Chapter 2. Earthquake Damage Scenario

CHAPTER 2. EARTHQUAKE DAMAGE SCENARIO

2.1 Earthquake Scenario Setting and Ground Motion

2.1.1 Fault in the Philippines

The Philippines is located in latitude 5° to 19°45' N. and longitude 116° to 128° E. Metropolitan Manila is located in the center of Luzon Island, between Manila Bay, which extends to the South China Sea, and Laguna de Bay. Many earthquake generators are distributed all over the country as shown in Figure 2.1.1.

Figure 2.1.1 Geological Faults in the Philippines

Source : PHIVOLCS

2.1.2 Earthquake Generators

The Eurasian Plate (or South China Plate) subducts eastward beneath Luzon Island along the Manila Trench, and the Philippine Sea Plate subducts westward along the East Luzon Trench simultaneously as shown in Figure 2.1.2. Because of this complex tectonic setting, Luzon Island shows high seismic activity. The Philippine Islands are sandwiched between two opposite subduction zones. A long, inland Philippine Fault Zone (PFZ) lies parallel to the subduction trenches. The PFZ is assumed to release the shear stress caused by the oblique subduction of the ocean plates. Many faults are identified around Metropolitan Manila; the West Valley Fault (WVF) and the East Valley Fault (EVF), which run north to south along the west and east edge of the Marikina Valley, are thought to pose the greatest threat to Metropolitan Manila due to their proximity.

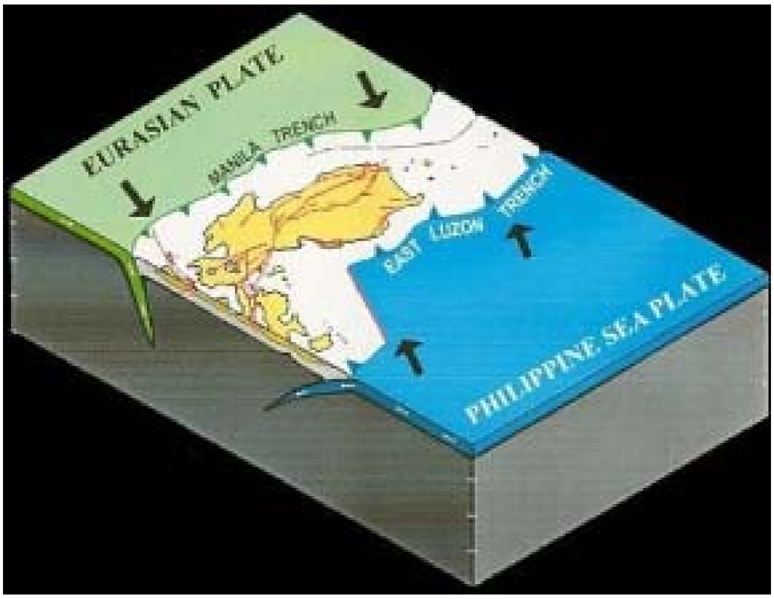

Figure 2.1.2 Subducting Plates under Luzon Island

Source: PHIVOLCS

The faults and trenches around Metropolitan Manila are shown in Figure 2.1.3. The fault traces based on geological survey (bold lines) are used for the analysis of inland fault and the fault traces based on seismic activities (thin lines) are used for the analysis of offshore fault.

Results of several trenching excavation surveys at WVF and EVF indicate that at least two or perhaps four large surface-rupturing events have occurred since AD 600. Therefore, the recurrence interval of the earthquakes generated is less than 500 years. Bautista (2000) has suggested that the 1658 and 1771 earthquakes could be candidate events for the EVF. However, no event along the WVF is known. If no earthquake had occurred at the WVF after the 16th century, then the earthquake occurrence along the WVF becomes a serious threat.

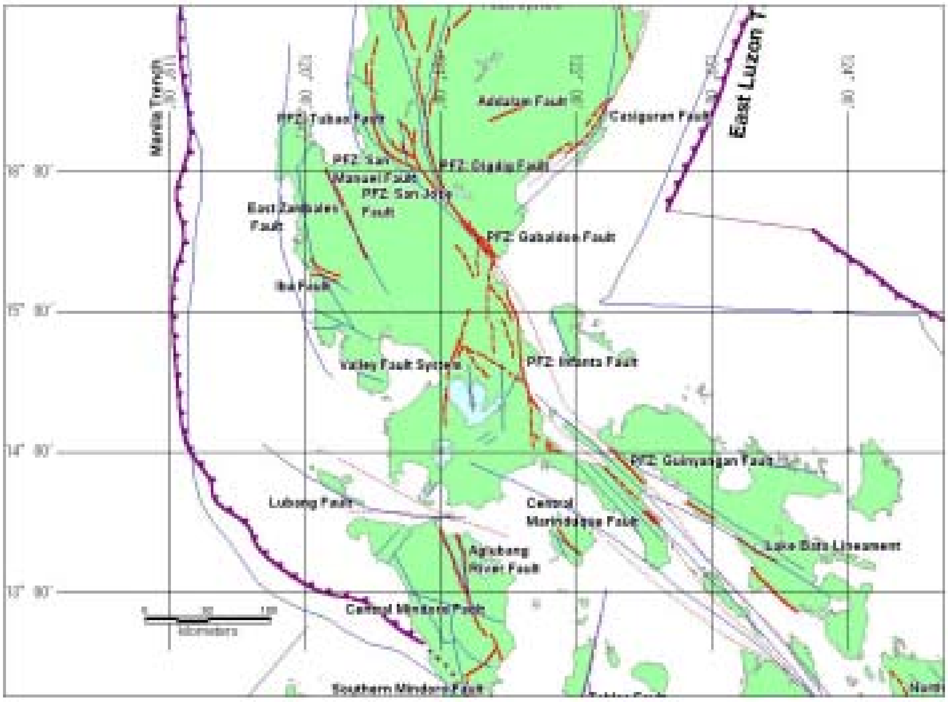

Figure 2.1.3 Distribution of Faults and Trenches around Metropolitan Manila

Source: PHIVOLCS

2.1.3 Earthquake Condition

The earthquakes that occurred before the start of instrumental seismic observation are called historical earthquakes.

The distribution of collected historical earthquakes is shown in Figure 2.1.4 and the instrumentally recorded earthquakes after 20th century is shown in Figure 2.1.5. M.L.P. Bautista (2000) has selected 36 historical and recent earthquakes that caused some damage to Metropolitan Manila. These 36 events are listed in Table 2.1.1 and the years of their occurrence are shown in Figure 2.1.4 and Figure 2.1.5. The events, those with year of occurrence underlined in Table2.1.1, are the 10 most damaging earthquakes to Metropolitan Manila. In the five events in 1658, 1771, 1863, 1880 and 1937, shaded by dark gray in Table 2.1.1, Metropolitan Manila is supposed to have experienced over 100 gal PGA on average ground condition. As for the source fault of these earthquakes, M.L.P. Bautista (2000) has supposed EVF as the source fault of 1658 and 1771 event, Infanta Segment of PFZ as the source fault of 1880 event and Laguna-Banahaw Fault that runs north to south along the east coast of Laguna Lake as the source fault of 1937 event. In these 36 hazardous earthquakes, only the 1677 event and the 1863 event have the description of tsunami around Metropolitan Manila. Those faults are listed as the source faults of the scenario earthquakes.

Table 2.1.1 Destructive Earthquakes that Affected Metropolitan Manila and Estimated PGA

Year	Month	Day	Ms	Distance(km)	PGA(gal)
1589					
1599	6	21		4.1	
1601	1	1			
1603					
1635					
1645	11	30	7.9	116.3	81.0
1658	8	19	5.7	12.5	202.6
1664	7	19			
1665	7	19			
1674					
1677	12	7	7.3	163.8	27.9
1728	11	28		18.9	
1767	11	13		41.1	
1770	12			41.1	
1771	2	1	5.0	14.1	113.2
1796	11	5	6.9	179.2	16.5
1824	10	26	7.4	103.2	69.8
1828	11	9	6.6	190.3	11.1
1830	1	18	6.3	94.2	34.3
1833	11	7			
1852	9	16	7.6	108.7	74.0
1862	3	4	6.1	113.0	21.2
1863	6	3	6.5	13.1	298.3
1869	10	1	6.6	70.9	66.8
1880	7	18	7.6	67.8	139.8
1892	3	16	6.6	214.2	8.2
1937	8	20	7.5	52.2	174.7
1942	4	8	7.5	118.9	59.6
1968	8	2	7.3	224.6	13.2
1970	4	7	7.3	152.2	32.5
1970	4	12	7.0	123.8	38.0
1972	4	26	7.2	153.8	29.4
1973	3	17	7.3	232.5	12.1
1974	2	19	6.1	139.0	14.3
1977	3	19	7.0	282.2	5.3
1990	7	16	7.8	124.6	67.8
1994	11	14	7.1	119.1	44.1
1999	12	12	6.8	203.2	11.2

Source: PHIVOLCS and Study Team

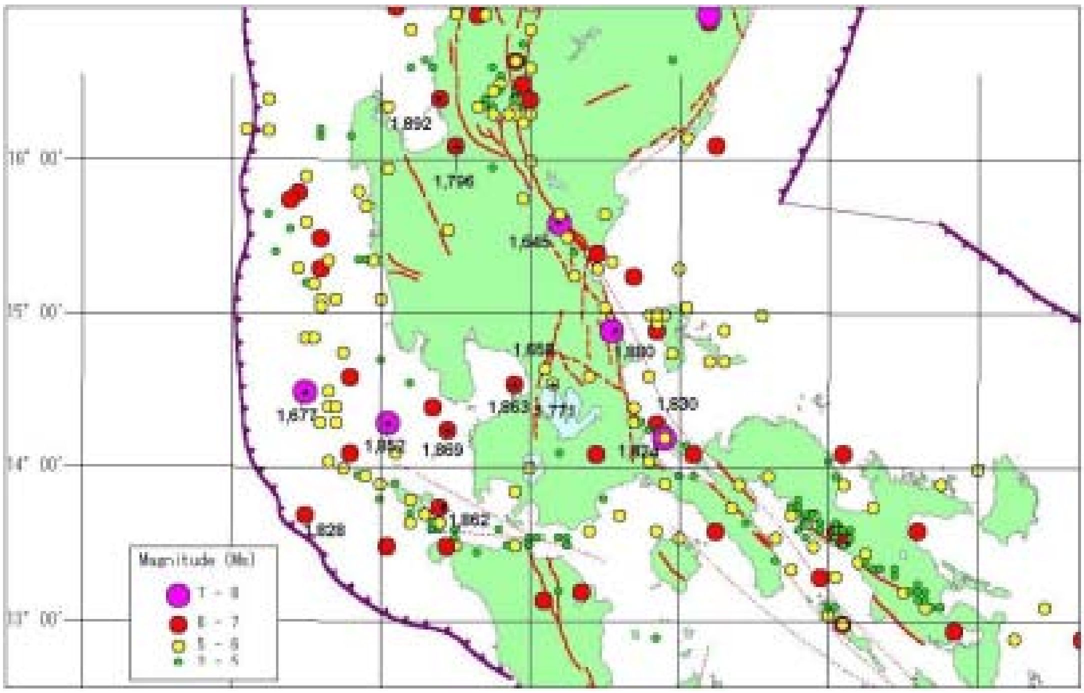

Figure 2.1.4 Distribution of Historical Earthquakes from 1608 to 1895

Source: M. L. P. Bautista and Oike K. (2000)

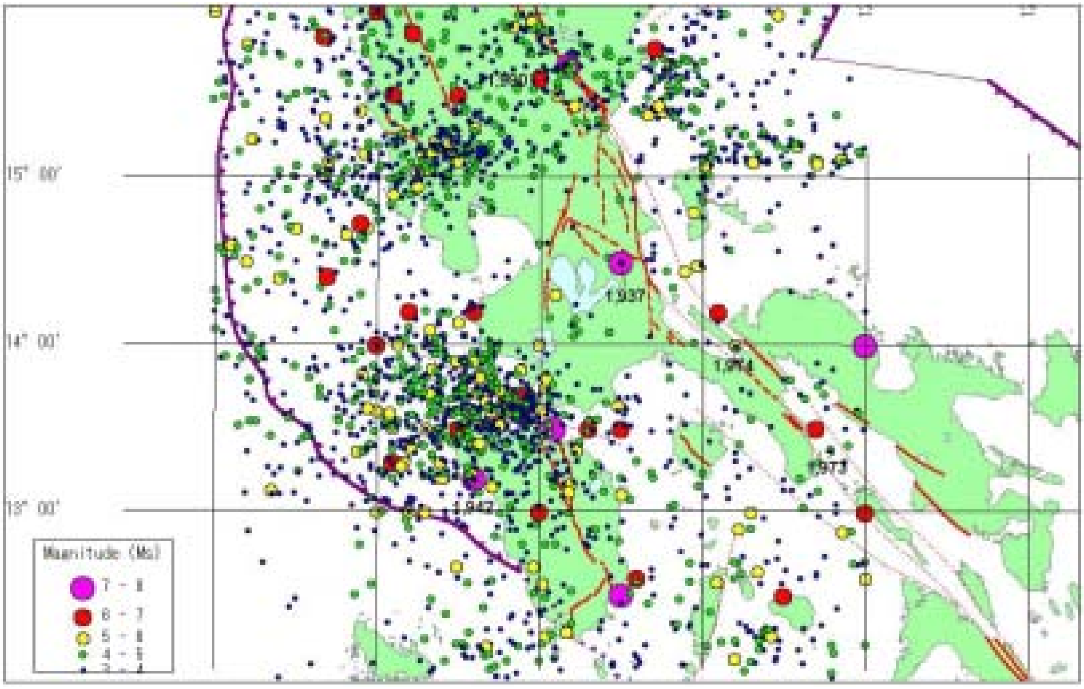

Figure 2.1.5 Distribution of Instrumentally Recorded Earthquakes from 1907 to 2002

Source: PHIVOLCS

2.1.4 Scenario Earthquakes

A total of 18 scenario earthquakes were set. Three types of fault length were used for the West Valley Fault (WVF) considering the low continuity in the north and south. Tsunami was evaluated for the movement of Manila Trench and re-occurrence of 1863 earthquake. The source faults of scenario earthquakes are shown in Figure 2.1.6. The black solid line and shaded area show the fault of scenario earthquakes. The precise fault parameters are shown in Table 2.1.2. The empirical formula by Wells and Coppersmith (1994) was used to calculate the earthquake magnitude and fault width from fault length.

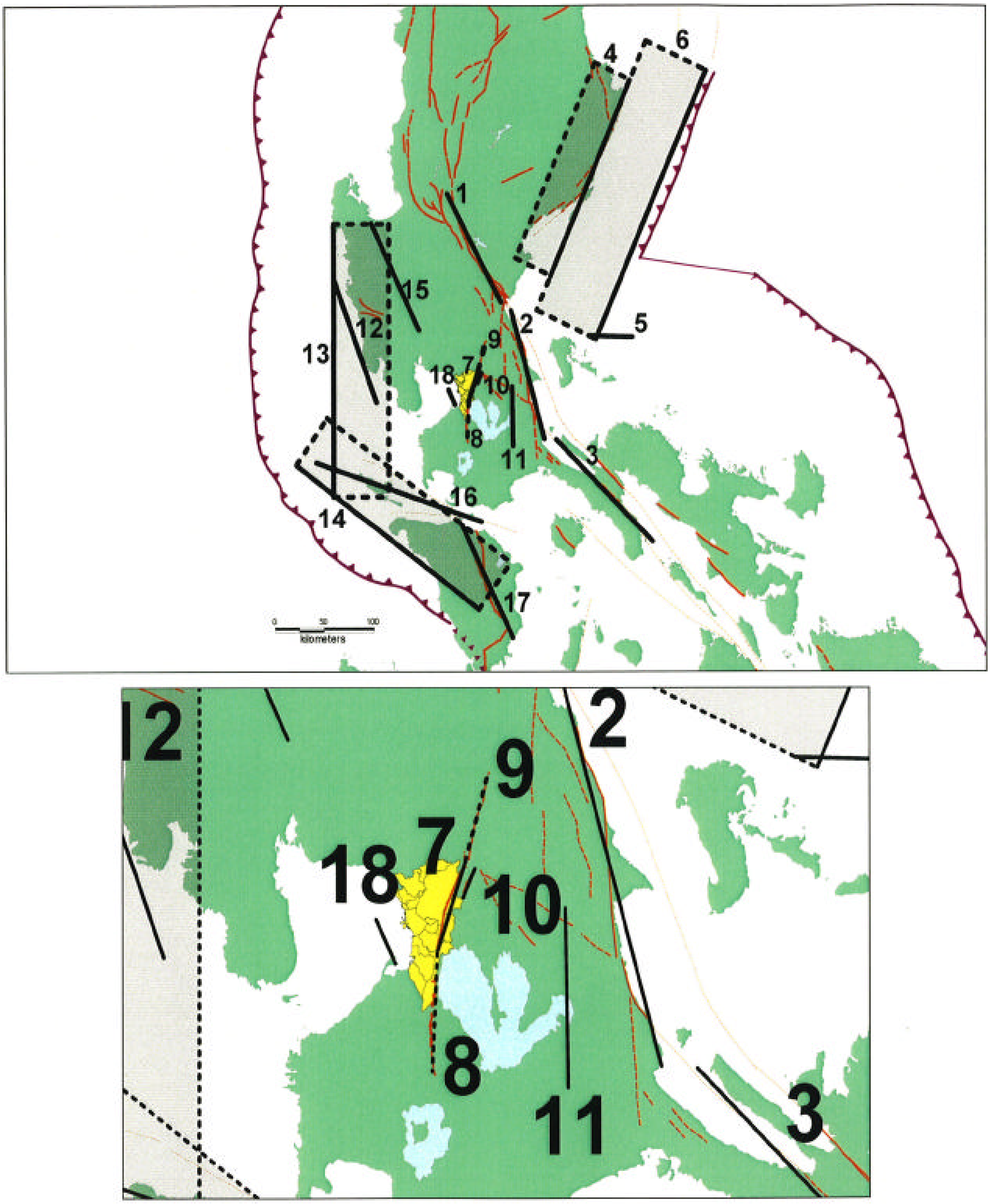

Figure 2.1.6 Scenario Earthquake Fault Models for Hazard Estimation

Source : PHIVOLCS and Study Team

Table 2.1.2 Fault Model Parameters of Scenario Earthquakes for Hazard Estimation

No.	Fault Name	Tectonics	Style	Magnitude	Fault Length (km)	Fault Width (km)	Dip Angle	Depth (km)	Past Earthquakes along the Fault	
									Y.M.D	Ms
1	PFZ: Digdig Segment	Crustal	SS	7.9	115	26	90	2	1645.11.30 1990.07.16	7.9 7.8
2	PFZ: Infanta Segment	Crustal	SS	7.6	125	27	90	2	1880.07.18	7.6
3	PFZ Ragay Gulf Segment	Crustal	SS	7.6	137	28	90	2	1824.10.26 1973.03.17	7.4 7.3
4	Casinguran Fault	Subduction	R	7.8	200	58	45	35	1968.08.01 1970.04.07	7.3 7.3
5	E-W Transform Fault	Crustal	SS	7.0	44	17	90	0	1970.04.12	7.0
6	East Luzon Trough	Subduction	R	8.0	275	71	25	0		
7	West Valley Fault	Crustal	SS	6.8	30	15	90	2	1658.08.19	5.7
8				7.2	67	21				
9				7.4	96	24				
10	East Valley Fault	Crustal	SS	6.3	10	9	90	2	1771.02.01	5.0
11	Laguna-Banahaw Fault	Crustal	SS	7.5	56	19	90	2	1937.08.20	7.5
12	West Boundary Fault	Crustal	R	7.5	120	42	90	0		
13	Manila Trench (16-14N)	Subduction	R	7.9	255	68	40	40	1677.12.07	7.3
14	Manila Trench (14-12.5N)	Subduction	R	7.9	227	63	35	35	1972.04.25	7.2
15	East Zambales Fault	Crustal	SS	7.4	110	26	90	2		
16	Lubang Fault	Crustal	SS	7.7	175	31	90	0	1942.04.08	7.5
17	Central Mindoro Fault	Crustal	SS	7.5	116	26	90	2		
18	1863 Earthquake	Crustal	SS	6.5	15	11	90	2	1863.06.03	6.5

SS : Strike Slip, R : Reverse Fault

2.1.5 Earthquake Ground Motion

The distribution of ground motion, seismic intensity, liquefaction potential, and slope stability were calculated for these 18 scenario earthquakes. Three modes, model 08 (West Valley Fault), Model 13 (Manila Trench), Model 18 (1863 Manila Bay), are selected for detailed mage analysis because these scenario earthquakes show typical and severe damages to Metropolitan Manila.

The distributions of the seismic intensity in PHIVOLCS Earthquake Intensity Scale (PEIS) for the three models are shown in Figure 2.1.7. Table 2.1.3 shows definition of the PEIS. Corresponding Modified Mercalli Intensity (MMI) and Japan Metrological Agency Intensity (JMAI) are included in the table.

Table 2.1.3 PHIVOLCS Earthquake Intensity Scale (PEIS)

Intensity Scale	Description	MMI	JMAI
I	**Scarcely Perceptible** - Perceptible to people under favorable circumstances. Delicately balanced objects are disturbed slightly. Still Water in containers oscillates slowly.	I	0
II	**Slightly Felt** - Felt by few individuals at rest indoors. Hanging objects swing slightly. Still Water in containers oscillates noticeably.	II	1
III	**Weak** - Felt by many people indoors especially in upper floors of buildings. Vibration is felt like one passing of a light truck. Dizziness and nausea are experienced by some people. Hanging objects swing moderately. Still water in containers oscillates moderately.	III	2
IV	**Moderately Strong** - Felt generally by people indoors and by some people outdoors. Light sleepers are awakened. Vibration is felt like a passing of heavy truck. Hanging objects swing considerably. Dinner, plates, glasses, windows and doors rattle. Floors and walls of wood framed buildings creak. Standing motor cars may rock slightly. Liquids in containers are slightly disturbed. Water in containers oscillate strongly. Rumbling sound may sometimes be heard.	IV	2-3
V	**Strong** - Generally felt by most people indoors and outdoors. Many sleeping people are awakened. Some are frightened, some run outdoors. Strong shaking and rocking felt throughout building. Hanging objects swing violently. Dining utensils clatter and clink; some are broken. Small, light and unstable objects may fall or overturn. Liquids spill from filled open containers. Standing vehicles rock noticeably. Shaking of leaves and twigs of trees are noticeable.	V	3
VI	**Very Strong** - Many people are frightened; many run outdoors. Some people lose their balance. motorists feel like driving in flat tires. Heavy objects or furniture move or may be shifted. Small church bells may ring. Wall plaster may crack. Very old or poorly built houses and man-made structures are slightly damaged though well-built structures are not affected. Limited rockfalls and rolling boulders occur in hilly to mountainous areas and escarpments. Trees are noticeably shaken.	VI	4
VII	**Destructive** - Most people are frightened and run outdoors. People find it difficult to stand in upper floors. Heavy objects and furniture overturn or topple. Big church bells may ring. Old or poorly built structures suffer considerably damage. Some well-built structures are slightly damaged. Some cracks may appear on dikes, fishponds, road surface, or concrete hollow block walls. Limited liquefaction, lateral spreading and landslides are observed. Trees are shaken strongly. (Liquefaction is a process by which loose saturated sand lose strength during an earthquake and behave like liquid).	VII	4
VIII	**Very Destructive** - People panicky. People find it difficult to stand even outdoors. Many well-built buildings are considerably damaged. Concrete dikes and foundation of bridges are destroyed by ground settling or toppling. Railway tracks are bent or broken. Tombstones may be displaced, twisted or overturned. Utility posts, towers and monuments mat tilt or topple. Water and sewer pipes may be bent, twisted or broken. Liquefaction and lateral spreading cause man- made structure to sink, tilt or topple. Numerous landslides and rockfalls occur in mountainous and hilly areas. Boulders are thrown out from their positions particularly near the epicenter. Fissures and faults rapture may be observed. Trees are violently shaken. Water splash or stop over dikes or banks of rivers.	VIII, IX	5-6
IX	**Devastating** - People are forcibly thrown to ground. Many cry and shake with fear. Most buildings are totally damaged. Bridges and elevated concrete structures are toppled or destroyed. Numerous utility posts, towers and monument are tilted, toppled or broken. Water sewer pipes are bent, twisted or broken. Landslides and liquefaction with lateral spreadings and sandboils are widespread. The ground is distorted into undulations. Trees are shaken very violently with some toppled or broken. Boulders are commonly thrown out. River water splashes violently on slops over dikes and banks.	X, XI	7
X	**Completely Devastating** - Practically all man-made structures are destroyed. Massive landslides and liquefaction, large-scale subsidence and uplifting of land forms and many ground fissures are observed. Changes in river courses and destructive seiches in large lakes occur. Many trees are toppled, broken and uprooted.	XII	7

Source: PHIVOLCS web site, http://www.phivolcs.dost.gov.ph/Earthquake/Scale/peis.html

MMI: Modified Mercalli Intensity

JMAI: Japan Metrological Agency Intensity

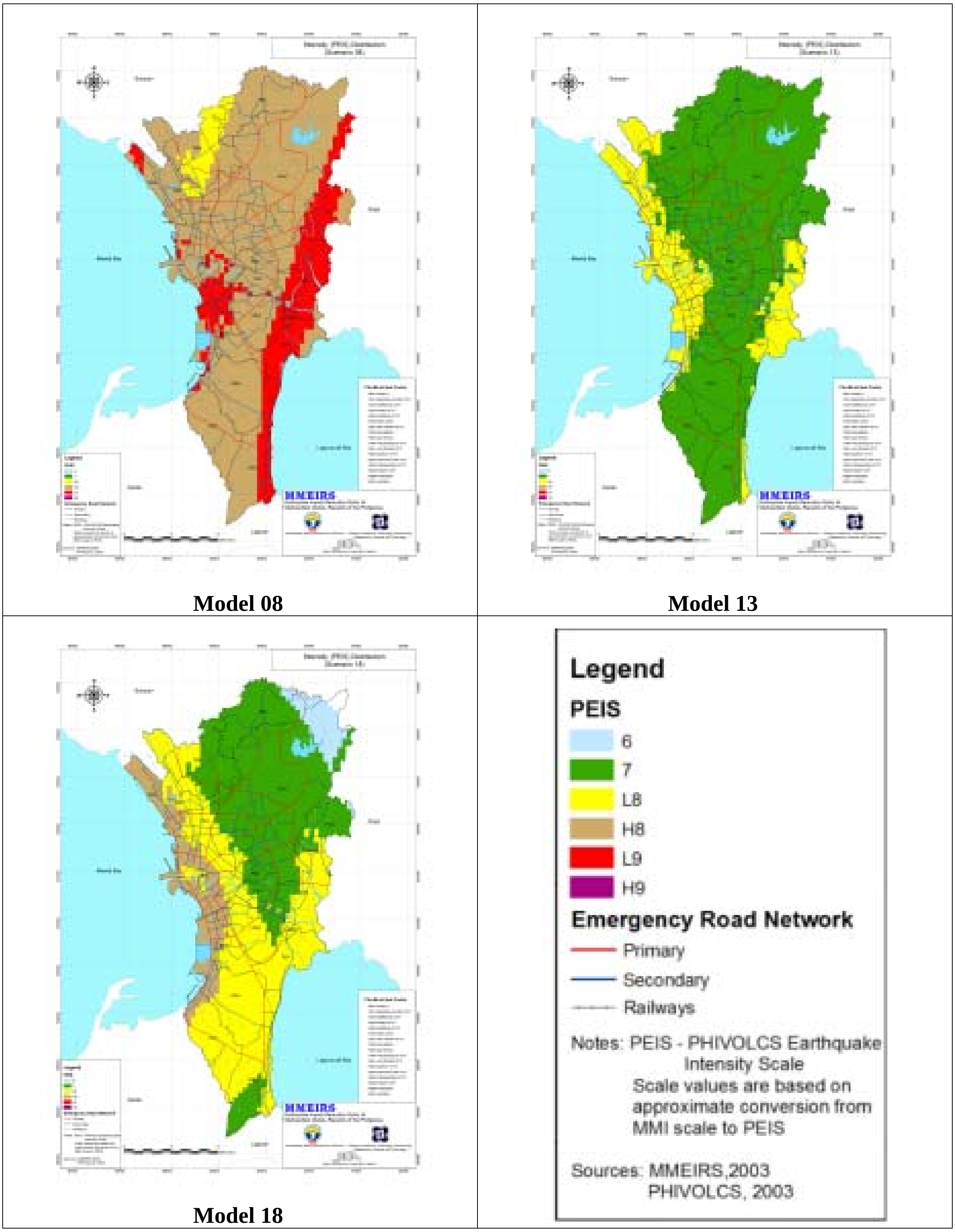

Figure 2.1.7 Distribution of Seismic Intensity in PHIVOLCS Earthquake Intensity Scale