Chapter 6.
Urban Conditions for Earthquake Disaster Management Consideration

Chapter 6. Urban Conditions for Earthquake Disaster Management Consideration

6.1. Data Related to Natural Conditions

6.1.1. Topography

(1) Topographic Map

a. Maps

Large-scale topographic data was necessary for the Study as basic data for the GIS database. This data was also necessary for the evaluation of slope stability.

1:1,000 scale paper maps and their corresponding 3D digital CAD files were created in Microstation format and then aggregated to 1:5,000 scale maps (472 sheets) by the Directorate of Photogrammetry, IMM in 1995 and 1997. Features are categorised into 62 levels. These series of maps cover the entire IMM jurisdiction area except Adalar District.

Another series of maps compiled in 1987 covers the Adalar District. This series consists of 1:1,000 scale paper maps and their corresponding digital CAD files.

İSKİ's 1:50,000 maps, are used for areas outside of those covered in the IMM maps.

Table 6.1.1 shows the topographic maps used by the Study Team. Their area covered by these maps is shown in Figure 6.1.1.

Table 6.1.1 Topographic Maps Used by the Study Team

Data	Source	Scale	Covering Area	Area by Sheet (km^2)	Year	Number of Sheet	Total Area (km^2)
Topographic Map	Directorate of Photogrammetry, IMM	1,5:000	IMM Except Adalar	5.8	1995 – 1997	472	2,754
Topographic Map	Directorate of Photogrammetry, IMM	1:1,000	Adalar	0.37	1987	69	25
			Bakırköy port		1995	1	0.37
			Same as 1:5,000			3,899	1,422
					1997	2,926	1,066
Topographic Map "İçmesuyu ve Atıksu Hatları, Barajlar, İçmesuyu ve Atıksu Havzaları	Directorate of Mapping Works, İSKİ	1:50,000	All the Study Area	1,538	2000	5	7,608

Source: JICA Study Team

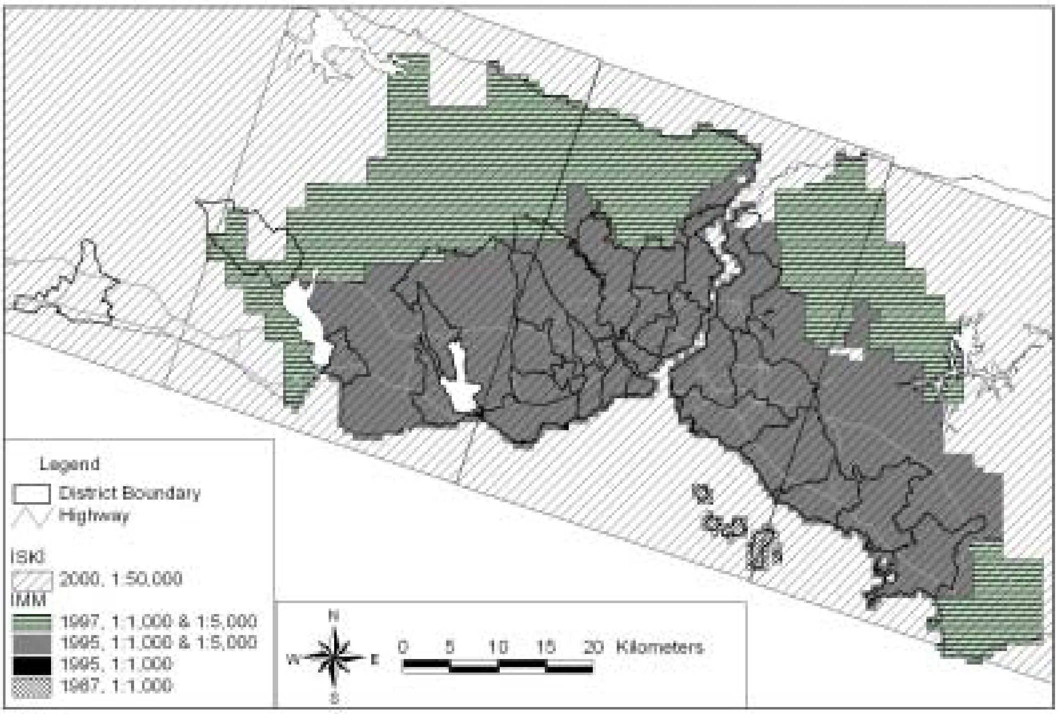

Figure 6.1.1 Area Covered by Topographic Maps Used by the Study Team

Source: IMM (1987, 1995 and 1997), ISKI (2000)

b. Datum

The geodetic datum used in İstanbul is "European 1950" (ED50).

c. Projection

Three projections, as shown in Table 6.1.2, are commonly used in İstanbul.

"UTM, 3 Derece" is normally used for IMM's large-scale data, such as 1:1,000 and 1:5,000 scale maps, because the central meridian (30° East) is near İstanbul and the distortion is smaller than "UTM, 6 Derece." The western parts of the Çatalca Municipality and Silivri Municipality areas are sometimes separated into the next western zone, of which the central meridian is 27° East.

The Study Team developed a GIS database on "UTM, 3 Derece."

Table 6.1.2 Projections Used in Istanbul

Name	Factors	
UTM, 3 Derece	Alias Name	"UTM, 3 degree" "UTM, İstanbul"
	Projection	Universal Transverse Mercator
	Central Meridian	30° E for the area between 28.5° E and 31.5° E (IMM, Büyükçekmece and eastern part of Çatalca), 27° E for the area between 25.5° E and 28.5° E (Silivri and western part of Çatalca)
	Reference Latitude	0
	Scale Factor	1.0000
	False Easting	500,000
	False Northing	0
UTM, 6 Derece	Alias Name	"UTM, Zone 35"
	Projection	Universal Transverse Mercator
	Central Meridian	27° E
	Reference Latitude	0
	Scale Factor	0.9996
	False Easting	500,000
	False Northing	0
Cadastral	Projection	Unknown
	Distance Units	Meter

d. DTM and Slope Gradient Data

For the DTM and slope analysis, the Study Team used IMM's 1:1,000 digital maps as base data. Elevation data of the 1:1,000 maps were processed to generate 50 m grid DTM data and 50m grid slope gradient data. An elevation map was compiled and is shown in Figure 6.1.3. A slope gradient distribution map was compiled and is shown in. Figure 6.1.4

(2) Topography of the Study Area

One of the most obvious features of the topography of Istanbul is the Bosphorus Strait, which separates Istanbul as part of both Asia and Europe. Both sides of the strait show steep mountainous topography while the other area of Istanbul is on relatively gentle hill topography. Another distinctive topographic feature is that no major plane is spread out in Istanbul. Generally, most of the rivers in Istanbul flow in a north-south direction on the European side and a NE-SW direction on the Asian side. These directions are perpendicular to the Marmara Sea shoreline. Locations of dividing ridges of the Marmara Sea in the south and the Black Sea in the north are different on both the European and Asian sides. It is near Black Sea on the European side and near the Marmara Sea on the Asian side. This difference causes a difference of the shape of the urbanised area on both sides. On the European side, the urbanised area goes inland while it remains seaside on the Asian side. The general topography of Istanbul is, thus, characterised by a gentle to medium configuration.

Elevation of the Study Area varies from 0 to 500m and elevation of most of the urbanised area is less than 150m. Elevation of the valley is almost less than 50m and the river gradient is relatively low. The gradient of the ground surface is varies from 0 to approximately 100% and the gradient of most of the urbanised area is less than 10%. In the northeast of the European side and the north of the Asian side, the ground surface gradient is over 10%. In the west of the European side and most of Asian side, the ground surface gradient of both sides of the valleys is 10 to 15%. In the northeast of the European side and the north of Asian side, the ground surface gradient of both sides of valleys exceeds 30%.

(3) Slope Gradient Condition

Figure 6.1.2 and Table 6.1.3 show the slope gradient distribution summarised by district and the calculated slope gradients. Districts Adalar, Beykoz, and Sariyer show the steepest slope prevailing areas. The slope area ratio of gradient less than 10% makes up 30% of these districts.

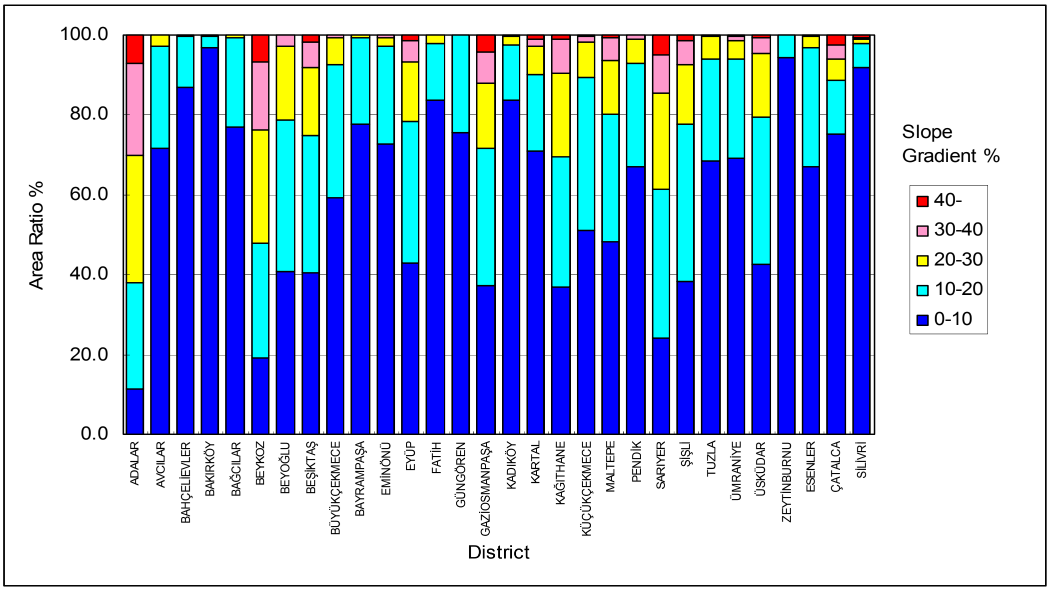

Figure 6.1.2 Slope Gradient Distribution for Each District

Note: Compiled by the JICA Study Team

Table 6.1.3 Area Ratio of Slope Gradient in Each District

District	Slope Gradient % Category				
	0-10	10-20	20-30	30-40	40 and over
Adalar	11.2	26.6	32.1	23.0	7.1
Avcilar	71.6	25.5	2.7	0.2	0.0
Bahçelievler	86.7	13.1	0.2	0.0	0.0
Bakirköy	96.7	3.2	0.2	0.0	0.0
Bağcilar	76.8	22.5	0.6	0.1	0.0
Beykoz	19.1	28.7	28.3	17.1	6.7
Beyoğlu	40.9	38.0	18.4	2.6	0.1
Beşiktaş	40.5	34.4	17.0	6.2	1.8
Büyükçekmece	59.2	33.5	6.7	0.6	0.0
Bayrampaşa	77.7	21.7	0.5	0.0	0.0
Eminönü	72.8	24.3	2.3	0.5	0.0
Eyüp	42.9	35.5	14.8	5.4	1.4
Fatih	83.7	14.3	1.9	0.1	0.0
Güngören	75.6	24.3	0.1	0.0	0.0
Gaziosmanpaşa	37.1	34.4	16.3	7.9	4.2
Kadiköy	83.7	13.8	2.2	0.3	0.0
Kartal	70.9	19.1	7.2	1.8	0.9
Kağithane	37.0	32.7	20.7	8.5	1.2
Küçükçekmece	51.1	38.1	8.9	1.6	0.4
Maltepe	48.3	31.9	13.4	5.5	0.9
Pendik	67.1	25.7	6.1	0.9	0.2
Sariyer	24.2	37.3	24.0	9.8	4.8
Şişli	38.4	39.2	15.1	5.8	1.6
Tuzla	68.4	25.4	5.7	0.4	0.0
Ümraniye	69.1	24.7	4.6	1.2	0.4
Üsküdar	42.5	37.0	15.8	4.0	0.7
Zeytinburnu	94.4	5.4	0.1	0.0	0.0
Esenler	67.0	29.7	2.9	0.2	0.1
Çatalca	75.2	13.4	5.4	3.6	2.4
Silivri	91.7	6.3	1.0	0.4	0.7

Note: Compiled by the JICA Study Team

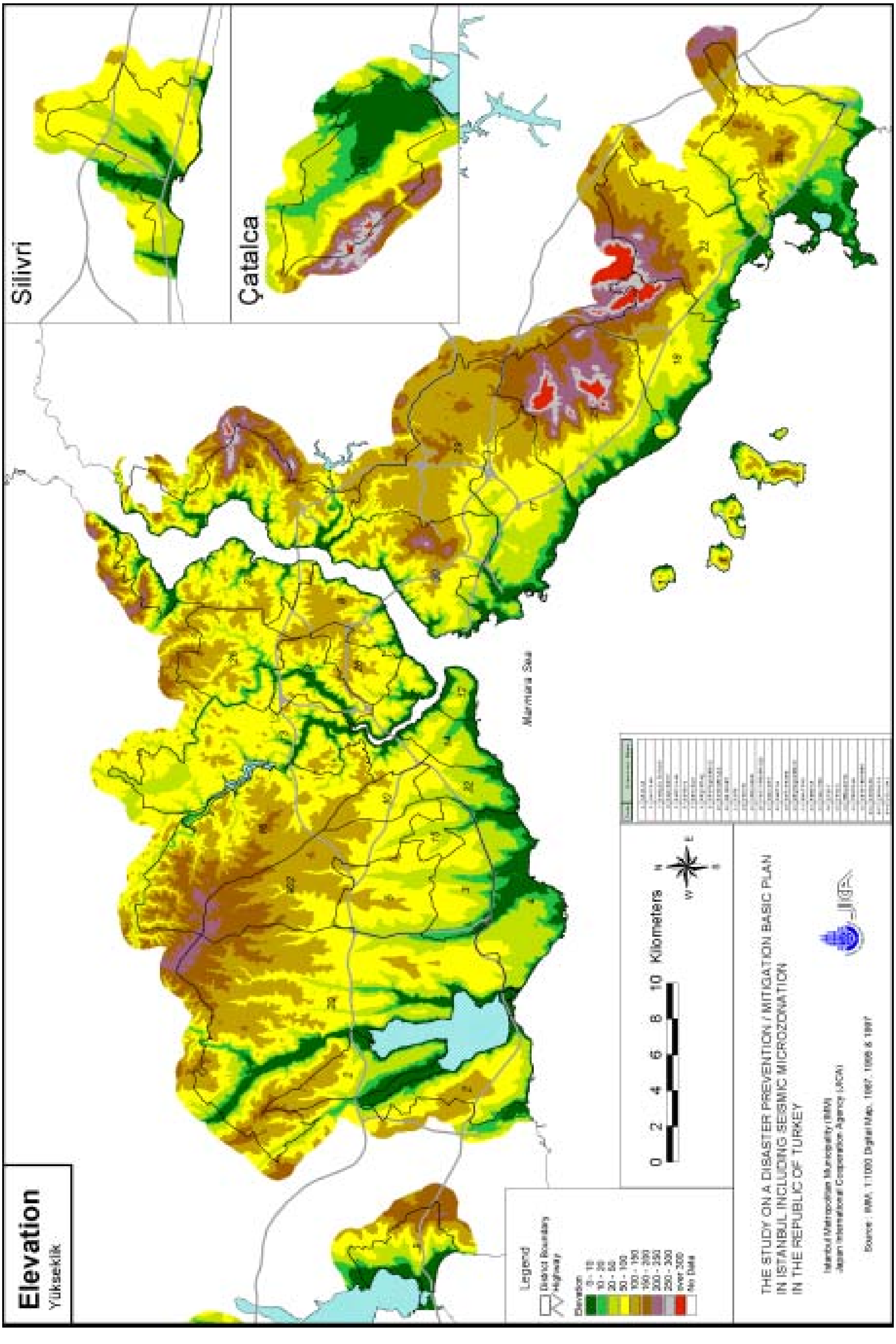

Figure 6.1.3 Elevation Map

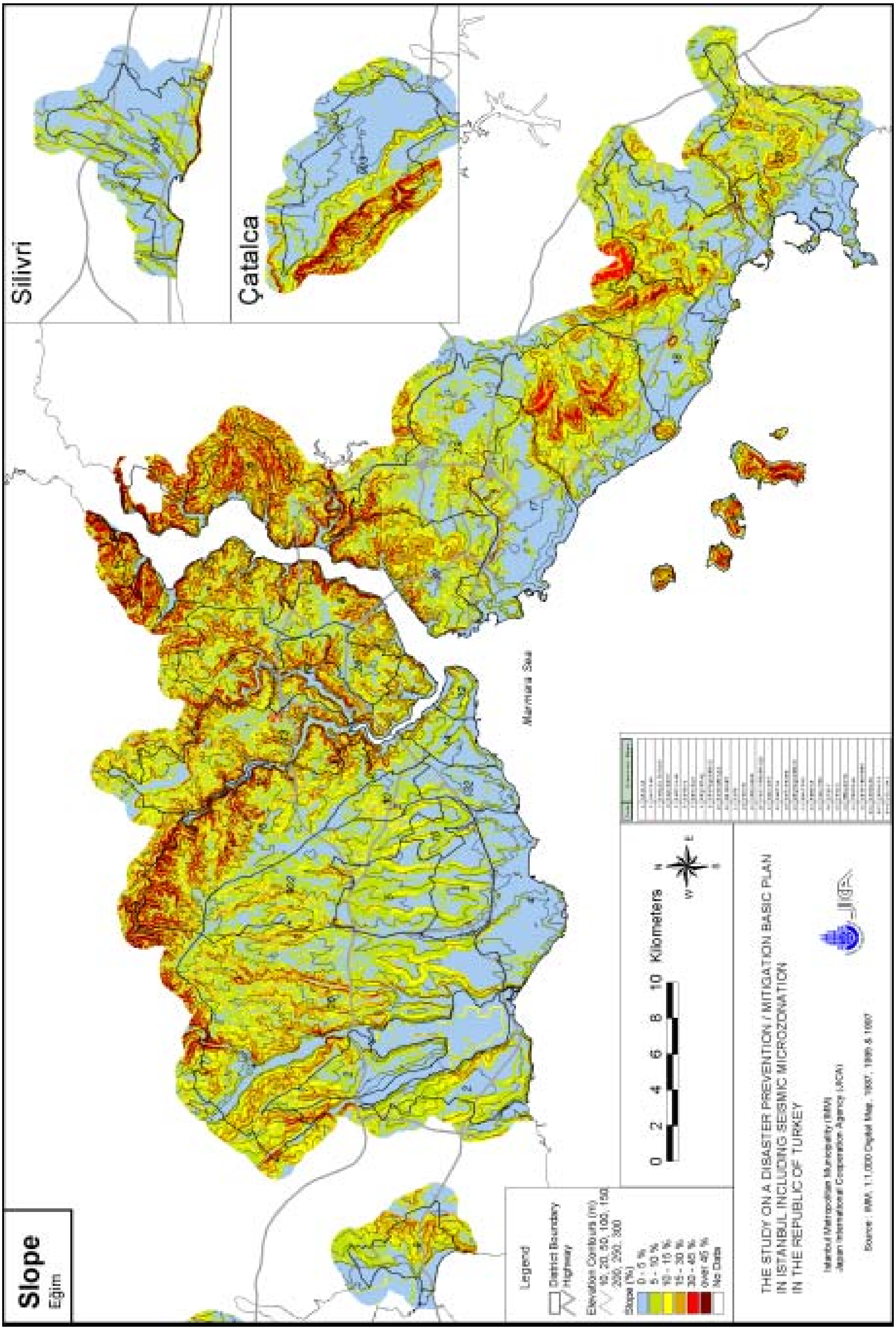

Figure 6.1.4 Slope Gradient Distribution Map

6.1.2. Geological Data

(1) Geological Map

The 1:50,000-scaled geological map of the Study Area was compiled by Prof. Dr. F.Y.Oktay and Dr. R.H.Eren in 1994. This map was later digitized by the City Planning Dept. of the Counterpart Agency in 1995. The reduced scale version of this map is illustrated in Figure 6.1.5. The Counterpart Agency later significantly improved this basic map by conducting supplemental geological surveys and by adding available borehole, geophysical exploration, and observation data. These maps were later reduced to a 1:5,000 scale in digital form. The JICA Study Team compiled these maps into GIS format, as shown in Figure 6.1.6. For the additional three districts, digital 1:25,000 scaled geological maps of M.T.A. (General Directorate of Mineral Research and Exploration Institute) were used. These maps were transformed into GIS format by the JICA team (Figure 6.1.7). Geological cross-sections were compiled through the mutual collaboration of the Study Team and the Counterpart Agency. These cross-sections are based on 1:5,000 geological maps and prepared for each 1,000 m grid system. Details are explained in Chapter 7 and cross-sections are attached in the Supporting Report.

(2) General Geology

The stratigraphical column of Istanbul and the Kocaeli peninsulas have been divided into lithostratigraphical units: namely, groups and formations (Oktay ve Eren, 1994). The oldest rock units in Istanbul and its neighborhood were formed in the Paleozoic era According to this classification, the oldest units of the Paleozoic era are named the “Istanbul” group. The Triassic sequence is named the “Gebze” group, the Upper Cretaceous-Lower Eocene age sediments are named the “Darıca” group, the Eocene age sediments are named the “Çatalca” group, the Oligocene aged basin fills are named the “Terkos” group, and the Upper Miocene age Paratethian sequence are named the“Halkalı” group, accordingly. Young sediments are not divided into lithostratigraphical units. Among these, only the Late Quaternary basin fills are named (“Kuşdili Formation”). The stratigraphical classification is summarised in Table 6.1.4.

Table 6.1.4 Stratigraphical Classification in Istanbul

AGE	GROUP	FORMATION	THICKNESS (m)	SYMBOL	EXPLANATIONS
Current		Dolgu	30	Yd	Waste, Antique rubble and made grounds
Quaternary-Current		Alüvyon	15	Qa	Loose pebbles-sand-clays
Late Quaternary (Holosen)		Kuşdili	70	Kşf	Clay with sand and pebble lenses
Quaternary		Alüvyon Yelpazeleri	30	Q (Suf)	Loose boulders-pebbles-sands-clays
Upper Miocene	Halkalı	Bakırköy	40	Baf	Mactra-bearing limestone-marl-clay intercalation
Upper Miocene		Güngören	175	Gnf	Grey coloured clays with sand lenses
Upper Miocene		Çukurçeşme	50	Çf	Loose boulders-pebbles-sands-clays
Middle Miocene		Çamurluhan	100	Çmf	Clays-marl alternation with lensoidal conglomerate-pebbly sandstone-sandstone and limestone intercalations
Oligocene	Terkos	Karaburun/Gürpınar	900	Kbf/Güf	Conglomerates-limestones, marls, coal seams, tuffs / Tuffites sandstones, clays
Middle Eocene-Oligocene	Çatalca	Ceylan	50	Cef	Mudstone with marl and clastic limestone intercalations
		Soğucak	200	Sf	Reefal and fore-reef carbonates
		Hamamdere	600	Haf	Limestone-marl alternation
Upper Cretase-Lower Eocene	Darıca	Şemsettin/Sarıyer	300	Şf/Saf	Micrite-marl-mudstone-tuffite alternation / Andesite, basalts and agglomerate intercalation
		Kutluca	56	Ktf	Limestones with Rudists
		Hereke Pudingi	75	Hpf	Micrites-Dolomitic limestones with dolomite intercalations
Triassic	Gebze	Tepecik	140	Tef	Halobian shales
		Hereke	800	Hf	Dolomitic limestone, limestones
		Erikli	40	Ef	Yellowish coloured sandy limestones and sandstones
		Kapaklı	1000	Kaf	Red continental clasties
		Kocatarla		Kof	Basalts
Lower Carboniferous	İstanbul	Trakya	1500	Trf	Grey shales with turbidite sandstone and conglomerates
Lower Carboniferous		Baltalimanı	30	Blf	Radiolarian black cherts
Middle-Upper Devonian		Tuzla	100	Tf	Nodular limestones
Lower-Middle Devonian		Kartal	750	Kf	Shales with calciturbidite intercalations
Silürian-Lower Devonian		Dolayoba	500	Df	Limestones (biyolitite, biosparite, biomicrite)
Middle Ordovisiyen		Gözdağ	700	Gf	Laminated grey shales with quartz arenite lenses
Middle Ordovisiyen		Aydos	310	Af	Quartz arenites with quartz conglomerate lenses
Lower Ordovisian		Kurtköy	150	Kuf	Lensoidal conglomerates-sandstones-shales

References for Section 6.1.2:

Çağlayan M. A., Yurtsever A., 1998, Maden Tetkik Vearama Genel Müdürlüğü Türkiye Jeoloji Haritaları No. 20, 21, 22, 23, Jeoloji Etütleri Dairesi Ankara

Oktay F. Y., Eren R. H., 1994, Geology of Istanbul Megapolitan Area, Istanbul Greater City Municipality, Directorate of Reconstruction, Department of City Planning

Jeologi / Jeoteknik Etüd Raporu – İstanbul Avrupa Yakası Güneyi 1/5000 Ölçekli İmar Planalarına Esas, 2001, T. C. İstanbul Büyükşehir Belediyesi, Planlama ve İmar Daire Başkanlığı, Zemin ve Deprem İnceleme Müdürlüğü

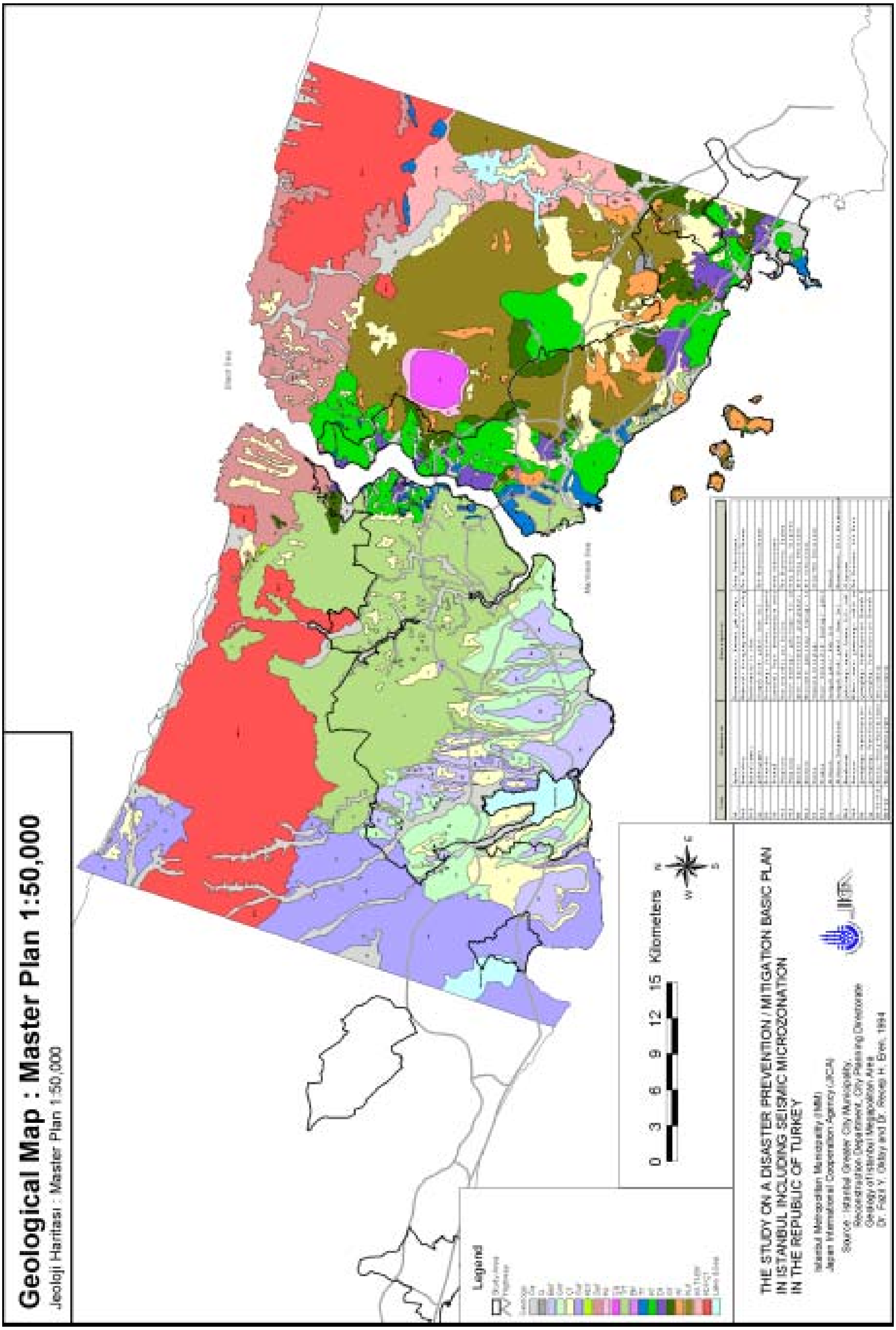

Figure 6.1.5 Geological Map (IMM Master Plan, 1:50,000)

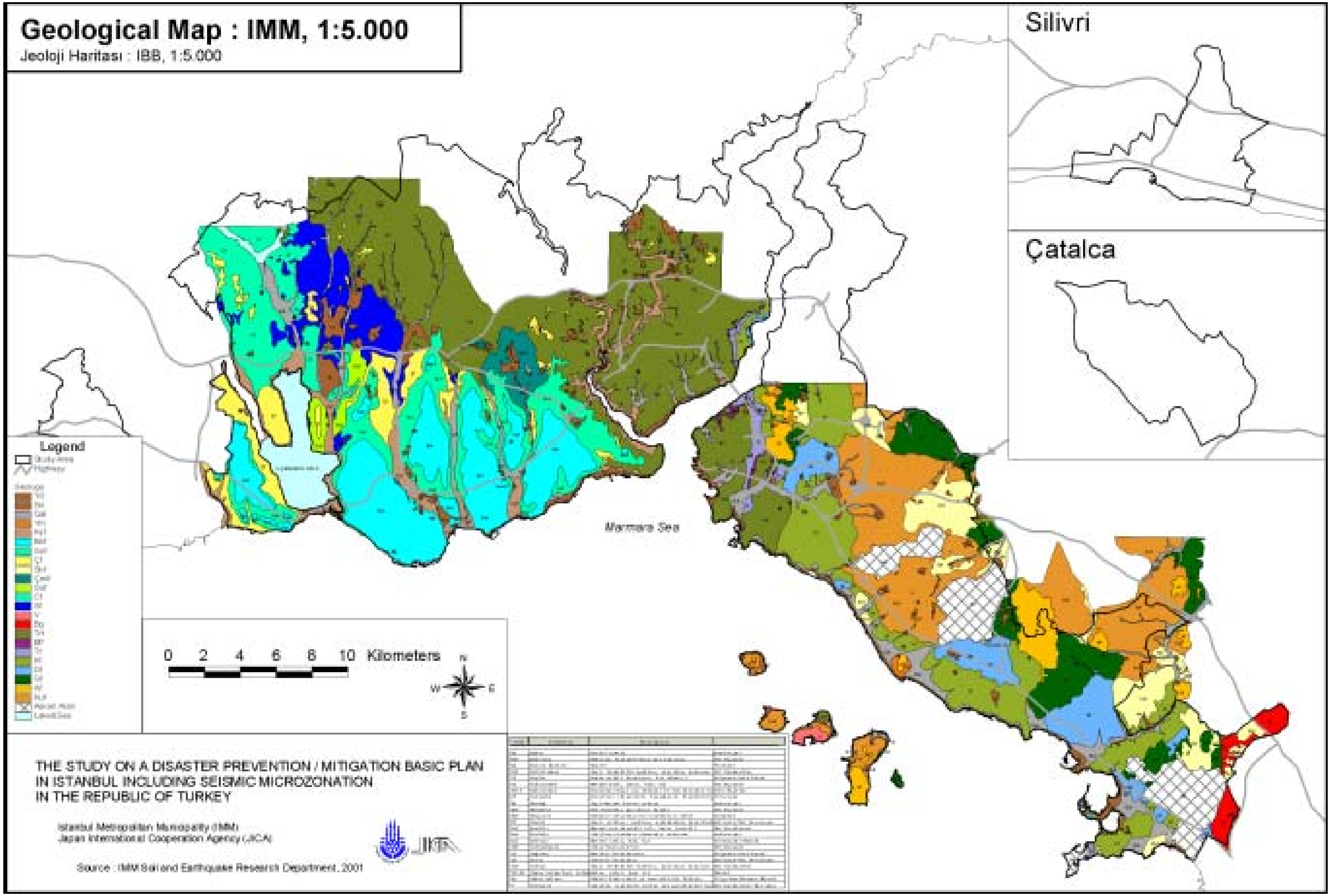

Figure 6.1.6 Geological Map (IMM, 1:5,000)

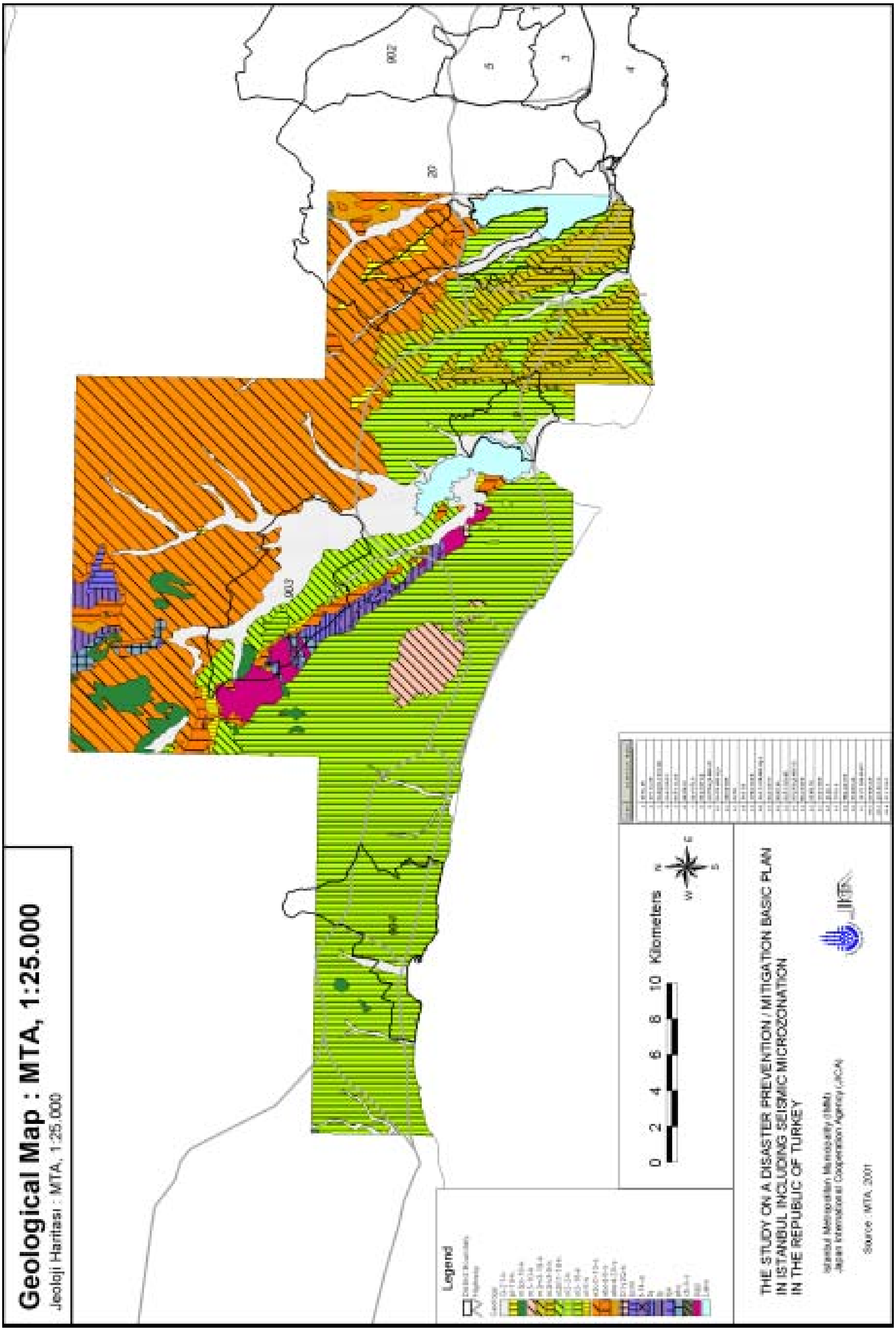

Figure 6.1.7 Geological Map (MTA, 1:25,000)

6.1.3. Geotechnical Data

(1) Soil Classification Map

Recently, the Counterpart Agency compiled 1:5,000 scale soil classification maps of Istanbul. The final report on the European side is already published and the report on the Asian side is now under final compilation. These maps are directly applied in building construction control and city planning. The 1:5,000 topographical and geological maps are used for mapping and the ground is categorised as shown in Table 6.1.5. Categorisation of the European side and the Asian side is different in detail, while the overall categorisation is almost similar. Surface geology and ground surface gradients are basic parameters for the detailed categorisation.

Table 6.1.5 Ground Classification of Istanbul City

Area	Category	Usage Limitations
European Side	YU	Suitable for settlement area
	AJ	Detailed geotechnical study required
	SA	Not suitable for settlement
	ÖA	Construction prohibited without precaution
Asian side	YU	Suitable for any kind of construction
	YÖUA	Stability study required
	AJE	Detailed geotechnical study required
	YUOA	Planning can be done for special purpose construction

Source: Department of Soil and Earthquake Research, Istanbul Metropolitan Municipality 2001

(2) Boring, Soil, and Geophysical Data

The Counterpart Agency has their archive for existing soil investigations and geophysical survey reports. All boring logs, laboratory tests, and survey results were collected and analyzed in the Study. Table 6.1.6 shows the summary of the data.

Table 6.1.6 Quantity of Available Boring Logs Data

	Number of Boreholes	Total Length (m)
European Side	1063	2832.86
Asian Side	703	27780.45
JICA Survey Borings	48	10596.46
Total	1814	41209.77

Source: JICA Study Team

Additional borings and geophysical surveys were carried out by the Study Team mainly to grasp shallow and deep Vs structures throughout the Istanbul area, especially on the European side where thick Tertiary formations prevail.

A suspension PS logging method developed in Japan was employed for the Study. It was carried out in boreholes and could obtain Vs at 1 m depths. Horizontal array microtremor measurements were also taken at the same locations of the PS logging to obtain deep Vs structures, up to the depth of approximately 500 m.

Simple borings and soil samplings were conducted in areas with prevailing alluvium deposits for the evaluation of liquefaction potential by in-situ and laboratory soil tests. Ground water levels were also monitored for the liquefaction potential analysis.

- Boring: 48 locations, total length: 2826.85 m
- Standard penetration test: 1092 nos.
- Undisturbed and disturbed sampling: 59 nos.
- Laboratory test: 85 sets
- Natural water content, Atterberg's limit, grain size, unit weight and specific gravity
- Water standpipe installation and monitoring: 9 locations
- PS logging: 39 locations, total length 2288 m
- Horizontal array microtremor measurement: 40 locations

A location map of these existing and additional ground surveys is shown in Figure 6.1.8. A geological database was developed through the Study. All of the borehole logs were digitised and stored into this database system and handed over to the Counterpart Agency.

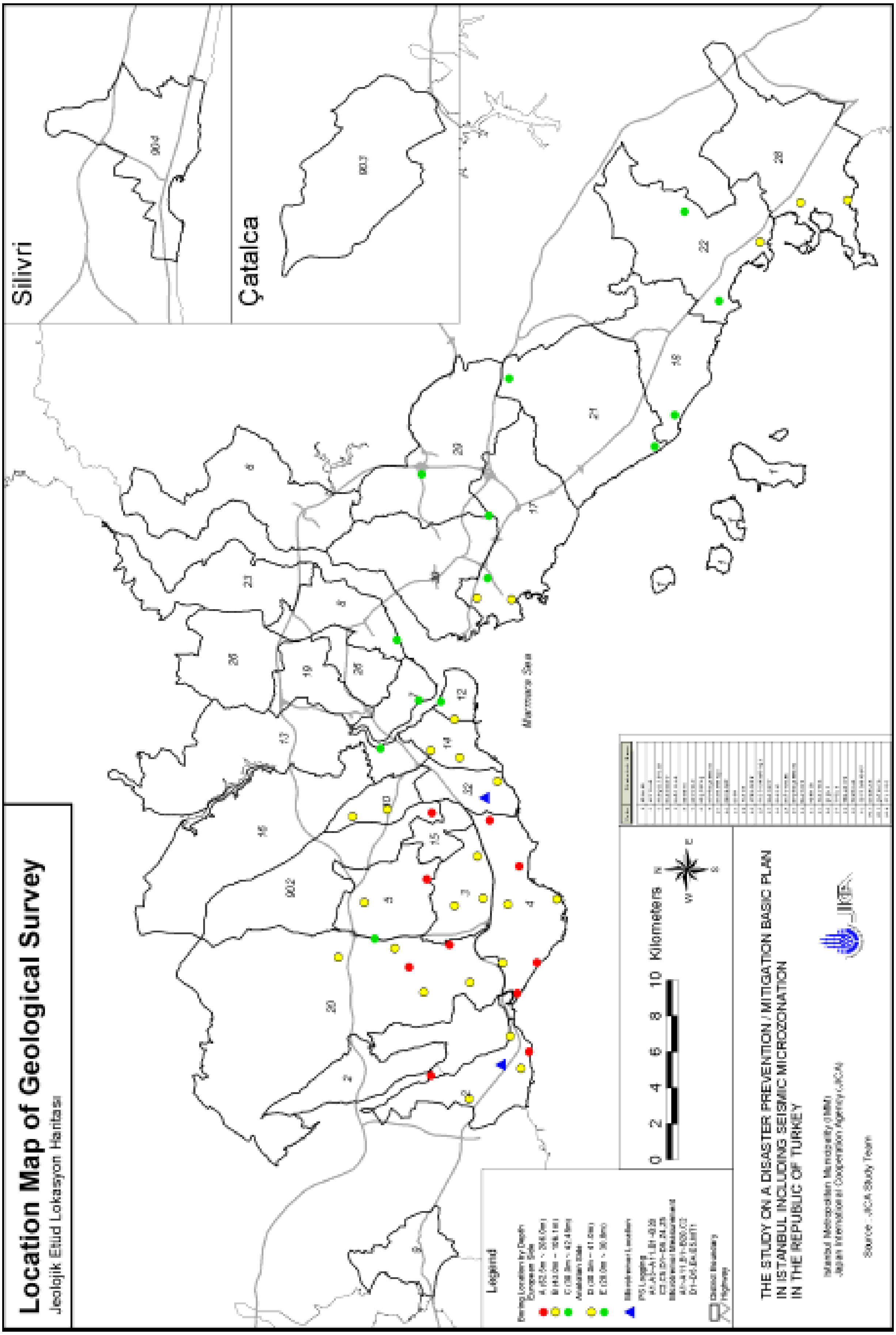

Figure 6.1.8 Location Map of Ground Survey

(3) Dynamic Property of Soil and Rock

The Department of Civil Engineering of the Istanbul Technical University is equipped with a dynamic soil test apparatus. Okur and Ansal (2001) studied undrained stress-strain behavior of low to medium plasticity clays obtained from earthquake regions in Turkey using this apparatus. Soil types are limited to normally consolidated to slightly overconsolidated clays and their proposed shear modulus and strain curves are reflected by the simple empirical equation as follows:

$$\frac{\boldsymbol{G}}{\boldsymbol{G}_{\max}} = \frac{35.09}{\dfrac{\gamma_a}{1 - 0.99\exp(-18.97 \times \boldsymbol{PI}^{-1.27})} + 34.74}$$

where **G** refers to shear modulus, $\boldsymbol{G}_{max}$ refers to shear modulus at small strain, γ_a refers toshear strain amplitude, and **PI** refers to Plasticity Index.

In discussions with Prof. and Dr. A. Ansal, it was confirmed that a study on the dynamic deformation property of soils has recently been started and published information is limited. Furthermore, dynamic deformation properties of soft rocks, which prevail in the Study Area, have not been studied in detail yet.

References for Section 6.1.3:

Avcılar Belediesi, Avcılar İlçesi 1000 Hektarlık Alanın İmara Esas Jeolojic - Jeofizik - Jeoteknik Etüt Raporu, Nisan 2001 İstanbul.

Cihat Saglam, Bağcilar Belediyesi Genel Zemin, Arastirmalari ile imar Planlarina Esas Jeolojik Jetekik Etudler ve Deprem Risk Analizlerine Dair Rapor, haziran, 2000.

Istanbul-Beyoğlu Ilcesi, Imar Plani Revizyonuna Esas, Jeolojik-Jeoteknik Etut Raporu.S

T.C. Istanbul Büyükşehır Belediesi, Planlama ve İmar DarieBaşkanlığı, Zemin ve Deprem İnceleme Müdürlüğü, İstanbul Avrupa Yakası Güneyi 1/5000 Ölçekli İmar Planlarina Esas, Jeoloji / Jeoteknik Etüd Raporu, Ocak 2001, İstanbul.

V.Okul and A. Ansal (2001): Dynamic characteristics of clays under irregular cyclic loadings, XV ICSMGE TC4 Satellite Conference on “Lessons Learned from Recent Strong Earthquakes”, 25 August 2001, pp.267-270.

6.1.4. Earthquake Related Data

(1) Tectonic Setting

The tectonic framework of the Anatolian peninsula is characterised by the collision of the Arabian and African plates with the Eurasian plate. The Arabian plate is moving northward relative to Eurasia at a rate of about 25mm/year, and the African plate is also moving northward at a rate of about 10mm/year. The Arabian plate collides into the southeast margin of Anatolian micro plate, forcing anti-clockwise rotation of the Anatolian micro plate, accommodated by right-lateral slip on the NAF (North Anatolian Fault). Recent GPS data show that the relative motion between the westward moving Anatolian micro plate and the Eurasian plate across the NAF fault is around 18 to 25 mm/year. The crustal deformation in the convergence zone is complex; many normal faults and graben exist from west of Anatolian peninsula to the Aegean Sea.

(2) Seismic Setting

Istanbul lies on an active seismic zone ranging from Java – Myanmar – Himalaya – Iran – Turkey and Greece, where many large earthquakes have occurred in the past as shown in Figure 6.1.9.

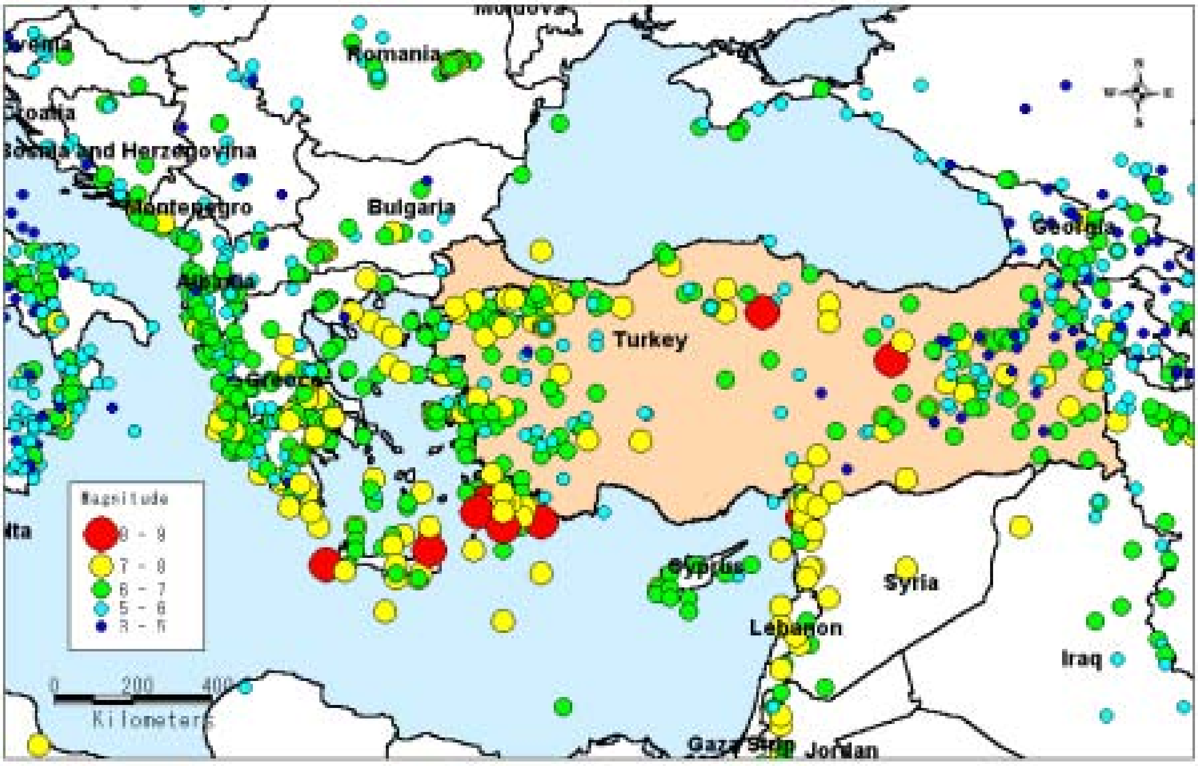

Figure 6.1.9 Hazardous Earthquakes around Turkey, Compiled from Utsu (1990)

Based on world wide historical catalogues, such as that of Utsu (1990), Istanbul (Constantinople) has suffered damage due to earthquakes repeatedly. Table 6.1.7 shows a summary of damaging earthquakes occurring in Istanbul before the 20th century. The seismic intensity in Istanbul for some earthquakes is estimated by the damage mentioned quite precisely in existing literature. Istanbul has experienced earthquakes equal or greater than intensity nine at least 14 times in historical years. This means Istanbul has suffered damage due to earthquakes every 100 years, on average.

Among the earthquakes listed above, three earthquakes caused serious damage to Istanbul as summarised below (based on Ambraseys and Finkel, 1991).

1509/ 09/ 10; M = 7.7

On this date, a destructive earthquake caused considerable damage throughout the Marmara Sea area, from Gelibolu to Bolu and from Edirne and Demitoka to Bursa. **Damage was particularly heavy in Istanbul, where many mosques and other buildings, part of the city walls, and about 1000 houses were destroyed, and 5000 people were killed**. Many houses and public buildings sustained various degrees of damage in Demitoka, Gelibolu, Iznik, and Bolu. The shock was felt within a radius of 750 km and was followed by a tsunami in the eastern part of the Marmara Sea.

1766/ 05/ 22; M = 6.5

On this date, a destructive earthquake in the eastern part of the Marmara Sea caused heavy damage, extending from Rodosto (Tekirdağ) to İzmit and to the south coast of the Sea from Mudanya to Karamürsel. Damage to buildings and tall structures were reported from as far as Gelibolu, Edirne, İzmit, and Bursa. **In Istanbul, many houses and public buildings collapsed, killing 880 people.** Part of the underground water supply system was destroyed. The Ayvad Dam located in upper Kağithane, north of Istanbul, was damaged, and in the vicinity of Sultanahmet, the roof of an underground cistern caved in. The earthquake was associated with a tsunami, which was particularly strong along the Bosphorus.

1894/ 07/ 10; M = 6.7

On this date, a destructive earthquake in the Gulf of İzmit and further to the east caused extensive damage in the area between Silivri, Istanbul, Adapazarı and Katırlı. Maximum effects were reported from the region between Heybeliada, Yalova, and Sapanca where most villages were totally destroyed with great loss of life. The shock caused the Sakarya River to flood its banks and the development of mud volcanoes. In Adapazarı, 83 people were killed and another 990 in the Sapanca area. **In Istanbul, damage was widespread and, in some places, very serious. Many public buildings, mosques, and houses were shattered and left on the verge of collapse, while most of the older constructions fell down, killing 276 and injuring 321 people.** Three of the dams for the water supply of Istanbul were badly damaged. The shock was associated with a tsunami, which, at Yeşiıköy, had a height of 1.5 m and caused the failure of submarine cables.

Table 6.1.7 Historical Earthquakes Affecting Istanbul

Year	Month	Day	Latitude	Longitude	Magnitude	Tsunami observed	Damaged area	Damage extent	Intensity at Istanbul
427			40.5	28.5			Turkey:Istanbul	severe	10
438			40.8	29	6.6		Turkey:Istanbul		9
440	10	26	41	29			Turkey:Istanbul	severe	7
441							Turkey:Istanbul	severe	
447	11	8	40.2	28	7.3	Yes	Turkey:Marmara Sea,Istanbul	severe	9
477	9	25	41	29	7.0		Turkey:Istanbul	severe	10
533	11	29	36.1	37.1			Syria:Aleppo(Halab)/Turkey:Istanbul	extreme	
541	8	16	40.7	39	6.6		Turkey:Istanbul		9
553	8	15	40.7	29.3	7.0		Turkey:Istanbul	severe	10
555	8	16	41	29	7.6	Yes	Turkey:Izmit(Nicomedia),Istanbul	some	
557	10	6	41	29			Turkey:Istanbul		
557	12	14	41.8	29	7.2	Yes	Turkey:Istanbul	severe	10
732			41	29			Turkey:Istanbul		
740	10	26	40.7	29.3	7.3	Yes	Turkey:Marmara Sea,Istanbul,Izmit	severe	
815	8		41	29			Turkey:Istanbul		
865	5	16	40.8	28	6.7		Turkey:Istanbul		9
957	10	26				Yes	Turkey:Istanbul		
975	10	26				Yes	Turkey:Istanbul,Thracian coast	some	
989	10	26	40.9	29.3	7.3		Turkey:Istanbul/Greece	some	
1037	12	18	41	29.5			Turkey:Buccellariis,Istanbul	some	
1063	9	23	40.8	28.3	7.0		Turkey:Istanbul		9
1082	12	6	40.5	28.5			Turkey:Istanbul (1083?)	some	10
1087	12	6	40.9	28.9	6.5		Turkey:Istanbul		9
1346							Turkey:Istanbul	some	
1419	5	11	41	28.6			Turkey:Istanbul	considerable	9
1490			41	29			Turkey:Istanbul		
1509	9	14	40.8	28.1	7.7	Yes	Turkey:Tsurlu,Istanbul	severe	10-11
1556	3	10	41	29			Turkey:Istanbul		
1556	5	10	41	29			Turkey:Rosanna near Istanbul	moderate	
1646	4	5				Yes	Turkey:Istanbul	some	
1659			41	29			Turkey:Istanbul		
1719	3	6					Turkey:Istanbul,Villanova	some	
1719	5	25	40.8	29.5	7.0		Turkey:Istanbul,Izmit	severe	
1754	9	2					Turkey:Istanbul,Izmit/Egypt:Cairo	some	
1766	5	22	40.8	29	6.5	Yes	Turkey:Istanbul	some	9-10
1856	2	22	41.3	36.3	6.1		Turkey:Karpan?,Korgo?,Istanbul	limited	
1894	7	10	40.6	28.7	6.7	Yes	Turkey:Geiwe,Istanbul,Adapazari	limited	

Source: Utsu(1990)

(3) Earthquake Catalogues

The following five earthquake catalogues were collected:

(a) Ayhan, E., E. Alsan, N. Sancaklı and S. B. Üçer: An Earthquake Catalogue for Turkey and Surrounding Areas, 1881 – 1980, KOERI, Boğazıçi University.

(b) Kalafat, D., G. Öz, M. Kara, Zç Öğütçü, Kç Kılıç, A. Pınar and M. Yılmazer (2000): An Earthquake Catalogue for Turkey and Surrounding Areas, 1981 – 1997, M>=4.0, KOERI, Boğazıçi University.

(c) Kalafat, D. (personal communication): Earthquake Information around Istanbul from 2100 B.C. to 1900 A.D., KOERI, Boğazıçi University.

(d) Kalafat, D. (personal communication): Earthquake Information around Istanbul from 1900 to 2000, KOERI, Boğazıçi University.

(e) Ambraseys, N.N., and C.F. Finkel, 1991, Long-term Seismicity of Istanbul and the Marmara Sea Region, Terra Nova, 3.

Catalogues (a) and (b) are catalogues for Turkey and surrounding areas with respect to earthquakes of magnitude less than 4.0. On the other hand, sources (c) and (d) are for Istanbul and the surrounding areas. For historical years (i.e., before 1900), the main source of data was “Soysal, H., S. Sipahiou., D. Kolk., Y. Altok (1981). Tkiye ve vresinin tarihsel deprem katalo. (M. 2100 - M.S. 1900), TUBAK, Project No. TBAG 341, 1981.” Catalogue data for the instrumental period (i.e., after 1900) was mainly obtained from “Catalogue of Earthquakes, UNDP/UNESCO Survey of the Seismicity of the Balkan Region, UNESCO Project Office, Skopje, 1974,” Bulletins of International Seismological Centre, 1964-1987,” and KOERI. Source (e) is a paper on long-term seismicity of the Marmara Sea, and the magnitudes and locations of historical earthquakes in this area are evaluated. Most of the work on this subject refers to this paper.

Figure 6.1.10 shows the epicentral distribution of historical earthquakes from 32 A.D. to 1897, according to Ambraseys and Finkel (1991). Many earthquakes have occurred in and around the Marmara Sea area, especially in the eastern area including İzmit Bay. Three earthquakes, namely those occurring in 1509, 1766, 1894, which seriously affected Istanbul are indicated in the figure. It is remarkable that no hazardous earthquakes occur in the northern land area than Marmara Sea.

Figure 6.1.11 is the distribution of instrumentally observed earthquakes with a magnitude over 5 from 1905 to 2001. There are three earthquakes with magnitudes greater than 7, 1912 (Ms = 7.3), 1964 (Ms = 7.0) and the 1999 İzmit Earthquake (Ms =7 .8, Mw = 7.4). There are no earthquakes with a magnitude greater than 6 in the northern half of the Marmara Sea.

Figure 6.1.12 is the distribution of all instrumentally observed earthquakes from 1905 to 2001. The high activity seen from the eastern end of the Marmara Sea to İzmit Bay can be attributed to the aftershocks of the 1999 İzmit Earthquake. Along the northern coast of the Marmara Sea, the western half shows high seismicity; however, the eastern shows low seismicity. Most of the events that occur inland have magnitudes less than 3.

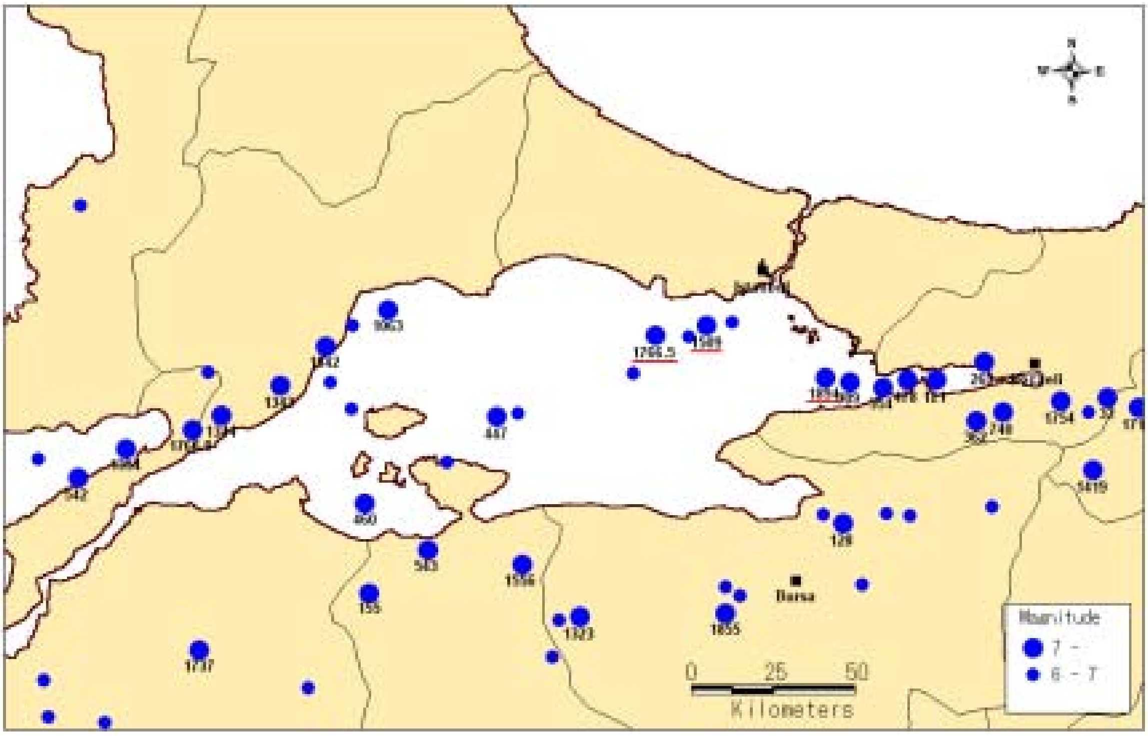

Figure 6.1.10 Epicentral Distribution of Historical Earthquakes, 32 A.D. – 1896

Source: Ambraseys and Finkel (1991)

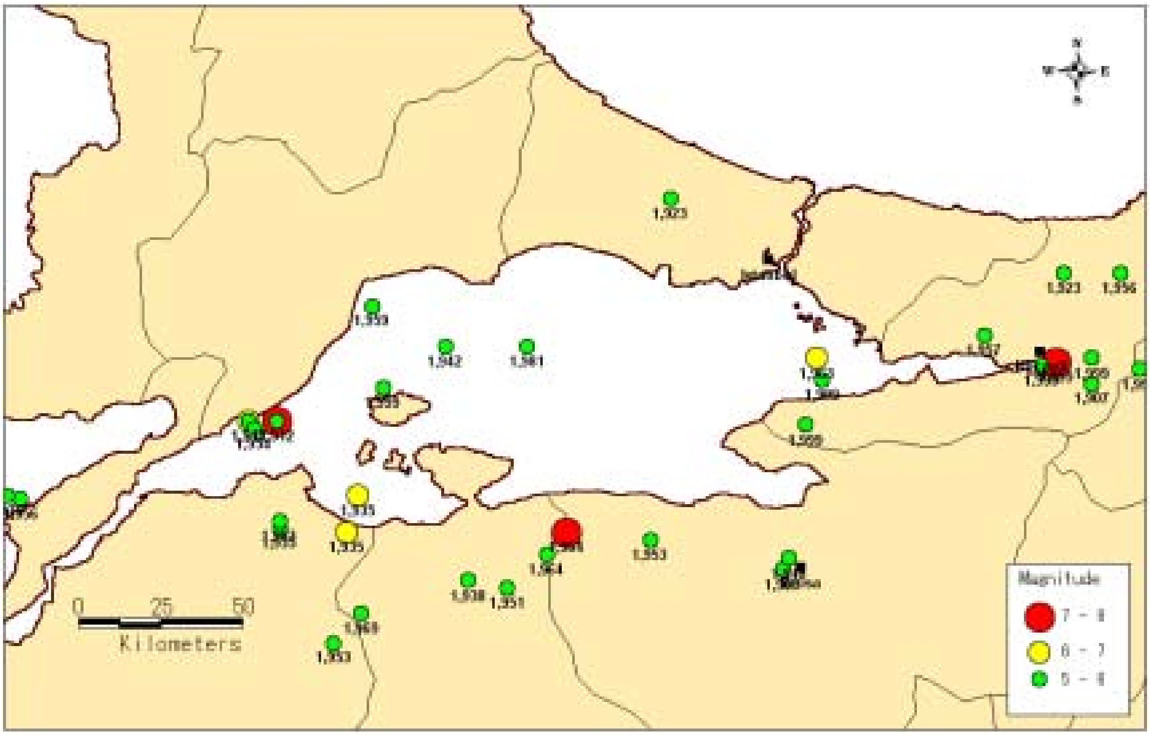

Figure 6.1.11 Epicentral Distribution of Earthquakes, M>=5, 1905 – 2001

Source: D. Kalafat

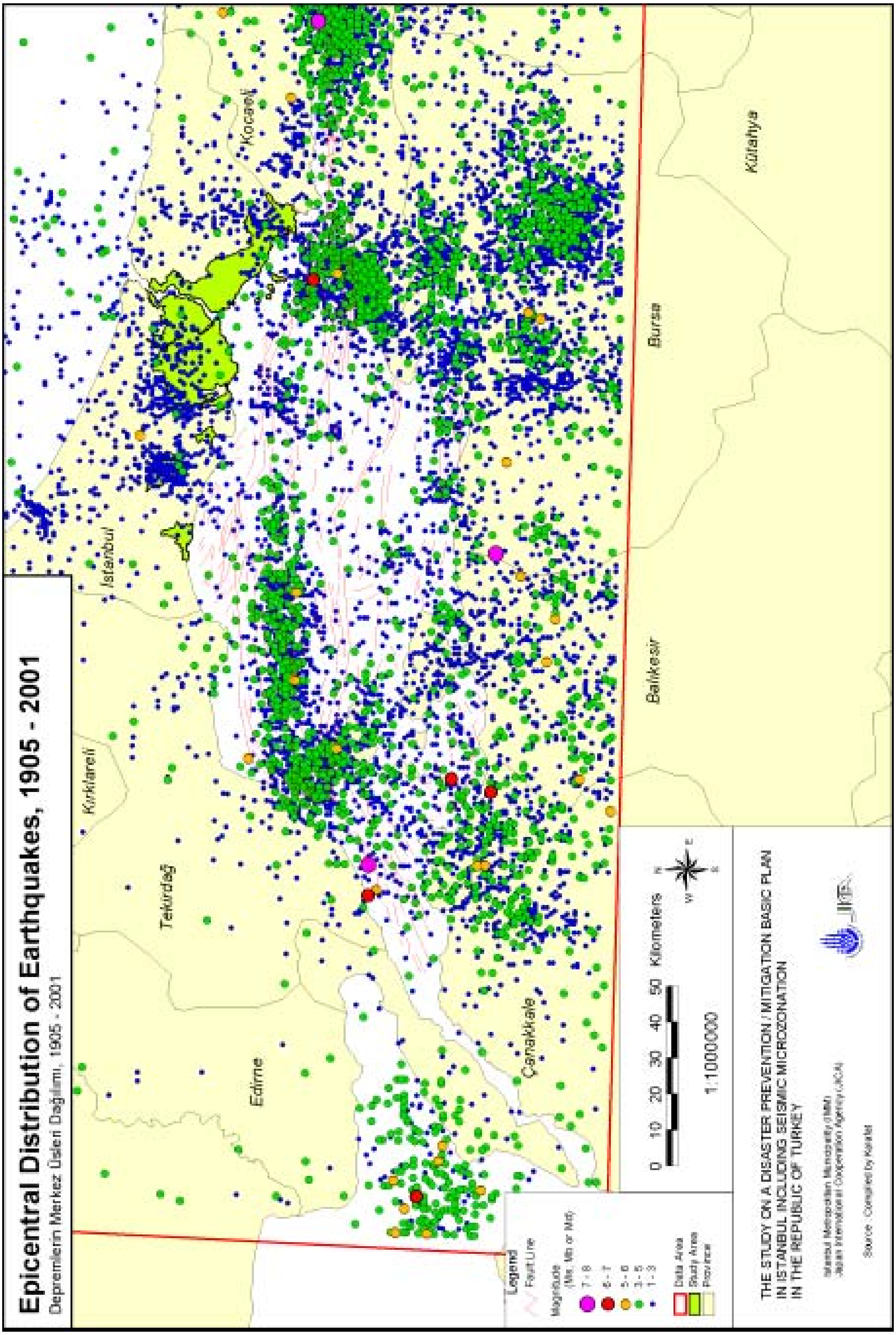

Figure 6.1.12 Epicentral Distribution of Earthquakes, 1905 – 2001

(4) Strong motion records

The following three organisations have permanent strong ground motion stations around Istanbul.

- KOERI : Kandilli Observatory and Earthquake Research Institute, Boğaziçi Universıty
- ITU : Istanbul Technical University
- ERD : Earthquake Research Department of General Directorate of Disaster Affairs

The ASCII digitally formatted strong motion wave records database was collected and contains over 1000 events from 1976. Figure 6.1.13 and Figure 6.1.14 show the strong motion stations and the distribution of events included in the waveform database, respectively. These records are used in the stage of earthquake motion analysis. Figure 6.1.15 shows the location of strong motion stations on a geological map.

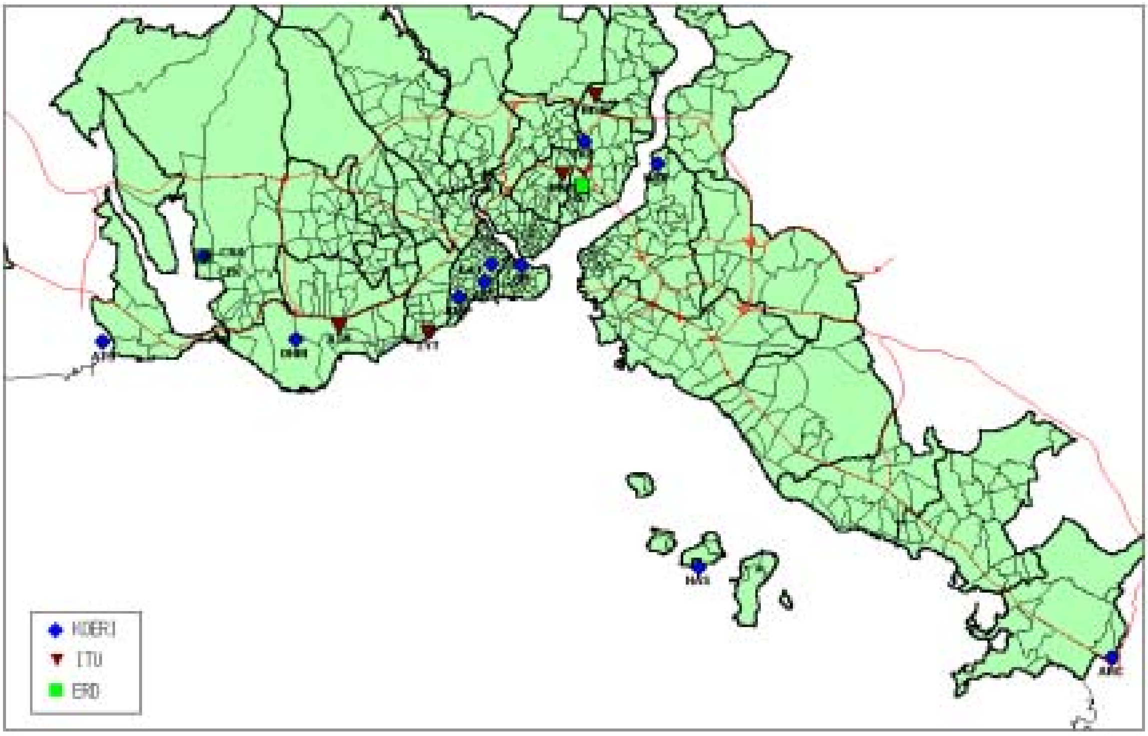

Figure 6.1.13 Location of Strong Motion Stations

Note: Compiled by the JICA Study Team

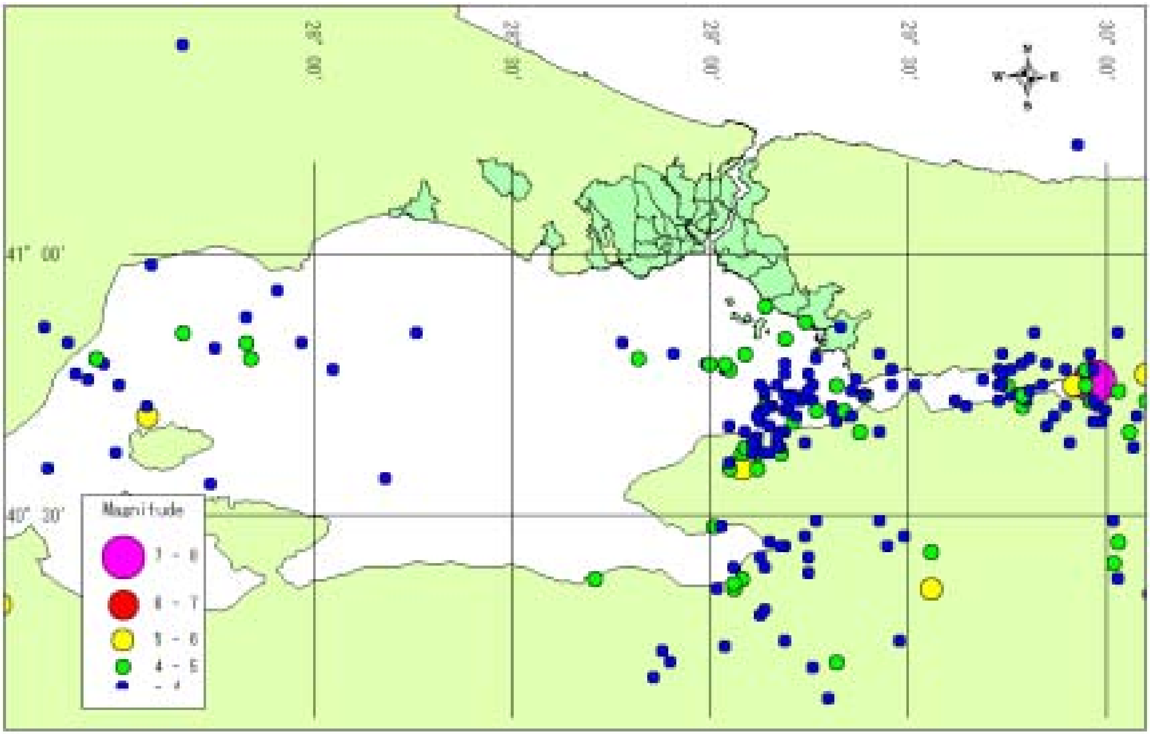

Figure 6.1.14 Distribution of Earthquakes with Strong Motion Record

Source: Özbey et al. (2001), Compiled by the JICA Study Team

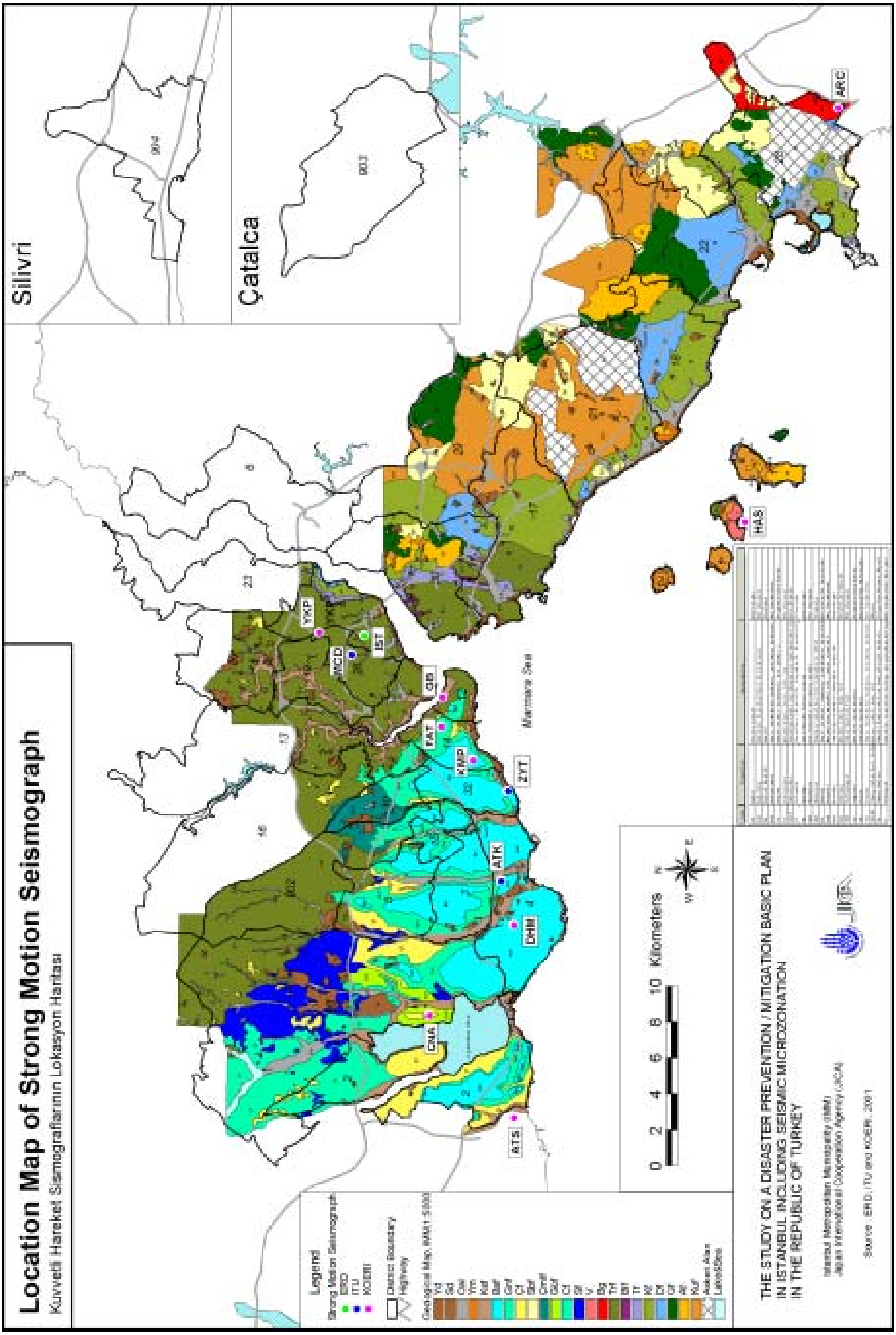

Figure 6.1.15 Location of Strong Motion Stations

References for Section 6.1.4:

Ambraseys, N.N., and C.F. Finkel, 1991, Long-term seismicity of Istanbul and the Marmara Sea region, Terra Nova, 3.

Ayhan, E., E. Alsan, N. Sancaklı and S. B. Üçer: An earthquake catalogue for Turkey and surrounding area, 1881 – 1980, KOERI, Boğazıçi University.

Kalafat, D. (personal communication): Between B.C.2100 – A.D.1900 Years Earthquake Information around Istanbul, KOERI, Boğazıçi University.

Kalafat, D. (personal communication): Between 1900 – 2000 Years Earthquake Information around Istanbul, KOERI, Boğazıçi University.

Kalafat, D., G. Öz, M. Kara, Zç Öğütçü, Kç Kılıç, A. Pınar and M. Yılmazer (2000): An earthquake catalogue for turkey and surrounding area, 1981 – 1997, M>=4.0, KOERI, Boğazıçi University.

Özbey, C., Y Fahjan, M. Erdik and E. Safak,2001, Strong Ground Motion Database for 18 August, 1999 Kocaeli and 12 November, 1999 Düzce Earthquakes, KOERI, Boğazıçi University.

Utsu, T., 1990, Table of world hazardous earthquakes.

6.1.5. Earthquake Damage Data for Risk Assessment

The information related to past earthquake damage is important in establishing the damage estimation method. It is also used to evaluate the estimated damage for scenario earthquakes. From the beginning of the Study, the Study Team gathered information on building damage in Istanbul due to the August 17, 1999 Izmit Earthquake.

Figure 6.1.16 shows the damage ratio distribution of buildings due to the Izmit Earthquake. The data source is the damaged building list compiled by the Governorship of the Istanbul Disaster Management Centre. The list contains the number of collapsed, heavily damaged, and moderately damaged buildings and the number of households in each building in each mahalle. In the Study Area, the number of collapsed buildings is 77, heavily damaged buildings are 305 and moderately damaged buildings are 1724 in total. It can be recognised from these figures that not only the well-known Avcilar area but also the Büyükçekmece and Bağcılar areas were damaged.

The building damage distribution in Avcilar is more precisely mapped. The Avcilar District Office has noted the damage grade of each damaged building and mapped the results in 1/5,000 scale. Figure 6.1.17 shows the damage ratio for each 500 m square grid. The total number of buildings, including undamaged buildings, foreach grid is determined from the 1/5,000 map of IMM.

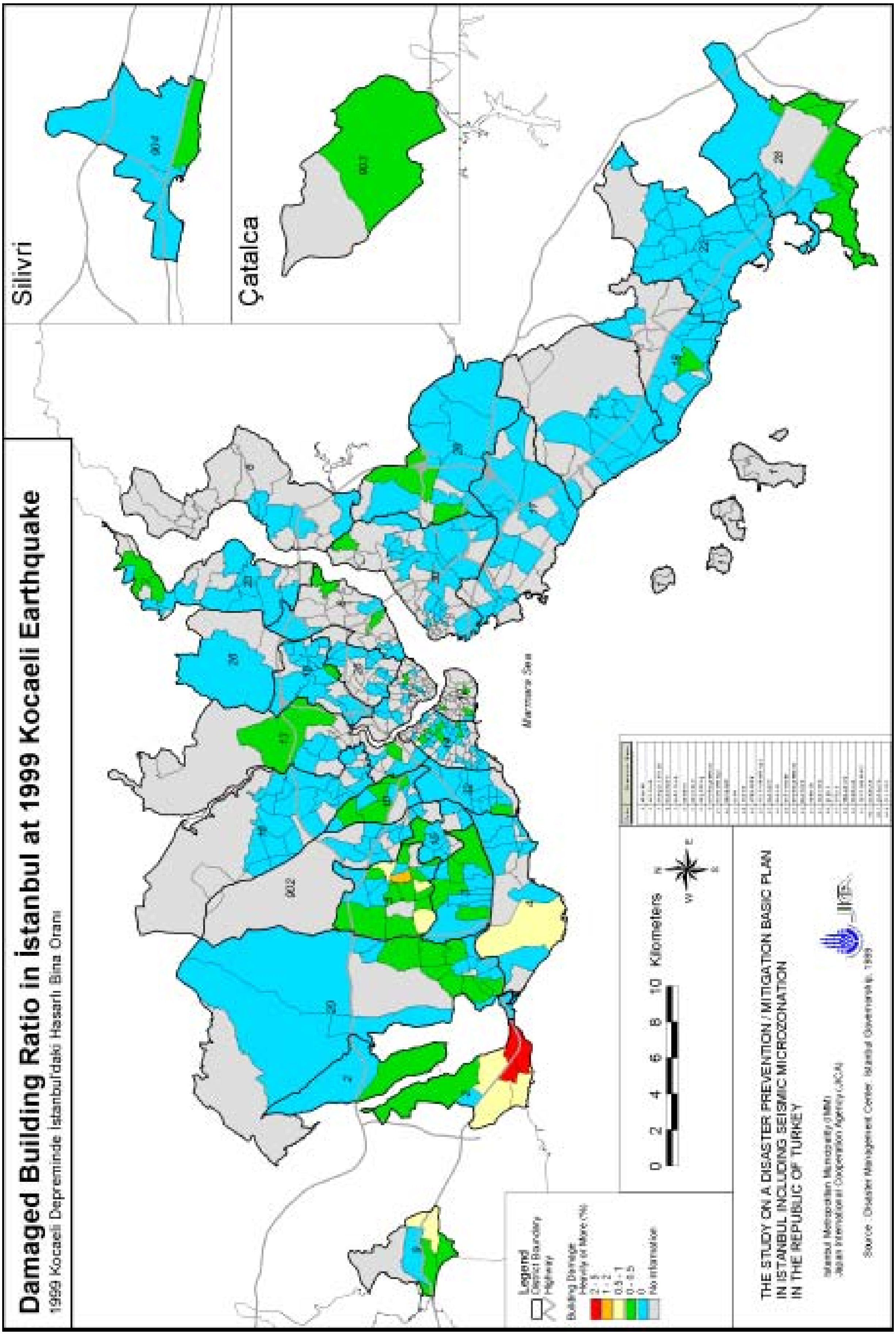

Figure 6.1.16 Building Damage Ratio by Izmit Earthquake - Heavy Damage or Greater

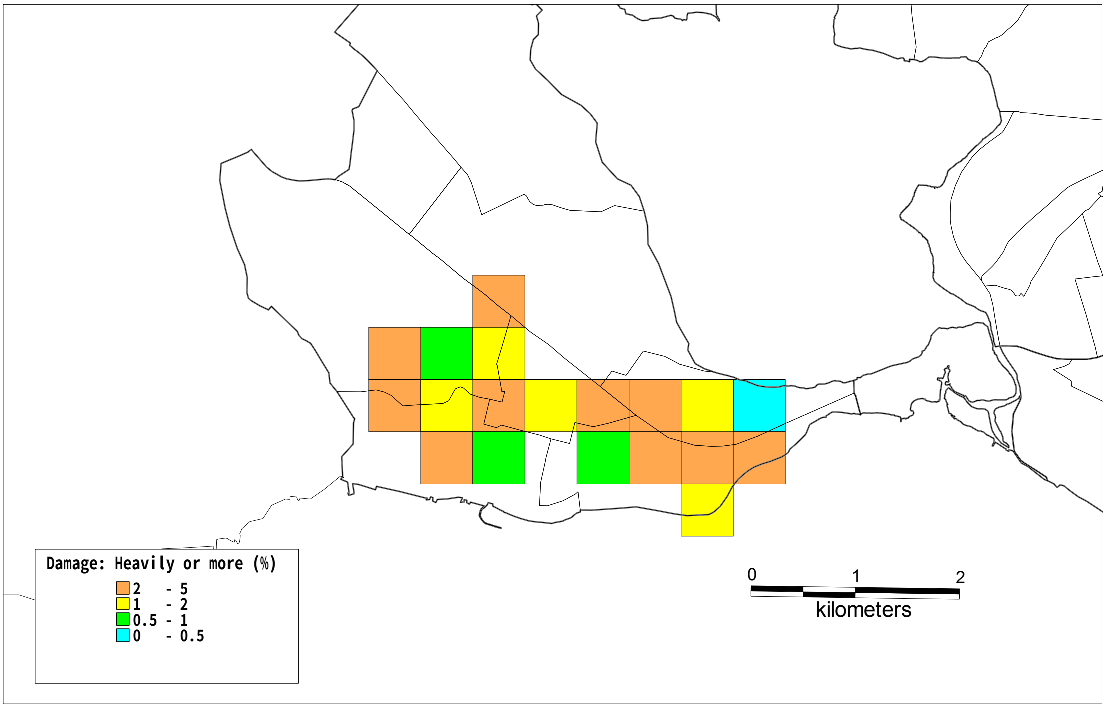

Figure 6.1.17 Building Damage Ratio by Izmit Earthquake in Avcilar – Heavy Damage or GreaterSource: Avcilar District Office, Compiled by the JICA Study Team

6.2. Data Related to Social Conditions

6.2.1. Population Data

According to the Population Census of 2000 by the State Institute of Statistics of the Prime Ministry (hereinafter referred to as SIS), the total population of Istanbul within its 27 districts and additional 3 districts (Büyükçekmece, Silivri and Çatalca) is 8,831,766 and its population density is 89 persons/hector. Population distribution by each mahalle is shown in Table 6.2.1.

Table 6.2.1 Population Distribution by District

District Code	District Name	No. of Mahalle	Area (ha)	No. of Mahalle more than		Highest Population Density		Population (Persons)	Population Density (persons / ha)	Population Density (persons / building)
				density of 500 persons / ha	density of 700 persons / ha	Density (persons/ha)	Mahalle Code			
1	ADALAR	11	1,100	0	0	80	1	17,738	16	3
2	AVCILAR	9	3,861	0	0	304	6	231,799	60	17
3	BAHÇELİEVLER	11	1,661	5	2	711	8	469,844	283	24
4	BAKIRKÖY	15	2,951	0	0	321	11	206,459	70	21
5	BAĞCILAR	22	2,194	3	0	673	16	557,588	254	15
6	BEYKOZ	19	4,156	0	0	132	5	182,864	44	6
7	BEYOĞLU	45	889	5	2	935	22	234,964	264	9
8	BEŞİKTAŞ	23	1,811	1	0	621	15	182,658	101	13
9	BÜYÜKÇEKMECE	6	1,474	N/A	N/A	N/A	N/A	34,737	24	10
10	BAYRAMPAŞA	11	958	0	0	466	4	237,874	248	12
12	EMİNÖNÜ	33	508	0	0	394	10	54,518	107	4
13	EYÜP	20	5,050	0	0	450	12	232,104	46	9
14	FATİH	69	1,045	25	3	864	56	394,042	377	12
15	GÜNGÖREN	11	718	6	2	870	7	271,874	378	26
16	GAZİOSMANPAŞA	29	5,676	2	0	548	23	667,809	118	12
17	KADIKÖY	28	4,128	0	0	365	11	660,619	160	17
18	KARTAL	20	3,135	0	0	211	19	332,090	106	14
19	KAĞITHANE	19	1,443	5	0	643	4	342,477	237	12
20	KÜÇÜKÇEKMECE	23	12,173	0	0	399	15	589,139	48	13
21	MALTEPE	21	5,530	0	0	284	2	345,662	63	14
22	PENDİK	29	4,731	0	0	192	23	372,553	79	9
23	SARIYER	23	2,774	0	0	234	9	212,996	77	7
26	ŞİŞLİ	28	3,543	4	0	616	8	271,003	76	12
28	TUZLA	11	4,998	0	0	119	8	100,609	20	7
29	ÜMRANİYE	14	4,561	0	0	298	904	443,358	97	10
30	ÜSKÜDAR	54	3,783	5	1	738	40	496,402	131	12
32	ZEYTİNBURNU	13	1,149	6	1	833	13	239,927	209	15
902	ESENLER	18	3,890	8	2	745	13	388,003	100	17
903	ÇATALCA	2	5,263	0	0	3	901	15,624	3	6
904	SİLİVRİ	5	3,828	0	0	226	902	44,432	12	5
Total		642	98,981	75	13	-	-	8,831,766	89	12

Note: N/A indicates that population data is not sub-divided by Mahalle; therefore, population data cannot be separated.

Source: Population Census 2000, SIS

Gaziosmanpaşa has the largest population counted at 667,809, and Kadiköy has the second largest population counted at 660,619. The district that has the smallest population is Çatalca, having 15,624. Within 27 districts in Istanbul, Adalar has the smallest population. The population in each mahalle is shown in Figure 6.2.1.

Population density by mahalle is also calculated, based on the Population Census 2000 compiled by SIS. Figure 6.2.2 shows population density by mahalle, and, thus, reflecting the the characteristics of congested areas. The average population density within the Study Area is 89 persons/ha. Güngören has the largest population density counted at 378 persons/ha and Fatih follows counted at 377 person/ha. On the contrary, Adalar, Büyükçekmece, Çatalca, and Silivri each have a rather small population density counted at 16 persons/ha, 24 persons/ha, 3 persons/ha and, 12 persons/ha, respectively.

As shown in Table 6.2.1, Fatih has 25 mahalles that have a population density of more than 500 persons/ha. In Table 6.2.2 a list of mahalles that have a population density of more than 500 persons/ha is provided for reference.

Table 6.2.2 List of Mahalles with Population Density Greater than 500 persons/ha

District Name	Mahalle Name	Area (ha)	Population	Population Density (persons/ha)
BAHÇELİEVLER	HÜRRİYET	57	40,385	707
	SOĞANLI	96	60,481	630
	SİYAVUŞPAŞA	81	57,692	711
	ZAFER	108	62,016	573
	ŞİRİNEVLER	108	55,563	513
BAĞCILAR	YENİGÜN	29	19,628	673
	YILDIZTEPE	61	32,596	533
	FATİH	62	35,328	570
BEYOĞLU	ÇUKUR	5	4,741	928
	FİRUZAĞA	10	5,488	526
	KADIMEHMET	14	8,056	576
	KALYONCU KULLUĞU	5	4,525	935
	YENİŞEHİR	11	5,982	567
BEŞİKTAŞ	MURADİYE	9	5,865	621
FATİH	ABDİ ÇELEBİ	10	6,710	646
	ALİ FAKİH	14	8,572	627
	ARABACI BEYAZIT	16	9,340	580
	BEYCEĞİZ	11	7,000	623
	CAMBAZİYE	16	8,109	514
	DERVİŞALİ	19	11,793	628
	HACI HAMZA	17	8,673	502
	HAMAMİ MUHİTTİN	8	4,843	640
	HAYDAR	12	5,983	501
	HIZIR ÇAVUŞ	5	3,446	659
	HOCAÜVEYS	24	13,503	557
	İBRAHİM ÇAVUŞ	14	8,777	630
	İSKENDERPAŞA	11	5,750	504
	KOCAMUSTAFAPAŞA	6	3,821	627
	KASIM GÜNANİ	9	5,651	625
	KATİP MUSLİHİTTİN	8	4,590	545
	KEÇECİ KARABAŞ	12	9,000	744
	KOCADEDE	11	6,036	555
	MELEKHATUN	14	9,891	717
	MUHTESİP İSKENDER	14	8,868	653
	MÜFTÜ ALİ	12	10,351	864
	NEVBAHAR	17	8,940	514
	SANCAKTAR HAYRETTİN	13	7,258	548
	SİNANAĞA	17	10,398	622
	UZUNYUSUF	16	10,781	687
GÜNGÖREN	AKINCILAR	26	20,689	805
	GÜNEŞTEPE	73	43,222	593
	MERKEZ	79	43,852	558
	GÜVEN	32	18,085	571
	HAZNEDAR	35	22,024	628
	M.ÇAKMAK	35	30,440	870

District Name	Mahalle Name	Area (ha)	Population	Population Density (persons/ha)
GAZİOSMANPAŞA	HÜRRİYET	47	25,248	538
	ŞEMSİPAŞA	35	19,348	548
KAĞITHANE	ÇELİKTEPE	52	28,600	551
	GÜLTEPE	20	12,627	643
	HARMANTEPE	29	18,568	633
	ORTABAYIR	37	20,904	560
	YAHYA KEMAL	30	16,028	530
ŞİŞLİ	BOZKURT	18	10,570	587
	DUATEPE	14	7,512	545
	ESKİŞEHİR	18	11,318	616
	FERİKÖY	24	12,912	532
ÜSKÜDAR	ARAKİYECİ HACI CAFER	10	6,481	643
	SOLAK SİNAN	10	5,855	562
	TABAKLAR	6	4,522	738
	TAVAŞİ HASANAĞA	7	4,277	622
	VALİDE-İ ATİK	13	6,893	518
ZEYTİNBURNU	ÇIRPICI	38	25,081	663
	GÖKALP	29	17,012	592
	NURİPAŞA	36	22,130	623
	VELİEFENDİ	40	24,564	611
	YENİ DOĞAN	16	8,816	564
	YEŞİLTEPE	21	17,621	833
ESENLER	DAVUTPAŞA	21	13,958	670
	FATİH	49	34,825	706
	KARABAYIR	69	42,464	620
	KAZIM KARABEKİR	50	30,452	615
	MENDERES	44	29,840	676
	MİMAR SİNAN	17	10,887	632
	NENE HATUN	50	37,209	745
	ORUÇ REİS	66	36,715	553

Source: Population Census 2000, SIS

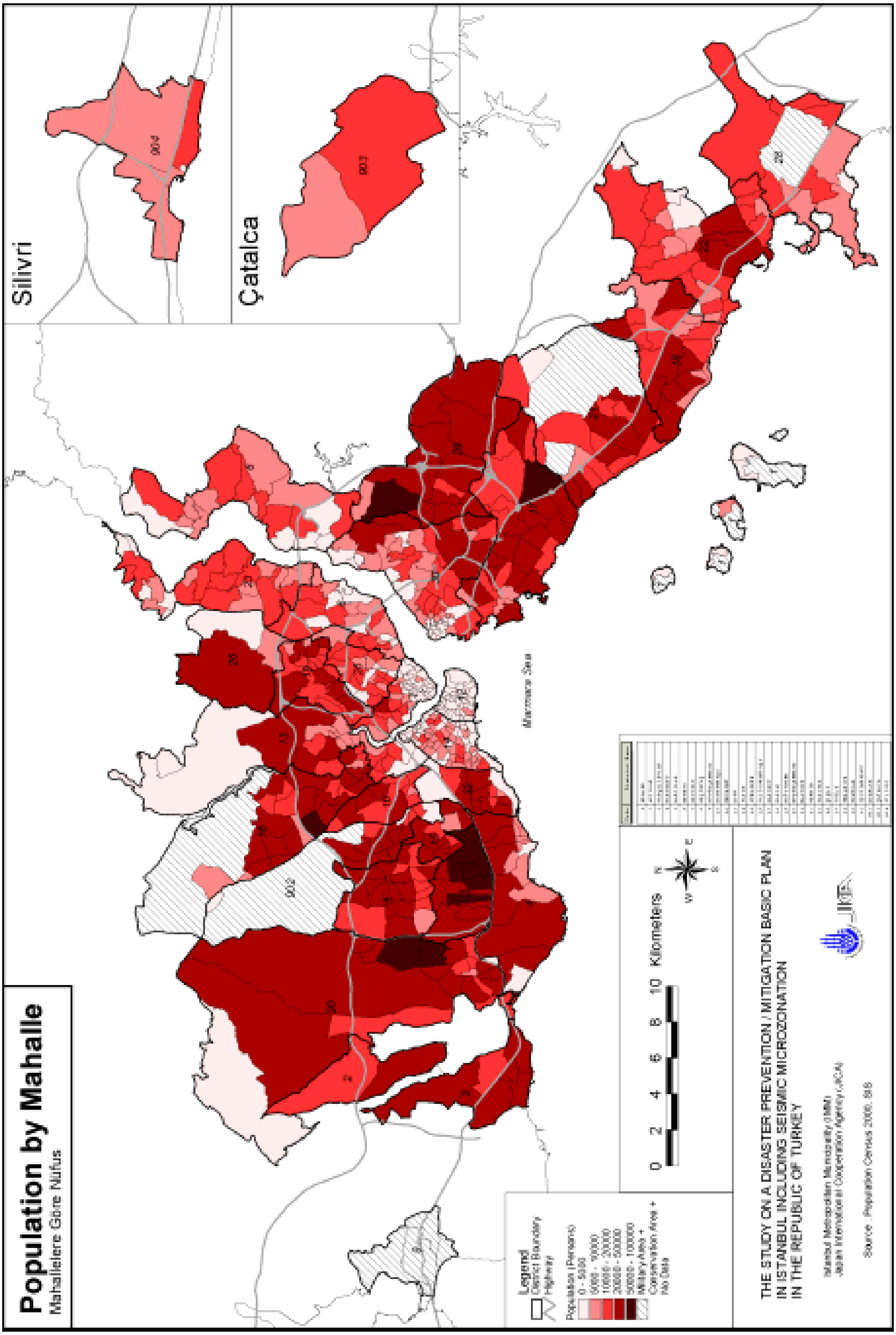

Figure 6.2.1 Population Distribution

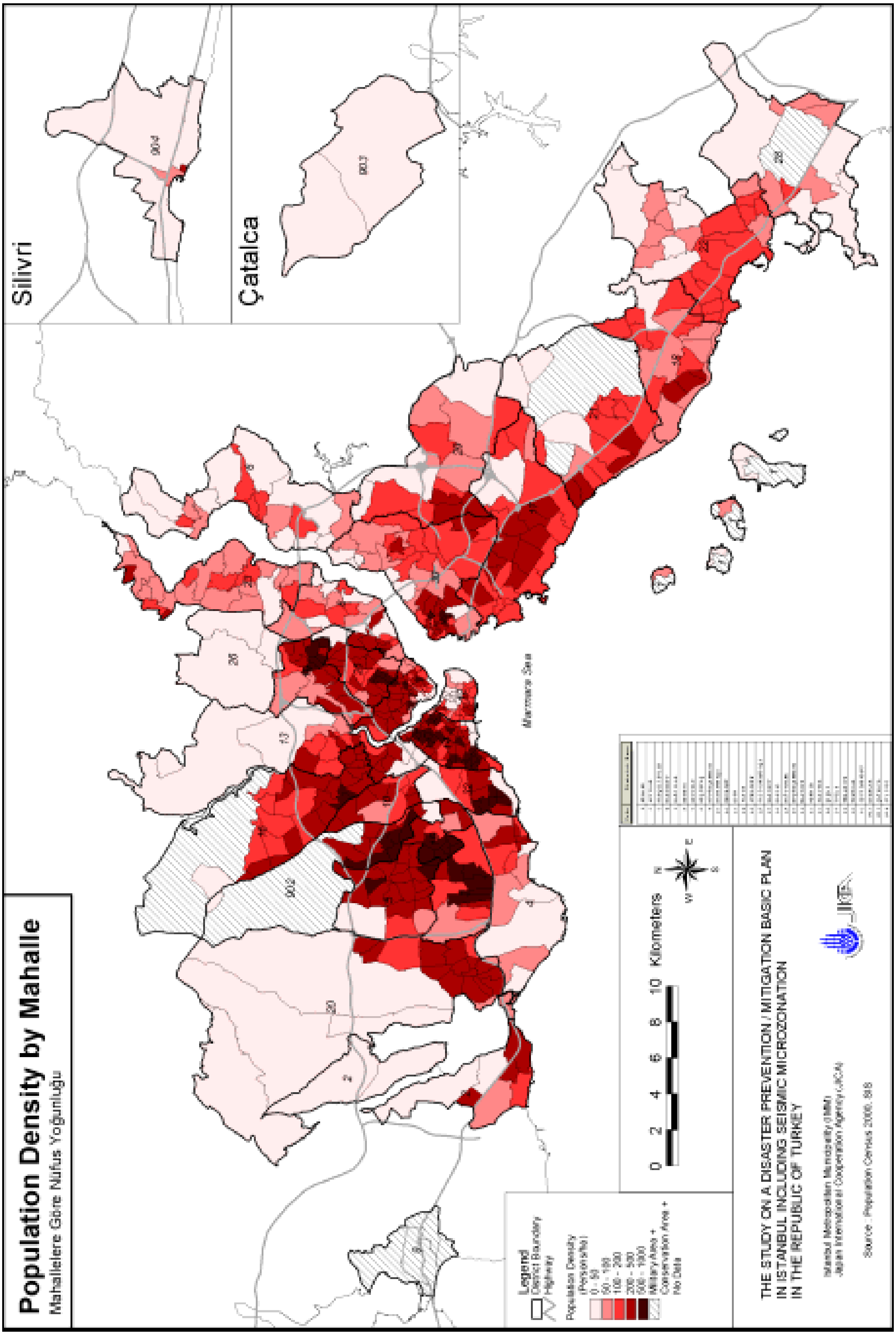

Figure 6.2.2 Population Density

6.2.2. Building Data

Building data within the Study Area is indispensable to the execution of damage estimation through seismic microzonation. The Study Team requested census data gathered by the SIS and received the data on the 16th of January 2002. The received data consisted of 1) structure type, 2) construction year, and 3) number of stories of each building, and these items were necessary to carry out the damage estimation within the Study. This data was obtained from a very comprehensive census and missing data are very few (for instance, among the total 724,609 buildings within the Study Area 0.9% of the structural type entries, 1.3 % of the construction year entries, and 0.4% of the number of stories entries are unknown. Therefore, these errors will not be taken into account in the Study. Table 6.2.3 shows the number of buildings and building density (buildings/ha) for each district.

Table 6.2.3 Building Distribution by District

District Code	District Name	Area (ha)	Population	Buildings	Building Density (Buildings/ha)
1	ADALAR	1,100	17,738	6,517	6
2	AVCILAR	3,861	231,799	14,030	4
3	BAHÇELİEVLER	1,661	469,844	19,690	12
4	BAKIRKÖY	2,951	206,459	10,067	3
5	BAĞCILAR	2,194	557,588	36,059	16
6	BEYKOZ	4,156	182,864	28,280	7
7	BEYOĞLU	889	234,964	26,468	30
8	BEŞİKTAŞ	1,811	182,658	14,399	8
9	BÜYÜKÇEKMECE	1,474	34,737	3,347	2
10	BAYRAMPAŞA	958	237,874	20,195	21
12	EMİNÖNÜ	508	54,518	14,149	28
13	EYÜP	5,050	232,104	25,716	5
14	FATİH	1,045	394,042	31,946	31
15	GÜNGÖREN	718	271,874	10,655	15
16	GAZİOSMANPAŞA	5,676	667,809	56,483	10
17	KADIKÖY	4,128	660,619	38,615	9
18	KARTAL	3,135	332,090	24,295	8
19	KAĞITHANE	1,443	342,477	28,737	20
20	KÜÇÜKÇEKMECE	12,173	589,139	45,816	4
21	MALTEPE	5,530	345,662	25,311	5
22	PENDİK	4,731	372,553	39,877	8
23	SARIYER	2,774	212,996	30,781	11
26	ŞİŞLİ	3,543	271,003	22,576	6
28	TUZLA	4,998	100,609	14,726	3
29	ÜMRANİYE	4,561	443,358	43,473	10
30	ÜSKÜDAR	3,783	496,402	43,021	11
32	ZEYTİNBURNU	1,149	239,927	15,573	14
902	ESENLER	3,890	388,003	22,700	6
903	ÇATALCA	5,263	15,624	2,573	0
904	SİLİVRİ	3,828	44,432	8,534	2
Total		98,981	8,831,766	724,609	7

Source: Building Census 2000, SIS

As indicated, according to the 2000 Building Census by SIS, the total number of buildings within the Study Area is counted at 724,609 buildings. Figure 6.2.3 shows building distribution by mahalle and Figure 6.2.4 shows duilding density by mahalle. In detail, Gaziosmanpaşa has the highest number of buildings in Istanbul, counted at 56,483. However, its area is rather large and its building density is 10 buildings/ha. Similar to their population distribution, the additional 3 districts have a low number of buildings.

Concerning building density, Fatih and Beyoğlu have the highest population density at 31 persons/ha and 30 persons/ha, respectively. On the contrary, Çatalca has the lowest population density in the Study Area.