SEISMIC VULNERABILITY OF HOSHANGABAD TOWN OF MADHYA PRADESH, INDIA.

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ABSTRACT :

Earthquakes cause enormous destructions and human suffering in developing countries. Environmental degradation, which is often a result of economic development associated with human settlement pattern, which ignore appropriate resource management, increases the vulnerability of these countries to the disasters and exacerbates their impact. The losses due to the earthquakes reduce the pace of sustained economic development and often lead to a heavy drain on available resources diverting them from pursuing developmental aims. While earthquakes cannot be prevented, measures need to be taken to reduce the extent of damages, specially in a vast country like India with a huge population base and scarce facilities. Proper urban planning strategies should be utilized to regulate urban development as per the extent of damages anticipated. The article is a brief account of a study being done on the city of Hoshangabad, in Madhya Pradesh, an earthquake prone city of India. The Objective of the study is to develop earthquake damage scenario by utilizing building and infrastructure inventories, topographical information, Demographical Data and other relevant facts and figures to suggest suitable urban planning strategies to minimise the risk of damages being faced by the town being an Earthquake prone town.

KEYWORDS: Earthquake Scenario, Vulnerable, Risk Assessment.

1. INTRODUCTION

Unique geo-cıımatıc conditions of the Indian sub-continent make the region vulnerable to natural disasters. This is a densely populated country with 313 people per sq. km., 54% of the land is vulnerable to earthquake. High levels of risk combined with low levels of coping mechanism result in major disruption or loss of lives and livelihood. State of Madhya Pradesh, along with Gujrat and Maharashtra has suffered from frequent earthquakes, both deadly and damaging. All earthquake activity is confined to Narmada Son fault zone which runs across the State (Fig.1). The districts traversed by the river Narmada in the State are liable to Intensity VII, Zone III. The districts which have more than one third to 100 percent of their area in this zone are, Betul, Chhindwara, Damoh, Dewas, Dhar, Hoshangabad, Indore, Jabalpur, Jhabua, east Nimar, West Nimar, Narsimhapur, Raisen, Sehore, Shahdol, Sidhi and Surguja. A number of earthquakes of Magnitude ≥ 5.0 to 6.5 are known to have occurred in and around the State. The latest was the Jabalpur earthquake of 1997, which caused severe damage to clay wall rural houses and the burnt brick buildings in the city of Jabalpur. Therefore, protective measures need to be taken in the buildings against earthquakes in all the earthquake prone districts, where there is a possibility of Intensity VII. Out of these districts some towns are coming in the high-risk zone (Fig.2). Hoshangabad is one of the towns, which comes very close to this high-risk zone. It is situated very close to another fault and hence close to a cross fault (Fig.1). Geotechnically the town is settled on thick alluvium which is a very thick layer of sand mixed with clay and silt, it is not very compact, it is very loose, which may increase the damages during minor earthquakes also. Hoshangabad town (Fig.3) is a district headquarter situated on the banks of the river Narmada. It is the town which is not only prone to earthquake but also flood.

Figure 1: Tectonic features of MP showing location of Hoshangabad town.

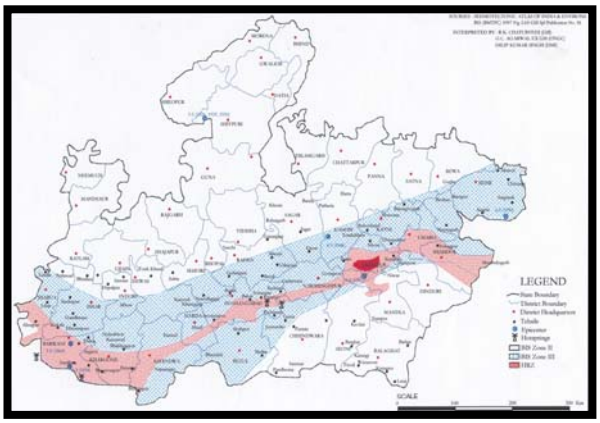


Figure 2: Earthquake Hazard Map of MP.

DISASTER HISTORY IN THE STUDY AREA

The Hoshangabad town ship is very close to the active SONATA fault, which is the root cause for seismic activities in the region. The area falls under seismic zone III, which comes under moderate seismic risk region. The region has experienced 7 earthquakes in last 150 years, among which two had magnitude more than 6.

STUDY AREA

Hoshangabad town is located in the south of Madhya Pradesh, on the banks of river Narmada, between 22º-20' North Latitude and 78º-00' East Longitude. Hoshangabad town (Fig. 3) is located about 75 Km from Bhopal, the State Capital. It is located on the National Highway No. 69, which

connects it to Bhopal towards North and to Itarsi towards South. It is located on the major trunk route linking Delhi, Bombay, Calcutta and Nagpur. Apart from one of the best rail connections to the North and South, Hoshangabad offers the sole road link to Pachmarhi (80 Km) via Piparia. State Highway No. 22 running parallel to rail line between Bhopal and Hoshangabad, opens up the hinterland, which is agriculturally very rich. The State Highway No. 15 connects it to Harda.

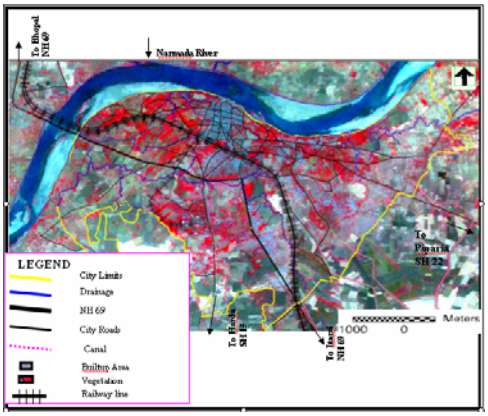


Figure 3: Base Map of study area.

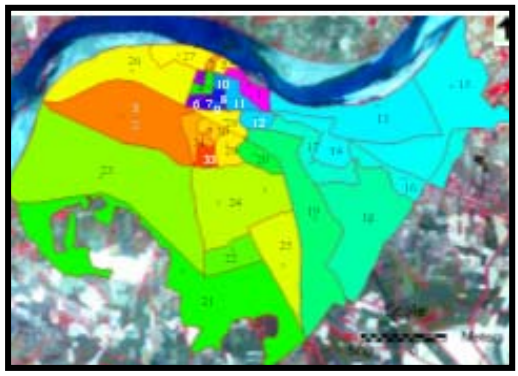


Figure 4: Ward Map of study area, Hoshangabad City.

METHODOLOGY

The above review of existing literature shows the hazard factor of the area further the disaster history of the area is also studied. Survey of India (SOI) toposheets, Satellite images, photographs, existing town maps and field survey has provided the base data. For studying the elements at risk, the Ward map, Population data, landuse map, Details of Housing, Types of roads etc is also studied.

Immediately after the disaster strikes the area, there is an urgent need of assessment of damage. The disasters are having their unique nature and negative impact of it is shown on the society. The objectives of damage assessment are to provide information of damage extent and severity of disasters, to mobilise resources for better rescue and relief for trapped and affected people to develop strategies for reconstruction and restoration of facilities.
If the damage is assessed before the occurance of a disaster measures can be taken beforehand to minimise the damages. Proper urban planning is an important tool, which one should utilize to regulate urban development as per the extent of damage anticipated.
In case of earthquake the buildings are the main cause of damage to life of human beings. Here the scenario has been developed only on housing stock excluding other infrastructure.

There are various ways by which buildings can be categorized. The criteria may be materials used for construction of wall, roof and floor, occupancy rate, Height of buildings. Since the scenario has been developed on the basis of The Medvedev Sponheuer-Karnik (MSK) Scale of Intensity. Further the categorisation is improvised using the Vulnerability Atlas of India. These are

1. A Type Adobe, Field stonemasonry, Unburnt brick walls.
2. B Type Burnt Brick Houses.
3. C Type RCC and framed structure.
4. X Type Others (Light building material GI sheet, Asbestos sheets).

Based on MSK scale (Source: IS: 1893-1984), the damage state has been classified in to five categories. Classification of Damage to Buildings:

Grade1 Slight damage- Fine cracks in plaster; fall of small pieces of plaster

Grade 2 Moderate damage-small cracks in walls; fall of fairly large pieces of plaster, panties slop off; cracks in chimneys; parts of chimney fall down.
Grade 3 Heavy damage- Large and deep cracks in walls; fall of chimneys.
Grade 4 Destruction- Gaps in walls; parts of buildings may collapse; separate parts of the building lose their cohesion; and inner walls collapse.
Grade 5 Total damage- total collapse of buildings.

The details of state of damage and impact of various types of buildings and their quantification may be referred at table 3. The extent of damage is stated qualitatively further deducing it to percentage. Definition of quantity is as follows:

Single, Few About 5 percent
Many About 50 percent
Most About 75 percent

The deducing into percentage is based on past earthquake experiences. The damage scenario has been worked out for all wards w.r.t. Varying intensity ranging from VI to VIII.

Table 1: Criteria for Damage Assessment: MSK Scale

Intensity	Particulars	Damage state	Type of building	Quantity	% of damage
VI	Fine cracks in plaster, fall of small pieces of plaster	1	B	Single	5
	Fine cracks in plaster, fall of small pieces of plaster	1	A	Many	50
	Small cracks in wall fall of fairly large pieces of plaster, pan tiles slip off, cracks in chimney, posts of chimney fall down.	2	A	Single	5
VII	Fine cracks in plaster, fall of small pieces of plaster	1	C	Many	50
	Small cracks in wall, fall of fairly large pieces of plaster, pantiles slip off, cracks in chimney, posts of chimney fall down.	2	B	Many	50
	Large deep cracks in wall, fall of chimney	3	A	Most	75
	Gaps in wall, parts of building may collapse separate parts of buildings lose their cohesion, inner wall collapse	4	A	FEW	5
VIII	Small cracks in wall, fall of fairly large pieces of plaster, pantiles slip off, cracks in chimney, posts of chimney fall down	2	C	Most	75
	Large deep cracks in wall, fall of chimney	3	C	Few	5
	Large deep cracks in wall, fall of chimney	3	B	Most	75
	Gaps in wall, parts of building may	4	A	Most	75

	collapse separate parts of buildings lose their cohesion, inner wall collapse Gaps in wall, parts of building may collapse separate parts of buildings lose their cohesion, inner wall collapse	4	C	Many	50
IX	Large deep cracks in wall, fall of chimney	3	C	Many	50
		4	C	Few	5
	Gaps in wall, parts of building may collapse separate parts of buildings lose their cohesion, inner wall collapse	4	B	Many	50
	Gaps in wall, parts of building may collapse separate parts of buildings lose their cohesion, inner wall collapse	5	B	Few	5
	Total collapse of building	5	A	Many	50
	Total collapse of building				
X	Gaps in wall, parts of building may collapse separate parts of buildings lose their cohesion, inner wall collapse	4	C	Many	50
	Total collapse of building	5	C	Few	5
	Total collapse of building	5	B	Many	50
	Total collapse of building	5	A	Most	75

With the help of the data collected using the damage assessment criteria earthquake damage scenario is cast. Earthquake damage scenario is a calculation of the effects of a single earthquake on a region. Usually a “maximum probable” or “maximum credible” magnitude earthquake is assumed, with a best guess location, based on known geological faults or seismic source zones.

The above hazard scenario will be analysed to suggest proper urban planning strategies to minimise the risk of damages being faced by the town being an Earthquake prone town.

DATA COLLECTION

For detail analysis, 33 wards of the township which come under Municipal Corporation have been taken for study (Fig. 4). The Municipal area covers 15,537 houses. To collect precise information about building stock distribution, a sample survey was conducted. In this regard, 5% buildings were surveyed and distribution was projected on the remaining building stock. The questionnaire has been developed for surveying the houses. The questionnaire includes detailed information about material used for roof, wall and foundation, economic condition of house owner, configuration of buildings etc. It was found that census housing stock distribution was coming near to the actual distribution. The distribution of categories of houses in 33 wards of town has been taken as distribution shown in Census report 2002. The scenario has been developed only on building stock excluding other infrastructure.

EARTHQUAKE DAMAGE SCENARIO

Based on experiences of past earthquakes, It is observed that A and B types are prone to damage at lower scale of intensity. The Hoshangabad town has 33 wards with population 97357.
Analysis shows that the damage severity shifts as the intensity increases. At Intensity VI, more damage is found to be of state 1. At Intensity VII the damage state increases to 2 and 3 with more damages in State 2. At Intensity VIII, damage is profound in C type of structures with more damages in type A and B. At varying intensities the damage of total building stock is as given at Table 1.

Table 2: Intensity and affected building stock

S. No	Intensity	Affected building stock	% Of affected building stock
1	VI	2014	12.96
2	VII	8188	52.70
3	VIII	11225	72.24

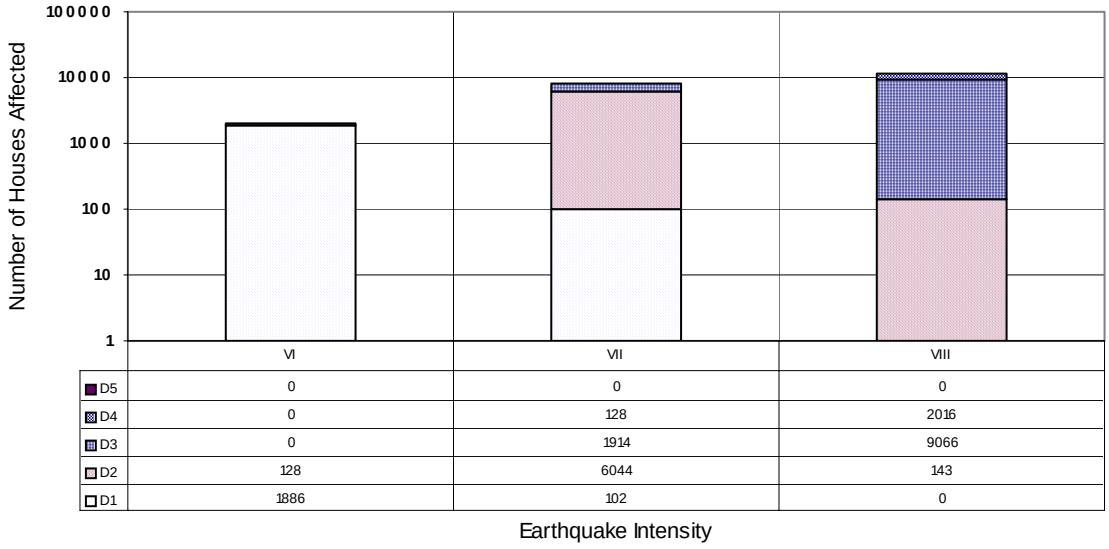


Figure 5 : Damage status at varying intensities

At varying intensities the damage in different wards can be seen in figure no. 6 and also in the fig.7, fig.8 and fig.9.

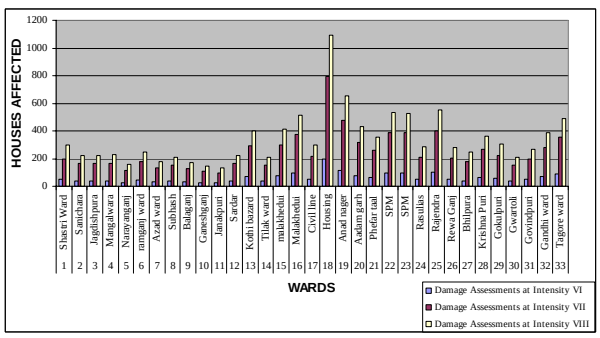


Figure 6 Damage to housing stock at varying intensities

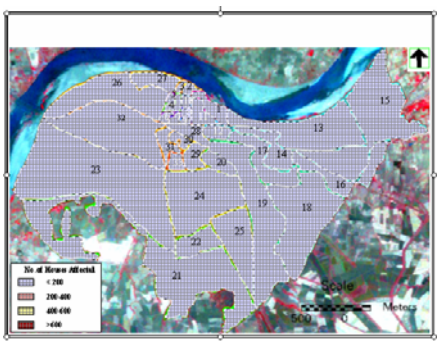


Figure 7: Damage to housing stock at intensity VI

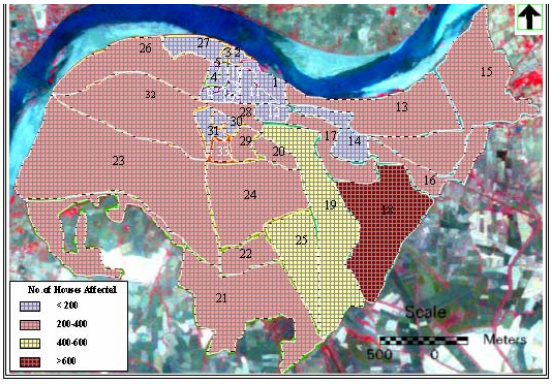


Figure 8: Damage to housing stock at intensity VII

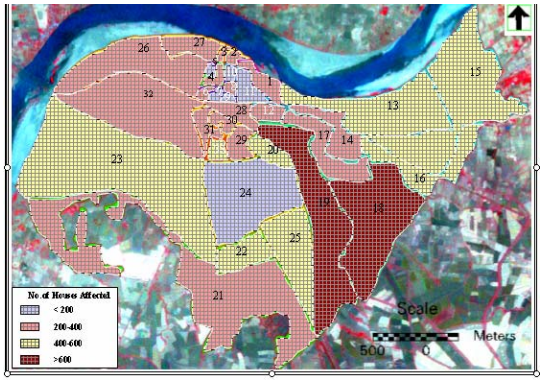


Figure 9: Damage to housing stock at intensity VIII

ANALYSIS & URBAN PLANNING STRATEGIES

As per the Earthquake Scenario, damage to houses may extend up to 73%. In view of such colossal damage, it is necessary to take immediate steps for earthquake safety of the area. Jagdishpura ward, Balaganj ward, Ramganj ward, Azad ward, Narayanganj ward, Subhash Ward, Tagore ward, Sanichara Ward, Ganeshganj ward and Gwartoli Ward are 10 most populated wards with congested streets and more occupation per house. It will be difficult to even provide rescue and relief to affected people due to its congestion. Subhash Ward, Krishna Puri Ward, SPM ward(East), Janakpuri ward, SPM ward(West), Gandhi ward, Tagore ward, Azad ward, Jagdishpura Ward, Shastri Ward are the wards with highest housing density i.e., density more than 700.

Hoshangabad town is situated on the bank of river Narmada having nearly 78 % of building stock of burnt brick and 16.50 % adobe and mud houses. Remaining 5 % buildings are either falling in concrete or other types. Based on experiences of past flood damages, It is observed that A and X types of housing stock is likely to be adversely affected and are prone to severe damage in low-lying areas.

Past experience shows that these brick masonry or mud buildings are moderate to high seismic vulnerable. The analysis shows that even at lower intensity of VI, about 13 % of buildings are going to be affected. At Intensity VII, more than half of building stocks are going to be affected. At Intensity VIII, nearly 73 % buildings are going to be affected with more towards higher damage states.

The detail of flood damage scenario indicates that the areas of eleven wards are coming under inundation at the worst scenario developed from the backwater of river Narmada. These wards are Sanichara Ward, Jagdishpura Ward, Kothibazar Ward, Malakhedui ward (south), Aadam garh ward, Phefar Taal ward, SPM ward (West), Rewa Ganj, Bhilpura Ward, Gwartoli Ward and Gandhi Ward respectively.

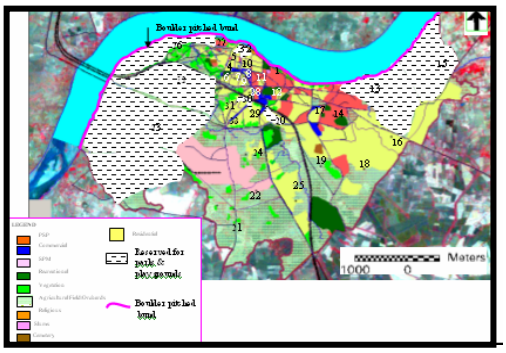
The town should be prepared for the worst possible scenario taken here which is the flood level of 978’ (298 m) which is considered to be most likely to occur. The areas which are likely to be worst affected at this scenario which are as follows:

Parks and play grounds, wood lands and gardens should be located here. People should be discouraged to make houses in these wards which come under flood affected low lying areas. The wards which come under flood affected low lying areas as mentioned above, which have soil conditions including the level of water table favorable to liquefaction or settlements under earthquake vibrations will have greater risk to buildings and structures so the existing structures should be relocated in the south western part of the town.

Table 3: Ward areas Worst affected by flood.

Ward No	Name	Area Under Inundation at 978' (298 m) (In Hectares)
2	Sarichara Ward	8.143555
3	Jagdishpura Ward	5.280048
13	Kothibazarward	99.04777
15	Malkhedi ward (south)	166.1698
20	Aadam garh ward	8.68791
21	Phefar taal ward	82.16096
23	SPM ward(West)	244.419
26	Rewa Ganj	56.53329
27	Bhalpura Ward	13.09243
30	Gwartoli Ward	5.073705
32	Gandhi ward	75.23808

Figure 10: Ward areas Worst affected by flood.



The density in the old city area i.e., ward no.'s 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 22, 23, 28 and 32 should be freezed to avoid further congestion and to avoid major losses in earthquake or flood event.

Phase wise retrofitting of all the housing stock should be undertaken which should be as follows:

Phase-I: Ward No.'s 18 & 19.

Phase-II: Ward No.'s 13, 15, 16, 20, 22, 23, 25 & 33.

Phase-III: Ward No.'s 1, 2, 3, 4, 6, 8, 12, 14, 17, 21, 24, 26, 27, 28, 29, 30, 31 & 32.

Phase-IV: Ward No.'s 5, 7, 9, 10 & 11.

As the area falls under Moderate Seismic Risk Zone, all the construction should be as per earthquake resistant building construction codes. By developing the existing corridors of the city, development of safer areas should be encouraged, which will reduce further congestion of the old city areas. Because of its strategic location on the National Highway and on the main Railway trunk route, Hoshangabad, has become a most sought often place for the people to settle, as compared to the surrounding places. Availability of resources like water etc. is contributing further to the urbanisation of the place. Development in the south-eastern side of the town should be encouraged by providing basic infrastructural facilities like roads, street lights, and water supply etc., coupled with lower land prices in these areas.

Through this study steps can be taken to contain the possible losses. In view of damage to houses and population, following Planning and Management Aspects should be taken care of:

PLANNING AND MANAGEMENT ASPECTS

The scenario study is the basic ingredient for development of disaster management plan for vulnerable area. Based on the severity of disaster, the plan has to be prepared. Following activities are required to be carried out for successful implementation of disaster reduction programme, provided availability of adequate funding support:

(i) Community Awareness

Though the region falls under moderate seismic hazard zone, but in recent past no major earthquake has been recorded. The people are not aware of seismic activities in the region. This is reflected in their living style and development. There is requirement of community awareness on following issues;

- **Building Construction and Retrofitting**: As the adages go "earthquake does not kill people but

buildings do". It is necessary to create awareness among construction engineers / structural engineers, skilled and unskilled masons about earthquake resistant building construction and retrofitting of buildings.

- **Search And Rescue Operation**: this is one of the major issues during response time. The community should develop skills for search and rescue for people trapped in collapsed houses and effective relief during response phase
- **Damage Assessment Techniques**: Damage Assessment techniques are very important to be known by the response officers or stakeholder. This makes the base for deployment of relief activities.
- **Do's and Don'ts**: Being in the moderate seismic risk zone, it is necessary to know the do's and don'ts at the time of disaster. Awareness should be created specially among vulnerable group of people viz. old aged, female and children.
- **Awareness** among policy makers/ stakeholders: policy makers and stakeholders play major role for policy decision. Creating awareness among them may help during decision for disaster mitigation and response.
- It is necessary to create awareness among community for opting disaster resistant construction. The building stocks, which are old and dilapidated, strengthening measure should be taken based on Indian Standard construction codes.

(ii) Construction and Retrofitting of Poor Building Stock / Infrastructure

- The area has 95% building stock, which is partially or fully vulnerable to earthquake shaking. So there is a dire need for earthquake retrofitting for poor and non-engineered construction.
- There is requirement for earthquake resistant building construction. The building byelaws include the earthquake resistant building construction but enforcement of such rules and laws are very poor. A stringent action from administration is desired.
- The infrastructure is required to be structurally strengthened. Special attention is to be given to roads and railways. All response centres should be well prepared for such eventualities. The lifelines should be strengthened in such a way that during disaster, it is affected to a minimum extent. Priority has to be fixed in three levels
  - **Priority 1** Defense Installation, industries, public utilities like hospitals, electricity installations, water supply, telephone exchange, aerodromes, Railway stations, commercial centres, libraries, other buildings or installations wit contents high economic values
  - **Priority** 2 Public institutions, government offices, universities and residential areas
  - **Priority** 3 Parks n play grounds, wood lands and gardens

(iii) Hazard Mapping

The local existing hazard which may trigger secondary hazards viz. liquefaction, land Subsidence and fire should be mapped and should be communicated to people of study area. The study area is having thick alluvium deposit with high ground water table causing the potential for liquefaction. But there is a need for details study to understand such phenomenon and mapping the same for study area.

(iv) Relief Inventories

- The availability and location of resources required for search, rescue and relief should be well documented. The database preparation, their updating should be done at regular interval.

(v) Infrastructure Mapping

- Ward level road network should be demarcated on map. This helps in selecting the shortest rout during crisis time for relief work
- The individual houses and structures with detail information should be marked on maps so as to work out the damage potential at micro level.
- All lifelines and infrastructures with their priority should be demarcated on the ward maps.

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