3.2.2. Ground Model

The soil is classified into 4 types, i.e. clayey soil, sandy soil, sand and clay (mixture or alternation), and gravelly soil. Each soil type is divided into 4 groups according to its N values, as shown in Figure 3.2.2. Based on the depth of the seismic bedrock and the soil condition above the bedrock, the ground is classified into 41 types as shown in Figure 3.2.3. The distribution of each soil type is shown in Figure 3.2.4.

Model No.	Depth (GL-m)																									
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	110	120	130	140	150	
1	C1	C1	C1	C1	C1	C1	CS3	CS3	CS3	CS3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C4
2	C1	C1	C2	C2	C2	C2	CS3	CS3	CS3	CS3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C4
3	C1	C1	CS1	CS1	CS1	CS1	CS3	CS3	CS3	CS3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C4
4	C1	C1	C2	C2	C2	C2	C2	C2	C2	C2	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C4
5	C1	C1	C1	C1	C1	C1	C2	C2	C2	C2	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3	C4
6	C2	C2	C2	C2	C2	C2	CS3	CS3	CS3	CS3	CS3	CS3	CS3	CS3	CS3	CS3	C2	C2	C2	C2	C2	C2	C2	C2	C2	C4
7	C1	C1	C2	C2	C2	C2	C2	C2	C2	C2	C3	C3	C3	C3	C4											
8	C1	C1	C2	C2	C2	C2	CS2	CS2	CS2	CS2	CS3	CS3	CS3	CS3	C4											
9	C2	C2	CS2	CS2	CS2	CS2	C3	C3	C3	C3	C2	C2	C2	C2	C4											
10	C1	C1	CS2	CS2	CS2	CS2	C3	C3	C3	C3	C2	C2	C2	C2	C4											
11	C2	C2	C3	C3	C3	C3	CS3	CS3	CS3	CS3	C2	C2	C2	C2	C4											
12	C2	C2	C2	C2	C2	C2	C2	C2	C2	C2	C4															
13	C2	C2	C2	C2	C2	C2	CS3	CS3	CS3	CS3	CS4															
14	C2	C2	C2	C2	C2	C2	CS2	CS2	CS2	CS2	CS4															
15	CS1	CS1	C2	C2	C2	C2	CS3	CS3	CS3	CS3	CS4															
16	C2	C2	C2	C2	C2	C2	CS3	CS3	CS3	CS3	CS4															
17	C2	C2	CS1	CS1	CS1	CS1	CS3	CS3	CS3	CS3	CS4															
18	G2	G2	CS1	CS1	CS1	CS1	G3	G3	G3	G3	G4															
19	C3	C3	C3	C3	C3	C3	G3	G3	G3	G3	G4															
20	C2	C2	C3	C3	C3	C3	CS3	CS3	CS3	CS3	CS4															
21	CS2	CS2	CS3	CS3	CS3	CS3	CS3	CS3	CS3	CS3	CS4															
22	C1	C1	C1	C1	C1	C1	C4																			
23	C2	C2	C2	C2	C2	C2	C4																			
24	CS2	CS2	CS2	CS2	CS2	CS2	CS4																			
25	C1	C1	CS2	CS2	CS2	CS2	CS4																			
26	CS1	CS1	CS3	CS3	CS3	CS3	CS4																			
27	G2	G2	G4	G4	G3	G3	G4																			
28	C2	C2	G3	G3	G3	G4																				
29	S3	S3	S3	S3	S3	G4																				
30	S3	S3	G3	G3	G3	G4																				
31	G3	G3	G3	G3	G3	G4																				
32	G2	G2	G3	G3	G4																					
33	G3	G3	G3	G3	G4																					
34	G3	G3	G3	G4																						
35	S3	S3	S3	G4																						
36	CS3	CS3	CS3	G4																						
37	C1	C1	C1	G4																						
38	C2	C2	C2	G4																						
39	G3	G3	G4																							
40	Pre-Miocene																									
41	Rock																									

Soil Name, Symbol and N Value

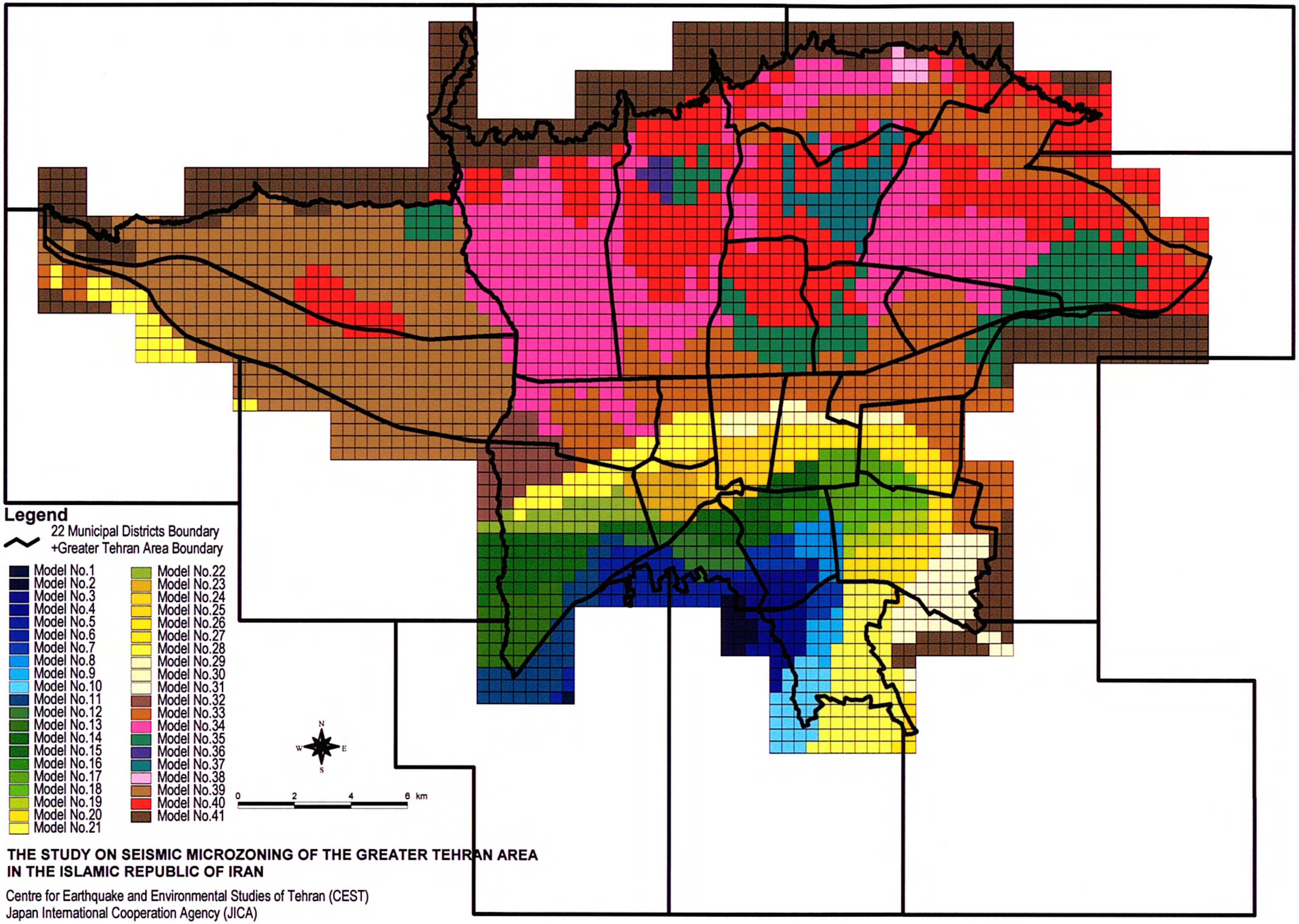
Clay	C1	C2	C3	C4
Average N Value	15	35	75	100
Sand and Clay	**CS1**	**CS2**	**CS3**	**CS4**
Average N Value	15	35	75	100
Sand	**S1**	**S2**	**S3**	**S4**
Average N Value	15	35	75	100
Gravel	**G1**	**G2**	**G3**	**G4**
Average N Value	15	35	75	100

G4 Engineering seismic bedrock and its soil type

Figure 3.2.3 Model Geological Log

Figure 3.2.4

Model Ground for Seismic Analysis



THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

Centre for Earthquake and Environmental Studies of Tehran (CEST)
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3.2.3. Soil Properties of the Ground Model

(1) Shear Wave Velocity

Figure 3.2.5 shows the relation between the N value of the standard penetration test and the shear wave velocity Vs. The N value is calculated as the equivalent to a 30cm penetration value Neq. Data for Neq values above 200 are excluded. Some scattered and linear relationship between the Neq and Vs values on a logarithmic scale is observed against the full range of Neq values. This relation is not dependent on soil type. The two parameters are correlated using the least square method and the following equation is defined as an input parameter for earthquake analysis.

$Vs=161N_{eq}^{0.277}$ (m/sec) ($N_{eq}<200$)

Relational expressions for Vs and the N value used in the Japanese Design Manual for Bridge are also shown in the figure. The equations are as follows:

Clayey Soil $Vs=102N^{0.29}$ (N<50)

Sandy Soil $Vs=81N^{0.33}$ (N<50)

Compared to the shear wave velocity of Japanese soil, that of the Study Area shows a bigger value. In Japan, the relationships are defined using mainly soft to medium soft soil, of which the N value is less than 50. On the other hand, the soil in Tehran area is much more overconsolidated, N value of which is up to 200.

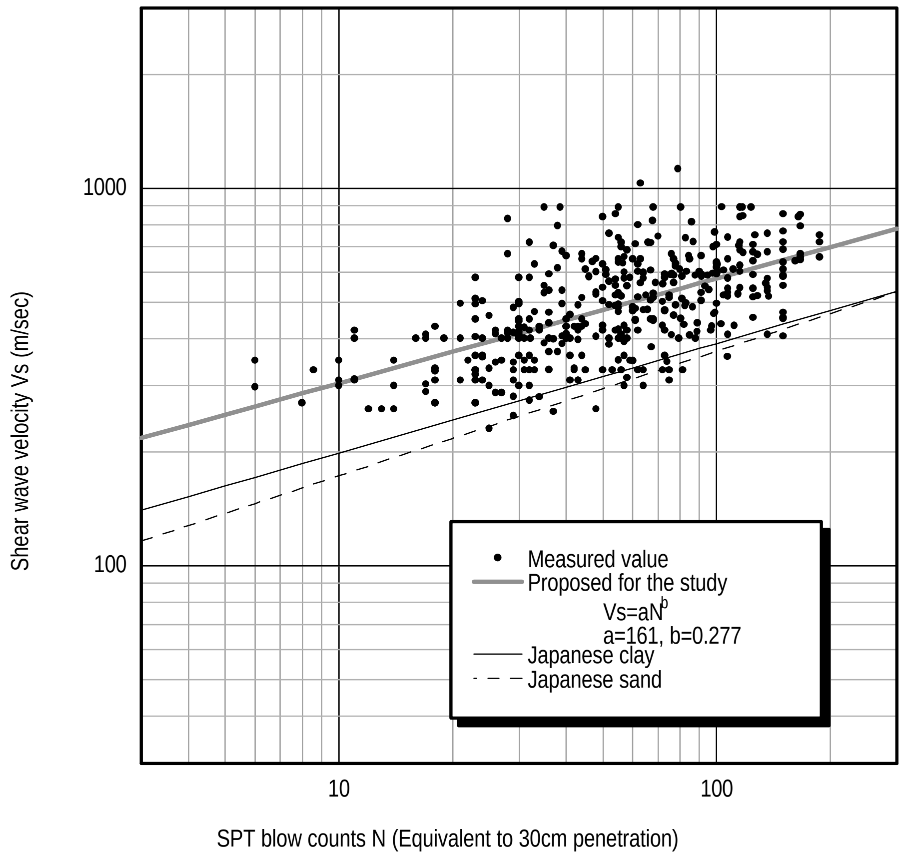


Figure 3.2.5 Relation between SPT Blow Counts and Shear Wave Velocity of Ground

(Result of geological site investigation of the Study)

3.3. Earthquake Scenario

3.3.1. Scenario Earthquake

(1) Concept

Applying a scenario earthquake can be very useful to a city for emergency response and seismic disaster prevention planning. Therefore, the earthquake that would severely damage Tehran should be assumed.

(2) Approach

There are a number of faults mapped in the Tehran area. Many of them are classified as Quaternary active faults. Recurrence interval and the latest events have not been investigated in detail, and it is difficult to determine when the scenario earthquake will occur using the deterministic approach. Therefore, a hypothesis based on a worst damage scenario is considered as a basic and indispensable approach to assess the earthquake resistance of the city.

(3) Historical earthquake

Fortunately, Tehran has not suffered any severe damage due to an earthquake in over 150 years. Some earthquakes that might have affected the Tehran area were picked out from the historical earthquake catalogue. These are shown in Figure 3.3.1. The largest observed PGA was 412 gal due to the earthquake in 855. The second largest acceleration occurred in 1830, and the third in 958. Berberian et al. (1999) suggested that the events in the year 958, 1830 and 1665 occurred on segments of the Mosha Fault. It has also been suggested that the event in 855 may have occurred at the South/North Ray Fault. Seismic activity at the North Tehran Fault is vague. Berberian et al. (1983) associated the events in 958 and 1177 to the North Tehran Fault.

(4) Proposed Scenario Earthquake

In conclusion, the following four models for scenario earthquakes were considered.

- Ray Fault Model
- North Tehran Fault (NTF) Model
- Mosha Fault Model
- Floating Model

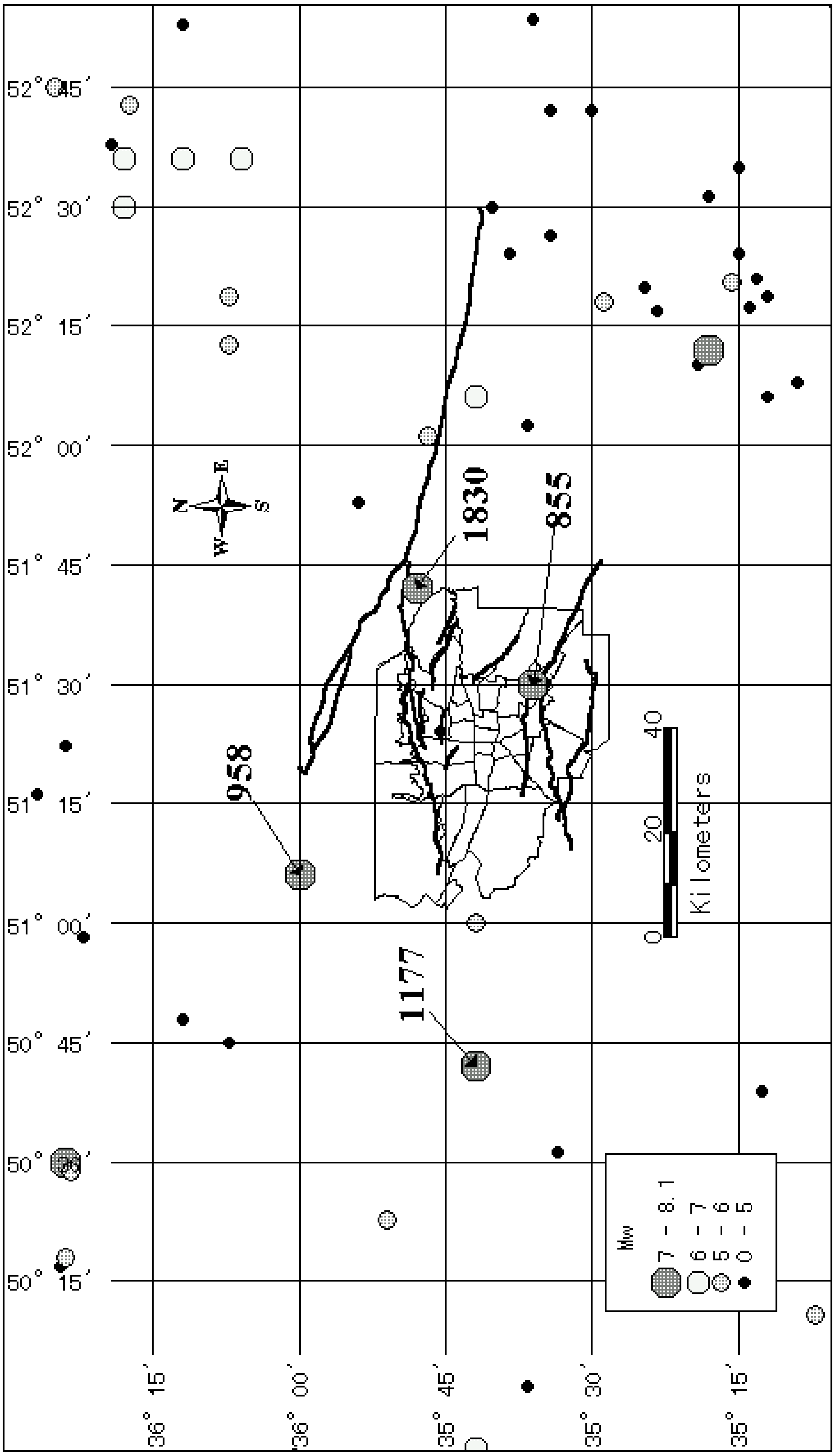


Figure 3.3.1 Historical Earthquake Distribution around Tehran

3.3.2. Earthquake Fault Model

The projection of fault model of scenario earthquakes is depicted by hatched area in Figure 3.3.2. Details of fault model parameter are summarised in Table 3.3.1.

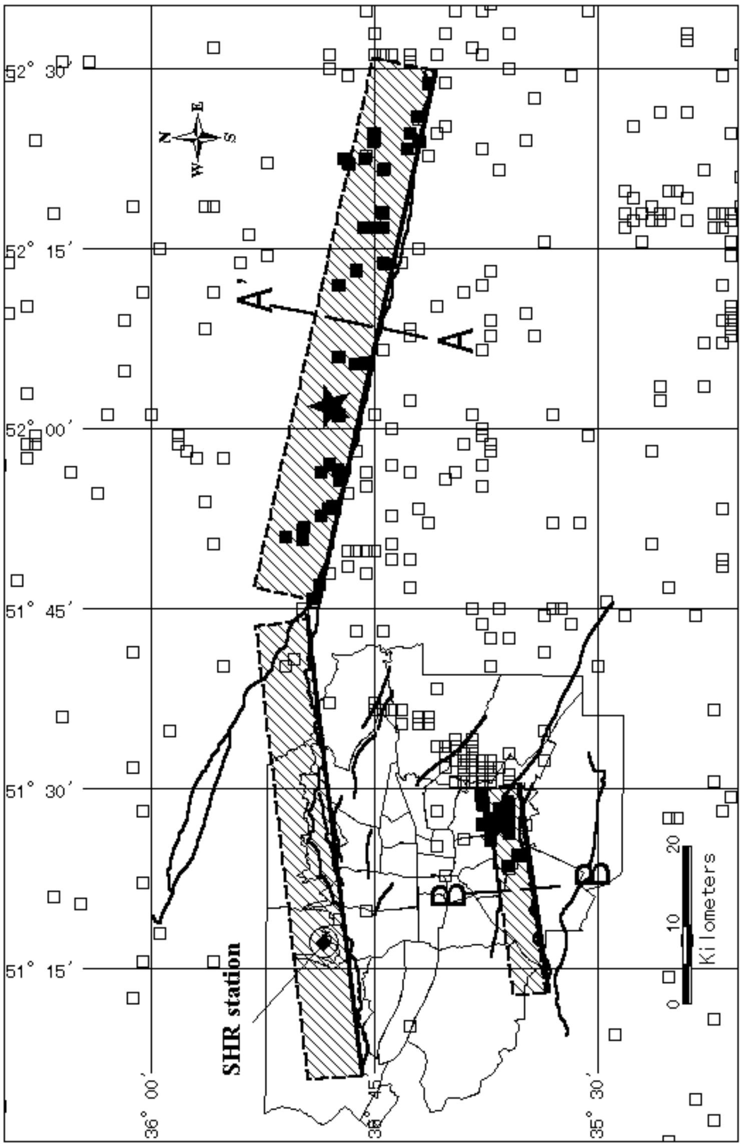


Figure 3.3.2 Distribution of Scenario Earthquakes

Table 3.3.1 Fault Model Parameters

		Ray Fault Model	NTF (North Tehran Fault) Model	Mosha Fault Model	Floating Model
Length (km)		26	58	68	13
Width (km)		16	27	30	10
Moment Magnitude (Mw)		6.7	7.2	7.2	6.4
Origin	N (degree)	35.8255	35.6815	35.5876	-
	E (degree)	51.7392	52.4955	51.5061	-
Azimuth (Clockwise from North) (degree)		263	263	283	263
Dip angle (degree)		75	75	75	75
Depth of upper limb (km)		5	0	0	5

3.4. Methods for the Analysis

3.4.1. Synthesis of the Seismic Waveform at the Engineering Bed Rock

Observed earthquake motion can be modelled by the convolution of slip distribution in time and space domain at the fault surface and the response of materials in propagation pass for unit slip (Green' s function). The idea of empirical Green' s function is to use an observed small event as Green' s function instead of a theoretical one to calculate a large event. The advantage of empirical Green' s function is that a small event contains propagation-path effects and local site effects if the propagation-path of the small even is the same as that of a large event. Many researchers studied empirical Green' s function method. In this study, Irikura (1986) was adopted.

3.4.2. Amplification of Subsurface Ground

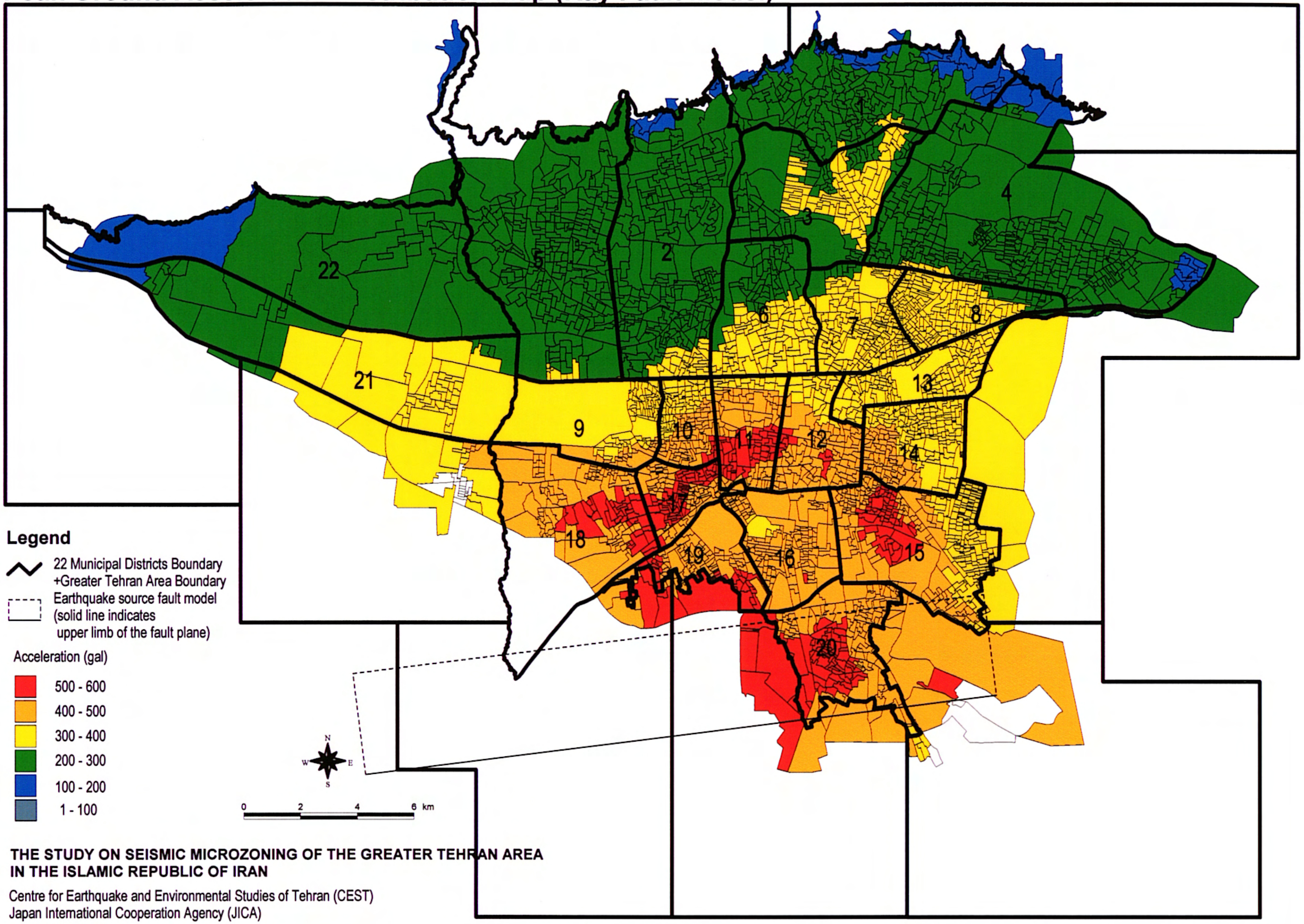
The amplification of the subsurface was analysed using a one-dimensional response analysis. Based on the ground classification and soil properties, a ground model for response analysis was made.

3.5. Calculation of Earthquake Ground Motion

The waveform at the ground surface is calculated from the waveform at engineering bedrock and subsurface amplification function.

Figure 3.5.1

Peak Ground Acceleration Distribution Map (Ray Fault Model)



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