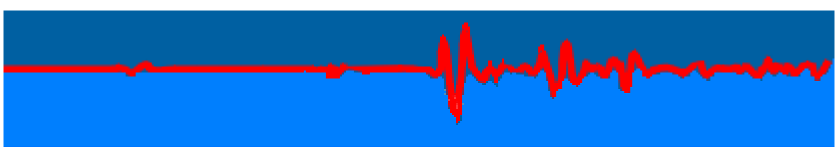
AKINCI HEPP

SEISMIC RISK ASSESSMENT



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SİAL YERBİLİMLERİ ETÜT VE MÜŞAVİRLİK LTD.ŞTİ.

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PROJE	**AKINCI HEPP-SEISMIC RİSK ASSESSMENT**
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1 INTRODUCTION AND PURPOSE

The purpose of this report is to determine the earthquake risk of **Akıncı HEPP (Hydroelectric Power Plant)** site which is planned to be built in Kelkit Valley in order to generate electric energy near Reşadiye town of Tokat city. The project site is located on 1.st degree of earthquake zone according to Turkish Earthquake Regionalization Map. The North Anatolian Fault is located very near at the project site which is known one of the most active faults in the world. Meanwhile, the Erba earthquake which occurred in 1942 at the middle part of North Anatolian Fault registered as M=7.0. Epicenter distance of this earthquake is 32 km to the project site.

Therefore, possible earthquake movements that may affect the project area in the future time periods are determined through an Earthquake Risk Analysis taking in the consideration the maximum magnitude of M = 8.5 for earthquake source (L-1).

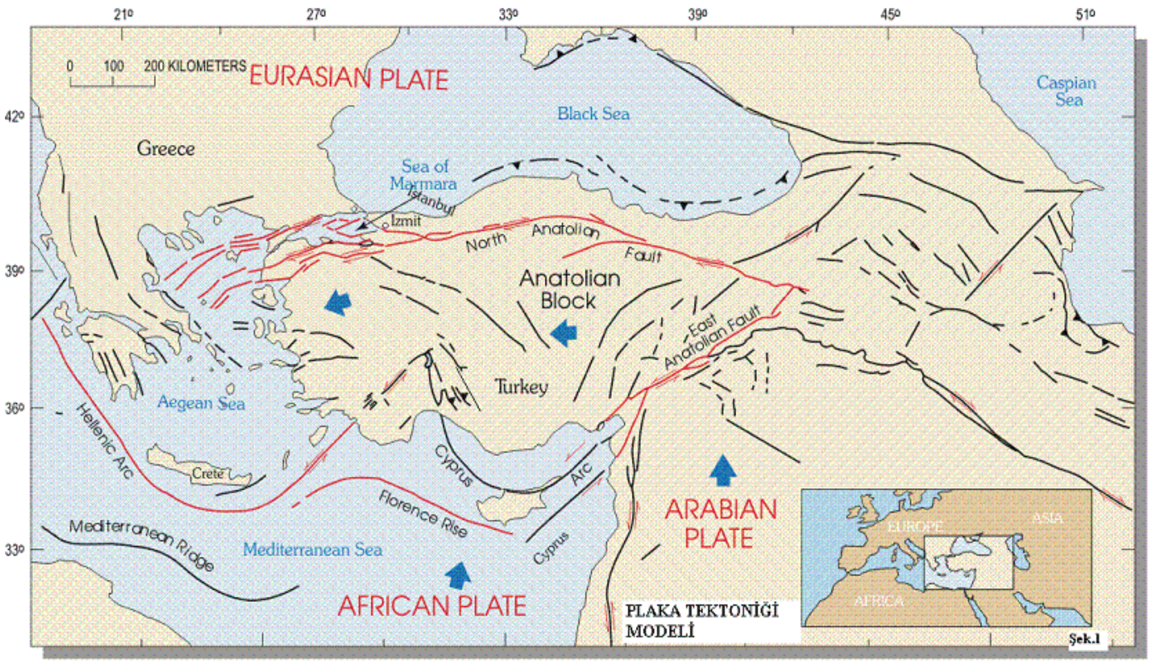
In this report, the earthquake risk of Akıncı **HEPP** site is calculated on the basis of probabilistic and deterministic methods and the selection of the earthquake parameters to be taken in the engineering project is made possible.

2 SEISMOTECTONIC CHARACTERISTICS OF TURKEY

It is well known fact that many earthquakes have been occurred in Turkey which located in Alpine-Himalayan seismic belt. Turkey is surrounded by three macro-plates i.e. Eurasian Plate, Arabian Plate and African Plate as shown in Figure 2.1 (Mc.Kenzie and Dewey). Moreover some micro-plates such as Agean Plate, Anatolian Plate, Black Sea Plate and Iran Plate are located in Turkey surrounded by three macro plates which mentioned above.

Fault developments and earthquake occurrences take place as the result of mutual relative movements among the micro and macro plates.

Figure 2.1: Turkey Tectonic Map and Surrounding Plates



Nearly 1170 strong earthquakes occurred in Anatolia in the historical period given by historical sources. (H.Soysal, 1981). Based on the instrumental data between the years 1903-2007, total 175 strong earthquakes occurred in Anatolia which caused a lot of damage and lost of life.

Some of them which occurred in last 20 years are given below:

Bala-2007 (M=5.9), Sivrice-2007 (M=5.9), Karlıova-2005 (M=5.9), Pülümür-2003 (M=6.1), İzmir-Urla-2003 (M=5.7), Bingöl-2003 (M=6.4), Sultandağı-2002 (M=6.4), Çankırı-Orta-2000 (Ms=5.9), Düzce-1999 (Mw=7.2), İzmit Körfezi-1999 (Mw=7.4), Adana-Ceyhan-1998 (Ms=6.3), Afyon-Dinar-1995 (Ms=6.0), and Erzincan-1992 (Ms=6.9))

Numbers of earthquakes (Ms > 5.5) that occurred in the last century in Anatolia are listed in below table (R.Demirtaş, R. Yılmaz; 2000).

Table 2.1: Number of Earthquakes (Ms > 5.5) that occurred in last century

Main Tectonic Belts	**Earthquake Numbers**
North Anatolian Fault	34
East Anatolian Fault	10
Aegean Graben System	33
East Anatolian Contractional Province	22
Cyprus-Hellenic Arc	13
Central Anatolian Ova Province	4
Black Sea Region	2

Project site of **Akıncı HEPP** is mainly under the effect of North Anatolian Fault. Because of this reason comprehensive information is given below for North Anatolian Fault (R.Demirtaş, R. Yılmaz; 2000).

The North Anatolian Fault

The North Anatolian fault is one of seismically very active fault in the world. Although initiation and termination points of the fault are controversial, it has been accepted that the fault starts near the Karlıova to the east where the East Anatolian fault meets, making a curvature outward in the central part and continues to the western end of the Mudurnu Valley segment. At this point it divides into two strands. The northern strand called İzmit-Sapanca fault extends from Sapanca Lake through the northern part of the Armutlu Peninsula toward inside the Marmara Sea. Here, it makes some steps forming troughs like a kind of pull-apart basin. It appears again on the land near Mürefte, continuing along the Saros Bay and then enters the Aegean Sea. The southern branch called İznik-Mekece fault runs from

Geyve through Mekece and passing south of İznik Lake to Gemlik Bay. It goes into the Marmara Sea, appearing near the Bandırma Bay and cutting the Kapıdağ Peninsula, continues in the Biga Peninsula and then enters the Aegean Sea. Consequently, total length of the fault is approximately 1000 km. The fault trace has 100m to few kilometers width to the east, whereas it widens up to 5 km in the west. In general, while the fault exhibits strike-slip faulting with reverse component in the east owing to constricting of the Arabian plate, by converse, western part shows normal component due to interaction of Aegean extensional regime. According to various authors it has been estimated that its cumulative displacement of the fault since the beginning time varies from 25 km to 85 km.

The North Anatolian fault has experienced to 34 damaging earthquakes during this century (1900-1995). Numerous investigations have focused on this fault especially after the 1939-1967 earthquake sequence. Even if Dewey (1976) put forward there was a migration started by the 1939 Erzincan earthquake and terminated by the 1967 Mudurnu Valley earthquake, we have pointed out that this sequence would be an earthquake cluster rapidly released within narrow time span rather than migration. This series ruptured for 800 km length of the fault. The Erzincan earthquake (Ms=7.9) of 26 December, 1939 was the greatest earthquake occurred in Turkey since the 1668 earthquake. The earthquake causing 32962 death produced ground breakage of 360 km long with average displacement of 4.5 m, extending from Erzincan through Erbaa to the south of Amasya (Ketin 1976). In examining the paleoseismological of this earthquake standpoint, namely rupture initiation and termination points controlled by geometric and mechanical barriers, the 1939 Erzincan earthquake rupture started at the end of eastern segment of the Erzincan pull-apart basin and continued to Erbaa-Niksar pull-apart basin, which has more than 5km wide. This earthquake has played role as a trigger to the other earthquakes of the 1939-1967 sequence. As a result of triggering, ruptures propagated westward. However, the only earthquake showing rupture propagation from east to west was the Ladik-Tosya earthquake of November 26, 1943. Thus, this earthquake is evidence for rapidly releasing of an earthquake cluster. Furthermore, the earthquakes before the 1967 Mudurnu Valley earthquakes took place in the eastern end of the North Anatolian fault near Varto. We can interpret that there happened similar earthquake clusters in 1667-1668 and 994-1045 reported by Ambraseys and Finkel (1988) brought about along the North Anatolian fault.

In examining space-time showing rupture zones, magnitudes and locations of mainshocks for well-known events from 1900 to 1995 on the North Anatolian fault, it can be clearly observed that initial failure was initiated in the central parts of the fault and later propagated toward its both ends. Consequently, these features indicate that there are significant differences in the different parts of the fault. Therefore, its different parts show different behavior in terms of paleoseismicity. Of course, there are some factors that control these behaviors. These are related to properties of geological, structural, mechanical and geometrical structures. Consequently, they control rupture initiation and termination points in terms of fracture mechanics. These factors controlling segment boundaries and recurrence models are representative of deep crustal structures explained by Aki (1984). The author accounts for these behavior with the model called" Asperity and Barriers ". According to his models, sources of earthquakes are located in transition between upper and lower crusts.

The significant features affecting rupture propagation are geometrical factors, such as intersection of faults, splitting of faults, steps and bends in strikes of faults. The North Anatolian fault intersects the East Anatolian fault, its conjugate fault, in the east. Whereas the fault divides into branches in the west. Moreover, stress regimes under the regions have an effect earthquake repeating times. In general, while the eastern part of the fault has being compressed, its western part is under tension. Thus earthquake re-ocurrence intervals vary in wide range depending on these regimes.

Being considered segmentation, the NAFZ contains few master segments of greater than 100 km in length and several small segments shorter than 100 km long. From east to the west, the master segments are the Erzincan segment of 360 km long (ruptured in 1939), the Ladik-Tosya segment of 280 km (ruptured in 1943), the Gerede segment of 160 km (ruptured in 1944) and the Saros segment of longer than 100 km (ruptured in 1912). The other segments are located at the eastern end (i.e. Varto segment (broken in 1966)) and on the branches to the west (Mudurnu Valley segment ruptured in 1957 and 1967). The northern strand is called Sapanca-İzmit and the southern strand is called İznik-Mekece (İznik-Mekece segment unruptured in the past century, Manyas segment ruptured in 1964, Yenice-Gönen segment ruptured in 1953 etc.). On the other hand, the master segments include some subsegments toward the both ends.

Historical records and especially trench results have revealed that some segments produced events repeated either average interval of 200-250 years or 50-100 years. As a result, the master segments have long re-ocurrence intervals, by converse the small segments show shorter repeating times. Thus, we consider that the four master segments have exhibited "Uniform slip model" the small segments tend to display “Characteristic earthquake model". As clearly observed, while the earthquakes rarely occurred along the master segments, they increased towards both ends of these segments. Besides, low slip regions of the master segments generated several closely spaced events in time.

It is clearly seen that there was clustering of earthquakes in the interval of 1940-1960. Historical earthquake records show that this type of cluster was periodically observed in the two different time intervals of 994-1045 and 1667-1668 (Ambraseys 1975, Ambraseys and Finkel 1988).

Since paleoseismologic studies in Turkey are under progress, so far segmentation on the North Anatolian fault has not been yet realized from point of view of earthquake hazard on the basis of some parameters, such as identifying initiation and termination points of individual segments, rupture lengths, slip amounts for each event, slip rate, elapse time since the last earthquake, re-ocurrence models and maximum earthquake magnitude the segment may generate. As mentioned above, the earthquakes of 1939, 1943 and 1944 accompanied with surface faulting of 360 km, 280 km and 160 km in length, respectively. Before occurrence of this sequence, it could be assumed that the 1912 Şarköy-Mürefte earthquake had produced more than 100 km surface rupture by thinking propagation into the sea at the both ends of 30 km rupture on land. Actually, lengths of surface ruptures have revealed an evidence for segmentation as a first step along the North Anatolian fault. Accordingly, we can interpret that the North Anatolian fault has around 10 segments, 4 of them being longer than 100 km are master segments. Based on space-time distribution of the instrumental period earthquakes occurred on the North Anatolian fault and historical earthquake records, three sites of probable seismic gaps can be estimated near both ends of the fault. These gaps are as follows;

1- Yedisu gap (the segments between Tanyeri (east of Erzincan) and Elmalıdere

2- Geyve gap (the segment extending from Geyve to İznik Lake)

3- Marmara gap (inside Marmara Sea)

Epicentral distribution including the interval between 1989 and1995 on the North Anatolian fault incorporating these three gaps shows that seismic activity of the long part of the fault due to 1939-1967 earthquake sequence is seismically very low. However, earthquake activities are relatively high in the vicinity of these gaps.

Erbaa earthquake with a Richter magnitude M=7.0, occurred in 1942 which caused serious casualty in Kelkit Valley (Pınar and Lahn, 1952). The epicentral distance of this strong earthquake is only 32 km to **Akıncı HEPP** project site. The length of the fault line was 50 km beginning from Niksar ending to Yeşilırmak generated by this earthquake.

Figure 2.2: Active Fault Zones and Historical Earthquakes

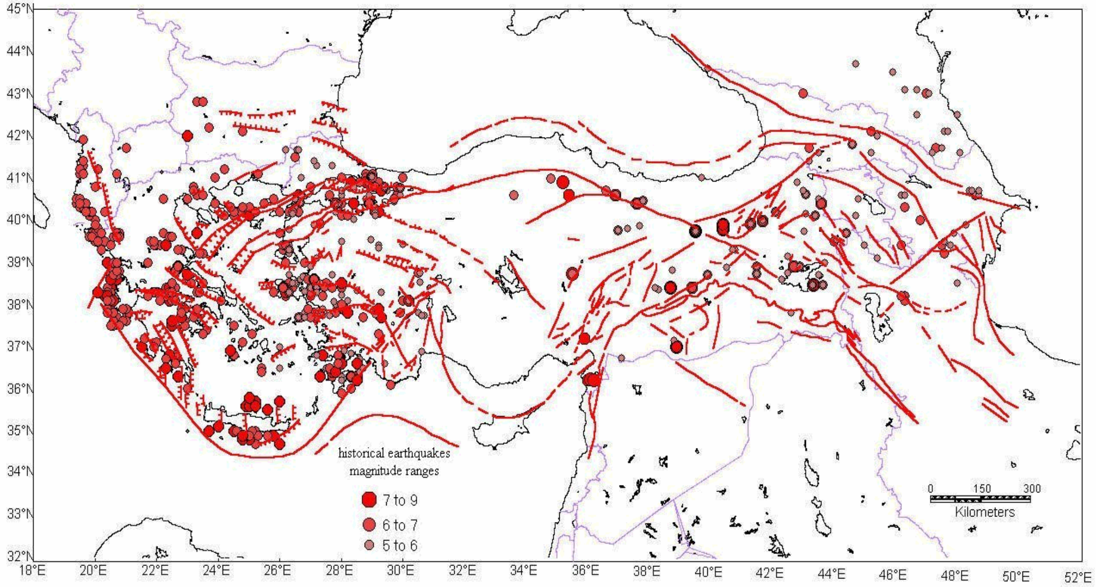


Figure 3a. Historical Seismicity with the Major Tectonic Features

3 SEISMIC RISK ASSESSMENT

3.1 Methodology

It is an important measure to construct the dams, buildings, engineering structures, factories, power plants and similar facilities that are located on active earthquake belts according to earthquake-resistant design. The seismic building code should be taken into account in the preparation and construction stages of the (architectural, static, concrete strength and equipment) projects.

The forces that affect the structure during an earthquake depend on the dynamic characteristics, ground conditions and weight of the structure. Therefore, appropriate and earthquake-resistant projects should be prepared and the project details should be followed at implementation stage.

Earthquake Risk Analysis is one of the studies which is carried out to determine the level of future seismic activity in the sites where buildings, dams, power plants and factories will be constructed and which provides the basis for earthquake-resistant design. Probabilistic and deterministic methods are used in earthquake risk analysis calculations.

Below are the advantages of probabilistic methods in comparison to deterministic ones:

- All magnitude values above a certain level in earthquake sources are included in the calculations.
- The effects of each source on different distances are taken into account in the analysis.
- It makes the comparison of the risks of two or more alternative project sites and the selection of appropriate design parameters possible.

In order to determine the maximum horizontal ground accelerations which are expected to affect the bedrock in the future, seismological data are studied at first stage at the construction site of **Akıncı HEPP** project. The earthquakes with a magnitude of four or more than four ($M \geq 4$) and that occurred in the study area between 1900 and 2006 are compiled from the international data center catalogues such as USGS (United States Geological Survey) and Boğaziçi University Kandilli Observatory (table 3.1).

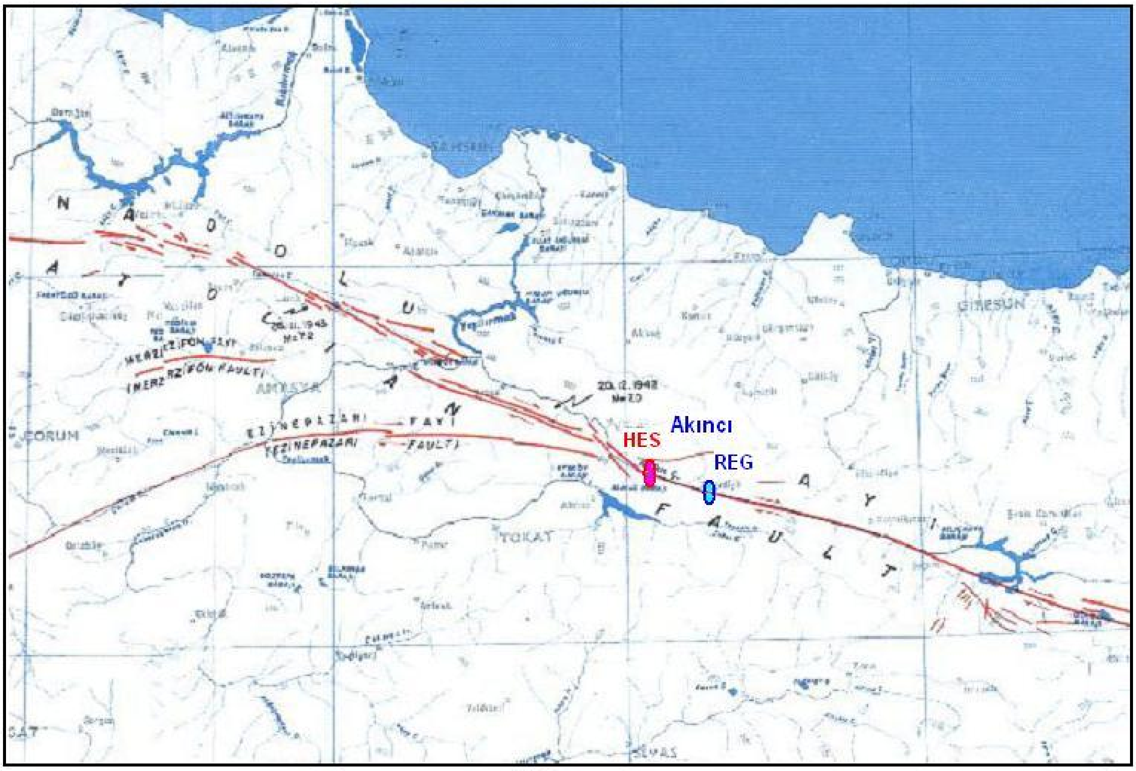
Table 3.1: The earthquakes list with a magnitude of (M≥ 4) occurred nearby Reşadiye between 1900 and 2006

SN	Date	Time	Latitude	Longitude	Ref	Depth (km)	Ms	Ref	Mb	Ref	Md	Ref	Ml	Ref	Mw	Ref
1	09.02.1909	11:24:00	40	38	9	60	6.3	E	5.9	R	6	R	6	R	6.2	R
2	09.02.1909	14:38:00	40	38	9	30	5.8	E	5.6	R	5.6	R	5.6	R	5.8	R
3	10.02.1909	19:49:00	40	38	9	30	5.7	E	5.5	R	5.5	R	5.5	R	5.8	R
4	24.01.1916	06:55:15.8	40,27	36,83	1	10	7.1	E	6.5	R	6.6	R	6.6	R	6.7	R
5	29.04.1923	09:34:40.5	40,07	36,43	1	10	5.9	E	5.6	R	5.7	R	5.6	R	5.9	R
6	18.05.1929	06:37:54.3	40,2	37,9	1	10	6.1	E	5.8	R	5.8	R	5.8	R	6	R
7	19.05.1929	06:33:18	40,2	37,9	Z	10	4.5	E	4.6	R	4.6	R	4.6	R	4.7	R
8	28.06.1929	22:18:44	40,2	37,9	Z	10	4.5	E	4.6	R	4.6	R	4.6	R	4.7	R
9	25.02.1934	16:26:29.2	40,31	36,56	1	40	4.5	E	4.6	R	4.6	R	4.6	R	4.7	R
10	27.12.1939	20:00:49	40,8	36,8	2	30	4.5	E	4.6	R	4.6	R	4.6	R	4.7	R
11	27.12.1939	22:34:13.3	40,83	36,8	1	10	4.9	E	4.9	R	4.9	R	4.9	R	5.2	R
12	28.12.1939	02:23:29.6	41,05	37,01	1	10	4.5	E	4.6	R	4.6	R	4.6	R	4.7	R
13	28.12.1939	03:25:28.3	40,47	37	1	40	5.7	E	5.5	R	5.5	R	5.5	R	5.8	R
14	07.06.1940	19:49:28.2	40,06	37,82	1	10	4.6	E	4.7	R	4.7	R	4.6	R	4.8	R
15	20.12.1942	14:03:7.8	40,87	36,47	1	10	7	E	6.4	R	6.5	R	6.5	R	6.7	R
16	19.08.1954	21:03:29.2	41,21	36,41	1	30	4.8	E	4.9	R	4.8	R	4.8	R	4.9	R
17	26.07.1960	12:36:23.4	40,56	37,25	1	40	4.6	E	4.7	R	4.7	R	4.6	R	4.8	R
18	01.04.1962	01:39:21.7	40,8	36,1	1	10	4.7	E	4.8	R	4.7	R	4.7	R	4.9	R
19	21.09.1964	18:07:3.6	41,1	37,6	4	33	4.2	R	4.4	4	4.3	R	4.3	R	4.5	R
20	15.12.1964	07:00:0.5	39,5	36,5	4	30	4.3	R	4.5	4	4.4	R	4.4	R	4.6	R
21	17.04.1971	16:37:39.3	41,24	37,08	4	33	4.7	R	4.8	4	4.7	R	4.7	R	4.9	R
22	15.07.1975	21:59:26.5	40,93	36,08	4	18	4.6	R	4.7	4	4.6	R	4.6	R	4.8	R
23	15.07.1975	21:59:27	40,93	36,08	4	18	4.7	E	4.8	R	4.7	R	4.7	R	4.9	R
24	07.12.1981	21:17:4.3	40,66	36	4	10	4.3	R	4.5	4	4.4	R	4.4	R	4.6	R
25	06.04.1984	22:13:30	40,52	36,63	4	13	3.7	R	4.1	4	4.2	R	4	R	4.2	R
26	29.07.1996	22:04:26.6	40,85	36,24	R	5	3.8	R	4.1	R	4	R	4	R	4.2	R
27	01.12.1996	16:33:51	40,48	37,22	4	25	4	R	4.3	4	4.1	R	4.2	R	4.4	R
28	11.06.1999	05:25:17	39,53	36,76	4	6	4.4	R	4.6	4	4.8	R	4.6	R	4.7	R
29	11.06.1999	05:26:04	39,5	36,6	4	23	4	R	4.3	4	4.3	R	4.2	R	4.4	R
30	28.12.1999	11:25:9.3	39,7	38	4	10	3.8	R	4.1	R	4	R	4	R	4.2	R
31	03.05.2001	06:10:22.4	40,58	36,66	N	10	3.9	R	4.2	N	4.1	R	4.1	R	4.3	R
32	03.02.2004	11:50:19.4	40,65	36,52	R	1	3.8	R	4.1	R	4	R	4	R	4	R

33	14.12.2004	22:24:19.5	39,77	36,73	R	10	3.6	R	4	R	4.1	R	4	R	4	R
34	12.05.2005	08:59:59.6	40,37	37,36	R	10	4.4	R	4.6	N	4.5	R	4.7	R	4.7	R
35	12.05.2005	09:25:39.1	40,34	37,36	R	10	4.9	R	4.9	N	4.8	R	4.9	R	5	R
36	07.07.2005	19:05:7.4	40,41	37,4	R	10	3.8	R	4.1	R	4	R	4	R	4.1	R
37	07.07.2005	19:33:8.9	40,49	37,36	R	2	3.8	R	4.1	R	4	R	4	R	4.2	R
38	29.08.2005	22:33:48.3	40,52	36,82	R	10	3.6	R	4	R	4.2	R	4.2	R	4.1	R
39	24.09.2005	01:37:17.5	40,36	37,38	R	7	3.6	R	4	N	4	R	4	R	4	R

At the second stage of risk analysis study, tectonical features (Figure 3.1) and seismological data (Figure 3.2) of the region are correlated and in the basis of this, a Seismotectonic Map is prepared (Figure 3.3). Two line sources for earthquakes which is symbolized with (L-1) and (L-2) on the map and thought to produce the earthquakes are determined.

Figure 3.1: Seismo-tectonic map of the area



TÜRKİYE DİRİ FAY HARİTASI
MTA. F.Şaroğlu, 1992

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Figure 3.2: Distribution of Earthquakes that occurred between 1900 and 2006

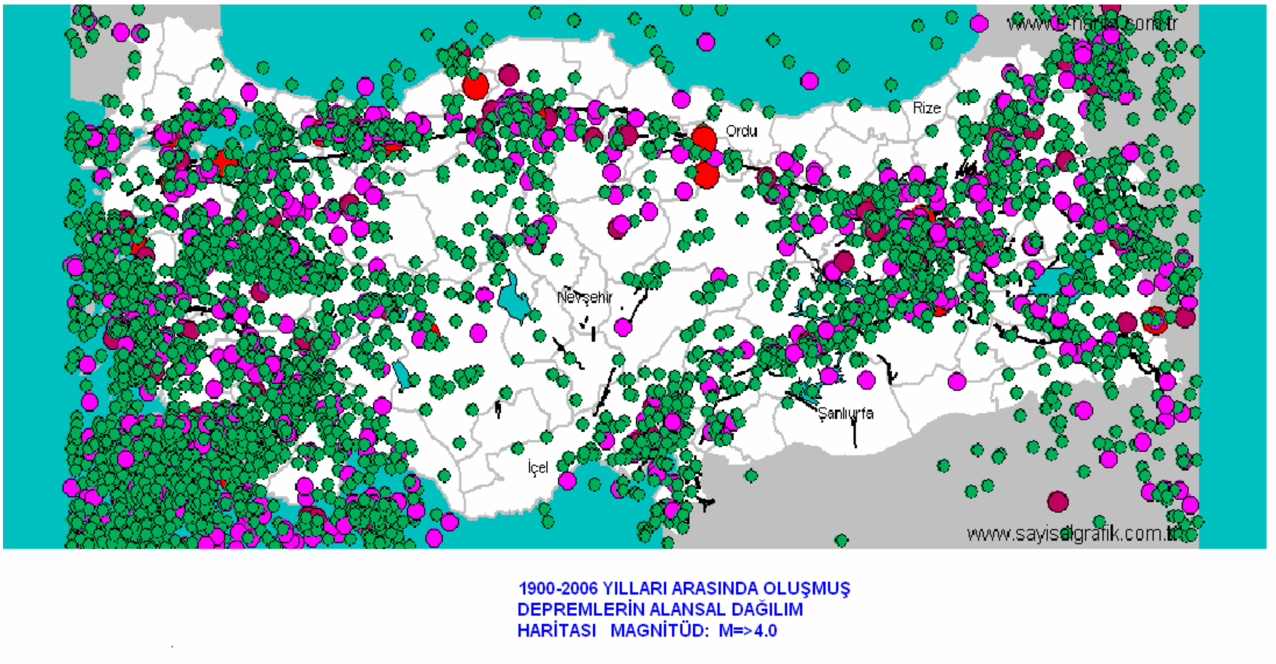
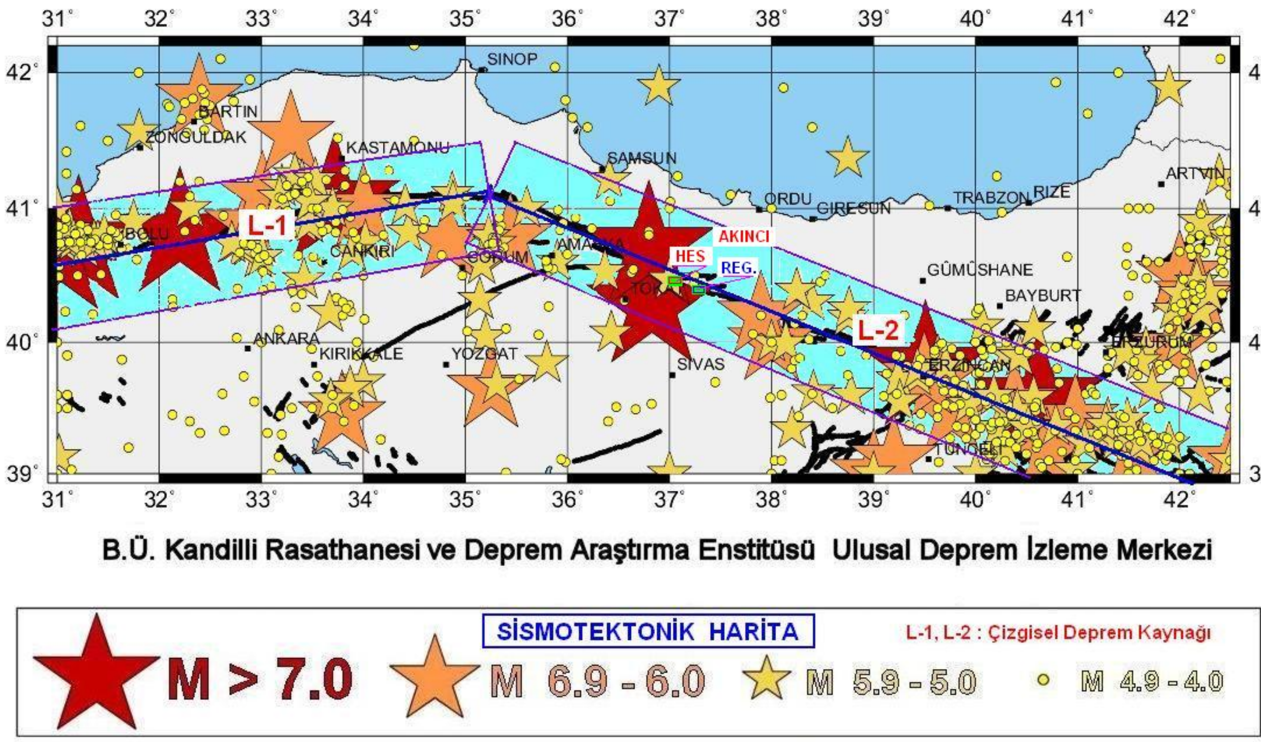


Figure 3.3: Seismo-tectonic map



The computer program used in risk analysis calculations is prepared according to Poisson probability theory. The source parameters determined for the line sources, the coordinates of **Akıncı HEPP** site and **Akıncı Regulator site** and the coefficients of attenuation relationship are inserted in the program and the acceleration-risk values are achieved.

3. 2. Theoretical Basis

The Poisson probability model stated below can be used to determine the future seismic activity.

$P_n(t) = e^{-\lambda t} (t)^n / n!$

$P_n(t)$ = the occurrence probability of n earthquakes in a period of t

n = number of earthquakes

λ= number of earthquakes within the unit time

Gutenberg-Richter (1956) developed a method which estimates the magnitudes of the earthquakes to happen in the future by studying the earthquakes in the past. The correlation stated below determines the relationship between the magnitude of the earthquake and the cumulative number of earthquakes.

$\text{Log } N(m) = \alpha + \beta M$

α, β= regression coefficients

M= magnitude

N= cumulative number of earthquakes

This relationship can either be first or second-degree linear.

$\text{Log}_e N_1 (M) = \alpha_1 + ß_1 M \quad M < M_0$

$\text{Log}_e N_2 (M) = \alpha_2 + ß_2 M \quad M > M_0$

Taking the length or area of the sources and the observation period into account, the transformations for;

$N(M) = N(m) / L.T; \alpha' = \alpha - \text{Log}_e (L.T)$ Line Source

$N(M) = N(m) / A.T; \quad \alpha' = \alpha - \text{Log}_e (A.T)$ Arial Source

are made and the below normalized recurrence relationships are achieved.

$\text{Log}_e N_1 (M) = \alpha'_1 + ß_1 M$

$\text{Loge } N_2 (M) = \alpha'_2 + ß_2 M$

N (M) = cumulative number of earthquakes with a magnitude of more than M,

N_1 (M) = cumulative number of earthquakes achieved by normalizing the N (M),

M_0 = the magnitude of the biggest earthquake that happened at the source

M_1 = the magnitude of the biggest earthquake expected to happen at the source

L = length of the line source (km)

A = area of the aerial source (km^2)

T = observation period (years)

α , ß = regression coefficients

α‘= the regression coefficient achieved by normalizingα.

The regression parameters for (L-1) and (L-2) Line Sources of earthquakes (Table 3.2) prepared on the Seismotectonic Map are determined with the help of the above correlations in order to calculate the earthquake risk of the **Akıncı HEPP Project** site. The result of the earthquake risk analysis is largely depending on to these parameters.

Table 3.2: Line Sources of Earthquake

Earthquake Source	α'_1	$ß_1$	α'_2	$ß_2$	M_0	M_1	**Hmean (km)**
L-1	-0,3286	-1,3228	5,8309	-2,2028	7,2	8,5	21
L-2	1,0101	-1,4170	18,4527	-3,7427	7,9	8,5	30

4 SOURCES OF EARTHQUAKES

It is assumed that the earthquakes that are taken into account during the earthquake risk analysis occurred by point, line and areal type sources of earthquakes. Main sources of earthquakes on the Seismotectonic map **(L-1)** and **(L-2)** which is used to calculate the earthquake risk of the **Akıncı HEPP Project** site is taken into consideration during calculations. The parameters of line type earthquake sources are stated in Table 3.2 and the acceleration-risk values created by these sources at **Akıncı HEPP Project** site are calculated in the risk analysis.

L-1 Line Source

(L-1) Line Source of Earthquake is placed on the North Anatolian Fault Zone between Düzce and Vezirköprü towns. It is 360 km long. The biggest earthquake on this source had a magnitude of $\mathbf{M_0}$=7.2, and an earthquake with a magnitude of $\mathbf{M_1}$=8.5 at maximum is expected on it. The average hypocenter depth determined is h=21 km.

L-2 Line Source

(L-2) Line Source of Earthquake is placed on the North Anatolian Fault Zone between Vezirköprü and Varto towns. It is 660 km long. The biggest earthquake on this source had a magnitude of $\mathbf{M_0}$=7.9, and an earthquake with a magnitude of $\mathbf{M_1}$=8.5 at maximum is expected on it. The average hypocenter depth determined is h=30 km.

Akıncı **HEPP Project** site is located on L-2 line source area and will affected mostly by this earthquake source.

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5 ATTENUATION RELATIONSHIP AND DETERMINISTIC EVALUATION

One of the most important issues in earthquake risk analysis study is the selection of the attenuation relationship which defines the correlation between the magnitude of the earthquake (M), hypocenter distance (R) and the maximum ground acceleration (A). Estava attenuation relationship which is used commonly in these studies and known to produce appropriate results is benefited in the determination of the earthquake risk of Akıncı **HEPP Project** site by using the probability method. Furthermore, the maximum acceleration values created at the **Akıncı HEPP** construction site by the earthquakes occurred at Tokat in 24.01.1916 (31.0 N , 15,2 E ; M=7.1) and Erba 20.12.1942 (33.19 N, 13.28 E; M=7.0) are directly calculated with deterministic method by making use of the attenuation relationships suggested by the below researchers (Table 5.1).

Table 5.1 Acceleration by Attenuation Relationships

Date and Magnitude	Distance to HEPP Site	ATTENUATION RELATIONSHIP						
		Instrumental	Estava	Gürpınar Savy	Olivera	Mc. Guire	Estava Rosen	Kata-yama
		Max. Horizontal Ground Acceleration (cm/s^2)						
4.01.1916 Tokat (7.1)	28 km	250	301	306	119	243	140	208
20.12.1942 Erbaa (7.0)	32 km	210	250	233	96	209	107	171

As a result of deterministic calculations made with reference to the earthquakes considered above, they will produce maximum ground acceleration at the **Akıncı HEPP** site is 306 cm/s^2. This is far below the MDE and OBE acceleration values achieved through probabilistic method.

6 EARTHQUAKES THAT HAVE OCCURRED IN THE REGION

The brief description of destructive earthquakes occurred in the investigation area are given below.

20.12.1942 Erba-Niksar Earthquake
It is reported as Magnitude M=7.0, hypocentral depth h=10 km and Epicenter Coordinated 40°.87 N, 36°.47 E.

18.05.1929 Suşehri Earthquake
It is reported as Magnitude M=6.1, hypocentral depth h=30 km and Epicenter Coordinated 40°.20 N, 37°.90 E.

24.01.1916 Tokat Earthquake
It is reported as Magnitude M=7.1, hypocentral depth h=10 km and Epicenter Coordinated 40°.27 N, 36°.83 E.

09.02.1909 Imranlı-Zara Earthquake
It is reported as Magnitude M=6.3, hypocentral depth h=60 km and Epicenter Coordinated 40°.00 N, 37°.90 E.

Historical Earthquakes in the Investigation Area:
According to historical sources it is understood that seven strong earthquakes occurred in the historical period before instrumental period in the investigation area. The spatial distributions of the earthquakes are given on historical map (see Fig 2.2). The magnitudes of these historical earthquakes which occurred on the middle section of North Anatolian Fault vary in between Mw 5 and 7.

The earthquake which occurred in the date 17.08.1668 with an intensity I= IX especially important. It is reported that this earthquake generated a fault line with the length of 380 km.

7 DESCRIPTION OF DESIGN EARTHQUAKE

7.1 General

The MDE and OBE concepts which are two different definitions by ICOLD with regard to design earthquake and the concept of MCE are explained below.

Maximum Design Earthquake (MDE) : It is the type of earthquake that has the magnitude according to which the structure is designed or its analyses are made and that is expected to cretae maximum ground movement. It is the ground movement acceleration which may probably exceed the estimation by 10 % within the 50 years economic life recommended for

MDE. An average 475 years of return period is taken into consideration for this type of a movement.

Operating Basis Earthquake (OBE) : The concept of OBE means a ground movement which can create only little damage to the structure. The Engineering structures and equipments shall be able to function normally after an earthquake at OBE level. It will be easy to cover the damages after an earthquake nearly as intense as an OBE but not more than that. In other words, OBE defines a ground movement which can not exceed the estimations by a probability of 50 % within a period of 100 years. The return period for this type of a movement is 144 years.

Maximum Credible Earthquake (MCE) : This concept defines the most intensive earthquake likely to happen at the seismotectonic area or the fault zone. The probability of occurrence is not important as these types of earthquakes happen within a wide period of 1000 to 10000 years.

7.2 Evaluation

The earthquake risk of **Akıncı HEPP** site and **Regulator** site which are planned to build in the Kelkit Valley near Reşadiye is determined by using the probabilistic method. Deterministic method is also used for calculations and for the comparison of the results.

Project area is located on 1.st degree of earthquake zone according to Earthquake Regionalization Map of Turkey. The Project area is also very near to North Anatolian fault. Even the North Anatolian Fault is passing through in center of **Regulator** site and cutting the Transmission Channel route at some certain points.

An earthquake source model is used in the determination of the earthquake risk of the **Akıncı HEPP** site and **Regulator** site by use of probabilistic method and with regard to the earthquakes occurred at the region with a magnitude of M≥4.0 between years 1900 and 2006.

The earthquake source parameters are set on (Table 3.1) and inserted in the computer program prepared according to Poisson probability theory. This made it possible to calculate the earthquake acceleration-risk values for the **Akıncı HEPP** site and **Regulator** site respectively. The acceleration-risk values determined in the light of various exceedance probabilities and economic lives are stated in detail in the Table 7.1 and Table 7.2 respectively.

Table 7.1: Akıncı HES acceleration – risk values

Probability of Exceedance (%)	Economic Life (Year)				
	1	50	100	200	1000
	Cm/s² (*%g.*) Maximum Horizontal Ground Acceleration				
1	**273.9** ***0.279***	**966.2** ***0.985***	**985.6** ***1.0***	**996.0** ***1.0***	**1000.0** ***1.0***
2	**191.9** ***0.196***	**925.6** ***0.944***	**964.0** ***0.983***	**983.7** ***1.0***	**1000.0** ***1.0***
3	**152.5** ***0.155***	**885.0** ***0.902***	**942.3** ***0.961***	**971.4** ***0.990***	**1000.0** ***1.0***
4	**135.8** ***0.138***	**844.4** ***0.861***	**920.6** ***0.938***	**959.1** ***0.978***	**996.2** ***1.0***
5	**120.6** ***0.123***	**803.8** ***0.819***	**898.9** ***0.916***	**946.8** ***0.965***	**990.6** ***1.0***
10	**87.0** ***0.089***	**600.8** ***0.612***	**790.6** ***0.806***	**885.3** ***0.902***	**962.8** ***0.981***
20	**51.2** ***0.052***	**400.3** ***0.408***	**573.8** ***0.585***	**762.3** ***0.777***	**907.0** ***0.925***
50	**34.8** ***0.035***	**231.7** ***0.236***	**329.6** ***0.336***	**451.2** ***0.460***	**739.9** ***0.754***

Table 7.2: Akıncı Regulator acceleration – risk values

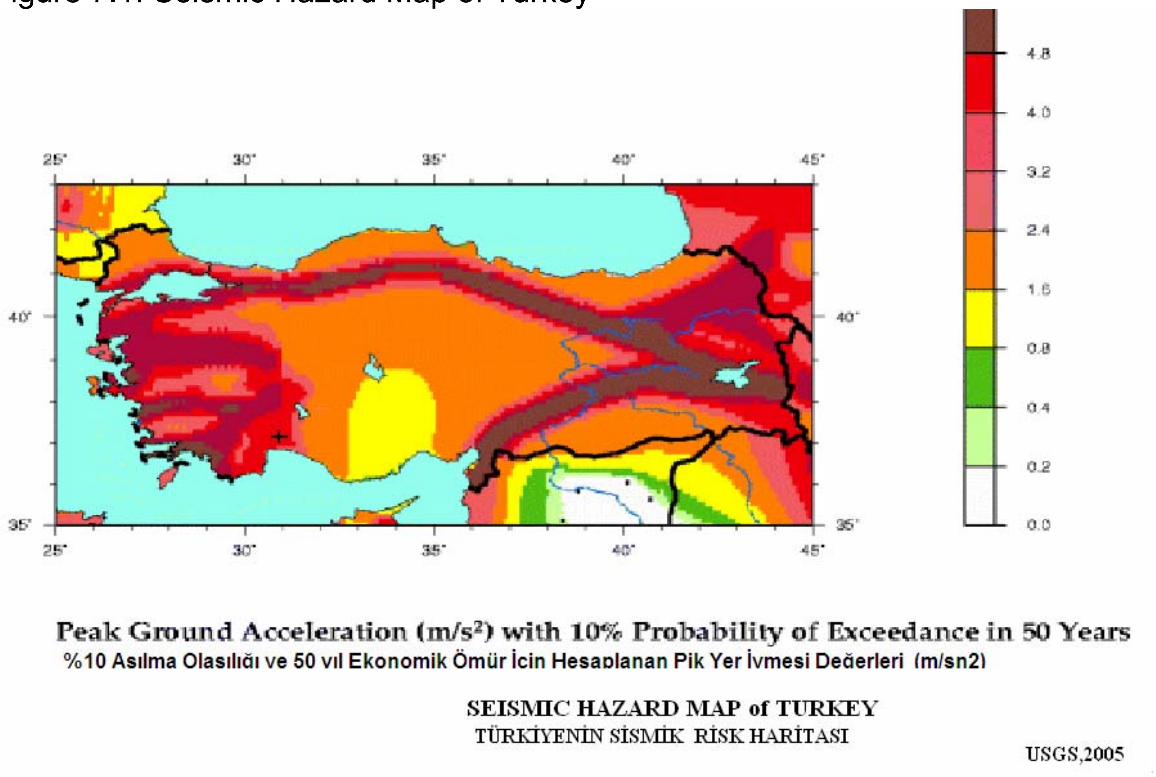
Probability of Exceedance (%)	Economic Life (Year)				
	1	50	100	200	1000
	Cm/s² (*%g.*) Maximum Horizontal Ground Acceleration				
1	**277.1** ***0.282***	**967.6** ***0.986***	**986.5** ***1.0***	**996.6** ***1.0***	**1000.0** ***1.0***
2	**193.5** ***0.197***	**928.2** ***0.946***	**965.4** ***0.984***	**984.6** ***1.0***	**1000.0** ***1.0***
3	**154.9** ***0.158***	**888.7** ***0.906***	**944.3** ***0.963***	**972.6** ***0.991***	**1000.0** ***1.0***
4	**137.0** ***0.140***	**849.2** ***0.866***	**923.2** ***0.941***	**960.6** ***0.979***	**997.5** ***1.0***
5	**122.1** ***0.124***	**809.8** ***0.825***	**902.1** ***0.920***	**948.5** ***0.967***	**991.9** ***1.0***
10	**87.7** ***0.089***	**612.4** ***0.624***	**796.5** ***0.812***	**888.4** ***0.906***	**964.2** ***0.983***
20	**52.6** ***0.054***	**406.5** ***0.414***	**585.4** ***0.597***	**768.2** ***0.783***	**908.7** ***0.926***
50	**34.9** ***0.036***	**234.2** ***0.239***	**337.7** ***0.344***	**456.7** ***0.466***	**742.1** ***0.756***

According to Table 7.1, for example, the maximum horizontal ground acceleration at the **Akıncı HEPP** site which is expected to have an exceedance probability of 5 % within an economic life of 50 years is a=803.8 cm/sn^2 or a=0.819 g. The maximum horizontal ground acceleration which is expected to happen with an exceedance probability of 10 % within a period of 100 years is calculated in the Table 7.2, as a=796.5 cm/sn^2 (a=0.812 g.).

Probabilities are presented in a wide range in order to provide ease in selection. In the deterministic study, the maximum acceleration values created by destructive earthquakes at the **Akıncı HEPP** site in the past are calculated directly and independently from probability method by making use of the attenuation relationships suggested by various researchers. The highest acceleration risk calculated by deterministic method is a=306 cm/s^2. This is far below the **MDE and OBE** acceleration values achieved by probability method and it proves that the values by probabilistic method are reliable.

The above mentioned ground acceleration values are also parallel to the values on Seismic Hazard Map of Turkey prepared by USGS-2006 (Figure 7.1).

Figure 7.1: Seismic Hazard Map of Turkey



8 CONCLUSIONS AND RECOMMENDATIONS

As a result, in the light of the above mentioned calculations and evaluations;

a) It is recommended for **Akıncı HEPP** construction site that

***MDE** value* : **600.8 cm/sn^2 (0.612 g)** peak ground acceleration
(For the return period of 475 years),

OBE value : **329.6 cm/sn^2 (0.336 g.)** peak ground acceleration
(For the return period of 144 years),

MCE value : an earthquake with a Richter magnitude of **M=8.5**

Horizontal Seismic Coefficient value k=0.25 value should be taken into account during the design of the project.

b) It is also recommended for **Akıncı Regulator** construction site that;

MDE value : **612.4 cm/sn^2 (0.624 g.)** peak ground acceleration
(For the return period of 475 years),

OBE value : **337.7 cm/sn^2 (0.344 g)** peak ground acceleration
(For the return period of 144 years),

MCE value : an earthquake with a Richter magnitude of **M=8.5**

Horizontal Seismic Coefficient value **k=0.25** should be taken into account during the project.

It can be adopted above seismic parameters of **HEPP** site during the design of penstocks and transmission channel. In order to design of power tunnel and tailrace, **HEPP** site seismic parameters can be reduced by % 30.

9 REFERENCES

1) Seismicity of Black Sea Region, B.U .Kandilli Observatory Earthquake Research Center, İstanbul, 2004

2) USCOLD, 1999, “Updated Guidelines for Selecting Seismic Parameters for Dam Project”

3) JICA, (1989) , “ Feasibility Study on Göktaş HEP Development Project”

4) Lomnitz,C., (1974), “Global Tectonics and Earthquake Risk”, Mexico

5) Erdik, M; Siyahi, B; Sesetyan, K (1992), Seismic Hazard Assessment for Hakkari Dam,

6) Özaydın, K., (1982) “Soil Dynamic” Publication of Turkish National Committe of Earth.Eng

7) Coyne Et Bellier & Aknil, (1991),“Seismic Risk Assessment for the Berke Dam”

8) Kocaefe,S, and Özmen,B., (1999) “The Seismicity and Earthquake Hazard of Ankara”

9) International Workshop on Disaster Prevention Management” Ankara, (ODTÜ)

10) Kaptan,C., (1999) “The Turkish Approach to Seismic Design” Hydropower & Dams

11) “17 Ağus. 1999 İzmit Golf Earthquake Report” General Directorate of Disaster Affairs Earthquake Research Division-2000, Ankara