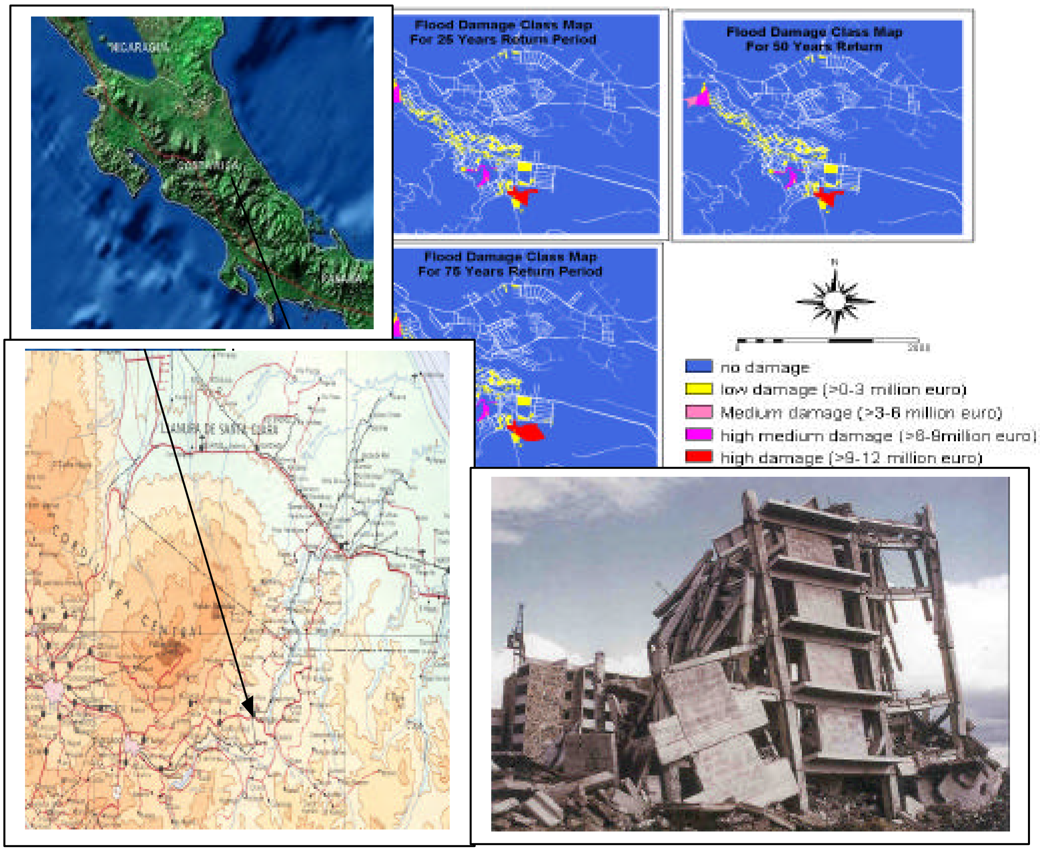
VULNERABILITY ANALYSIS AND RISK ASSESSMENT FOR SEISMIC AND FLOOD HAZARD IN TURIALBA CITY, COSTA RICA



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I. Introduction ... 3
1.1. Problem description ... 3
1.2. Objectives ... 3
1.3. Methodology ... 4
II. Description of The study area ... 6
2.1. Geographic setting ... 6
2.2. Geological condition ... 6
2.3. Geomorphologic condition and earth processes ... 7
2.4. Soil condition ... 7
2.5. Hydrological condition (including history of flood) ... 7
2.6. Land use and urban area ... 8
III. Hazards Assessment ... 8
3.1. Seismic hazard assessment ... 8
3.1.1. Literature review of seismic hazard ... 8
3.1.2. Methodology ... 8
3.1.3. Generation of seismic hazard maps ... 9
3.2. Flood hazard assessment ... 9
3.2.1. Literature review of flood hazard ... 9
3.2.2. Methodology ... 10
3.2.3. Generation of flood hazard maps ... 11
IV. Vulnerability Analysis ... 12
4.1. Element at risk and their attributes ... 12
4.1.1. Population vulnerability ... 12
4.1.2. Building vulnerability and specific risk ... 13
4.2. Seismic vulnerability ... 13
4.2.1. Methodology ... 13
4.2.2. Seismic vulnerability maps ... 13
4.3. Flood vulnerability ... 14
4.3.1. Methodology ... 14
V. Cost estimation and risk assessment ... 15
5.1. Cost estimation ... 15
5.1.1. Cost estimation for seismic hazard ... 15
5.1.2. Cost estimation for flood hazard ... 15
5.2. Risk assessment of Turrialba city ... 17
5.2.1. Seismic damage calculation ... 17
5.2.2. Flood damage calculation ... 17
5.2.3. Flood risk analysis ... 20
VI. Conclusion and recommendation ... 23
6.1. Conclusion ... 23
6.2. Recommendation ... 23
References ... 24

I. Introduction

1.1. Problem description

According to the United Nations Department of Humanitarian Affair (UNDHA, 1992), assessment involves a survey of a real or potential disaster to estimate the actual or expected damage and to make recommendations for prevention, preparedness and response. The survey of the expected damages for a potential disaster essentially consists of risk evaluation. Risk is defined as the expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to particular hazard for a given area and reference period. Base on mathematical calculations risk is the product of hazard and vulnerability, (UNDHA, 1992, WMO 1999).

Turialba City in Costa Rica is the city that is situated on the lower part of Turialba basin and at the foot of the steep slopes of the Turialba volcano. In term of the natural hazard phenomenon, Turialba city has at least two hazardous phenomenons, namely seismic hazard and flood hazard. The last heavy earthquakes in the surrounding of Turialba occurred in Limon 1991 and in Pejibaye in 1993, and cause some kind of alarm and awareness of the potential dimensions of one of the hazards that could hit the mayor urban area. (Lamadrid, 2002). Heavy rainfalls is common natural phenomenon in the Turialba city, which is caused flash floods of the Colorado River, the Gamboa Stream and some other small watercourses.

Due to these phenomenons in The Turialba city, it is necessary to do risk assessment in order to know how much would be the damage if a particular hazard occurs.

Risk assessment for seismic and flood hazards can be done using the state of the art of GIS. GIS tools (software package) is very important in creating a model, make evaluation and calculation on a certain return period of the particular hazardous phenomenon. In dealing with the assessment of seismic and flood hazards, the following objectives were established.

1.2. Objectives

1. To generate hazards maps for different return periods.
   a. To generate seismic hazard maps for different return periods (25,50,100 and 200 years) using attenuation laws, and soil amplification.
   b. To generate flood hazard maps for different return periods (25,50, and 75), maximum possible flood and flood erosion hazard along major rivers based on historical information, coming from questionnaires.
2. To identify element of risk and estimate the Vulnerability value.
   a. In terms of seismic hazard, to map vulnerability of the population for the night scenario and calculate the building vulnerability.
   b. In terms of flood hazard, to generate the vulnerability maps for 25, 50 and 75 return period, vulnerability maps for the maximum flood event and vulnerability maps for lateral erosion based on the vulnerability value of the content of building.
3. To calculate the damage and assess the risk, due to the particular hazard.
   a. In term of seismic hazard, to generate the night population risk, to estimate the market and replacement value of the building, and generate the risk maps.
   b. In terms of flood hazard, to generate the contents building cost maps, to generate the expected damage maps, to generate the risk maps, and to analyze the risk curve.

1.3. Methodology

To do those objectives some kind of methodologies are needed, either in seismic hazard or in the flood hazard. The methodologies will be explained on Figure 1.1 and Figure 1. 2.

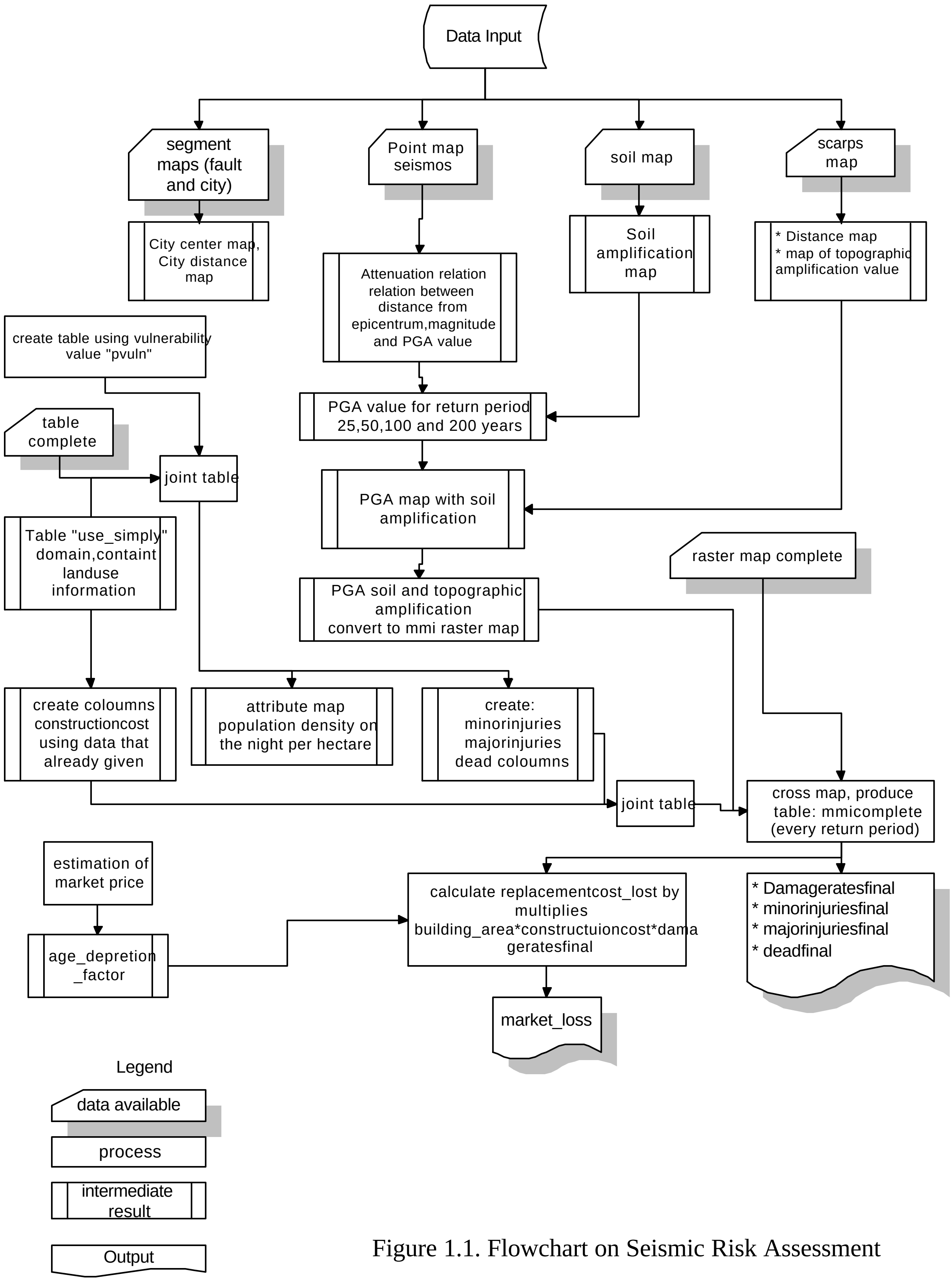


Figure 1.1. Flowchart on Seismic Risk Assessment

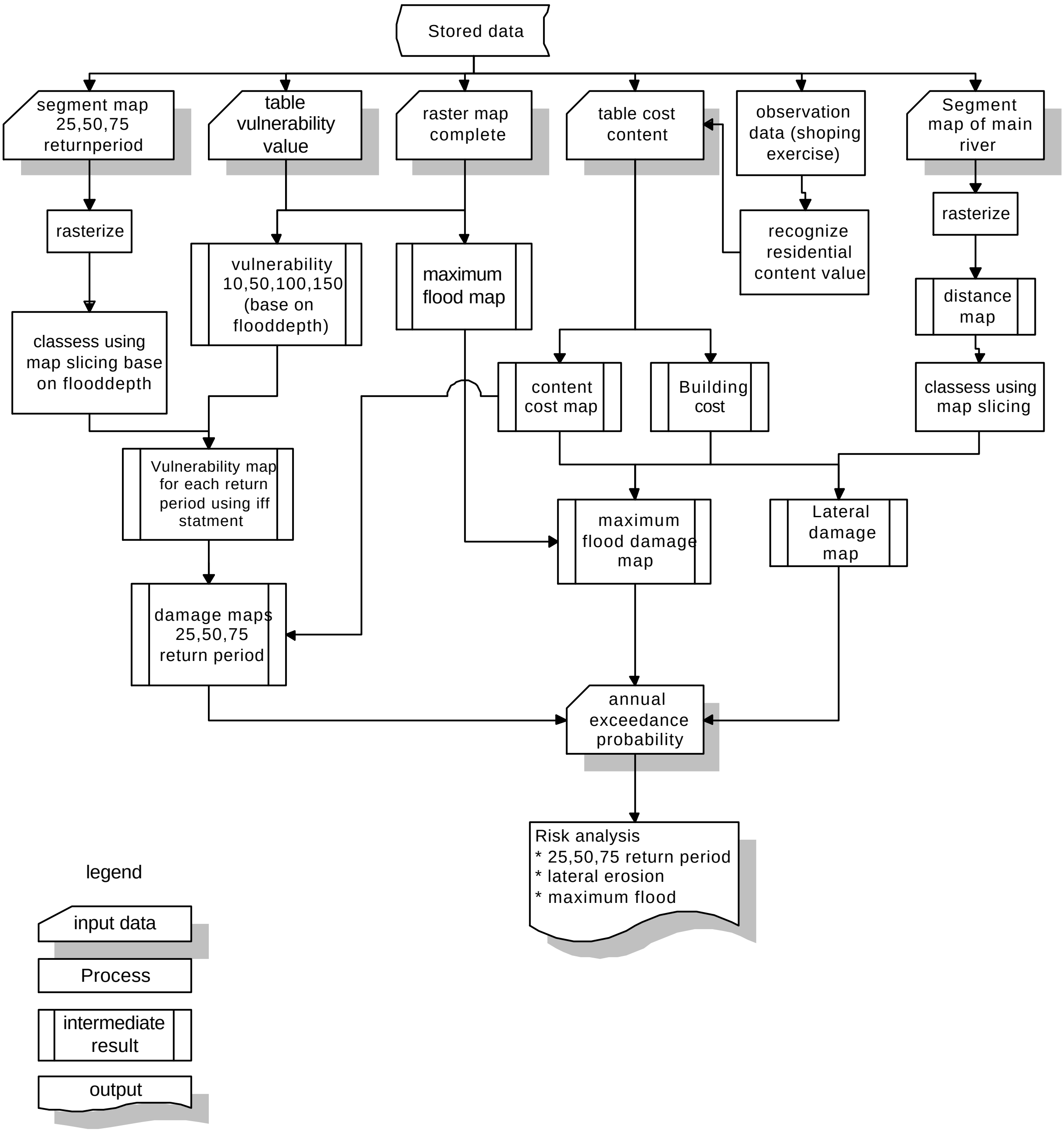


Figure 1.2. Flowchart on Flood Risk Assessment

II. Description of The study area

2.1. Geographic setting

Turrialba City is part of Cartago province, located to the east of Costa Rica´s capital, San Jose, in Central American region bordering both the Caribbean Sea and the North Pacific Ocean. Turialba city is shown on Figure 2.1.

Figure 2.1. Map showing geographic location of Turrialba city

The wet winds coming from the Caribbean Sea makes the area to be frequented by heavy rains and high humidity. The rainfall regime is variable from one year to the other without a well-defined dry season. The annual average rainfall for the whole basin area covering Turrialba is 2289.5mm (Badilla, 2002), while the average annual temperature in the middle and upper basins 16.9^{o}c and 8^{o}c. These climatic conditions have caused this particular region of Turrialba be affected by deep weathering of the rocks and the soils.

2.2. Geological condition

The geological history of the Turrialba area goes back to the Upper Cretaceous, when the Mesoamerican Trench was open and a back-arc regime developed, filling up a basin with sediments from a volcanic arc. The Central American is located mainly in the Caribbean plate which overrides the coco' plate in front of the pacific coast, where it borders the Mesoamerican trench. The plates are reported to move with velocities between 72 ± 3 and 102 ± 5 mm/yr in front of the Pacific coast of Costa Rica (Lamadrid, 2002), making the region tectonically active and susceptible to seismic activity.

Locally, predominantly volcanic and alluvial lithological units are found. Pyroclastic and Andesitic lavas are located around the Turrialba valley. The debris avalanche occupies the higher part of the area and is buried by Lahar layers and very recent alluvial deposits. Colluvial deposits are found mainly at the foot of the hills. They consist of coarse materials, principally gravel, pyroclastic and gravely sandy alluvial material.

2.3. Geomorphologic condition and earth processes

The genesis of the geomorphologic units in the region is strongly related to volcanic, denudation and accumulation processes. Steep slopes and abrupt changes in slope angles characterize Turrialba basin. The area is characterized by a series of faults and volcanic activity and landslides. Most fa ult lines are trending in a NE-SW direction while others in NW-SE direction thus being a contributing factor in the formation of the basin.

Due to the above different geological activities, the basin has had a non-uniform development (Badilla 2002). The geomorphologic units of the area as interpreted from the anaglyph image of the area are shown on Figure 2.2.

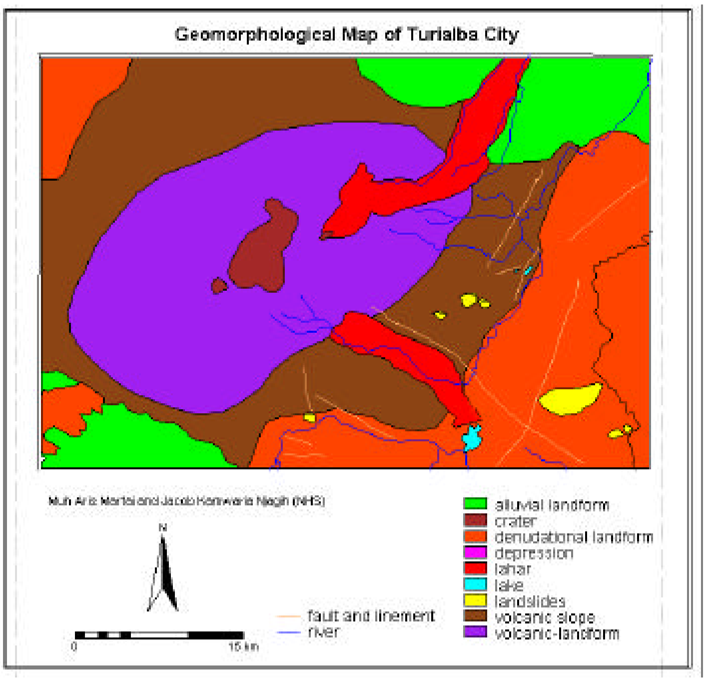


Figure 2.2. The geomorphologic units of the area as interpreted from the anaglyph image of the area

2.4. Soil condition

Soil characteristics are strongly related to the geomorphologic and lithologic units of the Turrialba urban area. Basically four soils types are distinguished: soils on slopes, soils on volcanic lavas and pyroclastic materials, (Lamadrid, 2002), alluvial soils and soils on debris avalanche. These have been deduced in terms of thickness, texture and lateral relations.

2.5. Hydrological condition (including history of flood)

Hydrologic studies have been carried out in the area with the use of HEC-1, (Badilla, 2002) and some peak discharges calculated for the main rivers in the study

region. The studies have also indicated a traversal area of five possible bottlenecks along the Gamboa stream and the Turrialba & Colorado River. In this way it has been established that Turrilba river has enough capacity for a 100-year return period discharge while the Gamboa stream and the Colorado river may overflow once every one or ten years respectively.
Flood historical data available dates back to 1737, (Badilla, 2002). From this historical data studies have been done and it was clear that there is a direct relationship between flood occurrence and daily precipitation and time of the year.

2.6. Land use and urban area

Most of the Turrialba area has changed land use from the forest to grasslands or agricultural areas especially in the upper Turrialba basin (Elena, 2002). This has actually led to increase in the discharge levels, lateral erosion and decrease in soil fertility. Turrialba city has also experienced a large population growth in the last decades and this combined with wrong policies in urban and landuse planning has intensified the flooding problems in the area.

III. Hazards Assessment

3.1. Seismic hazard assessment

3.1.1. Literature review of seismic hazard

The process of assessing seismic hazards starts with the identification of potential seismic sources, which are related to tectonic settings of a certain region. In assessing seismic sources, a plot map showing seismic events, local faults and tectonic events are the main tools. The historic seismicity of Turrialba indicates that 9 seismic events within the range of 5.0-7.5 and depth, 15km have occurred within 50 km distance to the area. It is assumed that Pacuere and Atirro are the faults responsible for seismic events close to the area. The most recent events experienced in Turrialba neighborhood are Pegibaye-1993 (M=5.3), Limon-1991 (M=7.6).

Earthquake frequency can be calculated based on the relationship between their occurrence and magnitude normally available from a seismic historical database. (Gutenberg and Richter, 1954). This relationship is expressed as:

$$\text{Log}(N)=a-b*M$$

Where N=the number of seismic events exceeding a given magnitude; a=constant related to seismic activity; b=constant of seismicity index; M=defined/given magnitude to look for recurrence. In Turrialba region, this relationship is given by the expression;
Log (N)=2.69-0.70*M.

3.1.2. Methodology

- Defining earthquake scenario, location of epicenter, magnitude and depth
- Calculate the attenuation using the amplification using the function of Joyner & Boore (1981)
- Calculate the amplification due to local soil conditions and topography using the soil and the scarps map
- Convert the Peak Ground Acceleration to modified Mercalli Intensity

3.1.3. Generation of seismic hazard maps

PGA (peak ground acceleration) is a short period ground motion parameter that is proportional to force. It is the most commonly mapped ground motion parameter since most building codes nowadays indicate the provisions under which buildings can withstand a certain horizontal force due to seismicity. In this case, PGA values calculated under rock conditions by Laporte et al (1994) and relationship between return period and exceedence probability were used. The values were extrapolated in order to arrange and select the periods of time in a convenient way. Table 3.1 shown the values used.

Table 3.1. PGA Values every return period

Return period (years)	25	50	100	200
Peak ground Acceleration (g)	0.18	0.19	0.2	0.23

Soil amplification is calculated by the use of a soil amplification map with an amplification value for each soil type. This is done for the return periods 25,50,100, and 200years. Topographic amplification has been based on the location and distance from the scarps in the study area. Certain weights have been given to different distances from the scarps as indicated in the Table 3.2.

Table 3.2. Weight Factor on The Different Distances

Distance range	Weight factor
0-50	1.083
50-100	1.055
>100	1.0

These weights were multiplied with PGA maps with soil amplification for all the return periods coming up with new PGA maps with amplification for soils and topography.
To convert the PGA values to the Modified Mercalli Intensity, the Trifunic &Brady (1975), relation is applied. MMI=1/0.3*(log10(PGA*980)-0.014). The four MMI maps for return periods 25,50,100 and 200 years are shown on Figure 3.3.

3.2. Flood hazard assessment

3.2.1. Literature review of flood hazard

Different degree of flood hazard is assigned to each Geomorphological unit, depending on slope, drainage pattern, grain size and permeability. In this way it is demonstrated that Turialba city is located in an area with high to medium flood hazard. The distribution of the floodwater within Turialba city is mainly determined by the existence, location and behavior of bottlenecks and critical points during a specific discharge. (Badilla, 2002).

3.2.2. Methodology

1. Generate the flood depth maps using contour interpolation and point interpolation. From segment maps that already given, create the raster maps using contour interpolation and slicing the result map in order to obtain different classes of flood depth. In term of point interpolation, create attribute map of polygon maps using the certain column that correlated with the every return period which is the table already given. Convert the polygon information to point information, and using the point interpolation generates the flood depth for every return period. In order to obtain the class map of flood depth, classify the result maps using slicing operation.
2. Generate the flood depth maps for maximum flood event using attribute map operation from the table with the attribute, which contain maximum flood information.
3. Generate the lateral erosion hazard map by rasterizing the segment maps of the main river. Use the distance formula to create the distance maps and followed by slicing operation to create classes, In order to obtain the relation between the distance and the lateral erosion.

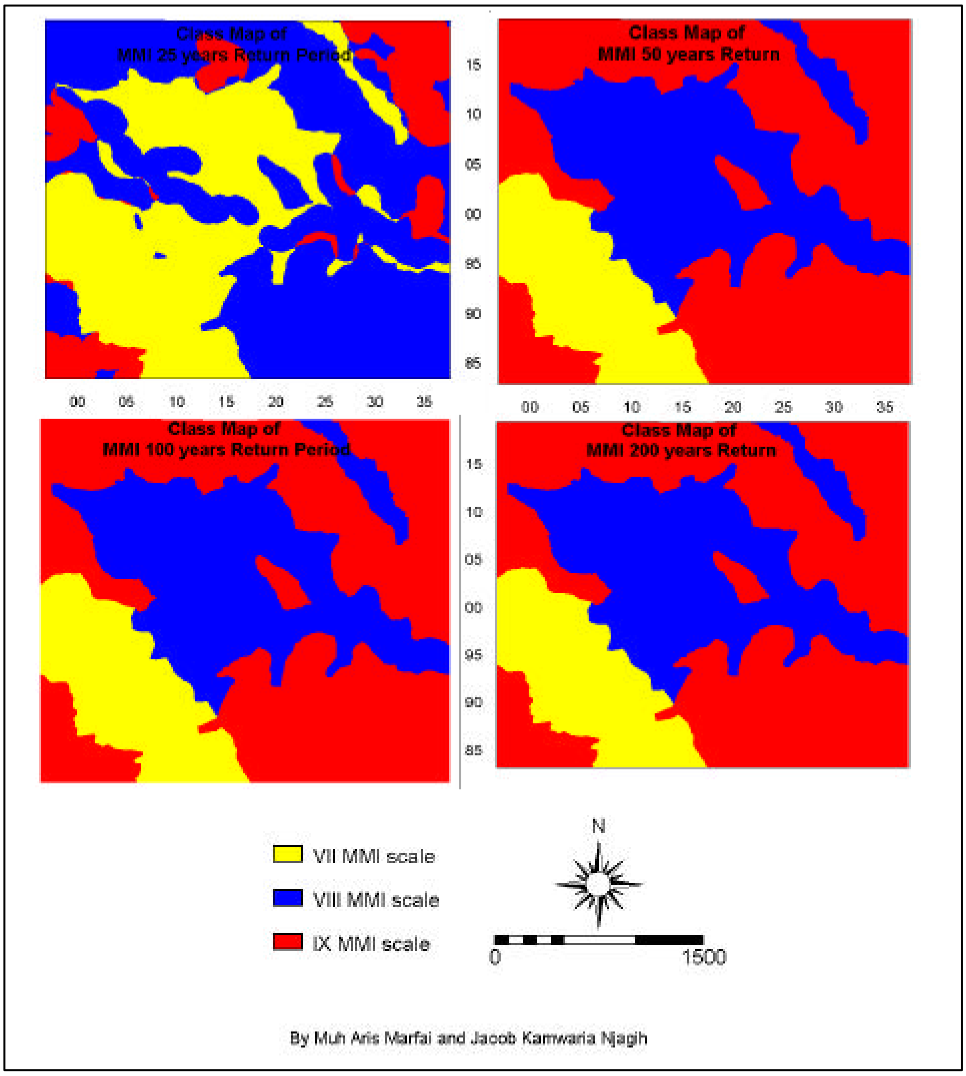


Figure 3.3. MMI maps for return periods 25,50,100 and 200 years

3.2.3. Generation of flood hazard maps

To generate the flood hazard maps, ILWIS software will be used. From the segment map for each return period, create raster maps that contain the flood depth information. From those maps, converted to class maps using slicing operation in ILWIS. Contour interpolation was chosen to create flood depth raster map than point interpolation, because the result is better and more detailed. Figure 3.4 is shows result from contour interpolation and point interpolation, Figure 3.5 is shows flood hazard map each return period, and Figure 3.6 is shows maximum flood hazard and lateral erosion hazard.

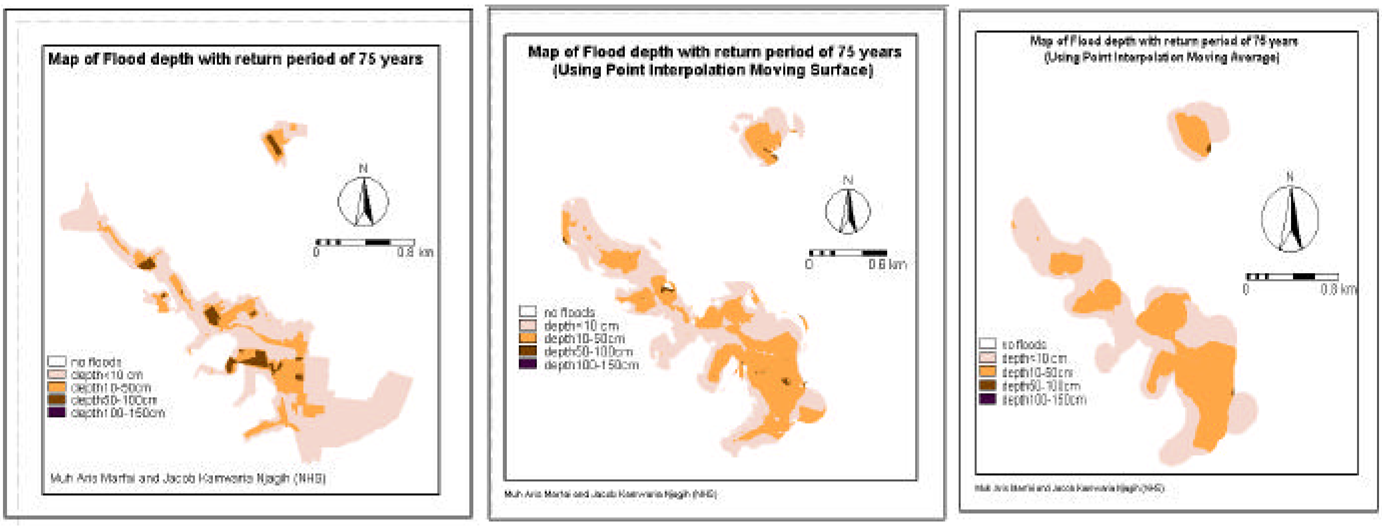


Figure 3.4. Result of contour interpolation and point interpolation

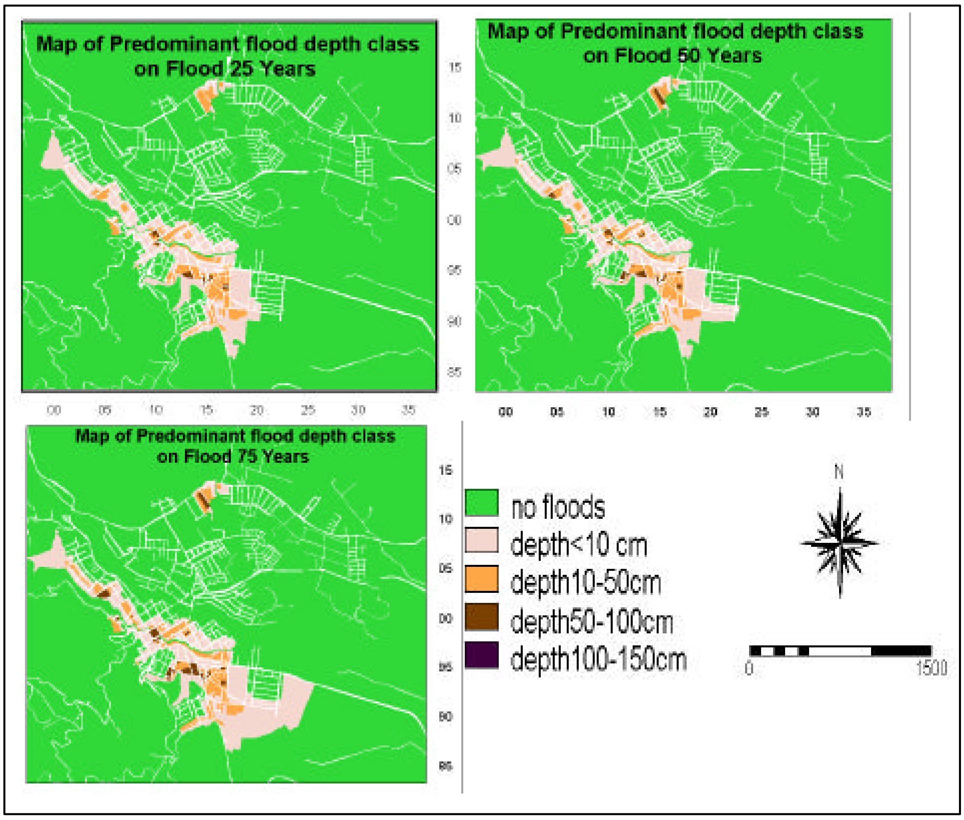


Figure 3.5. Flood hazard map each return period

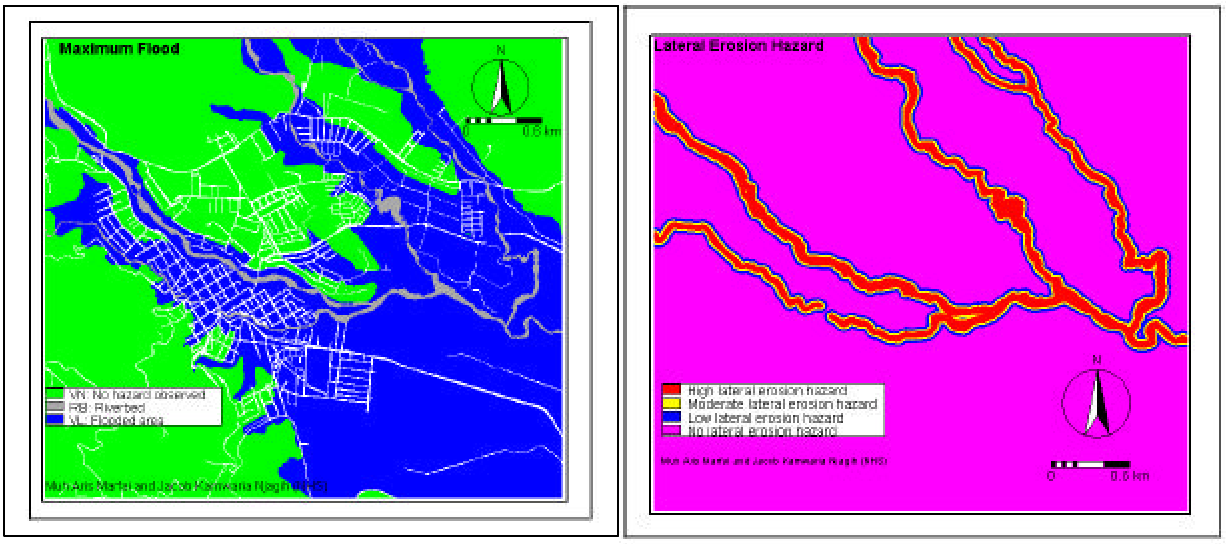


Figure 3.6. Maximum flood hazard and lateral erosion hazard

IV. Vulnerability Analysis

4.1. Element at risk and their attributes

4.1.1. Population vulnerability

Vulnerability, which is a key Topic in risk analysis is defined as the degree of loss to a given element or set of elements resulting from the occurrence of a natural disaster. It's normally given as a value between 0 and 1. Population vulnerability can easily be assed by use of census data, which will normally give the average number of persons per parcel and the relation to the building types. This was well exemplified by the questionnaire for 2001 Indian census.

In this case the vulnerability of the population for a night scenario (i.e. 6 pm to 7 am) was considered. This was done by calculating the population density of the city, which was done by approximating the number of persons per parcel. From the available data, the vulnerability values were calculated and related to damage of buildings for different classes as shown in Table 4.1.

Table 4.1. Vulnerability values related to damage of buildings for different classes

Damage of Building	Minor	Major injuries	Dead
None	0	0	0
Slight	0.00003	0.000004	0.000001
Light	0.0003	0.00004	0.00001
Moderate	0.003	0.0004	0.0001
Heavy	0.03	0.004	0.001
Major	0.3	0.04	0.01
destroyed	0.4	0.4	0.4

4.1.2. Building vulnerability and specific risk

Vulnerability to earthquakes in urban areas is largely related to building design and quality since it's these houses, which collapse and injure people. The nature of the construction and the materials used will greatly influence the kind of injuries inflicted.

4.2. Seismic vulnerability

4.2.1. Methodology

Since the classification developed during collection of data was not according Sauter and Shah's (1978), (after Montoya 2002), an interpretation is done to relate the two and give assign damage ratios according to the MMI classes. The following steps are followed:

1. A table "damage" is created using the domain type class "material". In the table, columns with MMI classes VII, VIII & IX as in the hazard maps are added. Then damage rates corresponding to the Sauter and Shah's study are filled.
2. The MMI maps for return periods 25,50,100 and 200 years are crossed each with the table complete. Each of the columns in the damage table are joined to the cross table.
3. In order to match the damage rates with MMI classes, the following formula was used;iff(mmi50=7,mmi_7,0) This is calculated for each of the return periods.
4. A "damageratefinal" map is created by adding all the rates.
5. The final damage rate is reclassified into same vulnerability classes as in table 4.1 to match those of population using the following formula:
   iff(damageratesfinal25=0,"none",iff((damageratesfinal25>0)and(damageratesfinal25<=0.05),"slight",iff((damageratesfinal25>0.05)and(damageratesfinal25<=0.1),"light",iff((damageratesfinal25>0.1)and(damageratesfinal25<=0.3),"moderate",iff((damageratesfinal25>0.3)and(damageratesfinal25<=0.6),"heavy",iff((damageratesfinal25>0.6)and(damageratesfinal25<=0.9),"major",iff((damageratesfinal25>0.9)and(damageratesfinal25<=1),"destroyed","?")))))))

4.2.2. Seismic vulnerability maps

Vulnerability maps were then created from population density and the three types of injuries, minor injuries, major injuries and the dead. The resulting of vulnerabilities created from population density map are shown on Figure 4.2.

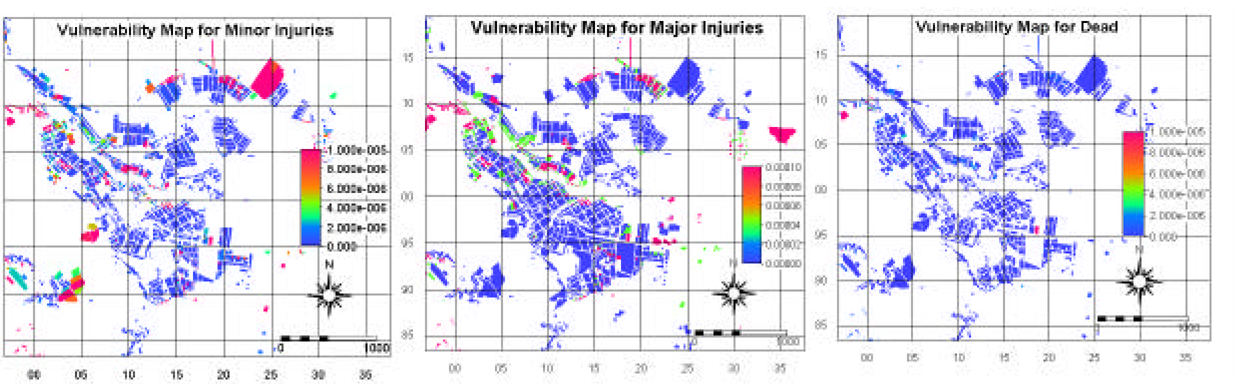


Figure 4.2. Vulnerability Maps for Minor Injuries, Major Injuries and Dead

4.3. Flood vulnerability

4.3.1. Methodology

Each flood depth has different level of property damage, hence resulting to different vulnerability value. Vulnerability maps for each flood return period would be generated using an "iff statement" in map calculation to select the appropriate vulnerability for every flood depth class. The iff statement as follow: Vulnerability25= iff (pred25="depth<10 cm",vul10,iff (pred25="depth10-50 cm",vul50,iff (pred25="depth50-100 cm",vul100,iff (pred25="depth100-150 cm",vul150,0))))

Using slicing operation (if the area covered by flood give 1 value otherwise 0) vulnerability maps for the maximum flood event and lateral erosion would be generated.

4.3.2. Flood vulnerability maps

Vulnerability maps for each return period (25,50, and 75 years) are shown on Figure 4.3, and vulnerability maps for maximum flood event and lateral erosion are shown on Figure 4.4.

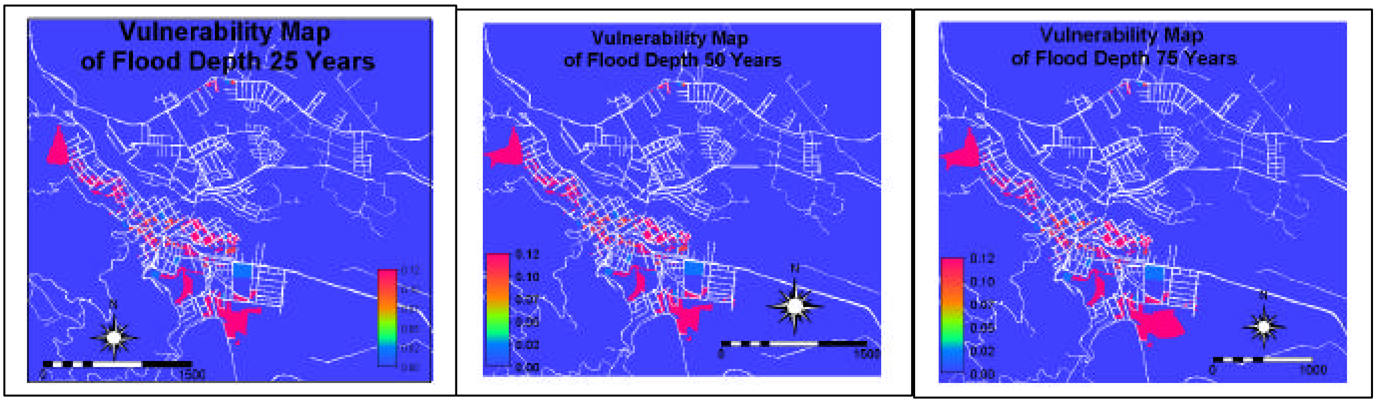


Figure 4.3. Vulnerability maps for each return period

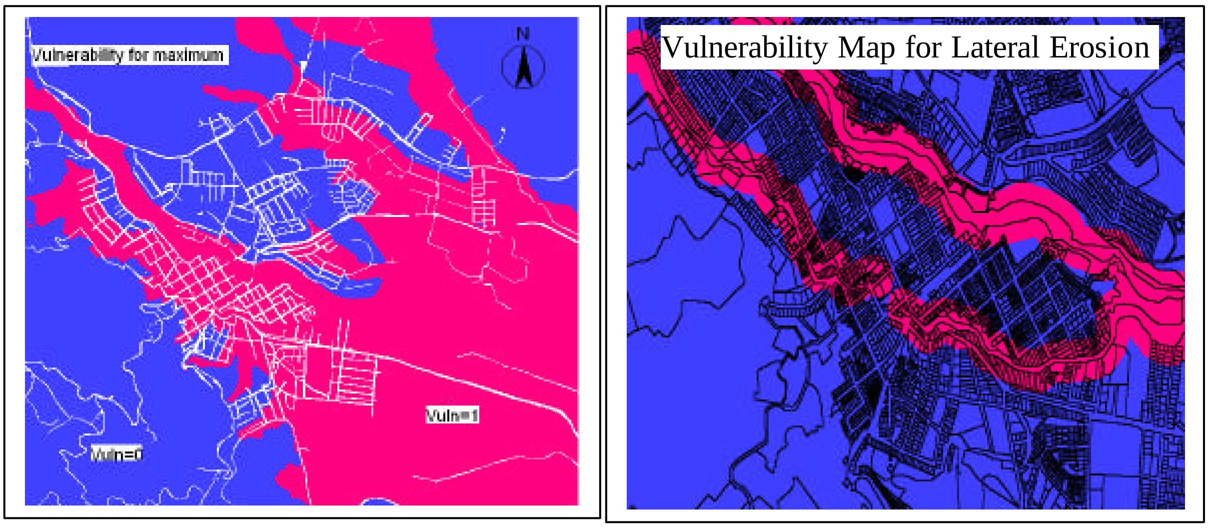


Figure 4.4. Vulnerability maps for maximum flood and lateral erosion

V. Cost estimation and risk assessment

5.1. Cost estimation

5.1.1. Cost estimation for seismic hazard

The replacement values for different land uses are incorporated into the cross tables for different return periods. Building area is also calculated by considering the floor value, total area and multiplying with a ratio of 0.66 assuming that 66% of the area is built and 34% garden.

5.1.2. Cost estimation for flood hazard

For the cost of the building caused by flooding, we use construction cost and the building area (5.1.1), to get building costs. Building cost map is shown on Figure 5.1. For cost of the content, estimate values used were derived from estimates based on field observation as shown in Table5.2. These estimates, together with the others provided for other land use types, were calculated per parcel and an attribute content map generated. Attribute Content map is shown on Figure 5.3.

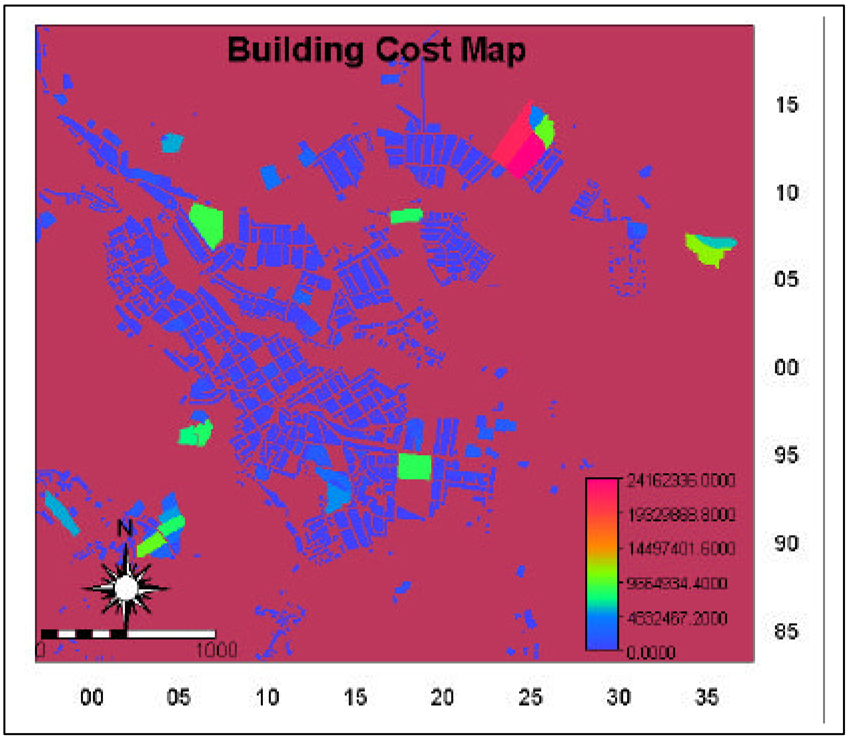


Figure 5.1. Building cost map

Table 5.2. Content cost estimation for residential properties

Content cost low income	Low medium income	medium income	high income		depth of flood 10 cm	50 cm	100 cm	150 cm
119	330	786	19500	Television set				yes
28	39	1500	3500	Radio system				yes
250	300	2495	9250	Sofa set		yes	yes	yes
225	660	2100	3400	beds		yes	yes	yes
130	169	979	1761	washing machine		yes	yes	yes
92	92	1400	4300	refrigerator		yes	yes	yes
99	135	400	1360	cooker			yes	yes
150	210	1670	12150	computers set			yes	yes
37	37	300	4000	DVD, video			yes	yes
	250	100	745	microwave				yes
		1300	5190	dinning set			yes	yes
		580	2100	Mattress		yes	yes	yes
		2000	9800	carpet	yes	yes	yes	yes
		80	139	Juicer-mixer			yes	yes
		230	520	Vacuum cleaner	yes	yes	yes	yes
		40	180	Rice cooker				yes
		80	149	Fryer			yes	yes
		30	80	Sandwich maker			yes	yes
		37	120	Grill			yes	yes
		50	139	Juicer			yes	yes
		400	70	Coffee-machine				yes
		100	816	Air-conditioner				yes
		400	390	Electric Blanket		yes	yes	yes
		80	1125	Dryer		yes	yes	yes
		80	419	Dish-washer		yes	yes	yes
		300	1500	Sun mobile		yes	yes	yes
		200	2000	Small Gym		yes	yes	yes
		100	2298	Video camera				yes
		400	250	Blender				yes
			750	lawnmower	yes	yes	yes	yes
			2000	lamps		yes	yes	yes
			500	Garden chairs		yes	yes	yes
			169	Oven		yes	yes	yes
			1050	electric stove		yes	yes	yes
1130	**2222**	**18217**	**91720**	**Total in Euros**				
1028.3	2022.02	16577.47	83465.2	dollars				
339339	667266.6	5470565.1	27543516	Colones				

10 cm=0	10 cm = 0	10 cm= 2230	10 cm= 11070
vul=0	**vul=0**	**vul= 0.122413131**	**vul= 0.120693415**
50 cm= 697	50 cm= 1221	50 cm= 10844	50 cm= 41034
vul= 0.616814159	**vul= 0.54950495**	**vul= 0.595268156**	**vul= 0.447383341**
100 cm= 983	100 cm= 1603	100 cm= 14791	100 cm= 64361
vul= 0.869911504	**vul= 0.721422142**	**vul= 0.811933908**	**vul= 0.701711731**
150 cm= 1130	2222	18217	91720
vul= 1	**vul= 1**	**vul= 1**	**vul= 1**

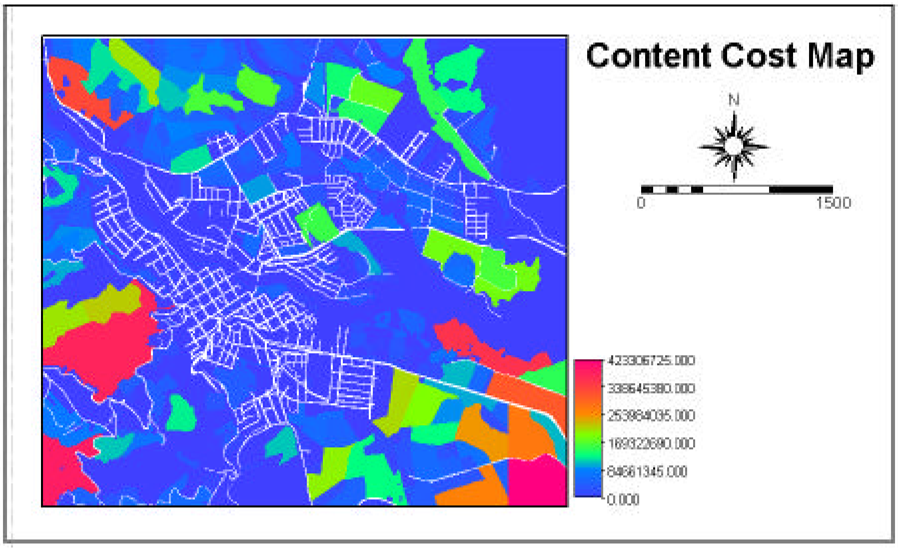


Figure 5.3. Content cost map

5.2. Risk assessment of Turrialba city

5.2.1. Seismic damage calculation

Replacement cost loss is derived from the product of building area, construction cost and the final damage rate (from 4.1). After applying age depreciation factor to the replacement cost, the market loss attribute map was generated. The market loss and replacement cost loss map are shown on Figure 5.4.

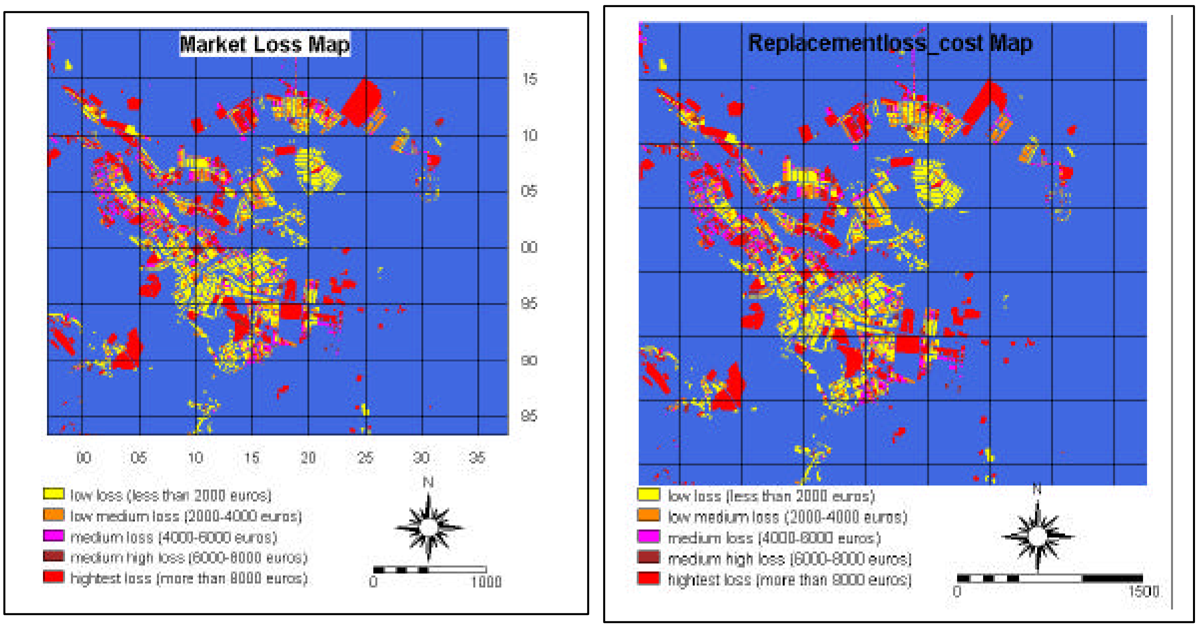


Figure 5.4. Market loss and Replacement loss cost maps

5.2.2. Flood damage calculation

The damage maps was generate from the multiplication between vulnerability maps and cost maps. For 25,50 and 75 years return period of flood damage maps would be generated from vulnerability each return period multiple by cost map, assumed that the flood only relatively low flood depth and low velocity. (Only content cost). For the maximum flood damage map and lateral erosion damage map would be generated from vulnerability multiplied by cost map, assuming that for the maximum flood scenario also structural damage is expected due to devastating lahar and for the lateral erosion assuming there will be collapse of the building into the riverbed (content cost and building cost). Detail information is writing down on Table 5.5, the damage maps for each return period are shown on Figure 5.6, and Damage maps for maximum flood and lateral erosion are shown on Figure 5.7.

Table 5.5. Generation of expected damage maps

Event	Vulnerability map	Cost map	Damage map (vulnerability * cost)
25 year return period	Vulnerability 25	Content cost	Damage 25
50 year return period	Vulnerability 50	Content cost	Damage 50
75 year return period	Vulnerability 75	Content cost	Damage 75
5000 year return period	Vulnerability 5000	Content cost+ building cost	Damage maximum flood
Lateral erosion	Vulnerability lateral	Content cost+ building cost	Damage lateral erosion

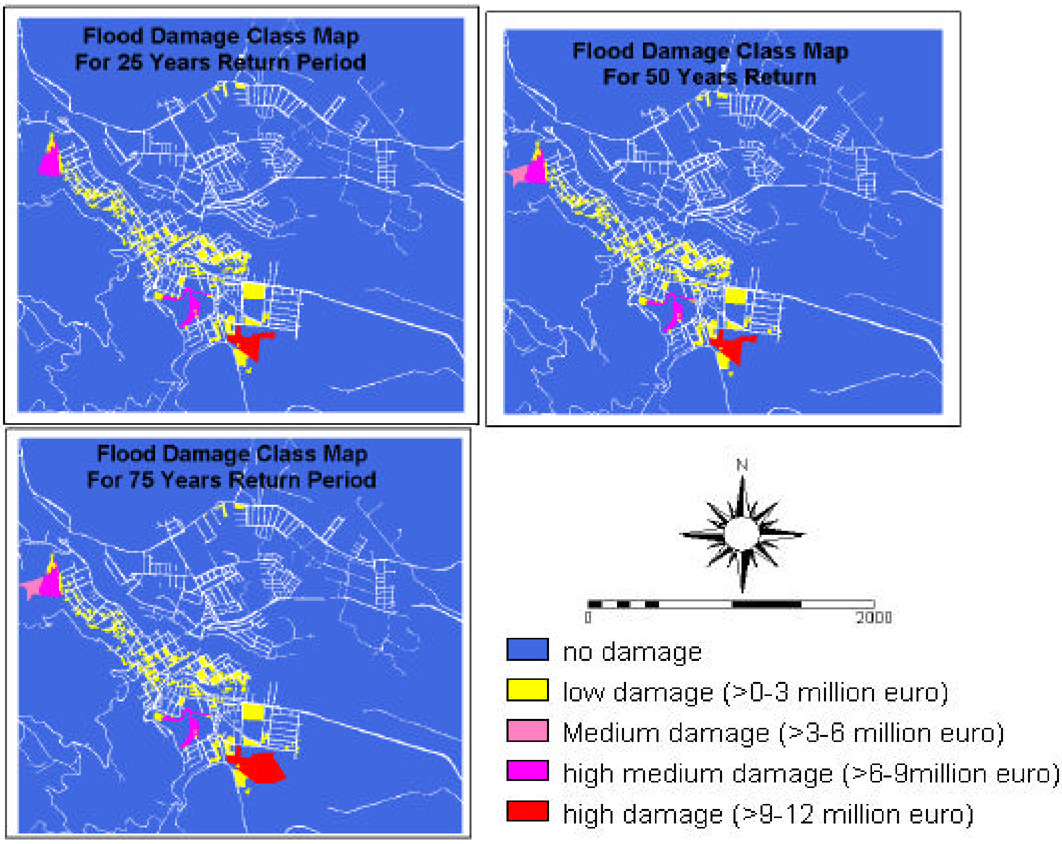


Figure 5.6. Damage maps for each return period

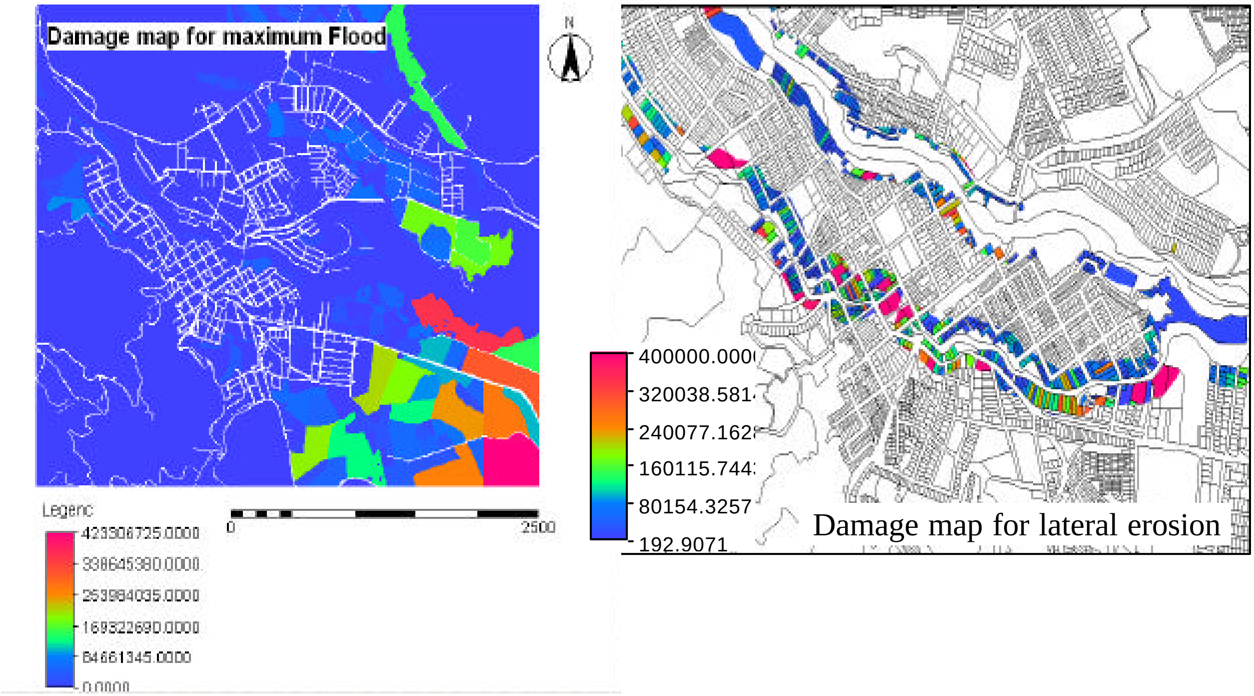


Figure 5.7. Damage maps for Maximum flood and lateral erosion

Base on from histogram, the total expected damage for each return period, maximum flood and lateral erosion can be calculated. Total expected damage for each return period round about 32-45 million euros. Figure 5.8 shows the detailed information about expected damage for each return period. Meanwhile, for maximum flood and lateral erosion is round about 423 million euros followed 182.77 million euros.

Return Period	Total loss (in million of euro)
25 years	32.379678
50 years	36.675188
75 years	45.974208

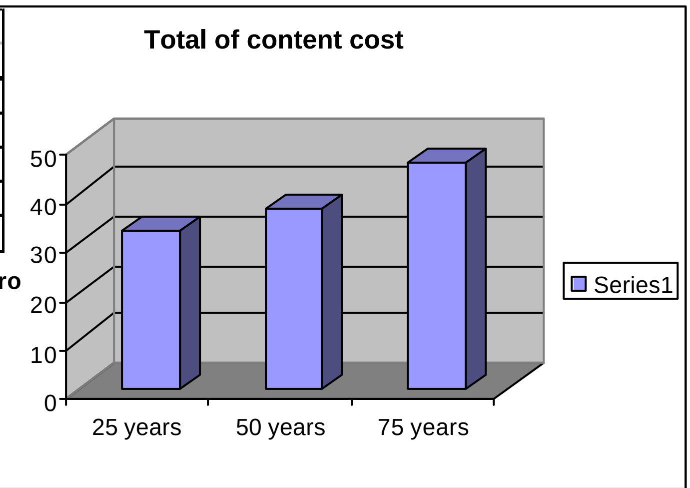


Figure 5.8. Total expected damage for each return period

5.2.3. Flood risk analysis

Risk means the expected degree of loss due to the specific hazard. In this case, risk is results from multiplying of probability factor, vulnerability and cost or in the other hand risk is probability multiple by expected damage. To generate the risk maps annual exceedance probability is needed. The annual probability for each different return period is shown on Table 5. 9, the annual expected damage (risk) for each return period shown on Figure 5.10, and annual expected damage for maximum flood shown on Figure 5.11.

Table 5.9. The annual probability each return period

Event	Damage map	Annual exceedance probability
25 year flood	Damage 25	0.04
50 year flood	Damage 50	0.02
75 year flood	Damage 75	0.01333
5000 year flood	Maximum damage	0.0002
Lateral erosion	Damage lateral	
	Class high	1*0.02=0.002
	Class moderate	0.5*0.02=0.01
	Class low	0.1*0.02=0.002

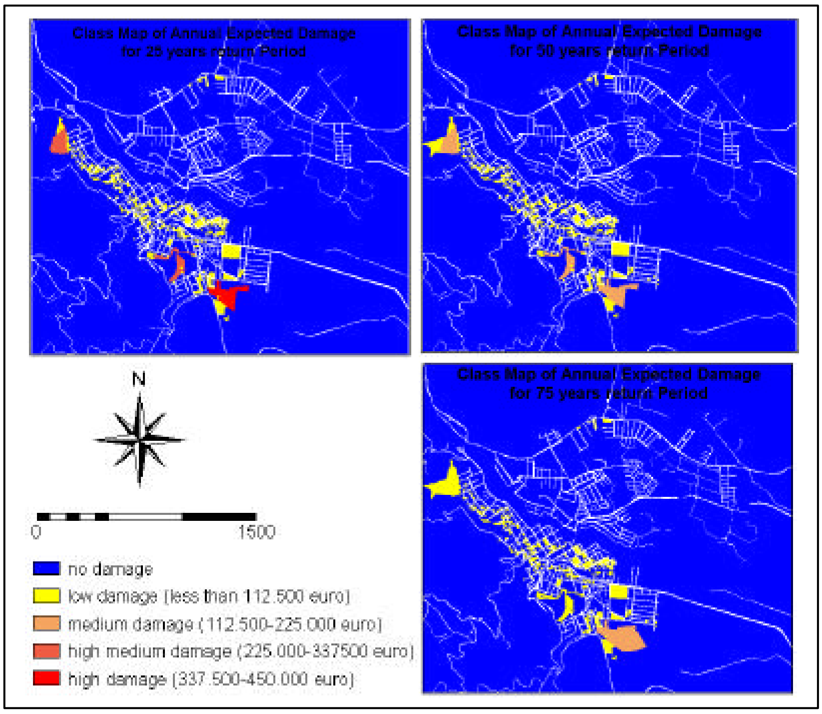


Figure 5.10. Annual expected damage maps for each return period

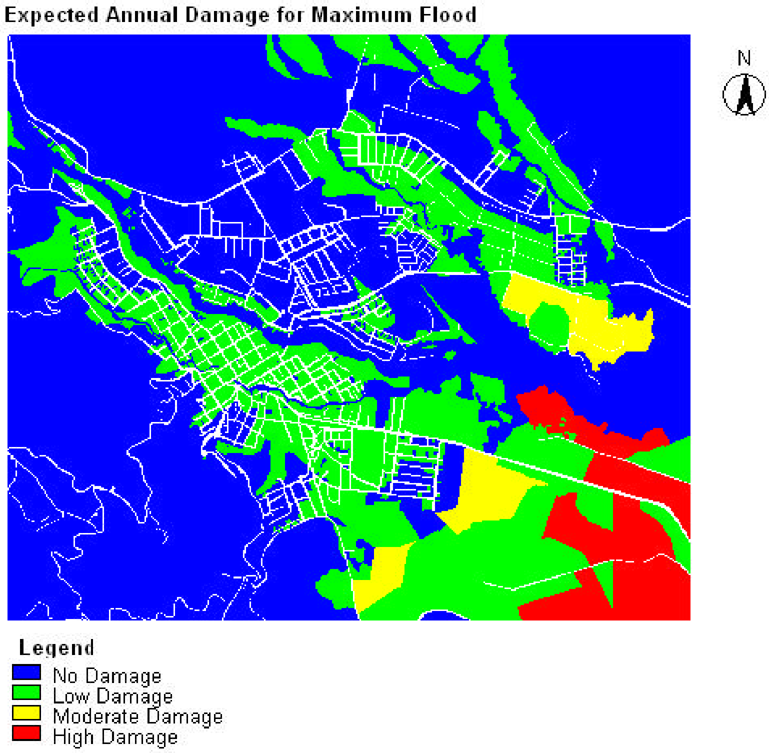
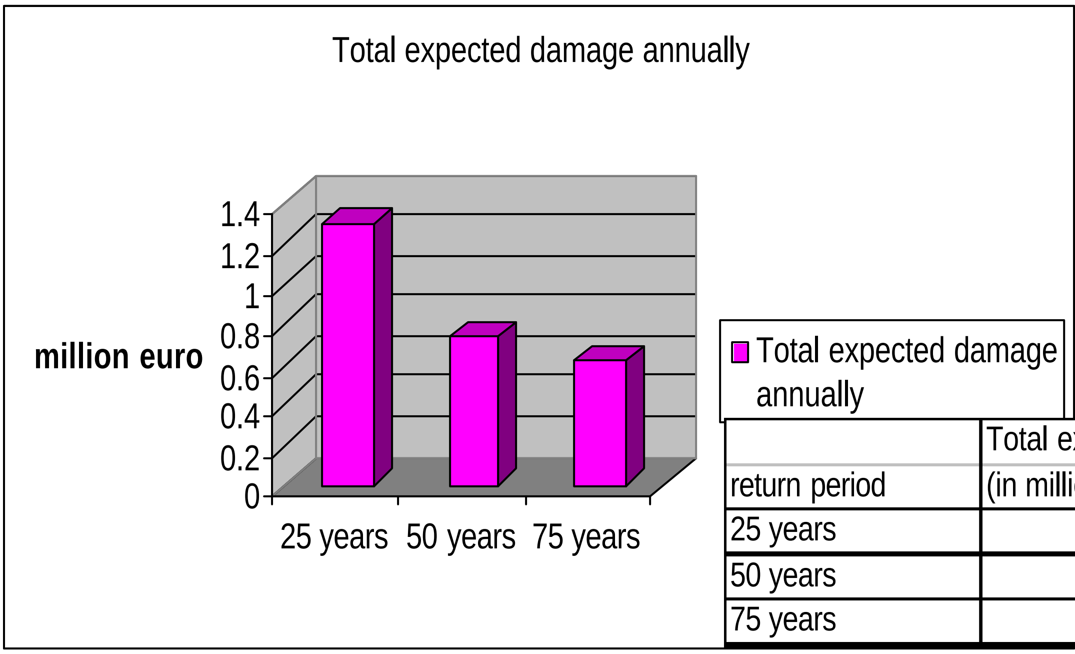


Figure 5.11. Annual expected damage maps for maximum flood

Total damage for each return period and for maximum flood can be calculate from the histogram. The total annual damage for each return period are shown on Figure 5.12 and for maximum damage shown on Figure 5.13.



return period	Total expected damage annually (in million euro)
25 years	1.295187
50 years	0.733503
75 years	0.611456

Figure 5.12. Total expected damage annually for each return period

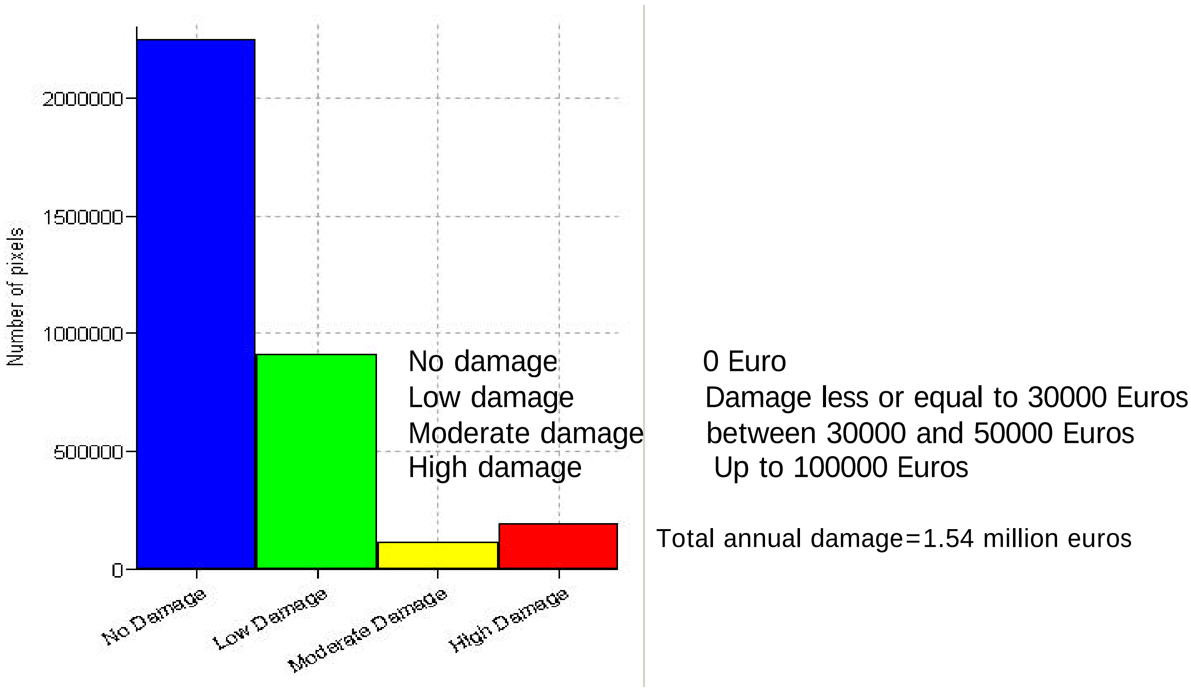


Figure 5.13 Total expected damage annually for maximum flood

Estimation for total loss every return period can be derived from risk curve or graph probability against loss. The risk curves generated from each return period and from lateral erosion are shown on Figure 5.14. To calculate the total loss and make estimation for certain probability on the total losses (total losses each return period and lateral erosion), values from both graphs for certain return periods are combined. The final risk curve is shown on Figure 5.15.

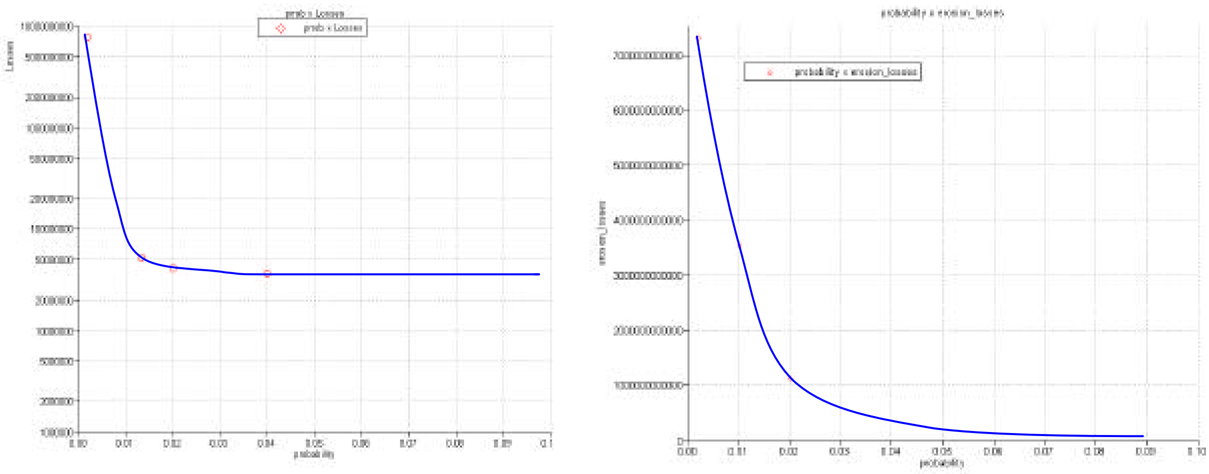


Figure 5.14. Flood risk curve and lateral erosion curve

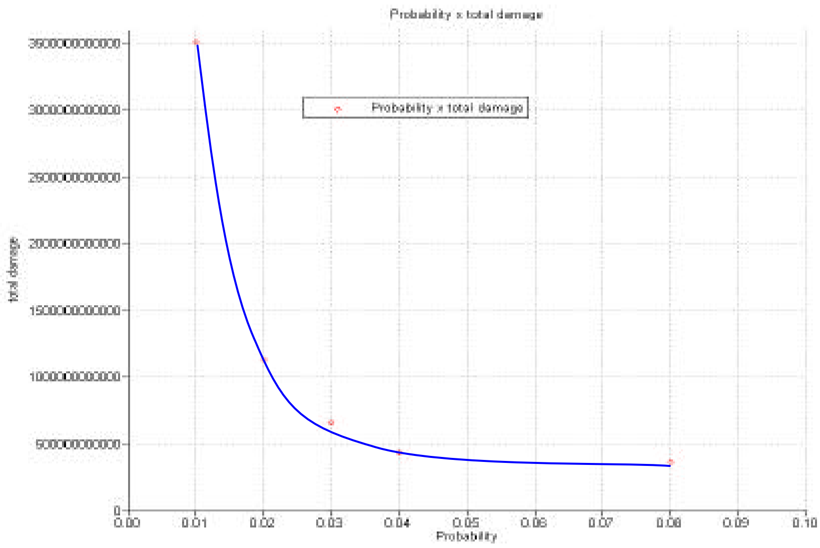


Figure 5.15. Total risk curve

VI. Conclusion and recommendation

6.1. Conclusion

For urban planning, risk assessment related to different types of hazards with time is very important. In this exercise, vulnerability to seismic and flood hazards was assessed based on different building materials and their content.

From the results, several conclusions are arrived at:

1. Particular attention to the topography and soil condition is very important in order to generate a valid and detailed seismic hazard map. The seismic hazard map in the study area is on three classes based on mercalli scale, namely 7, 8, and 9.
2. Damage calculation due to the seismic hazard is based on the vulnerability to seismic hazard on the 7,8 and 9-mercalli scale and building cost. In this case, only building cost factor is considered since at this scale, structure other than content is destroyed.
3. On the flood hazard maps, the differences between each return period not so high, because the interval of return period itself is only 25 year.
4. The proposed method for flood vulnerability assessment is based on the combination of an attribute map of element at risk and several flood scenarios for different return periods.
5. GIS technology represented a great advantage in this study, especially damage calculation, vulnerability and risk analysis.

6.2. Recommendation

1. In order to get a more detailed and realistic damage map, the depreciation factor applied to buildings should also be applied to contents since some could be highly depreciated.
2. Some incorrect distribution of damage value on flood hazard can be avoided by using detailed information in map analysis and table calculation, paying more attention on the agriculture area.
3. When assessing damage due to seismic hazards higher than 9 on mercalli scale, the cost of the content should be taken into consideration.

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http://www.safety.dtlr.gov.uk/bregs/floods/04.htmFlooding duration

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