12.2.3 Scenario Earthquakes

Historical earthquakes suggest that the Valley Fault System (VFS), Laguna-Banahaw Fault and Digdig and Infanta Segments of the Philippine Fault Zone (PFZ) may be the possible seismic sources that may cause much damage to Metropolitan Manila in the future. B. C. Bautista et al. (2002) proposed the earthquake source zones surrounding Metropolitan Manila based on the historical earthquakes, inland faults and trenches. The scenario earthquakes are set based on this study.

Table 12.2.2 shows the source zones that B. C. Bautista et al. (2002) has proposed. The distance, magnitude and estimated Peak Ground Acceleration (PGA) are analyzed and tabulated by the Study Team. Based on an analysis of historical earthquakes, the estimated PGA of all hazardous historical events, except three recent earthquakes, shows more than 50 gal. Using this criterion, faults, having an estimated PGA of over 50 gal, which are shaded in Table 12.2.2, are selected as source faults for scenario earthquakes in hazard analysis. In addition, E-W Transform Fault, presumed source fault of the 1970 event is also selected. The re-occurrence of 1863 event is added in spite of the indefinite source fault because this event caused great damage to Metropolitan Manila. A total of 18 scenario earthquakes are set. Three types of fault length will be used for the West Valley Fault (WVF) considering the low continuity in the north and south. Tsunami will be evaluated for the movement of Manila Trench and re-occurrence of 1863 earthquake.

The source faults of scenario earthquakes are shown in Figure 12.2.5. The black solid line and shaded area show the fault of scenario earthquakes. The location of Model 13 and Model 14 are placed on the subducting Eurasian Plate so as to minimize the shortest distance from Metro Manila to the fault plane.

The precise fault parameters are shown in Table 12.2.3. The empirical formula by Wells and Coppersmith (1994) was used to calculate the earthquake magnitude and fault width from fault length. The dip angle of subduction fault was decided from recent seismic activities. The dip angle of crustal fault was estimated to be vertical because there is no information. The depth of upper edge of inland crustal fault was supposed to be 2 km after Yamanaka et al. (2002).

Table 12.2.2 Source Zones Surrounding Metropolitan Manila and Estimated PGA

Fault	Distance1) (km)	Magnitude	Estimated PGA2) (gal)
PFZ: San Manuel Segment	163	6.9	20.4
PFZ: Digdig Segment	92	7.9	114.1
PFZ: Infanta Segment	62	7.6	154.5
PFZ Ragay Gulf Segment	99	7.6	85.3
Casiguran Fault	147	7.8	50.4
E-W Transform Fault	140	7.0	30.2
East Luzon Trough	140	8.0	63.2
West Valley Fault			
(Length=30km)	3	6.8	528.3
(Length=67km)	3	7.2	551.3
(Length=96km)	3	7.4	560.5
East Valley Fault	8	6.3	354.3
Laguna-Banahaw Fault	45	7.5	200.8
West Boundary Fault	91	7.5	90.1
Manila Trench (16-14N)	149	7.9	52.7
Manila Trench (14-12.5N)	173	7.9	39.1
East Zambales Fault	76	7.4	107.6
Lubang Fault	109	7.7	78.7
Aglubang River Fault	128	7.1	38.7
Central Mindoro Fault	124	7.5	55.4
Tablas Fault	231	7.5	14.4
1863 Earthquake	15	6.5	275.3

1) distance from center of Metropolitan Manila (14.5687N, 121.0203E)

2) by Fukushima and Tanaka (1990)

Source: PHIVOLCS and Study Team

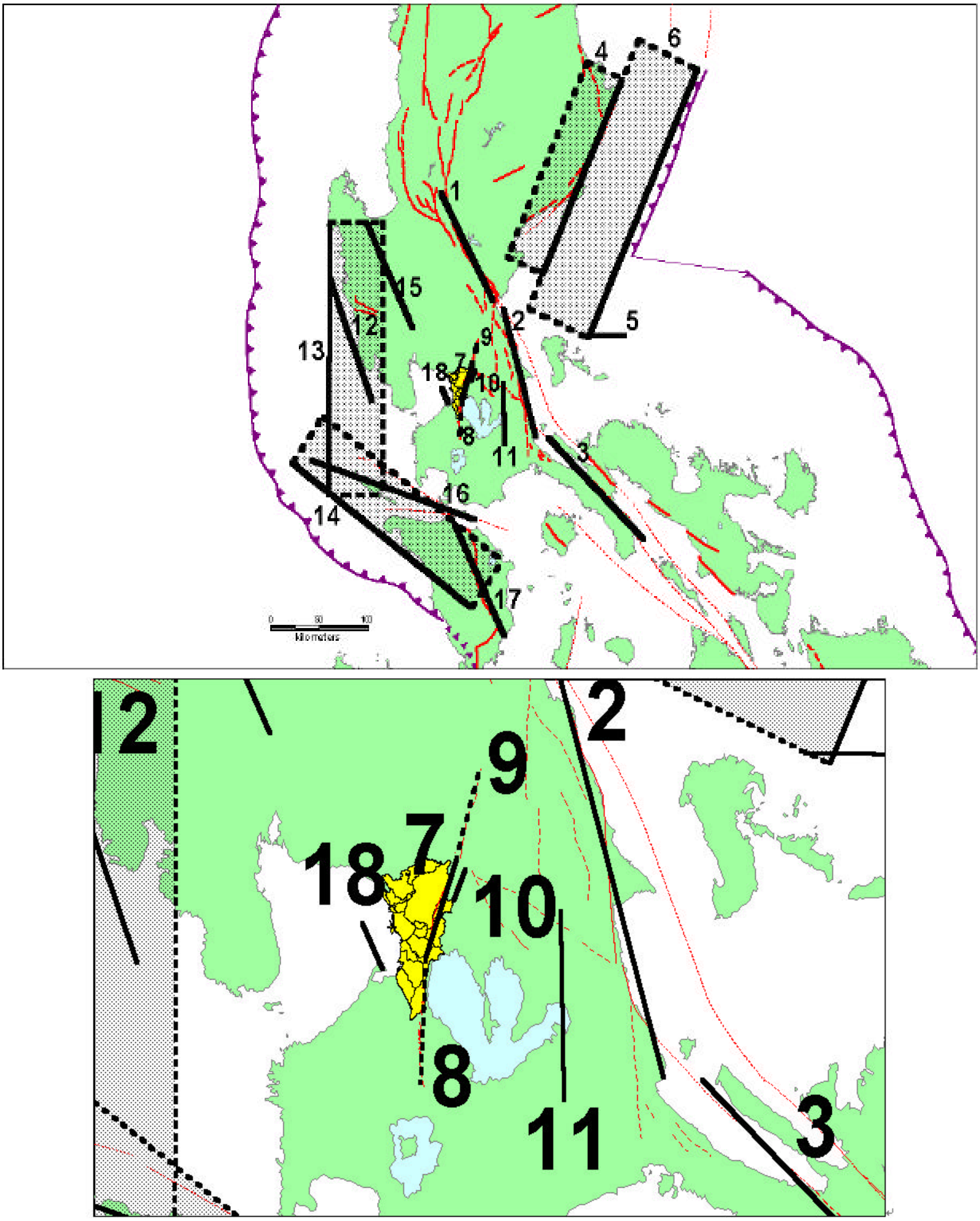

Figure 12.2.5 Scenario Earthquake Fault Models for Hazard Estimation

Source: PHIVOLCS and Study Team

Table 12.2.3 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	7.9
									1990.07.16	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	7.4
									1973.03.17	7.3
4	Casinguran Fault	Subduction	R	7.8	200	58	45	35	1968.08.01	7.3
									1970.04.07	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

References to section 12.2

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Yamanaka, H., N. Yamada, M. Takezono, J. R. Baul-Deocampo, C. Kumada, R. B. Tiglao, B. C. Bautista, Y. Takahashi and T. Samano, 2002, Explosion of Sedimentry Layers in Metropolitan Manila, the Philippines, for estimation of site effects, 11th. Japan Earthquake Engineering Symposium, CD-ROM No.64 (in Japanese with English Summary).

12.3 Ground Modeling and Those Parameters for Ground Motion Estimation

12.3.1 Feature of Ground Condition in Metro Manila

1) General

In this study, ground motion is estimated for consideration of damage properties, including damages to buildings and infrastructure. Effect of short periods properties of seismic motion to damage is important and this period property are mainly governed by amplification properties of subsurface soils. Therefore seismic analysis in this Study focuses the following matters:

1) Introduction of idea for engineering seismic bedrock
2) Detail consideration of seismic amplification properties of subsurface soil

Pyroclastic rock and tuff layer widely distribute in the study area, from ground surface in Central Plateau area and depth down to 120m in Coastal Lowland area and Marikina Plain. Results of PS logging shows shear wave velocity of these geological units exceed 700 m/sec. Study Team applied these pyroclastic rocks and tuffs as engineering seismic bedrock.

Terminology as shown in Table 12.3.1 is used for convenience sake in this study.

Table 12.3.1 Definition of Terminology for Engineering Seismic Bedrock and Subsurface Soil

Name	Objects	Major Geology
Rock	Engineering Seismic Bedrock	Pyroclastic Rocks and Tuff
Soil Deposit	Subsurface Soil	Quaternary soil and weathered "Rock"

2) Rock

In this Study engineering seismic bedrock is defined as pyroclastic rocks and tuff layer. A lot of outcrop of these rock self-stands such as a vertical cliff. Figure 12.3.1 shows schematic geological cross section in east-west direction. The Rock distribute at ground surface in Central Plateau area and gradually descending toward Manila bay in Coastal Lowland, while the Rock is close to Soil Deposit alongside of West Valley Fault in Marikina Plain.

Outcrop of Tuff

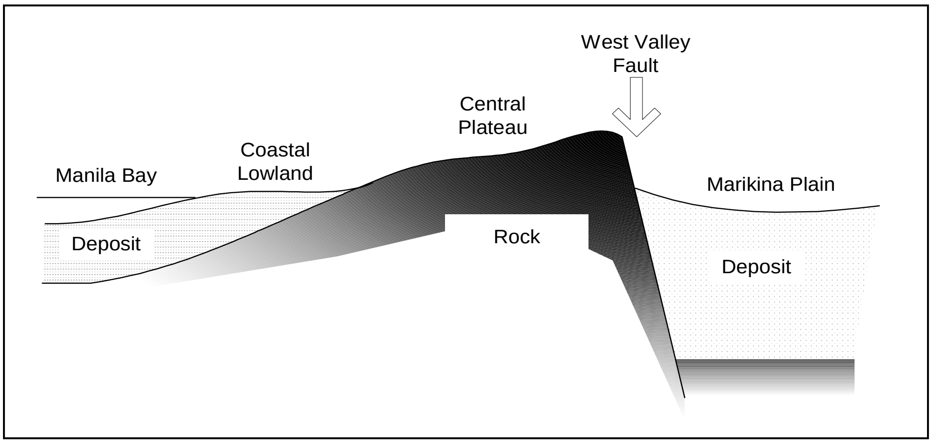


Figure 12.3.1 Schematic Diagram of Distribution of the Rock

3) Soil Deposit

(1) Distribution

Soil Deposit distributes above the Rock in Coastal Lowland and Marikina Plain. These are consisted with of clay, sand and gravel. In Coastal Lowland, thickness of the Soil Deposit gradually increases toward Manila bay. At the mouth of Pasig River, thickness of the Soil Deposit reaches to 60m and it forms small basin. In Marikina Plain, thickness of the Soil Deposit increases gradually from Marikina City to Taguig. Especially, in south part of Pateros, where Marikina River changes its direction from north south to east west, the thickness increases steeply. The thickness is considered as approximately over 100m at Laguna de Bay.

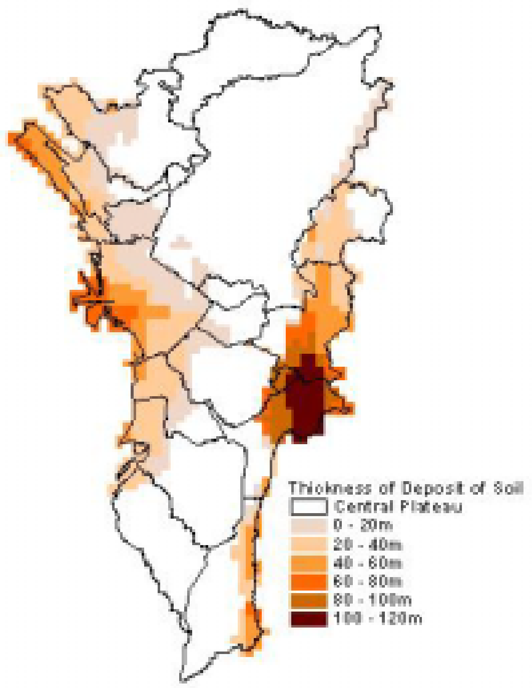


Figure 12.3.2 Thickness of Deposit of Soil Based on Model

Source: Study Team

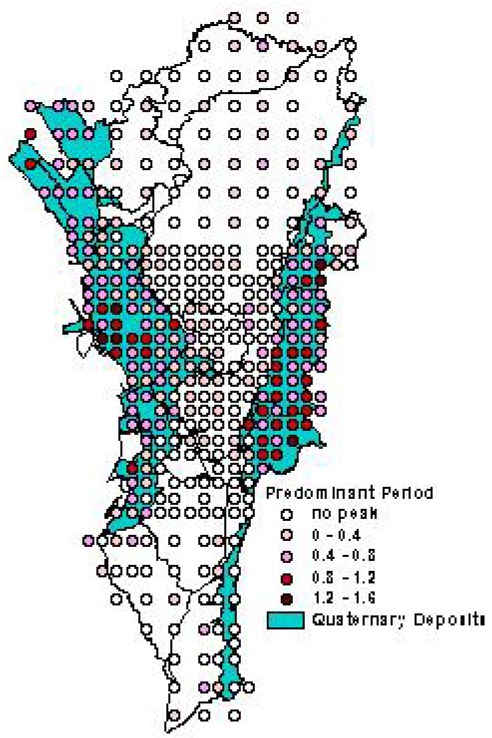


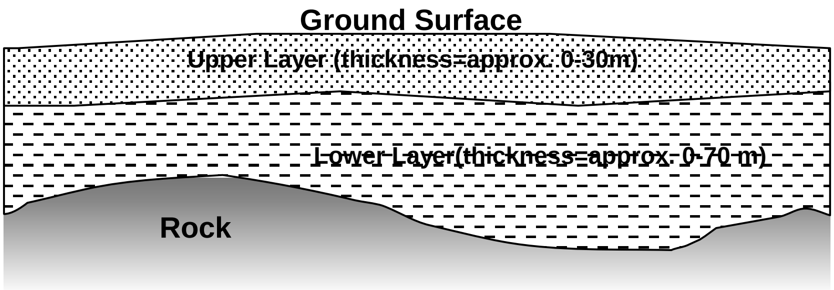
Figure 12.3.3 Distribution of Predominant Period Based on Existing Microtremor Measurement

Source: PHIVOLCS

(2) Stratigraphical Feature

The soil deposit shows typical features of color, consistency and so on and is classified into two layers, upper layer and lower layer as shown in Table 12.3.2.

Table 12.3.2 Stratigraphical Feature of Soil Deposit

	Upper Layer	**Lower Layer**
Color	Grayish	Yellowish
Consistency (N Value)	Soft/loose (N < 20)	Stiff/Dense (N > 20)
Shear Wave Velocity	Vs < 300	Vs > 300
Included	Shell, Organic etc.	Ash etc.
Picture		
Distribution of the Soil Deposit		

The upper layer distributes widely in lowland area of Metro Manila. It consists of very soft clayey soil and loose sandy soil. Hence, effect of amplification of seismic motion is important. Furthermore, possibility of liquefaction is high for a large earthquake motion.

The lower layer also distributes widely in lowland area of Metro Manila. Thickness reaches to approximately 30m at mouth of Pasig River and approximately 70m at Taguig. It consists of stiff clay and dense sand. Possibility of liquefaction is low compared to that of upper layer.

(3) Regional Feature

Coastal Lowland locates west side of Central Plateau and faces Manila bay. Marikina Plain locates between Central Plateau and mountainous area of Province of Rizal and also faces Laguna de bay. In Marikina Plain, Marikina River changes its direction at Sta. Rosa in Pasig City. Lowland of Muntinlupa is also called one part of Marikina Plain, however the plain is separated by Central Plateau in south part of Taguig. It is considered that sedimentation environment is different area by area and this affects variation of soil properties. Actually physical properties and shear wave velocities, those are investigated through the Study, differ to area by area. Hence, the lowland was separated into four regions as shown in Figure 12.3.4.

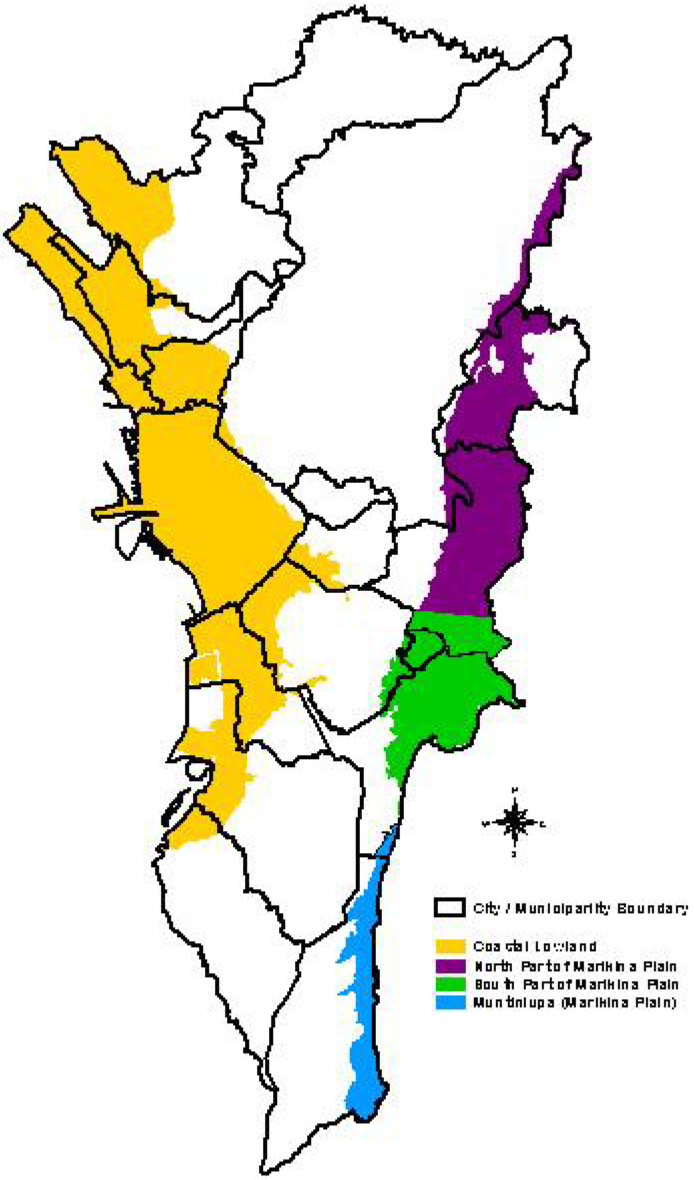


Figure 12.3.4 Four Regional Classification of Lowland Area

12.3.2 Ground Modeling for Seismic Motion Analysis

500m-grid system was applied as analysis unit for seismic motion calculation. Shear wave velocity profile model for each 500m-grid was set, which covers all the Study Area. Flow of the modeling is shown in Figure 12.3.5.

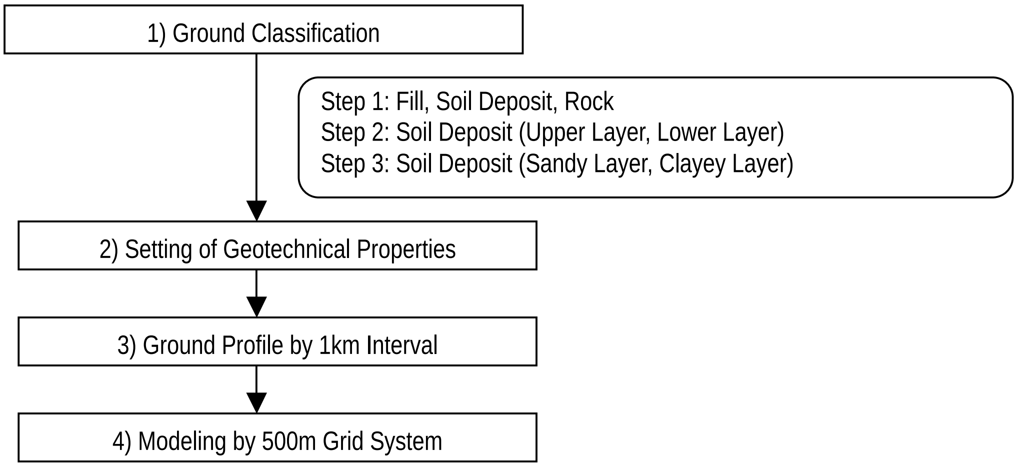


Figure 12.3.5 Flowchart for Ground Modeling for Seismic Motion Analysis

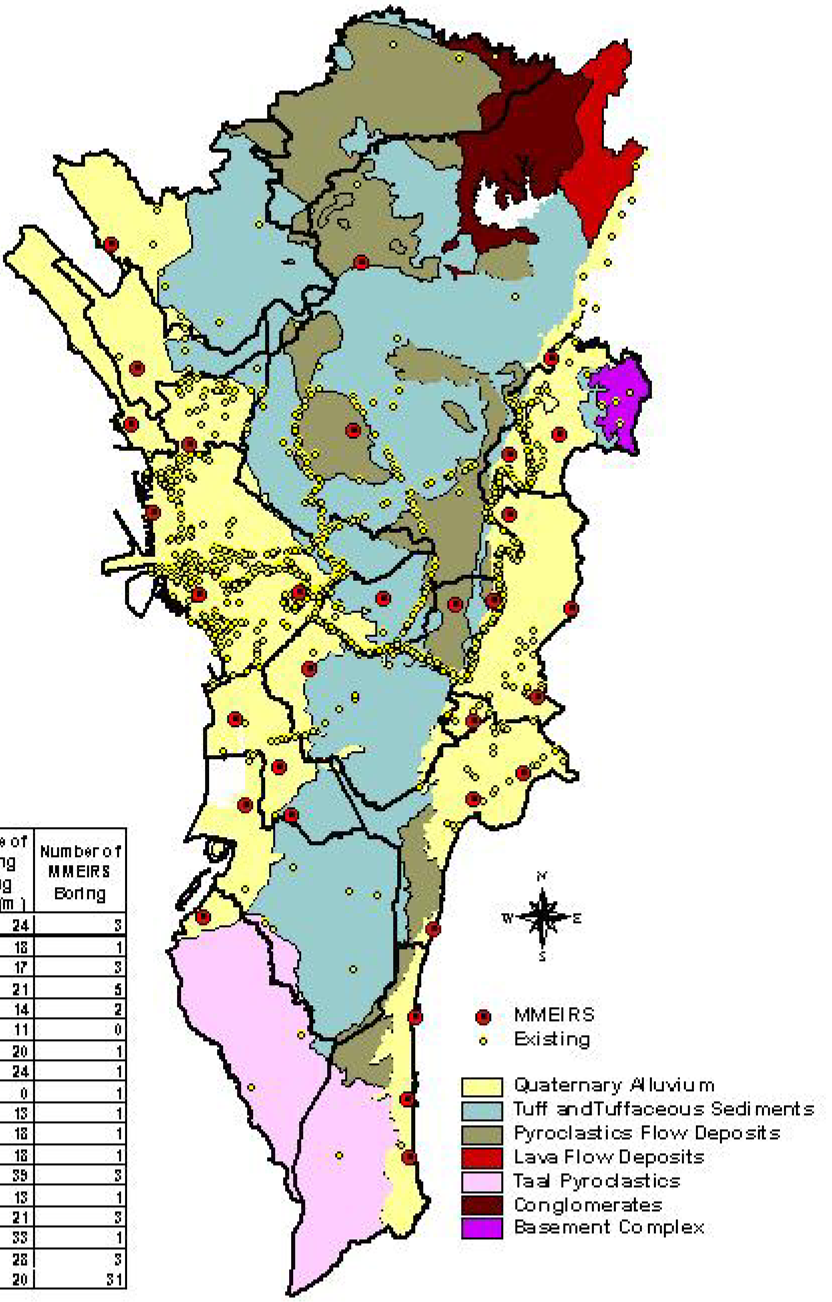
1) Ground Classification

Table 12.3.3 summarized data sources, which are applied for consideration of ground classification.

Table 12.3.3 Data Sources applied for Ground Classification

Source	Contents
MMEIRS	Investigation Drilling-----31 sites, L=1,133m Standard Penetration Test-----1,133 times PS Logging-----L=1,133m Laboratory Test-----420 samples
PHIVOLCS	Geological Map Geomorphological Map Geological Profile Boring Log-----Nos.=338
17LGU, DPWH, MERALCO	Boring Log-----Nos.=658

Figure 12.3.6 shows location of investigation boring, which includes boring in the Study and also existing ones. It is easy to find that data distribution is biased by area. Most of existing investigation borings do not reached to Rock, because their purpose was to confirm foundation depth of structures. Step 1 classification is to distinguish fill, deposit of soil and rock, which corresponds to geological map as shown in Table 12.3.4.



City/Municipality	Number of Existing Boring	Average of Existing Boring Depth (m)	Number of MMEIRS Boring
MANILA	351	24	3
MANDALUYONG	52	18	1
MARIKINA	96	17	3
PASIG	115	21	5
QUEZON	165	14	2
SAN JUAN	16	11	0
CALOOCAN	66	20	1
MALABON	14	24	1
NAVOTAS	0	0	1
VALENZUELA	8	13	1
LAS PINAS	5	18	1
MAKATI	46	18	1
MUNTINLUPA	12	39	3
PARANAQUE	8	13	1
PASAY	9	21	3
PATEROS	5	33	1
TAGUIG	28	28	3
Total	996	20	31

Figure 12.3.6 Location of Investigation Drilling

Table 12.3.4 Ground Classification Step 1, Major Classification

Geological Classification	Geological Map	Materials
Fill	Quaternary Deposits	Clay, Silt, Sand, Gravel, Garbage
Deposit of Soil	Quaternary Deposits	Clay, Silt, Sand, Gravel
Rock	Tuff, Pyroclastic, Lava Flow, Taal Pyroclastic, Conglomerates, Basement Complex	Sedimentary Rock, Volcanic Rock

(1) Fill

The fill distributes in shore of Manila bay and Lagna de bay. The fill was not classified in detail, because their shear wave velocity (Vs) was almost approximately 100m/sec regardless construction year and materials of the fill.

(2) Soil Deposit

The soil deposit was divided into upper layer and lower layer as Step 2 classification. These were further divided into three types each as Step 3 classification. Feature of SPT N value and shear wave velocity (Vs) were considered in this classification. Finally, this classification was further divided into clayey layer and sandy layer. Regional feature of soil deposit were considered for determination of soil properties. Regarding to gravelly soil, distribution and number of data are limited and regional feature was not taken into account.

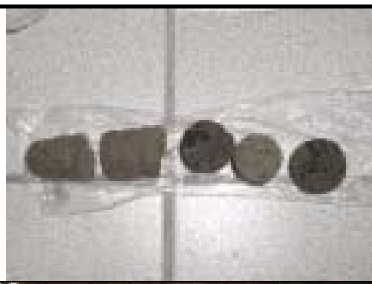
Table 12.3.5 Ground Classification Step 2 and 3, Classification of the Soil Deposit

Step 2 Classification	Step 3 Classification	Materials			
Upper Layer	1	Clayey	or	Sandy	Gravelly
	2	Clayey	or	Sandy	
	3	Clayey	or	Sandy	
Lower Layer	1	Clayey	or	Sandy	Gravelly
	2	Clayey	or	Sandy	
	3	Clayey	or	Sandy	

(3) Rock

Rock was divided into two categories. One is "soft rock", which shows low solidity or weathered condition, other one is "hard rock" as shown in Table 12.3.6. The hard rock shows shear wave velocity of 700m/sec distributes whole Metro Manila area. This hard rock was determined as seismic engineering bedrock in the Study.

Table 12.3.6 Classification of the Rock

Classification	Feature	Core Sample
Soft Rock	- This layer distributes on the Hard Rock - Core sample is not recovered - SPT applicable. - Sample is easy to break with finger-pressure. - Shear Wave Velocity shows around 500m/sec.	
Hard Rock	- Core recovery ratio is relatively high. - RQD is gained. - Shear Wave Velocity shows over 700m/sec.	

2) Setting of Geotechnical Properties

Shear wave velocity of ground was measured in the Study applying PS logging procedure. Figure 12.3.7 shows relation between velocity and N value. Correlation widely applied in Japan is also shown in the figure and these shows similar relation. Shear wave velocity, wet density and non-linear stress-strain characteristics of ground are required for calculation of ground motion. The shear wave velocity and the wet density were determined for each ground classification unit. Data on non-linear stress-strain characteristics of ground in Metro Manila are unavailable therefore existing data (Figure 12.3.8) in Japan were applied in this Study. This data were used in earthquake damage estimation in Tokyo Metropolitan Area. Table 12.3.7 shows summary of geotechnical properties by each area.

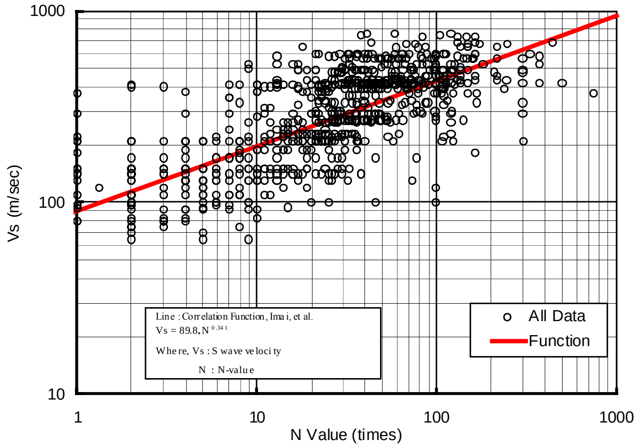
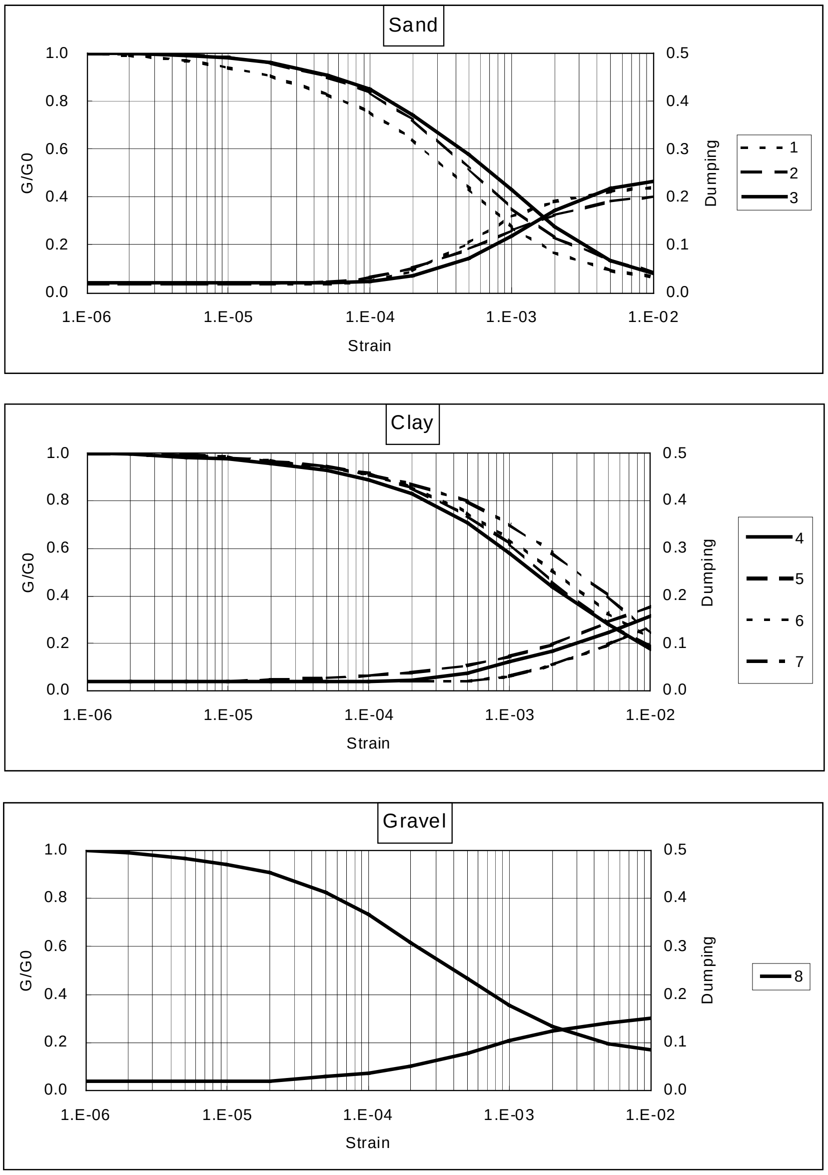


Figure 12.3.7 Relationship between N Value and Shear Wave Velocity



	Coastal Lowland	North Part of Marikina Plain	South Part of Marikina Plain	Mutinlupa (Marikina Plain)
F	1			
UC1	-	5	4	-
US1	2	2	2	-
UC2	4	5	4	4
US2	-	-	1	-
UC3	6	-	6	6
US3	2	-	-	2
UG	8			
LC1	7	-	6	6
LS1	-	-	-	3
LC2	-	-	6	7

- : no model

Figure 12.3.8 Non-Linear Stress-Strain Characteristics of Soil

Note: The figure of each curve shows the ground classification.

Table 12.3.7 Summary of Geotechnical Properties for Ground Motion Analysis

Layer	Code	Material	Coastal Lowland		Central Plateau		North Part of Marikina Plain		South Part of Malikina Plain		Muntinlupa (Marikina Plain)	
			Vs (m/sec)	γ_t (g/cm^3)	Vs (m/sec)	γ_t (g/cm^3)	Vs (m/sec)	γ_t (g/cm^3)	Vs (m/sec)	γ_t (g/cm^3)	Vs (m/sec)	γ_t (g/cm^3)
Fill	F	Mixture	120	1.75	-	-	120	1.75	120	1.75	120	1.75
Upper Layer	UC1	Clayey Soil	150	1.62	-	-	140	1.71	100	1.67	-	-
	US1	Sandy Soil	170	1.74	-	-	250	1.81	180	1.90	-	-
	UC2	Clayey Soil	130	1.53	-	-	210	1.66	130	1.56	110	1.56
	US2	Sandy Soil	170	1.70	-	-	210	1.73	140	1.73	140	1.67
	UC3	Clayey Soil	250	1.56	-	-	380	1.74	240	1.65	260	1.59
	US3	Sandy Soil	280	1.77	-	-	300	1.92	-	-	280	1.67
	UG	Gravelly Soil	240	2.00	-	-	240	2.00	240	2.00	240	2.00
Lower Layer	LC1	Clayey Soil	340	1.75	-	-	-	-	220	1.64	260	1.60
	LS1	Sandy Soil	430	1.96	-	-	-	-	280	1.88	270	1.71
	LC2	Clayey Soil	430	1.87	-	-	-	-	270	1.65	320	1.56
	LS2	Sandy Soil	-	-	-	-	-	-	290	1.75	460	1.75
	LC3	Clayey Soil	-	-	-	-	420	1.71	470	1.66	-	-
	LS3	Sandy Soil	-	-	-	-	420	1.86	520	1.82	-	-
	LG	Gravelly Soil	440	2.00	-	-	440	2.00	440	2.00	440	2.00
Rock	SR	Soft Rock	500	1.70	500	1.70	500	1.70	500	1.70	500	1.70
	HR	Hard Rock	700	2.00	700	2.00	700	2.00	700	2.00	700	2.00

Vs: Shear Wave Velocity

γ_t : Wet Density

3) Ground Profile for 1km Interval

Total of 58 ground property cross sections are compiled for every 1km interval. These include 39 sections for east-west direction and 19 sections for north-south direction and show distribution of ground classification as shown in Table 12.3.7. These are taken into account in the compilation.

Existing boring data includes only SPT N value and soil type. There is a good correlation between the shear wave velocity and the N value as shown in Figure 12.3.7, and N value distribution was fully considered.

In case that existing boring logs have description of rock, “Hard Rock” of the Study is defined as part of the rock with continuous high RQD (Rock Quality Designation) value.

In some place where data was limited as shown in Figure 12.3.6, the profiles were prepared considering geomorphological feature, results of existing microtremor measurement, and existing geological cross sections.

4) Modeling by 500m Grid

Finally ground column model of 500m-grid system is compiled based on the ground profile. This assumes ground condition in each grid is uniform.

Number of models in each area shows below,

Coastal Lowland -------------------------------	81
Central Plateau ---------------------------------	2
North Part of Marikina Plain ----------------	33
South Part of Marikina Plain ----------------	26
Muntinlupa (Marikina Plain) ----------------	15
Total --	157

Here, Figure 12.3.9 shows ground surface model and location of profile lines (red line), and Figure 12.3.10 and Figure 12.3.11 show model cross-sections.

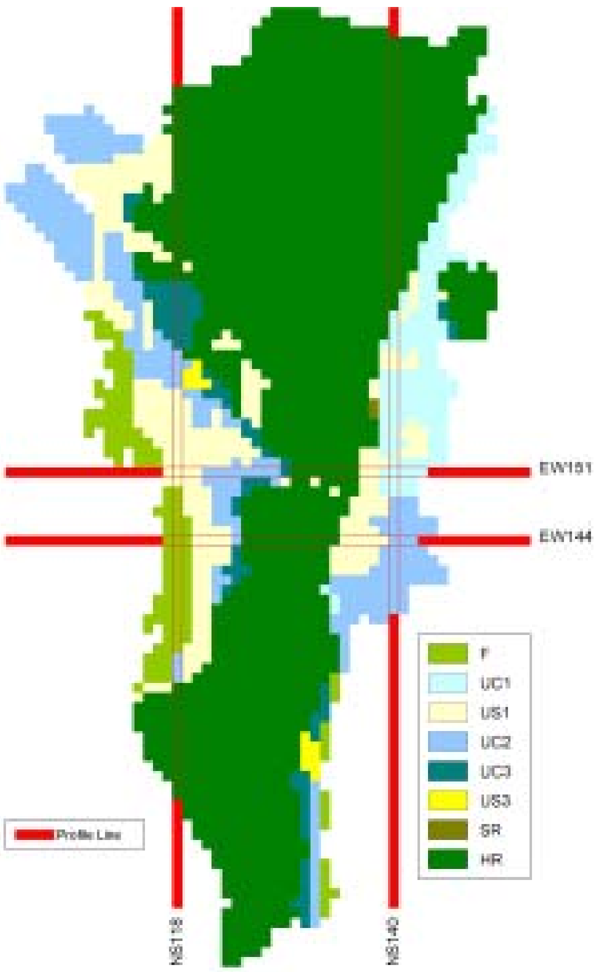


Figure 12.3.9 Ground Model Distribution at Ground Surface

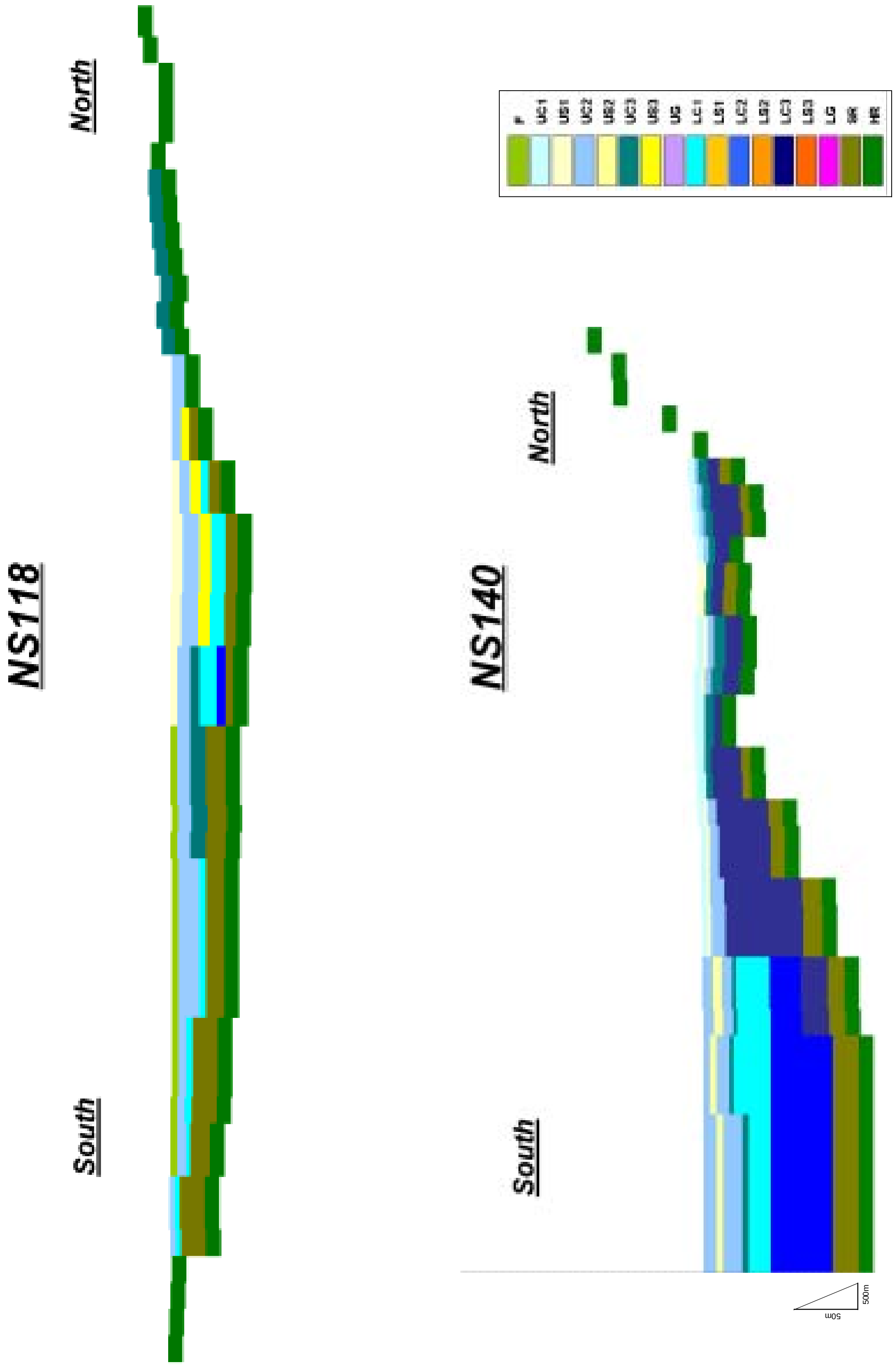


Figure 12.3.10 Model Cross Section: North-South Direction

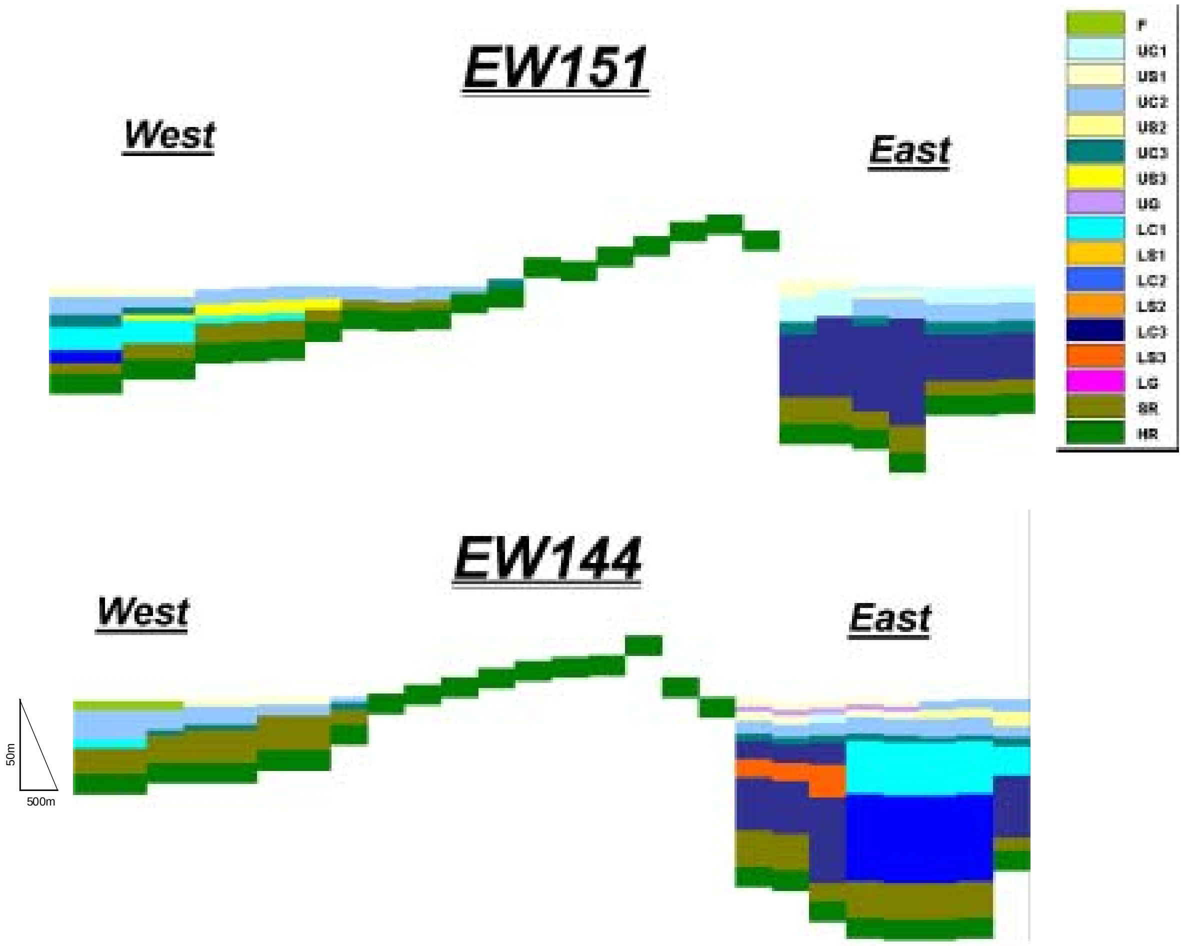


Figure 12.3.11 Model Cross Section: East-West Direction

5) Proposal for Future Improvement Work

As explained before, data of boring investigation is limited in some area of the Study area. It is strongly proposed that comprehensive collection and compilation of ground data shall be taken by PHIVOLCS. It is recommended that some agreements on data submission to PHIIVOLCS from related organization is prepared, once boring investigation is undertaken by some organization or private sectors.

Reference to section 12.3

Narag, Ishmael C., et al, 2000, Microtremor observation of Metropolitan manila, International Workshop on the Integration of Data for Seismic Disaster Mitigation in Metro Manila, pp.73-84

Matsuda, Iware, et al, Regional Division of Marikina Valley and Coastal Lowland, Metro Manila on the Basis of Soil Condition, International Workshop on the Integration of Data for Seismic Disaster Mitigation in Metro Manila, pp.43-62.

Tokyo Metropolitan Government, Study on Earthquake Damage Estimation in Tokyo area, 1988.

12.4 Estimated Ground Motion

12.4.1 General

The earthquake ground motion at arbitrary point can be expressed roughly by following equation.

$$E = Fs * Fr * Fa$$

E : earthquake ground motion at arbitrary point

Fs : source characteristics

Fr : propagation (dumping) characteristics in rock

Fa : amplification (transfer) function of sediment layer

The earthquake ground motion at arbitrary point is affected by source characteristics, propagation characteristics and transfer function (Figure 12.4.1). The following methods are adopted in the analysis taking the data availability into consideration.

1) Source Characteristics and Propagation Characteristics

The source characteristics and propagation characteristics are expressed in total as attenuation function with distance for seismic engineering bedrock. The tectonics and slip type of the fault, the magnitude of the earthquake and distance from the fault was taken into consideration. Most suitable empirical attenuation formula was selected from existing one through the evaluation with observed data in the study area.

2) Amplification Function of Sediment Layer

The 1D response analysis of sediment layer with numerical ground model over engineering seismic bedrock was used for amplification evaluation. The non-linearity of soil was considered.

The flow chart of earthquake analysis is shown in Figure 12.4.2. Based on the fault model, which was made in section 12.2, peak acceleration, peak velocity and acceleration response spectrum (5% dumping) was calculated with selected empirical attenuation formula. Next, the amplification factor was multiplied to get the peak ground acceleration (PGA), peak ground velocity (PGV) and acceleration response spectrum (Sa) at ground surface. The seismic intensity was evaluated based on the empirical relation between PGA, PGV and intensity.

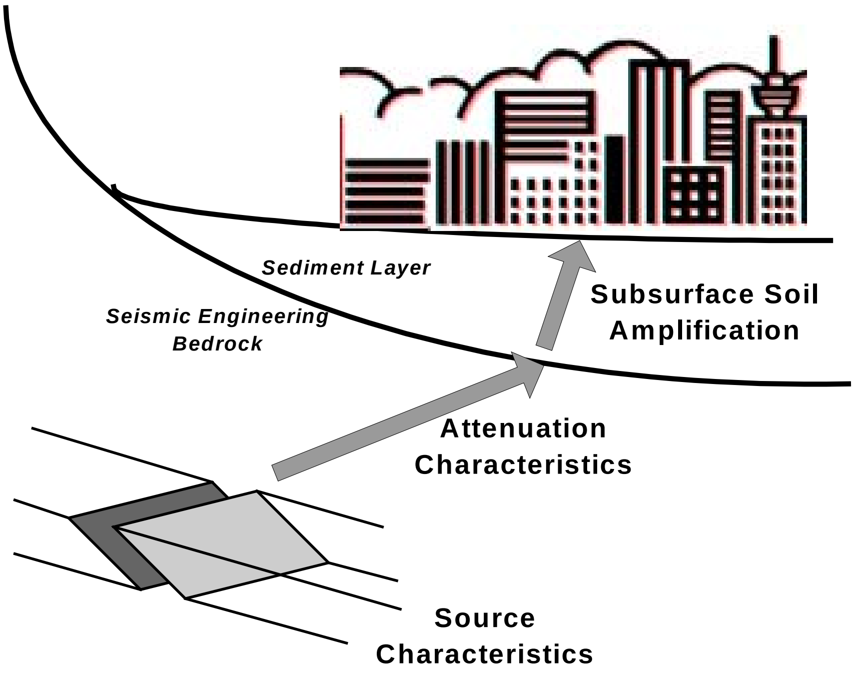


Figure 12.4.1 Schematic figure of seismic wave propagation and amplification

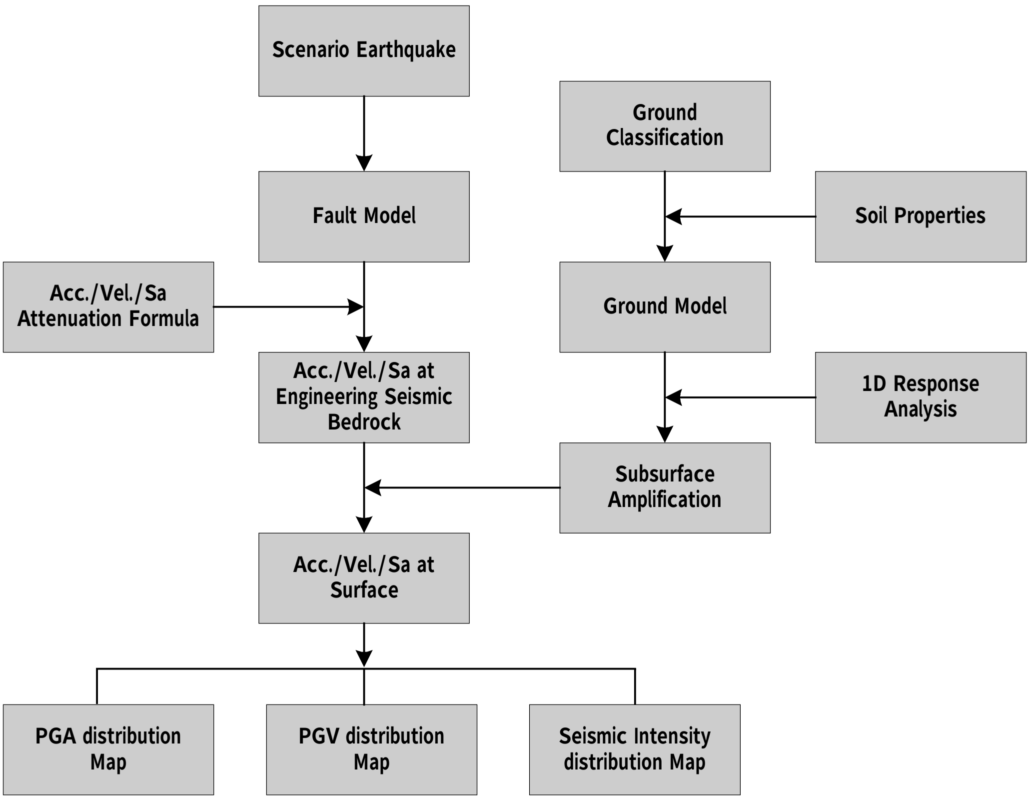


Figure 12.4.2 Flowchart of Earthquake ground motion analysis

12.4.2 Bedrock Motion Analysis Method

Many researchers proposed a lot of empirical attenuation functions from of old. The functions have different features and limitations based on the used strong motion database, classification methods and analysis methods. Therefore, it is important to select proper attenuation formula for the study based on the applicability of each formula.

The acceleration, velocity and acceleration response spectrum are evaluated in seismic motion analysis. The selection of attenuation formula is conducted separately for acceleration, velocity and acceleration response spectrum along the following policy.

- The crustal shallow earthquakes and the earthquakes that occur at the offshore subduction zone with larger magnitude are included in the scenario earthquakes. The formula that is applicable to these two different type earthquakes are selected separately.
- In the analysis of subsurface amplification, the layer of s-wave velocity 700 m/sec is treated as seismic engineering bedrock. The attenuation formula should be adapted to this ground condition.
- Select the best formula that can explain the observed strong motion records by strong motion observation network (MM-STAR).

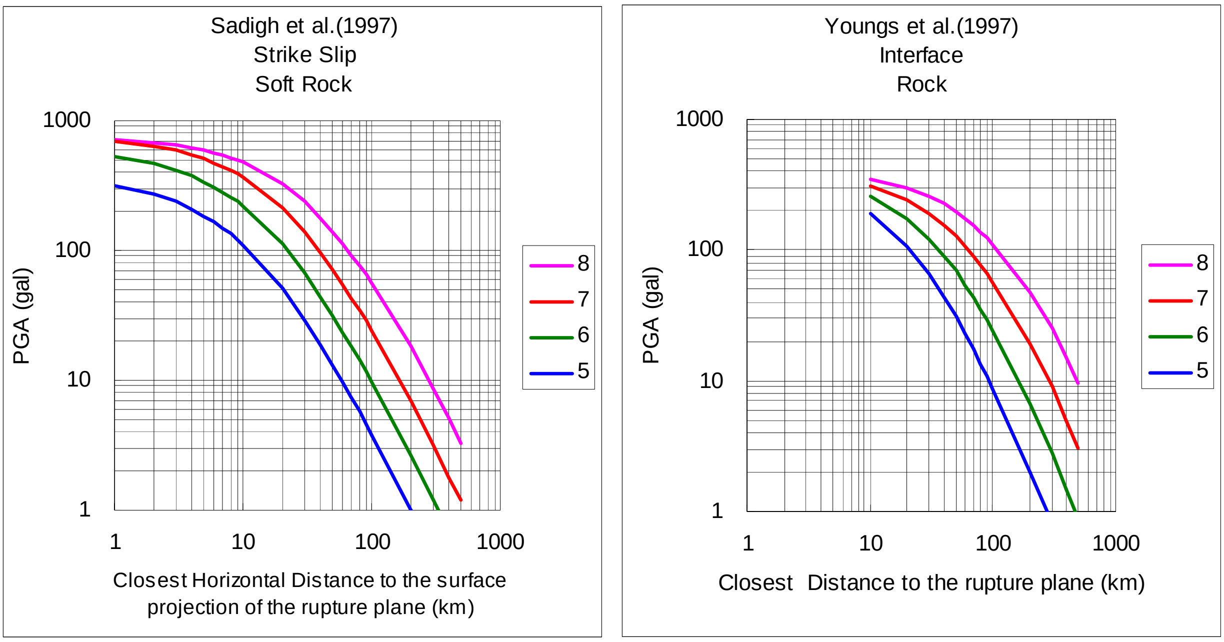
The selected formulas are shown in below.

<u>Crustal Earthquake</u>

Acceleration:	Sadigh et al. (1997)	(Figure 12.4.3 (a))
Velocity:	Si & Midorikawa (1999)	(Figure 12.4.4 (a))
Sa:	Abrahamson & Silva (1997)	(Figure 12.4.5 (a))

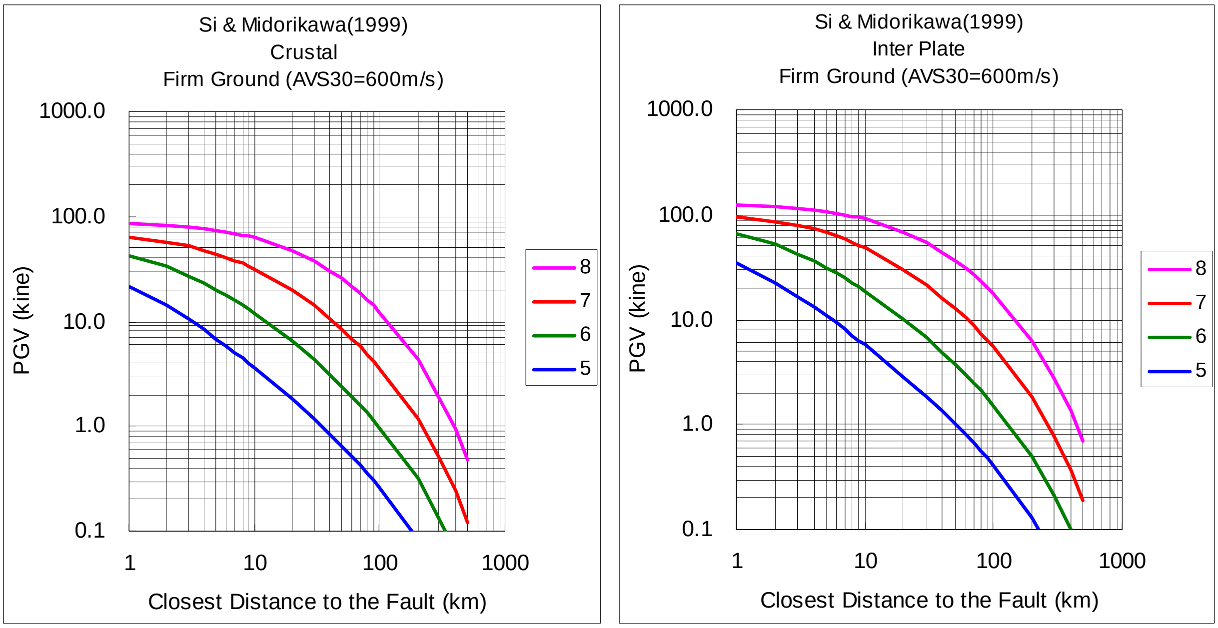
<u>Subduction Earthquake</u>

Acceleration:	Youngs et al. (1997)	(Figure 12.4.3 (b))
Velocity:	Si & Midorikawa (1999)	(Figure 12.4.4 (b))
Sa:	Annaka et al. (1997)	(Figure 12.4.5 (b))



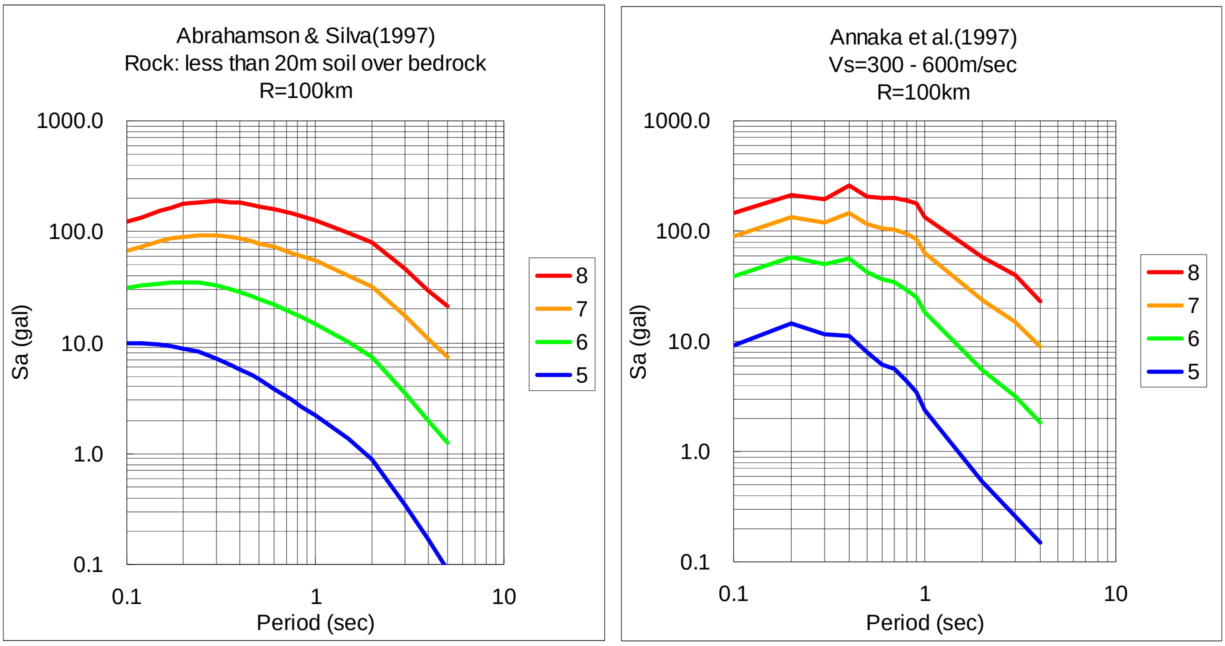
(a) Crustal (b) Subduction

Figure 12.4.3 Adopted Attenuation Formula for Acceleration



(a) Crustal (b) Subduction

Figure 12.4.4 Adopted Attenuation Formula for Velocity



(a) Crustal (b) Subduction

Figure 12.4.5 Adopted Attenuation Formula for Acceleration Response Spectrum

12.4.3 Subsurface Amplification Analysis Method

The amplification of subsurface soil over seismic engineering bedrock was estimated by 1D response analysis. The number of numerical ground model that was used for response analysis is 157, which was explained in section 12.3. The layer of s-wave velocity 700 m/sec is treated as seismic engineering bedrock.

The nonlinear effect of soil was considered in the analysis because several scenario earthquakes were expected to generate large seismic motion in Metro Manila. However, there is no dynamic soil laboratory test to evaluate the nonlinear dynamic property of soil in Philippines. The advance of the study in this field in Philippines is called for. In this study, the existing nonlinear dynamic property of soil, which was used in the seismic microzoning study of Tokyo Metropolitan Area, Japan, was used considering the similarity of soil, S-wave velocity and N-value.

The scenario earthquakes include both the near earthquake, such as VFS earthquake, and distant earthquake, such as Manila Trench and Luzon Trench earthquake. The predominant period of earthquake motion by the near earthquake is supposed to be shorter than that by the distant earthquake. To take this difference into the analysis, two type of seismic wave were used for the analysis. For near earthquake (Models 01, 02, 03, 05, 07, 08, 09, 10, 11, 12, 15, 16, 17, 18), the wave observed at Kobe JMA station and at bedrock of Port Island station on 1995 Kobe earthquake (M=7.2) were used for the analysis and the average amplification of these two analyses was used. These two waves were observed within several kilometers from the fault. For distant earthquake (Models 04, 06, 13, 14), the wave observed at PHV on Dec. 1999 Earthquake (M=6.8) and the wave observed at Akita on 1983 Nihonkai-Chubu Earthquake (M=7.8) were used for the analysis and the average amplification of these two analyses was used. These earthquakes occurred at the subduction zone and observed at 100 to 200 km away from focal region.

To examine the validity of the analysis method described above, the calculated earthquake motion by the analysis method was compared to the observed one by MM-STAR. The observed PGA at each station of MM-STAR except SKB, which locates out of Metro Manila was divided by the PGA at PHV station. This value is regarded as the amplification factor by the subsurface soil because PHV locates on engineering seismic bedrock. The circle in Figure 12.4.6 shows the average of amplification factor for several earthquakes on X-axis and the horizontal bar shows the differences by each earthquake. The circle also shows the amplification factor by the analysis on Y-axis and the vertical bar shows the difference by the input 4 waves mentioned above. The average amplification factor by the response analysis consists with the average amplification factor based on the strong motion observation. However, this validation was done only in the range of linear behavior of soil because almost all strong motion records show less than 10 gal (0.01g).

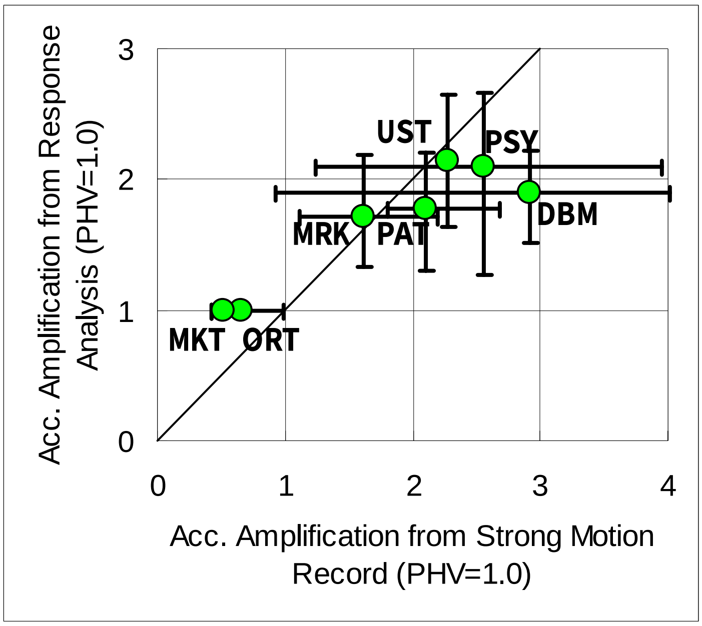


Figure 12.4.6 Amplification from Strong Motion and Response Analysis