ALOHA)



Threat/hazard zones overlaid on ward boundary and satellite data

PRODUCT NAME - SUPERIOR KEROSENE OIL (SKO)
STORAGE: VERTICAL TANK
DIAMETER: 10m
LENGTH/HEIGHT: 9.13m
CAPACITY: 640 KL
MODEL RUN: BOILING LIQUID EXPANDING VAPOUR EXPLOSION (BLEVE)

THREAT ZONE

Red: 910 meters-(10.0 kW/(sq m) = potentially lethal within 60 sec)

Orange: 1.3 kilometers-(5.0 kW/(sq m)=2nd degree burns within 60 sec)

Yellow: 2.0 kilometers- (2.0 kW/(sq m)=pain within 60 sec)

The overall Hazard Scenario of Tank No.1 (SKO) is given in table no. 3.1

Table 3.1 Overall Scenario of Tank No. 1 Superior Kerosene Oil (SKO) Vertical Tank, Ramnagar Storage, Silchar

Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	135 meters	4.9 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	910 meters	1.3 Kilometers	2.0 Kilometers

Table 3.2 Overall Scenario of Tank No. 2 Superior Kerosene Oil (SKO) – Vertical Tank, Ramnagar Storage, Silchar

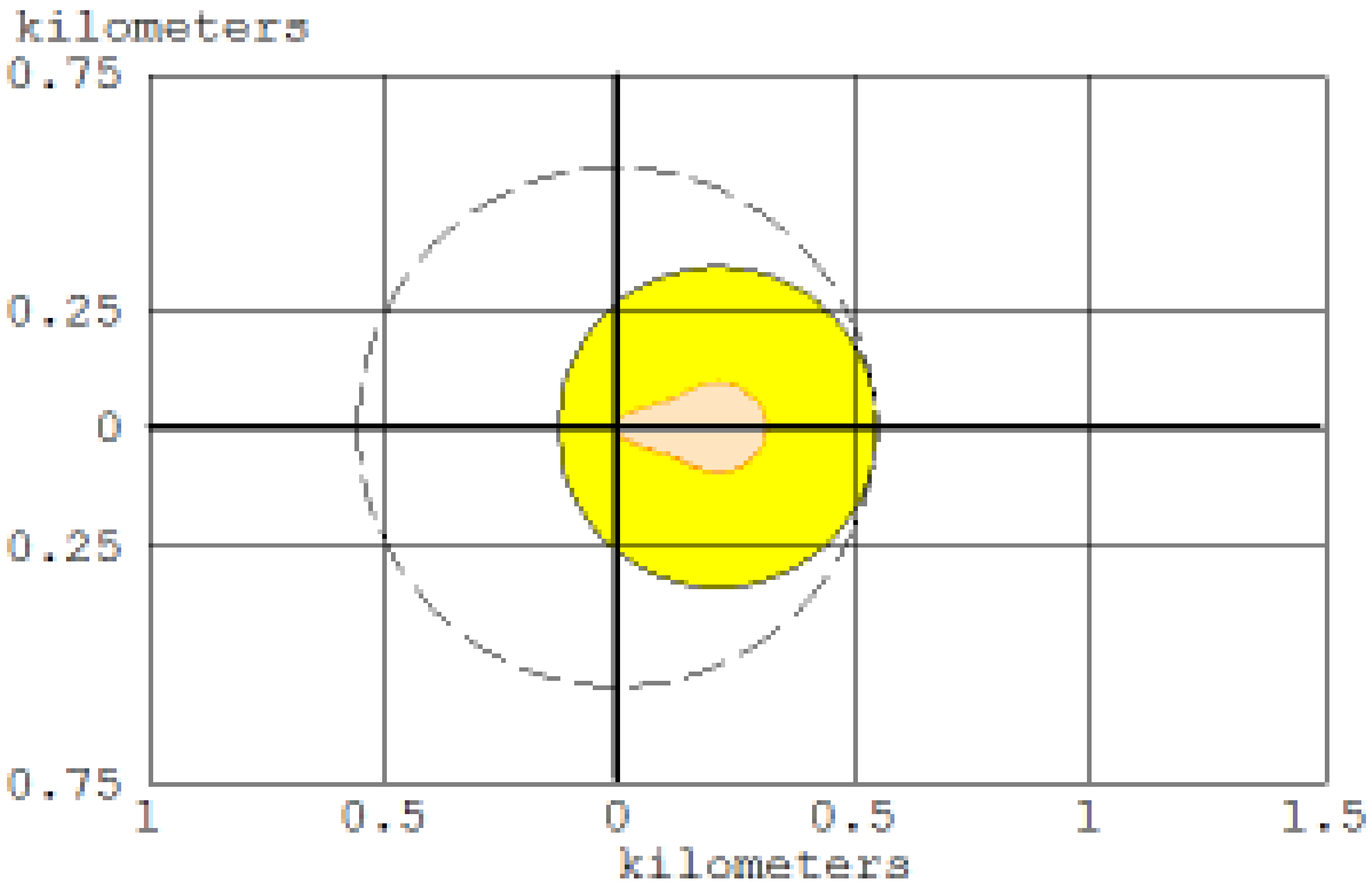
Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	135 meters	4.9 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	910 meters	1.3 Kilometers	2.0 Kilometers

Table 3.3 Overall Scenario of Tank No. 3 Motor Spirit (MS), Vertical Tank, Ramnagar Storage, Silchar

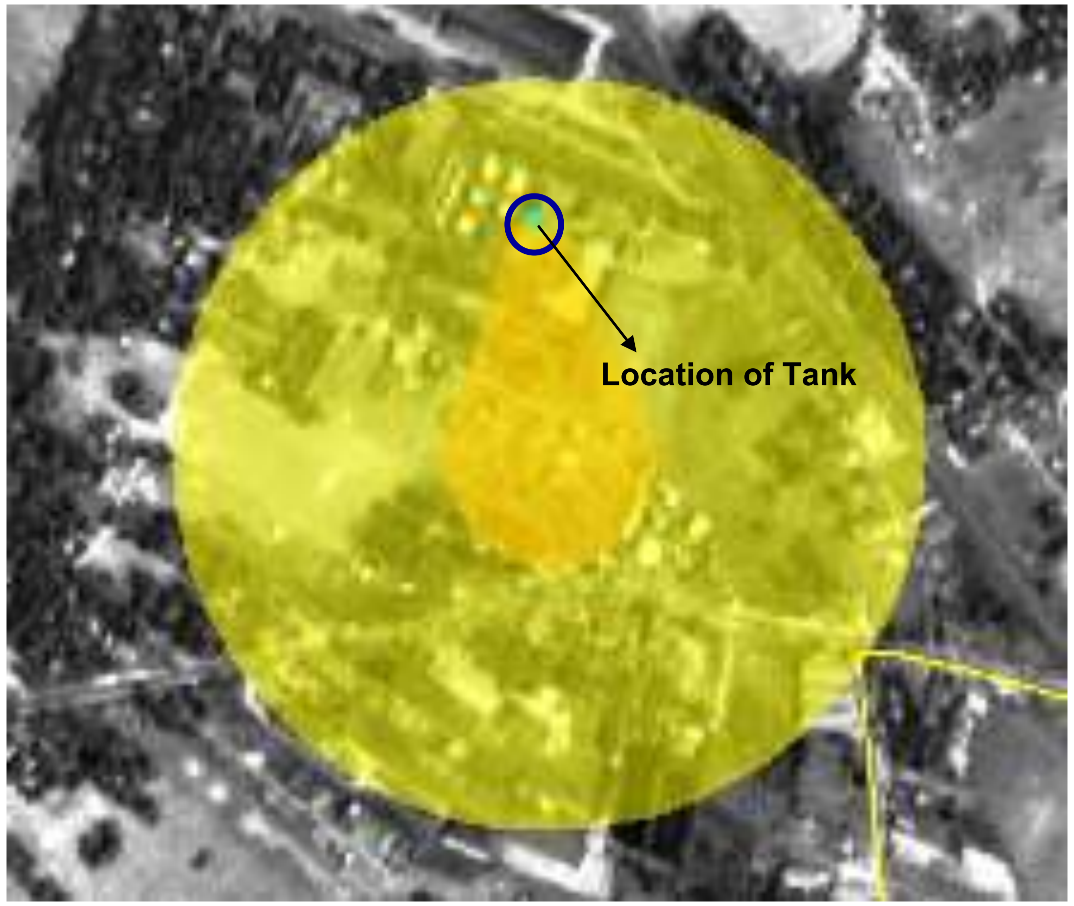
Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	372 meters	530 meters	No recommended LOC value
Flammable Area	Thermal Radiation if a flash fire occurs	396 meters	....	890 meters
Vapour Cloud Explosion (Congested)	Overpressure	LOC never exceeded	317 meters	553 meters
Pool Fire	Thermal Radiation	366 meters	508 meters	778 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	870 meters	1.2 Kilometers	1.9 Kilometers

Note: The table given above provides the hazard/threat zone information of each tank analyzed for the respective storage facility and different products. It is also important to note that the effect area or hazard/threat zone are mainly depends on the type of hazard modeled, physical and chemical properties of the products. Some of the tank shows same hazard/threat zone due to various reasons such as same size, storage capacity and product as well as same prevailing local atmospheric condition e.g. winds speed & direction, temperature, relative humidity etc. collected at a particular time of a day of the month of a year. It is also found that the impacts of Vapour Cloud Explosion (VCE) are mostly confined within the premises of the storage facility compared to other hazards modeled.

Figure 3.4 Blast Area of Vapour Cloud Explosion-Tank no. 4 Motor Spirit (MS), Vertical Tank, Ramnagar Storage, Silchar



Threat/hazard zones modelled by Areal Locations of Hazardous Atmosphere (ALOHA)



Threat/hazard zones overlaid on ward boundary and satellite data

PRODUCT NAME – MOTOR SPIRIT (MS)
STORAGE: VERTICAL TANK
DIAMETER: 10m
LENGTH/HEIGHT: 16m
CAPACITY: 620 KL
MODEL RUN: VAPOUR CLOUD EXPLOSION (VCE)

THREAT ZONE

Red : LOC was never exceeded - (8.0 psi = destruction of buildings)
Orange: 317 meters - (3.5 psi = serious injury likely)
Yellow: 553 meters - (1.0 psi = shatters glass)
– – – - : Confidence line

The overall Hazard Scenario of Tank No.4 (MS) is given in table no. 3.4

Table 3.4 Overall Scenario of Tank No. 4 Motor Spirit (MS), Vertical Tank, Ramnagar Storage, Silchar

Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	372 meters	530 meters	No recommended LOC value
Flammable Area	Thermal Radiation if a flash fire occurs	396 meters	…………	890 meters
Vapour Cloud Explosion (Congested)	Overpressure	LOC never exceeded	317 meters	553 meters
Pool Fire	Thermal Radiation	366 meters	508 meters	778 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	870 meters	1.2 Kilometers	1.9 Kilometers

Table 3.5 Overall Scenario of Tank No. 5 Motor Spirit (MS), Vertical Tank, Ramnagar Storage, Silchar

Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	372 meters	530 meters	No recommended LOC value
Flammable Area	Thermal Radiation if a flash fire occurs	396 meters	…………	890 meters
Vapour Cloud Explosion (Congested)	Overpressure	LOC never exceeded	317 meters	553 meters
Pool Fire	Thermal Radiation	366 meters	508 meters	778 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	870 meters	1.2 Kilometers	1.9 Kilometers

Table 3.6 Overall Scenario of Tank No. 6 High Speed Diesel (HSD), Vertical Tank, Ramnagar Storage, Silchar

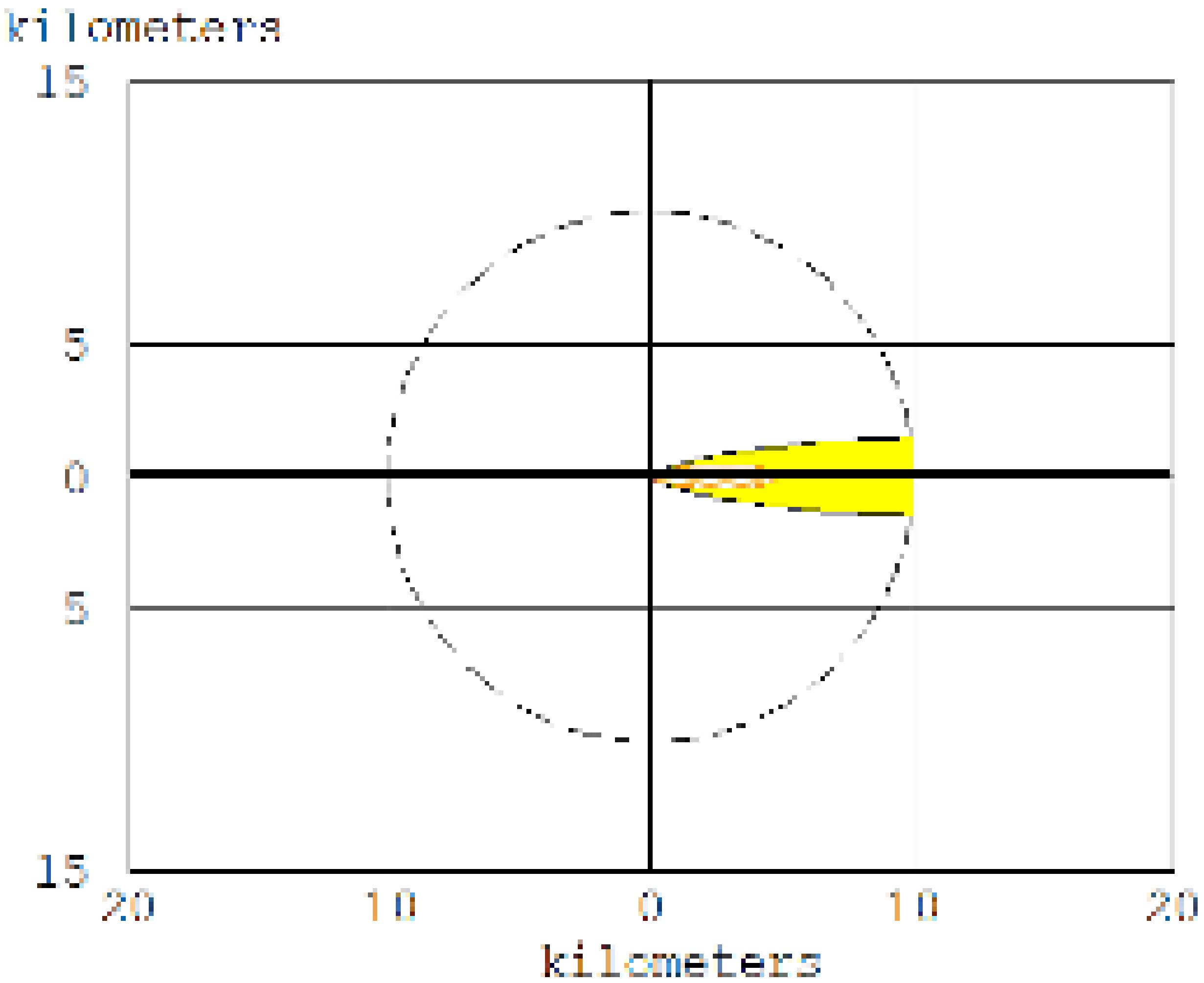
Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	135 meters	4.9 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	1.3 kilometers	1.8 Kilometers	2.9 Kilometers

Table 3.7 Overall Scenario of Tank No. 8 Superior Kerosene Oil (SKO), Vertical Tank, Ramnagar Storage, Silchar

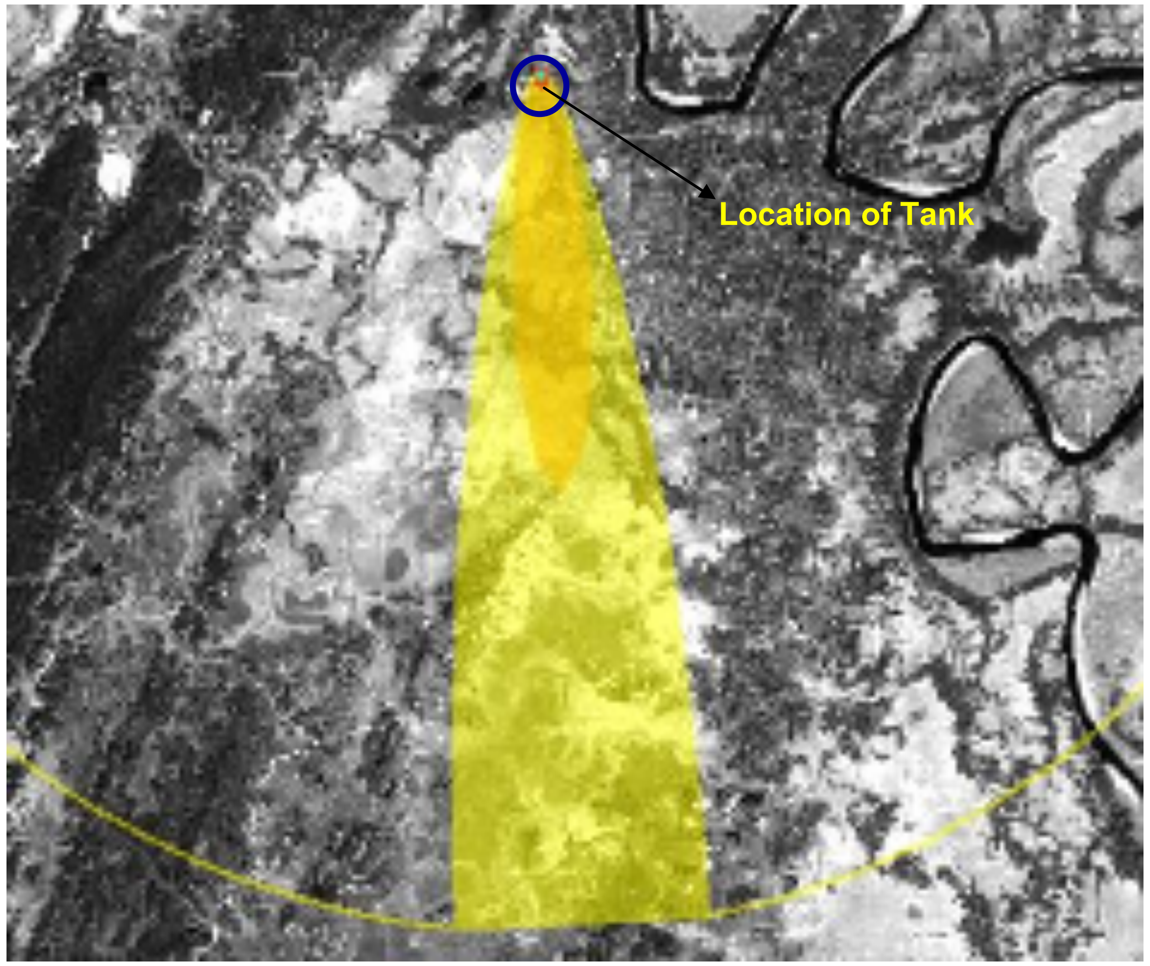
Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	135 meters	4.9 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	1.3 kilometers	1.8 Kilometers	2.9 Kilometers

Note: The table given above provides the hazard/threat zone information of each tank analyzed for the respective storage facility and different products. It is also important to note that the effect area or hazard/threat zone are mainly depends on the type of hazard modeled, physical and chemical properties of the products. Some of the tank shows same hazard/threat zone due to various reasons such as same size, storage capacity and product as well as same prevailing local atmospheric condition e.g. winds speed & direction, temperature, relative humidity etc. collected at a particular time of a day of the month of a year. It is also found that the impacts of Vapour Cloud Explosion (VCE) are mostly confined within the premises of the storage facility compared to other hazards modeled.

Figure 3.5 Toxic Area of Vapour Cloud-Tank no. 7 - High Speed Diesel (HSD), Vertical Tank, Ramnagar Storage, Silchar



Threat/hazard zones modelled by Areal Locations of Hazardous Atmosphere (ALOHA)



Threat/hazard zones overlaid on ward boundary and satellite data

PRODUCT NAME – HIGH SPEED DIESEL (HSD)
STORAGE: VERTICAL TANK
DIAMETER: 10m
LENGTH/HEIGHT: 16m
CAPACITY: 2000 KL
MODEL RUN: TOXIC AREA OF VAPOUR CLOUD

THREAT ZONE

Red : 141 meters - (7.9 ppm = PAC-3)
Orange: 4.9 kilometers - (0.031 ppm = PAC-2)
Yellow: greater than 10 kilometers - (0.0028 ppm = PAC-1)
– – – – : Confidence line

The overall Hazard Scenario of Tank No.7 (HSD) is given in table no. 3.8

Table 3.8 Overall Scenario of Tank No. 7 High Speed Diesel (HSD), Vertical Tank, Ramnagar Storage, Silchar

Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	135 meters	4.9 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	1.3 kilometers	1.8 Kilometers	2.9 Kilometers

Table 3.9 Overall Scenario of Tank No. 9 Superior Kerosene Oil (SKO), Vertical Tank, Ramnagar Storage, Silchar

Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	135 meters	4.9 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	1.3 kilometers	1.8 Kilometers	2.9 Kilometers

Table 3.10 Overall Scenario of Tank No. 18 High Speed Diesel (HSD), Horizontal Tank, Ramnagar Storage, Silchar

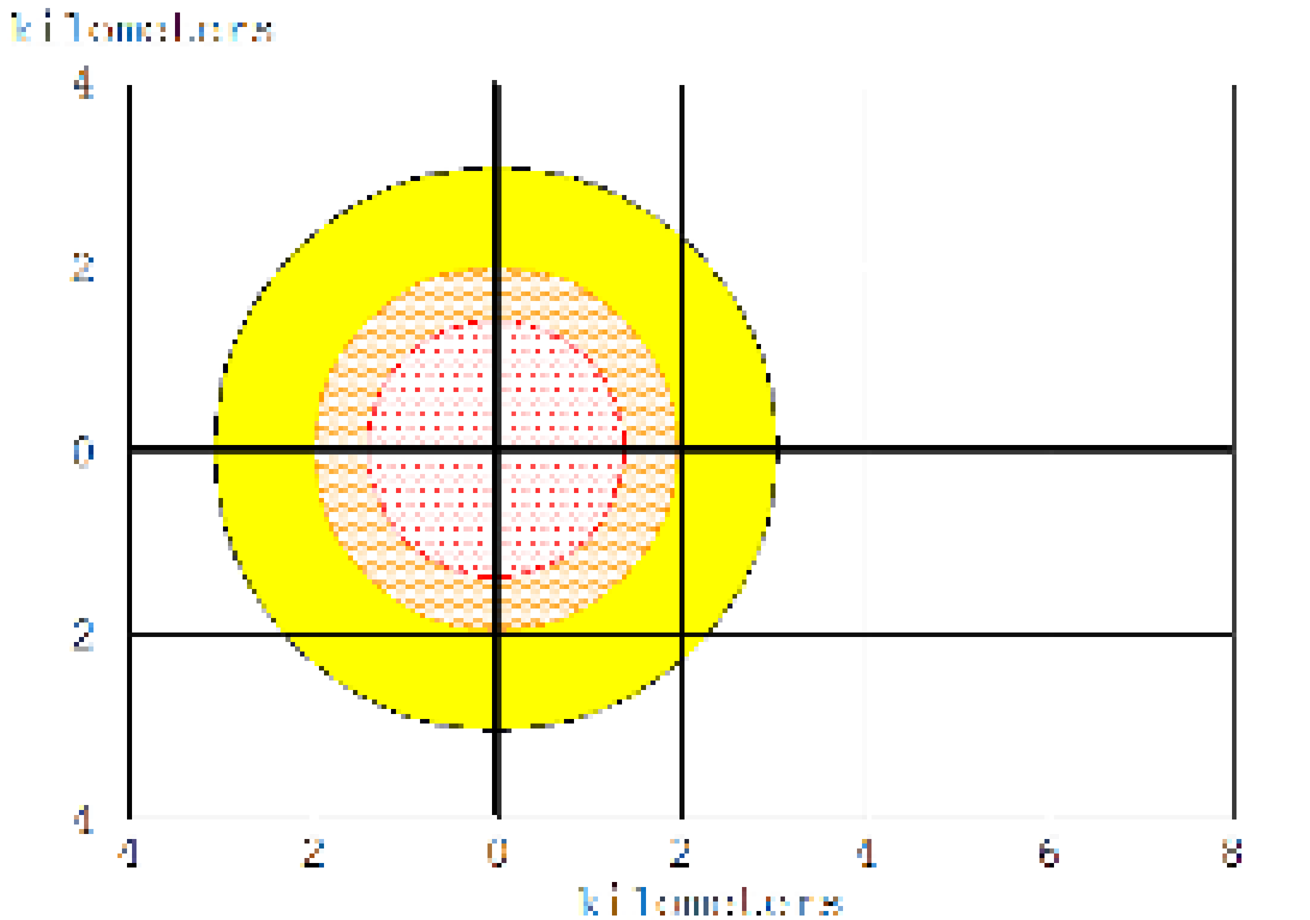
Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	113 meters	4.0 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	507 meters	716 meters	1.1 Kilometers

Table 3.11 Overall Scenario of Tank No. 19 Superior Kerosene Oil (SKO) Horizontal Tank, Ramnagar Storage, Silchar

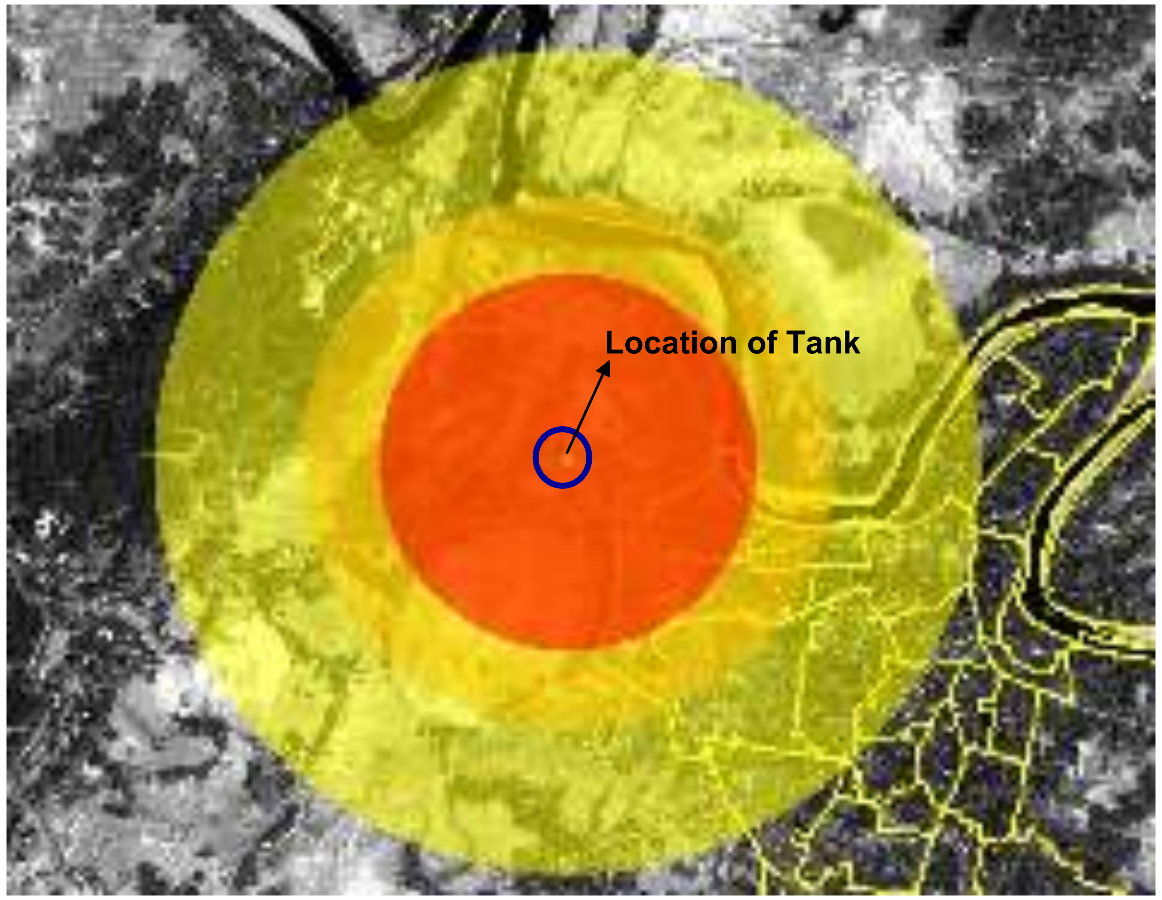
Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	113 meters	4.0 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	507 meters	716 meters	1.1 Kilometers

Note: The table given above provides the hazard/threat zone information of each tank analyzed for the respective storage facility and different products. It is also important to note that the effect area or hazard/threat zone are mainly depends on the type of hazard modeled, physical and chemical properties of the products. Some of the tank shows same hazard/threat zone due to various reasons such as same size, storage capacity and product as well as same prevailing local atmospheric condition e.g. winds speed & direction, temperature, relative humidity etc. collected at a particular time of a day of the month of a year. It is also found that the impacts of Vapour Cloud Explosion (VCE) are mostly confined within the premises of the storage facility compared to other hazards modeled.

Figure 3 6 Thermal radiation (heat) from BLEVE -Tank no. 22 – High Speed Diesel (HSD), Vertical Tank, Ramnagar Storage, Silchar



Threat/hazard zones modelled by Areal Locations of Hazardous Atmosphere (ALOHA)



Threat/hazard zones overlaid on ward boundary and satellite data

PRODUCT NAME – HIGH SPEED DIESEL (HSD)
STORAGE: VERTICAL TANK
DIAMETER: 11m
LENGTH/HEIGHT: 17.5m
CAPACITY: 2500 KL
MODEL RUN: : BOILING LIQUID EXPANDING VAPOUR

THREAT ZONE

Red: 1.4 kilometers- (10.0 kW/(sq m)=potentially lethal within 60 sec)

Orange: 2.0 kilometers-(5.0 kW/(sq m)=2nd degree burns within 60 sec)

Yellow: 3.1 kilometers - (2.0 kW/(sq m)=pain within 60 sec)

The overall Hazard Scenario of Tank No. 22 (HSD) is given in table no. 3.12

Table 3.12 Overall Scenario of Tank No. 22 High Speed Diesel (HSD), Vertical Tank, Ramnagar Storage, Silchar

Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	141 meters	5.0 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	1.4 kilometers	2.0 kilometers	3.1 Kilometers

Table 3.13 Overall Scenario of Tank No. 23 High Speed Diesel (HSD), Vertical Tank, Ramnagar Storage, Silchar

Scenario	Threat/Hazard Modeled	Red Zone	Orange Zone	Yellow Zone
Toxic Dispersion	Toxicity	141 meters	5.0 kilometers	Greater than 10 kilometers
Flammable Area	Thermal Radiation if a flash fire occurs	LOC was never exceeded		
Vapour Cloud Explosion (Congested)	Overpressure	No explosion: no part of the cloud is above the LEL at any time		
Pool Fire	Thermal Radiation	349 meters	478 meters	723 meters
BLEVE (Boiling liquid expanding vapour explosion)	Thermal Radiation	1.4 kilometers	2.0 kilometers	3.1 Kilometers

Note: The table given above provides the hazard/threat zone information of each tank analyzed for the respective storage facility and different products. It is also important to note that the effect area or hazard/threat zone are mainly depends on the type of hazard modeled, physical and chemical properties of the products. Some of the tank shows same hazard/threat zone due to various reasons such as same size, storage capacity and product as well as same prevailing local atmospheric condition e.g. winds speed & direction, temperature, relative humidity etc. collected at a particular time of a day of the month of a year. It is also found that the impacts of Vapour Cloud Explosion (VCE) are mostly confined within the premises of the storage facility compared to other hazards modeled.

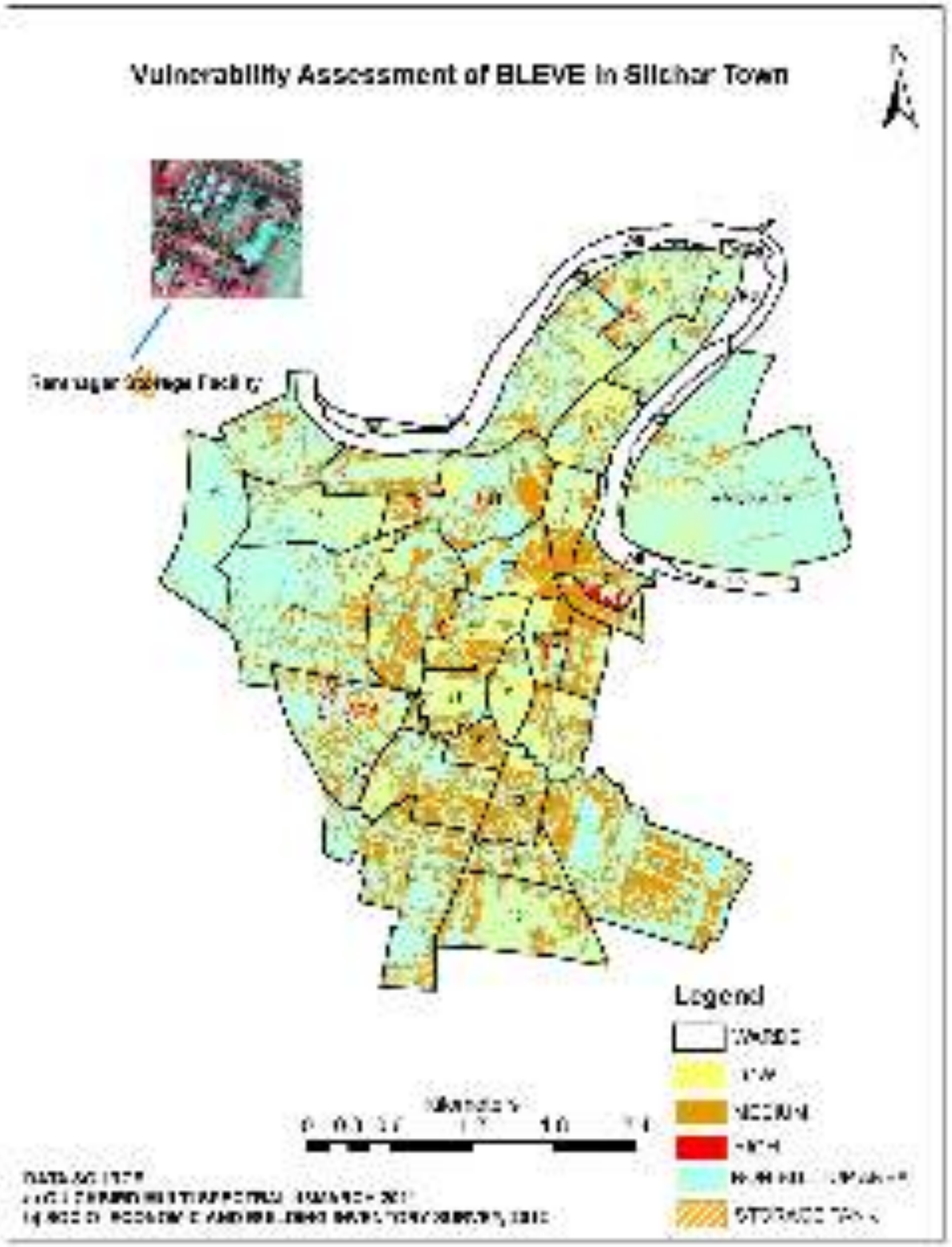


Figure 3.7 Building Vulnerability for Boiling Liquid Expanding Vapour Explosion

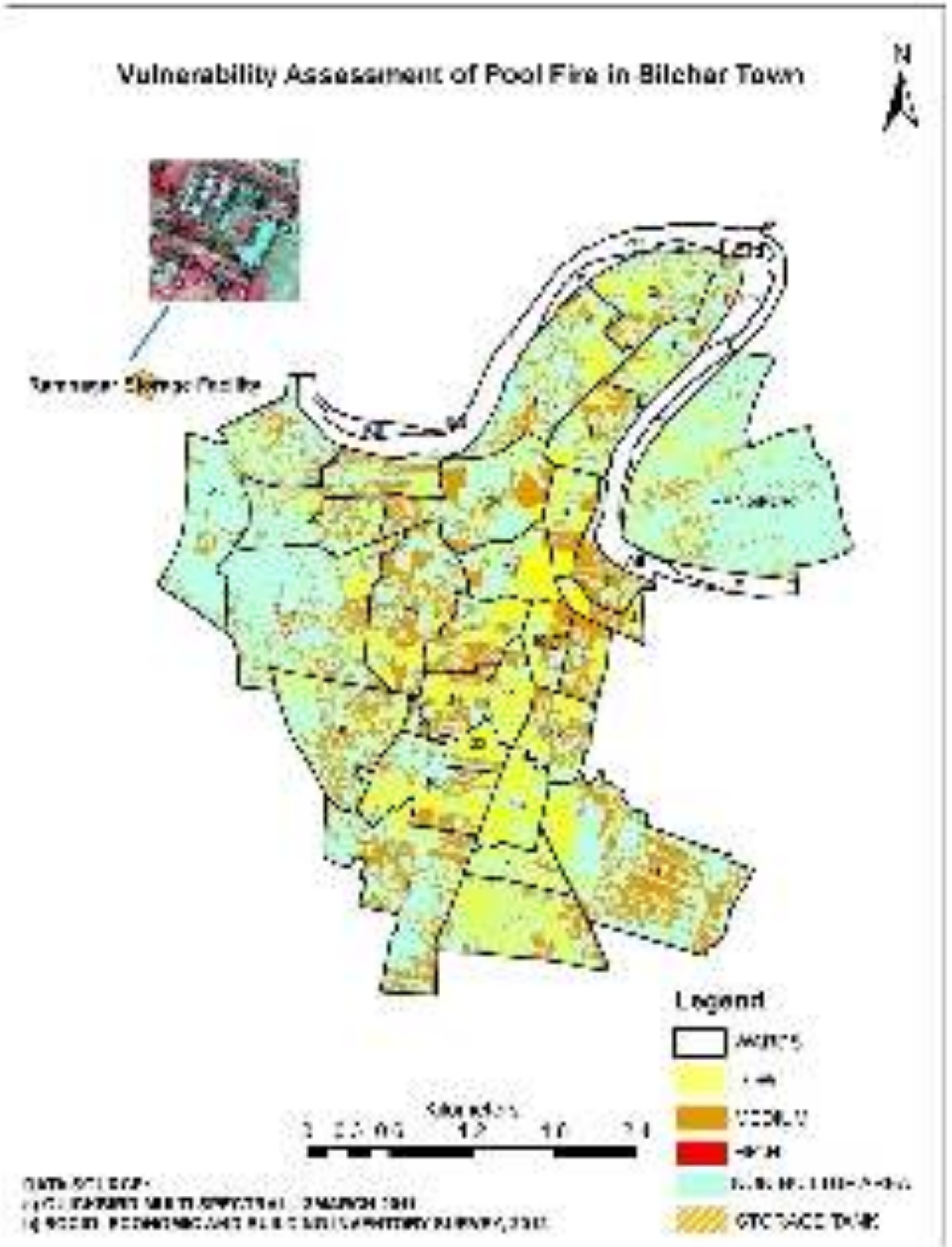


Figure 3.8 Building Vulnerability for Pool Fire Hazard

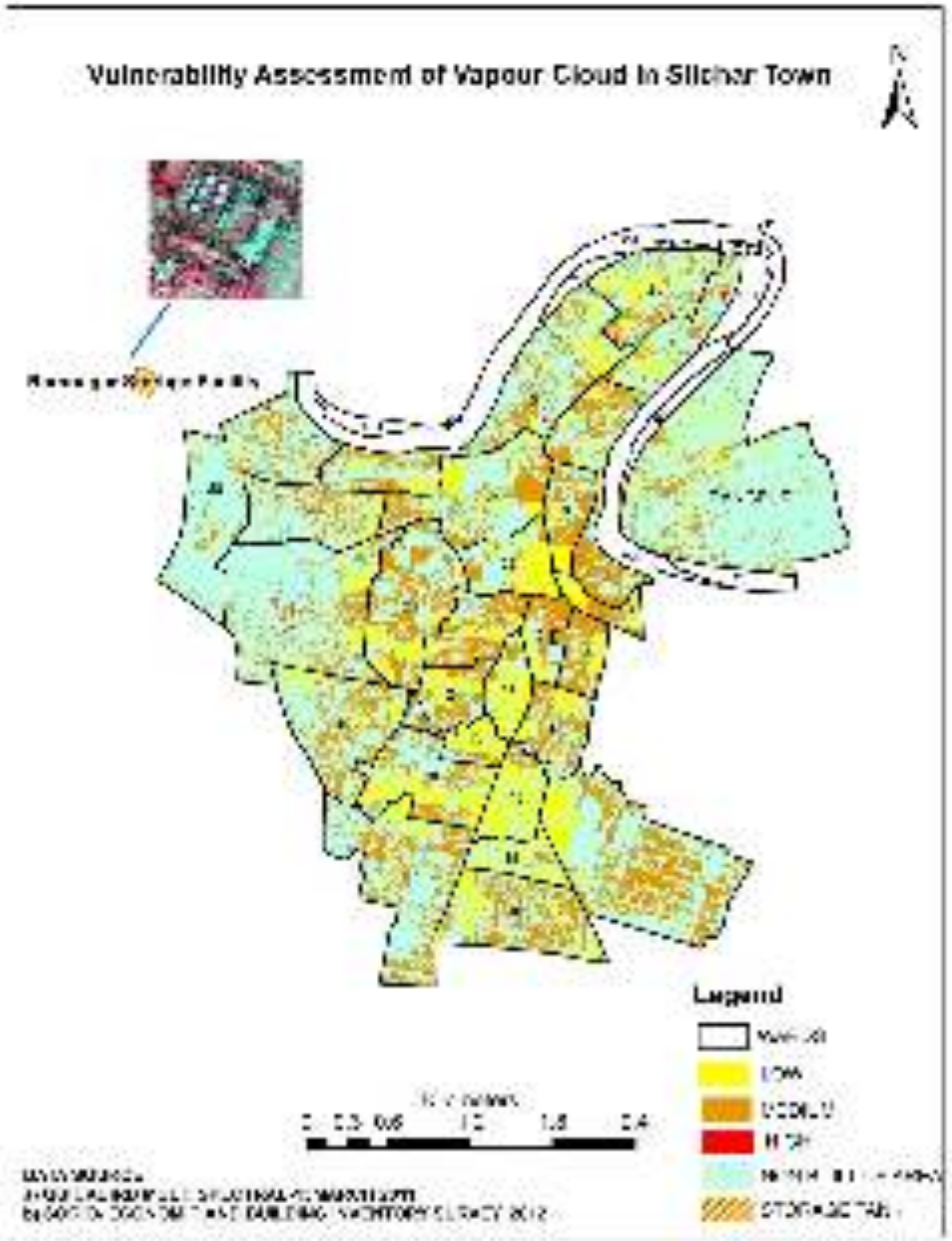


Figure 3.9 Building Vulnerability for Vapour Cloud Explosion Hazard

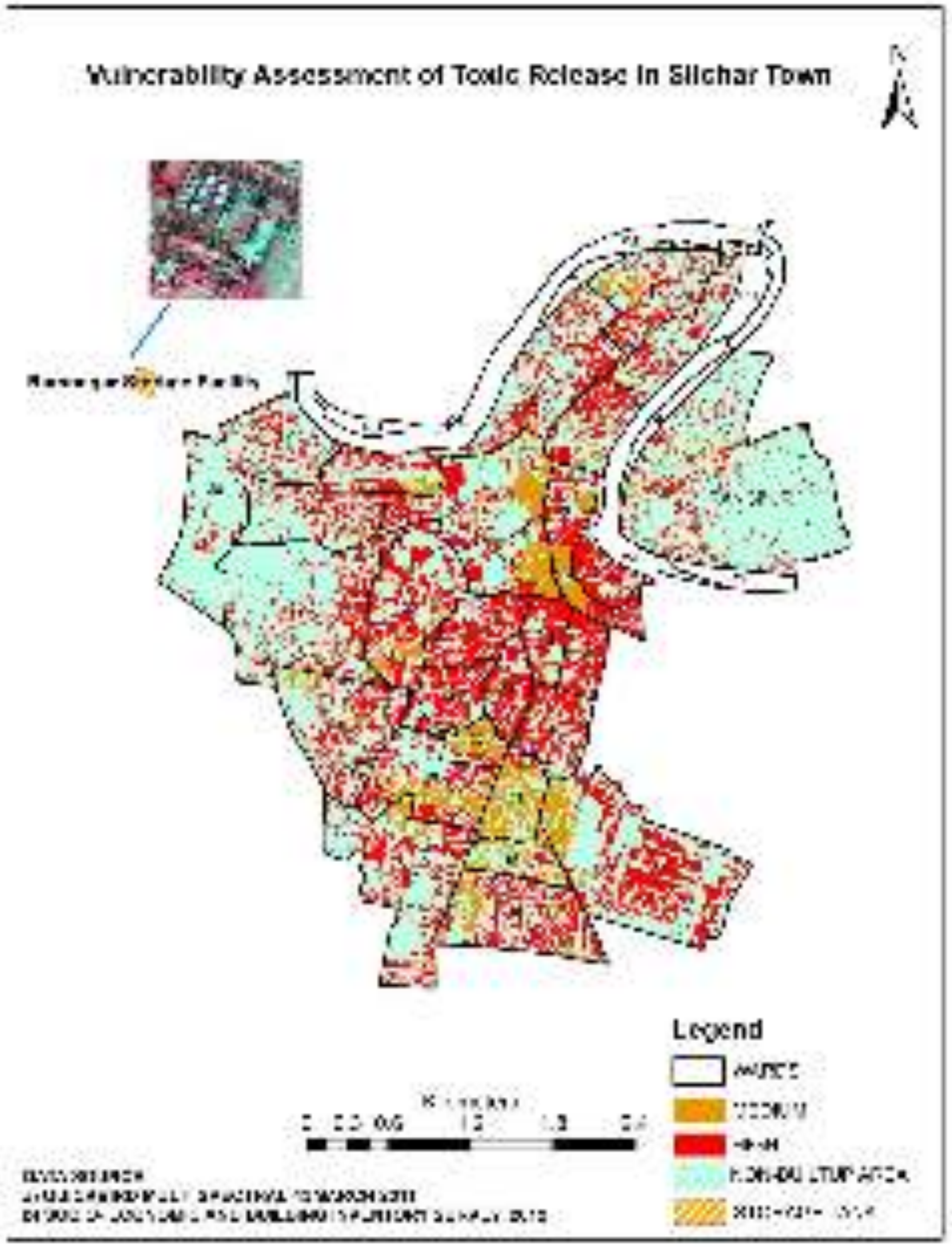


Figure 3.10 Building Vulnerability for Toxic Release

Table 3.14 Areas under Different Vulnerability Zones for BLEVE Hazard

HIGH	MEDIUM	LOW
Ward no. 24 (Centre) Trunk Road	Ward no. 10 (East)	Ward no. 1(South, North) Malugram Road
Ward no. 26 (Centre) Tarapur	Ward no. 1 Malugram Road, ItakolaMalluram, ItakolaGonaila, Itakola Malluram High School	Ward no. 2 (Centre) Itakola Road
Ward no. 2 (South) Itakola Road	Ward no. 11 (North west) Ambikapatty, Sunil Sarkar Road, ArunChanda Road, Desha, Bandhu Road	Ward no. 3 (East) ItakolaRerman Road, Rahaman Patty, Daccai Patty
	Ward no. 12(Centre) BILPAR	Ward no. 4 (West, South)
	Ward no. 13 K.C road, Sonai Road	Ward no. 6 (North) Central Road, Ukil Patty
	Ward no. 14 (Rammohan Road, Ramsundar Road, Ramakrishna Road,Mahaprbhu Lane, Kali Krishna Road, Mukta ram Road)	Ward no. 8 (East) Fatak bazaar
	Ward no. 15(Rabindra Sarant, 1st Link Road)	Ward no. 9 (East) Bilpar
	Ward no. 16 (West, East, North)2nd Link Road	Ward no. 10 (West) Radhamahab Road
	Ward no. 17 (Mahatma lane, Udayachal Lane, Ekdalia Lane, Rmakrishna Lane, Bankimsarani)	Ward no. 11 (Centre to South) Ambikapatty, Sunil Sarkar Road, ArunChanda Road
	Ward no. 18 (Bankim Lane, Sahati Lane, Indrani Lane, Sundari Mohan Lane, M. M. Park B B D Lane, K C Road)	Ward no. 12 (South west, North east) BILPAR
	Ward no. 19 (Cheng Kuri Road, M. A. Lane.)	Ward no. 16 (Centre, East)2nd Link Road
	Ward no. 2 (Itakola Road)	Ward no. 18 (South West) Bankim Lane, Sahati Lane, Indrani Lane, Sundari Mohan Lane
	Ward no. 20 (Rangirkhari)	Ward no. 19 (East, West) Cheng Kuri Road
	Ward no. 21 (North, South) College Road, Ambikapatty	Ward no. 21(Centre) College Road
	Ward no. 22 (South, West) Ambikapatty	Ward no. 22 (North east) Ambikapatty
	Ward no. 23 (East and West)	Ward no. 23 (South east) Central road
	Ward no. 24 (Trunk Road, PWD Road, Park Road, Tarapur-24,)	Ward no. 24 (West) Trunk Road, PWD Road
	Ward no. 25 (R. K. mission Road, Vivekanand Road Lane 1-3-7-12)	Ward no. 25 (North west) R. K. mission Road, Bishnupur Sil-3
	Ward no. 26 (Tarapur)	Ward no. 26 (North east) Chandmari Malini Road, Ashram Road, SishuMandir Area
	Ward no. 28 (North) Itakola Manipur Para, ItakolaGhat, Itakola Swami Road, Ramnagar	Ward no. 27 (Tarapur Gunomoi Road, TarapurMaluni Hills)
	Ward no. 3 Itakola Rerman Road, Rahaman Patty, Daccai Patty, Bani Para, Khasai Patty	Ward no. 2 (South) Itakola Road, Itakola Rrya Patty, Itakola Kalibari Road
	Ward no. 4	
	Ward no. 6 Central Road, Ukil Patty, D.c Office, Municipal Office Court, Post office	
	Ward no. 7(North, West) Sadarghat Road, JaniganjMahavirMagh	
	Ward no. 8 Fatak bazar	
	Ward no. 9 (west) Bilpar	
	Rongpur (Centre)	

Table 3.15 Areas under Different Vulnerability Zones for Pool Fire Hazard

HIGH	MEDIUM	LOW
Ward no. 1(North east) Malugram Road, ItakolaMalluram	Ward no. 1 Malugram Road	Ward no. 1 (South) Malugram Road, Itakola, Malluram, Itakola, Gonaila, Itakola Malluram High School
Ward no. 2(Centre) Itakola Road	Ward no. 2 (South East, North) Itakola Road	Ward no. 2 (North west) Itakola Road
Ward no. 28(North west) Itakola Manipur Para, ItakolaGhat, Itakola Swami Road, Ramnagar	Ward no. 3 (Centre to East) Rahaman Patty, Daccai Patty, Bani Para, Khasai Patty	Ward no. 3 (South east) Daccai Patty
Ward no. 3 (West, North east) ItakolaRerman Road, Rahaman Patty, Daccai Patty, Bani Para, Khasai Patty	Ward no. 4 Natun patty, daccai patty	Ward no. 4 (South) Natun patty, daccai patty
Ward no. 26(Centre) Tarapur T V Centre, Vivekanand Road, Chandmari Malini Road	Ward no. 6 (North, Centre) Central Road, Ukil Patty	Ward no. 6 (South, North) Central Road
	Ward no. 7 Sadarghat Road	Ward no. 8 (West, East) Fatak bazaar
	Ward no. 8 (East) Fatak bazar	Ward no. 9 (East) Bilpar
	Ward no. 9 (West) Bilpar	Ward no. 10 (West) Radhamahab Road
	Ward no. 10 (East) Radhamahab Road	Ward no. 11 (North) , Sunil Sarkar Road, ArunChanda Road
	Ward no. 11 (North West) Ambikapatty, Sunil Sarkar Road, ArunChanda Road	Ward no. 12 (North East, South west)
	Ward no. 12(public school road)	Ward no. 13 Sonai road
	Ward no. 14 Kanakpur Road, RadhaMadrab, College Road,	Ward no. 14 (West) Kanakpur Road
	Ward no. 16 (East, North, South East) 2nd Link Road	Ward no. 15 1st Link Road
	Ward no. 17 KathalBagan Road, Mahatma lane, Udayachal Lane	Ward no. 16 (Centre) 2nd Link Road
	Ward no. 18 (North, South) Bankim Lane, Sahati Lane, Indrani Lane, Sundari Mohan Lane, M. M. Park, Happy Valley Road	Ward no. 18 (South, Centre) Sahati Lane, Indrani Lane, Sundari Mohan Lane, M. M. Park, Happy Valley Road
	Ward no. 19 Cheng Kuri Road, M. A. Lane	Ward no. 19 (North west) Cheng Kuri Road
	Ward no. 20 (South) Tarani Road, BholaGiri lane, Rangirkhari	Ward no. 20, Rangirkhari
	Ward no. 21 (South, north) College Road	Ward no. 21 (centre) College Road
	Ward no. 22 (South, west) Ambikapatty	Ward no. 22 (North east) Ambikapatty
	Ward no. 23 (West) Central road	Ward no. 23 (East) Central road
	Ward no. 24 Trunk Road, PWD Road, Park Road, Tarapur-24,	Ward no. 25 (South) Bishnupur Sil-3, Vivekanand Road Lane 1-3-7-12
	Ward no. 25 Bishnupur Sil-3, Vivekanand Road Lane 1-3-7-12,	Ward no. 26 (North east) Tarapur T V Centre, Vivekanand Road, ChandmariMalini
	Ward no. 26 Tarapur T V Centre, Vivekanand Road, Chandmari, Malini Road, Ashram Road, SishuMandir Area	Ward no. 27 (East) Tarapur
	Ward no. 27 TarapurMaliniBeel, TarapurMohon Lane	Ward no. 28 (North east) Itakola, Manipur Para
	Ward no. 28 Itakola, Manipur Para	

Table 3.16 Areas under Different Vulnerabilitv Zones for Toxic Release Hazard

HIGH	MEDIUM	LOW
Ward no. 1 Itakola, Gonaila, Itakola, Malluram High School	Ward no 2 (North west corner) Itakola Road	No area in this zone
Ward no. 2 Itakola Road	Ward no 4 (Centre) Natun patty	
Ward no. 3 Rahaman Patty, Daccai Patty, Bani Para, Khasai Patty, Itakola Road,	Ward no 6 (Centre) Central Road	
Ward no. 4 Natun patty, daccai patty	Ward no 14 (West north corner) Ramchandran Road, Rammohan Road, Ramsundar Road, Ramakrishna Road,	
Ward no. 6 Central Road	Ward no 15 RabindraSarant, 1st Link Road	
Ward no. 7 Sadarghat Road, Janiganj, MahavirMagh	Ward no 16 (West) 2nd Link Road	
Ward no. 8 (East) Fatak bazaar	Ward no 18 (South centre) Bankim Lane, Sahati	
Ward no. 9 Bilpar	Ward no 19 (West north corner) Cheng Kuri Road, M. A. Lane.	
Ward no. 10 Radhamahab Road	Ward no 20 (North) BholaGiri lane, Rangirkhari	
Ward no. 11 Ambikapatty, Sunil Sarkar Road, ArunChanda Road, Desha, Bandhu Road	Ward no 23 (East) Central road	
Ward no. 12 public school road	Ward no 24 (East) Trunk Road, PWD Road	
Ward no. 13 (North) Sonai road, k.c road	Ward no 25 (Centre south) 25 R. K. mission Road, Bishnupur Sil-3, Vivekanand Road Lane 1-3-7-12	
Ward no. 14 (East) Kanakpur Road, RadhaMadrab, College Road, Ramchandran Road, Rammohan Road, Ramsundar Road, Ramakrishna Road,		
Ward no. 15(South east corner) RabindraSarant, 1st Link Road		
Ward no. 16 2nd Link Road		
Ward no. 17 KathalBagan Road, Mahatma lane, Udayachal Lane, Ekdalia Lane, Rmakrishna Lane, Bankimsarani		
Ward no. 18(North, South, West) Bankim Lane, Sahati Lane, Indrani Lane, Sundari Mohan Lane, M. M. Park B B D Lane, K C Road		
Ward no. 19 Cheng Kuri Road, M. A. Lane.		
Ward no. 20(South) Tarani Road, BholaGiri lane, Rangirkhari		
Ward no. 21 College Road, Ambikapatty		
Ward no. 22 Ambikapatty		
Ward no. 23(West, South east corner) Central road		
Ward no. 24(West) Trunk Road, PWD Road		
Ward no. 25 R. K. mission Road, Bishnupur Sil-3, Vivekanand Road Lane 1-3-7-12		
Ward no. 26 Tarapur T V Centre, Vivekanand Road, Chandmari, Malini Road, Ashram Road, SishuMandir Area		
Ward no. 27 Tarapur, Gunomoi Road, Tarapur Malini Beels, Tarapur, Malini Beel, Tarapur Mohon Lane		
Ward no. 28 Itakola Manipur Para, ItakolaGhat, Itakola Swami Road, Ramnagar		

Table 3.17 Areas under Different Vulnerability Zones for Vapour Cloud Hazard

HIGH	MEDIUM	LOW
Small portion of ward no. 1 Malugram Road	Ward no. 1(North) Malugram Road	Ward no. 2(Centre) Itakola Road
Small portion of ward no2 Itakola Road	Ward no. 2(South) Itakola Road	Ward no. 3(north east corner) Itakola, Rerman Road, Rahaman Patty, Daccai Patty
Small portion of ward no3 Daccai Patty	Ward no. 3 Rahaman Patty, Daccai Patty,	Ward no. 6(South) Central Road
Small portion of ward no 26 Tarapur	Ward no. 4 Natun patty, daccai patty	Ward no. 8(West) Fatak bazar
Small portion of ward no,28 Itakola Manipur Para, Ramnagar	Ward no. 6 Central Road	Ward no. 9(East) Bilpar
	Ward no. 7 Sadarghat Road, Janiganj MahavirMagh	Ward no. 10(South west) Radhamahab Road
	Ward no. 8(East) Fatak bazar	Ward no. 11) Ambikapatty
	Ward no. 9(West) Bilpar	Ward no. 12(North east) Ramakrishna Road, Mahaprbhu Lane, Kali Krishna Road, Mukta ram Road
	Ward no. 10(East) Radhamahab Road	Ward no. 13 Sonai road
	Ward no. 11(North west) Ambikapatty, Sunil Sarkar Road, ArunChanda Road	Ward no. 14(North west corner) Ramakrishna Road, Mahaprbhu Lane, Kali Krishna Road, Mukta ram Road
	Ward no. 12	Ward no. 15
	Ward no. 14(East) Ramakrishna Road, Mahaprbhu Lane, Kali Krishna Road, Mukta ram Road	Ward no. 16(West) 2nd Link Road
	Ward no. 16 2nd Link Road	Ward no. 17(North) Mahatma lane, Udayachal Lane, Ekdalia Lane, Rmakrishna Lane, Bankimsarani
	Ward no. 17 Mahatma lane, Udayachal Lane, Ekdalia Lane, Rmakrishna Lane, Bankimsarani	Ward no. 18(Centre) Happy Valley Road
	Ward no. 18(South, North) B D Lane, K C Road (W), Panchayet Road, Srimaa Lane, Happy Valley Road	Ward no. 20 Tarani Road, BholaGiri lane, Rangirkhari
	Ward no. 19 Cheng Kuri Road, M. A. Lane.	Ward no. 21(North west) College Road, Ambikapatty
	Ward no. 20(South) Tarani Road, BholaGiri lane, Rangirkhari	Ward no. 22(Centre) Ambikapatty
	Ward no. 21(South, North east) College Road, Ambikapatty	Ward no. 23(East)
	Ward no. 22 Ambikapatty	Ward no. 24(North west corner) Trunk Road, PWD Road
	Ward no. 23(East) Central road	Ward no. 25(South Centre) R. K. mission Road
	Ward no. 24 Trunk Road, PWD Road, Park Road, Tarapur-24,	Ward no. 26(East) Tarapur T V Centre, Vivekanand Road, Chandmari, Malini Road, Ashram Road
	Ward no. 25 R. K. mission Road, Bishnupur Sil-3, Vivekanand Road Lane 1-3-7-12	Ward no. 27(East) Tarapur, Malini Beel, TarapurMohon Lane
	Ward no. 26 Tarapur T V Centre, Vivekanand Road, Chandmari Malini Road, Ashram Road, SishuMandir Area	
	Ward no. 27 TarapurGunomoi Road, Tarapur Malini Beels,, Tarapur, Malini Beel, Tarapur, Mohon Lane	

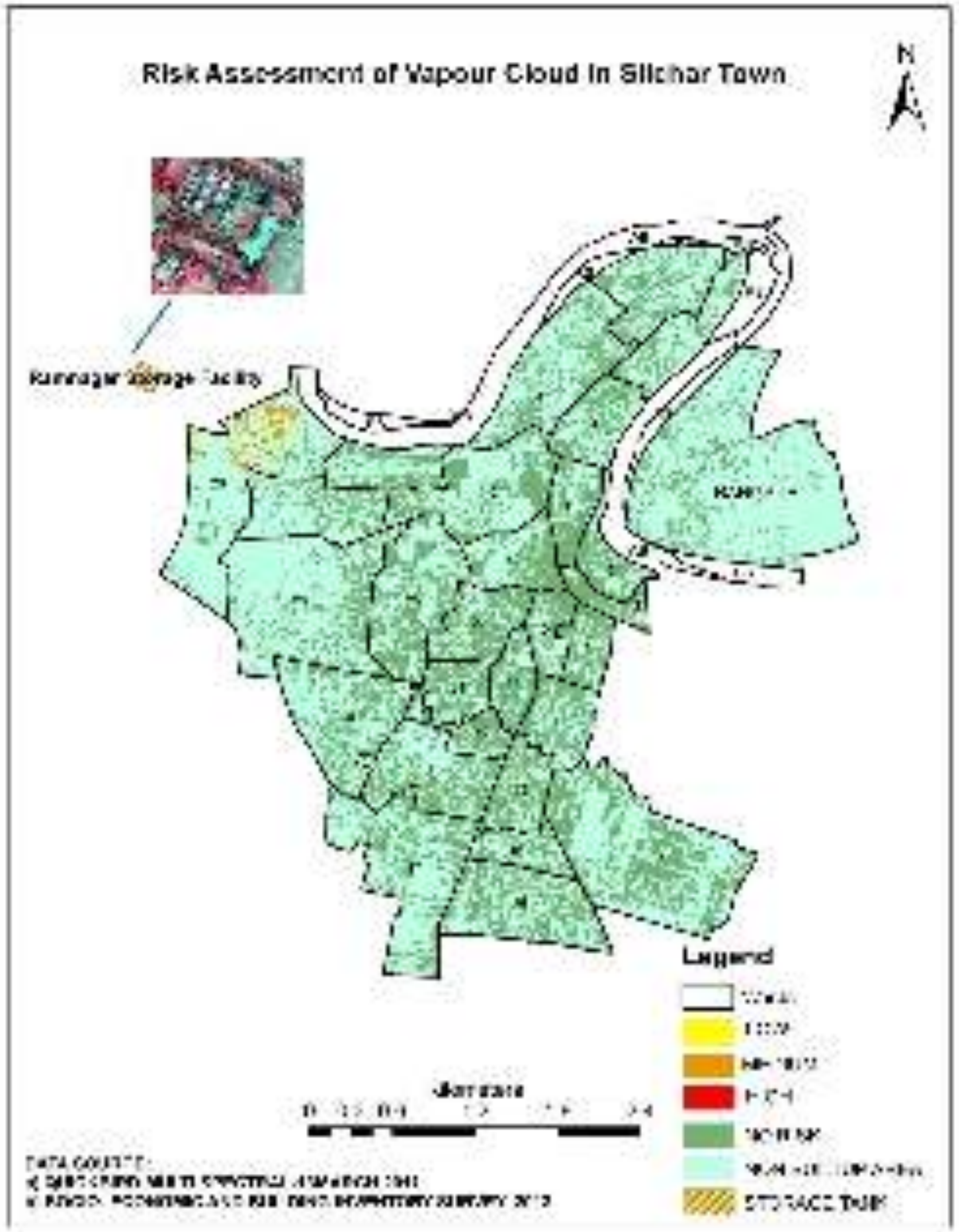


Figure 3.11 Risk Assessment for Vapour Cloud Hazard

Figure 3.12 Risk Assessment for Pool Fire Hazard

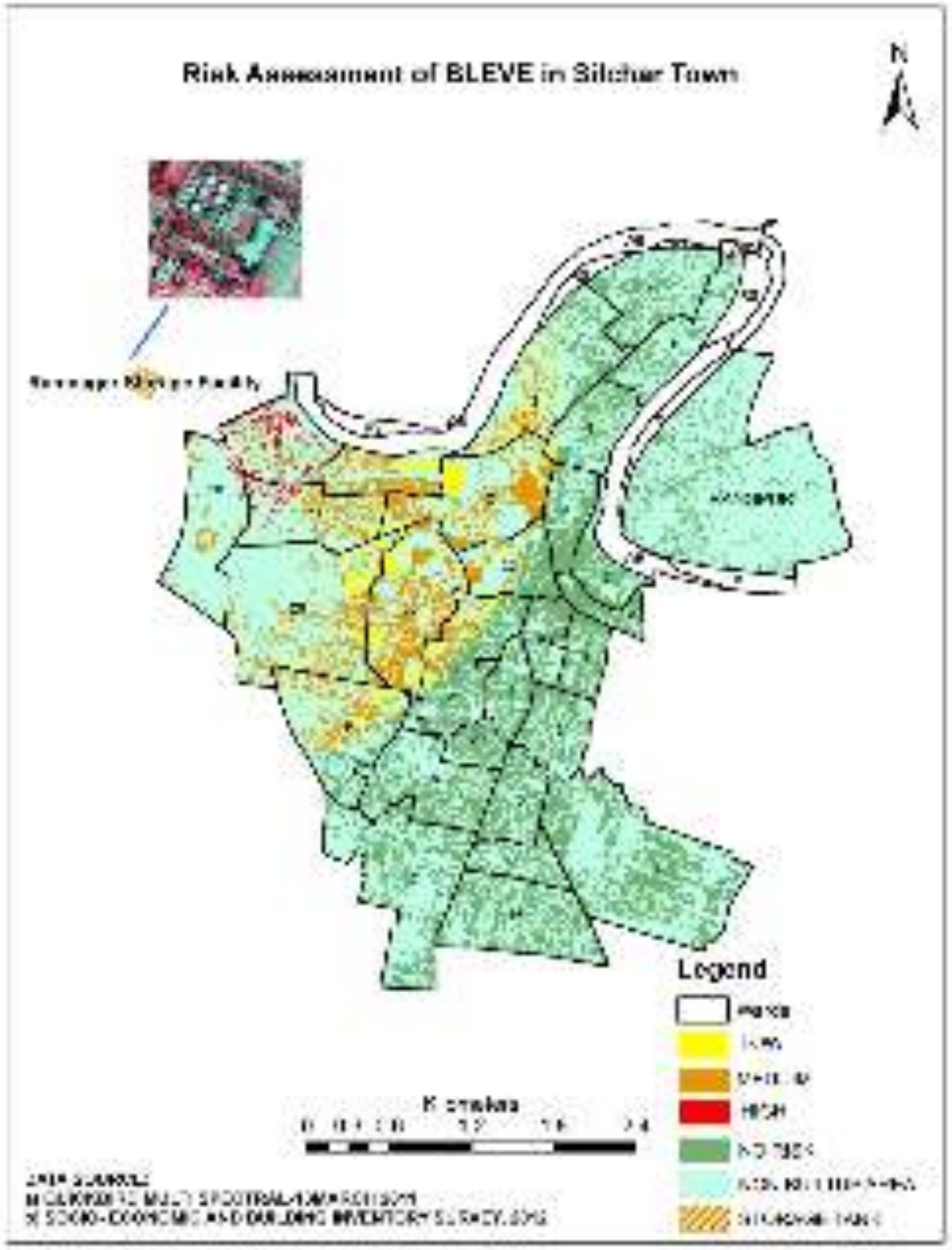


Figure 3.13 Risk Assessment for BLEVE Hazard

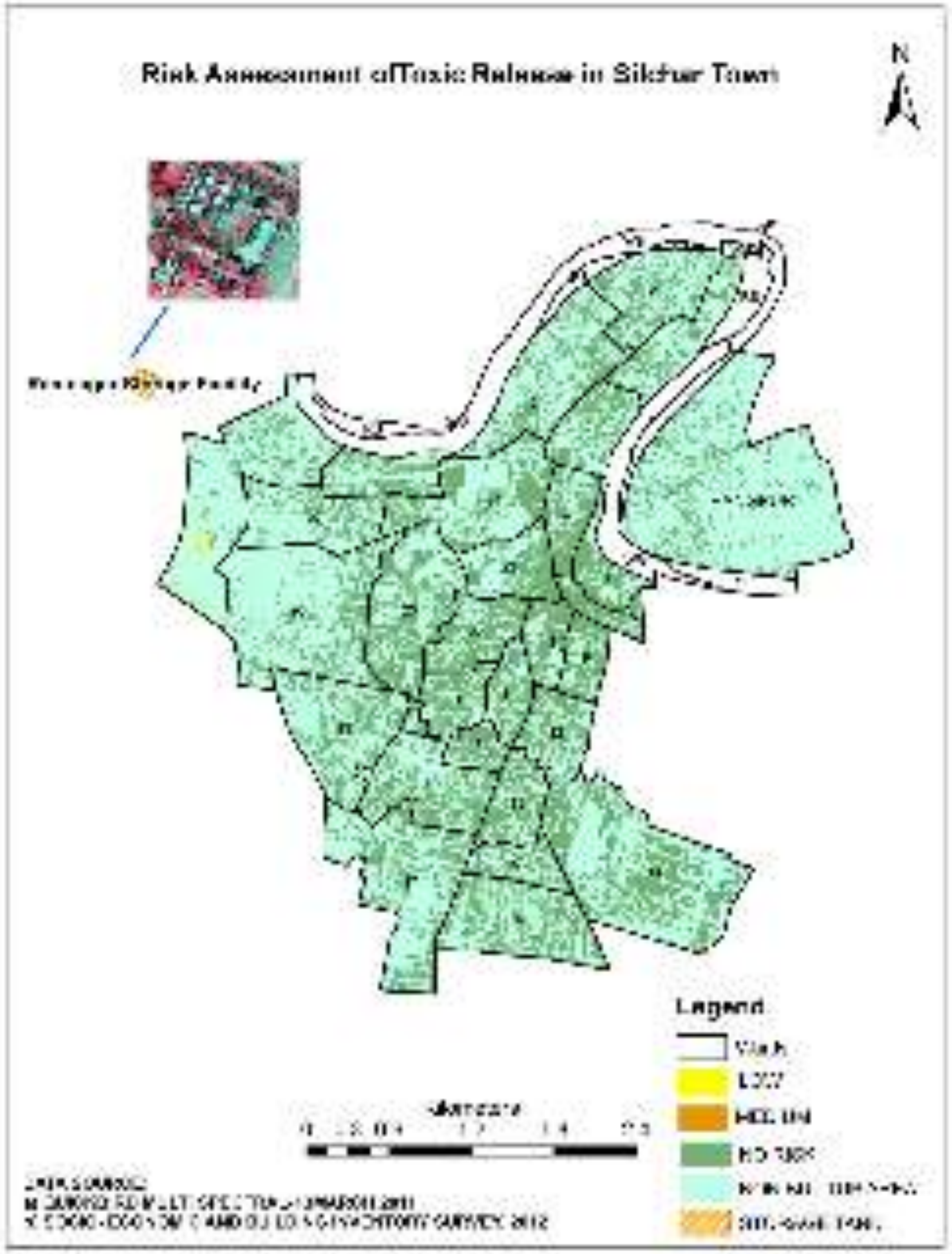


Figure 3.14 Risk Assessment for Toxic Release Hazard

Table 3.18 Areas under BLEVE Risk Zone

HIGH	MEDIUM	LOW
Ward no. 28 (North east) Itakola Manipur Para, ItakolaGhat, Itakola, Swami Road, Ramnagar	Ward no. 28 (Centre, South)) Itakola Manipur Para	Ward no. 3 (Centre) Itakola
Ward no. 27 (North west) Tarapur Gunomoi Road, Tarapur, Malini Beel,	Ward no. 27 (Centre to East) Tarapur	Ward no. 24 (West) Trunk Road, PWD Road, Park Road, Tarapur-24,
	Ward no. 26 Ashram Road, SishuMandir Area, Tarapur T V Centre, Vivekanand Road	Ward no. 26 (East) Tarapur T V Centre
	Ward no. 25 R. K. mission Road, Bishnupur Sil-3, Vivekanand Road Lane 1-3-7-12,	Ward no. 25 (North west, South west) R. K. mission Road
	Ward no. 23 Central road	Ward no. 22 (East) Ambikapatty
	Ward no. 24 Trunk Road, PWD Road, Park Road, Tarapur-24,	Ward no. 4 (Southeast) Natun patty, daccai patty
	Ward no. 3 (West, Centre) ItakolaRerman Road, Rahaman Patty	Ward no. 19 (East) Cheng Kuri Road
	Ward no. 22 (South, West) Ambikapatty	
	Ward no. 19 (North, West) Cheng Kuri Road, M. A. Lane.	

Table 3.19 Areas under Vapour Cloud Risk Zone

HIGH	MEDIUM	LOW
Ward no. 28 (North west) Itakola , Manipur Para	Ward no. 28 Itakola Manipur Para, ItakolaGhat, Itakola Swami Road, Ramnagar	Ward no. 28 (West) ItakolaGhat, Itakola Swami Road
	Ward no. 27(North west corner) Tarapur Maluni Hills, Tarapur, MaliniBeel, Tarapur, Mohon Lane	

Table 3.20 Areas under Toxic Release Risk Zone

HIGH	MEDIUM	LOW
No area in this zone	Ward no. 28 (South) ItakolaGhat	Ward no. 28 (Centre) ItakolaGhat, Itakola Swami Road

Table 3.21 Areas under Pool Fire Risk Zone

HIGH	MEDIUM	LOW
No area in this zone	Ward no. 28 (West) ItakolaGhat, Itakola Swami Road	Ward no. 28 (West) ItakolaGhat, Itakola Swami Road

Table 3.22 Number of Persons likely to be affected during BLEVE in different risk

WARDS	LOCALITIES	LOW RISK	MEDIUM RISK	HIGH RISK
WARD NO.3	Itakola Rerman Road, Rahaman Patty, Daccai Patty, Bani Para, Khasai Patty	767	2889	11
WARD NO.4	Itakola rahman Bari, Sachanghat Sil	109	12	0
WARD NO.19	Cheng Kuri Road, M. A. Lane	313	1408	0
WARD NO.22	Ambikapatty	440	1002	0
WARD NO.23	Central road	63	375	0
WARD NO.24	Trunk Road, PWD Road, Park Road, Tarapur-24	819	3205	0
WARD NO.25	R. K. mission Road, Bishnupur Sil-3, Vivekanand Road Lane 1-3-7-12	489	3394	0
WARD NO.26	Tarapur T V Centre, Vivekanand Road, Chandmari Malini Road, Ashram Road, Sishu Mandir Area	514	1428	0
WARD NO.27	Tarapur Gunomoi Road, Tarapur Malini Beels, , Tarapur Malini Beel, Tarapur Mohon Lane	120	1794	536
WARD NO.28	Itakola Manipur Para, Itakola, Ghat, Itakola Swami Road, Ramnagar	0	533	702

Table 3.23 Number of Persons likely to be affected during Pool Fire in different risk

WARDS	LOCALITIES	LOW RISK	MEDIUM RISK	HIGH RISK
WARD NO.28	Itakola Manipur Para, Itakola Ghat, Itakola Swami Road, Ramnagar	2	6	0

Table 3.24 Number of Persons likely to be affected during Toxic Release Hazard

WARDS	LOCALITIES	LOW RISK	MEDIUM RISK	HIGH RISK
WARD NO.28	Itakola, Manipur Para, Itakola Ghat, Itakola Swami Road, Ramnagar	116	3	0

Table 3.25 Number of Persons likely to be affected during Vapour Cloud Hazard

WARDS	LOCALITIES	LOW RISK	MEDIUM RISK	HIGH RISK
WARD NO.27	Tarapur, Gunomoi Road, Tarapur Malini Beel, Tarapur, Tarapur Mohon Lane	0	144	0
WARD NO.28	Itakola, Manipur Para, Itakola Ghat, Itakola Swami Road, Ramnagar	38	598	15

Table 3.26 Localities likely to be affected by Pool Fire Threat/Hazard

High-(10.0 kW/(sq m) = potentially lethal within 60 sec)	Medium - (5.0 kW/(sq m)=2nd degree burns within 60 sec)	Low – (2.0 kW/(sq m)=pain within 60 sec)
No Ward/locality under this zone	No Ward/locality under this zone	Ward No. 28 South western corner of Malini Bill, Industrial area, E & D colony

Table 3.27 Localities likely to be affected by BLEVE Threat/Hazard

Ward No.	High-(10.0 kW/(sq m) = potentially lethal within 60 sec)	Medium - (5.0 kW/(sq m) = 2nd degree burns within 60 sec)	Low – (2.0 kW/(sq m) = pain within 60 sec)
3	No ward/locality under this zone	No ward/locality under this zone	Ithkola (South and South west corn portion)
19			Chengkori Rd, Satsang Ashram (Major portion of the Area)
20			Tarani Road (small part of extreme north west corner)
21			Civil Hospital, College Rd (Extreme north west corner)
22			Jail Rd (Western half portion)
23			Nazira Patty, Shillong Patty, Gopalganj (More than western half portion)
24			Police Ground, Gandhi Bagh Rd (Entire ward)
25			Tarapur, Jhalupara (Entire ward)
26		Uttar Khishnapur, Vivekananda Rd (Centre to entire NW corner)	Uttar Khishnapur, Vivekananda Rd (Central to entire south east corner)
27	Tarapur, TV Centre (West-north west corner)	Tarapur, TV Centre (major portion)	Tarapur, TV Centre (extreme eastern part)
28	Major portion (Malini Beel, Industrial area, E & D colony)	Ward no. 28 North East corner (Malini Beel, Industrial area, E & D colony),	No ward/locality under this zone

Table 3. 28 Localities likely to be affected by Toxic Release Threat/Hazard

Ward No.	High (7.9 ppm = PAC-3)	Medium (0.031 ppm = PAC-2)	Low (0.0028 ppm = PAC-1)
26	No ward/locality under this zone		Uttar Khishnapur, Vivekananda Rd (west – south west corner)
28		Malini Beel, Industrial area, E & D colony (extreme north west corner)	Malini Beel Industrial area, E & D colony (central, N-NW and southern part)

Table 3.29 Localities likely to be affected by Flammable Area of VC Threat/Hazard

Ward No.	High - (12600 ppm = 60% LEL = Flame Pockets)	Low- (2100 ppm = 10% LEL)
27		Tarapur, TV Centre (extreme north weatern part)
28	Malini Beel Industrial area, E & D colony (extreme north west corner)	Malini Beel, Industrial area, E & D colony (some part of central and western portion)

SEISMIC HAZARD ASSESSMENT

SILCHAR TOWN

4. SEISMIC HAZARD

4.1 INTRODUCTION

The northeast India region is highly populated, and seismically most active which fall in the zone V in the seismic zoning map of India (Fig. 4.1). The past seismicity and seismotectonics of the region are well documented by Kayal (2008) and Nandy (2001). In the recent years since 2001, the region is fairly well equipped with the digital weak motion as well as with strong motion instruments to identify the seismic source zones and to understand the seismic processes in the region (e.g. Kayal et al., 2012).

Present day tectonics of northeast India region is complicated because of north-south convergence of the Indian plate, a continent-continent collision between the Indian plate and Eurasian plate along the Himalayan arc (e.g. Molnar et al., 1977; Seeber et al., 1981; Ni and Barazangi, 1984) and the east-west convergence and folding in the Indo-Burma ranges due to atypical continent-continent subduction along the Burmese arc (e.g. Mitchell, 1981 Curray et al., 1982; Kayal, 1996). Based on the distribution of epicentres and geological/tectonic setting, the whole region is divided into five seismotectonic blocks or zones (Kayal, 1996 and 2008): (i) Northeast Himalayan collision zone, (ii) Indo-Burma subduction zone, (iii) Eastern Himalaya syntaxis zone, and (iv) Shillong Plateau-Mikir massif-Assam valley and (v) Bengal basin-Tripura fold belt intra-plate zones (Fig. 4.2).

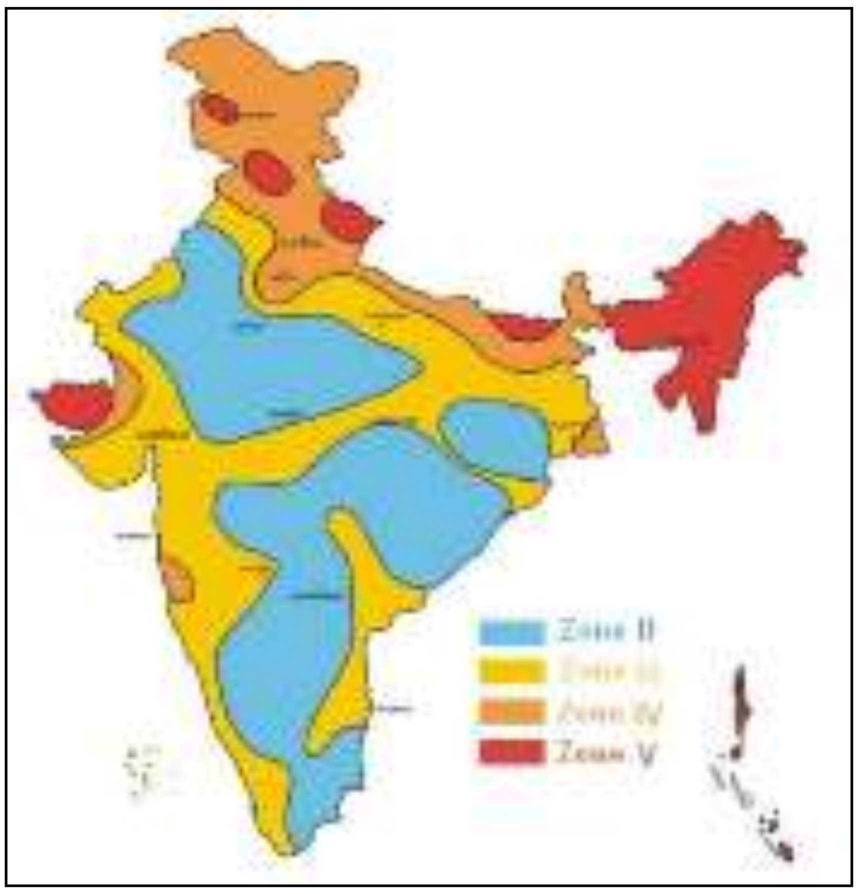


Figure 4.1 Seismic zoning map of India (BIS, 2004). Northeast India is marked as zone V, seismically most damage prone region.

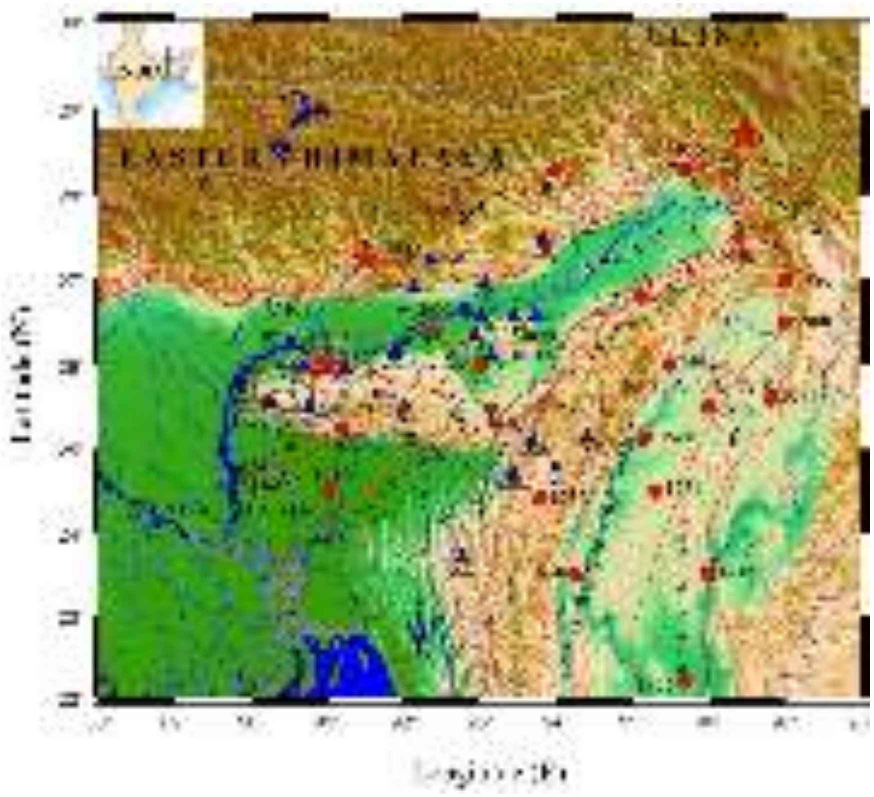


Figure 4.2 Map showing major tectonic features of northeast India region and the large earthquakes (from Kayal et al., 2012).

Two great earthquakes (Ms ~ 8.0) are shown by large red stars, and the large earthquakes (8.0 > M >7.0) by circles; the years of occurrences are annotated. The digital seismic stations are shown by blue triangles, and the 2009 felt earthquake (Mw 5.4) is shown by smaller red star. The hat-shaped maximum intensity zone, isoseismal XII (MM scale), of the 1897 great earthquake is also shown (after Richter, 1958). The major tectonic features in the region are indicated; MCT: Main Central Thrust, MBT: Main Boundary Thrust, MFT: Main Frontal Thrust, DF: Dauki Fault, DT: Dapsi Thrust, Db.F: Dhubri Fault; Dh.F: Dudhnoi Fault, OF: Oldham Fault, CF: Chedrang Fault, BS: Barapani Shear Zone, KF: Kopili Fault, NT: Naga Thrust, DsT: Disang Thrust and EBT: Eastern Boundary Thrust. The right lateral movement of the Dauki and Kopili faults are shown.

4.2 Scope

Since 1980 several organizations (like GSI, NGRI, NEIST, IMD and some local universities) are running seismic networks/stations, temporary as well permanent, in the northeast India region. These data are published in the form of seismological bulletins, reports and research papers. Since 2001, the permanent networks/stations are upgraded with digital broadband instruments, and several research activities are undertaken using these high precision digital seismic data. recent seismicity map using the ISC (International Seismological Centre) catalog data for the period 1964-2008 (Fig 4.3). With the inception of the global network in 1964, and subsequent up gradation of the networks with digital broadband instruments globally as well as nationally, location quality of the earthquakes has been much improved, and this map gives us a firsthand information about the level of seismic activity of the different seismic zones mentioned above. The map clearly shows an intense activity at the Indo-Burma subduction zone, and also high level of seismic activity in the Himalayan collision zone, Assam syntaxis zone and also in the Shillong plateau-Assam valley intra-plate zone.

Figure 4.3 Recent seismicity map based on the ISC data (1964-2008). Zone A: Himalayan collision, Zone B: Indo-Burma subduction, Zone C: Assam syntaxis, Zone D: Shillong plateau-Assam valley, and Zone E: Bengal basin- Tripura fold belt. Inset: Showing Indian plate movement from the Carlsberg Ridge (CBR), HA: Himalayan arc, BA: Burmese arc (modified from Kayal, 1996).

4.3 Objectives

The study has the following objectives:

- To prepare an inventory of the relevant published literature to review the tectonic processes and earthquake source zones in the northeast India region.
- To estimated the predominant frequency (PF) for higher ground amplification with available sub-surface data.
- To estimate the peak ground acceleration (PGA) for impending large earthquakes from the near field and far field seismic sources

4.4 Methodology

In assessing the Seismic Hazard of any urban area, *site response analysis* plays a major role. Lessons from destructive earthquakes shows that due to differing site response, the amount of damage varies considerably within same epicentral area. So a term known as *microzonation* has generally been recognized as the most accepted tool in seismic hazard assessment and risk evaluation.

A general methodology or flow chart in doing the seismic microzonation of a region can be divided into the following major heads (fig 4.4).

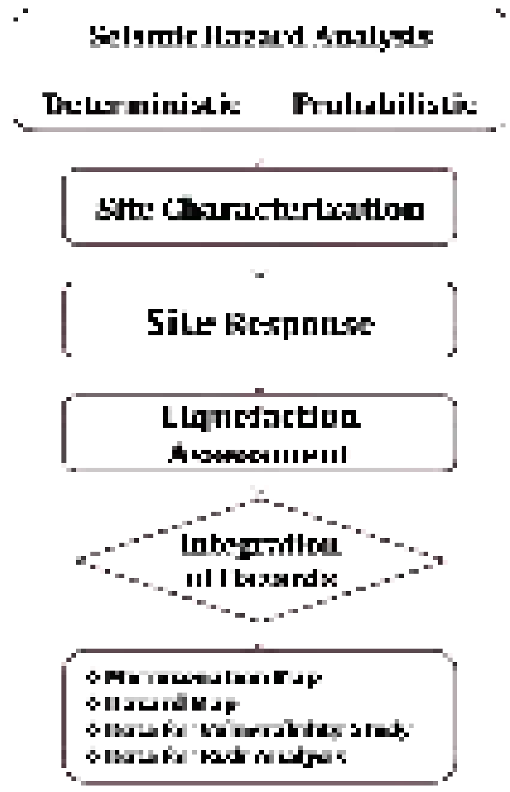


Figure 4.4 Flow chart of the Methodology for Seismic Hazard Assessment

4.4.1 Site Characterization

Empirical attenuation relationships are generally employed in estimating seismic hazards in either deterministic or probabilistic approaches (ISSMGE, 1999). These attenuation relationships could be based on the *Intensity* of the earthquake, PGA, PGV, SA or other factors. Attenuation relations based on seismic intensity are developed using isoseismals of historic earthquakes. Instrumentally measured PGA or PGV are, however, more reliable. The instrumentally based attenuation relations typically yield the natural logarithm of a ground shaking parameter, such as acceleration or spectral acceleration (PGA or SA), as a function of magnitude and distance (Finn et al., 2004). The reliability of the derived relationships depends on the quality and quantity of data and on distance and magnitude ranges used in the analysis (Mualchin, 1996).

According to the MoES (Ministry of Earth Sciences), Govt of India manual, two attenuation relationships used for the northeast India region: (i) The relationship developed by Sharma and Bungum (2006) for the Himalaya collision zone, and (ii) the attenuation relationship obtained by Youngs et al (1997) for the subduction zone earthquakes.

4.4.2 Site Response

Once the probable earthquake characteristics are determined, the second step is evaluating the ground motion characteristics on the surface while accounting for local geological and geotechnical site conditions. Local site effects are considered the most significant factors in microzonation. Site effects are natural anomalies to the ground motion. Many unconsolidated subsurface materials above the bed-rock can amplify earthquake ground motions resulting in damage to structures even far from the epicenter. Local site effects can significantly alters the amplitude, frequency and duration of earthquake ground motion and there by influences the degree of damages to buildings and other structures. It has been recognized that earthquake damage is generally larger over soft sediments than on firm bed or rock outcrops. This is particularly important because most of the urban settlements are along river valleys over such young, soft surface deposits, and site response study is very essential. Assessment of the local site effects includes *site amplification, predominant frequency, liquefaction hazard, landslides, tsunami* etc.

Approaches to the evaluation of local site effects depend on the level of zonation, i.e., mapping scale.

- Grade I method of zonation involves evaluating the local site effects using existing information that is readily available from published reports and other sources.

- Grade II methods of zonation require additional investigations. These investigations include geophysical and geotechnical investigations, and soil sampling from boreholes for laboratory tests.

- Grade III methods of zonation require the conducting of ground response analyses (including the one-dimensional equivalent-linear and nonlinear analyses) and 2D and 3D analyses.

4.5 Published Seismic Hazard Maps

The Global Seismic Hazard Assessment Program (GSHAP 2003) provides seismic hazard map that depicts a hazard level (PGA) of 0.24 g to 0.40 g along the Himalaya, Assam syntaxis and the Burmese arcs, and the present study areas in the Assam valley lie in the range of 0.32 to 0.40 g which are demarcated as high seismic hazard zone (Fig. 4.5).

Sharma et al. (2006) prepared PGA map for entire north east India region which gives the estimated PGA value for 10% and 20% exceedance in 50 years. The spectral acceleration values for major cities are given in Table 4.1.

Das et al. (2005) have carried out another study based on a regionalization free seismicity model and by adopting the PSHA formulation of Anderson and Trifunac (1977, 1978). They have obtained significantly varying seismic hazard levels over the region in the form of pseudo-spectral acceleration (PSA)

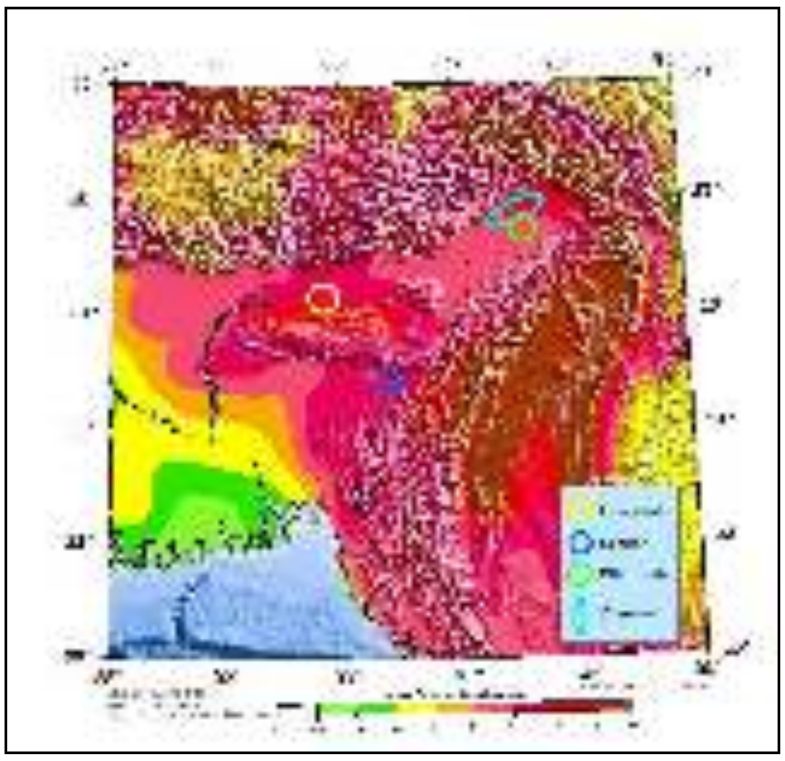


Figure 4.5 present study areas: Guwahati, Silchar, Dibrugarh and Dhamaji are shown. The whole northeast India region is demarcated as a high seismic hazard zone (GSHAP, 2003)

Table 4.1

(SA for the major cities in northeast India)

Periods (sec)	Agaratala	Guwahati	Itanagar	Jorhat	Shillong
0.03	0.33316	0.46888	0.44388	0.42908	0.48367
0.1	0.7148	0.95714	0.90816	0.89031	0.99388
0.2	0.84337	1.03469	0.98265	0.9852	1.07296
0.3	0.66531	0.85153	0.75204	0.75816	0.91837
0.4	0.45459	0.5898	0.50714	0.51327	0.64643
0.5	0.36429	0.47653	0.40714	0.41327	0.52653
0.75	0.24541	0.325	0.27857	0.28163	0.35765
1	0.175	0.23418	0.20255	0.20306	0.25459
1.5	0.11276	0.15561	0.13776	0.13571	0.16531
2	0.07816	0.11122	0.09918	0.09679	0.11684

response for both horizontal and vertical motions. Their study is first of its kind for the region, as it attempts to directly estimate the hazard levels in terms of structural response. Seismic hazard maps have been prepared for the northeast India in the form of uniform hazard contours for pseudo-spectral acceleration at stiff sites. These maps are for the horizontal component of ground motion and for different values of exposure time, confidence level and natural period. A comparison with the codal provisions given by the Bureau of Indian Standards code (BIS, 1893 (Part 1): 2002) shows that the pseudo spectral accelerations specified in the code for northeast India are broadly consistent with the hazard level corresponding to 10% probability of exceedance and 50 years service life, and that the present practice of specifying seismic hazard through peak ground acceleration and a fixed spectral shape may be inappropriate for structures in most areas of the region. Comparison of PSHA and codal PSA values (in g) for horizontal component at different time periods are given in Table 4.2.

Table 4.2

(Comparison of PSHA and Codal value for the major cities in northeast India)

PSHA values for P = 0.1 and Y = 50 yrs										
Period	GH	IT	KH	DG	SH	SC	IM	AZ	AG	Codal value
0.04	0.28	0.28	0.35	0.28	0.3	0.38	0.43	0.29	0.41	0.54
0.06	0.37	0.37	0.47	0.37	0.39	0.52	0.57	0.39	0.53	0.72
0.08	0.51	0.51	0.65	0.52	0.53	0.69	0.79	0.55	0.69	0.81
0.12	0.64	0.64	0.84	0.66	0.67	0.89	1.02	0.7	0.87	0.9
0.17	0.7	0.72	0.94	0.75	0.74	0.99	1.16	0.77	1	0.9
0.24	0.6	0.65	0.85	0.67	0.66	0.85	1.03	0.67	0.9	0.9
0.34	0.45	0.52	0.66	0.56	0.5	0.62	0.74	0.52	0.7	0.9
0.48	0.31	0.37	0.43	0.38	0.36	0.41	0.47	0.37	0.48	0.86
0.7	0.3	0.32	0.33	0.3	0.34	0.34	0.37	0.3	0.47	0.49
1	0.29	0.32	0.28	0.28	0.34	0.3	0.31	0.28	0.46	0.36

GH: Guwahati; IT: Itanagar; KH: Kohima; DG: Dibrugarh; SH: Shillong; SC: Silchar, IM: Imphal; AZ: Aizawl; AG: Agartala.

The MoES (2008) published seismic hazard microzonation maps of the Guwahati city area, which was carried out under the then DST project by multi-organizations using multidisciplinary methods. This map has been our reference map to estimate Predominant Frequency (PF) of some new borehole data obtained for the present study.

4.6 Study Area

Seismic hazard describes the potential for dangerous, earthquake related natural phenomena such as ground shaking, fault rupture, soil liquefaction. These phenomena could result in adverse consequences, such as the destruction of buildings and loss of lives. Assessment of seismic hazard in terms of ground motion depends on regional seismicity, attenuation of ground motion intensity and local site effect. The most important factor in defining surface ground motions is the local site effects. Therefore, assessment of site effects depends on the level of zonation.

The seismicity of the study region and its surrounding area is closely related to the geodynamics of the subduction and collision process. Unlike deterministic seismic hazard analysis, the probabilistic analysis allows uncertainity in size, location, rate of reccurrence and effect of earthquakes to be explicitly considered in the evaluation of seismic hazard. The probabilistic sesismic hazard requires the parameter 'b' of magnitude-frequency relation, the mean return period and maximum regional magnitude. In the present study seismic hazard parameters have been evaluated using ZMAP tool. places. Large earthquakes in the past caused widespread damage to life and property in this terrain. Hence seismic hazard assessment is very much essential for the study area t

Silchar is the headquarters of Cachar district in the state of Assam in India. It is the economic gateway to the state of Mizoram and part of Manipur. The city of Silchar is the second largest city of Assam after Guwahati in terms of population and municipal area. The study area is with latitude of 24.829 degree North and longitude of 92.819 degree East.

Study area having a radius of 300 km around the city center of Silchar Township, has been selected for seismicty study as per Regulatory Guide 1.16519. Regional, geological and seismological details for the Silchar city have been collected by using literature review, study of Seismotectonic map and remote sensing data. The study area is depicted in figure 4.6. covers major part of Assam, Mizoram, Arunanchal Pradesh, Tripura, Meghalaya and Manipur, Nagaland and Bangladesh.

4.7 Tectonics and Seismicity of the Study Area

The study region has been placed in zone V, the highest level of seismic hazard potential, according to the seismic zonation map of India. The study area is seismically active being surrounded by Kapili fault to the North, Naga thrust, Indo Burma ranges to the East, Tripura Belt, Mizu Folds to the south, Bangladesh basin to the South west and Shillong Plateau to the West. Any major Earthquake in the surrounding zones will definitely affect Silchar.

More than 200 earthquake of magnitude greater than 5 has taken place around the study area since 1762 Among them , some of the significant earthquakes that shook Silchar are 1869 Cachar Earthquake (M 7.5), 1918 Srimangal (Bengal Basin) earthquake (M 7.9), 1984 Cachar Earthquake (M 5.8). Figure 4.6 depicts the recent past seismicity in the study region during 1762-2008 along with the magnitude of those events.

4.8 Site Response (Literature Review):

A detailed Literature Review has been done for the study area and the PGA map prepared by Sharma et al (2006) has been redrawn and presented in Fig 4.8 to get first hand information on the ground motion effect of the study area. The two attenuation relationships used for this study are- Sharma and Bungum (2006) and Youngs et al (1997). The relationship by Sharma and Bungum (2006) has been developed based on the data acquired in the Himalayas. The attenuation relationship by Youngs et al (1997) has been developed for subduction zone earthquake. The results of the probabilistic seismic hazard analysis in the study made by Sharma et al may be used for the seismic microzonation of the area and for earthquake engineering use. The approximated PGA value for Silchar Town is 0.4g.

We have also studied seismicity of the study area indicating depth ranges and bvalue to identify the seismogenic zone and seismogenic depth. The b-value is found to be 0.8 (Fig 4.7) and as it is discussed earlier the frequency-magnitude relation, *b-value*, is one of the basic seismological characteristics to describe an ensemble of earthquakes. The b-value is normally close to 1.0 in a seismically active area. The depth section plot depicts that accept the Indo Burma Ranges most of the earthquakes are of depth< 60km. As we move towards higher longitude the depth also increases due to subduction zone earthquakes.

4.9 Estimation of Seismic Potential:

A complete catalogue is very much important for the determination of seismic potential parameters such as Mmax, a-value, b-value and Lambda. So only the complete part of dataset is used to calculate the hazard parameters using ZMAP tool. The strong ground motion at the surface is estimated using the CRISIS program (Ordaz, 2007). The hazard parameters estimated as mentioned has been used to compute the strong ground motion in terms of Peak Ground Acceleration. The two attenuation relationships used for this study are- Abrahamson and Silva (1997) and Youngs et al (1997). The relationship by Abrahamson and Silva (1997) has been developed for shallow crustal earthquakes in active tectonic zones. The attenuation relationship by Youngs et al (1997) has been developed for subduction zone and therefore applied in the present case. Thus estimated PGA value for 10% exceedance in 50 years is shown in Fig. 4.9.

The estimated PGA for our study area is within the range of 0.36 to 0.49g.

4.10 Estimation of Predominant Frequency:

Following the Ibs-von Seht and Wohlenberg (1999) relationship as given below, predominant frequency (PF) is empirically derived from the basement depth as obtained from the borehole data:

$$\mathbf{m = 96}(f^{-1388})$$

where 'm' is the basement depth in metre and 'f' in Hz is the predominant frequency of the site under consideration.

The result is depicted in the Table 4.3. The fundamental frequency varies from 2.8 to 9.53 Hz depending on the soil condition. However this study is not complete because of lack of data.

4.11 Results

The high seismic activity around the study area with PGA of 0.36 to 0.49g has made it a mandate to restrict the unplanned growth of buildings in Silchar city. Because it's not the earthquake but the buildings or unplanned constructions that kills people. A disaster like earthquake can't be stopped but at least we should be prepared to face the consequences.

The United States Geological Survey developed an Instrumental Intensity scale which maps peak ground acceleration and peak ground velocity on an intensity scale similar to the felt Mercalli scale.

Instrumental Intensity	Acceleration (g)	Velocity (cm/s)	Perceived Shaking	Potential Damage
I	**< 0.0017**	< 0.1	Not felt	None
II-III	**0.0017 - 0.014**	0.1 - 1.1	Weak	None
IV	**0.014 - 0.039**	1.1 - 3.4	Light	None
V	**0.039 - 0.092**	3.4 - 8.1	Moderate	Very light
VI	**0.092 - 0.18**	**8.1 - 16**	Strong	Light
VII	0.18 - 0.34	**16 - 31**	Very strong	Moderate
VIII	0.34 - 0.65	**31 - 60**	Severe	Moderate to heavy
IX	0.65 - 1.24	**60 - 116**	Violent	Heavy
X+	> 1.24	**> 116**	Extreme	Very heavy

So according to the table our study area belongs to severe shaking zone.

4.12 Conclusion:

The present study, a broad Seismic hazard assessment of Silchar is not accounting any in-situ measurement as suggested by ASDMA. So the study can't be considered as Seismic Microzonation. But with the available data the calculation has been made the range of PGA value for Silchar along with the Predominant frequency for the available borelog site. The study reveals that the area is seismically active with b-value 0.8 and PGA ranges from 0.35-0.4 (g) (Sharma et al). Site characterization for Silchar is incomplete due to unavailability of data.

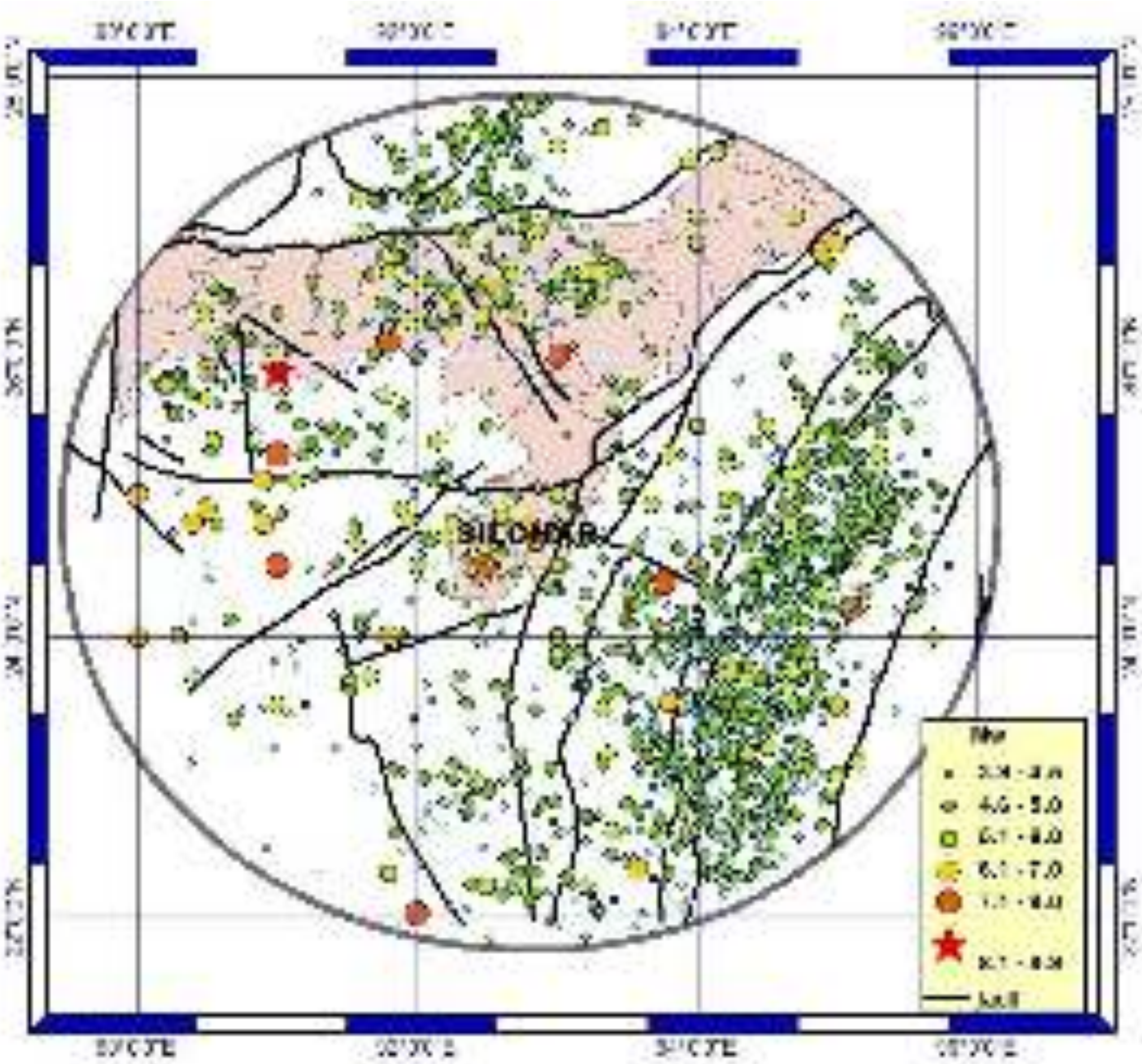


Figure 4.6 Seismicity Map of Silchar

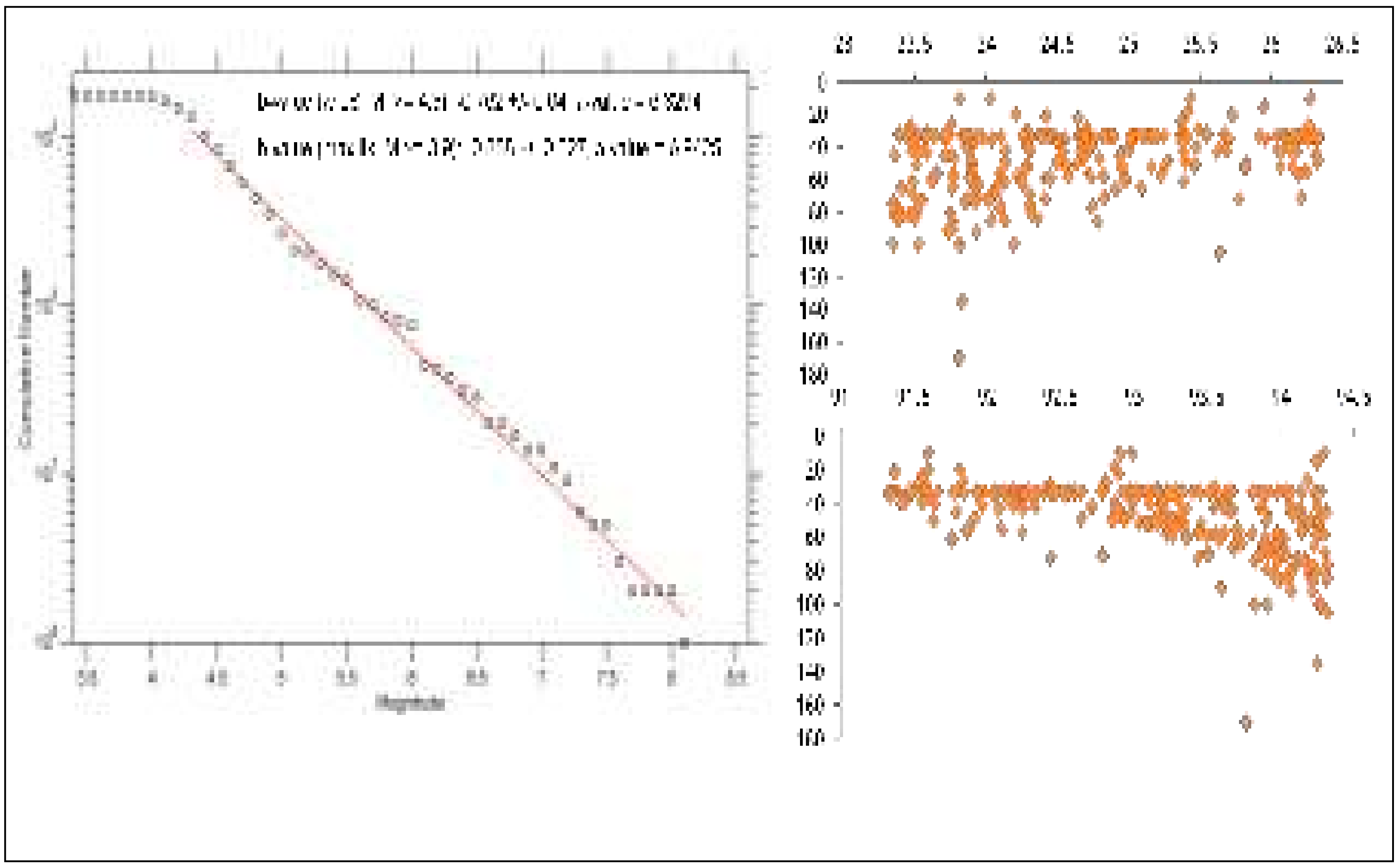


Figure 4.7 b-value plot and Depth Section plot of Silchar area (in and around 300km radius)

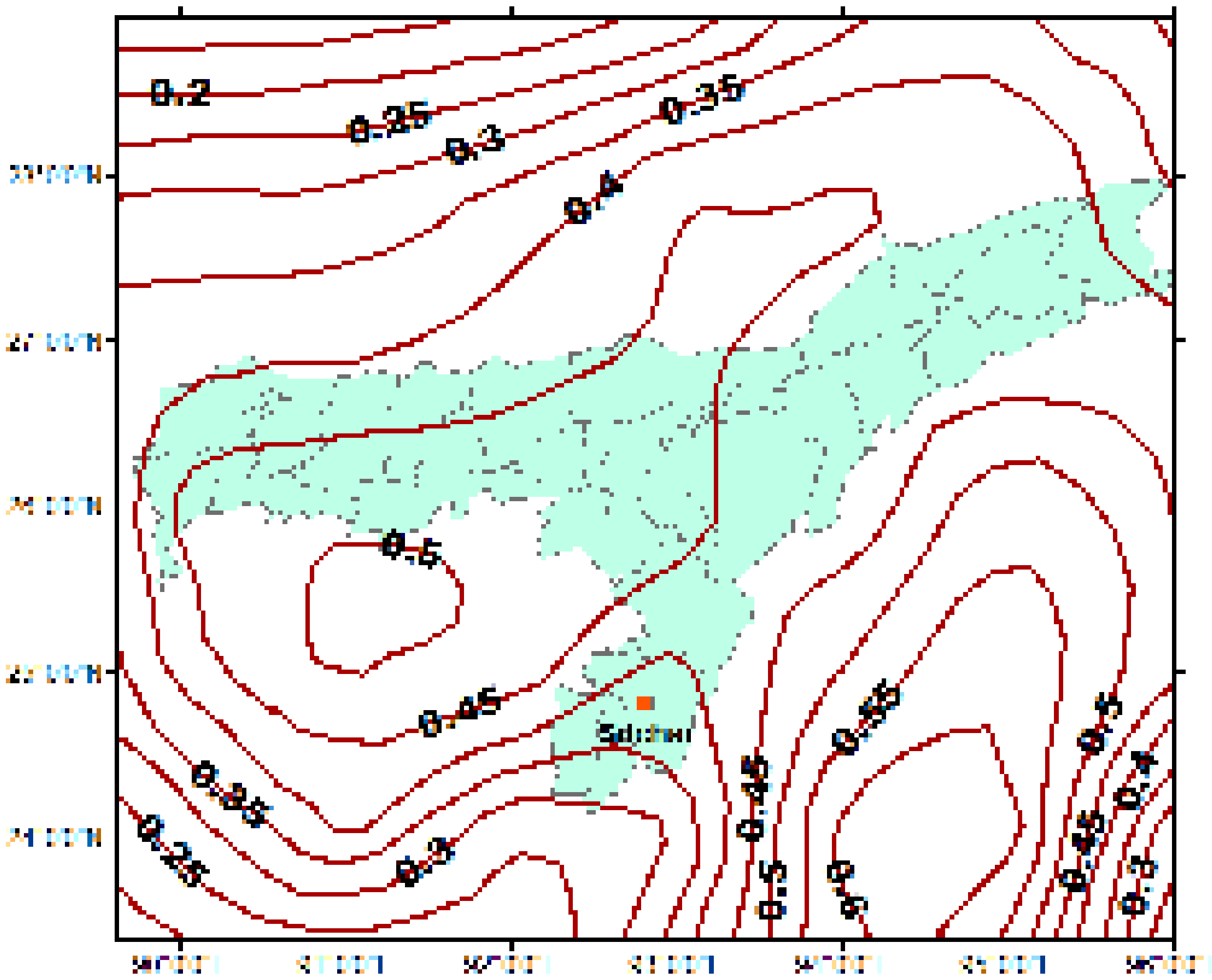


Figure. 4.8. PGA values for 10% exceedance values in 50 years for NE Indian region (Sharma et al (2006)

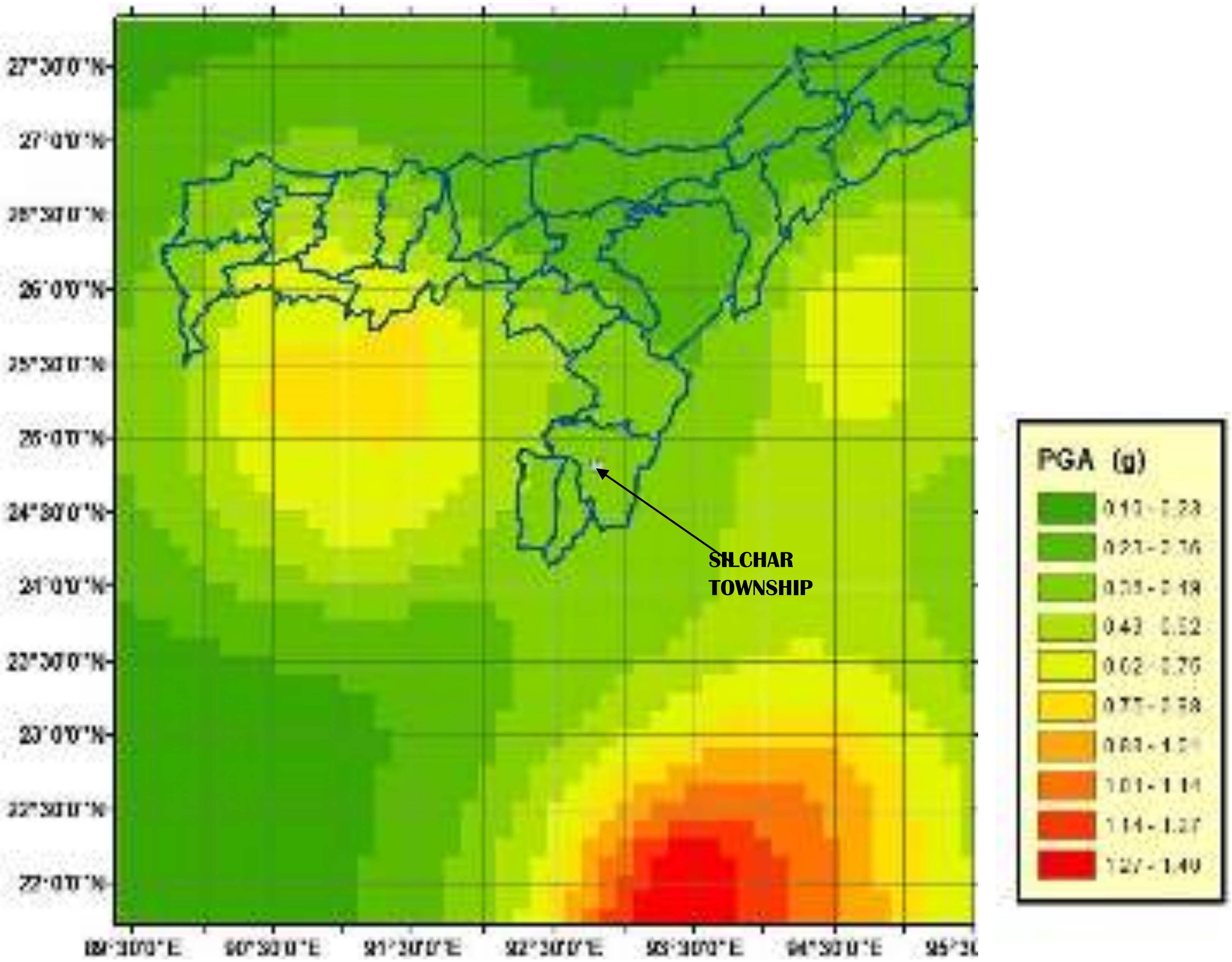


Figure 4.9 PGA (g) shaded map for 10% exceedance in 50 years (NESAC)

TABLE 4.3: PREDOMINANT FREQUANCY OF SILCHAR TOWNSHIP

LOCATION	Basement Depth(m)	N value	Fundamental frequency (HZ)
Non Teaching Staff Quarters,Assam University, Silchar	5.5	19	7.85
SriGouri C.H.C, Karimganj	15	20	3.81
Katakhal Road over Bridge	32	25	2.21
Location not given	15	21	3.81
Salchapra Road over Bridge	12	15	4.47
Katakhal Road over bridge	32	27	2.21
All India Radio, karimganj	15	10	3.81
Salchapra Road over Bridge	22	12	2.89
All India Radio, karimganj	9.2	28	5.42
All India Radio, karimganj	9	7	5.5
Katigorah side (Right Bank) at Badarpurghat	16.5	19	3.56
Katigorah side (Right Bank) at Badarpurghat	17.5	25	3.41
between Salchapra and Srikona	5.7	10	7.65
between Salchapra and Srikona	4.2	8	9.53
between Salchapra and Srikona	15	17	3.81
between Salchapra and Srikona	15	16	3.81
ONGC Drill site, Baskandi	13.5	18	4.11
between Salchapra and Srikona	15	17	3.81

ANNEXURE - I

QUESTIONNAIRE FOR SOCIO-ECONOMIC CHARACTERISTICS

- Building Name & ID:
- Lat/Long:
- Address:
- City/Village:
- Building-use/type:Residential/Commercial/Institutional/Public Buildings/Industrial/Mixed Built up/Vacant land/open space.
- Building Construction type:-Masonry/RCC/Steel building/Timber building.
- No: of Floors:-
- Building Date:
- Average Population:

Age	<14	14-60	60>
M			
F			

- No. Of People:
- Building Age: <5yrs ☐ 5-15yrs ☐ >15yrs ☐

Age group	12AM -2 AM	2 AM - 4 AM	4 AM - 6 AM	6 AM- 8 AM	8 AM- 10 PM	10 AM -12 PM	12 PM -2 PM	2 PM- 4 PM	4 PM - 6 PM	6 PM -8PM	8 PM- 10 PM	10 PM -12AM
<14												
14-60												
60>												

- Flood Level: Ankle ☐ Knee ☐ Waist ☐ Chest ☐ Chest + ☐
- Flood Duration: 1 Day ☐ 2Day ☐ More than 2 days ☐
- Any other relevant information including field check.

QUESTIONNAIRE FOR BUILDING INVENTORY

Building Name & ID:

Lat/Long:

Address:

Building Age: <5yrs ☐ 5-15yrs ☐ >15yrs ☐

Ward/Village:

Sl. No	NO. OF FLOOR (Stories)	STRUCTURE 1. Type A* 2. Type B* 3. Type C* 4. Type X*	ROOF CGI=C Cement=cc Tin Sheet=TS Others=O	WALL Brick=BR CGI=C Bamboo=B Wooden= W Stones=S Mixed=M( )	FLOOR Mud=M Cement=C Bamboo=B Wooden=W Mixed=M( )	USE Residential=R Institutional=Inst Industrial-Ind Commercial=C ( ) Public=P ( ) Mixed=M ( )	EXISTANCE Walls=W Displace-ment/Tilt=D Drainage-DR Footpath=F Retaining Wall=PW	POPU-LATION
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1								
2								

*Note

Type A= Rural structures bamboo reinforced biomass wall cladding, thatched/CI sheet roof, Un-burnt brick house, Assam type houses in timber frame

Type B= Brick Masonry Wall 6”*6” to 10”*10” corner columns with lintel bend and tie, timber trussed CI sheet roof, building of large blocks and prefabricated type, half timbered structures, building in natural hewn stone

Type C= Reinforced Concrete Building Engineered & Non-engineered with beam, column & Slab construction, well built wooden structures

Type X= other types not covered in A, B, C

Rural Structure

Brick Masonry Wall building

Reinforced concrete building

PLATE 1: Building characteristics in Silchar Town

SILCHAR Z-FLOOD SURVEY

PLATE 2a Silchar Town Locality - Z Flood Survey

PLATE 2b Silchar Town Locality - Z Flood Survey

PLATE 2c Silchar Town Locality - Z Flood Survey

PLATE 2d: Silchar Town Locality - Z Flood Survey

SL_NO	EASTING	NORTHING	HEIGHT	CODE
1	480081.912	2747347.597	22.254	GL
2	480100.058	2747368.276	22.418	GL
4	480169.564	2747473.280	22.619	GL
5	480153.892	2747451.682	21.413	GL
6	480167.453	2747426.557	20.425	GL
7	480140.597	2747430.434	22.602	GL
8	480139.900	2747430.005	22.645	GL
9	480103.618	2746815.734	20.741	GL
10	480133.270	2746844.396	20.500	GL
11	480165.638	2746841.302	20.186	GL
12	480200.207	2746848.474	21.486	GL
13	480182.611	2746856.480	20.769	GL
14	480157.298	2746868.342	20.435	GL
15	480206.778	2746875.884	23.212	GL
16	480182.840	2746892.006	20.556	GL
17	480362.412	2746973.443	19.171	GL
18	480324.644	2746936.202	21.361	GL
19	480340.459	2746980.892	22.413	GL
20	480210.379	2746910.643	20.883	GL
21	480232.082	2746898.557	22.852	GL
22	480247.804	2746881.533	22.339	GL
23	480268.099	2746857.917	21.083	GL
24	480273.015	2746869.698	21.073	GL
25	480309.013	2746892.166	20.953	GL
26	480225.217	2746812.950	21.788	GL
27	480244.373	2746803.566	21.057	GL
28	480259.400	2746822.410	20.966	GL
29	480296.672	2746793.596	21.236	GL
30	480285.856	2746816.161	20.886	GL
31	480298.014	2746860.756	21.125	GL
32	480329.955	2746850.843	21.081	GL
33	480365.930	2746839.967	21.001	GL
34	480398.092	2746881.736	21.042	GL
35	480385.845	2746835.324	20.895	GL
36	480408.829	2746828.791	20.644	GL
37	480444.064	2746816.400	20.841	GL
38	480465.504	2746975.782	22.067	GL
39	480456.455	2746946.500	21.338	GL
40	480490.070	2746976.081	19.811	GL
41	480461.592	2746871.549	20.720	GL
42	480454.215	2746851.963	20.808	GL
43	480423.588	2746849.588	20.954	GL
44	480413.500	2746868.356	20.898	GL
45	480429.042	2746883.890	20.446	GL
46	480437.734	2746906.963	20.784	GL
47	480467.663	2746898.517	22.697	GL
48	480482.144	2746936.745	21.053	GL
50	480497.843	2746889.228	22.996	GL
51	480484.251	2746844.181	22.995	GL
53	480458.706	2746766.053	22.186	GL
54	480470.842	2746761.919	23.110	GL
56	480444.716	2746743.184	23.048	GL
57	480461.547	2746726.689	23.119	GL
58	480347.954	2746576.704	23.117	GL
59	480368.026	2746603.624	23.101	GL
60	480349.926	2746618.707	21.485	GL

PLATE 2e Z-Flood Survey for Silchar - DGPS Control Points

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