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APPENDIX 1

HISTORICAL EARTHQUAKES

Appendix.1. Historical earthquakes that affected the Marmara Region (Ambraseys & Finkel, 1991)

32 A.D.
An earthquake shook the province of Bithynia; most houses in Nicaea (Iznik) were destroyed. The shock has been experienced in Istanbul and even in Athens.

69 A.D.
Nicomedia (Izmit), the capital of Bithynia, was destroyed. The damage should be extensive, since the city was rebuilt.

121 A.D.
A major earthquake in Bithynia destroyed completely Nicomedia (Izmit) and the greater part of Nicaea (Iznik).

358 August 24
A catastrophic earthquake in Bithynia totally destroyed Nicomedia (Izmit) and its district killing, among others, the vice-governor and two bishops who happened to be in the city. Nicaea (Iznik), Constantinople, and Perinthus (n. Marmaraereğlisi), as well as many other towns, were damaged. Landslides, ground deformations and a seismic sea-wave in Nicomedia, followed by a conflagration, completed the destruction. The shock was strongly felt in Asia Minor as far as the district of Pontus.

362 December 2
Nicomedia (Izmit) was totally destroyed as well as a good part of Nicaea (Iznik). Springs dried up. As a measure of relief the authorities lowered the price of essentials. The earthquake was felt in Constantinople (Istanbul) and allegedly damaged the newly built cathedral of St. Sophia.

396
An earthquake in Constantinople (Istanbul) and vicinity, followed by aftershocks that obliged the people to stay in the open. No evidence has been preserved about the degree of damage done in and outside the capital.

402 June
An earthquake felt in Constantinople (Istanbul) which caused considerable concern.

403
A strong earthquake was felt at Constantinople (Istanbul). Aftershocks continued for four months. The shock possibly originated at some considerable distance from the city.

407 April 1
An earthquake caused damage in Hebdomen (Bakırköy) and in Constantinople (Istanbul) (particularly districts of Kaenupolis and Xerolophos). Sea wave is also reported to have occurred. The epicenter is estimated to be located offshore.

412
An earthquake in Constantinople (Istanbul) caused damage to the city walls.

447 November 6
Preceded by a damaging earthquake on 26 January, a catastrophic earthquake in the Sea of Marmara destroyed many towns in the provinces of Bithynia, Phrygia and Hellespont. In Constantinople

(Istanbul), public buildings and houses damaged in January were ruined, and the greater part of the city wall and 57 of its 96 towers were overthrown. The shock was followed by a damaging sea-wave and by aftershocks that continued for months.

460 April 7
This earthquake caused extensive damage in the province of the Hellespont and in the greater part of Thrace. Cyzicus (n. Erdek) and villages in the interior were totally destroyed, with great loss of life. In places the ground opened up.

478 September 25
A destructive earthquake in the eastern part of the Sea of Marmara totally destroyed Helenopolis (Karamürsel) and Nicomedia (İzmit) and caused severe damage in Constantinople (Istanbul). Damaging sea wave and aftershocks are also reported.

484
A destructive shock in the western part of the Marmara Sea region caused damage in Thrace and serious loss of life. Sistos (Şehitlikler) and Callipolis (Gelibolu) were 'destroyed completely' and Tenedos (Bozcaada) sustained serious damage. Lampsacus (Lapseki) and Abydus (Çanakkale) were heavily damaged and the Long Walls of the Chersonesus at Hexamili (n. Ortaköy) were breached. Near Sistos tar oozed out of the ground. Minor damage extended to Constantinople.

542 August 16
A severe earthquake in Constantinople (Istanbul) caused considerable damage and loss of many lives. Many houses and a number of churches collapsed and the walls near the Golden Gate were damaged. The shock overturned a number of statues and other free-standing monuments.

543 September 6
An earthquake that destroyed half of the city of Cyzicus (Erdek), was severe at Constantinople (Istanbul) where it caused minor damage.

554 August 16
A destructive earthquake caused severe damage in Nicomedia (Izmit) and in Constantinople (Istanbul). Several other towns have also been affected. Sea flooded the cost inland to a distance of two miles and aftershocks continued for a long time.

557 December 11
A destructive shock affected the northern coast of Marmara Sea, especially west of Regium (Küçükçekmece) and Constantinople (Istanbul). The destruction extended over a large area, but the limits are unknown.

740 October 26
The earthquake caused enormous material and human loss in many towns of Thrace and Bithynia, especially in Nicomedia (İzmit), Praenetos (Karamürsel) and Nicaea (Iznik). The sea retired form the land permanently, changing the coastline. In Constantinople (Istanbul) a considerable part of the city walls were destroyed and buildings were damaged.

861 April 10
A severe earthquake in Constantinople (Istanbul) was preceded and followed by many shocks. A number of houses, public buildings and a small section of the city walls were damaged. Aftershocks continued 40 days.

869 January 9
An earthquake caused considerable damage in Constantinople (Istanbul), killing a number of people. The shock damaged the cathedral of Sta Sophia, part of which collapsed. The church of the Apostles which was damaged by the earthquake of 861, collapsed, together with the church of the Virgin at Sigma. A long series of aftershocks, some of them strong enough to cause additional damage in the city, continued for 40 days.

925 August
A major earthquake somewhere in Thrace produced an enormous cleft in the ground. Many villages and churches were totally destroyed. The shock apparently caused some damage to Athos as well.

989 October 25
A destructive earthquake in the eastern part of the Sea of Marmara caused extensive damage to villages and towns in the provinces of Thrace and Bithynia. In Constantinople (Istanbul) many houses collapsed and public buildings and parts of the city walls were damaged or destroyed. Damage was equally heavy in Nicomedia (Izmit) and was in places aggravated by a seismic sea-wave.

1011 March 9
Preceded by a strong foreshock in January, a destructive earthquake in the provinces of Byzantium caused great loss of life. In Constantinople (Istanbul) a few public buildings and houses were destroyed.

1032 August 13
A destructive earthquake centering somewhere on the Asiatic side of the Marmara Sea region, caused the collapse of public buildings and of an aqueduct. In Constantinople (Istanbul) the shock damaged the land walls.

1037 December 18
An earthquake, probably a large aftershock of the major earthquake on the North Anatolian Fault Zone of May 1035 in Gerede, caused some damage in Constantinople (Istanbul).

1063 September 23
This was a severe earthquake that spread desolation particularly along the north coast of the Sea of Marmara, and ruined many districts which lay between Constantinople (Istanbul) and Dardanelles. The walls of town, aqueducts, churches and public buildings were thorn down throughout all southern Thrace particularly at Myriophyto (Mürefte), Panion (n. Barbaros), and Redestos (Tekirdağ). In Constantinople (Istanbul), houses were ruined and a few public buildings were damaged or destroyed. Aftershocks continued to be felt in Constantinople (Istanbul) for two years. Most probably the shock originated from the Sea of Marmara off shore Cyzicus.

1296 June 1
An earthquake in Constantinople (Istanbul) caused considerable damage, particularly to a number of old houses, public buildings and free-standing structures and to the city walls as well. The earthquake, which was followed by aftershocks for many days, affected even more the Asiatic provinces, but details are lacking. As a consequence of the earthquake, the emperor was obliged to return to Constantinople.

1323
An earthquake in Constantinople (Istanbul) caused severe damage to buildings, churches and monumental columns. There is good evidence that this earthquake destroyed Militopolis (n. Karacabey), and perhaps Apollonia (Apolyontköy). This shock marks the beginning of a period of

seismic activity in this part of the Marmara region, during which the earthquakes of 12 May 1327, which destroyed Lopadion (Ulubad), and of 17 January 1332, were widely felt.

1332 January 17
This earthquake was felt very strongly in Constantinople (Istanbul) and was followed by violent thunderstorms and heavy seas which caused serious damage to buildings and the sea walls. The shock itself caused no damage.

1343 October 18
Followed by an almost equally destructive aftershock, an earthquake in the western part of the Marmara Sea caused extensive damage to Thrace and along the coast to Chersonesus (Gelibolu Peninsula). Among other towns, Myriophyto (Mürefte) and Hora (Hoşköy) were almost destroyed with great loss of life and Lysimachia (Bolayir) was ruined. In Constantinople (Istanbul) the city walls were breached and some of the fortification towers were partly destroyed. Houses, public buildings and churches suffered different degrees of damage. The aftershock, that took place a few hours after the earthquake, was equally damaging throughout the region. It was followed by a seismic sea-wave that flooded the coast to a great distance and cast sailing ships on land, the sea advancing 12 stadia (2.2 km) inland on flat ground and causing extensive damage to settlements and towns along the coast of Thrace. Aftershocks continued to be felt for almost a year. The earthquake had serious social and financial repercussions.

1344 November 6
This was probably a large aftershock of the earthquake of 1343 in Thrace. It destroyed completely the region of Ganohora (Gaziköy) on the west coast of the Sea of Marmara, including the castles of Ganos (Gaziköy), Hora (Hoşköy), Marmara Island, and the Long Walls of the Chersonesus or Tihos at Hexamili (n. Ortaköy). The shock seems to have been experienced very strongly at Constantinople (Istanbul), where it caused some damage to the city walls. Aftershocks continued for a few weeks.

1346 May 19
During the autumn of 1345 and again in the spring of 1346 new shocks were felt in Constantinople (Istanbul). The earthquake of 19 May 1346 caused some damage to a number of free-standing structures and to the church of Sta Sophia, the eastern part of which collapsed. It is not possible to locate the epicentral area of this event.

1354 March 1
This earthquake ruined the region along the coast of the Marmara Sea, from Redestos (Tekirdağ) to Madytos (Hacıabad), including Callipolis (Gelibolu), and other places in Thrace where many lives were lost. The earthquake damaged houses and the walls of Constantinople as well as numerous settlements south of Madytos and in the districts of Thrace and Macedonia as well as in Tenedos (Bozcaada).The shock was felt over a large area.

1400 January
An earthquake was strongly felt in Constantinople (Istanbul) as well as Bursa.
1419 March 15
This earthquake most probably occurred in the eastern North Anatolian fault but its effects extended to Constantinople (Istanbul).

1489 January 16
An earthquake in Istanbul caused the collapse of a number of minarets. The earthquake probably had an epicenter some distance from Istanbul, but no information is available for the damage caused outside the city.

1509 September 10
A destructive earthquake that 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 seismic sea-wave in the eastern part of the Sea of Marmara. Aftershocks, some of them destructive, continued intermittently for almost two years.

1542 June 12
A destructive earthquake in Thrace caused extensive damage and great loss of life in the region between Gelibolu, Edirne and Istanbul. In Istanbul, 1700 houses are said to have been ruined and 4500 people killed. The epicentral area involved cannot be identified, but a possible location would be the central part of the north coast of the Sea of Marmara.

1556 May 10
A destructive shock in the east part of the Sea of Marmara ruined many places including Aydıncık (n. Erdek), and killed a large number of people. Damage extended to Bursa and Istanbul where many houses, mosques and parts of the city walls were ruined. The walls of Aya Sofya were cracked and the Fatih Mosque had to be repaired. The details of this event suggest that its epicenter must be sought offshore in the Sea of Marmara.

1567 October 1
This earthquake caused damage in the Sapanca area and to some unnamed villages in a district where a landslide was triggered by the shock. Damage extended to Izmit and to Istanbul, where a few houses collapsed. It is unlikely that the damaging effects of the earthquake extended beyond the limits of Sapanca.

1648 June 28
This earthquake damaged multistorey houses, chimneys and the spires of minarets in Istanbul. There is no information that the shock was felt elsewhere. The details of the effects of the shock in Istanbul suggest that the city was some distance from the epicentral region of a relatively large-magnitude earthquake, possibly in Transylvania.

1659 February 17
A large earthquake was felt throughout the western part of the Ottoman Empire. In Tekirdağ churches and mosques and in Istanbul old buildings, houses and chimneys were ruined. The effects of the earthquake suggest that the shock was of large magnitude and originated possibly in the Aegean Sea.

1688 September 10
This earthquake was felt rather strongly in Istanbul. The absence of any other information than causing heavy damage inland, suggest that the earthquake originated from somewhere in Karesi province.

1689 April 25
An earthquake was felt over a large area of northwestern Anatoila and Thrace, particularly along the west coast of the Black Sea. In Istanbul and Edirne several houses, mosques and towers were damaged by the shock and most probably by the high winds documented at about this time, which necessitates repairs to various buildings in Istanbul. The epicentral area involved is impossible to identify, but a likely location would be the Maritsa Valley.

1690 July 11
A damaging earthquake in Istanbul caused a number of houses to collapse killing 20 people. At Büyükçekmece a minaret collapsed. The absence of data from other towns suggests the possibility that this was a local shock with an epicenter offshore. Aftershocks continued to be felt for several days.

1707 June 2
This earthquake caused non-structural parts of the castle of Sedd ül-bahr to collapse. The shock was felt strongly at Izmir and was predictable in Istanbul. The data suggest and epicenteral region south of the Dardanelles.

1719 May 25
Preceded by damaging foreshocks a major earthquake in the east part of the Sea of Marmara. Villages and towns on either side of the Gulf of Izmit, in Yalova, Pazarköy, Karamürsel, Kazıklı, Izmit, in the region of Sevenit (Sapanca ?) and as far as Düzce were destroyed or badly damaged; it is said that more than 6000 (?) people were killed in this earthquake. Considerable damage was done to houses, buildings and to the city walls of Istanbul, where 40 mosques and 27 towers were ruined. There was also significant damage in Akviran, Çatalca, Çekmece, and Heybeliada. The shock was strongly felt in Edirne, where it caused some minor damage, and in Chios, Izmir, Athos, Thessaloniki, Nish (?) and in Anatolia (?). Aftershocks continued for about a month.

1730 June 10
In this earthquake, the greater part of the castle in the district of Evreşe (n. Kadıköy) was destroyed (?) and much damage was done to villages along the road from Athos to Istanbul. The shock was strongly felt in Athos and was reported from Istanbul. Ambraseys and Finkel assume that the epicentral area was located offshore, in the Gulf of Muariz (Saros).

1752 July 29
A destructive earthquake in Thrace: Zerna (n. Ibriktepe), Hafsa and Hasköy were completely ruined and many people were killed. Considerable damage was done to houses and public buildings in Edirne where 100 people were killed; almost all minarets collapsed and part of the castle and wall were ruined. The ground was rent in places and elsewhere it liquefied, filling up wells. Aftershocks continued for more that a year.

1754 September 2
A great earthquake in the Gulf of Izmit and further to the east where villages were totally destroyed and the ground was opened. It is said that about 2000 people were killed. The lighthouse at Bendereğli (Ereğli) on the Black Sea was destroyed. There was much damage done at Üsküdar and in the Balat, and in Istanbul many old masonry houses and buildings collapsed and 60 people were killed by the main shock and by damaging aftershocks that continued for weeks; some mosques and parts of the city walls were also damaged. The main shock was associated with a seismic sea-wave which caused no damage. The shock was also reported from Izmir and Ankara (?). The shock does not seem to have caused serious damage to the south of Marmara Sea. Possible location of the epicentral area would be in the Izmit area.

1766 May 22
A destructive earthquake in the east part of the Sea of Marmara caused heavy damage extended from Rodosto (Tekirdağ) to Izmit 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, Izmit 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 on the upper Kağıthane, north of Istanbul, was damaged, and in the vicinity of Sultanahmet, the roof of an underground cistern caved in. It is said

that about 4000 people lost their lives. The earthquake was associated with a seismic sea-wave which was particularly strong along the Bosphorus and in the Gulf of Mudanya where it caused considerable damage. Damage extended inland, mainly to the north and west, as far as Edirne and to Gelibolu. In Çatalca and surrounding villages all masonry houses were totally destroyed. It is said that about 4000 people lost their lives. The shock was felt strongly along the west coast of Black Sea. Damaging aftershocks continued for weeks, the sequence lasting for over a year. Ambraseys and Finkel (1991) assume that the epicentral region of this earthquake was offshore in the Sea of Marmara.

1766 August 5
A major earthquake in the west of the Sea of Marmara completed the destruction caused by the shock of 22 May and enlarged the affected area west of Rodosto (Tekirdağ). The region between Silivri and Tenedos (Bozcaada) was ruined with loss of life. The district of Ganohora (Tekirdağ) was totally destroyed and that of Gelibolu suffered heavy losses. The castles along the Dardanelles up to Sedd ül-bahr and in Evreşe were damaged. Damage extended to Bursa, Istanbul, throughout Thrace to Edirne, and in the district of Biga. Damaging aftershocks throughout the Marmara Sea area continued for almost a year.

1776 May 29
An earthquake caused widespread but minor damage along the coast from Gelibolu to Istanbul. Buildings and houses affected by the large earthquakes of 1766 and since repaired, were again damaged. Most probably this earthquake originated offshore.

1800 September 26
A series of earthquakes was felt in Istanbul as a result of which a public building was damaged.

1802 October 26
A large earthquake in eastern Transylvania caused some damage to the houses and to the covered bazaars in Istanbul and Edirne. The epicentral area of this event is outside the Marmara region.

1809 February 7
A large earthquake with an epicenter probably located offshore the Dardanelles, almost totally destroyed the region of Eskistanbul (the part of the mainland opposite Bozcaada (Tenedos), and caused damage on the island of Gökçeada (Imroz).

1855 February 28
The main shock came 15 minutes after a violent foreshock in the Hüdavendigar district - Bursa. Some old buildings and walls partly collapsed.

1859 August 21
A damaging earthquake with an epicenter offshore the Dardanelles caused heavy damage and liquefaction on the island of Gökçeada.

1877 October 13
An earthquake with an offshore epicentral area in the Sea of Marmara caused heavy damage to the Marmara Islans.

1893 February 9
This earthquake had an offshore epicenter in the Gulf of Saros. It caused considerable damage to Gökçeada.

1894 July 10

A destructive earthquake in the Gulf of Izmit 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 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 seismic sea-wave, which at St. Stephanos (Yeşilköy) had a height of 1.5 m., and caused the failure of submarine cables. Liquefaction of the ground and landslides were reported from the epicenter region, particularly from the area between Sapanca and Adapazarı. The shock was felt as far as Bucharest, Sofia, Yannina, Crete and Konya, and it was not followed by a significant aftershock sequence.

APPENDIX 2

ATTENUATION RELATIONSHIPS

Appendix.2. Attenuation Relationships Applicable to the Study Area

A.2.1. Boore et. al. (1997) Attenuation Relationship:

The Boore et al. (1997) PGA and Spectral Acceleration attenuation relationship given by the following expressions is based on the selected strong motion data from western North America. The equations predict the random horizontal component peak acceleration and 5% damped pseudo acceleration response spectra in terms of moment magnitude, distance and site conditions for strike-slip, reverse slip or unspecified faulting mechanism. Site conditions are represented by the shear wave velocity averaged over 30m, and recommended values of average shear velocity are given for typical rock and soil sites and for site categories used in the NEHRP (National Earthquake Hazard Reduction Program - BSSC, 1994) seismic code provisions.

Table A. 2.1.Recommended values of average shear wave velocity.

NEHRP Site Class B	1070 m/s
NEHRP Site Class C	520 m/s
NEHRP Site Class D	250 m/s
Rock	620 m/s
Soil	310 m/s

The earthquake mechanism is expressed with the help of a coefficient, namely b_1.

The ground motion estimation equation is:

$$\ln(Y) = b_1 + b_2 (M\text{-}6) + b_3 (M\text{-}6)^2 + b_5 \ln r + b_V \ln (V_S / V_A)$$

where:

$$r = (r_{jb}^2 + h^2)^{1/2}$$

In this equation;
Y = peak horizontal accelerations in g
M= moment magnitude M ≥5.00
r = closest distance from rupture to the station in km r ≥ 20km.
r_{jb} = closest horizontal distance from the station to a point in km.
V_S = average shear-wave velocity to a depth of 30 m (m/s) (Table A. 2.1)
b_1 = b_{1SS} for strike-slip earthquakes
= b_{1RS} for reverse-slip earthquakes
= b_{1ALL} if mechanism is not specified

b_{1SS}, b_{1RS}, b_{1ALL}, b_2, b_3, b_5, b_V, V_A and h = Coefficients presented in Table A. 2.2

The smoothed coefficients in the equations for predicting ground motion were determined using a weighted, two-stage regression procedure. In the first stage, the distance and site condition dependence were determined along with a set of amplitude factors, one for each earthquake. In the second stage, the amplitude factors were regressed against magnitude to determine the magnitude dependence.

Table A. 2.2. Smoothed coefficients for Boore et. al. (1997) PGA and SA attenuation relationship

Period	b_{1SS}	b_{1RS}	b_{1ALL}	b_2	b_3	b_5	b_V	V_A	h	$\sigma_{\ln Y}$
PGA	-0.313	-0.117	-0.242	0.527	0.000	-0.778	-0.371	1396	5.57	0.520
0.10	1.006	1.087	1.059	0.753	-0.226	-0.934	-0.212	1112	6.27	0.479
0.11	1.072	1.164	1.130	0.732	-0.230	-0.937	-0.211	1291	6.65	0.481
0.12	1.109	1.215	1.174	0.721	-0.233	-0.939	-0.215	1452	6.91	0.485
0.13	1.128	1.246	1.200	0.711	-0.233	-0.939	-0.221	1596	7.08	0.486
0.14	1.135	1.261	1.208	0.707	-0.230	-0.938	-0.228	1718	7.18	0.489
0.15	1.128	1.264	1.204	0.702	-0.228	-0.937	-0.238	1820	7.23	0.492
0.16	1.112	1.257	1.192	0.702	-0.226	-0.935	-0.248	1910	7.24	0.495
0.17	1.090	1.242	1.173	0.702	-0.210	-0.933	-0.258	1977	7.21	0.497
0.18	1.063	1.222	1.151	0.705	-0.216	-0.930	-0.270	2037	7.16	0.499
0.19	1.032	1.198	1.122	0.709	-0.212	-0.927	-0.281	2080	7.10	0.501
0.20	0.999	1.170	1.089	0.711	-0.207	-0.924	-0.292	2118	7.02	0.502
0.22	0.925	1.104	1.019	0.721	-0.198	-0.918	-0.315	2158	6.83	0.508
0.24	0.847	1.033	0.941	0.732	-0.189	-0.912	-0.338	2178	6.62	0.511
0.26	0.764	0.958	0.861	0.744	-0.180	-0.906	-0.360	2173	6.39	0.514
0.28	0.681	0.881	0.780	0.758	-0.168	-0.899	-0.381	2158	6.17	0.518
0.30	0.598	0.803	0.700	0.769	-0.161	-0.893	-0.401	2133	5.94	0.522
0.32	0.518	0.725	0.619	0.783	-0.152	-0.888	-0.420	2104	5.72	0.525
0.34	0.439	0.648	0.540	0.794	-0.143	-0.882	-0.438	2070	5.50	0.530
0.36	0.361	0.570	0.462	0.806	-0.136	-0.877	-0.456	2032	5.30	0.532
0.38	0.286	0.495	0.385	0.820	-0.127	-0.872	-0.472	1995	5.10	0.536
0.40	0.212	0.423	0.311	0.831	-0.120	-0.867	-0.487	1954	4.91	0.538
0.42	0.140	0.352	0.239	0.840	-0.113	-0.862	-0.502	1919	4.74	0.542
0.44	0.073	0.282	0.169	0.852	-0.108	-0.858	-0.516	1884	4.57	0.545
0.46	0.005	0.217	0.102	0.863	-0.101	-0.854	-0.529	1849	4.41	0.549
0.48	-0.058	0.151	0.036	0.873	-0.097	-0.850	-0.541	1816	4.26	0.551
0.50	-0.122	0.087	-0.025	0.884	-0.090	-0.846	-0.553	1782	4.13	0.556
0.55	-0.268	-0.063	-0.176	0.907	-0.078	-0.837	-0.579	1710	3.82	0.562
0.60	-0.401	-0.203	-0.314	0.928	-0.069	-0.830	-0.602	1644	3.57	0.569
0.65	-0.523	-0.331	-0.440	0.946	-0.060	-0.823	-0.622	1592	3.36	0.575
0.70	-0.634	-0.452	-0.555	0.962	-0.053	-0.818	-0.639	1545	3.20	0.582
0.75	-0.737	-0.562	-0.661	0.979	-0.046	-0.813	-0.653	1507	3.07	0.587
0.80	-0.829	-0.666	-0.760	0.992	-0.041	-0.809	-0.666	1476	2.98	0.593
0.85	-0.915	-0.761	-0.851	1.006	-0.037	-0.805	-0.676	1452	2.92	0.598
0.90	-0.993	-0.848	-0.933	1.018	-0.035	-0.802	-0.685	1432	2.89	0.604
0.95	-1.066	-0.932	-1.010	1.027	-0.032	-0.800	-0.692	1416	2.88	0.609
1.00	-1.133	-1.009	-1.080	1.036	-0.032	-0.798	-0.698	1406	2.90	0.613
1.10	-1.249	-1.145	-1.208	1.052	-0.030	-0.795	-0.706	1396	2.99	0.622
1.20	-1.345	-1.265	-1.315	1.064	-0.032	-0.794	-0.710	1400	3.14	0.629
1.30	-1.428	-1.370	-1.407	1.073	-0.035	-0.793	-0.711	1416	3.36	0.637
1.40	-1.495	-1.460	-1.483	1.080	-0.039	-0.794	-0.709	1442	3.62	0.643
1.50	-1.552	-1.538	-1.550	1.085	-0.044	-0.796	-0.704	1479	3.92	0.649
1.60	-1.598	-1.608	-1.605	1.087	-0.051	-0.798	-0.697	1524	4.26	0.654
1.70	-1.634	-1.668	-1.652	1.089	-0.058	-0.801	-0.689	1581	4.62	0.660
1.80	-1.663	-1.718	-1.689	1.087	-0.067	-0.804	-0.679	1644	5.01	0.664
1.90	-1.685	-1.763	-1.720	1.087	-0.074	-0.808	-0.667	1714	5.42	0.669
2.00	-1.699	-1.801	-1.743	1.085	-0.085	-0.812	-0.655	1795	5.85	0.672

The standard deviation of the natural logarithm of the ground motion is represented by $\sigma_{\ln Y}$. The corresponding values of $\sigma_{\ln Y}$ for discrete periods are given in Table A. 2.2.

A.2.2. Sadigh et. al. (1997) Attenuation Relationship

Sadigh et. al (1997) developed a new attenuation relationship based on strong motion data primarily from California earthquakes. Relationships are presented for the geometric mean of the two

horizontal componenets, strike-slip and reverse-faulting earthquakes, rock and deep firm soil deposits, earthquakes of moment magnitude M between 4 and 8+ and distances up to 100km.

The site conditions representative of rock attenuation models given here should be accepted as soft rock. The deep soil data are from sites with greater than 20m of soil over bedrock.

Attenuation relationships of horizontal Response Spectral Acceleration (5% damping) are given in two separate equations according to the soil condition.

The general form of the equation for rock sites is as follows:

$$\ln(y) = C_1 + C_2M + C_3(8{,}5\text{-}M)^{2.5} + C_4\ln[r_{rup} + \exp(C_5+C_6M)] + C7\ln(r_{rup}+2)$$

y = PGA or SA (in g) represented by the geometric mean of the two horizontal components,

C_1 to C_7 =amplitudes given in Table A. 2.3

M = moment magnitude,
r_{rup} =Minimum distance to the fault rupture surface (km).

Relationship for reverse/thrust faulting are obtained by multiplying the given strike-slip amplitudes by 1.2.

Table A. 2.3. Coefficients of horizontal response spectral accelerations (5% damping) for rock sites (Sadigh et. al., 1997)

Period	C_1	C_2	C_3	C_4	C_5	C_6	C_7
For M ≤ 6.5							
PGA	-0.624	1.0	0.000	-2.100	1.29649	0.250	0.0
0.07	0.110	1.0	0.006	-2.128	1.29649	0.250	-0.082
0.10	0.275	1.0	0.006	-2.148	1.29649	0.250	-0.041
0.20	0.153	1.0	-0.004	-2.080	1.29649	0.250	0.0
0.30	-0.057	1.0	-0.017	-2.028	1.29649	0.250	0.0
0.40	-0.298	1.0	-0.028	-1.990	1.29649	0.250	0.0
0.50	-0.588	1.0	-0.040	-1.945	1.29649	0.250	0.0
0.75	-1208	1.0	-0.050	-1.865	1.29649	0.250	0.0
1.00	-1.705	1.0	-0.055	-1.800	1.29649	0.250	0.0
1.50	-2.407	1.0	-0.065	-1.725	1.29649	0.250	0.0
2.00	-2.945	1.0	-0.070	-1.670	1.29649	0.250	0.0
3.00	-3.700	1.0	-0.080	-1.610	1.29649	0.250	0.0
4.00	-4.230	1.0	-0.100	-1.570	1.29649	0.250	0.0

Period	C_1	C_2	C_3	C_4	C_5	C_6	C_7
For M > 6.5							
PGA	-1.274	1.1	0.000	-2.100	-0.48451	0.524	0.0
0.07	-0.540	1.1	0.006	-2.128	-0.48451	0.524	-0.082
0.10	-0.375	1.1	0.006	-2.148	-0.48451	0.524	-0.041
0.20	-0.497	1.1	-0.004	-2.080	-0.48451	0.524	0.0
0.30	-0.707	1.1	-0.017	-2.028	-0.48451	0.524	0.0
0.40	-0.948	1.1	-0.028	-1.990	-0.48451	0.524	0.0
0.50	-1.238	1.1	-0.040	-1.945	-0.48451	0.524	0.0
0.75	-1.858	1.1	-0.050	-1.865	-0.48451	0.524	0.0
1.00	-2.355	1.1	-0.055	-1.800	-0.48451	0.524	0.0
1.50	-3.057	1.1	-0.065	-1.725	-0.48451	0.524	0.0
2.00	-3.595	1.1	-0.070	-1.670	-0.48451	0.524	0.0
3.00	-4.350	1.1	-0.080	-1.610	-0.48451	0.524	0.0
4.00	-4.880	1.1	-0.100	-1.570	-0.48451	0.524	0.0

The standard deviation of ln(y) for rock sites is given in Table A. 2.4.

Table A. 2.4. Standard deviation for horizontal response spectral accelerations for rock sites (Sadigh et. al., 1997)

Period	$\sigma_{\ln Y}$
PGA	1.39-0.14M; 0.38 for M ≥ 7.21
0.07	1.40-0.14M; 0.39 for M ≥ 7.21
0.10	1.41-0.14M; 0.40 for M ≥ 7.21
0.20	1.43-0.14M; 0.42 for M ≥ 7.21
0.30	1.45-0.14M; 0.44 for M ≥ 7.21
0.40	1.48-0.14M; 0.47 for M ≥ 7.21
0.50	1.50-0.14M; 0.49 for M ≥ 7.21
0.75	1.52-0.14M; 0.51 for M ≥ 7.21
1.00	1.53-0.14M; 0.52 for M ≥ 7.21
>1.00	1.53-0.14M; 0.52 for M ≥ 7.21

Similarly, the equation for deep soil sites is given as follows:

$$\ln(y) = C_1 + C_2M - C_3\ln(r_{rup} + C_4e^{C5M}) + C_6 + C_7(8.5\text{-}M)^{2.5}$$

where:
y= PGA or SA (in g) represented by the geometric mean of the two horizontal components,
C_1 = -2.17 for strike slip earthquakes,
-1.92 for reverse and thrust earthquakes,
C_2 = 1,
C_3 = 1.70,
C_4 = 2.1863, C_5 = 0.32 for $M \leq 6.5$,
C_4 = 0.3828, C_5=0.5882 for M>6.5,
r_{rup}=Minimum distance to the fault rupture surface(km).

Coefficients C_5, C_6, C_7 and standard deviations for deep soil sites are presented in Table A. 2.5

Table A. 2.5. Coefficients C_5, C_6, C_7 and standard deviations for deep soil sites.

Period	C_6 Strike-Slip	C_6 Reverse	C_7	Standard Error[1]
PGA	0.0	0.0	0.0	1.52-0.16M
0.07	0.4572	0.4572	0.005	1.54-0.16M
0.10	0.6395	0.6395	0.005	1.54-0.16M
0.20	0.9187	0.9187	-0.004	1.565-0.16M
0.30	0.9547	0.9547	-0.014	1.58-0.16M
0.40	0.9251	0.9005	-0.024	1.595-0.16M
0.50	0.8494	0.8285	-0.033	1.61-0.16M
0.75	0.7010	0.6802	-0.051	1.635-0.16M
1.00	0.5665	0.5075	-0.065	1.66-0.16M
1.50	0.3235	0.2215	-0.090	1.69-0.16M
2.00	0.1001	-0.0526	-0.108	1.70-0.16M
3.00	-0.2801	-0.4905	-0.139	1.71-0.16M
4.00	-0.6274	-0.8907	-0.160	1.71-0.16M

1. Standard error for magnitudes greater than M 7 set equal to the value for M 7

A.2.3. Campbell (1997) Attenuation Relationship:

Campell (1997) provided the following attenuation equations using accelerograms generated by western USA and other worldwide earthquakes of moment magnitude (M_W) ≥ 5 and sites with distances to seismogenic rupture (R_{SEIS}) ≤ 60 km.

For the estimation of PGA values Campbell (1997) uses the following expression:

$$\ln(A_H) = -3.512 + 0.904M - 1.328 \ln[R_{SEIS}^2 + (0\ 149e^{0.67M})^2]^{1/2} + [1.125 - 0.112\ln(R_{SEIS}) - 0.0957M]F + [0.440 - 0.171 \ln(R_{SEIS})] S_{SR} + [0.405 - 0.222 \ln(R_{SEIS})] S_{HR} + \varepsilon$$

where:

A_H = median of the geometric mean of the two horizontal PGA (g)
M = moment magnitude,
R_{SEIS} = the closest distance to seismogenic rupture on the fault (km),
F = 0 for strike-slip and normal faulting earthquakes and 1 for reverse, reverse-oblique, and thrust faulting earthquakes,
S_{SR} = 1 for soft-rock sites,
S_{HR} = 1 for hard-rock sites,
$S_{SR} = S_{HR} = 0$ for alluvial sites,
ε = random error term with mean of zero and a standard deviation equal to the standard error of estimate of $\ln(A_H)$.

The standard error of estimate of $\ln(A_H)$ is as the following expression:

when $A_H < 0.068$g
$\sigma = 0.55$
when $0.068\text{g} \le A_H \le 0.21$g
$\sigma = 0.173 - 0.140 \ln(A_H)$
when $A_H > 0.21$g
$\sigma = 0.39$

The relationship relating σ to M is given by the expression:

when $M < 7.4$
$\sigma = 0.889 - 0.0691M$
when $M \ge 7.4$
$\sigma = 0.38$.

A.2.4. Erdik et. al. (1985) Attenuation Relationship

In order to assess the attenuation of intensities for earthquakes associated with the North Anatolian Fault in both parallel and transverse directions, Erdik and Eren (1983) and Erdik et. al., (1985) proposed a set of attenuation relationships. In the analysis they utilized an iso-seismal data set covering the earthquakes occurred on the North Anatolian and the East Anatolian Faults. All of the events were of strike-slip mechanism and their inclusion enhanced the success of the statistical regression analysis.

The correlation of intensity (I) with the logarithm of the PGA and the epicentral intensity (Io) with magnitude yields the following regression equation in terms of (I-Io) versus R and I versus M and R as follows:

$\text{Io-I} = \text{co} + c_1 \text{lnR} + \text{c2R}$ and $I = c_3 + c_4 M + c_5 \text{lnR} + c_6 R$

where:

c_o to c_7 = regression constants
R = distance parameter

The attenuation of the intensities in transverse direction to the North Anatolian Fault based on regression analysis is given as;

$I-Io = -1.237 + 1.216\ln R + 0.004R$ $\quad\quad \sigma(I-Io) = 0.53$
and
$I = -0.34 + 1.545M - 1.237\ln R - 0.001R$ $\quad\quad \sigma_I = 0.60$

where,

Io and I denote, respectively, the mean epicentral intensity and the mean intensity at a distance R in transverse direction to the fault and standard deviation. σ is the standard deviation of the dependent parameter (.Figure A.2. 1 and Figure A.2. 2.)

Distance parameter, on the other hand, has been used by some researchers in terms of $(R^2+c_7^2)^{1/2}$ to account for the near field effects, source depth and magnitude dependent distance parameter. The use of the distance parameter as $(R^2+c_7^2)^{1/2}$ yields the following equations:

$Io-I = -2.43 + 1.71 \ln (R^2+4^2)^{1/2} + 0.007 (R^2+4^2)^{1/2}$ $\quad\quad \sigma(I-Io) = 0.43$
and
$I = 10.45 + 0.14M-1.69\ln (R^2+4^2)^{1/2} + 0.012(R^2+4^2)^{1/2}$ $\quad\quad \sigma_I = 0.74$

For three intensity levels, the attenuation of the intensities in parallel direction to the North Anatolian Fault based on regression analysis is given as;

$\ln D_{VIII} = 2.20\ M - 11.32$ $\quad\quad \sigma = 0.47$ $\quad\quad r^2 = 0.782$
$\ln D_{VII} = 1.80\ M - 8.40$ $\quad\quad \sigma = 0.34$ $\quad\quad r^2 = 0.829$
$\ln D_{VI} = 2.02\ M - 9.55$ $\quad\quad \sigma = 0.45$ $\quad\quad r^2 = 0.726$
where,

D = end to end contour interval distances (Figure A.2. 3.);
σ = standard deviation
r^2 = correlation coefficient
In Figure A.2. 4. theoretical isoseismic maps associated with different magnitude earthquake on the North Anatolian Map (NAF) is illustrated.

A.2.5. Özbey (2001) Attenuation Relationship

Özbey (2001) developed an empirical attenuation relationship for estimating peak horizontal acceleration (PHA) using an un-weighted one-stage regression analysis. A data set based on earthquakes from northwestern Turkey earthquakes, most of them recorded after the 17 August 1999 main shock, was used in the regression analyses. Magnitude and distance were used as independent variables.

Inherently the relationship is applicable to strike-slip earthquakes. Strong-motion records with fault-distances greater than 200 km were drawn out of the data set. The data set used has 14 B-class, 78 C-

class, and 449 D-class (NEHRP Site Classification) records. Events with magnitudes equal to 4.0 or greater were used in the regression analyses. Because of the limitations of magnitude scales, duration magnitude was used for the events with magnitude equal to 6.0 or less, and moment magnitude for the 17 August 1999, Kocaeli (Mw=7.4) and the 12 November 1999, Düzce (Mw=7.2) mainshocks. The closest horizontal distance to the vertical projection of the fault-rupture (the "Joyner-Boore distance") was used for the 17 August 1999 and the 12 November 1999 main shock records, and epicentral distance for the other records in the data set. For small magnitude crustal earthquakes the source distance is close to the epicentral distance, with an uncertainty not normally larger than that associated with the determination of the epicenter.

Regarding all the facts listed above, the attenuation model is valid for $M \geq 4.0$ strike-slip events and NEHRP D-class soil sites.

The Özbey (2001) PGA attenuation is given as follows:

$$\log(a) = -2.6517 + 0.4524\ M - 0.986\ \log(R^2+h^2)^{1/2}$$
with h=7

where "a" is the peak horizontal acceleration in *g*, "M" is the moment magnitude, and "R" is the closest distance to the surface projection of the fault rupture in km, and "h" is a parameter that accounts for the saturation with distance and the fact that the source of peak motion is not necessarily the closest point on the surface projection of the fault, or from the epicenter. The standard deviation (σ) of the equation is 0.3576.

The attenuation relationship that includes the anelastic attenuation is given by the following expression:

$$\log(a) = -2.5491 + 0.4501\ M - 0.00056\ (R^2+h^2)^{1/2} - 1.0622(R^2+h^2)^{1/2}$$

where h=7

The standard deviation (σ) is equal to 0.3578.

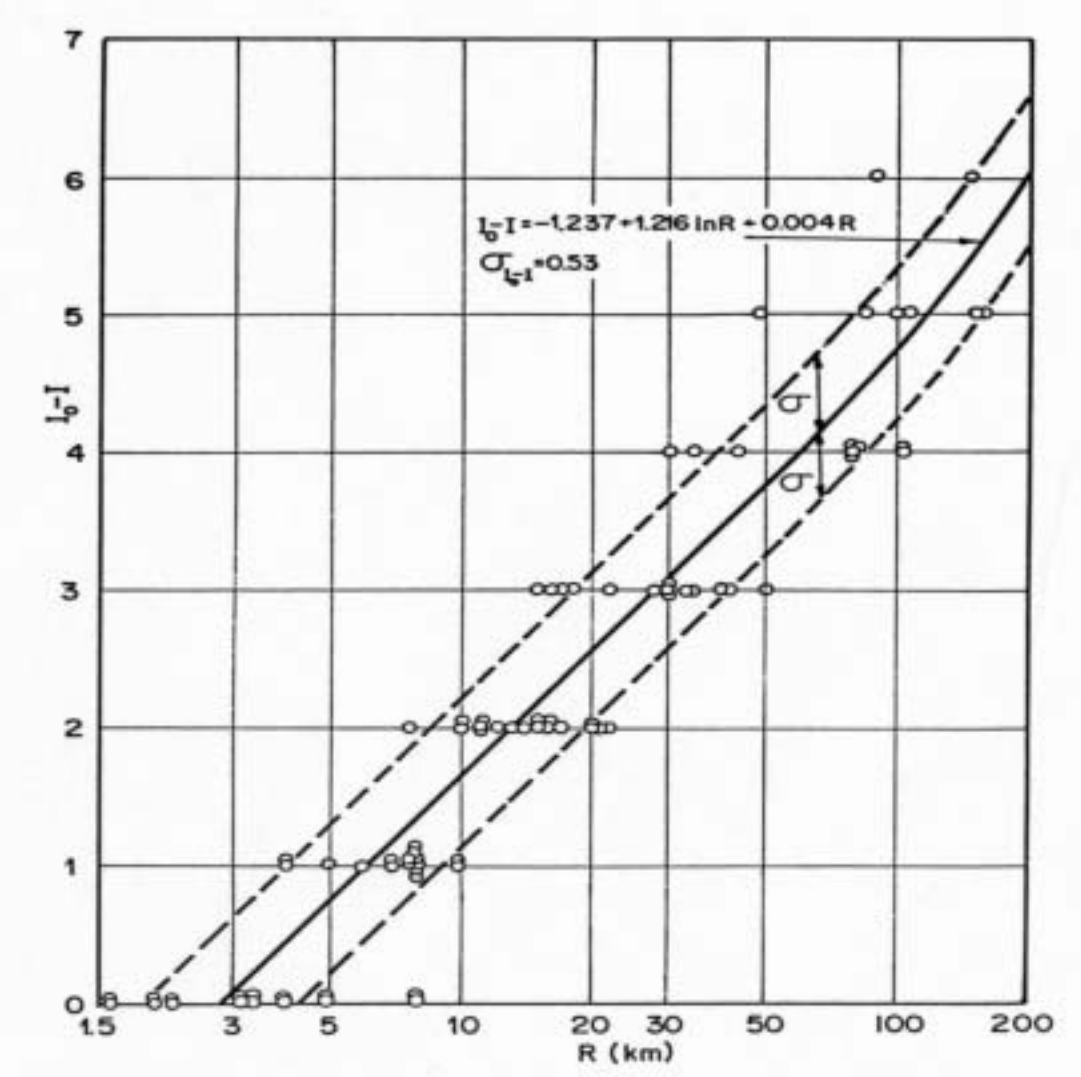

Figure A.2. 1. Attenuation of intensity in transverse direction to NAF (Erdik and Eren,1983)

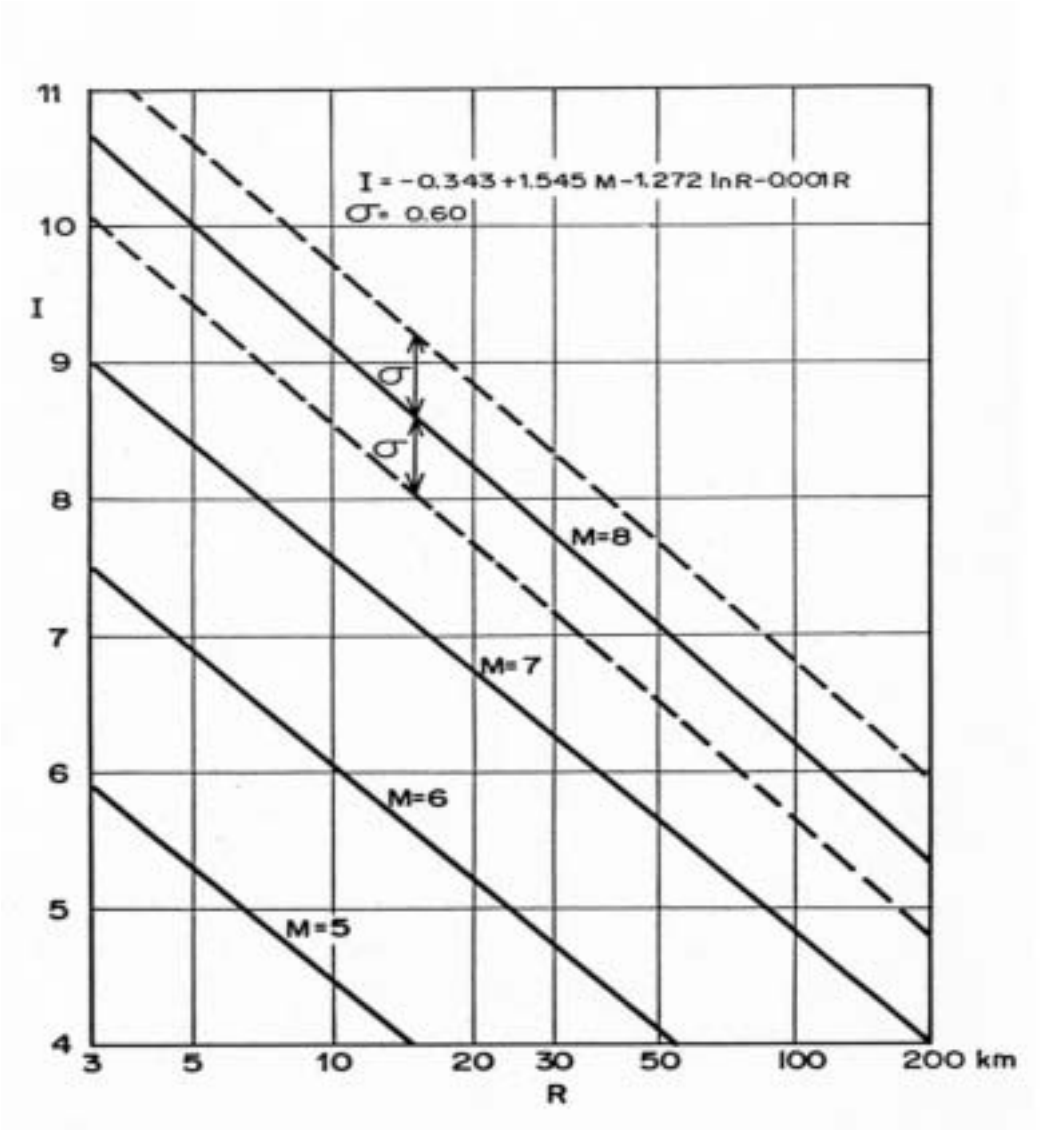

Figure A.2. 2**.** Attenuation of intensity in transverse direction to NAF (Erdik and Eren,1983)

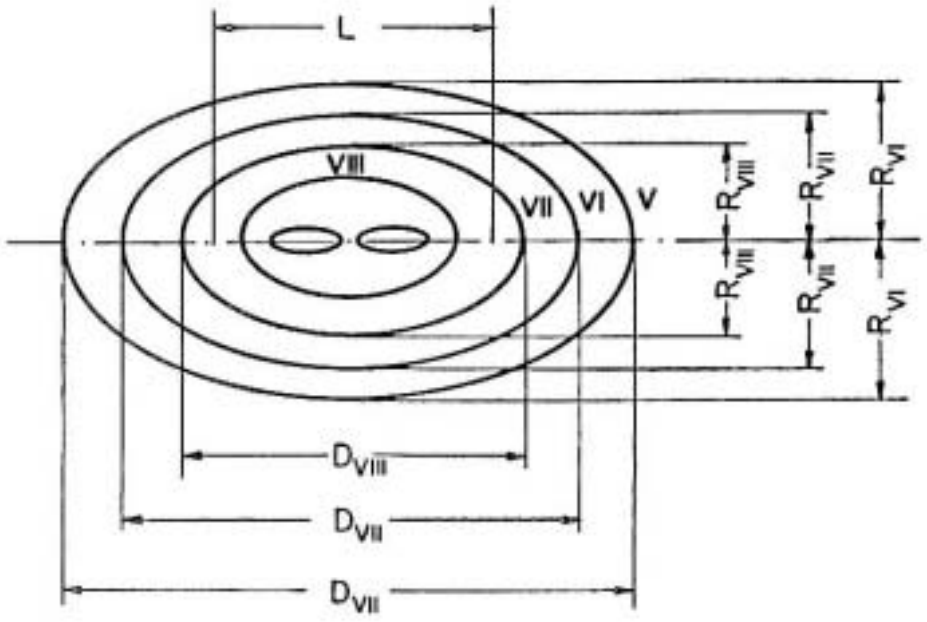

Figure A.2. 3. Idealized isoseismal map(Erdik and Eren,1983)

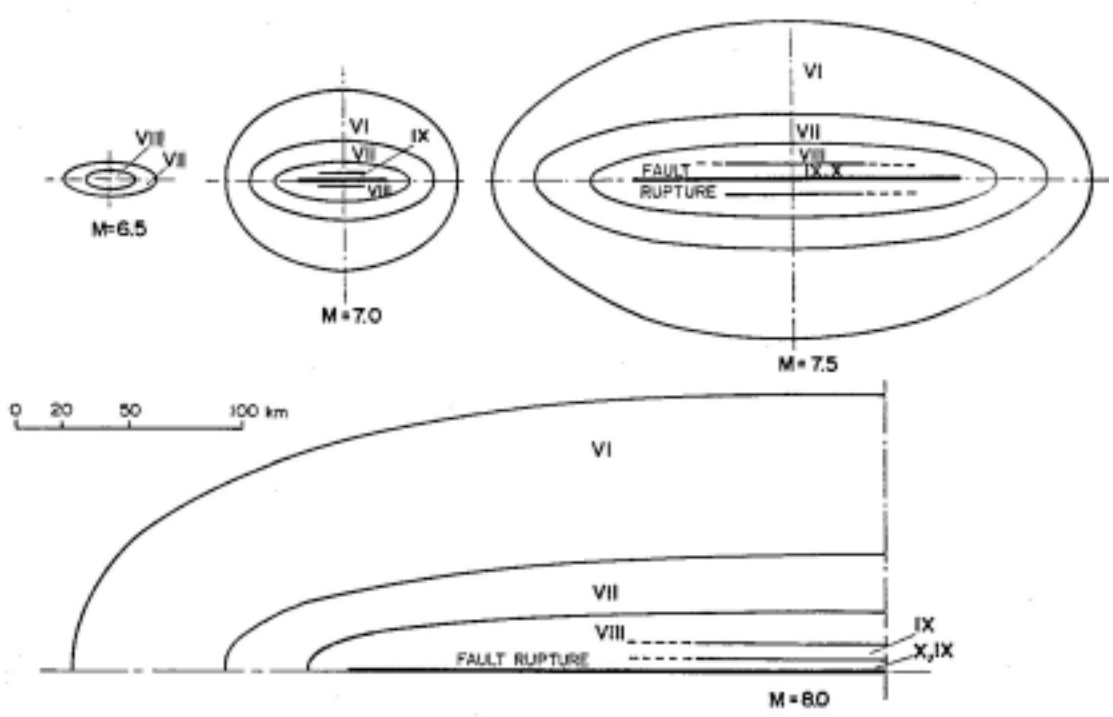

Figure A.2. 4. Theoretical isoseismal maps associated with NAF for different magnitude earthquakes (Erdik and Eren, 1983)

REFERENCES

Erdik, M. and U. Eren (1983), Attenuation of Intensities for Earthquake Associated with the North Anatolia Fault, Report prepared for Turkish Electricity Authority- Nuclear Power Plants Division, METU-EERC, Ankara

APPENDIX 3

EARTHQUAKE LOSS QUESTIONNARISE AND DATABASE

Appendix.3. EARTHQUAKE QUESTIONNAIRE

I. **GENERAL INFORMATION ABOUT THE INDUSTRIAL FACILITY**

- Name :……
- Address :……
- Postal Code :…… Coordinates: ……..North …… East
- Industrial Sector * :……
- Total Annual Revenue :…….. US$
- Total Land Area :…….. m^2 Total Covered Area :……m^2
- Total Number of Employees :……
- Soil Type : ☐Rock ☐ Stiff Soil ☐Loose Soil
- Construction Period : ☐pre 1960 ☐ 1961-1970 ☐1971-1980 ☐1981-1990 ☐1991-2000

II. PROPERTY DAMAGES

- Did you have a PD insurance? ☐Yes ☐No
- Which of the following damages have you suffered?

	Loss Amount	*Total Replacement Value*
• Building:	…….. US$	……. US$
• Machine and Equipment:	…….. US$	……. US$
• Stock:	…….. US$	…….. US$

- None: ☐

III. BUSINESS INTERRUPTION

- Did you have a BI insurance? ☐Yes ☐No
- Did you suffer any BI loss? ☐Yes ……US$ ☐No
- Which of the following damages were the direct cause of the BI?
  ☐Building ☐Machine and Equipment ☐Stock ☐Human
- Which of the following damages were the in-direct cause of the BI?
  ☐Customer ☐Supplier ☐Infrastructure ☐Other :……

IV. MISCELLENEOUS INFORMATION

- Did you suffer any fire/explosion damage following the earthquake? ☐Yes ☐No

What is the percentage of the financial loss due to fire/explosion? ……%

Please describe the damage ……

……

……

- How long did it take to recover to the normal operation? …… days

Could the down-time be less? (Please describe)……

- Did you have any of the following plans at hand?
  ☐Evacuation ☐Contingency ☐Crisis Team ☐Disaster ☐None

Did you suffer any non-insurable losses (i.e. loss of market share) ? (Please describe)

……

……

(*) :Please refer to the industry classification list provided.

V. INFORMATION ABOUT THE BUILDINGS

Please provide this information for each building in your facility

Name of the building: _____

- Function of the Building:
  ☐ Manufacturing ☐ Retail ☐ Warehouse ☐ Office ☐ Others :……
- Number of similar buildings :……
- Building Type:
  ☐ Reinforced Concrete ☐ Steel ☐ Prefabricated ☐ Masonry ☐ Composite*
- Number of stories (excluding the basement) ☐ 1-3 ☐ 4-7 ☐ >8
- Height of the building (above ground level) ☐ <10m ☐ 10-20m ☐ >20m
- Design Period: ☐ <197☐ 1975-1998 ☐ >1998
- Building Damage Level:**
  ☐ None ☐ Slight ☐ Moderate ☐ Heavy ☐ Total Collapse

Please describe the damage ……

……..……

……..……

……..……

……

- Damage to Machinery and Equipment: ☐ Yes (Please describe the damage) ☐ No

……..……

……..

……...

……..

……

- Damage to Stock and Storage: ☐ Yes (Please describe the causes of damage) ☐ No

……..……

……..……

……..……

……..……

……..

(*) :Composite, i.e. such as prefabricated columns used with a steel construction roof

(**) :Please refer to the attached damage photos

VI. DAMAGE TO OTHER FACILITIES

(such as free standing Machine and Equipment groups, stock in open spaces etc.)

Please provide this information for each group of M&E and/or stock

- Description ……..
- Type ☐Machine and Equipment ☐Stock
- Please describe the damage

……..……

……..……

……..……

……..……

……..……

……..

Table 3.1 Questionaire Date Base

Industrial Sector	Locality	Intensity MSK	Annual Turnover USD	No of employees	Total Area m2	Covered Area m2	Soil type	Construction Period	Direct Damage, USD Building	Machine&Equipment	Stock	Business Interruption USD	Fire Following Earthquake
Tire Production	Kullar Izmit	IX	-	535	171 263	64 309	soft soil	1961-1970	220 000 / -	180 000 / -	60 000 / -	1 380 000	no
Tire Production	Beşköprü Adapazarı	IX		900	324 047	88 504	soft soil	1961-1970	528 000 / -	154 000 / -	3 829 000 / -		no
Chemical	Körfez Kocaeli	IX	123 400 000	781	187 913	86 811	soft soil	1971-1980	6 670 000 total damage			67 000 000	no
Electrical Equipment	İzmit	IX	101 755 000	409				1981-1990	236 000 / -	-	10 745 / -	yes	no
Paper and paper products	Kullar Izmit	IX	80 000 000	330	424 500	92 500	soft soil	1961-1970 / 1981-1990	1 507 862 / -	185 453 / -	843 700 / -	yes	no

Table 3.1. Questionaire Date Base(Cont)

Industrial Sector	Locality	Intensity MSK	Annual Turnover USD	No of employees	Total Area m2	Covered Area m2	Soil type	Construction Period	Direct Damage, USD Building	Machine&Equipment	Stock	Business Interruption USD	Fire Following Earthquake
Paper and paper products	Dilovası Kocaeli	VIII	30 600 000	144	59 196	21 500	soft soil	1961-1970	1 279 000 / -	-	-	70 000	no
Petrochemicals	Yarimca	IX	70 000 000	75	18000	500	stiff soil?	1981-1990	0.4 %	0.5 %	0%	125 000	no
Food	Gebze	XIII	35 000 000	47	32 965	7000	soft soil	1981-2000	1%	0%	11%	800 000	no
Petrochemicals	Körfez	IX	60 000 000	90	34 500	8 800	soft soil	1981-1990	35%	1.14 %	1.8 %	2 000 000	no
Plastic Products	Akyazi	IX	21 981 000	160	63 500	5 500	soft soil	1991-2000	1%	6.7%	7.6%	1 942 648	yes

Table 3.1. Questionaire Date Base(Cont)

Industrial Sector	Locality	Intensity	Annual	No of	Total	Covered	Soil type	Construction	Direct Damage, USD			Business	Fire
		MSK	Turnover	employees	Area	Area		Period	Building	Machine&Equipment	Stock	Interruption	Following
			USD		m2	m2						USD	Earthquake
	Adapazarı												
Onduline	Sapanca	VIII	20 000 000	176	113 000	-	soft soil	1971-1980	3.7 %	1.2%	2.5 %	865 496	no
Paper and paper products	Bursa	VI	6 000 000	78	8 000	6 500	soft soil	1991-2000	3 800 / -	no damage	no damage	180 000	no
Metal Products	Izmit	IX	70 000 000	113	110 000	21 000	stiff soil	1991-2000	63%	9.8 %	77%	7 600 000	yes
Cement	Darica	VIII	49 628 000	196	1 600 000	-	stiff soil	pre 1960	3.5 %	0.4 %	0%	1 200 000	no
Electrical Equipment	Haramidere Istanbul	VII	50 804 643	600	-	19 000	stiff soil	1991-2000	rented	510 947 / 510 947	4 641 748 / -	130 753	no
Metal Products	Izmit	IX	96 573 695	485	91 411	50 000	soft soil	1981-1990	1 471 596 / -	215 592 / -	20 950 / -	2 360 487	no

Table 3.1. Questionaire Date Base(Cont)

Industrial Sector	Locality	Intensity MSK	Annual Turnover USD	No of employees	Total Area m2	Covered Area m2	Soil type	Construction Period	Direct Damage, USD Building	Machine&Equipment	Stock	Business Interruption USD	Fire Following Earthquake
Hygiene products	Istanbul	VI	98 551 565	260	16 322	11 208	soft soil	1981-1990	380 200 /-	none / -	none / -	1 000 000	no
Petrochemicals	Derince	IX	-	87	119 000	-	soft soil	1961-1970	81 299 / -	95 122 / -	157 565 / -	yes	no
Glass and glass products	Gebze	XIII	-	530	800 000	200 000	soft soil	pre 1960	-	-	2 554 626/ -	yes	no
Textiles	Adapazari	IX	3 012 942	200	7154	5100	soft soil	1991-2000	1 869 700 / -	528 620 / -	487 740 / -	1 000 000	no
Paper and paper products	Yalova	IX	80 000 000	350	-	-	soft soil	1981-1990	25%	- / -	-/ -	3 000 000	no
Food	Düzce	IX	50 000 000	185	-	-	-	-	1.3 %	0.2 %	no / 31 765 000	100 000	no

Table 3.1. Questionaire Date Base(Cont)

Industrial Sector	Locality	Intensity MSK	Annual Turnover USD	No of employees	Total Area m2	Covered Area m2	Soil type	Construction Period	Direct Damage, USD Building	Machine&Equipment	Stock	Business Interruption USD	Fire Following Earthquake
Chemical	Adapazari	IX	15 368 639	73	104 618	10 500	soft soil	1991-2000	44%	12%	14%	yes	no
Energy	İzmit	IX	40 000 000	50	20 585	5 800	soft soil	1991-2000	350 000 / -	400 000 / -	no	no	no
Beverages	Bursa	VI	-	200	69 270	31 224	stiff soil	1991-2000	10%	0%	no	-	no
Beverages	Yenibosna Istanbul	VI	-	200	30 000	14 000	soft soil	1981-1990	50 000 / 12 931 226	- / 18 964 424	-	-	no
Beverages		VI	-	200	120 000	45 000	stiff soil	1991-2000	0.9%	0.004%	15 075 / -	-	no
Steel products	Izmit-Köseköy	IX	50 000 000	301	136 015	-	soft soil	1981-1990	6 500 000 / -	600 000 / -	27 000 / -	1 400 000	no
Petrochemicals	Yarimca	IX	-	1386	1 250 000	-	stiff soil	1961-1980	4 795 059 / -	1 129 000 / -	778 000 / -	-	no
Automotive	Arifiye Sakarya	IX	121 149 000	505	86 085	30 500	soft soil	1991-2000	22 600 / -	158 200 / -	90 400 / -	yes	no
Machinery	İzmit	IX	4 300 000	100	52 262	23 553	soft soil	1961-1970	51 000 / -	245 000 / -	no / -	75 000	no

Table 3.1. Questionaire Date Base(Cont)

Industrial Sector	Locality	Intensity	Annual	No of	Total	Covered	Soil type	Construction	Direct Damage, USD			Business	Fire
		MSK	Turnover	employees	Area	Area		Period	Building	Machine&Equipment	Stock	Interruption	Following
			USD		m2	m2						USD	Earthquake
Steel products	İzmit	IX	1 600 000	35	15 000	1 150	-	1991 -2000	83 000 / -	53 000 / -	- / -	-	no
Automotive	İzmit	IX	-	140	17 200	7 000	stiff soil	1991-2000	19 000 / -	no / -	- /-	yes	no
Steel products	Gebze	VIII	6 000 000	195	9682	4319	stiff soil	1991-2000	1 000 / -	no / -	no / -	no	no
Steel Products	İzmit	IX	1 366 222	50	28 000	5 000	soft soil	1991-2000	85 225 / -	1 700 / -	8 120 / -	-	no
Food	Kosekoy Izmit	IX	100 000 000	325	132 000	16 000	stiff soil	1991-2000	- / -	- / -	- / -	5 000 000	no
Chemical	Tavsancil Gebze	VIII	-	95	200 000	2 000	soft soil	1961-2000	20 000 / -	_ / -	- / -	no	no
Automotive	Muallim koyu Gebze	VIII	385 000	46	3950	3580	stiff soil	1991-2000	250 000 / -	- / -	- / -	60 000	no
Plastic Products	Gebze	VIII	24 252 000	1000	25 000	14 502	stiff soil	1981-2000	17 921 / -	3680 / -	- / -	800 000	no
Automotive	Çayırova Gebze	VIII	18 000 000	280	30 000	10 000	-	1961-1970	600 000 / -	- / -	- / -	no	no
Plastic Products	Çayırova Gebze	VIII	30 000 000	223	19 000	10 000	soft soil	1991-2000	85 000 / -	- / -	- / -	no	no
Plastic Products	Gölcük	X	300 000	18	1 200	1 000	stiff soil	1971-1980	300 000 / -	15 000 / -	5 000 / -	-	no

Table 3.1. Questionaire Date Base(Cont)

Industrial Sector	Locality	Intensity	Annual	No of	Total	Covered	Soil type	Construction	Direct Damage, USD			Business	Fire
		MSK	Turnover	employees	Area	Area		Period	Building	Machine&Equipment	Stock	Interruption	Following
			USD		m2	m2						USD	Earthquake
Chemical	Körfez	IX	6 000 000	304	74 392	44 024	stiff soil	pre 1960	30 000 / -	30 000 / -	100 000 / -	100 000	no

Table 3.1.. Questionaire Date Base (Right Part) (Cont)

Industrial Sector	Locality	Time to normal operation,days	Loss of market	Insurance		Reasons for business interruption	Damage Description
				Property damage	Business Interruption		
Tire Production	Kullar Izmit	10	15%	no	no	building machine&equipment customer	Cracks and partial collapse of the infll walls of the steel production building Damage to piping, movement of machines In the prefabricated RC storage building there was damage in the beam-column connections products became unusuable due to debrıs and dust.
Tire Production	Beşköprü Adapazarı	15	15%	no	no	building machine&equipment human customers	Column damage and collapse of exterior walls in the RC-steel production building Collapse of interior and exterior partition walls in the steel production/storage building Loss of stock due to the collapse of walls and dust and debris. Sliding of the foundation of the oil tank, damage to underground piping.
Chemical	Körfez Kocaeli	352		yes	no	building machine&equipment supplier	In the RC packaging building damage to column-beam-slab connections, fall of plaster in some infill walls In the RC office building 1-2mm cracks in beam-column connections, fall of plaster In the RC storage building damage to columns; cracks in the column heads near the roof truss support damage to the conveyor system in the storage building In the raw material storage building, fall of some roof beams due to damaged column head-roof truss connections and associated damage to the roof cover In the RC production building damage to beam-column connections The 4-storey RC administration building sustained heavy damage RC residential buildings sustained medium damage Some process equipments were damaged in their anchorages In the port cracks in the concrete slab, damage to the pile heads
							An expert report suggests a larger freeboard for the tanks and point out improper anchorage of vertical vessels

Table 3.1.. Questionaire Date Base (Right Part) (Cont)

Industrial Sector	Locality	Time to normal operation,days	Loss of market	Insurance Property damage	Business Interruption	Reasons for business interruption	Damage Description
Electrical Equipment	İzmit	48	-	yes	yes		In the composite production building widespread cracks, wide cracks in the chimney and water tower, misalignment of machines, damage to the bulb stock.
Paper and paper products	Kullar Izmit	74 for part 1 20 days for part 2	no	yes	no	building	11 RC prefabricated storage buildings and 1 prefabricated garage building completely collapsed 1 RC prefabricated building is heavily damaged. Walls of one storage building is damaged due to the toppling of paper rolls. The final product storage building in part 1 is heavily damaged. In part 2 infill walls are damaged, roof truss is damaged. Storage racks are largely damaged. Production equipment damaged due to toppling and sliding. Raw material used in production was lost as a result of building damage.
Paper and paper products	Dilovası Kocaeli	3	no	yes	no	human	In the 2 RC administration buildings fall of plaster, cracks less than 1 mm wide. In the RC prefabricated production building cracks in teh beams, damage to the beam-column connections, roof damage.
Petrochemicals	Yarimca	60	-	yes	yes	stock, supplier	Fall of plaster and some cracks in the administration building Fall of plaster in the RC in the power and guards building Supports of spherical tanks damaged and strengthened by adding bracings after the earthquake Damage to the foundations of spherical tanks, concrete pulverized. Concrete slabs in the open spaces were damaged. Damage to the foundation of the water tank. Damage in water channel.
Food	Gebze	7	yes	yes	yes	building machine&equipment stock	In the composite office building fall of plaster and damage to the infill walls. Stock damage due collapse of one storage building in Gölyaka

Table 3.1.. Questionaire Date Base (Right Part) (Cont)

Industrial Sector	Locality	Time to normal operation,days	Loss of market	Insurance Property damage	Business Interruption	Reasons for business interruption	Damage Description
						human	
						lifelines	
Petrochemicals	Körfez	15	yes	yes	yes	building	In the steel storage building heavily damaged racks and associated product loss
							In the steel production building cracks in the infill walls and floor slab, misalignment of machine & equipment
						stock	
						customers	In the masonry office building cracks in the walls, partial collapse of some walls.
							Damage to the tanks
Plastic Products	Akyazi Adapazarı	47	-	yes	yes	machine&equipment	Machine & equipment and raw material in the composite production building is damaged as a result fire
							In the same building collapse of partition walls
							In the prefabricated office building there is damage to the roof cover
Onduline	Sapanca	14	no	yes	yes	building	In the composite production building damage to the infill walls and beams due to the collapse of a nearby chimney.
						machine&equipment	Damage to the machine&equipment and raw materials in this part of the building.
						stock	In the RC storage building major cracks in the beam-column connections and deformed bars.
							In the composite production building damage in floor slab due to diffrential settlement, seperation of walls from the frame, cracks in the infill walls.
						human	
						supplier	In the Rc administration building cracks in the beam-column joints and infill walls.
						lifelines	In the steel storage building doors are misaligned and bended
							Toppling of stocks, damage to the foundations of the tanks
Paper and paper products	Bursa	none	no	yes	yes	customers	In the composite production building crack in one column
							Cracks in the water channel
Metal Products	Izmit	21	-	yes	yes	building	In the steel buildings used for production, storage and administration, cracks in the infill walls, total collapse of infill walls in some portions due to the weight of the raw material
						machine&equipment	Sliding of machine &equipment, bending in metal parts,
						stock	Complete loss of stock due to toppling and moisture.
						supplier	Damage in the tanks for chemical storage, acid spill-out
						lifelines	
Cement	Darica	17	no	yes	yes	building	Masonry main office building containing the control room as well had cracks in its walls and had to be strengthened.
						machine&equipment	
						customers	

Table 3.1.. Questionaire Date Base (Right Part) (Cont)

Industrial Sector	Locality	Time to normal operation,days	Loss of market	Insurance Property damage	Business Interruption	Reasons for business interruption	Damage Description
						lifelines	
Electrical Equipment	Haramidere Istanbul	16	no	yes	no	building	Rented RC production building collapse completely.
						machine&equipment	Associated complete loss of machine&equipment and stocks.
						stock	Complete loss of four transportation trucks as a result of building damage.
Metal Products	Izmit	38	yes	yes	yes	building	In the RC office building, one corner column damaged, heavy damage in the infill walls, widespread fall of plaster, shear cracks in some columns
						lifelines	In the RC cafeteria building cracks in columns and floor slabs, widespread cracking in the infill walls, cracks in the beams.
							In the RC maintanence building cracking in the columns, cracks in the infill walls.
							In the RC storage building heavily damaged
							In the steel production building damage to welding, breaking of rivets, buckling of braces, damage to the bolts in column-foundation connections, damage to the roof truss due to bending of elements, damage to the crane and its railing
							Collapse of one portal crane, the second deformed in one of its legs.
							Silo toppled, damaged piping, racks toppled damaging stored parts.
							Damage to peripheral walls
Hygiene products	Istanbul	2.5	-	yes	yes	building	In the two composite production buildings damage to the columns
						human	In the two RC adminisitration buildings cracks in the walls
Petrochemicals	Derince	7	no	yes	no	building	In the RC production buildings, damage to the roof truses, cracks in the infill walls, cracks in beams and columns
						machine&equipment	Two ports became unusuable
						stock	Sliding of machine and equipment, associated piping damage
						human	RC supports of tanks damaged,
						supplier	Piping to the port completely damaged.
						lifelines	All stock completely lost
Glass and glass products	Gebze	4	-	yes	no	building	In the RC storage buildings cracks in columns and walls
						machine&equipment	Chimney damaged, had to be demolished.
						human	In several RC buildings cracks in the beams, fall of plaster
						supplier	In production buildings cracks in RC beams, columns and walls
						lifelines	In the RC office buildings cracks and fall of plaster in walls
							Major loss of stock.

Table 3.1.. Questionaire Date Base (Right Part) (Cont)

Industrial Sector	Locality	Time to normal operation,days	Loss of market	Insurance Property damage	Business Interruption	Reasons for business interruption	Damage Description
Textiles	Adapazari	in 2000 still no oper.	yes	yes	no	building	Prefabricated main production building, housing storage areas and offices completely collapsed.
						machine&equipment	Complete loss of machine and equipment, raw material and stock.
Paper and paper products	Yalova	50	yes	yes	yes	building	In the two production buildings beam damage, cracks in walls, damage in the RC supports of the roof truss, damage in the supports of mobile cranes, equipment damage due to fall of RC roof cladding.
						machine&equipment	In the workshop, roof collapse, heavy damage in the walls, all equipment lost accordingly.
							In trafo building medium damage
							In the warehouse for chemicals, cracks in the walls
							In the RC administration building damage in the ground floor, cracks in frame and walls.
Food	Düzce	15	-	yes	yes	building	RC production building slightly damaged, cracks in plaster, crack in one column
						machine&equipment	RC administration building heavily damaged, widespreadand serious cracking in beams, columns and walls, plastic hinges.
							Food processing unit was broken due to shaking, had to be repaired.
Chemical	Adapazari	150	no	yes	no	building	RC administration building heavily damaged
							In the composite production building, precast column damage.
							In the composite warehouse steel roof truss collapsed, causing heavy damage in columns.
							In the composite production building heavy damage in the members of the steel roof truss. Some columns damaged.
							Tanks sustained damage in their RC foundations in form of cracks
Energy	İzmit	24	-	yes	no	machine&equipment	RC production building slightly damaged.
							Some damage in machine&equipment, details not given
Beverages	Bursa	-	-	yes	yes	building	In the RC administration building cracks in plaster in some walls, slight cracking in one column.
							Prefabricated storage building swayed, hinges in some column tops
							In the garage seperation of walls from frame, displaying collapse risk.
Beverages	Yenibosna Istanbul	-	-	yes	yes	building	In the precast storage and production buildings cracks in the walls
							In the RC adminsitration building cracks in walls, damage in suspended ceilings
Beverages		-	-	yes	yes	building	In the prefaricated production+office+storage building cracks in walls, suspended ceiling damage, cracks in floor slab-wall connections.
						machine&equipment	Some movement of equipment, deformation in aluminum cable channels.
							Damage to stock due to toppling, cracking, breaking.
Steel products	Izmit-Köseköy	30	yes	yes	yes	machine&equipment	RC office building cracks in plaster; cracks in four beams, misalignment of some equipment

Table 3.1.. Questionaire Date Base (Right Part) (Cont)

Industrial Sector	Locality	Time to normal operation,days	Loss of market	Insurance Property damage	Business Interruption	Reasons for business interruption	Damage Description
						lifelines	In prefabricated production building nine beam-column connection failure im nine cases, cracks in nine columns
							Cracks in the pedestal of the mechanical weighing equipment in the production building
							In the RC warehouse thin plaster cracks; stocks and racks damaged due to toppling; damage in piping of fire and airconditioning systems
							RC chemical treatment building slight cracking in plaster
Petrochemicals	Yarimca	80	-	-	no	-	
Automotive	Arifiye Sakarya	12	no	yes	no	machine&equipment	In the composite production building cracks < 1mm in the RC parapet walls
Machinery	İzmit	180	yes	no	no	building	In the composite production building beam-column system damaged heavily.
						human	Cranes derailed, misalignment of rails.
							Cracks in the office building
Steel products	Gebze	1	yes	yes	no	building	Some cracks and fall of plaster in buildings
						customers	
Steel Products	İzmit	10	yes	yes	yes	building	cracks in walls of masonry production building
						lifelines	Prefabricated production building collapsed completely, damaging all machine and equipment and causingheavily stock losses.
							Toppling of machine and equipment, stock damage
Steel products	İzmit	180	-	no	no	building	RC office building heavily damaged due to pounding with the adjacent steel production buildingand had to be demolished
						human	In the steel production building damage to roof and wall covers, cracks in brick infill walls, occasional collapses damaging nearby equipment
							Computer systems fell of desks,
Automotive	İzmit	15	yes	yes	yes	building	RC office and production building medium damaged, partial damage in heating system and piping for water.
						customers	
Food	Kosekoy Izmit	90	yes	yes	yes	building	Prefabricated production+storage+office building: partial roof collapse, all infill walls either cracked or collapse, damaging nearby equipment, minor cracking in colmuns, complete loss of susended ceilings, stock damage due to collapse of racks.
						machine&equipment	Wastewater treatment plant: minor cracking in columns and pools
						customers	Tank collapse, associated piping damage and damage in nearby equipment

Table 3.1.. Questionaire Date Base (Right Part) (Cont)

Industrial Sector	Locality	Time to normal operation,days	Loss of market	Insurance Property damage	Business Interruption	Reasons for business interruption	Damage Description
Chemical	Tavsancil Gebze	1	-	yes	yes	-	RC Production building, shear cracks in infill walls
Automotive	Muallim koyu Gebze	21	yes	yes	no	building customers	In the RC production building cracks in columns in beams.
Plastic Products	Gebze	10	yes	yes	no	machine&equipment financing	In the RC office building suspended ceiling damage, cracks in infill walls. Piping damage in the cooling water system, welding damaged at pipe connections, had to be replaced.
Automotive	Çayırova Gebze	3	yes	no	no	machine&equipment lifelines	In the RC office building shear cracks in outer columns, hinges in beam-column connections, cracking of infill walls In the steel production building minor seperations in bracings
Plastic Products	Çayırova Gebze	1	no	yes	yes	machine&equipment lifelines	Steel production building swayed 10 degrees
Plastic Products	Gölcük	30	-	no	yes	building customers lifelines	Cracks and breaks in columns, minor damage in equipment due to shaking
Chemical	Körfez	151	-	yes	no	machine&equipment	Loss of acid due to splashing in tanks Generally light damage in buildings

The original files are also provided in excel format