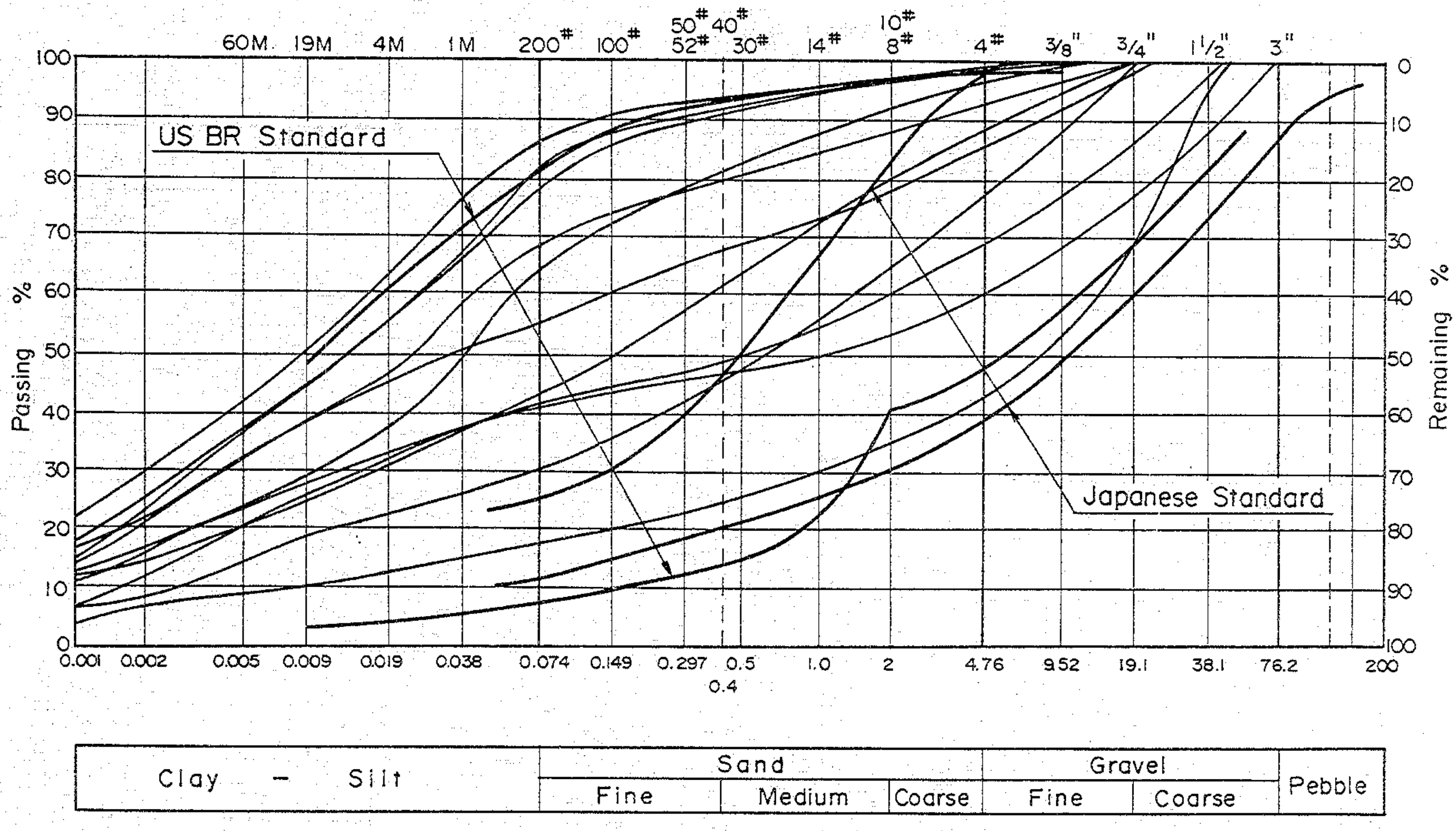


Fig. 7-17 Sieve Analysis of Tavusker Borrow Material

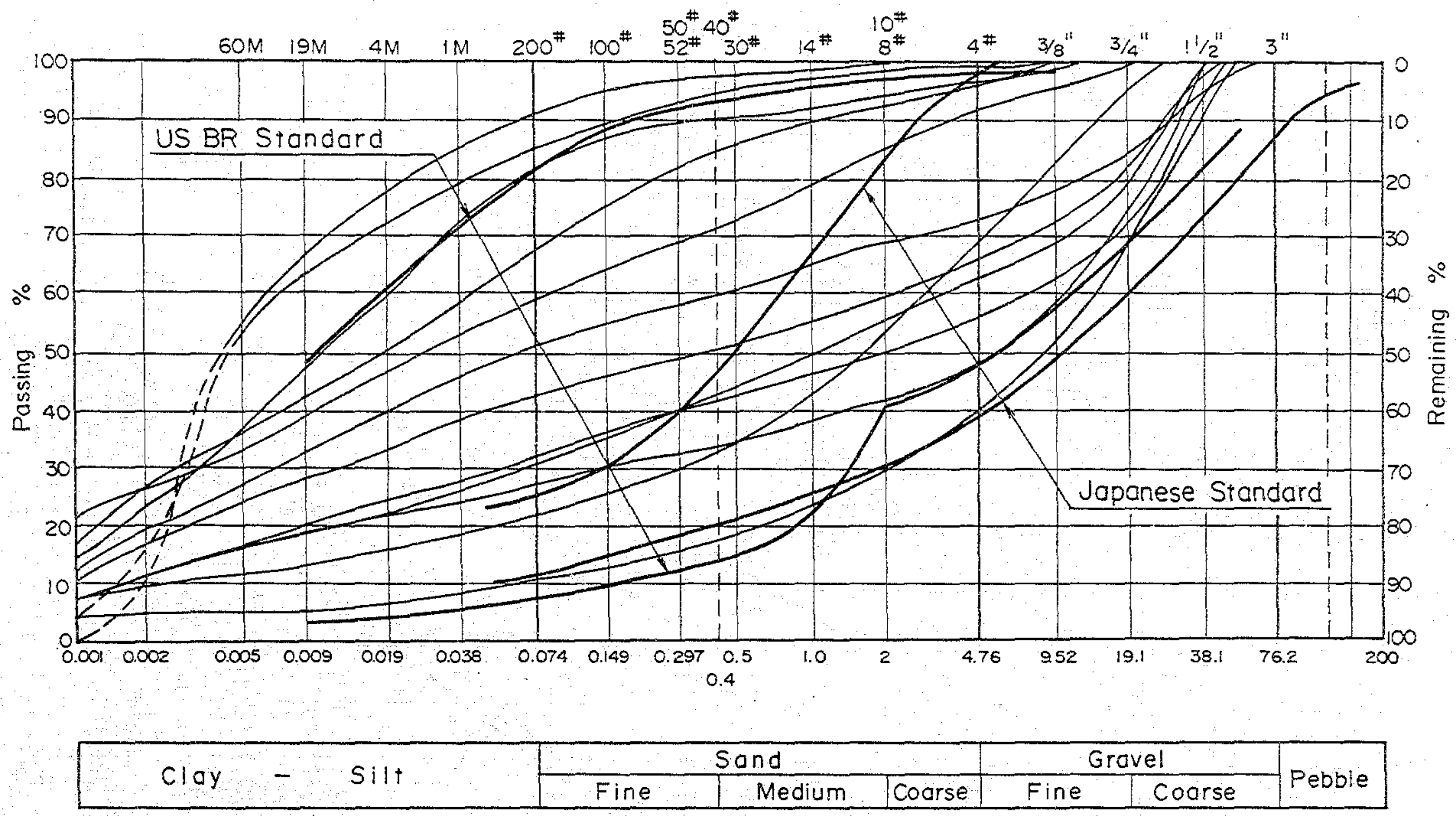


Fig. 7-18 Sieve Analysis of Bulanik Borrow Material

7.4.2 Concrete Aggregate

The thicknesses of the river-bed deposits at the Olur dam site and the Ayvalı dam site are very large, being approximately 44 m and approximately 60 m, respectively. When constructing rockfill dams at the two sites it is thought amply possible for these river-bed deposits to be excavated and used for fine filter material and for concrete aggregates. Large quantities of river-bed deposits also exist upstream and downstream of the two dam sites, and it will be quite possible for these to be collected, classified, and used as concrete aggregates.

Investigations concerning concrete aggregates were made with 7 pits for Olur Dam aggregates and 8 pits for Ayvalı Dam aggregates. The locations of these pits are shown in Figs. 7-19 and 7-21.

The river-bed sand-gravel to become these concrete aggregates mainly consist of gravel and sand from volcanic rocks and granite of maximum diameters 10 to 20 cm, but depending on the location, there are cases of intercalations of fine sand and silt in thicknesses of several meters.

o Gradation, Specific Gravity, Absorption, Other

Test results and ASTM standards for coarse and fine aggregates are given in Tables 7-8 and 7-9. Gradation curves are shown in Figs. 7-20 and 7-22.

Of the aggregates to be used in the Olur Project, those from 0-2 are especially high in fine-particle content, but there are no problems in particular regarding fines collected from pits at the other locations. Regarding coarse aggregates, it is thought there will be no special problems in using except for 0-2.

Of aggregates to be used in the Ayvalı Project, the material from A-4 is high in fine-particle content, but there are no problems in particular regarding fines from the other pits. There is no problem at all concerning coarse aggregates. However, values of soundness tests among the tests on fines for the Ayvalı Project are in excess of standard values.

o Alkali-Aggregate Reaction Tests

The results of tests according to ASTM C 289 are shown in Fig. 7-23 and Fig. 7-24.

According to these results, the various samples are harmless with regard to alkali-aggregate reaction. All samples were collected from river-bed sand-gravel.

Of aggregates for Llur, FM-5 and FM-7 are at the borderline, but are not inside the deleterious range, and it is thought there will be no problem. However, if a concrete dam is to be constructed, it is thought necessary for long-term tests to be carried out using cement and aggregates.

o Soft Particle Tests of Coarse Aggregates

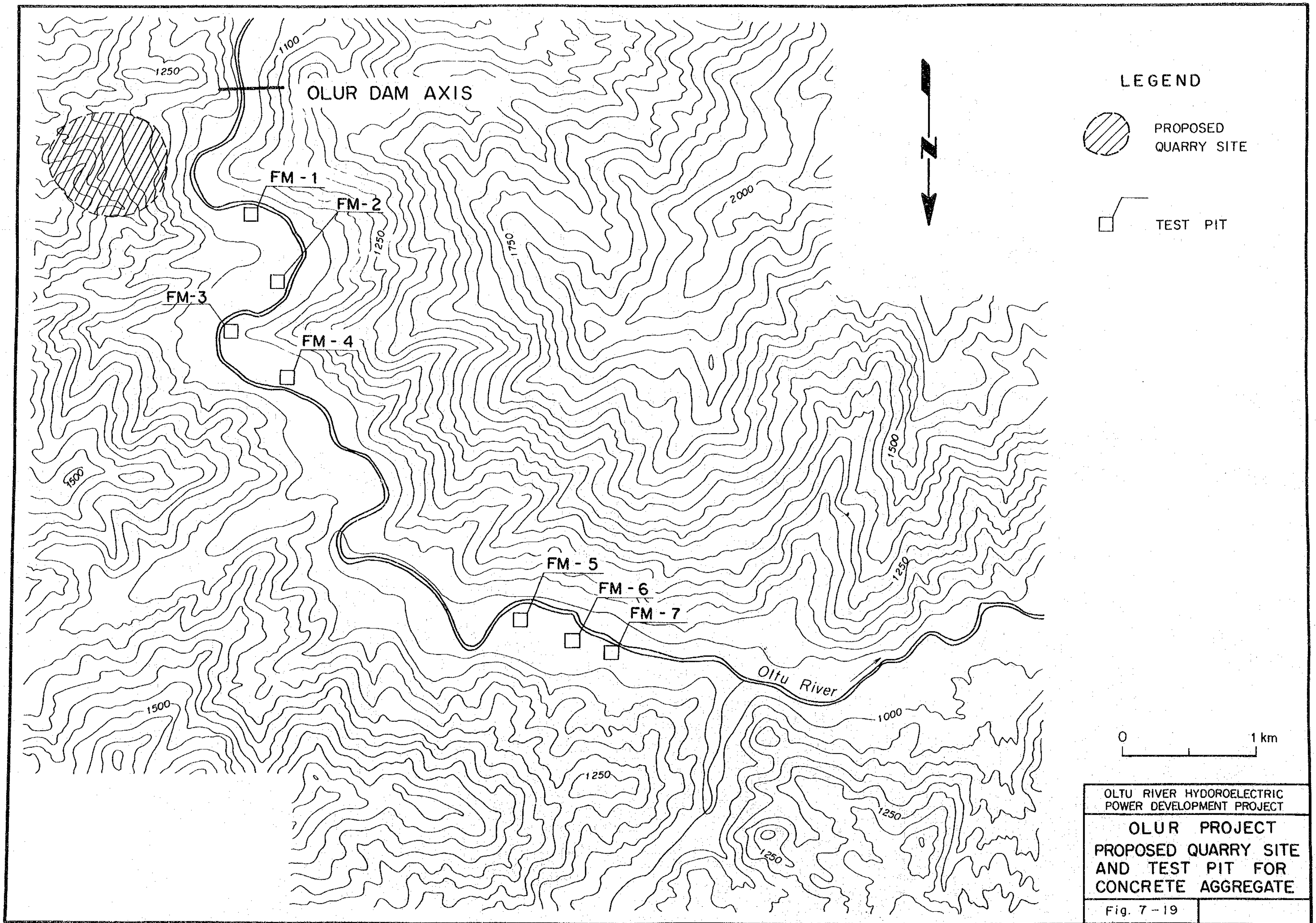
Scratch hardness tests have been carried out on coarse aggregates for Olur and Ayvalı, according to which, because gravels belonging to the Oltu Formation are contained, there is a comparatively high content of soft gravels. However, unit weight and specific gravity are high, while abrasion loss is not very great, and it is thought there will be no problem in particular when using as concrete aggregate.

As for "ASTM C 851-76, Scratch Hardness Test," it was deleted from concrete tests in 1984.

7.4.3 Rock Material

Rock materials for the Olur dam are planned to be collected from the right bank immediately downstream of the dam as shown in Fig. 7-19. The rock is granite porphyry and adequate quantities are available.

Rock materials for the Ayvalı dam are planned to be collected from the left bank immediately upstream of the dam as shown in Fig. 7-21. The rocks are tuff and andesite and it is considered there are adequate quantities.



OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

OLUR PROJECT

PROPOSED QUARRY SITE AND TEST PIT FOR CONCRETE AGGREGATE

Fig. 7 - 19

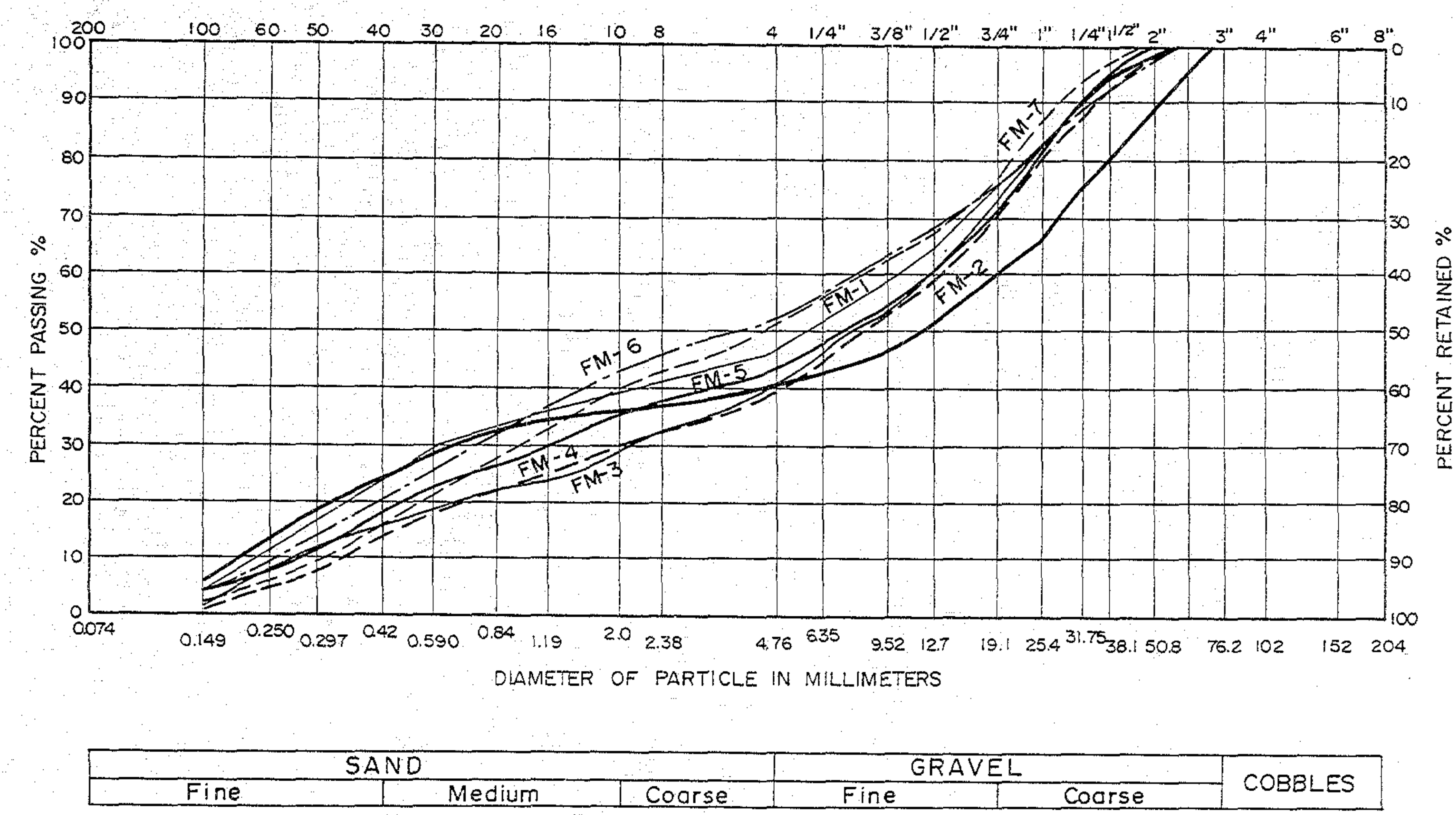
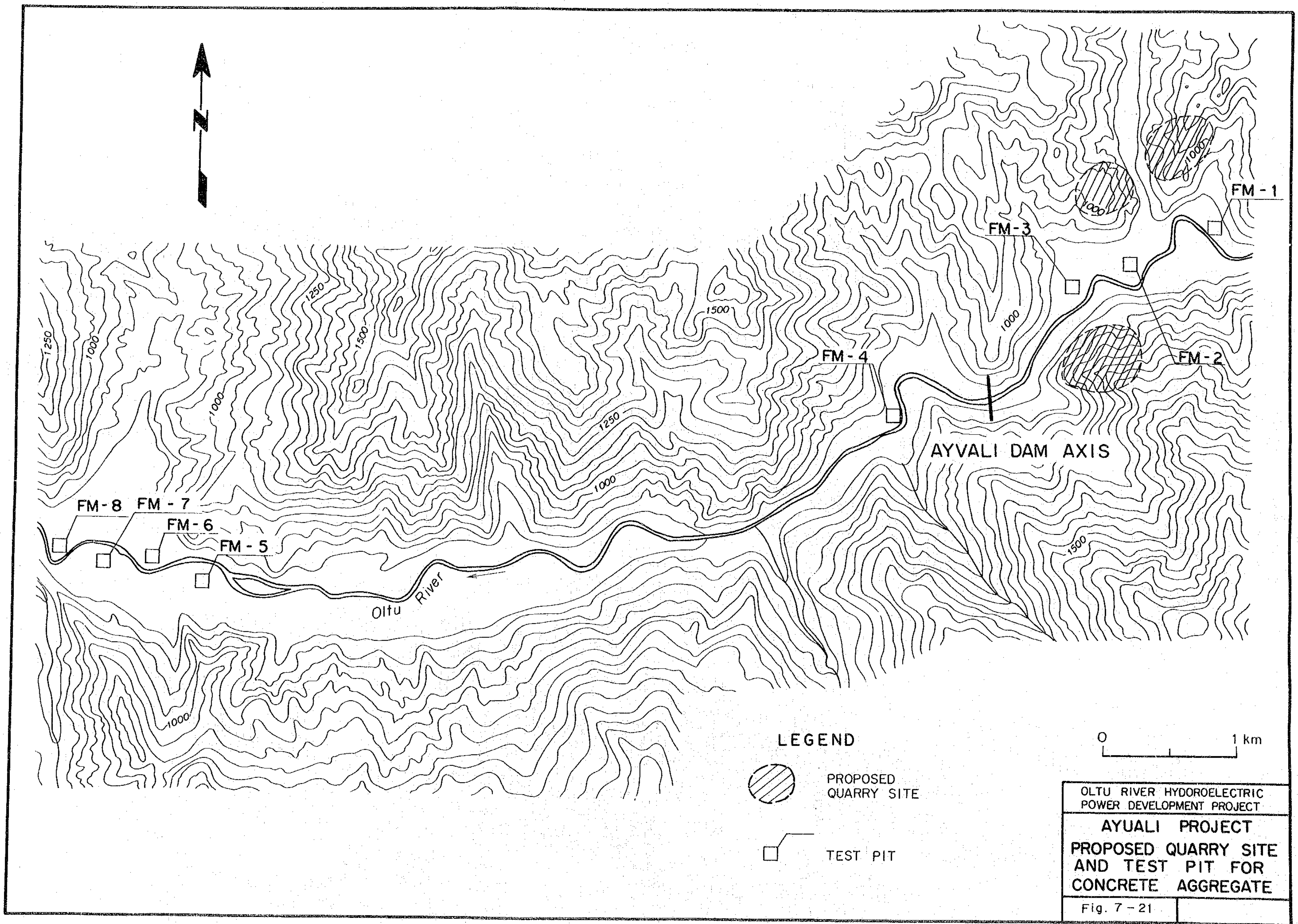


Fig. 7-20 Gradation Analysis Curve of Olur Project



N
FM - 1
FM - 2
FM - 3
FM - 4
FM - 5
FM - 6
FM - 7
FM - 8
AYVALI DAM AXIS
Oltu River
1000
1250
1500
LEGEND
PROPOSED QUARRY SITE
TEST PIT
0
1 km
OLTU RIVER HYDOROELECTRIC POWER DEVELOPMENT PROJECT
AYUALI PROJECT
PROPOSED QUARRY SITE AND TEST PIT FOR CONCRETE AGGREGATE
Fig. 7 - 21

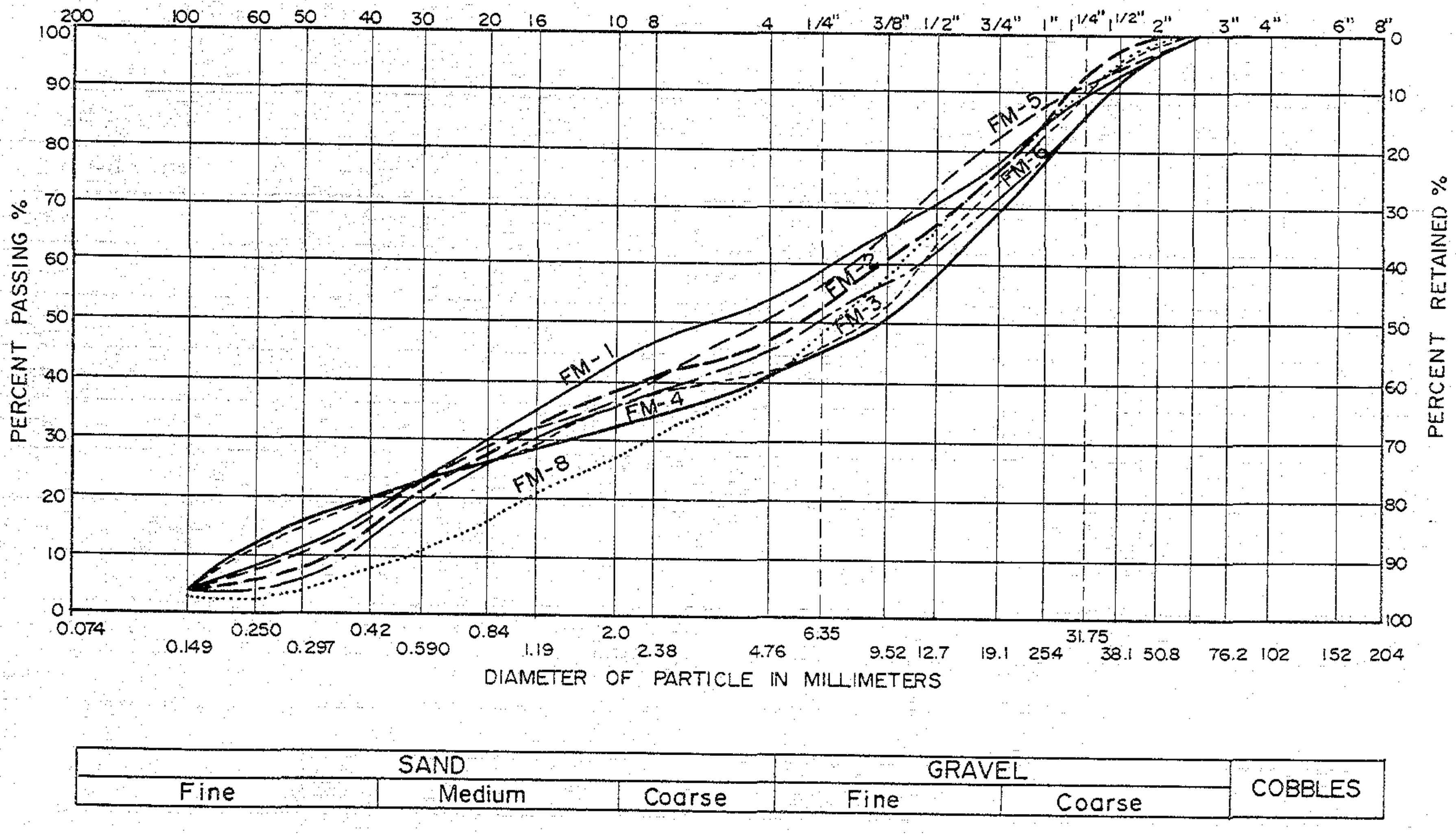


Fig. 7-22 Gradation Analysis Curve of Ayvalı Project

Table 7-8(a) Test Results and ASTM Standard (Concrete Aggregate) of Fine Aggregate of Olur Project

		Fine Aggregate							
		ASTM	0-1	0-2	0-3	0-4	0-5	0-6	0-7
Grading		See Fig. 7-16							
Finesse Modulus		2.3 ~ 3.1	2.30	1.8	2.7	2.8	2.5	2.5	2.9
Bulk	Dry	---							
Specific	Surface dry	---	2.69	2.67	2.71	2.72	2.72	2.72	2.71
Gravity	Apparent	---							
Absorption %		---	2.0	2.5	1.8	1.6	1.4	1.8	1.4
Abrasion		less than 50%	4.2	4.2	3.8	3.8	4.0	4.1	3.8
Soundness		less than 10%	10.7	13.1	8.5	8.5	7.5	7.9	
Unit weight t/m^3		---	1.74	1.715	1.835	1.845	1.825	1.820	1.835
Clay lumps		less than 3%	---	---	---	---	---	---	---
Quantity of soft particle (%)		less than 5%							
Organic impurities		---	A.Sari	A.Sari	A.Sari	Renksiz	Renksiz	Renksiz	Renksiz

Table 7-8(b) Test Results and ASTM Standard (Concrete Aggregate) of Coarse Aggregate of Olur Project

		Coarse Aggregate							
		ASTM	0-1	0-2	0-3	0-4	0-5	0-6	0-7
Grading		See Fig. 7-16							
Finess Modulus		---	---	---	---	---	---	---	---
Bulk	Dry	---							
Specific	Surface dry	---	2.65	2.67	2.64	2.67	2.65	2.67	2.68
Gravity	Apparent	---	---						
Absorption %		---	2.0	1.4	1.6	1.6	1.7	1.5	1.5
Abrasion		less than 50%	20.1	21.7	19.8	19.8	19.4	19.2	19.0
Soundness		less than 18%	9.6	6.0	8.5	10.8	9.9	9.7	9.3
Unit weight t/m^3		---	1.755	1.790	1.720	1.790	1.865	1.865	1.863
Clay lumps		less than 2%	No	No	No	No	No	No	No
Quantity of soft particle (%)		---							
Organic impurities		---	---	---	---	---	---	---	---

Table 7-9(a) Test Results and ASTM Standard (Concrete Aggregate) of Fine Aggregate of Ayvalı Project

		Fine Aggregate								
		ASTM	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
Grading		See Fig. 7-17								
Finess Modulus		2.3 ~ 3.1	2.8	2.5	2.6	2.2	2.8	2.9	2.8	3.3
Bulk	Dry	---								
Specific	Surface dry	---	2.70	2.68	2.68	2.70	2.71	2.70	2.70	2.69
Gravity	Apparent	---								
Absorption %		---	2.0	2.0	1.8	1.8	1.4	1.6	1.6	1.6
Abrasion		less than 50%	3.4	3.6	3.3	3.3	3.4	3.4	3.3	3.4
Soundness		less than 10%	10.9	12.4	14.5	12.7	10.3	8.7	10.7	9.8
Unit weight t/m^3		---	1.780	1.800	1.725	1.820	1.780	1.780	1.780	1.680
Clay lumps		less than 3%								
Quantity of soft particle (%)		less than 5%								
Organic impurities		---	A.Sari	A.Sari	A.Sari	A.Sari	A.Sari	A.Sari	A.Sari	A.Sari

Table 7-9(b) Test Results and ASTM Standard (Concrete Aggregate) of Coarse Aggregate of Ayvalı Project

		Coarse Aggregate								
		ASTM	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
Grading		See Fig. 7-17								
Finess Modulus		---	---	---	---	---	---	---	---	---
Bulk	Dry	---								
Specific	Surface dry	---	2.67	2.67	2.63	2.66	2.67	2.65	2.66	2.64
Gravity	Apparent	---								
Absorption %		---	1.6	1.6	1.8	1.6	1.5	1.6	1.5	1.4
Abrasion		less than 50%	17.0	17.7	17.4	17.6	17.5	17.6	17.3	16.4
Soundness		less than 18%	8.4	9.6	12.5	12.8	7.6	6.7	9.1	7.4
Unit weight t/m^3		---	1.935	1.900	1.825	1.827	1.825	1.900	1.825	1.900
Clay lumps		less than 2%	No	No	No	No	No	No	No	No
Quantity of soft particle (%)		---	---	---	---	---	---	---	---	---
Organic impurities		---	---	No	No	No	No	No	No	No

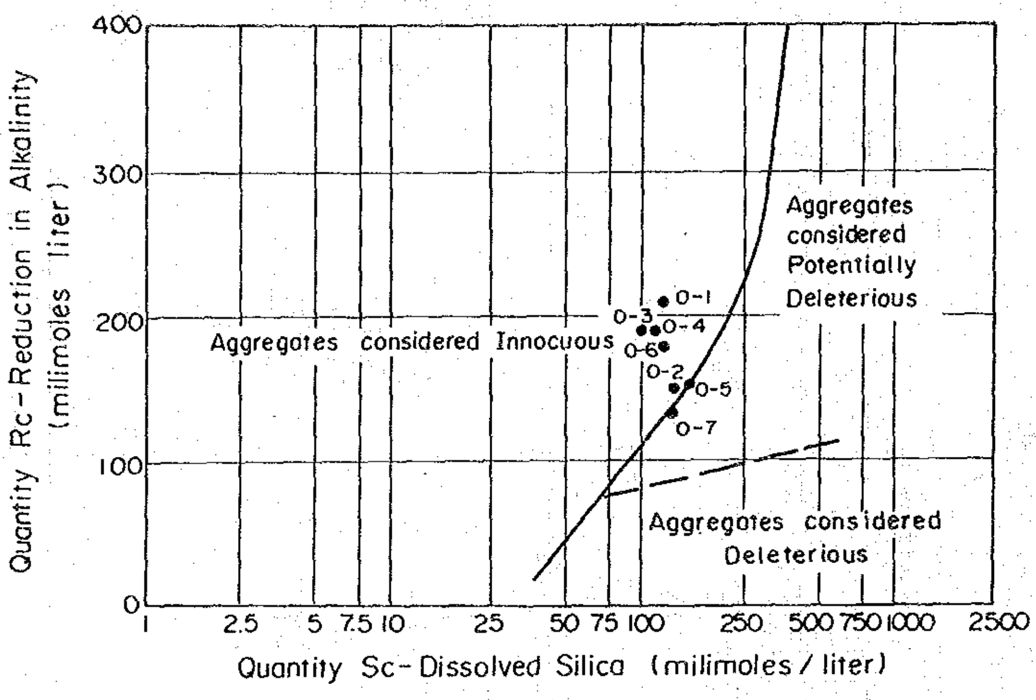


Fig. 7-23 Alkali-Aggregate Reaction of Olur Project

Table 7-10 Alkali-Aggregate Reaction of Olur Project

Sample Number	Alkali Reactivity (m mol/L)	Dissolved Silicate (m mol/L)
0-1	210	123
0-2	150	139
0-3	190	100
0-4	180	123
0-5	150	170
0-6	190	115
0-7	130	146

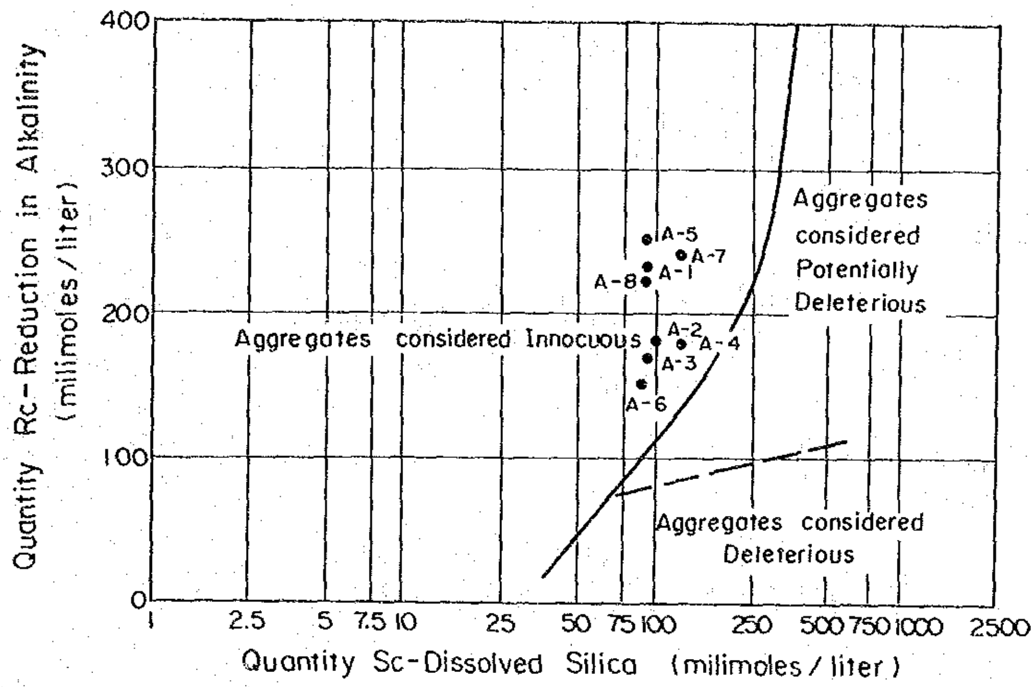


Fig. 7-24 Alkali-Aggregate Reaction of Ayvalı Project

Table 7-11 Alkali-Aggregate Reaction of Ayvalı Project

Sample Number	Alkali Reactivity (m mol/L)	Dissolved Silicate (m mol/L)
0-1	220	97
A-2	180	100
A-3	170	94
A-4	180	131
A-5	250	94
A-6	150	88
A-7	240	123
A-8	230	94

Chapter 8 SEISMIC ANALYSIS

Chapter 8

SEISMIC ANALYSIS

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Chapter 8 SEISMIC ANALYSIS

8.1 Structural Geology of Turkey

8.1.1 Geological Outline

The Anatolian Peninsula region has been subjected to the repeated organic movements since the beginning of Paleozoic age, and presents a complex geology. Concerning the structural geology of Turkey, it can be classified into four east-west oriented tectonic zones. Namely, they are in order from the north, the Pontids, Anatolids, Taurids, and Border Folds as shown in Fig. 8-1.

In the Pontids, Cretaceous to Paleogene rhyolitics-basaltic volcanic rocks are predominant, while there is partial distribution of Jurassic to Cretaceous ophiolite. In the Anatolids, strongly deformed Eocene to Miocene marine clastic rocks and Quaternary volcanic rocks are distributed on the basement rocks of Jurassic to Cretaceous ophiolite and slightly metamorphosed rock. The continental deposits of Pliocene to Quaternary are distributed at the mountainland basins. The basement of the Taurids consists mainly of Precambrian to Mesozoic strata and ophiolite, while Eocambrian to Pliocene neritic sedimentary rocks are predominant in the Border Folds.

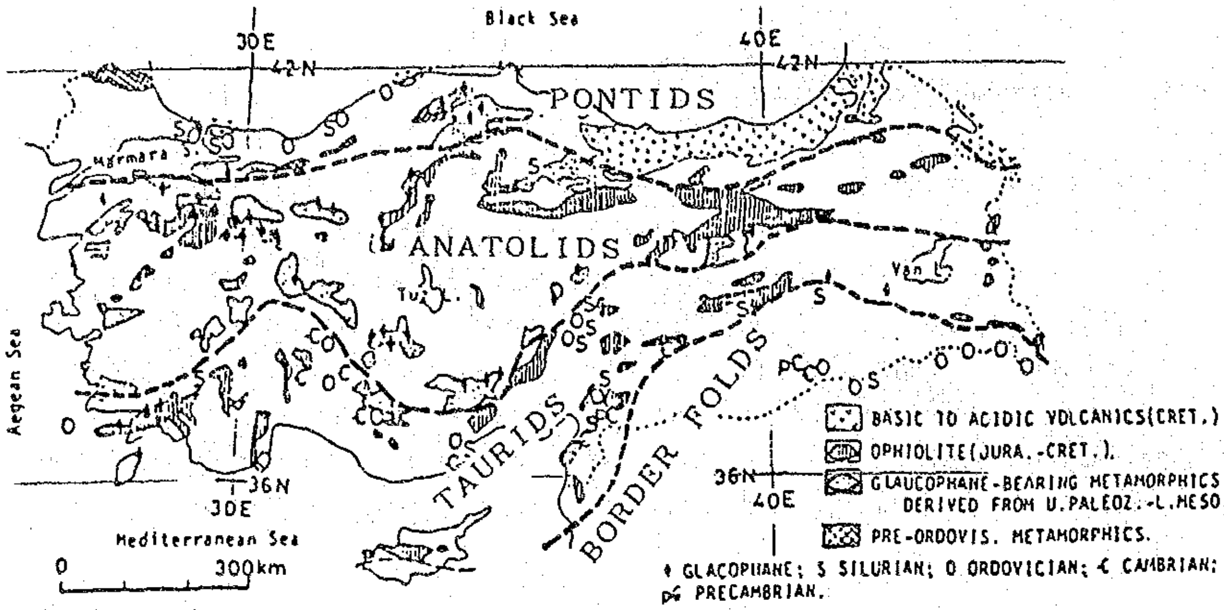


Fig. 8-1 Tectonic Zone of Turkey (after Hirano, 1981)

8.1.2 Neotectonics of Turkey

Various plate tectonics models around Turkey have been proposed by McKenzie (1973), Alptekin (173), Papazachos (1974), Dewey & Sengor (1979), and others.

Turkey is surrounded by three macro-plates, i.e. Eurasian Plate, Arabian Plate and African Plate, as shown in Fig. 8-2. Basically, Arabian and African Plates are drifting toward north relatively against Eurasian Plate causing the tectonic compressive stress field.

Moreover, many micro-plates such as Aegean Plate, Iran Plate, Anatolian Plate (Turkey Plate) and Black Sea Plate are located in Republic of Turkey surrounded by the three macro-plates which are mentioned above.

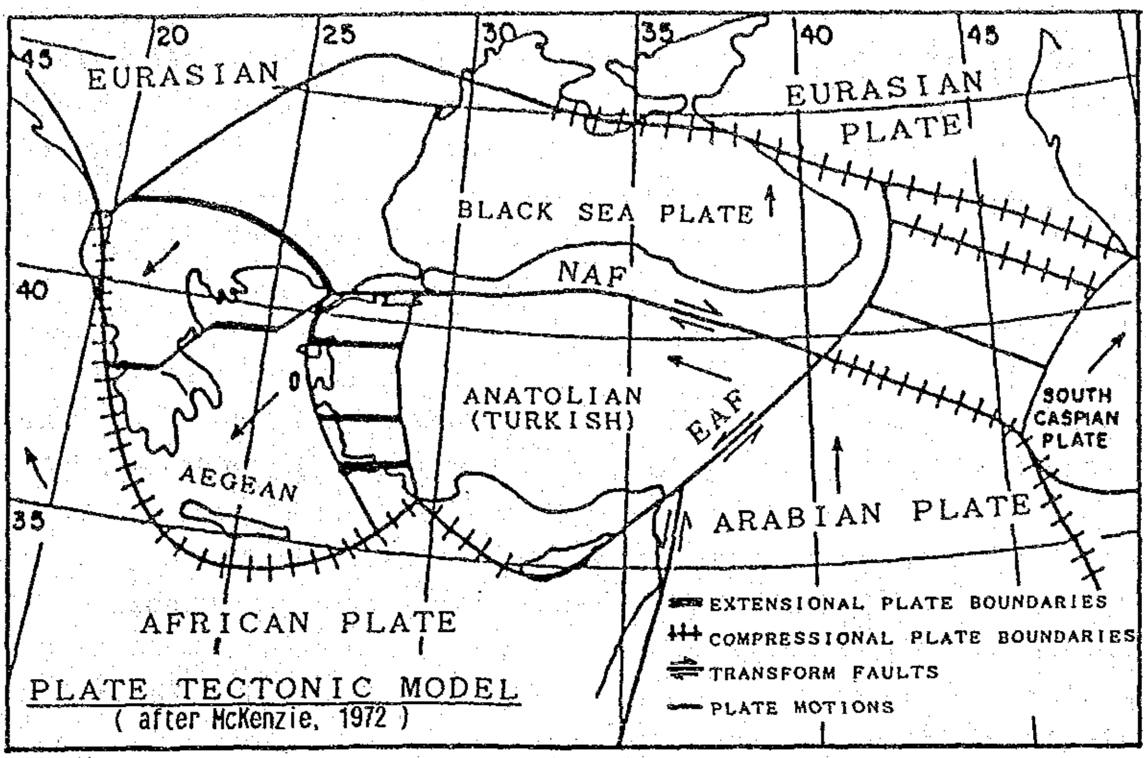


Fig. 8-2 Typical Plate Tectonics Model

8.1.3 North Anatolian Fault and East Anatolian Fault

The Anatolian Peninsula region is divided by two transform faults named North Anatolian Fault and East Anatolian Fault, which make up the plate boundaries. Particularly, these two transform faults prominently divide the previously-mentioned tectonic zones.

The North Anatolian Fault extends east-west, presenting a gentle arc bulging northward at the northern part of Turkey and its total length is in excess of approximately 1,000 km. It is a morphologically distinct and seismically active right lateral strike-slip fault. The accumulated horizontal displacement of it was considered to be 70 to 80 km in the past, but recently, some researcher says that it should be 20 to 30 km, and this subject requires further study. The occurrence of the North Anatolian Fault is said to have been 10 to 12 million years ago, but the direction of displacement has not always been consistently right-handed horizontal and it appears there was a time in the middle of Pliocene Epock when a left-handed horizontal displacement was indicated. Many active faults, earthquake faults and mountainland basins are distributed along this fault, while there have been also volcanic activities, and it may be seen that this is a first-class structure of the Quaternary Period.

The East Anatolian Fault divides the Taurids, and on land it has a length of approximately 560 km with a strike of N60°E - S60°W. It shows a thrust-fault nature at the southwestern part, but a left-handed lateral displacement is prominent on the whole. It is covered by Quaternary volcanic rocks and the displacement topography is not always distinct, while the degree of activity is slightly lower compared with the North Anatolian Fault, but this is also a paramount structure of this region. The fault intersects the North Anatolian Fault east of Karliova to comprise a triple junction. As a consequence, the Anatolian Plate sandwiched by the two faults would apparently shift westward.

As described in the foregoing, the neotectonics of Turkey are made complex reflecting the mutual movements between the plates in the field of tectonic stress from north-south compression caused by the northward-drifting Arabian Plate since the late Miocene Epoch.

8.2 General Seismicity of Turkey

8.2.1 Seismological Outline

It is well known that many earthquakes have occurred in Turkey, which is located in Alphine-Himalayan seismic zone. As explained before, three macro-plates, i.e. Eurasian Plate, Arabian Plate and African Plate, develop the mutual movements around Turkey. And moreover, Micro-Plates such as Aegean Plate, Iran Plate, Anatolian Plate and Black Sea Plate develop the mutual complicated movements, in Turkey.

These micro-plates are small, but move rapidly. The cause of the local increase in Seismic activity of this region is attributed to the existence of these small but rapidly moving micro-plates.

Fig. 8-3 clearly shows the distribution of the major fault systems in Turkey. It can be understood that the major faults are running along the border zone of the micro-plates which are mentioned above.

Shortly speaking, earthquakes in Turkey occur as a result of relative movements among the many macro/micro plates i.e. Eurasian Plate, African Plate, Arabian Plate, Aegean Plate, Iran Plate, Anatolian Plate (Turkey Plate) and Black Sea Plate.

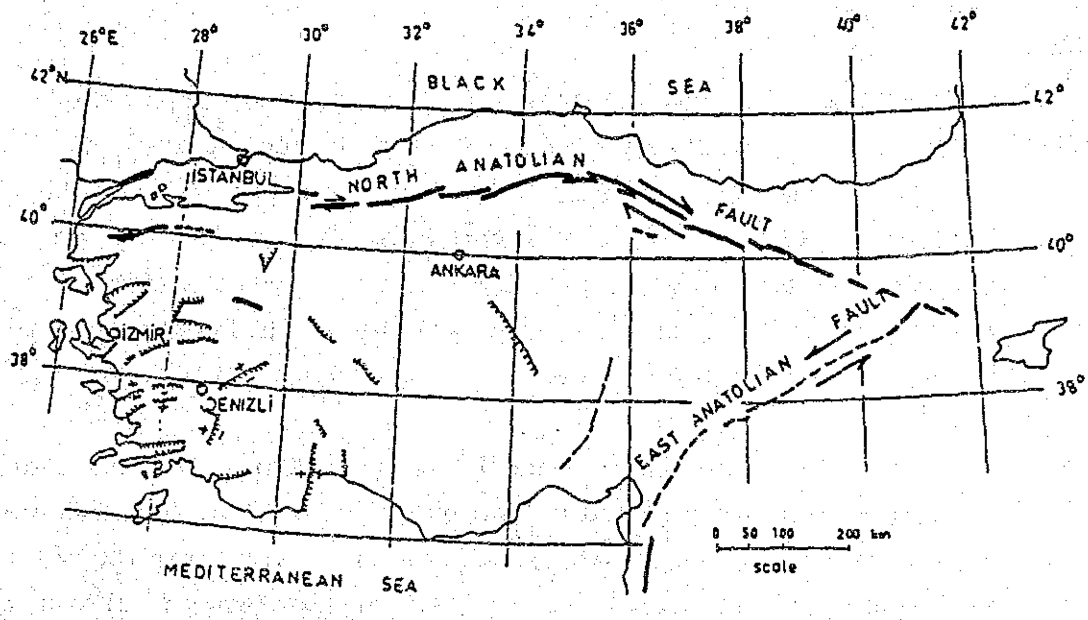


Fig. 8-3 Major Fault Systems in Turkey

8.2.2 Seismic Activities

Epicenters of 5,980 earthquakes which occur in Turkey during the period 1901 - 1985 are indicated in Fig. 8-4. The location map of the larger earthquakes ($Ms \geq 6$) of the period 1899 - 1983 is also given in Fig. 8-5.

By the way, the seismic active zone for Turkey can be classified into four groups as follows, taking plate tectonics model, distribution of active faults, and occurrence of historical earthquakes into consideration.

(1) North Anatolian Fault Region

The North Anatolian Fault is a transform fault which is situated in the boundary between the Black Sea Plate and the Anatolian Plate (Turkey Plate). The number of earthquakes larger than magnitude 5.5 ($M \geq 5.5$) in the North Anatolian Fault region has exceeded 60 since 1900. They are the shallow-focal-depth earthquakes conforming to the right-lateral fault.

Meanwhile, the earthquake which occurred at Erzincan in 1939 at the eastern part of the North Anatolian Fault registered M 7.9, which is the strongest in this century in Turkey. Since then, earthquakes in this region have occurred every so many years, and it is well-known that the hypocenters of these earthquakes have shifted westward in a remarkably orderly manner.

According to the investigations thus far, the earthquake faults which were produced as results of these earthquakes do not strictly coincide in cases, but approximately, they are produced by repeated cycles of motion of the active faults running roughly parallel in the vicinity of the North Anatolian Fault. In view of the cumulative vertical displacement of the active faults and the vertical displacements of the individual earthquake faults the return period can be estimated to be of the order of several hundred or several thousand years (< 5,000 yr).

The earthquake faults are in a number of multiple echelon arrangements composed of segments made of echelon fissures, the smallest of which are ten and several centimeters. Small-scale echelon arrangements with segment lengths of less than several hundred meters are arrayed in correspondence with the lateral displacement of related transform faults. On the other hand, large-scale echelon arrangements of segment lengths ten and several kilometers do not necessarily correspond with related transform faults. This is because they are affected by geological anisotropies near the ground surface such as existing fissures and volcanic rock mass.

(2) East Anatolian Fault Region

The East Anatolian Fault is a transform fault which is situated in the boundary between the Anatolian Plate (Turkey Plate) and the Arabian Plate. Shallow earthquakes conforming to the left-lateral fault are predominant in the East Anatolian Fault region. Most of them have occurred less than 25 km in focal depth. The recurrence of the earthquakes larger than magnitude 5.5 ($m \geq 5.5$) in this region is around 12 years.

(3) West Anatolian Region

Rather deeper earthquakes conforming to the normal faults along the east-west graben are predominant in the West Anatolian region.

(4) Other Regions

They have relatively low seismic activities in the area except for the regions (1), (2) and (3) in Turkey.

Total Number of Plots in the Area of $\Delta \leq$ 1,000.0 (km) is 5,980.

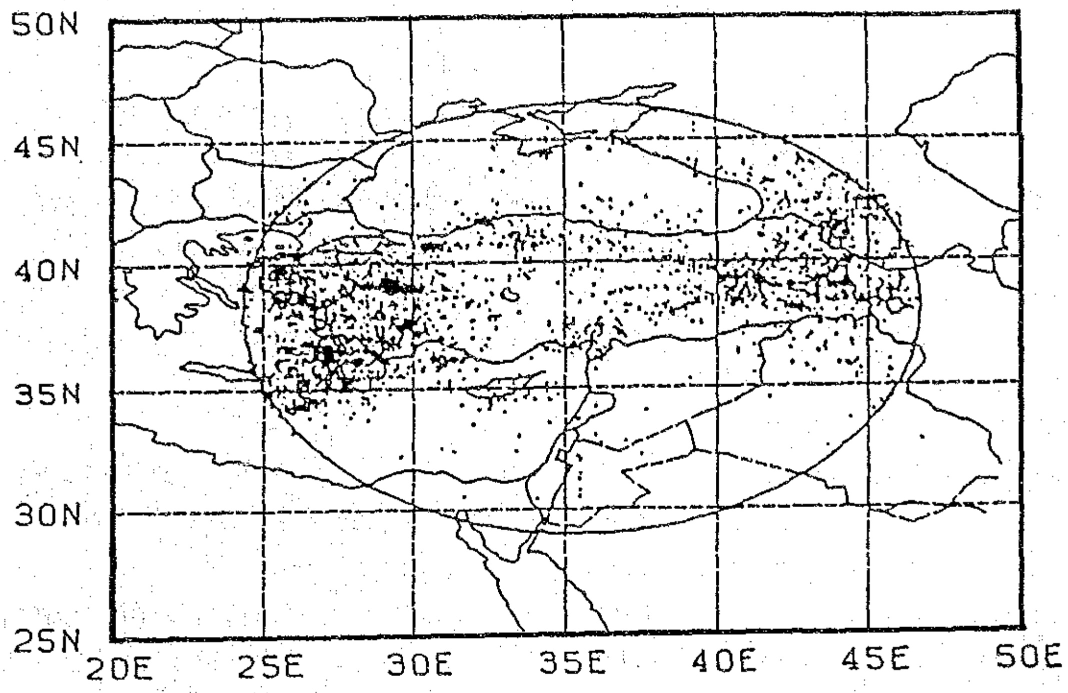
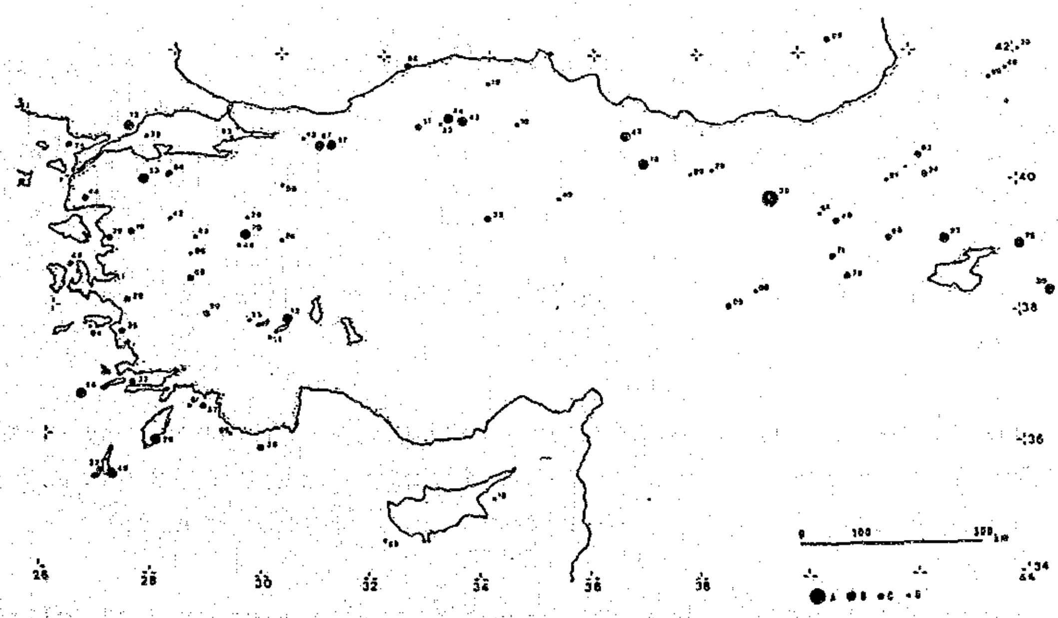


Fig. 8-4 Seismicity of All Data from 1901 - 1985



Map of the northeast Mediterranean region under study (34° N to 42° N and 26° E to 44° E), i.e. Turkey, Cyprus, northern Syria, Lebanon, Iraq, frontiers of Iran and the USSR. The map shows the location of the larger earthquakes ($M_s \geq 6$) of the period 1899-1983. Numbers refer to the last two figures of the year in which a particular earthquake occurred. A implies $8.0 > M_s \geq 7.5$; B : $7.5 > M_s \geq 7.0$; C: $7.0 > M_s \geq 6.5$; D : $6.5 > M_s \geq 6.0$.

Fig. 8-5 Location of the Larger Earthquakes (Ms ≥ 6) of the Period 1899 - 1983

8.3 Design Seismic Coefficient

8.3.1 Design Seismic Coefficient for Existing Dams

To determine the design seismic coefficient for the Project, the correlation between seismic risk and adopted design seismic coefficient for the existing and planned dams in Turkey was studied. The design seismic coefficients (horizontal ground level seismic coefficients) for the 184 dam sites were in hand out of 74 dam sites (Dams and Hydroelectric Power Plant in Turkey, 1990).

Available seismic risk map for Turkey was prepared in 1972 by the Government of Turkey (IMAR ve ISKAN BAKANLIGI). Then, the correlation between seismic risk and the design seismic coefficient was studied by comparing the seismic risk map with the dam location. The seismic risk map for Turkey which shows the 5 zones relating to the degree of risk covering the whole of Turkey is given in Fig. 8-6. The result of the survey is also given in Fig. 8-7.

Consequently, the results can be summarized by item as follows;

- The maximum value of adopted design seismic coefficient was 0.18,

- The minimum value of adopted design seismic coefficient was 0.05,

- The value of 0.18 as design seismic coefficient was adopted for 1 site out of 45 sites, similarly 0.15 for 18 sites, 0.12 for 4 sites, 0.10 for 16 sites and 0.05 for 6 sites,

- The coefficient 0.15 is noticeable in 1st degree zone given in Fig. 8-6,

- The coefficient 0.12 or 0.10 is noticeable in 2nd degree zone,

- The coefficient 0.15 or 0.10 is noticeable in 3rd degree zone, and

- The coefficient 0.05 is noticeable in 4th degree zone.

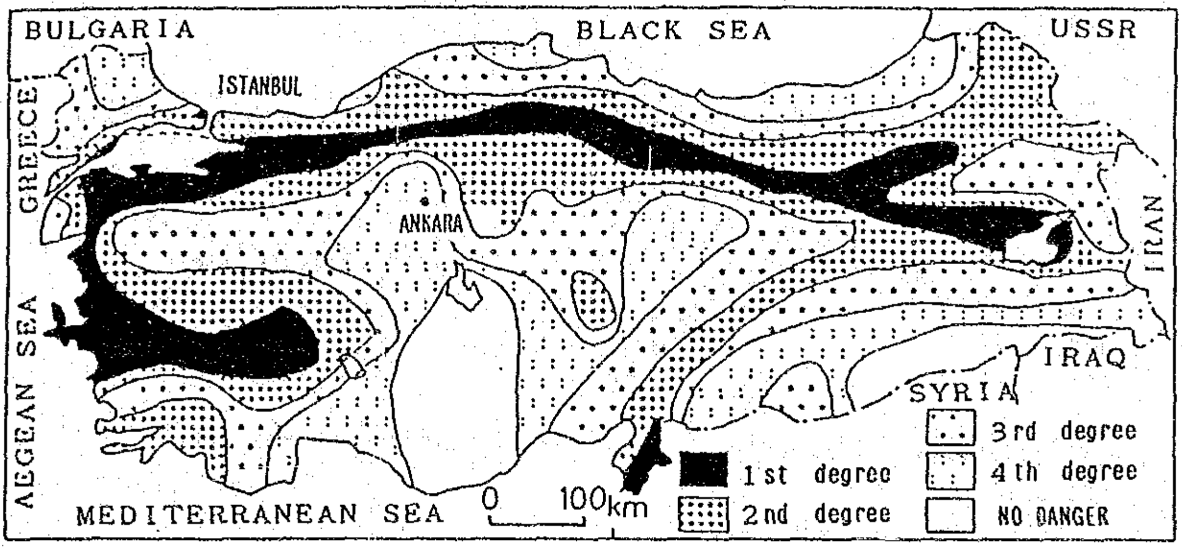


Fig. 8-6 Seismic Risk Map for Turkey (1972)

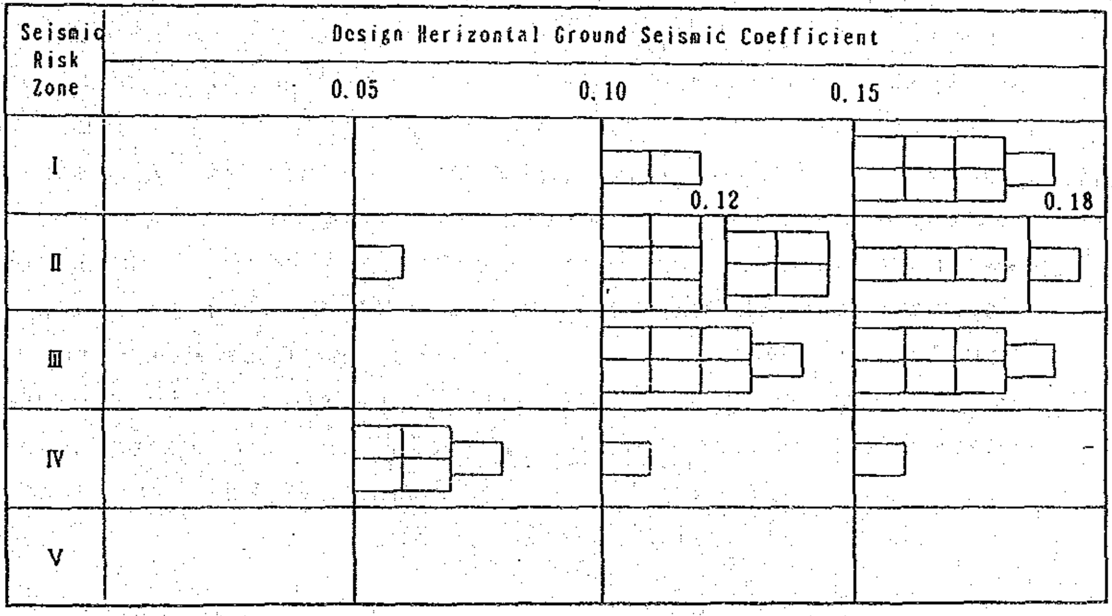


Fig. 2.8.2-7 Design Seismic Coefficient used for Dams in Turkey

In this study, the reasonable results are obtained, that is the high coefficient was adopted for the hazardous zone, and on the contrary the low coefficient for the safer zone.

Considering above-mentioned tendency, it can be standardized as follows from the viewpoint of earthquake-resistant design for dams in Turkey.

- The design seismic coefficient 0.15 can be applied for the 1st degree zone
- The coefficient 0.15 - 0.12 for the 2nd degree zone
- The coefficient 0.12 - 0.10 for the 3rd degree zone
- The coefficient 0.10 - 0.05 for the 4th degree zone

8.3.2 Estimation of Maximum Acceleration at the Sites

(1) Analysis Method

The estimation of the maximum ground acceleration at the Ayvali and the Olur dam site by statistical probability analysis was performed to determine the design seismic coefficient. The seismicity data used in this study are those compiled by NOAA (National Oceanic and Atmospheric Administration Environmental Data Service). The number of earthquakes which occurred within the radius of 200 km from the site during the period from 1900 to 1987 is 3,402 for the Ayvali dam site, and 3,742 for the Olur dam site. Of previously proposed attenuation models which express maximum ground acceleration A (gal), in terms of earthquake magnitude M and hypocentral distance R (km), four models shown below are used in this study.

$$\text{Log } A = 3.090 + 0.347\,M - 2\,\text{Log }(R+25) \qquad 1)$$

proposed by C. Oliveira

$$\text{Log } A = 2.674 + 0.278\ M - 1.301 \text{ Log } (R+25) \qquad 2)$$

proposed by R.K. McGuire[2]

$$\text{Log } A = 2.041 + 0.347\ M - 1.6 \text{ Log } R \qquad 3)$$

proposed by L. Esteva and E. Rosenblueth[3]

$$\text{Log } A = 2.308 + 0.411\ M - 1.637 \text{ Log } (R+30) \qquad 4)$$

proposed by T. Katayama[4]

A probabilistic model based on the "Theory of Extreme Values" can be established by taking an equal time interval of one year. Although a probability function of the maximum ground acceleration expected at a certain particular dam site is not known, it is reasonable to suppose that the function should be associated with the third-type asymptotic distribution.

(2) Results of Seismic Risk Analysis at the Ayvalı Dam Site

The distributions of magnitudes and epicentral distances regarding seismological data used in the seismic risk analysis at the Ayvalı dam site (41°55′ east longitude, 40°46′ north latitude) are given in Table 8-1. The number of earthquakes yearly from 1990 to 1987 are given in Table 8-2, while the estimated values of maximum accelerations in the earthquakes with the greatest effects on the site in each of the years are given in Table 8-3.

The seismic risk analysis results based on the statistical probability theory technique concerning the Ayvalı dam site are shown in Figs. 8-8 to 8-11.

(3) Results of Seismic Risk Analysis at the Olur Dam Site

The distributions of magnitudes and epicentral distances regarding seismological data used in the seismic risk analysis at the Olur dam site (42°11′ east longitude, 40°45′ north latitude) are given in Table 8-4. The number of earthquakes yearly from 1990 to 1987 are given in Table 8-5, while the estimated values of maximum accelerations in the earthquakes with the greatest effects on the site in each of the years are given in Table 8-6.

The seismic risk analysis results based on the statistical probability theory technique concerning the Olur dam site are shown in Figs. 8-12 to 8-15.

(4) Maximum Accelerations Assumed for the Ayvalı and the Olur Dam Sites

The maximum accelerations at the ground surface assumed for the Ayvalı and the Olur dam sites can be put together in Tables 8-7 and 8-8 from the previously-mentioned seismic risk analysis.

As can be comprehended from the tables, the results of estimation of maximum acceleration vary greatly depending on the attenuation equation applied. Since such uncertainties exist in the seismic risk analysis, and as evaluations are on the conservative side, a value enveloping Table 8-7 or Table 8-8 is to be considered as the assumed maximum acceleration for each site.

In effect, 180 gal is to be taken as the maximum acceleration at the ground surface during earthquake for the Ayvalı dam site, and 150 gal for the Olur dam site.

Further, the 180 gal for the Ayvalı dam site and the 150 gal for the Olur dam site approximately correspond to a return period of 10,000 years.

Table 8-1 **Distribution of Magnitude and Epicentral Distance of Seismicity Data Used for the Ayvalı Dam Site**

	0<=D<50	<100	<200	Total
0<M<3.0	58	245	2691	2994
<3.5	0	0	0	0
<4.0	0	1	1	2
<4.5	8	5	13	26
<5.0	9	12	62	83
<5.5	12	12	111	135
<6.0	1	16	96	113
<6.5	1	10	32	43
<7.0	0	3	9	12
<7.5	0	0	1	1
<8.0	0	0	0	0
8.0<=	0	0	0	0
UNKNOWN	0	0	0	0
TOTAL	89	304	3016	3409

D: Epicentral distance (km)
M: Magnitude

Table 8-2 Number of Earthquakes in a Year during the Period from 1901 to 1987 for the Ayvalı Dam Site

YEAR	N	SUM OF N	YEAR	N	SUM OF N
1901	1	1	1948	13	250
1902	1	2	1949	17	267
1903	6	8	1950	7	274
1904	3	11	1951	4	278
1905	7	18	1952	11	289
1906	6	24	1953	10	299
1907	4	28	1954	11	310
1908	4	32	1955	1	311
1909	3	35	1956	3	314
1911	2	37	1957	11	325
1912	5	42	1958	16	341
1913	6	48	1959	14	355
1914	2	50	1960	5	360
1915	2	52	1961	8	368
1916	1	53	1962	551	919
1917	2	55	1963	423	1342
1919	1	56	1964	400	1742
1923	2	58	1965	360	2102
1924	20	78	1966	454	2556
1925	12	90	1967	78	2634
1926	16	106	1968	75	2709
1927	2	108	1969	74	2783
1928	5	113	1970	82	2865
1929	6	119	1971	53	2918
1030	4	123	1972	56	2974
1931	3	126	1973	37	3011
1932	8	134	1974	42	3053
1933	1	135	1975	62	3115
1934	4	139	1976	134	3249
1935	18	157	1977	34	3283
1936	8	165	1978	73	3356
1937	5	170	1979	3	3359
1938	10	180	1980	3	3362
1939	7	187	1981	1	3363
1940	23	210	1982	7	3370
1941	15	225	1983	14	3384
1943	1	226	1984	12	3396
1944	1	227	1985	4	3400
1946	4	231	1986	7	3407
1947	6	237	1987	2	3409

Table 8-3 (a) Maximum Accelerations of the Year at the Ayvalı Dam Site during the Period from 1900 to 1987

(gal)

Year	Attenuation Equation			
	Oliveira's Eq. ACC.	McGuire's Eq. ACC.	Esteva & Rosenblueth's Eq. ACC.	Katayama's Eq. ACC.
1990	0.0	0.0	0.0	0.0
1901	8.97	40.29	7.91	20.60
1902	2.68	17.56	2.50	7.03
1903	14.53	55.15	12.88	30.12
1904	3.91	21.96	3.51	8.97
1905	13.01	58.44	11.73	38.80
1906	38.05	104.77	37.73	66.17
1907	4.73	27.83	4.43	13.95
1908	5.51	27.44	4.87	11.76
1909	2.13	14.78	2.00	5.51
1910	0.0	0.0	0.0	0.0
1911	0.21	2.16	0.19	0.29
1912	0.18	1.97	0.17	0.27
1913	3.74	22.47	3.45	9.90
1914	1.78	12.30	1.64	4.02
1915	1.56	10.36	1.41	3.21
1916	0.13	1.56	0.12	0.20
1917	0.25	2.37	0.22	0.33
1918	0.0	0.0	0.0	0.0
1919	1.22	6.76	1.18	1.18
1920	0.0	0.0	0.0	0.0
1921	0.0	0.0	0.0	0.0
1922	0.0	0.0	0.0	0.0
1923	0.20	2.08	0.18	0.28
1924	21.56	77.56	19.01	51.34
1925	12.56	49.08	11.13	25.35
1926	5.06	28.21	4.63	13.63
1927	0.23	2.37	0.21	0.31
1928	8.44	35.38	7.50	15.46
1929	3.59	19.68	3.18	7.29
1930	2.60	16.19	2.35	5.86
1931	4.14	24.03	3.79	10.75
1932	3.91	21.96	3.51	8.97
1933	0.13	1.57	0.12	0.20
1934	17.30	56.84	16.65	27.50
1935	7.93	38.38	7.09	20.29
1936	4.12	23.95	3.77	10.71
1937	2.62	16.64	2.39	6.25
1938	3.29	19.46	2.97	7.64
1939	2.14	14.58	1.99	5.31
1940	6.88	34.43	6.07	18.32
1941	4.86	27.46	4.45	13.18
1942	0.0	0.0	0.0	0.0
1943	5.51	27.44	4.87	11.76
1944	4.74	24.30	4.18	9.82
1945	0.0	0.0	0.0	0.0
1946	12.50	50.79	11.01	27.90
1947	7.60	35.41	6.71	17.09
1948	2.75	17.05	2.49	6.38
1949	7.53	39.41	6.95	22.73
1950	2.75	17.45	2.52	6.76
1951	8.87	39.13	7.81	19.29

Table 8-3 (b) Maximum Accelerations of the Year at the Ayvalı Dam Site during the Period from 1900 to 1987

(gal)

Year	Attenvation Equation			
	Oliveira's Eq. ACC.	McGuire's Eq. ACC.	Esteva & Rosenblueth's Eq. ACC.	Katayama's Eq. ACC.
1952	13.32	52.93	11.74	29.32
1953	3.05	19.55	2.85	8.26
1954	4.18	24.91	3.89	11.70
1955	0.14	1.65	0.13	0.21
1956	0.78	4.99	0.71	0.81
1957	2.57	16.83	2.83	6.80
1958	2.77	17.34	2.53	6.61
1959	5.56	28.45	4.94	12.81
1960	2.39	15.74	2.21	5.89
1961	2.81	17.04	2.53	6.38
1962	2.41	13.78	2.13	4.12
1963	2.79	16.94	2.51	6.19
1964	5.98	28.07	5.27	11.58
1965	3.49	21.50	3.24	9.38
1966	6.86	36.80	6.35	20.70
1967	4.43	26.26	4.13	12.74
1968	35.39	85.64	80.95	42.61
1969	7.13	30.50	6.37	12.23
1970	13.34	46.24	12.81	20.32
1971	6.52	29.45	5.76	12.12
1972	13.47	46.25	13.06	20.13
1973	10.68	39.40	10.04	16.40
1974	1.45	10.65	1.41	3.34
1975	18.09	59.88	17.36	30.32
1976	12.82	44.12	14.11	20.89
1977	6.40	26.52	5.93	10.42
1978	3.78	19.30	3.34	8.15
1979	1.14	8.76	1.06	2.48
1980	5.78	24.22	5.39	8.05
1981	1.55	10.55	1.39	3.06
1982	2.71	15.36	2.39	5.29
1983	25.17	78.37	23.64	45.39
1984	45.23	98.11	118.40	44.62
1985	8.20	33.50	7.40	13.74
1986	18.09	50.28	27.96	18.41
1987	3.52	17.77	3.12	5.66

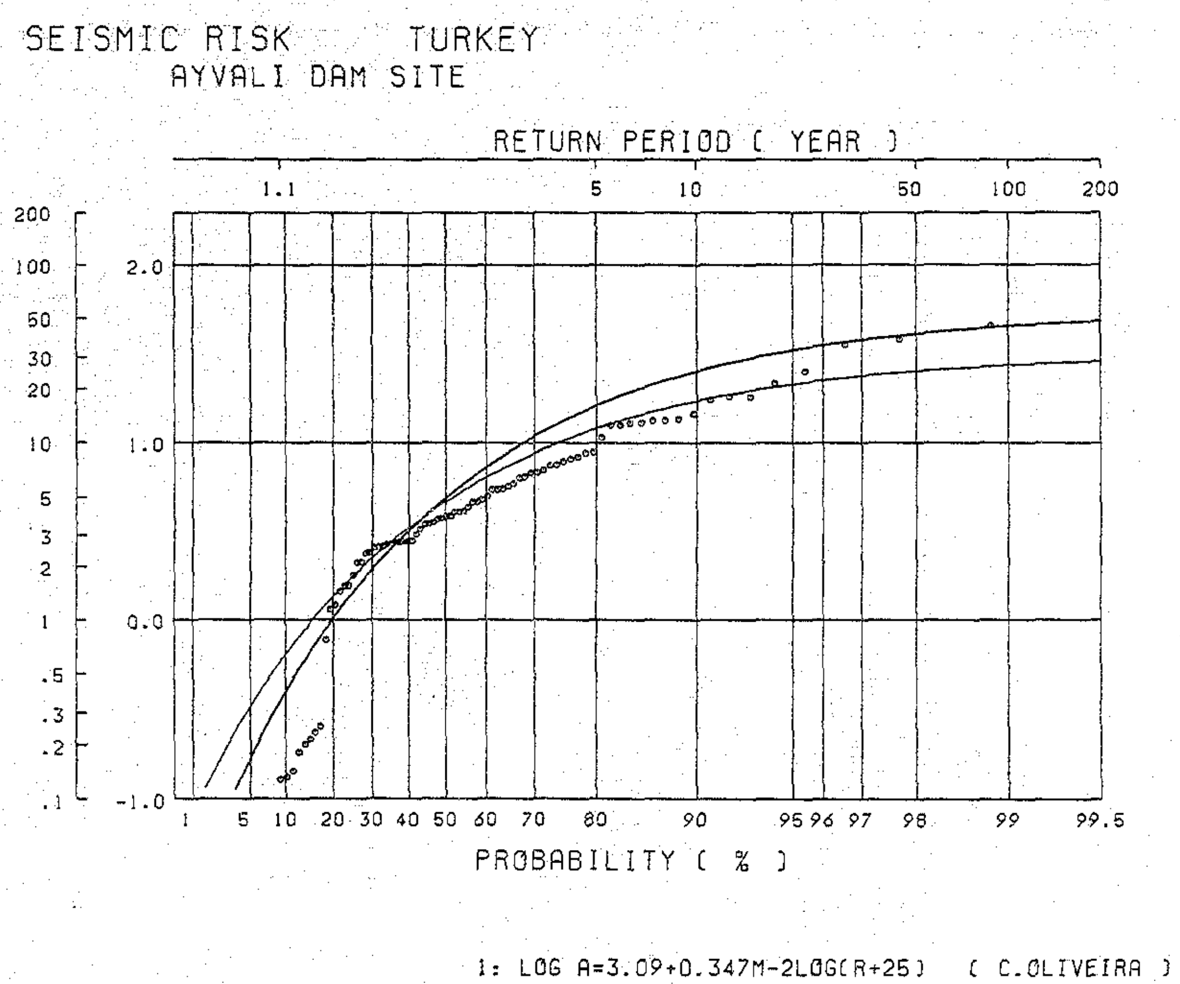


Fig. 8-8 Maximum Acceleration for Return Period at the Ayvalı Dam Site Estimated by Oliveira's Equation

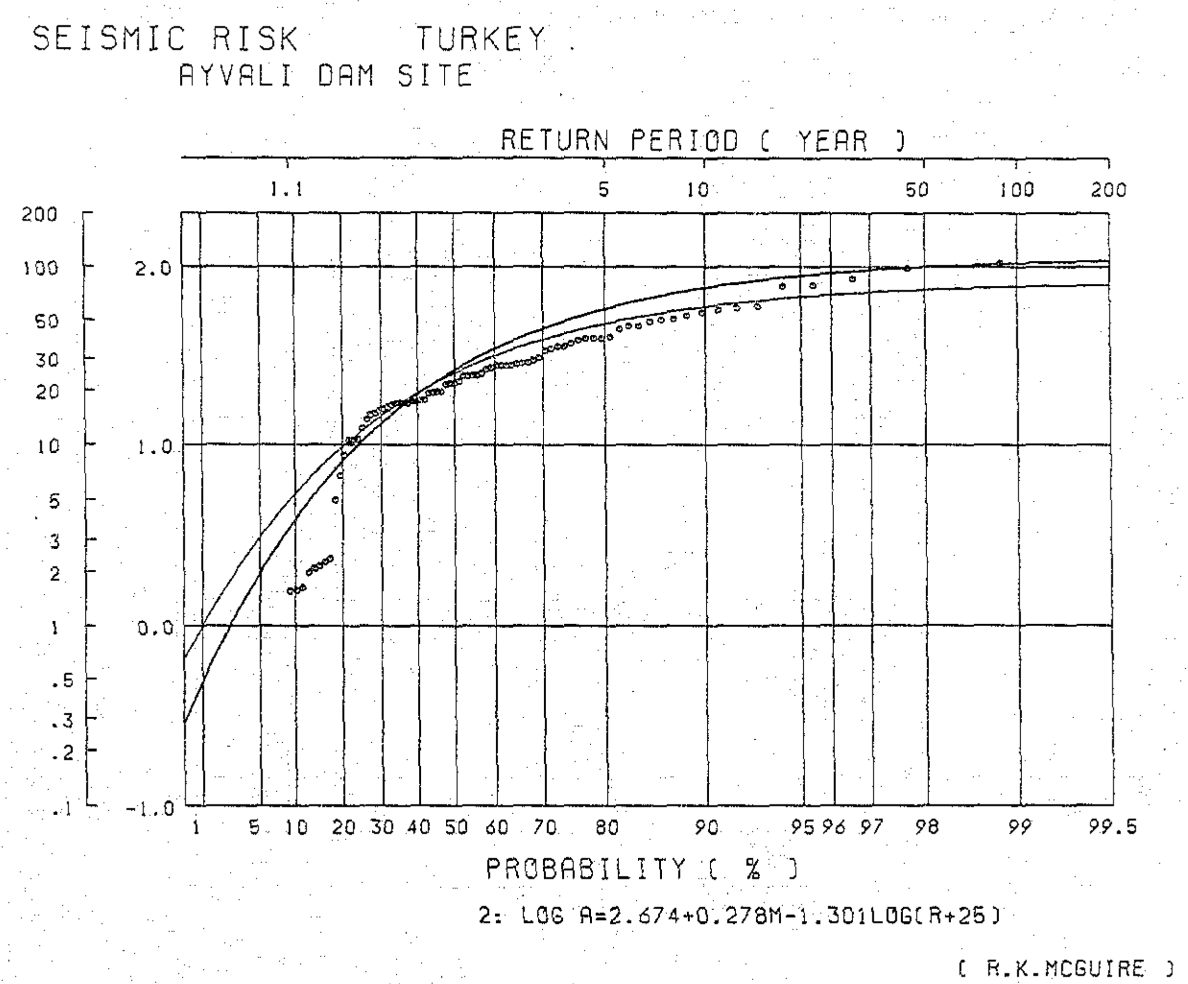


Fig. 8-9 Maximum Acceleration for Return Period at the Ayvalı Dam Site Estimated by McGuire's Equation

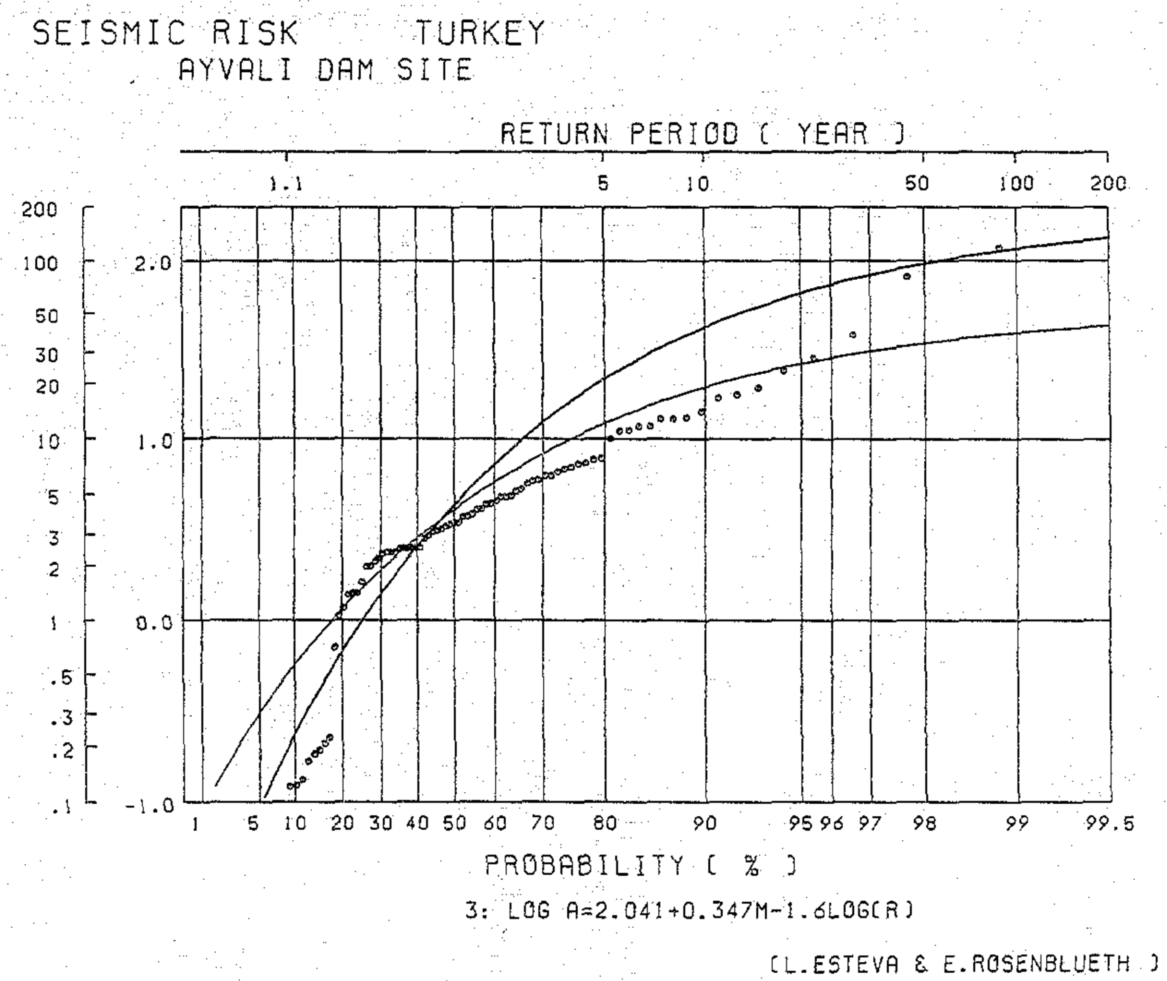


Fig. 8-10 Maximum Acceleration for Return Period at the Ayvalı Dam Site Estimated by Esteva & Rosenblueth's Equation

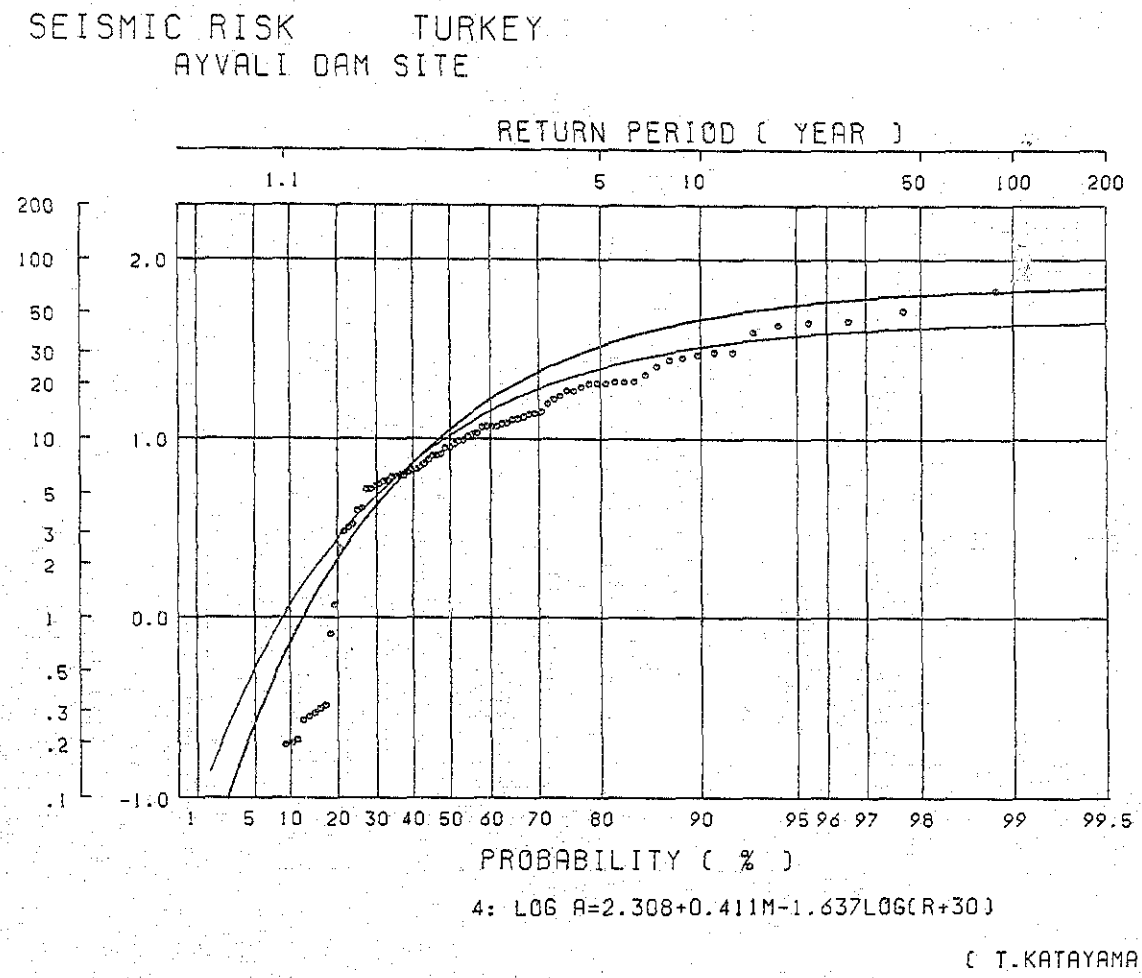


Fig. 8-11 Maximum Acceleration for Return Period at the Ayvalı Dam Site Estimated by Katayama's Equation

Table 8-4 **Distribution of Magnitude and Epicentral Distance of Seismicity Data Used for the Olur Dam Site**

	0<=D<50	<100	<200	Total
0<M<3.0	82	275	2928	3285
<3.5	0	0	0	0
<4.0	0	1	11	12
<4.5	8	4	28	40
<5.0	11	14	62	87
<5.5	11	13	117	141
<6.0	0	21	101	122
<6.5	2	8	31	41
<7.0	0	3	9	12
<7.5	0	0	1	1
<8.0	0	0	0	0
8.0<=	0	0	1	1
UNKNOWN	0	0	0	0
TOTAL	114	339	3289	3742

D: Epicentral distance (km)
M: Magnitude

Table 8-5 Number of Earthwuakes in a Year during the Period from 1900 to 1987 for the Olur Dam Site

YEAR	N	SUM OF N	YEAR	N	SUM OF N
1901	2	2	1948	13	288
1903	7	9	1949	19	307
1904	3	12	1950	7	314
1905	7	19	1951	4	318
1906	7	26	1952	11	329
1907	4	30	1953	9	338
1908	4	34	1954	6	344
1909	4	38	1955	1	345
1910	2	40	1956	3	348
1911	3	43	1957	9	357
1912	8	51	1958	16	373
1913	6	57	1959	15	388
1914	3	60	1960	5	393
1915	4	64	1961	9	402
1916	3	72	1962	646	1048
1917	1	75	1963	450	1498
1919	2	76	1964	421	1919
1923	3	78	1965	392	2311
1924	20	101	1966	491	2802
1925	12	113	1967	81	2883
1926	19	132	1968	80	2963
1927	2	134	1969	79	3042
1928	6	140	1970	85	3127
1929	6	146	1971	53	3180
1030	4	150	1972	60	3240
1931	4	154	1973	42	3282
1932	9	163	1974	51	3333
1933	1	164	1975	65	3398
1934	4	168	1976	140	3538
1935	17	185	1977	54	3592
1936	8	193	1978	95	3687
1937	12	205	1979	4	3691
1938	10	215	1980	3	3694
1939	7	222	1981	1	3695
1940	25	247	1982	10	3705
1941	15	262	1983	14	3719
1943	1	263	1984	12	3731
1944	1	264	1985	4	3735
1946	5	269	1986	6	3741
1947	6	275	1987	1	3742

Table 8-6 (a) Maximum Accelertions of the Year at the Olur Dam Site during the Period from 1900 to 1987

(gal)

Year	Attenvation Equation			
	Oliveira's Eq. ACC.	McGuire's Eq. ACC.	Esteva & Rosenblueth's Eq. ACC.	Katayama's Eq. ACC.
1900	0.0	0.0	0.0	0.0
1901	7.70	36.49	6.83	18.27
1902	0.0	0.0	0.0	0.0
1903	20.51	67.50	19.12	38.36
1904	3.80	21.55	3.41	8.76
1905	12.67	57.45	11.46	38.00
1906	37.08	103.03	36.54	64.87
1907	5.02	28.92	4.67	14.62
1908	4.76	24.96	4.23	10.48
1909	2.52	16.49	2.33	6.31
1910	2.17	14.95	2.03	5.59
1911	0.27	2.49	0.24	0.35
1912	3.11	19.80	2.91	8.40
1913	4.63	25.82	4.20	11.74
1914	2.25	14.32	2.03	4.84
1915	2.47	16.66	2.32	6.59
1916	2.75	17.73	2.55	7.03
1917	0.29	2.59	0.25	0.36
1918	0.0	0.0	0.0	0.0
1919	1.42	7.47	1.43	1.32
1920	0.0	0.0	0.0	0.0
1921	2.73	17.77	2.54	7.13
1922	0.0	0.0	0.0	0.0
1923	0.25	2.40	0.22	0.33
1924	21.81	78.13	19.24	51.80
1925	17.14	60.09	15.52	32.31
1926	6.46	33.05	5.80	16.54
1927	0.31	2.73	0.27	0.39
1928	12.37	45.38	11.37	20.83
1929	4.59	23.10	4.04	9.02
1930	3.37	19.16	3.00	7.20
1931	3.35	20.92	3.12	9.07
1932	3.80	21.55	3.41	8.76
1933	0.14	1.62	0.13	0.20
1934	11.83	44.40	10.75	20.51
1935	10.51	46.10	9.29	25.36
1936	4.80	26.44	4.34	12.09
1937	2.46	16.59	2.31	6.55
1938	4.25	22.98	3.78	9.37
1939	2.66	16.82	2.43	6.33
1940	8.05	36.72	7.09	19.83
1941	5.55	29.95	5.04	14.67
1942	0.0	0.0	0.0	0.0
1943	4.76	24.96	4.23	10.48
1944	4.09	22.10	3.63	8.75
1945	0.0	0.0	0.0	0.0
1946	10.86	46.36	9.57	24.98
1947	8.78	38.89	7.74	19.15
1948	3.49	19.92	3.12	7.71
1949	8.77	37.11	7.75	20.49
1950	2.58	16.75	2.38	6.43
1951	9.25	40.23	8.15	19.94

Table 8-6 (b) Maximum Accelertions of the Year at the Olur Dam Site during the Period from 1900 to 1987

(gal)

Year	Attenvation Equation			
	Oliveira's Eq. ACC.	McGuire's Eq. ACC.	Esteva & Rosenblueth's Eq. ACC.	Katayama's Eq. ACC.
1952	12.18	49.75	10.73	27.34
1953	2.92	19.01	2.75	7.99
1954	3.66	21.22	3.27	9.14
1955	0.17	1.84	0.15	0.24
1956	1.07	6.17	1.02	0.04
1957	2.62	17.19	2.43	6.98
1958	3.51	20.23	3.15	7.98
1959	5.29	27.55	4.71	12.52
1960	2.42	15.83	2.23	5.88
1961	3.10	19.00	2.83	7.58
1962	3.19	18.20	2.82	7.42
1963	3.43	19.40	3.06	7.31
1964	4.54	23.49	4.01	9.33
1965	3.14	20.06	2.94	8.61
1966	6.63	36.03	6.16	20.16
1967	3.16	19.85	2.94	8.33
1968	51.06	112.35	94.23	57.93
1969	5.55	25.92	4.90	10.06
1970	14.31	48.40	13.94	21.44
1971	6.09	28.18	5.37	11.50
1972	17.66	54.26	19.10	24.10
1973	16.47	52.21	17.11	22.84
1974	1.76	12.10	1.99	3.90
1975	15.79	51.15	16.28	25.15
1976	18.75	60.93	17.94	30.66
1977	5.71	26.63	5.04	10.51
1978	13.57	71.45	14.38	56.21
1979	1.42	10.08	1.29	2.94
1980	8.70	31.68	8.88	11.02
1981	1.29	9.34	1.17	2.64
1982	2.94	16.17	2.59	5.30
1983	30.07	87.98	50.30	52.03
1984	45.37	104.41	72.66	53.72
1985	12.21	40.36	13.19	16.07
1986	11.32	37.08	13.19	13.00
1987	2.44	14.01	2.15	4.25

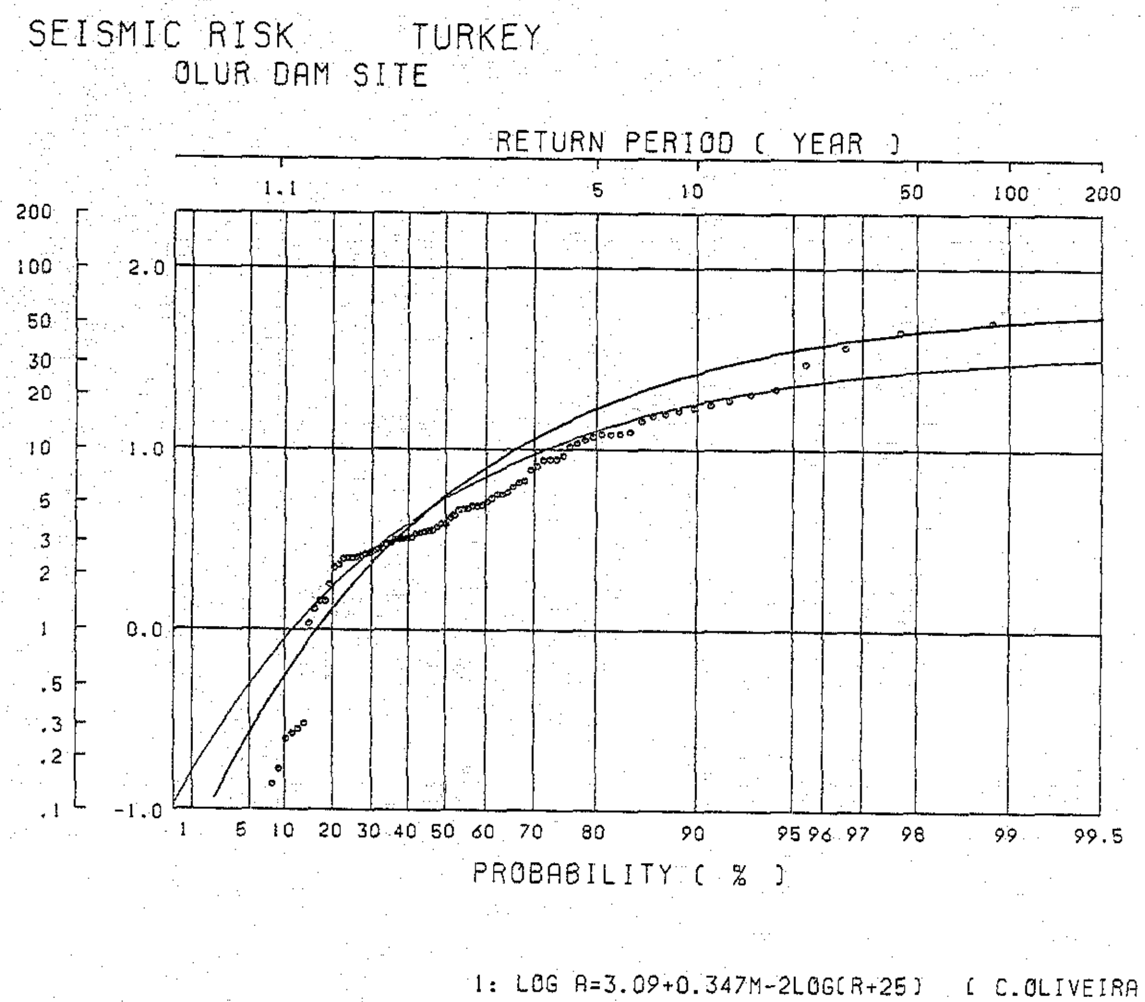


Fig. 8-12 Maximum Acceleration for Return Period at the Olur Dam Site Estimated by Oliveira's Equation

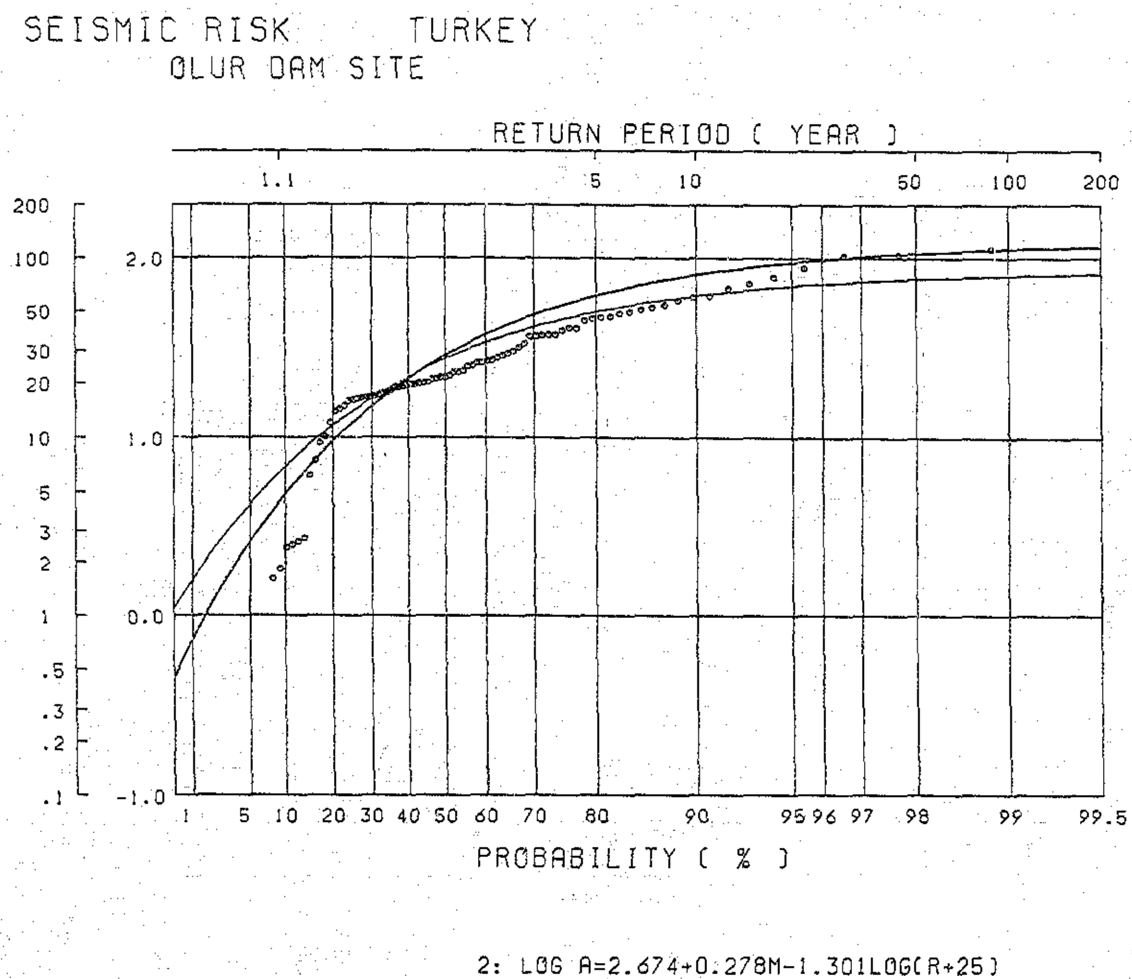


Fig. 8-13 Maximum Acceleration for Return Period at the Olur Dam Site Estimated by McGuire's Equation

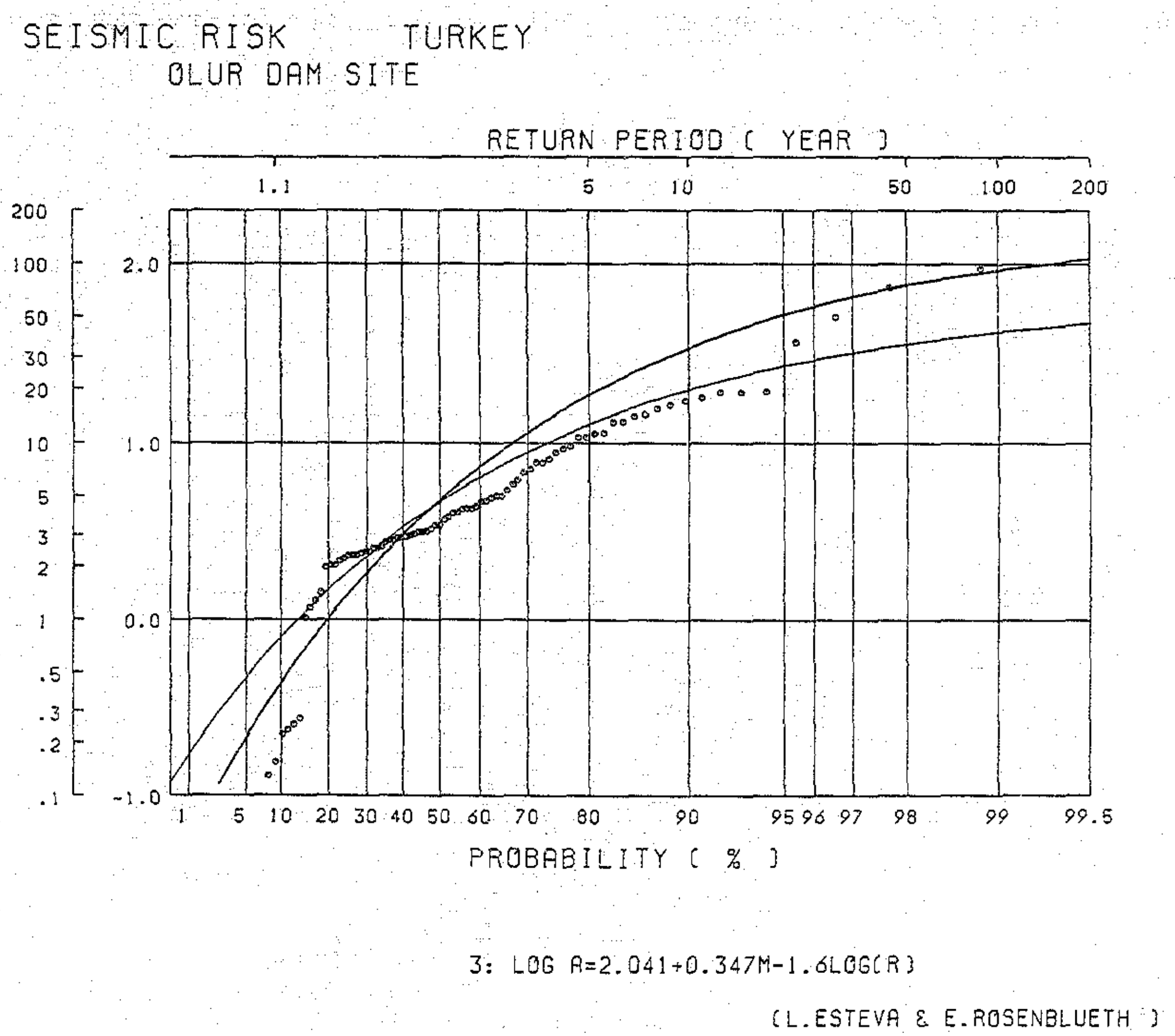


Fig. 8-14 Maximum Acceleration for Return Period at the Olur Dam Site Estimated by Esteva & Rosenblueth's Equation

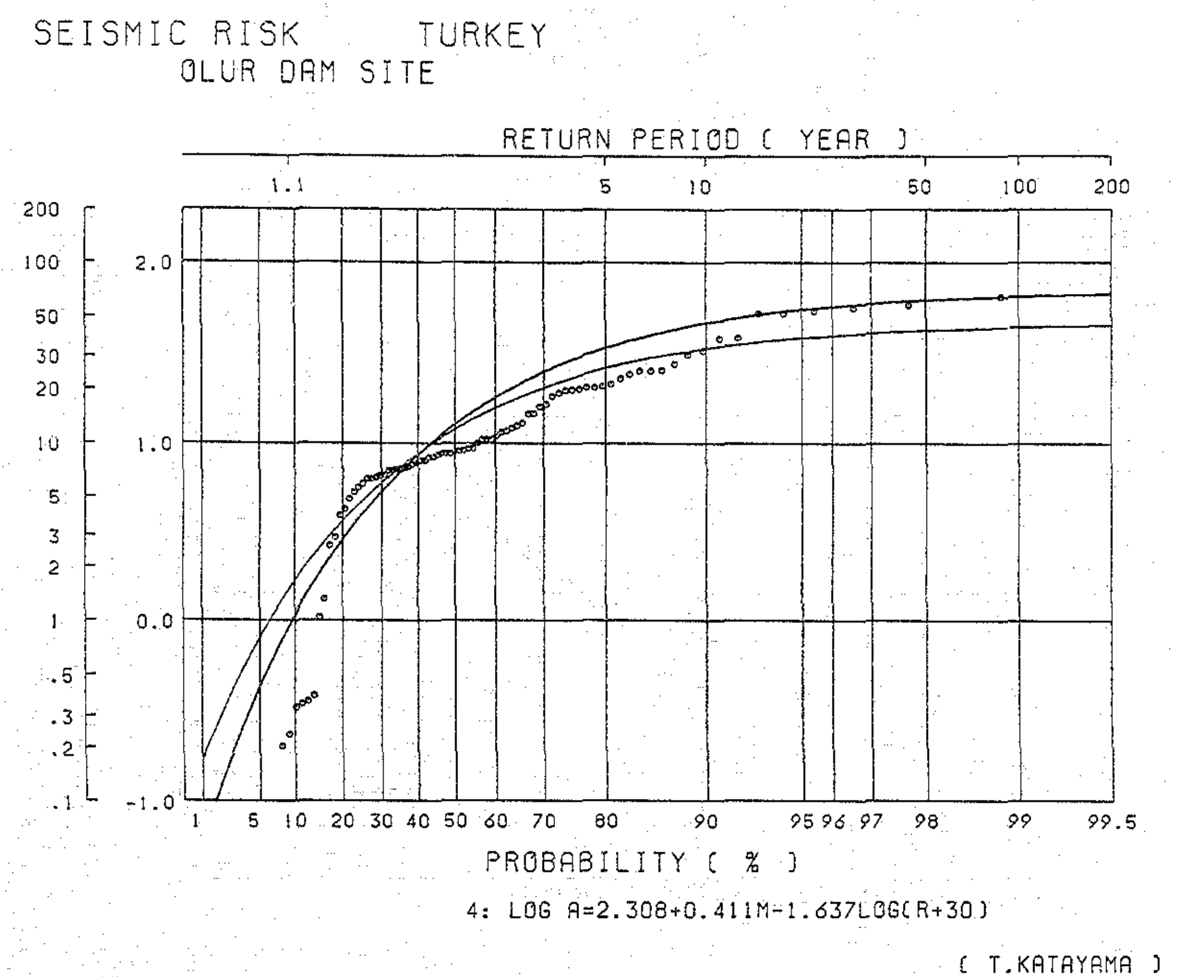


Fig. 8-15 Maximum Acceleration for Return Period at the Olur Dam Site Estimated by Katayama's Equation

Table 8-7 **Maximum Accelerations Expected at the Ayvalı Dam Site for Six Return Periods**

Attenuation Equation	Return Period (Year)					
	50	100	200	500	1000	10000
Oliveira Equation	41.1	45.4	48.4	51.0	52.3	54.2
McGuire Equation	100.2	105.2	108.5	111.0	112.1	113.5
Esteva & Rosenblueth Equation	96.5	117.4	135.1	153.3	163.5	182.4
Katayama Equation	63.2	66.6	68.6	70.2	70.8	71.5
Probability	0.98	0.99	0.995	0.998	0.999	0.9999

Table 8-8 **Maximum Accelerations Expected at the Olur Dam Site for Six Return Periods**

Attenuation Equation	Return Period (Year)					
	50	100	200	500	1000	10000
Oliveira Equation	45.4	51.0	55.2	59.0	61.0	64.3
McGuire Equation	106.9	112.7	116.5	119.5	120.8	122.7
Esteva & Rosenblueth Equation	75.7	92.5	107.3	123.2	132.6	151.5
Katayama Equation	62.1	65.2	67.1	68.5	69.1	69.8
Probability	0.98	0.99	0.995	0.998	0.999	0.9999

Table 8-9 Supposed Maximum Acceleration for the Ayvalı Dam Site and the Olur Dam Site

Dam Site	Maximum Acceleration at Ground Surface (gal)
Ayvalı	180 gal
Olur	150 gal

8.3.3 Design Horizontal Seismic Coefficient Used in Earthquake-resistant Design

(1) Design Horizontal Seismic Coefficient of Ground

Regarding the relationship between the maximum horizontal acceleration of earthquake motion and the design horizontal seismic coefficient, the following equation will generally be valid:

$$Kh = R \cdot \frac{A_{max}}{980} \quad \cdots\cdots\cdots \quad 5)$$

where, Kh: Design horizontal seismic coefficient
R: Conversion factor
A_{max}: Maximum horizontal acceleration of earthquake motion (gal)

The design horizontal seismic coefficient of the above equation is what is called effective seismic coefficient or equivalent seismic coefficient, and the following proposals have been made in research in Japan.

1) $Kh = (0.35 \sim 0.42)\ A_{max}/980$ (effective value of steady sine wave) 6)

2) $Kh = 0.33\ (A_{max}/980)^{1/3}$ (Noda[5], 1975) . . . . . . 7)

3) $Kh = 0.072 + 0.332\ (A_{max}/980)$ (Matsuo[6], 1984) . 8)

4) $Kh = (0.13 \sim 0.34)\ A_{max}/980$ (Hakuno[7], 1984) . . 9)

5) $Kh = (0.50 \sim 0.60)\ A_{max}/980$ (Watanabe[8], 1984) . 10)

In the Technical Guideline of Aseismic Design of Nuclear Power Plants[8] published in 1987, the following equation is proposed as a result of overall evaluation and taking into account these cases of study.

$$Kh = (0.40 \sim 0.60)\ A_{max}/980 \quad \ldots\ldots\ldots \quad 11)$$

The concept of effective seismic coefficient (equivalent seismic coefficient) was derived so that the largeness of stresses produced in ground and structures by earthquake motions will be equivalent for cases of handling dynamically (dynamic analysis by input of earthquake motion) and for cases of handling statically (static analysis using design seismic coefficient). The conversion factor which will be required for calculating effective seismic coefficient (equivalent seismic coefficient) is thought to be largely dependent on the frequency characteristics of design input earthquake motions. That is, for an earthquake motion with long-period components predominant, a large value (for example; 0.6) should be taken for the conversion factor. And for an earthquake motion with short-period components predominant, a small value (for example; 0.4) can be taken for the conversion factor.

As described before, the maximum acceleration assumed at the Ayvalı dam site and the Olur dam site is to be 180 gal and 150 gal, respectively. Consequently, applying Eq. (11), the design horizontal seismic coefficient of ground at the Ayvalı dam site and the Olur dam site will be 0.07 ~ 0.11 and 0.06 ~ 0.10, respectively.

Since the frequency characteristics of earthquake motions during earthquakes at the sites cannot necessarily be estimated distinctly at the present time, it is judged to be reasonable to take the design horizontal seismic coefficient of ground at the dam site as 0.15 for an evaluation on the conservative side.

(2) Design Horizontal Seismic Coefficient for Dam

Regarding the design horizontal seismic coefficients for dam, as shown in Table 8-10, the same value as the design horizontal seismic coefficient of ground is to be adopted for fill dam and gravity dam. For arch dam, a value twice the design horizontal seismic coefficient of ground is to be adopted.

Table 8-10 Design Horizontal Seismic Coefficient for Dam

Dam Type	Design Horizontal Seismic Coefficient
Fill Dam	0.15
Gravity Dam	0.15
Arch Dam	0.30

(3) Afterward

The determination of optimum configuration and cross section of a dam, and the basic stability evaluation of the dam during earthquake are normally made according to the seismic coefficient method. The design seismic coefficient to be used in the seismic coefficient method, is evaluated considering a conversion factor for the maximum acceleration of earthquake motion assumed for the site. The value of the conversion factor can be thought to depend on the frequency characteristics of the earthquake motions assumed, and the dynamic characteristics of the dam and foundation rock to be considered in the earthquake-resistant design. Therefore, it is desirable to ascertain the seismic stability of the dam by dynamic analysis. The appropriateness of the design seismic coefficient can be verified by comparison of dynamic and static analysis.

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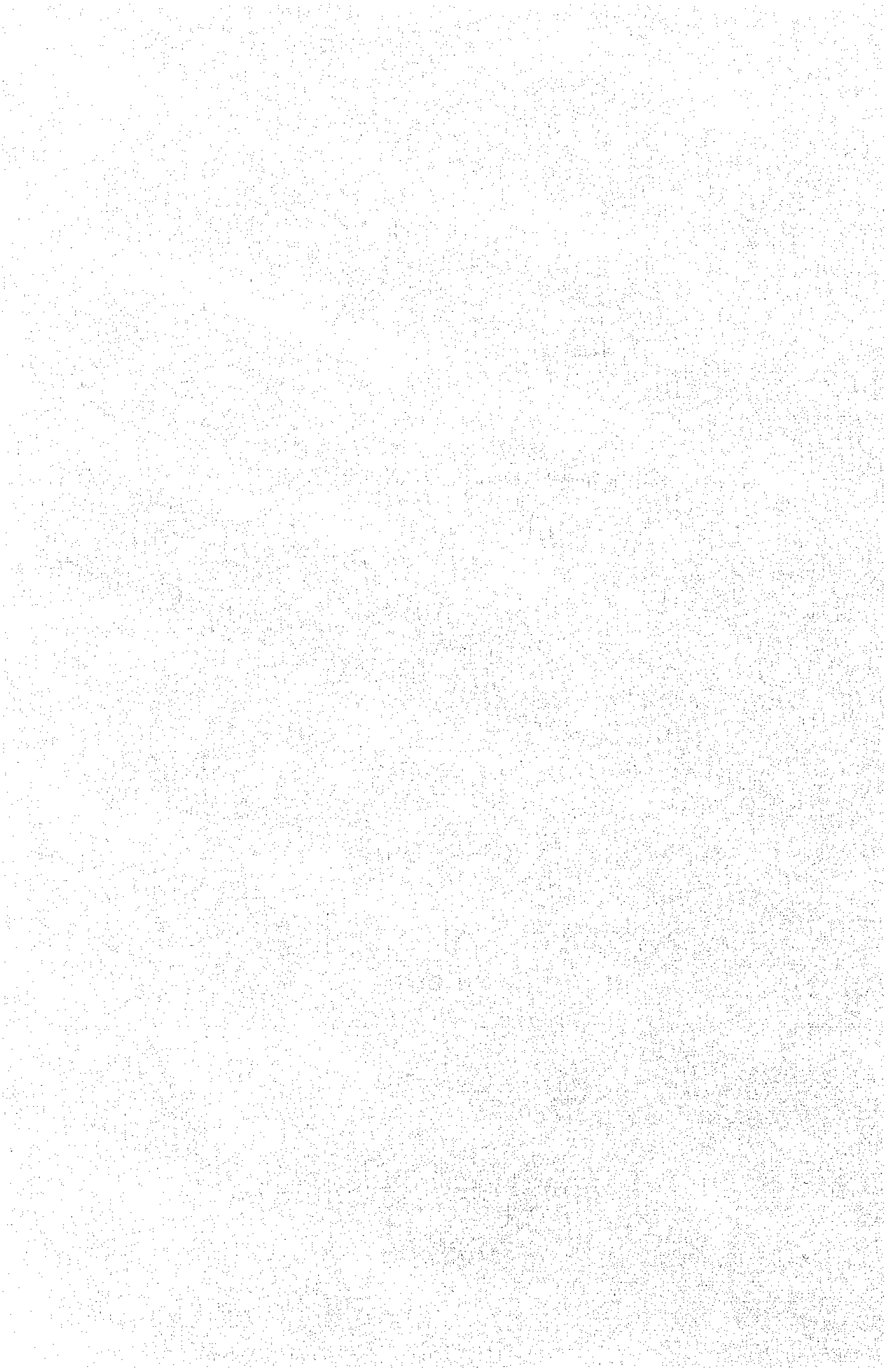
Chapter 9 DEVELOPMENT PLANS



Chapter 9

DEVELOPMENT PLANS

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Chapter 9 DEVELOPMENT PLANS

9.1 Review of Existing Development Scheme

9.1.1 Outline of Oltu River Development Project

In the Master Plan concerning the Çoruh River Hydroelectric Power Development Project formulated by EİE in 1982, it is planned for the Çoruh River mainstream to be developed in stepped form at 11 development sites, while numerous development sites were planned for the various tributaries also. Regarding the Oltu River, which is one of the major tributaries, there were the three development sites of Olur, Ayvalı, and Şakartepe planned in cascade form in the stretch from the midstream vicinity of EL. 1,100 m to near the end of the backwater of the Yusufeli Reservoir.

Upstream of EL. 1,100 m, the basin is finely divided by tributaries such as the Penek River, with their suitability as hydroelectric development sites abruptly diminished and there are no development sites planned.

In 1990, EİE newly set up a Master Plan for the Oltu River Basin. In this Master Plan, there were the four projected development sites of Olur, Ormanağzı, Ayvalı, and Şakartepe selected between the vicinity of EL. 1,100 m and the end of the backwater of Yusufeli Reservoir, and four different alternative development schemes of two-stepped development, three-stepped development, and four-stepped development according to the combinations of these development sites as shown in Fig. 9-1, and upon comparison studies, the two-stepped development plan consisting of the Olur and Ayvalı projects was selected as the hydroelectric power development plan for the Oltu River.

Regarding project features of alternative development schemes, the Master Plan Report mentions only two alternatives including the two-stepped development which is the optimum plan as shown in Table 9-1.

As for Oltu River tributaries, the Çayasan project site has been selected on the Tortum River for a run-of-river project.

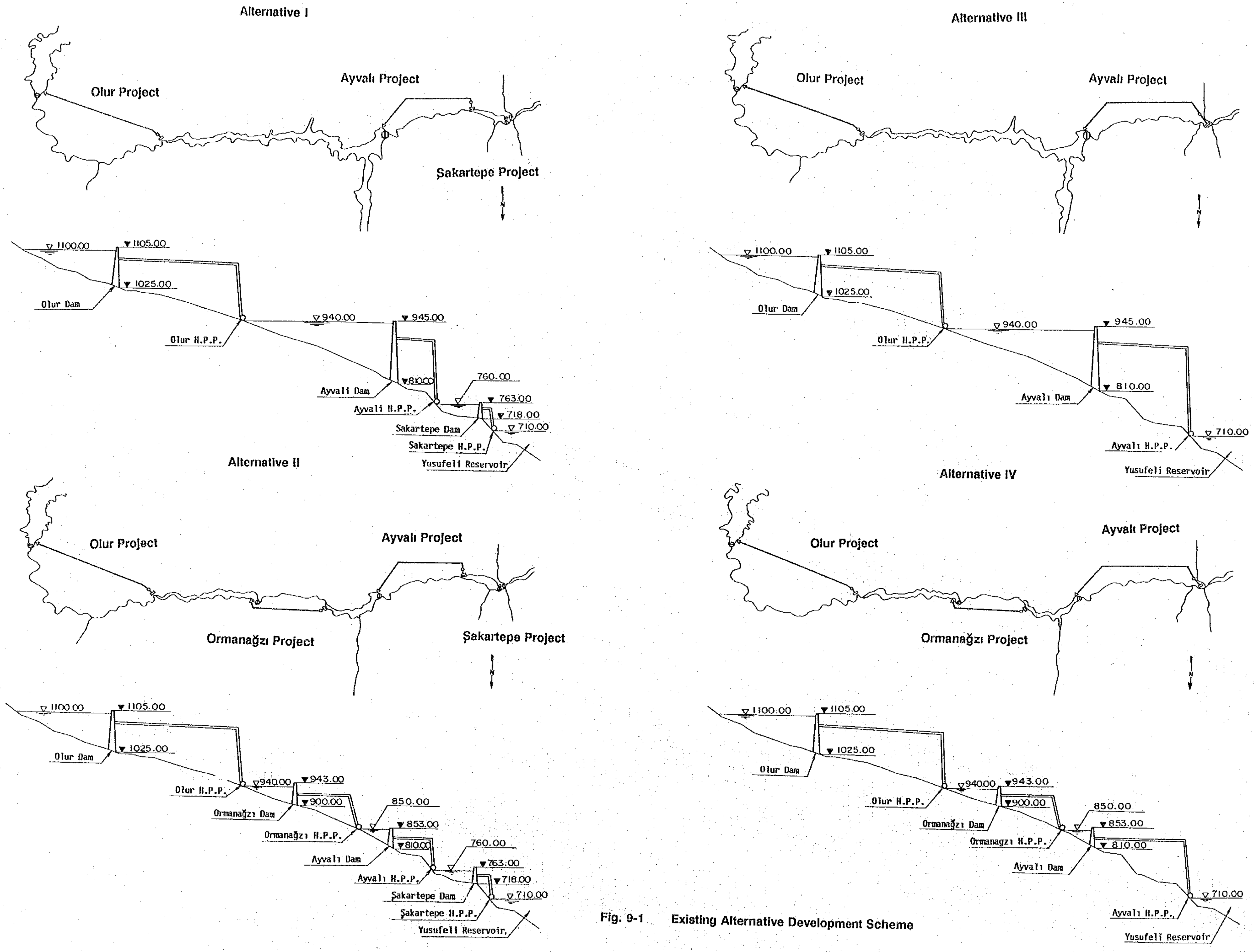

Fig. 9-1 Existing Alternative Development Scheme

Table 9-1 Outline of Alternative Development Scheme by Master Plan

Item	Unit	Alternative I				Alternative III		
		Olur Project	Ayvalı Project	Şakartepe Project	Total	Olur Project	Ayvalı Project	Total
Catchment Area	km^2	3,509	4,517			3,509	4,517	
Annual Inflow	10^6 m^3	523.0	823.8			523.0	823.8	
Reservoir								
High Water Level	m	1,100.00	940.00	760.00		1,100.00	940.00	
Low Water Level	m	1,078.00	900.00	745.00		1,078.00	900.00	
Gross Storage Capacity	10^6 m^3	272.50	425.07	15.1		272.50	425.07	
Effective Storage Capacity	10^6 m^3	152.50	274.69	12.3		152.50	274.69	
Dam								
Type		Rockfill	Rockfill	Homogeneous fill		Rockfill	Rockfill	
Riverbed Elevation	m	1,025.00	810.00	728.00		1,025.00	945.00	
Crest Elevation	m	1,105.00	945.00	763.00		1,105.00	810.00	
Crest Length	m	280.00	448.00	154.00		280.00	448.00	
Height from Riverbed	m	80.00	135.00	35.0		80.00	135.00	
Volume	m^3	3,800,000	10,103,800	358,990		3,800,000	10,103,800	
Headrace Tunnel								
Type		Pressure	Pressure	Pressure		Pressure	Pressure	
Inner Diameter	m	3.50	5.00	3.50		3.50	5.00	
Length	m	7,560	4,160	300.0		7,560	8,400	
Penstock								
Number of Penstock Lines		2	2	1		2	2	
Diameter	m	2.20		3.50		2.20	3.03	
Length	m	250		75		250	750	
Development Plan								
Tail Water Level	m	940.00	760.00	710.00		940.00	710.00	
Gross Head	m	160.00	180.00	50.00		160.00	230.00	
Installed Capacity	MW	46.0	130.0	15.0	191.0	46.0	170.0	216.0
Average Energy Production	GWh	158.56	337.17	59.48	555.21	158.56	426.52	585.08
Annual Firm Energy Production	GWh	106.00	192.72	11.13	309.85	106.00	280.32	386.32

9.1.2 Review of Existing Development Schemes

(1) Basic Principles of Reexamination

Since 1990, EİE has been carrying out field investigations of topography, geology, etc. concentrating on the two projects of Olur and Ayvalı, and as mentioned in 9.1.1, in the Master Plan Report, other than mentioning about the Ormanağzi Project, the river deposits are thick at the dam foundation portion so that it would not be economical. There are no descriptions in concrete terms, while EİE states there is a necessity for the appropriateness of abandonment of the Şakartepe Project to be reconfirmed.

Because of this, a review was made of the appropriateness of abandoning the two projects of Ormanağzı and Şakartepe.

The reexaminations were made by comparisons of the two aspects of power generating capabilities and power generation costs in alternative schemes, but for runoffs of the projected sites, the reviewed runoffs given in 6.2.3 were used, while unit prices of 1991 were used for estimating construction costs.

(2) Review of Existing Development Schemes

1) Development Area

The Oltu River at its most upstream part has steep river gradients, but the basin is finely divided by numerous tributaries, and at the upstream part, down to the vicinity of EL. 1,100 m where the right-bank tributary Penek River joins it, the catchment area is small at approximately 1,900 km^2, while the river gradient is around 1/150 and gentle, so that it is not suitable for a development project.

Downstream of where the Oltu River merges with the Penek River, the catchment area increases to 3,500 km^2, while the river gradient down to the end of the backwater of Yusufeli Reservoir becomes steep at about 1/90 when shortcuts by waterways are considered. There are sites such as Olur and Ayvalı which are suitable for reservoirs and are suited to power generation projects.

Of the tributaries joining the Oltu River downstream of the confluence with the Penek River, the main ones are the three of Olur, Tavusker, and Anzav, but all are small-scale rivers having catchment areas under 500 km^2, and are not suitable for power generation projects.

Therefore, it is judged reasonable for the section for development of power generation projects in the Oltu River Basin to have been limited to the Olut River mainstream from the vicinity of EL. 1,100 m to the end of the backwater of Yusufeli Reservoir.

2) Comparison Studies of Alternative Development Schemes

(a) Ormanağzı Project

Alternative IV including the Ormanağzı Project, as shown in Fig. 9-2, aim for improvement in the economics of the projects through reduction in dam size by dividing the Ayvalı project in Alternative III with the Ormanağzı Project for two-stepped development consisting of the two projects of Ormanağzı and Ayvalı.

According to this alternative, as shown in Table 9-2, the height of Ormanağzı Dam would be 56 m from the river bed and 108 m from the dam foundation rock, and the dam volume would be as much as 2,500 x 10^3 m^3. Ayvalı Dam would have a high water level of 850 m, and if made a blanket type, the height would be 43 m and the dam volume 1,500 x 10^3 m^3. The accumulated volume of the Ormanağzı and Ayvalı dams would be reduced to 65% of the volume of Ayvalı Dam with high water level of 940 m, but construction costs such as for cofferdams, diversion tunnels, spillways, etc. would be greatly increased because there would be two dams.

The headraces in this alternative plan would be reduced in cross section to approximately 33% compared with the case of high water level of Ayvalı Dam of 940 m. But tunnel length would be increased approximately 78%. Because of this, the reduction in construction cost of the entire alternative plan would be held to around 10%. On the other hand, the effective storage capacities of the two reservoirs of Ormanağzı and Ayvalı, when the sedimentation capacities are considered, are no more than daily regulating capacities and the power generation capability of the two projects of Ormanağzı and Ayvalı would be decreased 21% from the power generation capability of the Ayvalı Project having high water level of 940 m. In this way, even if the project scale were to be reduced by the Ormanağzı Project in this alternative, improvement in the economics of the plan would not be achieved, and therefore, the abandonment of the Ormanağzı Project is reasonable.

(b) Şakartepe Project

Immediately upstream of the end of the backwater of Yusufeli Reservoir, there are the Anzav Valley and the Bulanik Valley flowing in from the left and right banks. In the Master Plan, Ayvalı Power Station is planned as a surface type, and unless a large detour is made of these rivers by the headrace, it would be unavoidable for the locations of the powerhouse and the tailrace outlet to be selected upstream of the confluences of these rivers with the Oltu River. Because of this, the tail water level of Ayvali Power Station would be set at an elevation more than 15 m higher than the high water level of Yusufeli Reservoir, and idle head would result. Therefore, in the Master Plan, the Şakartepe Project consisting of construction of Şakartepe Dam in the vicinity of the end of the Yusufeli Reservoir backwater is being contemplated as Alternative I as shown in Fig. 9-2 aiming for elimination of the idle head at Ayvalı Power Station and shortening of waterway length.

Since the river deposits of the Oltu River in the general area of the Şakartepe dam site are very thick at more than 80 m, the dam would be of blanket type, and for waterway shortening effect of the Ayvalı Project to be expected, it would be necessary for the high water level of the Şakartepe Project to be made about 760 m. Hence, the Şakartepe dam site would be selected upstream of the Anzav River confluence because of the elevation of the river bed at the Şakartepe dam site. Therefore, as indicated in Table 9-2, the idle head above Yusufeli Reservoir would not be eliminated even with the Şakartepe Project, the result being simply that of the Ayvalı Project of Alternative III being divided into the two projects of Ayvalı and Şakartepe, and the increase in power generation capability would be no more than about 0.6% gained from the utilization of the remaining catchment area between Ayvalı Dam and Sakartepe Dam. On the other hand, the construction cost would be increased 12% or more with the economic demerit of minute subdivision of the project offsetting the effect of shortening of the waterway.

In the Master Plan, even in Alternative III, which is the two-stepped development plan according to the two projects of Olur and Ayvalı, Ayvalı Power Station is planned to be a surface type, and it would be unavoidable for the powerhouse location to be selected upstream of the Anzav Valley confluence. However, since the Anzav Valley is very steep with a riverbed gradient under 1/20, if an underground powerhouse were to be provided upstream of the Anzav Valley confluence with the Anzav Valley crossed by a tailrace, the tailrace tunnel at the Anzav Valley site would be provided in the foundation rock without the increase in waterway length which would have resulted from the great upstream detour, so that the tailrace outlet can be provided inside Yusufeli Reservoir, and the complete utilization of the remaining head would become possible.

In this way, improvement in the economics of the project cannot be achieved by means of the Şakartepe Project, and abandonment of the Şakartepe Project is reasonable.

(c) Conclusion of Review

The conclusion of the review was that, as stated in (a) and (b), Alternative III for two-stepped development with the two projects of Olur and Ayvalı would be optimum for the hydroelectric power development project of the Oltu River as judged from the two aspects of power generating capability and power generation cost.

Table 9-2 Comparative Study on Alternative Development Scheme

Item	Unit	Alternative IV				Alternative I				Alternative III		
		Olur Project	Ormanağzı Project	Ayvalı Project	Total	Olur Project	Ayvalı Project	Şakartepe Project	Total	Olur Project	Ayvalı Project	Total
Catchment Area	km^2	3,509	4,083	4,517		3,509	4,517	4,782		3,509	4,517.0	
Annual Inflow	10^6 m^3	518.7	692.0	822.1		518.7	822.1	841.7		518.7	822.1	
Reservoir												
High Water Level	m	1,100.0	940.0	850.0		1,100.0	940.0	757.0		1,100.0	940.0	
Low Water Level	m	1,078.0	936.0	846.0		1,078.0	900.0	757.0		1,078.0	900.0	
Gross Storage	10^6 m^3	272.5	42.9	23.3		272.5	447.1	11.5		272.5	447.1	
Effective Storage	10^6 m^3	152.5	1.0	1.5		152.5	283.6	-		152.5	283.6	
Dam												
Type		Rockfill	Rockfill	Branket		Rockfill	Rockfil	Branket		Rockfill	Rockfill	
Height	m	131	107	43		131	195	37		131	195	
Volume	10^3 m^3	3,693	2,500	1,500		3,693	11,400	800		3,693	11,400	
Headrace Tunnel												
Inner Diameter	m	4.1	4.4	4.5		4.1	5.5	-		4.1	5.5	
Length	m	8,100	4,200	8,500		8,100	6,280	-		8,100	8,500	
Penstock												
Length	m	393	220	630		393	360	125		393	940	
Development Plan												
Normal Water Level	m	1,092.7	938.0	848.0		1,092.7	926.7	757.0		1,092.7	926.7	
Tail Water Level	m	943.0	850.0	725.0		943.0	757.0	725.0		943.0	725.0	
Gross Head	m	149.7	88.0	123.0		149.7	169.7	32.0		149.7	201.7	
Effective Head	m	140.7	85.3	112.6		140.7	162.6	29.0		140.7	189.7	
Firm Discharge	m^3/s	11.1	12.0	12.7		11.1	17.6	18.0		11.1	17.6	
Maximum Discharge	m^3/s	44	47	50		44	70	72		44	70	
Installed Capacity	MW	54	33	48	135	54	100	17	171	54	116	170
Firm Peak Power	MW	45.6	31.8	46.2	123.6	45.6	81.2	15.7	142.5	45.6	95.7	141.3
Annual Energy Production												
Average Energy	GWh	202.5	125.2	173.9	501.6	202.5	322.0	53.5	578.0	202.5	364.2	566.7
Firm Energy	GWh	112.3	69.7	101.2	283.2	112.3	203.5	34.4	350.2	112.3	246.1	358.4
Investment Cost	10^9 TL	592.0	423.3	501.0	1,516.3	592.0	1,008.2	286.0	1,886.2	592.0	1,081.3	1,673.3
Unit Construction Cost												
kW Cost	10^6 TL	10.9	12.8	10.4	11.2	10.9	10.2	17.9	11.0	10.9	9.3	9.8
kWh Cost	10^3 TL	2.9	3.4	2.9	3.0	2.9	3.1	5.3	3.3	2.9	3.0	2.9