EARTHQUAKE VULNERABILITY ASSESSMENT OF GUWAHATI URBAN CENTRE

J . Pathak[1]

[1] *Asstt. Professor, Dept. of Structural Engineering , Assam Engineering College*
Email: jayanta_pathak@rediffmail.com

ABSTRACT :

Urban seismic risk in Guwahati is increasing with population growth and the encroachment of vulnerable built-in environment into areas susceptible to seismic hazard. The city lies in zone V and is the gateway to seven north-eastern states of India. Under the initiative of the Department of Science & Technology an effort has been made to enhance the understanding of the vulnerability of the built-up environment of the Guwahati city and generate seismic risk map on the Geographical Information System (GIS), based on hazards evaluated through an already accomplished seismic microzonation mapping. An inventory of building data has been created to facilitate risk mapping by appropriate indexing of the risk involved due to potential hazard to the existing buildings/structures. The current building map of Guwahati has been completed on GIS with 85,000 building footprints covering the entire Guwahati Metropolitan Area. The building map has been prepared using both field survey and satellite imagery. The vulnerability of existing building stock in the Guwahati Metropolitan area have been studied both qualitatively and quantitatively. The Rapid Visual Screening (RVS) procedure has been adopted for qualitative vulnerability assessment of the structures and first level vulnerability analysis has been completed based on building typology and survey data. The first level seismic risk map has been prepared by overlaying the building inventory data on the final seismic hazard map considering the weighted contribution of all existing hazards as evaluated from the microzonation study. An attempt has been made to identify buildings susceptible to landslide hazard and hazard due to potential liquefiable area.

KEYWORDS: Building Vulnerability Seismic Hazard Risk

1.0 INTRODUCTION

Urban seismic risk in Guwahati is increasing with population growth and the encroachment of vulnerable built-environment into areas susceptible to seismic hazard. The city lies in zone V and is the gateway to seven north-eastern states. Department of Science and Technology (DST) initiated the seismic microzonation of the Guwahati city. The Department of Science & Technology initiated this project with an objective to enhance the understanding of the vulnerability of the built environment of the Guwahati city and draw risk map based on hazards evaluated through the seismic microzonation initiative. As a part of this project an inventory of building data has been developed , wherein , a large sample of more than 8000 buildings have been surveyed physically along with mapping of 85000 buildings from satellite data, which represents building types scattered over 60 municipal wards. To bring this whole exercise to a meaningful logical conclusion for engineering use – it is of utmost important to overlay of the building vulnerability data on various hazard maps prepared under microzonation project to evaluate risk maps to manage seismic disaster reduction measures, including preparedness, seismic retrofit, emergency response activities and city planning. An exhaustive exercise of creating an inventory of building data of Guwahati Urban Centre has been completed for preparation of various risk map of Guwahati city. The first risk map has been provided by overlaying the building inventory data on the final hazard map considering the weighted contribution of all existing hazards as evaluated from the microzonation study. The risk map due to landslide hazard and hazard from potential liquefiable areas are also presented.

2.0. IMPORTANCE OF THE STUDY

The first attempt to create Vulnerability Atlas of India -ASSAM (Building Materials & Technology Promotion Council-1999),) details out vulnerability tables wherein damage risk levels for earthquakes are defined based on the intensity scale such as Very High, High, Moderate, Low, and Very Low, and categorization of houses has been carried out based on distribution of houses by predominant materials of roof and wall, according to 1991 Census. The earthquake damage risk associated for Guwahati urban area varies from very low, low, & medium for Type-C, Type-B, & Type-A houses respectively.

An estimate of losses for future earthquakes is essential for city like Guwahati and a seismic risk map of the city prepared from survey of existing building will be important for:

A. Land-use planning from a map-based analysis that identifies those parts of the city where buildings are at various level risk of damage.
B. Prioritization of retrofit or abatement programs from estimate of building damage, thus providing the basis for establishing programs to mitigate or strengthen buildings that may collapse in earthquakes.
C. Local emergency response and contingency planning from estimates of casualties and of damage to buildings and utilities.
D. Medical and relief agency preparedness and response to casualties and homelessness.

3.0. THE APPROACH & METHODOLOGY

The approach for assessment of seismic vulnerability of buildings involves estimation of seismic vulnerability of existing building stock both quantitatively and qualitatively. The quantitative approach covers demand-capacity computation, while the qualitative procedure has been based on structural / non-structural damage grade indexing as per national & international state-of-the-art procedures viz. Rapid Visual Screening (RVS) Procedure (Applied Technology Council -1988). The methodology adopted in carrying out the survey and indexing damage potential to various buildings are in line with the proposed methodology by Ministry of Home Affairs (MHA), India. The quantitative approach covers demand-capacity computation broadly as outlined in ATC-40(Applied Technology Council-1996). Evaluation is a complex process, which has to consider not only the design of building but also the deterioration of the material and damage caused to the building, if any. The non-availability of a reliable estimate of earthquake parameters, to which the building is expected to be subjected during, its residual life poses another challenge. The rebound hammer was usually used to assess the compressive strength of concrete structural members, wherever access was provided in reinforced concrete structure. In view of above constraints, the present study is limited to seismic evaluation of representative buildings of different typology viz. Type-A (Mud/RR Masonry,

Adobe), Type-B (Brick Masonry Buildings), and Type-C (RCC Buildings), and projects a generalized pattern of building response to future seismic ground motion in different wards/zones of Guwahati urban area. The results are mapped for different types of buildings viz. Adobe/Mud houses (Type-A), Masonry buildings with RCC corner columns and Lintel band (Type-B) and reinforced concrete (Type-C) buildings. An attempt has been made to prepare seismic risk map with engineering, seismological inputs on vulnerability of engineered and non-engineered structures including parameters of population living in dwelling susceptible to damage and other exposure factors.

3.1 Site Visit & Building Survey

The region delineated under Guwahati Metropolitan Area includes Guwahati Municipal Corporation (GMC) area measuring 262 sq. km, North Guwahati Town Committee, Amingaon Census Town and 21 revenue villages. In addition to the above area are the Narengi Cantonment areas, Guwahati Refinery (IOCL) area, NF railway Colony which show planned cluster of buildings. In order to evaluate seismic vulnerability of building stocks in Guwahati urban area, house to house survey was carried out – involving physical measurement to get accurate building footprint, chainage of building reference point along with collection of socio-economic data. The comprehensive house to house survey was limited to Guwahati Municipal area, which is divided into 60 numbers of municipal wards as delineated by Guwahati Municipal Corporation. All these wards do not show any cluster formation making it imperative to collect data from each building carrying out house to house survey. The other demarcated area viz. cantt., refinery and railway colony area in Maligaon has well defined cluster formation and therefore building footprints are being generated from satellite imagery. Survey of representative samples from these areas is carried out. In addition, Narengi Cantonment Area, Refinery area, NF railway area and surrounding revenue villages have been considered as a separate zone. The revenue villages around Guwahati are kept out of the survey as all these villages are mostly dominated by houses built from bamboo reinforced biomass as cladding and thatched / CI sheet roofing, which have very low vulnerability. However, footprints of these building stocks are being incorporated from satellite imagery with the building type attribution as Type A to get a complete picture of the Guwahati metropolitan area.

Fig. 1 and Fig 2 show the building footprint map and building typology distribution map with height respectively.

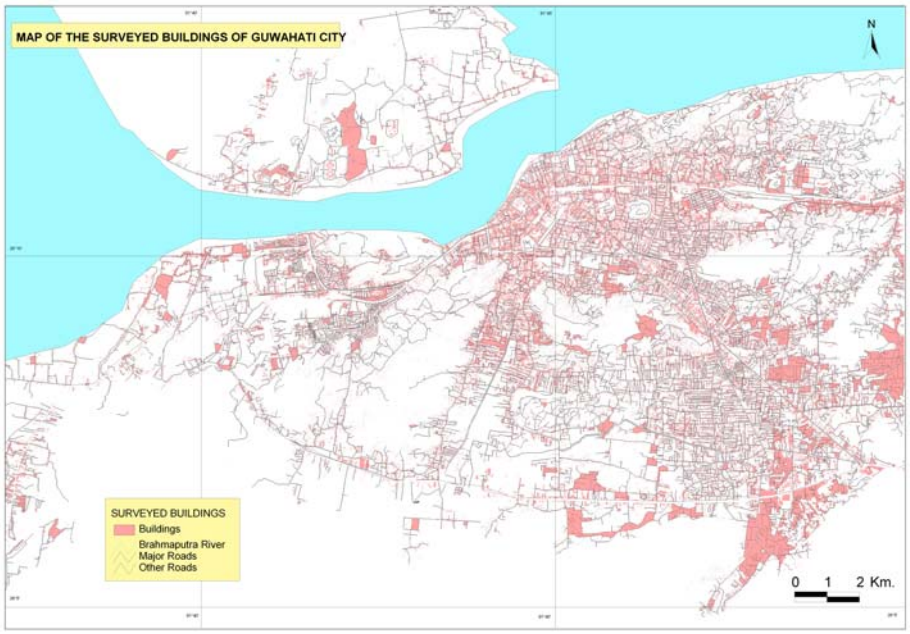

Figure 1: Existing Building Footprints in Guwahati Metropolitan Area

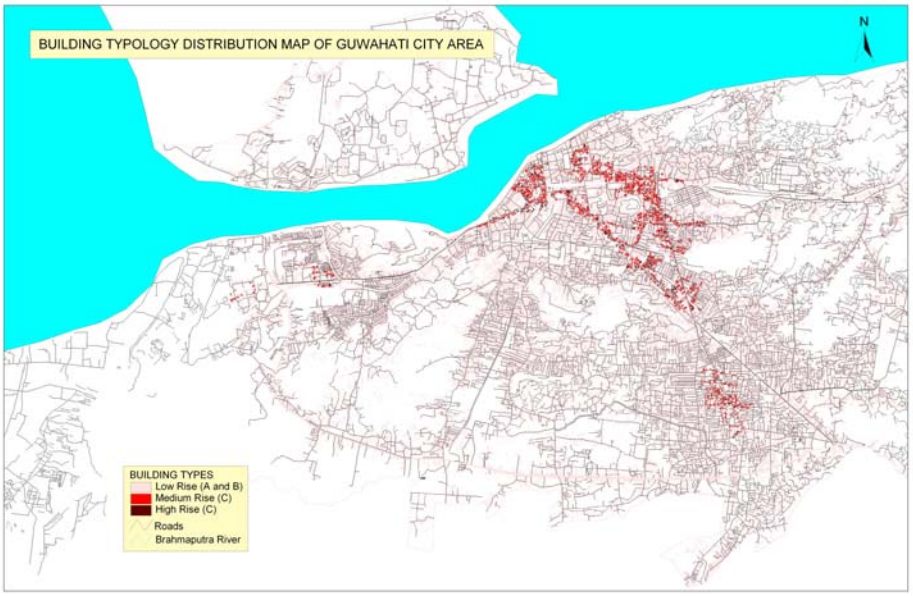

Figure 2: Existing Building Typologies in Guwahati Metropolitan Area

The majority of houses in the villages around Guwahati urban area are of Assam Type categorized in TYPE-A & B - (a) brick masonry wall, 6"X6" R.C. Column, lintel band, tie and with Timber truss. (b) Bamboo reinforced Biomass Wall cladding with roofs made of thatch of bamboo supported on bamboo purloins. These building have very low vulnerability.The Existing building stock in municipal area of Guwahati city is comprised of RC framed structure. (TYPE-C - around 85%). These dwellings units are mainly 2 to 3 storey with 3.00 to 3.3 m average storey height. Most of the residential dwelling units are non-engineered, but has earthquake resistant elements in-built viz. tie beams, column sizes are minimum 250mm X 250mm. In most of such buildings the column reinforcements are 4-16 TOR. There are few such buildings, which were built around 1965-70 are reinforced with mild steel. There has been phenomenal increase in construction of multi-storied apartment and commercial buildings, which are mostly G+5 to G+8 RC building. These buildings are engineered in a sense that the buildings are designed by engineers as per IS:1893 (Bureau of Indian Standards-2002) , which has been made mandatory by the urban regulatory authority about 10 years ago, but about 20% of these buildings are found deficient while quantitative analysis was done as per newly amended IS:1893-2002. Implementation of BIS provisions regarding earthquake resistant design & construction were found to be absent almost in all the non-engineered TYPE-C residential buildings.

The study found that most of the residential buildings in Guwahati are constructed based on socio-economic consideration rather than engineering approach. The majority of building stock (about 85%) composed of Type-C buildings. The TYPE-B and TYPE-A buildings in residential area (about 15%) are though non-engineered, they have earthquake resistant construction features inbuilt in them. General construction of RC framed buildings are of nominal concrete of M15 grade (1:2:4) ranging from 3 to 4 story with story height of 3.00 to 3.30 m (Type-C Structures) having RCC slab of 120-140 mm thickness and 200-250 mm thick brick masonry in CM (1:6) as infill. Figure 5 shows some typical building types existing in Guwahati.

3.2 Quantitative Seismic Vulnerability for Masonry Buildings

The demand placed by an earthquake i.e. lateral forces at various levels, as per IS:1893-2002(Bureau of Indian Standards-2002), along with gravity load calculations were carried out for sample buildings, and later check in terms of Demand Capacity Ratio (DCR) for shear resistance, combined stress, overturning, and stability of non-structural failures for long and short walls. The DCR greater than unity, indicates that the building is seismically vulnerable in respective criterion, whereas DCR less than one implies the building to be safe under earthquake loads. The check for non-structural element implies the falling hazard of parapet wall. he above analogy has been used to estimate seismic vulnerability in terms of various failure modes i.e. collapse,

excessive cracking, falling of walls

Figure 5: Existing Building Typologies in Guwahati Urban Area

including parapet walls. The city of Guwahati fortunately does not have many loads bearing structures, and the only area where such structures are located are the NF Railway colony, where all the official residences are on load bearing wall structure ranging from one to even three stories.

3.3 Quantitative Seismic Vulnerability for RC Buildings

In order to critically evaluate the RC framed buildings, selected building sample were modeled using structural analysis software under combination of earthquakes & other loads for computing the member end forces in each structural member. The sample structures have been analyzed for design basis earthquake (DBE) loads, the earthquake loads which can reasonably be expected to occur at least once during the lifetime of the structure. In order to calculate the DCRs, the calculated reinforcement of structural members has been compared with provided reinforcement. The DCRs calculated for flexure and shear gives the idea about inherent ductility and strength of member to ensure safety & serviceability during severe shocks.

The DCR greater than one for flexure indicates that the longitudinal reinforcement in columns & beams are inadequate leading to failure. The possibility of failure of such buildings is excessive cracking leading to collapse. Whereas DCR greater than one in shear indicates that the lateral ties provided are not sufficient leading to brittle failures i.e. catastrophic failure. In this case, there is possibility of diagonal cracking in structural elements. Based upon above analogy, DCRs for flexure, shear and stability of non-structural members viz. parapet wall etc., the seismic vulnerability of the structures are evaluated in terms of failure modes i.e. excessive cracking, diagonal cracking and falling hazard respectively, for sample RC buildings have been computed.

4.0 Summary - Prognostic Damage Scenario of Guwahati Urban Area & First Risk Map

The damage scenario is being worked out in a ward is based on representative building surveyed for different building typologies and not final and complete. It is found that Type-A, Type-B & Type-C buildings are 10%, 40%, & 30% vulnerable respectively. Unlike in other parts of India – rural housing in general in North-eastern are very light and devoid of use of load bearing walls and stones. The roofing is very light rendering them very safe against earthquake. For Type-B buildings, the postulated failure modes have been categorized as excessive cracking (EC); falling of walls (FW); falling hazard of non-structural members (FH); and combination thereof - Excessive cracking + falling of wall (EC+FW); excessive cracking + falling hazard (EC+FH); falling of wall + falling hazard (FW + FH); excessive cracking + falling of wall + falling hazard (EC + FW + FH); and safe buildings (which do not have any failure). Similarly, the various failures modes for assessing seismic vulnerability of Type-C buildings are identified as excessive cracking (EC), diagonal cracking (DC); falling hazard of non-structural members (FH); and combination thereof and safe buildings. The prognostic damage scenario for Type-C buildings in Guwahati urban area also being worked out. The buildings in, rural structures-bamboo reinforced biomass wall cladding and thatched roof/CI sheet (classified as Type-A), comprises of 4-5% of total building stock in Guwahati Metropolitan area. All the buildings are light weight with sturdy ductile bamboo framing showing seismic resistant measures and are of very low vulnerability. About 15 % building stock in Guwahati area composed of Type-B buildings which include ordinary brick masonry buildings with 6”X6” corner column and lintel bend& tie beams. As regards to seismic damage scenario, around 60% buildings are safe, while 40% buildings are likely to suffer damages in form of excessive cracking, falling of walls, falling hazard of non-structural component and combination thereof. The engineered RC construction in the region typically consists of RC Moment Resisting Frames (Type-C) with in filled brick masonry walls, which constitutes about 85% of total building stock. The buildings are found to be designed for earthquake loads with deficient provisions for ductility. In case of an earthquake around 70% buildings are safe whereas rests of Type-C buildings are likely to suffer damages in the form of soft-storey failure, excessive cracking, diagonal cracking, falling hazard and its combination. This study will finally presents the seismic damage scenario of Guwahati urban area taking into account all prevalent construction practices, material of construction, quality/workmanship of construction, types of buildings. The geological / geotechnical parameters based on ground realities are to be collated and overall vulnerability of the building stock based on topographical variation, site response, sub-structure vulnerability to liquefaction leading to building collapse are being incorporated .

The first risk map based on available cumulative hazard index from microzonation study has been presented in figure 6. The risk map of building based on landslide hazard has been worked out overlaying the building map on landslide hazard map (Fig. 7). An attempt has been made to derive risk map from liquefaction potential hazard map by identifying the building falling in liquefiable are of the city (Fig. 8).

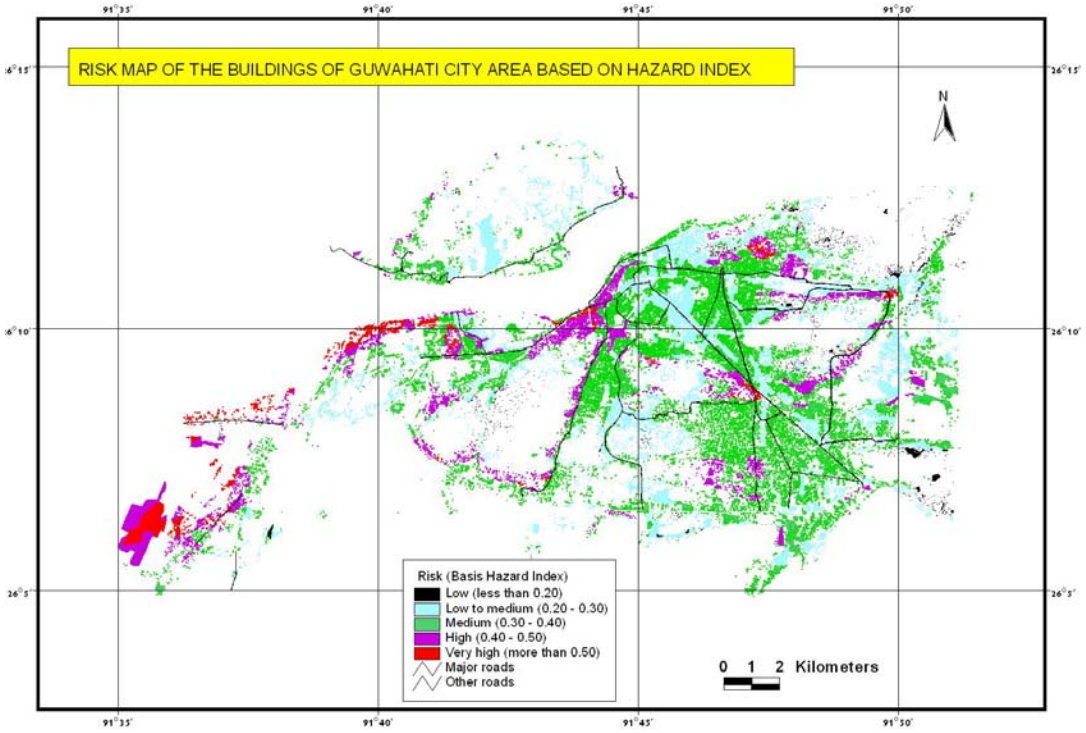

Figure 6: First Risk Map based on Cumulative Hazard Index from Microzonation

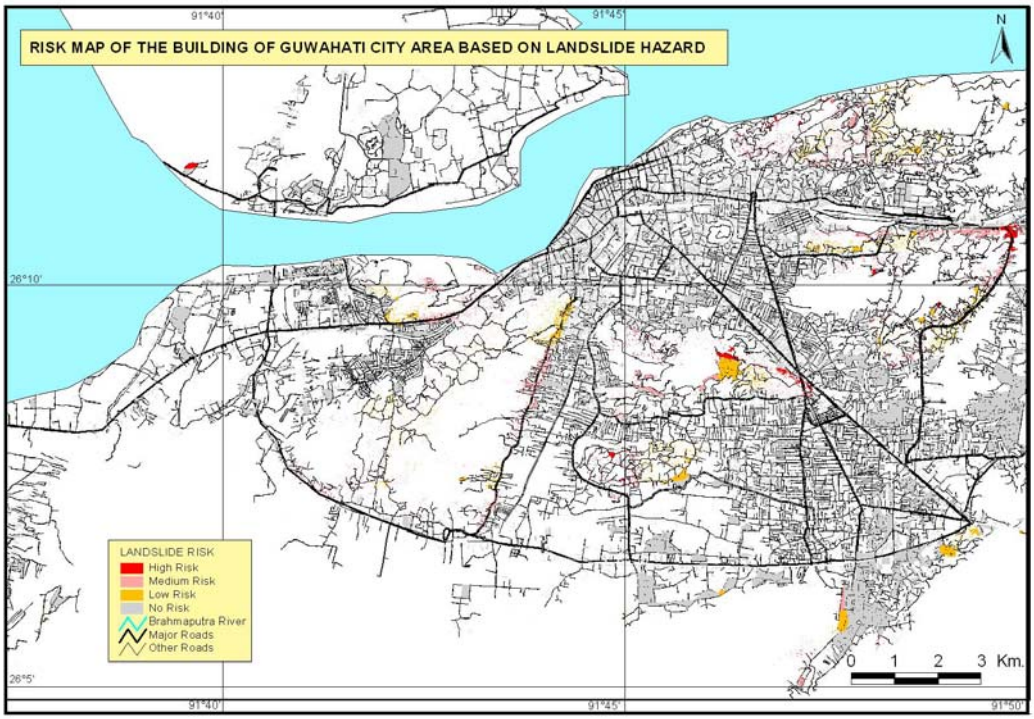

Figure 7: Risk Map of Building based on Landslide Hazard in Guwahati Metropolitan Area

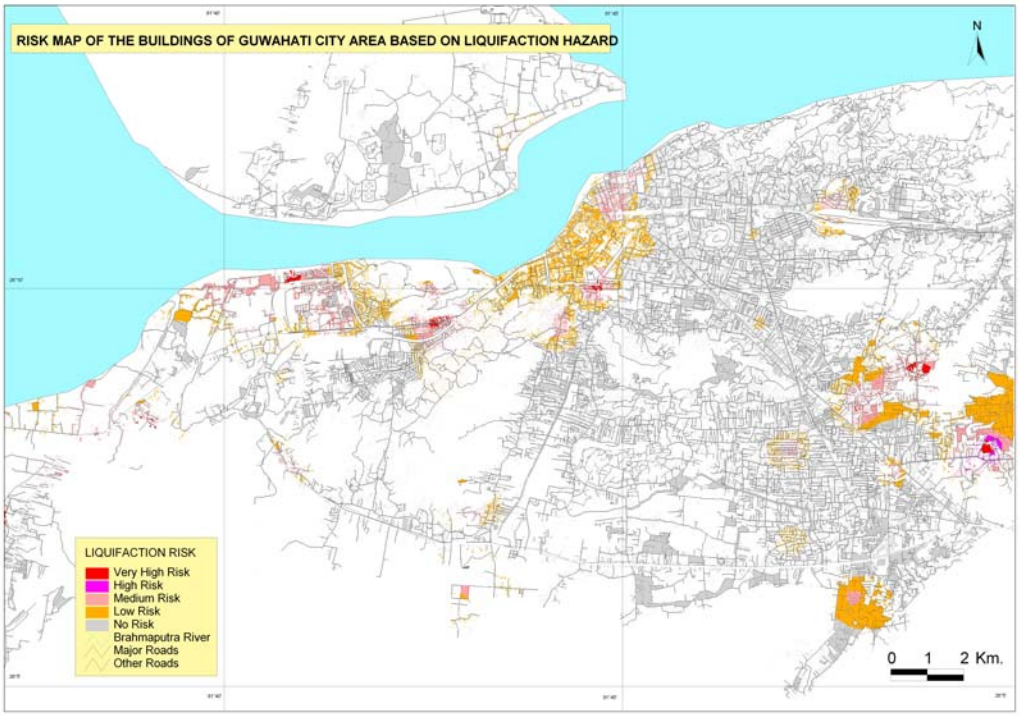

Figure 8: Risk Map of Building based on Liquefaction Potential in Guwahati Metropolitan Area

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