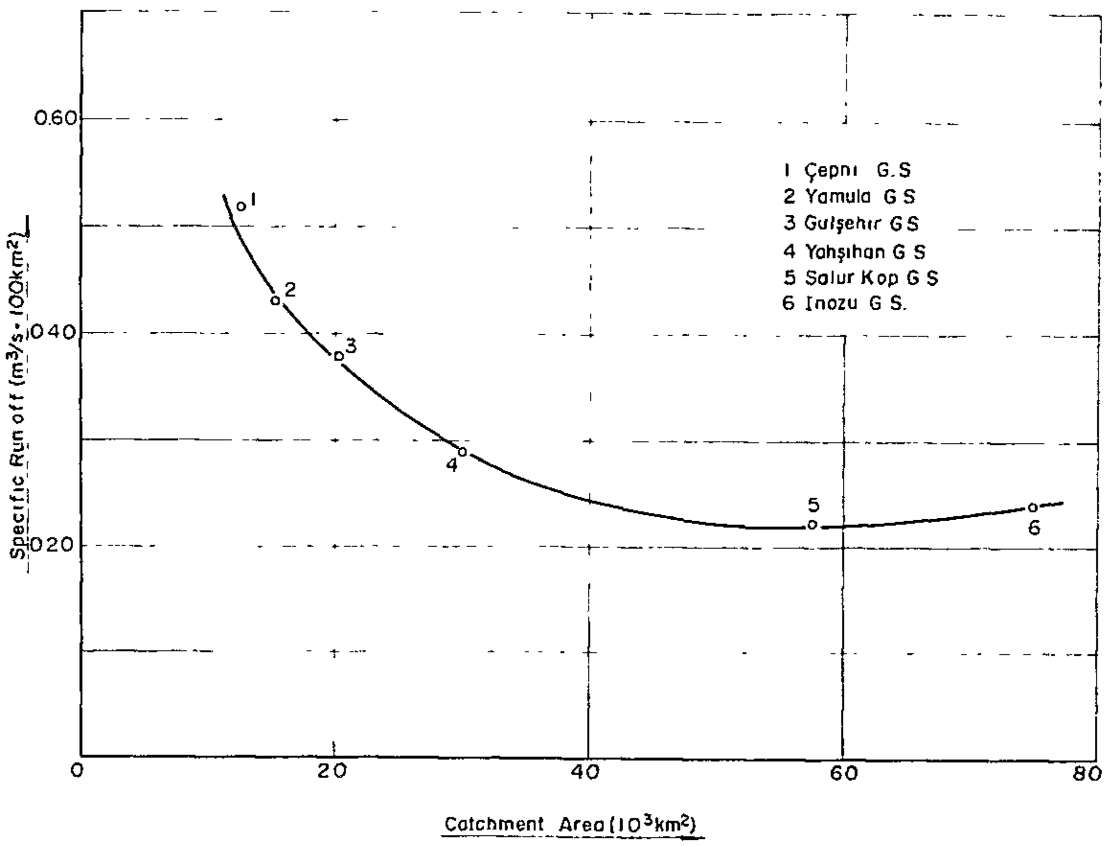
3.3 ESTIMATION OF RUN-OFF AT PROJECT SITE

3.3.1 River Run-Off

The catchment area of the Kepez Hydroelectric Power Development Project site is 64,724 km^2. This figure was determined by a 1/100,000-scale topographical map. The catchment area of the Boyabat site is 64,675 km^2, the catchment area ratio to the Kepez site being 99.92%, and it is considered there is almost no difference in run-offs between the two sites.

The curve for the catchment area versus the annual average specific run-off per 100 km^2 (hereinafter simply called specific run-off) of catchment area of the Kızılırmak River is indicated in Fig. III-3-3.

Fig.III-3-3 Specific Run-off of Kızılırmak River



According to this, the specific run-off at Yamula Gauging Station (catchment area 15,362 km2) which was 0.43 m^3/sec/100 km^2 becomes rapidly decreased to 0.38 m^3/sec/100 km^2 at Gülşehir Gauging Station (catchment area 20,368 km^2) and 0.29 m^3/sec/100 km^2 at Yahşihan Gauging Station (catchment area 30,023 km^2) as the river flows through the dry Central Anatolia Plateau, and with a catchment area of 50,000 km^2, it becomes 0.22 m^3/sec/100 km^2 at the vicinity of the confluence with the tributary Delice River, and roughly one half of the figure for Yamula Gauging Station.

Following this, the tributaries, Devres River, Gökirmak River with specific run-offs of 0.40 m^3/sec/100 km^2 are combined, and increasing although very slightly, the specific run-off becomes 0.24 m^3/sec/100 km^2 at Inözü Gauging Station (catchment area 74,992 km^2).

In November 1957, Hirfanlı Dam and Kesikköprü Dam were constructed upstream on the Kızılırmak River so that the effects by regulating these reservoirs must be considered, but with regard to Kesikköprü Reservoir, since its effective storage capacity is small, it was judged that the effect of regulation by this reservoir can be ignored and only regulation by Hirfanlı Reservoir was taken into consideration.

For the method of calculating run-off, since the catchment area of the Kızılırmak River is large and the run-off durations of the various basins differ, it was judged better to adopt the method of calculating by correlations of annual run-offs, especially correlations of cumulative run-offs, rather than the method of calculating by catchment area ratios.

3.3.2 Applied Run-off Gauging Stations

The run-off gauging stations used to determine the run-off at the site of Kepez Dam and the observation periods of the run-off data (monthly data) are indicated in Fig. III-3-4. The run-off data of their gauging stations are as indicated in Appendix.

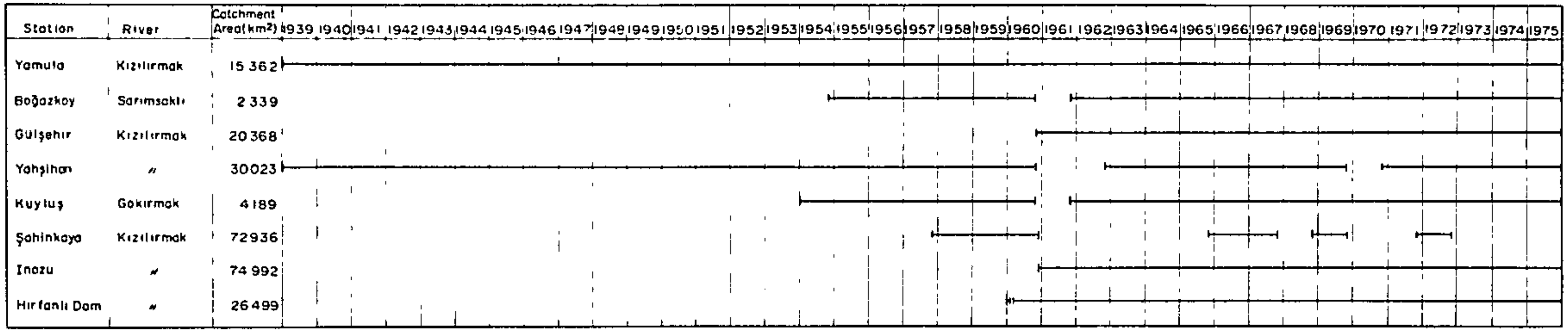
3.3.3 Period of Analysis for Run-off

It was decided that a period as long as practicable should be adopted for run-off analyses. Run-off measuring was first started on the Kızılırmak River in March 1938 at Yamula Gauging Station followed by Yahşihan Gauging Station in June of the same year, consequently, the period of analysis for run-off was selected to be the 37 years from January 1939 to December 1975.

3.3.4 Estimation of Natural Run-off

In estimation of run-off, the effect of regulation at Hirfanlı Reservoir was first eliminated. That is, the run-off at the Hirfanlı dam site in the condition before construction of Hirfanlı Dam, the run-off at the Kepez dam site, and the run-off at the Altınkaya dam site (hereinafter called the respective natural run-offs) were computed respectively for the 37 years.

Fig III-3-4 Existing Run-off Data



Next, setting up operation rules for Hirfanlı Reservoir and manipulating the natural run-off, the run-offs at the Kepez dam site and the Altınkaya dam site in their present states (hereinafter called the respective present run-offs) were computed respectively for the 37 years.

As stated in 3.3.1, the correlation method depending on cumulative run-off was used as the basis, with supplementation made by the method using catchment area ratios.

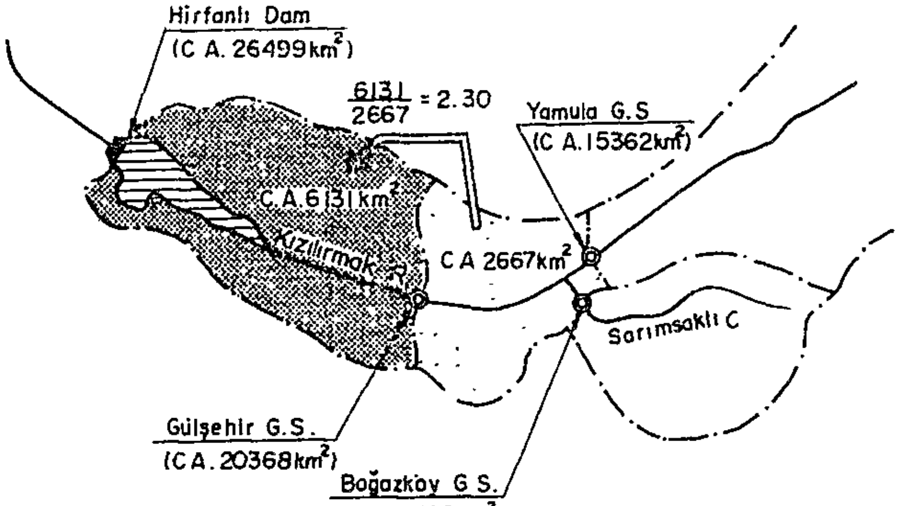
(1) Natural Run-off at Hirfanlı Dam Site (Catchment area 26,499 km^2)

Since there is no run-off gauging station at the Hirfanlı dam site, conversions were made from the run-off at Gülşehir Gauging Station (catchment area 20,368 km^2).

Since the part of the basin (catchment area 6,131 km^2) between the Hirfanlı dam site and Gülşehir Gauging Station is a dry area in Anatolia, the run-off of this part is taken to be the run-off of the area (catchment area 2,667 km^2) surrounded by Gülşehir Gauging Station, Yamula Gauging Station (catchment area 15,362 km^2) and Boğazköy Gauging Station (catchment area 2,339 km^2) on the tributary Sarımsaklı River, which is then converted by the catchment area ratio (6,131/2,667 = 2.30).

Therefore, the run-off at the Hirfanlı dam site will be the run-off at Gülşehir Gauging Station plus the above converted run-off (see Fig. III-3-5). The rate between the run-off obtained for the Hirfanlı dam site and the run-off at Gülşehir Gauging Station is 1.068.

Fig. III-3-5 Estimation of Natural Run-off at Hirfanlı Dam Site



For any period where run-off data are lacking for Gülşehir Gauging Station, they are obtained from the correlations with Yamula Gauging Station and Yahşihan Gauging Station (catchment area 30,023 km²). However, with regard to the run-off at Yahşihan Gauging Station, evaporation from the reservoir is taken into consideration for the period after construction of Hirfanlı Dam.

The cumulative correlation between the annual run-offs at Gülşehir Gauging Station and Yamula Gauging Station (hereinafter termed "double mass curves") are indicated in Fig. III-3-6 and the double mass curves between Gulsehir Gauging Station and Yahşihan Gauging Station are indicated in Fig. III-3-7.

The natural run-off at the Hirfanli dam site are calculated by the formulae below.

January 1939 - September 1957

$$Q_{\text{Hirfanlı natural}} = 0.980 \times Q_{\text{Yahşihan}}$$

October 1957 - November 1959

$$Q_{\text{Hirfanlı natural}} = 1.204 \times Q_{\text{Yamula}}$$

December 1959 - December 1975

$$Q_{\text{Hirfanlı natural}} = 1.068 \times Q_{\text{Gülşehir}}$$

(2) Natural Run-off at Altınkaya Dam Site (Catchment area 74,541 km²)

Inozú Gauging Station (catchment area 74,990 km²) and Şahinkaya Gauging Station (catchment area 72,936 km²) are located in the vicinity of the Altınkaya dam site. It is considered there is no difference in run-off between the two according to the Altınkaya Feasibility Report.

In order to eliminate the effect of Hirfanlı Reservoir, the natural run-off at the Hirfanlı dam site determined previously and the run-off at Yahşihan Gauging Station are used. As run-off at Yahşihan Gauging Station for any period that run-off data are lacking, the figure adding the run-off between Yahşihan Gauging Station and Hirfanlı Dam to the actual measured discharge from Hirfanlı Reservoir is used.

For the period before start of measurements at Şahinkaya Gauging Station, the correlation between Yahşihan Gauging Station and Inözü Gauging Station are taken and its coefficient is used. The double mass curves between the two are indicated in Fig. III-3-8.

The natural run-off at the Altınkaya dam site are calculated by the formula below.

January 1939 - September 1957

$$Q_{\text{Altınkaya natural}} = 2.329 \times Q_{\text{Yahşihan}}$$

Fig. III-3-6 Double Mass Curve between Gülşehir G.S. and Yamula G.S.

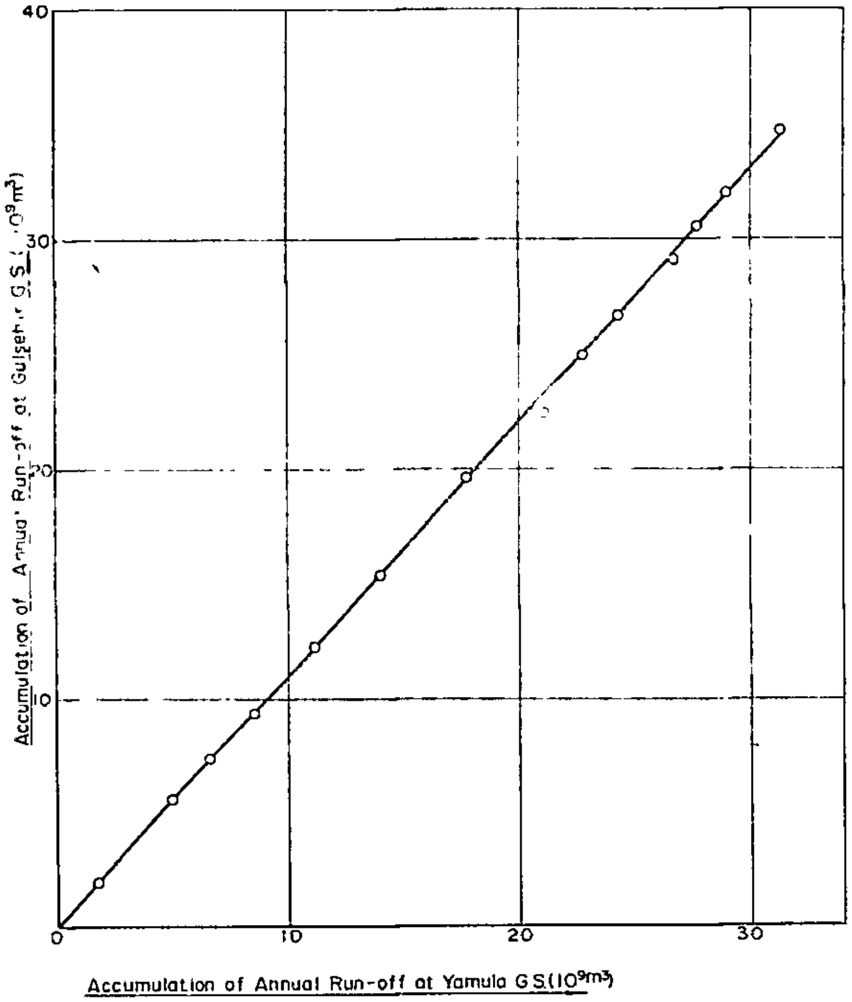


Fig. III-3-7 Double Mass Curve between Yahşihan G.S. and Gülşehir G.S.

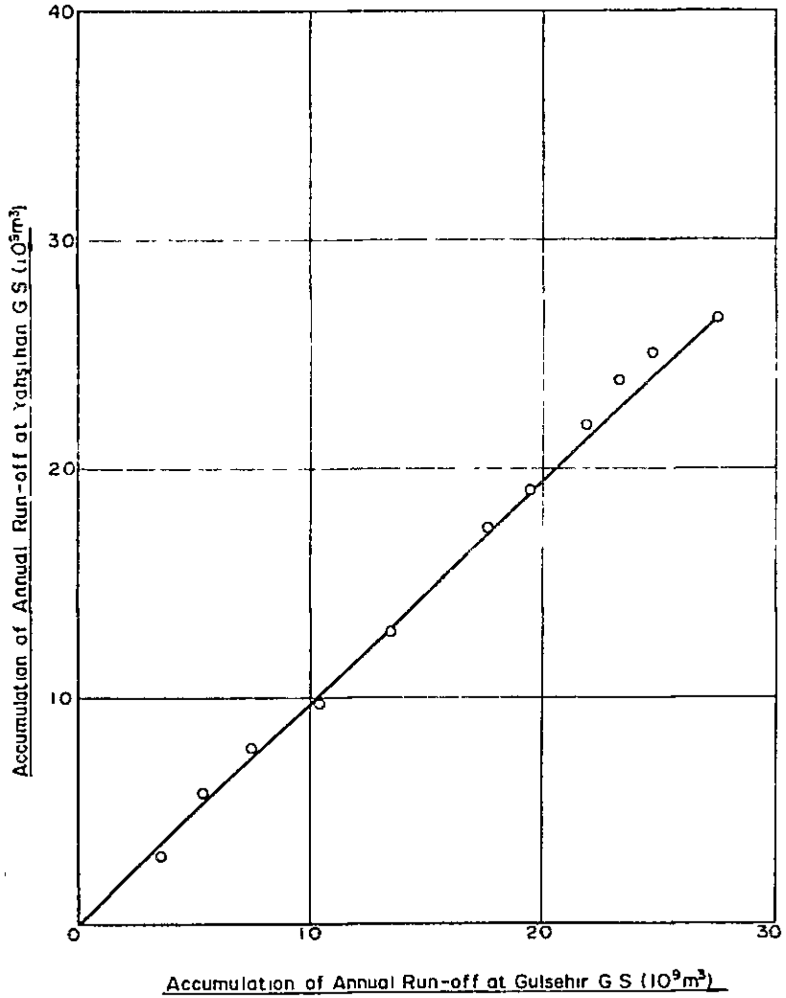
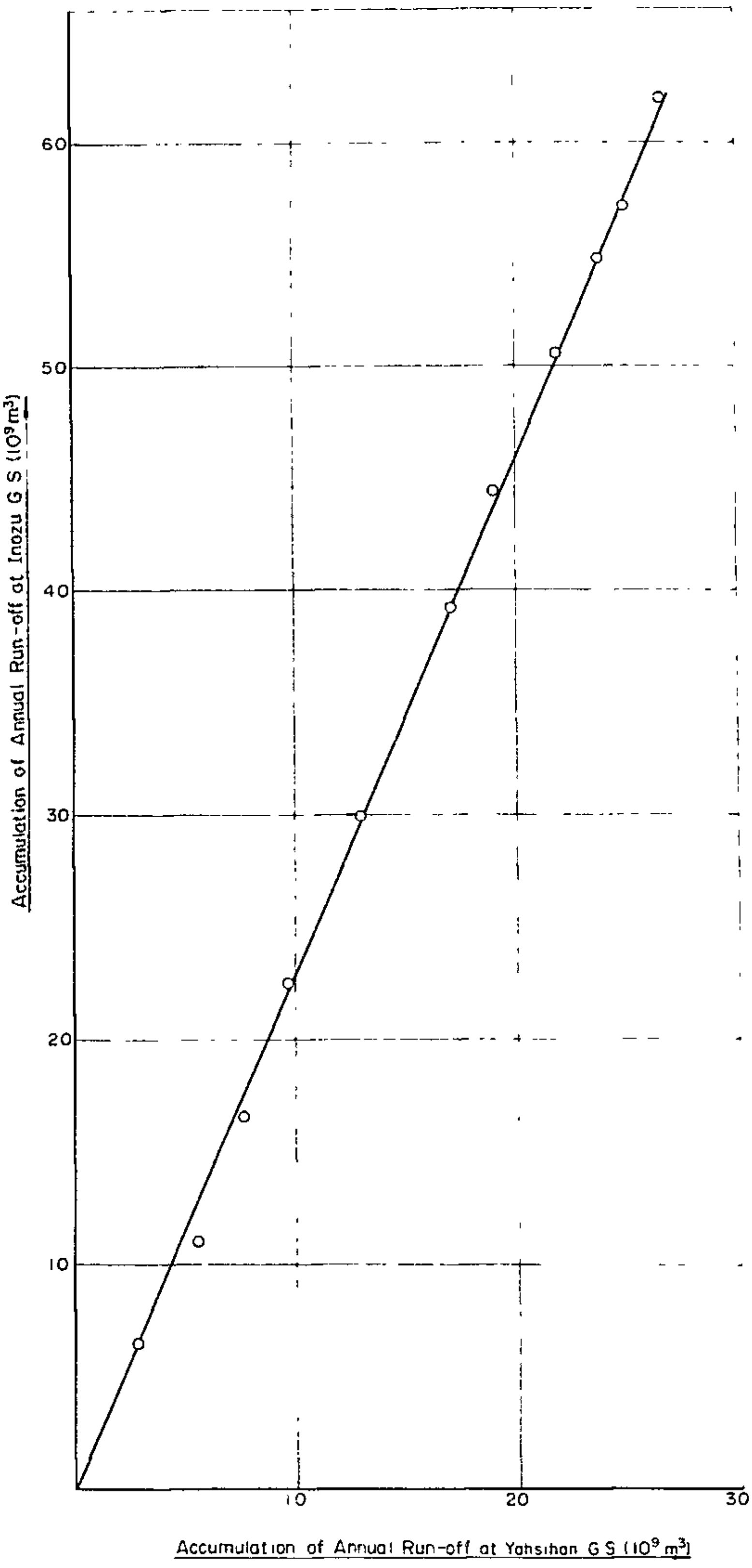


Fig.III-3-8 Double Mass Curve between Inozü GS and Yahşıhan GS



October 1957 - December 1975

$$Q_{\text{Altınkaya natural}} = Q_{\text{Inözü (or }}Q_{\text{Şahinkaya)}} - Q_{\text{Yahşihan}} + 1.021 \times Q_{\text{Hirfanlı natural}}$$

However, for the period of measurements lacking at Yahşihan Gauging Station,

$$Q_{\text{Altınkaya natural}} = Q_{\text{Inözu (or }}Q_{\text{Şahinkaya)}} - (0.022 \times Q_{\text{Gülşehir}} + Q_{\text{HD}}) + 1.021 \times Q_{\text{Hirfanlı natural}}$$

where

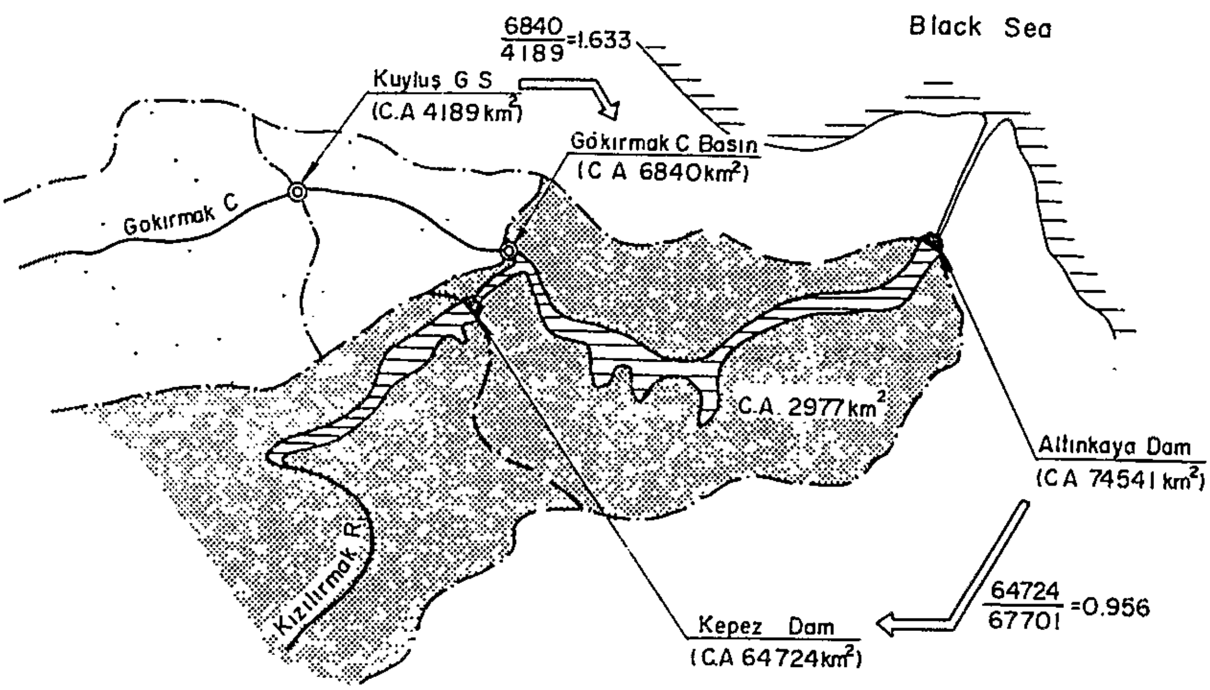
Q_{HD} : measured discharge from Hirfanlı Reservoir

(3) Natural Run-off at Kepez Dam Site (Catchment area 64,724 km^2)

The Kepez dam site is situated about 13 km upstream of the confluence with the Gökırmak River.

On the Gökırmak River there are the Durağan Gauging Station (catchment area 6,839 km^2) and the Kuyluş Gauging Station (catchment area 4,189 km^2) of which the latter has more complete data and higher reliability. Consequently, the run-off of the Gökırmak River Basin (catchment area 6,840 km^2) using the Kuyluş Gauging Station run-off based on catchment area ratio (6,840/4,189 = 1.633) is used. The run-off (catchment area 67,701 km^2) on deducting the run-off of the Gökırmak River from the natural run-off at the Altınkaya dam site is converted to the Kepez dam site run-off by catchment area ratio (64,724/67,701 = 0.9560) (see Fig. III-3-9).

Fig. III-3-9 Estimation of Natural Run-off at Kepez Dam Site



For any period that run-off data for Kuyluş Gauging Station are lacking, the run-off is determined by correlating the Kepez dam site natural run-off obtained for the period concerning which run-off data are available with the natural run-off at the Altınkaya dam site. The correlation between the two sites is indicated in Fig. III-3-10.

The natural run-off at the Kepez dam site are calculated by the formulae below.

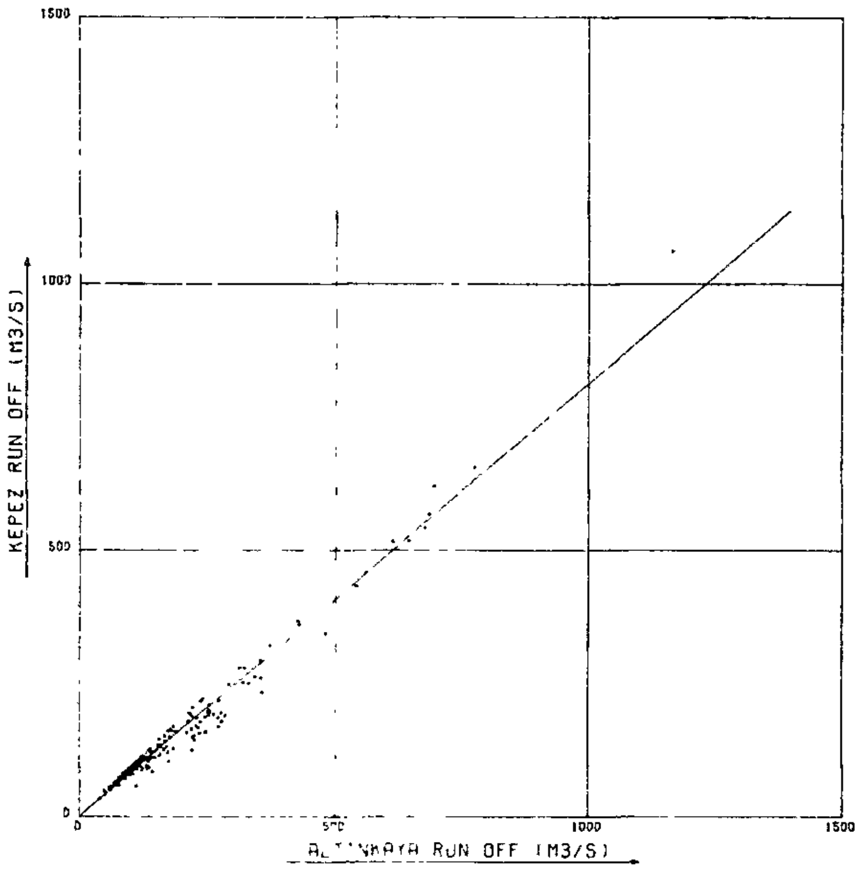
December 1953 - September 1960, October 1961 - December 1975

$$Q_{Kepez\ natural} = 0.9560 \times (Q_{Altınkaya\ natural} - 1.633 \times Q_{Kuyluş})$$

Other periods

$$Q_{Kepez\ natural} = 0.8494 \times Q_{Altınkaya\ natural} - 4.0354$$

Fig. III-3-10 Correlation between Kepez Site and Altınkaya Site



3.3.5 Operation of Hirfali Reservoir

The description of Hirfanlı Dam and Power Station are indicated in Table III-3-1. The operation rules of Hirfanlı Reservoir are formulated considering the following points with operation calculations made by computer employing monthly average run-offs.

(1) The run-off of wet years are stored for supplementing in dry years in order to make the firm discharge during the period of calculation as large as possible.

(2) For the period of a year, the run-off during the wet season is to be stored for supplementing during the dry season.

(3) Over-flow discharge from the reservoir is to be made as small as possible.

(4) The energy producted is to be made as large as possible.

The firm discharge determined from the 37-year mass curve is 57 m^3/sec.

As a further note, the operation rules are set up as an expediency to compute the present run-offs at the Kepez and Altınkaya dam sites and are different from the actual operation rules. The result of operation calculation of Hirfanlı Reservoir is indicated in Table III-3-2.

Taking account of the inflow and discharge at Hirfanlı Reservoir obtained according to the above, the present run-offs at the Kepez and Altınkaya dam sites are respectively computed.

The inflow and discharge at the Hirfanlı dam site is indicated in Fig. III-3-11 and Table III-3-3, the natural and present run-offs at the Kepez dam site in Fig. III-3-12, Table III-3-4 and Table III-3-5, and the natural and present run-offs at the Altınkaya dam site in Fig. III-3-13, Table III-3-6 and Table III-3-7.

Table III-3-1 Brief Description of Hirfanlı Reservoir and Power Station

Item	Unit	Description
Reservoir		
High Water Level	m	856.55
Normal Water Level	m	851.00
Standard Design Water Level	m	846.50
Low Water Level	m	842.00
Available Depth	m	9.00
Reservoir Area	km^2	272 (EL. 851.00)
Gross Storage Capacity	10^6m^3	5,980
Effective Storage Capacity	10^6m^3	1,980
Dam		
Type		Rockfill, inclined core
Dam Height x Crest Length	m	82 x 364
Slope		Upstream 1:1.3 (EL. 860 - EL. 840)
		1:2.4 (EL. 840 - EL. 800)
		Downstream 1:1.3
Power Station		
Normal Tailwater Level	m	785.55
Normal Effective Head	m	60.0
Maximum Discharge	m^3/sec	196.5
Maximum Output	MW	96

Table III-3-2 Summary Operation Study of Hirfanlı Reservoir

Year	Inflow (10^6 m^3)	Evaporation (10^6 m^3)	Outflow for Energy (10^6 m^3)	Outflow from Spillway (10^6 m^3)
1939	1956.8	314.0	1797.6	0.0
1940	3319.3	336.2	2275.6	18.9
1941	3909.5	337.2	3269.5	355.3
1942	3754.3	337.2	3059.0	305.7
1943	3563.1	337.9	2815.0	424.2
1944	2996.7	336.9	2726.2	0.0
1945	2395.4	334.6	2168.2	0.0
1946	2644.6	336.3	2203.1	19.4
1947	2447.1	332.8	2209.9	0.0
1948	3315.8	337.5	2641.7	205.4
1949	3189.0	337.2	2527.6	300.2
1950	3720.6	338.4	2848.1	494.6
1951	2067.5	328.6	1954.3	0.0
1952	2694.0	334.7	2331.6	163.9
1953	2406.4	334.4	1971.1	0.0
1954	3954.5	337.7	2676.4	790.2
1955	1442.8	315.4	1872.3	0.0
1956	2186.4	311.7	1802.5	0.0
1957	2110.9	311.2	1797.6	0.0
1958	2028.7	312.3	1797.6	0.0
1959	2062.3	303.7	1797.6	0.0
1960	2997.2	333.6	2048.7	0.0
1961	1349.4	304.8	1797.6	0.0
1962	2033.0	300.2	1797.6	0.0
1963	3775.6	336.3	2365.3	0.0
1964	1976.6	334.9	1953.2	0.0
1965	2230.8	332.9	1834.8	0.0
1966	3163.2	334.3	2795.1	0.0
1967	3230.3	336.9	2460.2	250.9
1968	4494.7	338.4	3354.0	747.0
1969	3712.7	338.1	3169.8	244.5
1970	2030.0	328.7	2102.4	0.0
1971	1888.1	315.3	1797.6	0.0
1972	2637.1	331.7	1802.5	0.0
1973	1414.2	314.2	1797.6	0.0
1974	1551.9	286.9	1797.6	0.0
1975	2977.8	317.3	1797.6	0.0
Average	2692.7	326.8	2249.0	116.8

Fig. III-3-11
Monthly Average Run-off
at Hirfanlı Dam Site

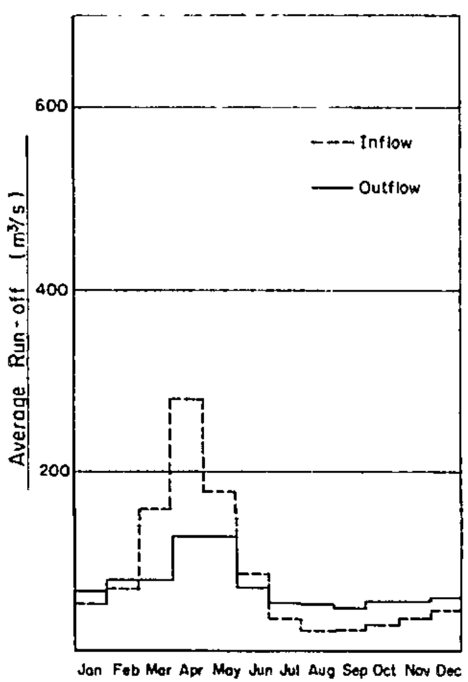


Fig. III-3-12
Monthly Average Run-off
at Kepez Dam Site

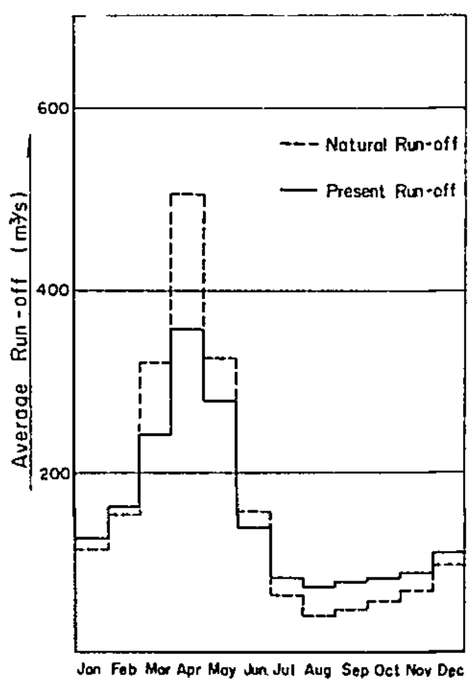


Fig. III-3-13
Monthly Average Run-off
at Altınkaya Dam Site

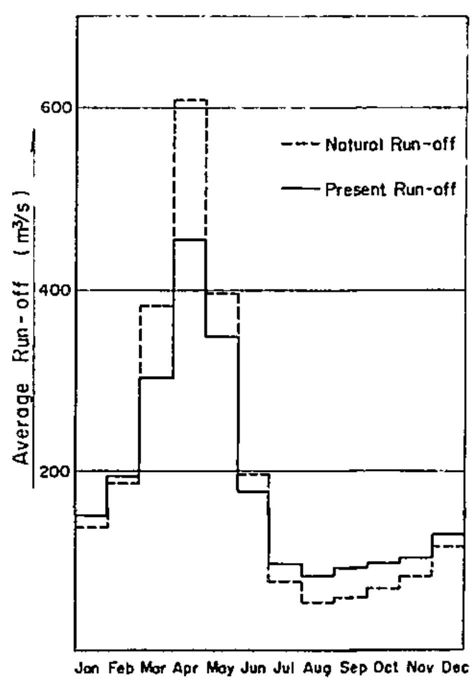


Table III-3-3 Monthly Natural Run-off at Hirfanli Dam Site

(10^6 m^3)

Year	Jan	Feb	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep	Oct.	Nov.	Dec	Total
1939	133.09	125.44	245.18	513.89	319.10	142 20	72.64	64.39	68.69	84.58	76.75	110.86	1956.81
1940	160.14	243.24	393.67	1092.99	440.89	273.22	131.03	76.39	68.20	93.10	153.26	193.35	3319.24
1941	226.67	316.75	982.06	1036.05	505.49	165.81	119.86	92.99	86.55	108.29	150.13	118.87	3909.52
1942	156.98	210.69	559.49	1147.40	592 52	220 40	95.24	73.79	91.63	119.27	173.85	313.02	3754.28
1943	205.59	183.96	283.40	1176.69	757.34	277.63	122.00	90.66	86.34	103.68	125.63	150.15	3563 07
1944	175.03	213.45	673.16	621 90	433.26	259.20	116.91	72.64	74.29	92.03	123 48	141.42	2996.77
1945	141.50	126 14	190.01	687.48	545.30	169.62	82.31	68.62	67.13	95.65	99.69	122.00	2395.45
1946	122 22	125.15	280.67	594.97	666.20	265.19	107.91	75 08	79.19	106.04	106.22	115.84	2644.68
1947	143.48	198.64	638.08	513 22	200 13	155.70	94.47	74.78	76.75	81.85	112 88	157.09	2447.07
1948	166.70	220.02	232.67	865.62	806.63	398.08	121.60	82.52	84.19	107.40	107.90	122.51	3315.84
1949	109.17	135.14	290.58	942.97	832.21	226.59	102.42	78.29	95.57	111.64	125.95	138.55	3189.08
1950	116.62	135 81	571.73	1012.54	916 31	266.25	139.84	102.61	88.49	116.62	121.82	131.91	3720.55
1951	152.48	138.67	294.97	268.14	298 51	243.83	133.76	74.00	77.53	114.47	124.26	146.91	2067.53
1952	142.12	254.72	283 51	1096.80	378 48	187.30	73.31	44.19	33.13	42.83	61.92	95.75	2694.06
1953	99.10	126 91	195.42	830.35	484.31	228.93	106.23	52.12	59.18	70.17	82.22	71.46	2406.40
1954	111.13	174.25	578.11	1421.69	802.90	268.22	128.56	91.92	76.75	84.77	93.67	122.51	3954.48
1955	156 71	152.87	251.85	255.88	239.23	86.13	40.07	35.17	39.79	47.25	52.72	85.07	1442.74
1956	105.82	168.48	303.81	645.43	387.30	164.46	84.96	52.63	56.06	63.61	76.15	77.73	2186.44
1957	81.64	99 86	439.34	315.65	454.90	307.93	126.63	56.68	53.42	49.23	62.96	60.67	2110 91
1958	76.17	110.85	345.43	609.98	345.57	274.08	62.57	34.18	30.59	37.07	40.20	62.00	2028.69
1959	85.12	74.51	311 26	568.84	353.15	236.26	68.25	44.17	39.71	52.98	66.54	161.48	2062.27
1960	173.56	250.23	484.66	945 10	504.32	217.34	103.81	49.76	49.33	63.21	74.34	81.58	2997.24
1961	77.75	96.77	167 45	388 75	146.64	140.12	48.37	30.24	37.48	48.05	54.79	113.00	1349.41
1962	124.33	146.22	642.49	429.03	247.03	112.03	43.15	34.82	35.77	50.09	58.63	109.36	2032.95
1963	300.76	404.88	518.30	750.28	574.60	551.29	170.88	84.05	84.27	101.67	110.55	124.09	3775.62
1964	84.58	93.76	473 22	494.16	245.42	228.98	69.18	39.29	48.39	57.34	62.70	79.47	1976 49
1965	87.48	81 38	402.00	625.97	417.59	169.28	75.72	45.59	44.43	68.46	82.35	130.06	2230 31
1966	459.67	472.69	569.56	655.21	344.63	159.05	84.48	58.84	62.47	79.79	80.20	136.60	3163.19
1967	139.17	120.98	306.94	1127 49	670 06	219.15	123.45	72.64	75.40	92.91	117.50	165.10	3230.79
1968	178.03	222 77	1034.45	1299.01	641.34	363.22	116.19	89.70	95.80	115.01	150.08	189.01	4494.61
1969	196.09	162.55	810.72	982.13	678.92	219.05	140.35	87.60	81.91	105.42	97.72	150.07	3712.73
1970	163.52	255 15	472 58	432.42	175.27	103.29	61.09	46 15	44.53	66.42	80.74	128.80	2029.96
1971	126.55	96.11	235.83	468.53	297.44	204.41	62.59	76 25	59.15	62.17	74.34	124 76	1888.13
1972	77 86	105.61	344.44	622.34	566.59	367.93	142.06	75.53	76.36	93.24	94.40	70.79	2637.15
1973	69 85	91.64	170.77	345 80	286.78	157.54	59.49	37.58	36.62	43.15	51.04	63.96	1414.22
1974	53.84	80.20	368.04	329.37	311.98	87.79	38.57	33.88	57.46	45.51	75.40	69.93	1551.97
1975	71.89	83.73	485.51	782.63	866.14	270.42	106.71	55 01	46.27	60.56	73.59	75 40	2977.86
Average	141.96	170.28	427.87	726.94	479.31	226.70	96.67	63.69	64.02	79.34	93.96	121.92	2692.66

Table III-3-4 Monthly Natural Run-off at Kepez Dam Site

(10^6 m^3)

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul.	Aug	Sep.	Oct	Nov	Dec	Total
1939	257 82	243 47	484 12	1026 90	633 33	276 59	135 79	119 16	128 20	159 90	111 15	212 93	3822 66
1940	312.46	460.90	783 66	2195.92	879 18	541 08	253 70	142.89	127.22	177.12	298 91	379 48	6572 75
1941	146 76	629.62	1971.60	2060.96	1009.60	324 29	231 12	176 89	164 23	207.79	292 58	229 16	7764 65
1942	306 11	115 55	1118 58	2305.69	1185.25	434 47	181 49	138 13	174 49	229.97	310 19	621 01	7451 26
1943	404.22	361.57	561.26	2364 81	1517.98	550.00	235 46	172 19	163 81	198.50	243 16	292.27	7065 23
1944	342.51	420 77	1348.07	1244 94	863.76	512.75	225 17	135 79	139.48	174 95	238 80	274 70	5921.69
1945	274.86	244 85	372.75	1377 29	1089 92	331.96	155 35	127.71	125 06	162.27	190 75	235 16	4706 23
1946	235 58	242 69	555.77	1190 53	1334 00	524 88	207.01	140.72	149.35	203 24	203 99	223 03	5211 30
1947	278.79	391.26	1277 22	1025.52	393 14	303 86	179 88	140 13	144.45	154 41	217.42	306.30	4812 38
1948	325.69	434.02	458 84	1736.95	1617.49	793 10	234.65	155 78	159 46	206 00	207.36	236 48	6565 42
1949	209 56	263.02	575 75	1893.02	1669 10	446 94	195 95	147.23	182 45	214 54	243 75	268.91	6310 22
1950	224 61	264.42	1143.33	2033.45	1838 86	527 03	271 51	196.30	168 17	224.61	235 16	255.44	7383 19
1951	296.98	270.15	584.64	530.82	591.74	481 75	259 22	138.55	146.03	220.27	240 38	285.73	4046 26
1952	276.06	504 05	561.50	2203 61	753.19	367 60	137.19	78.42	56.40	75.66	114 54	182 43	5310 70
1953	169.20	246 42	383.65	1665 72	966.82	451 66	203 61	94.41	109.02	130.81	155 52	144 66	4741.50
1954	236 98	361.45	1145.90	3113.93	1700.54	515.34	270 97	198.47	158 29	178.30	198 62	262 22	8311 01
1955	340 08	329.04	551 59	521.20	527 75	180 53	81 10	60.64	43.88	86.59	98.44	162 15	2982.99
1956	208 81	303.90	573 02	1300.90	794 90	304 02	175 49	115 44	121.23	136.41	161.51	167 16	4362.79
1957	177.26	206.87	972.77	698.04	903.45	654.69	276 09	124 65	96.53	57.45	85.59	140 08	4394.08
1958	182.24	240.61	703.43	899.04	440 17	458 34	107.64	62 81	91 16	33.37	39 76	78 83	3337.40
1959	172.19	138 84	577.36	744.81	427.66	358 06	82.17	53.27	80.02	131.11	142 12	250 73	3159.34
1960	283.80	361 96	663.12	1169.85	608.34	288 33	157.46	87 07	129.57	59.89	13 71	144 02	3967.12
1961	150 04	322.21	514.47	751.47	286.05	341 26	118.89	62.62	85.87	106.36	93.73	213.39	3046.36
1962	189.04	352.84	1012.01	593 78	248.34	110 19	19.26	13.71	14.70	77.59	109 28	311.55	3052.29
1963	589.30	896.41	862.74	1065 05	999.47	707.41	208.94	72.85	76.05	107.08	134.19	218.61	5938.10
1964	109.36	233.92	744.49	578.28	246.76	460 88	82 84	27.96	6 61	61.82	87 12	211.03	2851.07
1965	159.82	374.23	1289 52	1081.85	626.16	264.85	88 12	86.78	50.83	86.94	74.55	259.48	4443.13
1966	1210.69	885.74	973 57	1171.14	556 76	238.13	151 41	125.91	124.60	132.98	128.67	258 92	5958.52
1967	321.78	247.70	903.02	1986.64	1263 03	327.76	204 82	80.73	120.24	192.47	209.69	355.48	6213.36
1968	586.03	653.96	2028.46	1819.74	899.22	606.84	208 89	150.37	225.74	215.08	266.07	414.05	8074.45
1969	497 19	525 98	1068.16	1682.88	1197 16	376.05	210 84	133.71	168 51	258.17	260.29	518.97	7497.91
1970	577.57	987.44	1232.09	844.89	236 72	187.69	84 72	93.15	103.97	183.85	198 05	364.80	5094.94
1971	403.93	261 68	619.09	970 21	568.01	489 50	91.92	87.13	172.34	164.24	209 41	376.90	4414.36
1972	197.45	265.22	694 27	888 36	922.71	548.65	230.96	133.04	218.66	218.53	222.34	155.00	4695.19
1973	183.44	260.60	531 80	658 76	407 06	262 10	54.53	30 77	77.86	91.31	102.25	175.33	2835.81
1974	133 09	158.22	531.50	418.37	410 60	120 04	33.48	24.56	72.42	62.97	63.92	171 10	2200.27
1975	165 66	193.66	858.91	1027 26	1790 08	447.43	128.40	52 98	87.84	188.88	192 07	220 38	5353.55
Average	309.66	377.71	860.33	1320 63	875 79	408.54	166.92	107.65	120.67	151.12	174.57	258 87	5132.46

Table III-3-5 Monthly Present Run-off at Kepez Dam Site

(10^6 m^3)

Year	Jan.	Feb.	Mar.	Apr	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1939	277 10	255 93	391 61	660 75	466.90	282 14	215.83	207.44	207.26	227.99	215 45	254.74	3663.44
1940	304 99	380 48	542 86	1390 06	849.51	487 92	275.34	219.41	206.76	236.69	293.41	360.54	5547.97
1941	531.15	704.35	1515.84	1909.53	981 50	306 22	263.93	236.61	225.43	252.17	290.20	262.97	7479.90
1942	338 07	490 28	851.81	1945.56	1146 78	397 98	238.91	217.00	230.61	263 37	314 38	626.91	7061.66
1943	488 65	436.30	430 53	1868.83	1479.49	504.48	266.13	234.20	225.22	247.48	265 27	294.78	6741.36
1944	412 88	495.38	1081 24	964 41	761.42	461.56	260.93	215 83	212.93	235.59	263.06	285.95	5651.18
1945	286 03	312 42	335 42	867.72	981.98	310 08	225 71	211.75	205.68	239.29	238.80	266.13	4481.01
1946	266 34	255 64	427.77	743.31	1173.14	479 75	251.77	218.32	217.91	249.87	245.51	259.86	4789.19
1947	287 98	439 25	1010.45	744.89	345.67	295.90	238.08	218.02	215.45	225 23	252.28	301.88	4575.18
1948	311 66	409.59	378.63	1226 98	1542.57	747.66	265 72	225.92	223.02	251 26	247.20	266 63	6097.04
1949	253.06	312.34	437.84	1404.37	1630.58	404.25	246.20	221.61	234 63	255.57	265.55	283.03	5949.03
1950	266 72	339 15	876 56	1673.40	1800 34	492.89	284.34	246.36	227.42	260.66	261.38	276.20	7005.42
1951	378.43	344 88	442.34	410 42	445.90	385 66	278.13	217.22	216.25	258.47	263.87	291.49	3933.06
1952	286 62	434 35	430 66	1707.77	725 04	328 04	216.55	186.90	171.02	185.51	200.36	239.40	5112.22
1953	242 77	257.40	340 91	983.12	784.61	394.58	250 06	194.96	197.59	213.31	221 05	225.87	4306.23
1954	278 53	325.09	779.76	2753 69	1662.05	479 23	295 08	259.22	229.29	246 20	252.69	292 37	7853.20
1955	336.03	388 77	452.41	413.06	441.19	242.14	193.70	178.14	151.84	192.01	193.47	229.75	3412.51
1956	255.65	278 25	421.87	803.21	560 27	287.30	243 20	215 48	212.91	225.47	233.10	242.10	3978.81
1957	248 29	244.90	686.10	530.74	601.22	494.50	302.12	218.64	190.85	160.89	170.37	232.08	4080.70
1958	258.73	267.66	510 66	436 80	247.27	332 01	197.75	181.30	208.32	148.97	147.30	169.49	3106.26
1959	239.74	202 22	418.77	323.71	227.18	269.54	166.60	161.78	188.05	230.80	223.33	241.91	2893.63
1960	262.91	254.54	331.13	372.50	478 84	242 84	206.32	189.98	227.99	149.35	87.12	215.10	3018.62
1961	224.96	363.34	499.68	510.47	292.08	348.88	223.19	185.05	196.14	210.98	186.68	253.06	3494.51
1962	217 38	344 52	522.18	312.49	153.98	145.90	128.78	131.56	126.67	180.18	198.39	354.86	2816.89
1963	441.21	629 43	497.11	462.52	795.75	653.39	190.73	141.47	139.53	158.08	171.38	247.19	4527.79
1964	177.44	302 03	477.69	297.74	154 01	391.70	166.33	141.34	105.96	157.14	172.16	284.23	2827.77
1965	225 01	430.74	1040 18	603.62	398.47	243 31	165.07	193.86	154.15	171.15	139.94	282.09	4047 59
1966	1018.14	888 43	783 94	890.59	456.21	226.83	219.60	219.74	209.87	205.86	186.21	274.99	5590.41
1967	335.28	264.61	748 75	1405.36	1224 54	292.51	234 04	160.76	192.59	252 22	239 94	343.05	5693.65
1968	615.31	728 58	1520.31	1700.56	860.73	572.16	245.37	213.33	277.68	252.73	263.74	430.42	7680.92
1969	581.61	600 71	1383.74	1340.45	1158.68	340.90	223.16	198.58	234.34	305.42	310.31	521.56	7199.46
1970	622 33	1062 17	965.32	564.36	214.11	232.14	178.29	199.67	207.18	270.09	265.06	388.66	5167.38
1971	430.04	303.46	535.92	649.43	423.24	432.84	182.00	163.54	260.94	254 74	282.81	404.81	4323.77
1972	272 26	302 43	502 49	413 76	508.79	328.46	241.56	210.17	290 04	277.96	275.69	236.88	3860.49
1973	266.26	306.85	513.69	460 70	272.96	252.31	147.71	145.87	188.98	200.63	198.96	264.04	3219.16
1974	231.92	215.91	316.13	236 75	251.29	179.99	147.58	143 35	162 70	170 13	136.26	253.83	2445.84
1975	246.44	247.82	526.06	392 38	1076 61	324.75	174.36	150 63	189.32	280.99	266.22	297.65	4173.23
Average	343 74	400.55	646.72	929 08	745.27	367.37	222.92	196 62	204.39	224.45	228.35	296.12	4805.58

Table III-3-6 Monthly Natural Run-off at Altinkaya Dam Site

(10^6 m^3)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1939	316.27	298.12	582.69	1221.30	758.36	337.94	172.60	153.02	163 24	200.99	182.37	263.42	4650.32
1940	380.57	578.07	935.57	2597.57	1047.79	649.32	311.39	160.95	162.08	221.26	364.25	459.48	7888.30
1941	538.71	752.73	2333.88	2462.22	1201.32	394.09	284.82	221.02	205.68	257.37	356 76	282.52	9291.12
1942	373.10	500 73	1329.64	2726 81	1408 12	523.82	228.38	175.35	217.75	283.46	413 16	743 87	8922.19
1943	488.62	437.17	673.51	2796.41	1799.86	659.82	289.94	215.45	205.18	246.41	298.57	356.82	8467.76
1944	415.96	507.28	1599 81	1477.98	1029 63	615.99	277.83	172.60	176 52	218 69	293.44	336.11	7121.84
1945	336.30	299.74	451.58	1633 79	1295.89	403.13	195.63	163.06	159.56	227 32	236.88	289.94	5692.82
1946	290.45	297.44	667.03	1413.94	1583.26	630.24	256.46	178.41	188.15	252 01	252 46	275.29	6285.14
1947	340.96	472.11	1516.40	1219.67	475.58	370.06	224.50	177.71	182.37	194.51	268.27	373.34	5815.48
1948	396.16	522.87	552.93	2057.22	1916.98	946 03	289.00	196.11	200.05	255.25	256.45	291 12	7880.17
1949	259.43	321.15	690.55	2240.97	1977.76	538 49	243 41	186.07	227.11	265.30	299.30	329.31	7578.85
1950	277.16	322.79	1358.75	2406.31	2177.62	632.78	332.36	243.84	210.31	277.16	289.53	313.45	8842.06
1951	362.36	329.54	701.02	637.24	709.37	579.47	317.90	175.84	184.24	272.05	295.31	349 13	4913.47
1952	337.72	605.33	673.78	2606.62	899.46	445.10	174.23	105.05	78.72	101.81	147.17	227.56	6402.55
1953	235.48	301 60	464.41	1973.37	1150.96	544.03	252.44	123.88	140.67	166.73	195.41	169.81	5718.79
1954	264.12	414.12	1373.86	3378.65	1908.15	637.42	305.53	218.45	182.37	201.50	222.63	291.12	9397.92
1955	372.40	363.29	598.54	608.08	568.54	204 72	95.24	83.59	94 53	112.28	125.32	202.17	3428.70
1956	251.53	400.37	721.99	1533.89	920.41	390 82	201.92	125.08	133 23	151.14	180.97	184.70	5196.05
1957	194.00	237.32	1044.12	750.18	1081.11	731.77	300.92	139.49	126.96	82.17	112.67	180.04	4980.75
1958	225.09	303.17	875.89	1174.10	562.04	610.65	139.49	87.80	127.73	56.73	63.27	108.61	4334.57
1959	210.60	170.99	796.37	1000.18	586.36	548.21	114.69	91.71	109.15	158.80	173.85	286.48	4247.39
1960	318.30	411.90	734.15	1389.75	711.78	360.18	183.39	105.50	150.36	83.22	28.46	182 29	4659.2[illegible]
1961	189.36	390.82	618.42	897.01	349.50	414.07	152.70	86.46	113.43	128.08	115.01	250.16	3705.02
1962	223.19	417.75	1237.26	735.71	325.24	137.76	22.47	14.87	46.40	103.52	129.69	391.56	3785.62
1963	742.48	1126.26	1096.59	1329.64	1324.87	887.09	261.68	85.82	98.52	139.92	164.88	261.47	7519.22
1964	134.64	283.73	907.44	687.84	394.98	707.62	126.31	49.34	30.12	82.47	114 33	287.04	3605.86
1965	213.23	464.10	1621.74	1407.12	827.25	371.93	108.10	104.16	72.76	109.71	101 97	316.99	5719.06
1966	1391.32	1027.10	1137.73	1525.18	717.76	329.08	171.93	144.07	142.48	154.76	151.09	289.78	7182.28
1967	356.20	275.01	1022.48	2342.78	1539.14	512.49	253.14	107.75	161.87	226.78	239.45	424.23	7461.32
1968	689.58	812.57	2348.47	2136.66	1034.02	666.14	233.21	185.18	299.32	264.33	310.65	465.77	9445.90
1969	556.81	634.77	1931.74	2019.97	1489.38	483.33	250.30	148.95	195.51	289.48	292.66	579.42	8872.32
1970	653.96	1116.34	1414.06	992.50	305.44	252.82	94.71	101 46	114.46	203.02	220.92	401.01	5870.70
1971	469.90	300.03	766.29	1180.79	809.57	665.21	114.61	104.56	201.19	188.77	238.80	425.79	5465.51
1972	241.19	322.85	856.87	1122.41	1182.67	653.05	347.92	190.41	263.68	305.18	306.06	209.50	6001.79
1973	228.63	362.08	724.96	875.06	523.12	348.96	76.92	78.35	93.80	112.84	130.79	219.31	3734 82
1974	163.54	192.59	645.28	504.58	524.83	147.43	47.19	34 60	83.49	73.47	78 38	193.70	2689 08
1975	197.48	229.68	1023.71	1223.97	2147.33	556.01	146.56	64.17	100 73	211.30	217.16	247.67	6365.77
Avarage	368.56	454.15	1027.82	1575.34	1061.23	510.46	205 35	134.60	152.53	185.94	212.66	309 7[illegible]	6198.37

Table III-3-7 Monthly Present Run-off at Altinkaya Dam Site

(10^6 m^3)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul.	Aug.	Sep	Oct.	Nov.	Dec.	Total
1939	335 81	310 58	490 17	855.15	591.93	343.49	252 63	241.30	242.30	269.07	253.37	305.23	4491.06
1940	373 10	477.64	694.56	1791.72	1018 11	596.16	333 03	257 47	241.63	280.83	358 73	440 54	6863.52
1941	623 10	827.46	1878.12	2290.78	1173 22	376.02	317.63	280.70	266.87	301.75	354.38	316.32	9006.35
1942	405.05	575 46	1062 87	2366 68	1369.65	487 32	283.80	254.23	273.87	316.85	387.06	749 74	8532.56
1943	573 04	511 90	542 78	2300.43	1761.37	614.30	320.60	277.46	266.59	295.40	320.68	359 33	8143.88
1944	466 32	581 90	1332 99	1197.45	927.29	564 80	313.59	252.63	249.97	279.33	317 70	347.36	6851.33
1945	347.47	367.31	414.24	1124.23	1187.95	381.26	265.99	247.11	240.17	284.34	284 94	320 60	5465.61
1946	320 90	310 19	539 03	966.71	1422 39	585.12	301.21	256.00	256.71	298.64	293 98	312 11	5862 99
1947	350 15	520.10	1249.63	939.13	428 12	362.10	282.71	255 60	253.37	265.32	303.13	368 92	5578.28
1948	382 13	498 44	472 93	1547.24	1842 07	900.59	320.07	266.26	263.61	300.52	296.29	321 27	7411.42
1949	302 93	370 48	552.63	1752.32	1939.24	495.80	293.66	260.45	279.29	306.33	321.10	343 42	7217.65
1950	319.27	397.52	1091.98	2046.25	2139.10	598.65	345.19	293.90	269.57	313.21	315 45	334 21	8464 30
1951	443 81	404.27	558 71	516.84	563.54	483.38	336 81	254 50	254.46	310.24	318 79	354.89	4800.24
1952	348.27	535.62	542 94	2110.77	871.31	405.54	253.59	213 52	193.34	211 65	232 99	284.47	6204.01
1953	289 05	312.58	421.66	1290.76	968 75	486.96	298.88	224 42	229.24	249.23	260.94	251 02	5283.49
1954	305 66	377.76	1007.72	3018.41	1869.66	601.32	329.63	279.20	253.37	269.39	276 70	321 27	8910.09
1955	368.36	423.02	499.36	499.94	481.98	266.33	207.84	201.09	202.49	217.70	220.35	269 77	3858.23
1956	298 37	374.71	570 85	1036.20	685.78	374.10	269.63	225.12	224.91	240.20	252 56	259.64	4812.07
1957	265.03	275 35	757 45	582.27	776.88	571.59	326.95	233.58	221.28	185.61	197.46	272 05	4667 40
1958	301.59	330.22	683.13	711.87	369.14	484.32	229.59	206.29	244.89	172.33	170.81	199 27	4103.45
1959	278 15	234.37	637.78	579.08	385.88	459.69	199.11	200.21	217.18	258.49	255.05	277.67	3982 66
1960	297.41	304.48	402.16	592.40	582.28	314 69	232.24	208 41	248.78	172.68	101.87	253.38	3710.78
1961	264.28	431 95	603 63	656.01	355.53	421.69	256.99	208.89	223 69	232.70	207.96	289 83	4153 15
1962	251.53	409.43	747 43	454.43	230.88	173.48	131.99	132.71	158.37	206.10	219.00	434.87	3550.22
1963	594.39	859.28	730.96	727.11	1121.15	833.07	243.47	154.44	162.00	190.92	202.07	290.04	6108.90
1964	202.73	351.84	640.65	407.31	302 23	638.44	209.80	162.71	129.47	177.79	199 38	360.24	3782.59
1965	278.42	520 61	1372.41	928.90	599 56	350 39	185.05	211 25	176.07	193 92	167 37	339.59	5323 54
1966	1198.77	1029 78	948.10	1244.63	617.21	317.78	240 12	237.90	227.76	227 64	218 64	305.85	6814.18
1967	369.70	291 92	868.20	1761.50	1500.65	477 24	282.36	187.78	234 21	286.54	269 70	411.60	6941.60
1968	718 86	687.18	1840 33	2017.48	995.53	631 46	269.69	248 15	351.27	301 99	308 32	482 14	9052.40
1969	641 24	709.50	1647.32	1677.54	1450.89	448 18	262.62	213.82	261.35	336.73	342 69	582 02	8573 90
1970	698 71	1191.07	1147 29	711.97	282.84	297.28	166.28	207.98	217.68	289.27	287.92	424 87	5943.16
1971	496.01	341.81	683 13	860 00	664.81	608.55	204.68	180.98	289.79	279 28	312.21	453.69	5374.94
1972	316.00	360.05	665.10	647.82	768 75	432.86	358.53	267.55	335.07	364 61	359 41	291.38	5167.13
1973	311 44	408.34	706.86	677.00	389 01	339.16	170 11	153.45	204.92	222 36	227 50	308.02	4118.17
1974	262.38	250.29	429 91	322.96	365.52	207.39	161.29	153 39	173 77	180 63	150 72	276.44	2934 69
1975	278 26	283.84	690 87	589.08	1433.65	433 33	192 52	161 83	202.20	303 41	291.31	324.94	5185 44
Average	402 64	476 98	814.21	1183 79	930.70	469.29	261 35	223.57	236.26	259.27	266 45	346.93	5871.50

3.4 PRECIPITATION

The annual precipitation distribution in the Republic of Turkey is as indicated in Fig. III-3-14 and the annual precipitation distribution in the Kızılırmak River Basin in Fig. III-3-15.

According to the above, the annual precipitation in the Anatolian Plateau, the inland part of Turkey, is less than 500 mm. The Kepez Hydroelectric Power Development Project basin is mostly in this region with the exception of a small part. Areas with relatively large precipitation are only the most upstream part of the Kızılırmak River and the vicinity of the Devres River Basin at the downstream part of the project area.

The precipitation condition is of the same trend everywhere in the basin with more precipitation in the period from December to May, two thirds of the annual precipitation occurring during this half-year period. The month of May has the most precipitation with about 50 to 60 mm. July and August have the least precipitation with about several mm. The monthly average precipitations at the several gauging stations in the basin are indicated in Fig. III-3-16.

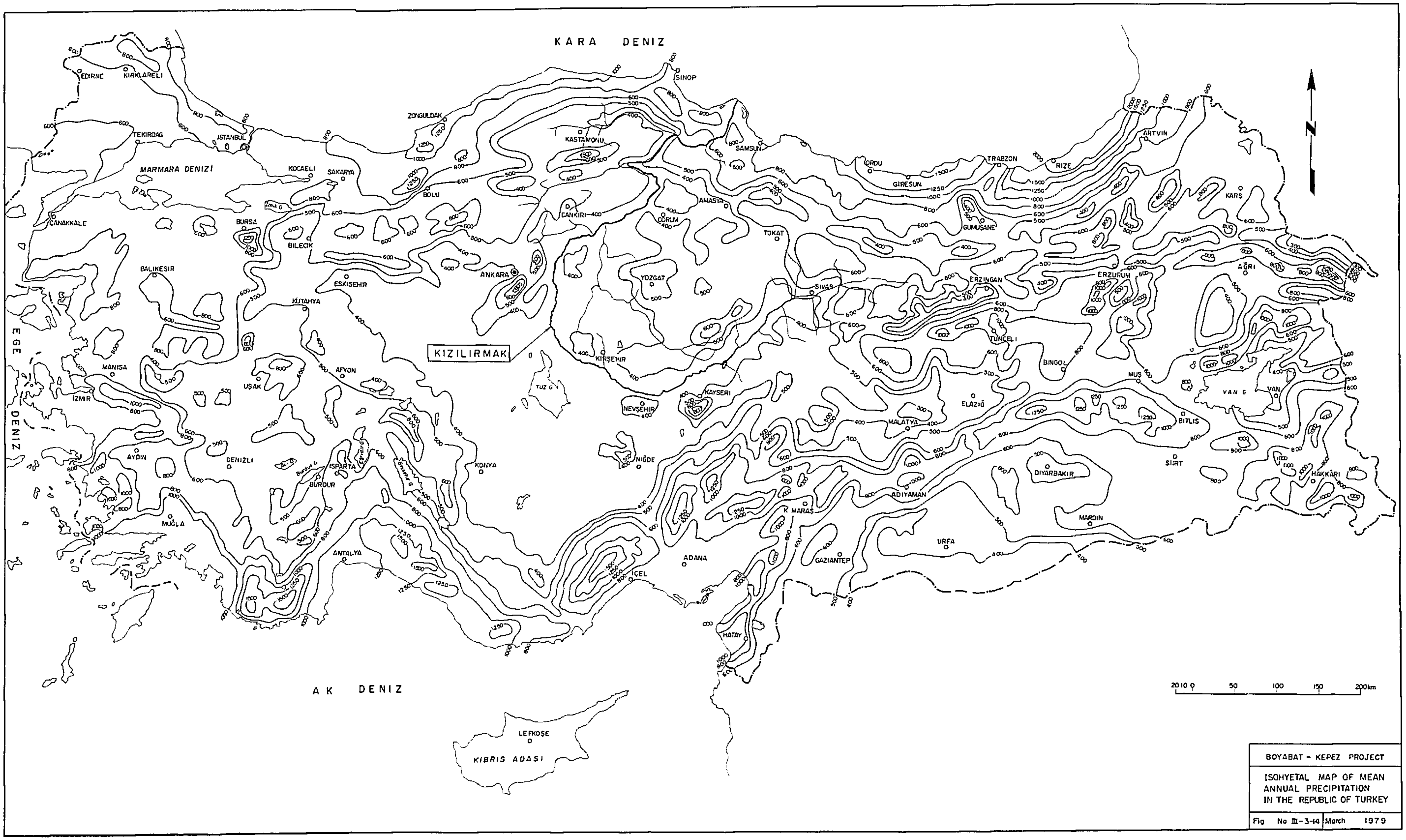
There is snowfall in the winter at places of high altitude on the Anatolian Plateau and at Sivas Gauging Station at the upstream part of the Kızılırmak River snowfall of about 1 m is measured.

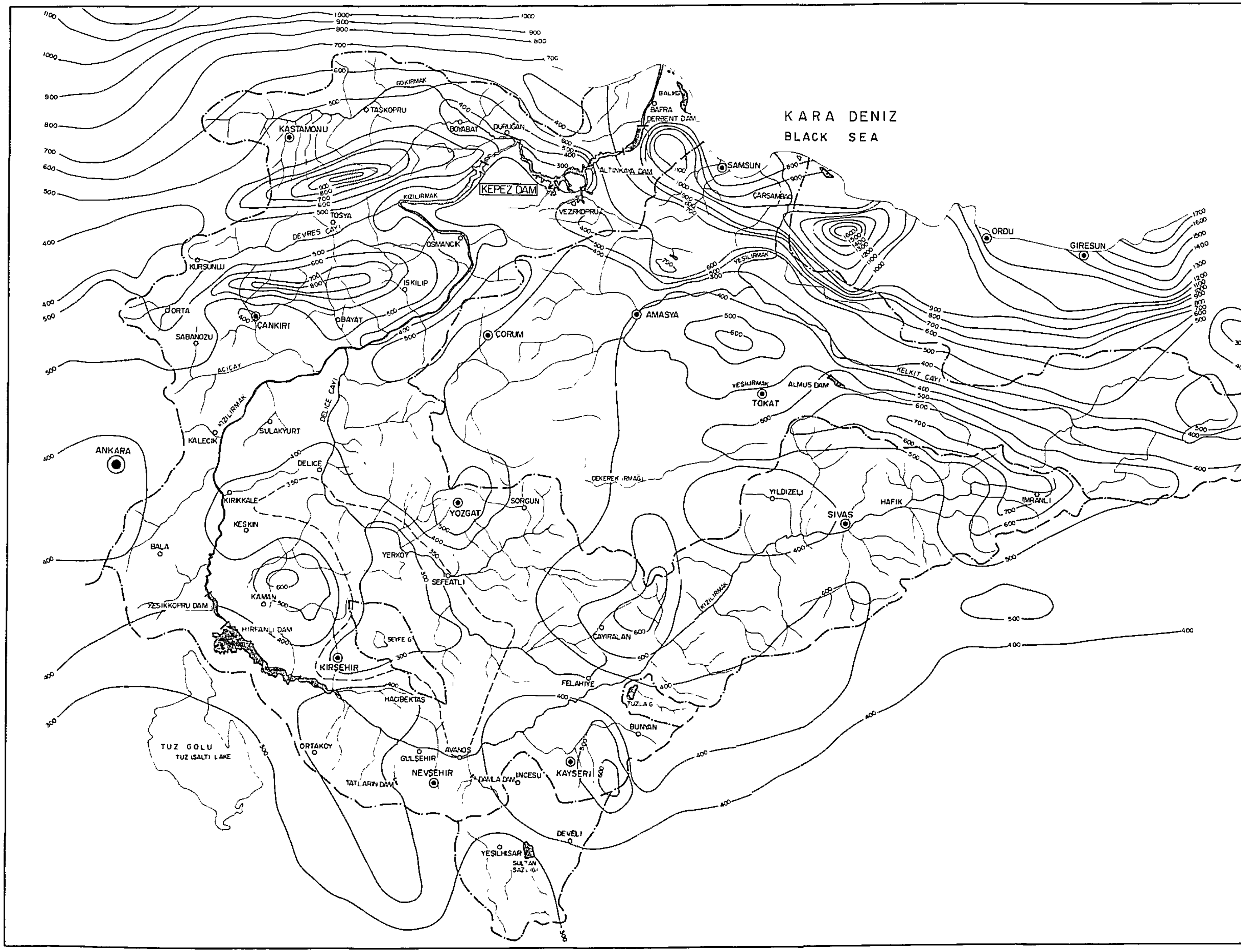
The periods of measurement at gauging stations in the vicinity of the Kepez dam site are indicated in Fig. III-3-17 and precipitation data in Appendix.

3.5 TEMPERATURE

The periods of measurement of monthly maximum temperatures, monthly minimum temperatures and monthly mean temperatures at gauging stations in the vicinity of the Kepez dam site are shown in Fig. III-3-18 and the temperature data in Appendix.

The annual mean temperature at the Kepez dam site is 13°C, July to August being hottest with a maximum temperature of 40°C and January being coldest with a minimum temperature of -16°C.


KARA DENIZ
AK DENIZ
EGE DENIZ
MARMARA DENIZI
KIZILIRMAK
KIBRIS ADASI
LEFKOSE
EDIRNE
KIRKLARELI
TEKIRDAG
ISTANBUL
ÇANAKKALE
BURSA
BALIKESIR
MANISA
IZMIR
AYDIN
MUĞLA
DENIZLI
UŞAK
KÜTAHYA
BILECIK
ESKISEHIR
KOCAELI
SAKARYA
BOLU
ZONGULDAK
KASTAMONU
SINOP
ÇANKIRI
ANKARA
AFYON
ISPARTA
BURDUR
ANTALYA
KONYA
TUZ G
KIRŞEHIR
NEVŞEHIR
NIĞDE
IÇEL
ADANA
HATAY
KAYSERI
YOZGAT
ÇORUM
AMASYA
SAMSUN
TOKAT
SIVAS
ORDU
GIRESUN
TRABZON
RIZE
ARTVIN
GÜMÜŞANE
ERZINCAN
ERZURUM
KARS
AĞRI
TUNCELI
BINGÖL
ELAZIĞ
MALATYA
ADIYAMAN
K MARAŞ
GAZIANTEP
URFA
DIYARBAKIR
MARDIN
SIIRT
BITLIS
MUŞ
VAN
VAN G
HAKKÂRI
N
20 10 0 50 100 150 200km
BOYABAT - KEPEZ PROJECT
ISOHYETAL MAP OF MEAN
ANNUAL PRECIPITATION
IN THE REPUBLIC OF TURKEY
Fig No III-3-14 March 1979



BOYABAT - KEPEZ PROJECT

ISOHYETAL MAP OF MEAN ANNUAL PRECIPITATION OF KIZILIRMAK BASIN

Fig No III-3-15 March 1979

Fig.III-3-16 Monthly Average Precipitation at Gauging Stations in Kızılırmak Basin

( ) Annual Precipitation (mm)

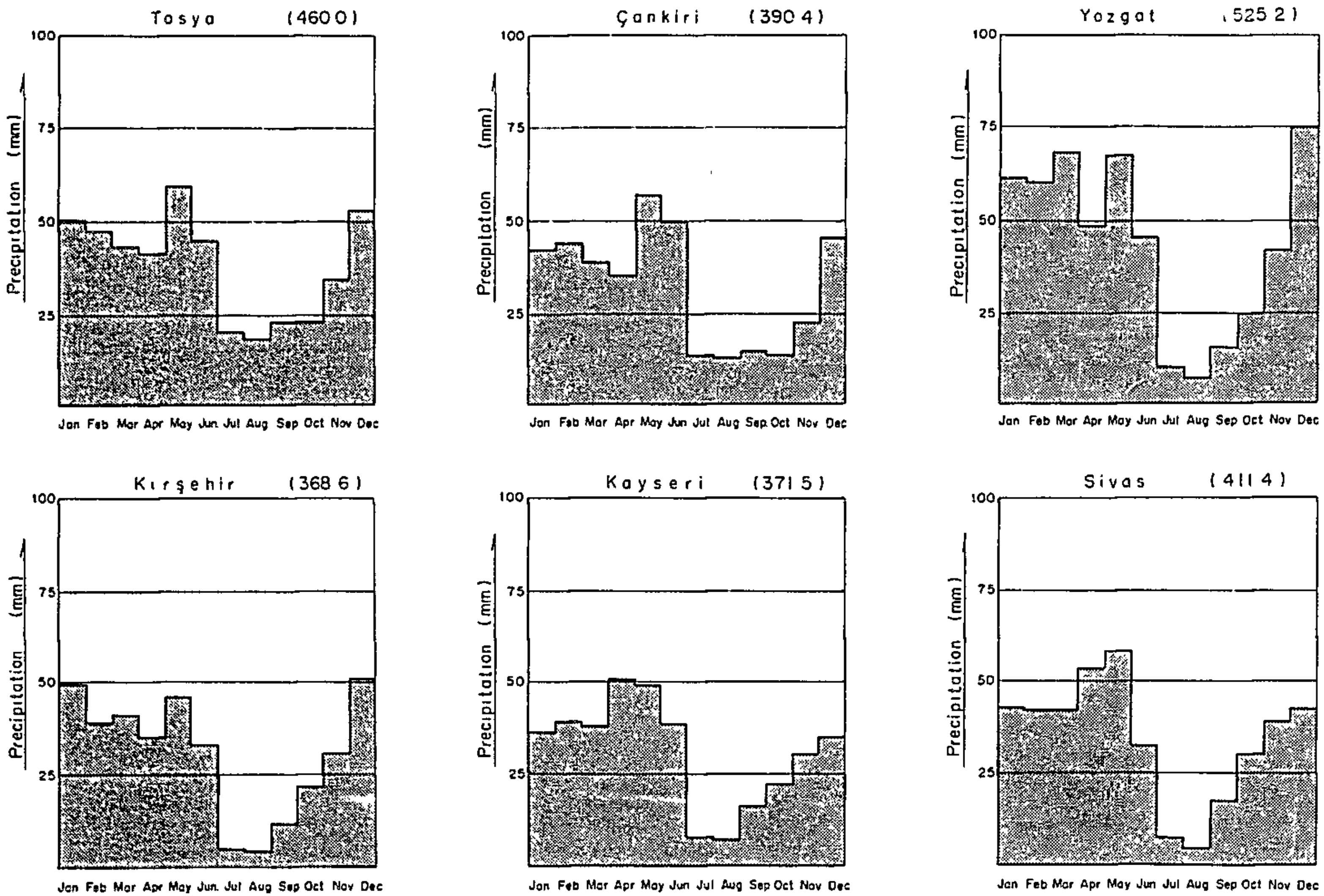


Fig III-3-17 Existing Precipitation Data

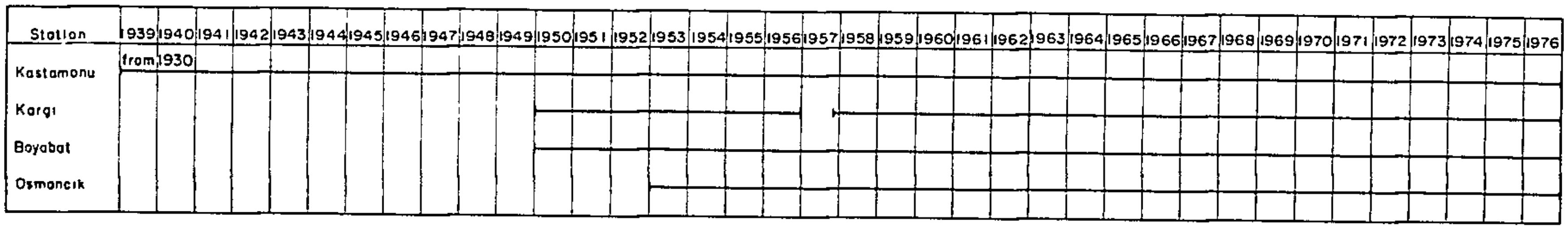
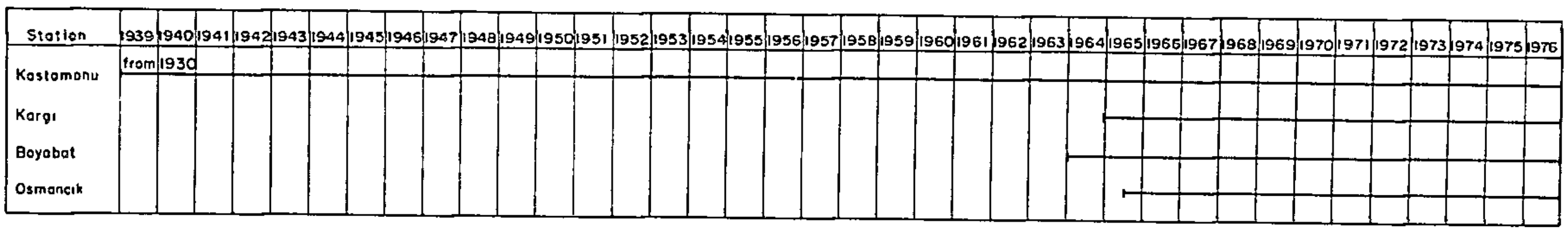


Fig. III-3-18 Existing Temperature Data



3.6 EVAPORATION

With regard to evaporation from the reservoir surface, it is necessary to consider that the condition of evapotranspiration through vegetation prior to construction of the reservoir will be replaced by evaporation from the water surface after reservoir construction, and this difference must be taken into account as the evaporation from the reservoir.

The Kepez Hydroelectric Power Development Project basin is in a dry region, while the vegetation in reservoir area is scarce, and therefore, a fair amount of evaporation from the reservoir may be considered to take place.

Evaporation measurements at Kastamonu Gauging Station near Kepez Reservoir are used for computations. Monthly average evaporation are obtained from data of the 15-year period from January 1962 to December 1976, and with the correlation factor for evapotranspiration from vegetation as 0.70, the evaporation from the reservoir is determined.

The monthly evaporation from Kepez Reservoir determined are indicated in Table III-3-8.

Table III-3-8 Monthly Evaporation from Kepez Reservoir

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Evaporation (mm)	7.2	10.9	20.1	50.4	72.5	98.3	125.3	114.7	72.6	38.3	15.9	11.1	637.3

3.7 DESIGN FLOOD FLOW

There are two kinds of design flood flows, one obtained by the physical method based on probable maximum precipitation (PMP) for determining the discharge capacity of a spillway, and the other obtained by the statistic method to determine the discharge capacity of a diversion tunnel, but in this Report the design flood flow calculated by DSİ is adopted, the outline being as described below.

The physical method gives the probable maximum precipitation that may happen, if all factors contributing to the generation of precipitation are to reach their critical conditions, simultaneously from which the probable maximum flood can be obtained. In this study, the probable maximum precipitation is estimated by the Herchfield method and then the maximum probable flood including snowmelt flood is estimated using the synthetic unit hydrograph method by Synder.

The flood by the statistic method is usually called statistic probable flood which is calculated by Gumbel's method based on past flood records at a given water gauging station and flood flow at the project site is converted by 2/3 power of drainage area correlation.

3.7.1 Maximum Probable Flood

The catchment area of the Kızılırmak River at the project site is 64,724 km^2 of which 26,499 km^2 comprise the upstream area of the Hirfanlı dam site, the remaining 38,255 km^2 being the catchment area between the Hirfanlı dam site and the project site.

Taking the characteristics of the Kızılırmak River Basin into consideration an isohyetal map of probable maximum precipitation is prepared dividing the basin into the 6 catchment areas below. The probable maximum run-off hydrographs of the subdivided catchment areas are estimated from their precipitations, and providing for time lags in the various subdivided catchment areas on these hydrographs, the probable maximum inflow hydrograph for the project site is obtained.

Upstream of Hirfanlı dam site

Between Delice confluence and Hirfanlı dam site

Acicay branch

Delice branch

Devres branch

Between Delice confluence and project site

The arrangement of the subdivided catchment areas is indicated in Fig. III-1-19.

(1) Precipitation

Preparing an isohyetal map of mean annual precipitation employing data from meteorological gauging stations situated in the Kızılırmak River Basin and neighboring basins, the result is as shown in Fig. III-3-15.

The technique described below is used to determine probable maximum precipitation.

(a) The probable maximum precipitation in the area upstream of the project site is determined by frequency analysis based on daily maximum precipitation in each year from 1850 to 1976. In making the frequency analysis the data are arranged in order from the heaviest measured total daily maximum precipitation and the mean value and standard deviation are obtained. The probable maximum precipitation is calculated by the Herchfield method using the equation below.

$$I_{PMP} = (I + K \times S) \times 1.13$$

where

I_{PMP} : probable maximum precipitation (mm)

I : mean value of series of daily maximum precipitations in each year (mm)

K : number for calculating I_{PMP}

(K = 15 assumed)

S : standard deviation of series (mm)

Based on the above, the average value of daily probable maximum precipitations of the catchment area of 38,225 km^2 between Hirfanlı and the project site will be 94 mm.

(b) As results of analysis using the same frequency analysis technique as above on daily local probable maximum precipitation from data on the respective maximum precipitations at 32 meteorological gauging stations in the catchment area where long-time measurements have been made, an average figure of 184 mm/day is obtained.

In Fig. III-3-20, the results of analysis on the depth-area relation of 24-hour probable maximum precipitation by the physical method is indicated.

(2) Precipitation Distribution

As results of study of the design precipitation center where maximum flow in the project area will be produced, it is found that the maximum precipitation of the entire Kızılırmak River Basin will be produced if the local design precipitation center is selected at a location on the boundary line between the basins of the Gökırmak River and the Debres River. Consequently, putting the 184 mm/day design precipitation center at the above location and preparing an isohyetal map for the entire basin using depth-area curves, the result is as given in Fig. III-3-21.

(3) Design Precipitation Distribution with Respect to Time

In order to estimate the distribution with respect to time of the 24-hour average probable maximum precipitation of 94 mm in the basin, the 6 storm rainfall data indicated in Fig. III-3-22 are selected and the distributions with respect to time of these storm rainfalls are examined and the distributions with respect to time of 36-hour rainfalls are prepared. The results are given in Fig. III-3-23.

(4) Run-off

The relation between rainfall and run-off are deduced from curves prepared by the U.S. Soil Conservation Service. The correlations between observed run-offs and rainfalls obtained from Kızılırmak River tributaries are examined, but since the coefficient of run-off indicates a large figure, the coefficient of run-off is determined from hydrologic and soil characteristics.

Unit hydrographs are prepared for the beforementioned 6 subdivided basins by Snyder's method based on rainfall distributions with respect to time of these catchment areas. The superposed run-off hydrographs of the subdivided basins are indicated in Fig. III-3-24.

(5) Snowmelt Hydrograph

The principal basin in the project area where heavy snowfall is seen is the area upstream of the Hirfanlı dam site and it is found as a result of study that the snowmelt period of this basin is the month of March. Investigating the maximum temperatures on the 1st, 5th, 10th and 15th of March in this basin and assuming that these maximum temperatures have correlations with a Hazen distribution, the maximum probable temperature is estimated. Meanwhile, in order to prepare a snowmelt hydrograph, a value of 1 mm/day. °C is obtained from the correlation between recorded temperature and run-off as the maximum snowmelt factor.

The snowfall thickness and the boundary of the snowfall area upstream of the Hirfanlı dam site are investigated to find the mean elevation of the snowfall area and snowmelt hydrographs per 1,000 km^2 are prepared converting maximum probable temperature to this mean snowfall elevation. The results are given in Fig. III-3-25.

Since the peak of the run-off hydrograph for the Kepez dam site will be higher to present the worst condition if the peak of the snowmelt hydrograph of the area upstream of the Hirfanlı dam site are made to overlap with the peak of the Delice rainfall-runn-off hydrograph, it is decided to make this coincide with the peak of the hydrograph for Delice.

(6) Hydrograph at Project Site

The hydrograph of probable maximum flood at the project site is prepared taking time lagging into account on hydrographs made for the 6 subdivided basins. The result is indicated in Fig. III-3-26.

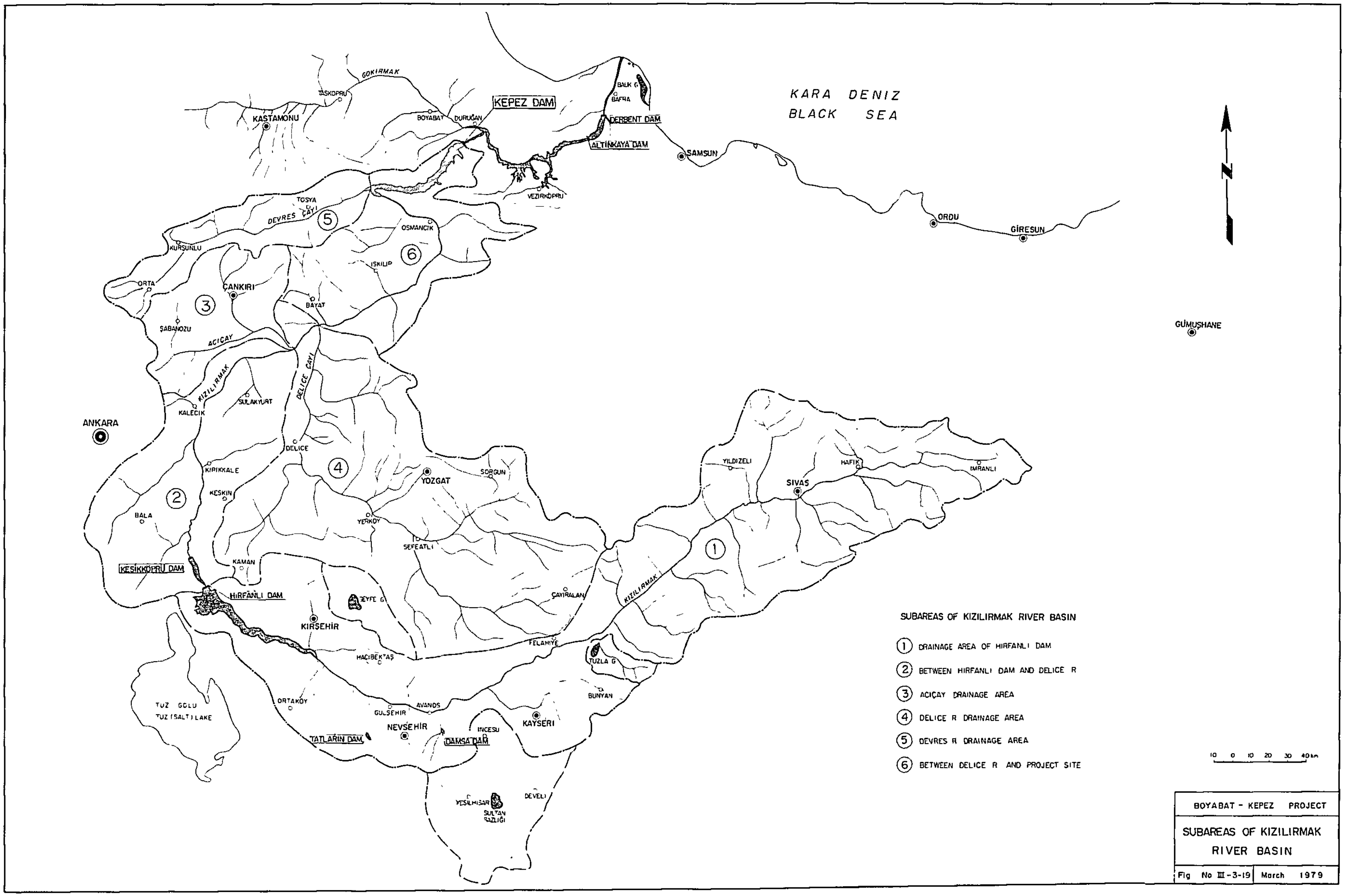
According to this hydrograph the design flood flow of the spillway will be 9,300 m^3/sec.

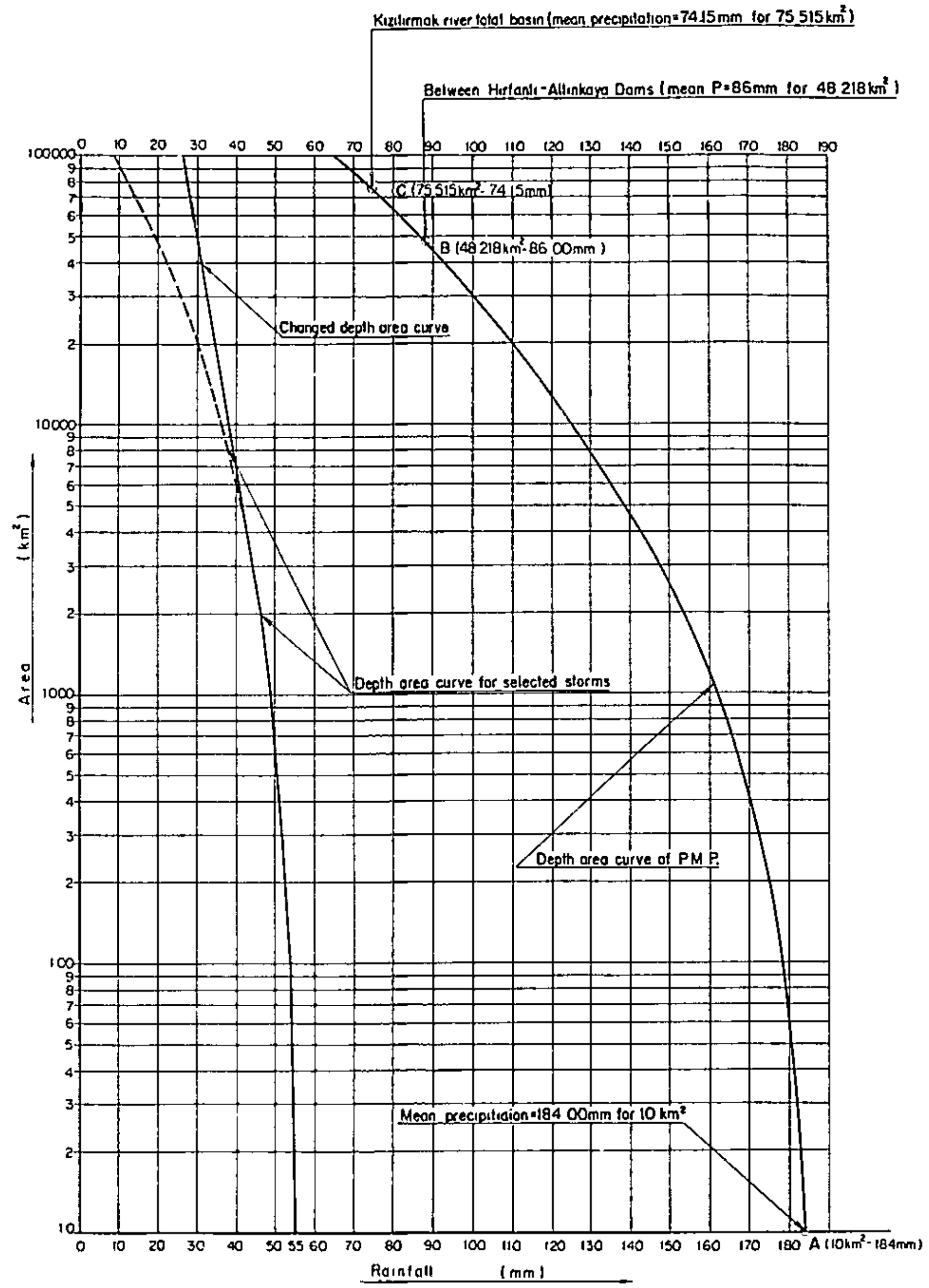
3.7.2 Statistic Flood

The data of Avşar Bridge Run-off Gauging Station (catchment area; 60,560 km^2) on the Kızılırmak River are used to examine the statistic probable flood required for design of the diversion tunnel of the project. The flood frequency curve indicated in Fig. III-3-27 is prepared by Gumbel's method from the hydrograph of flood discharge measured at this run-off gauging station.

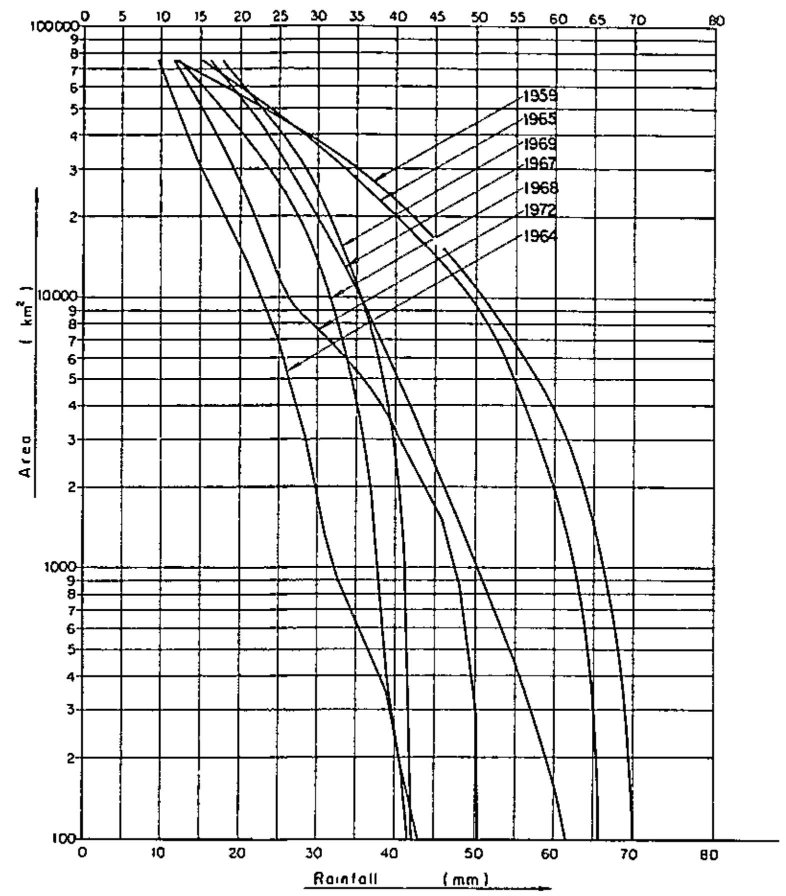
A dimensionless hydrograph is then prepared from data having the largest volume (10 days duration) from among the observed hydrographs, and this hydrograph and the total volume of the flood frequency curve are checked and a good correlation is obtained.

Based on this flood frequency curve, and in consideration that the dam is to be a concrete dam, the 10 years return period of 1,355 m^3/sec is adopted as the design flood of the diversion tunnel.


KARA DENIZ
BLACK SEA
KEPEZ DAM
DERBENT DAM
ALTINKAYA DAM
KASTAMONU
BOYABAT
DURUĞAN
BAFRA
SAMSUN
ORDU
GIRESUN
GUMUSHANE
TOSYA
DEVRES ÇAYI
OSMANCIK
ISKILIP
KURSUNLU
ORTA
ÇANKIRI
BAYAT
ŞABANOZU
ACIÇAY
KIZILIRMAK
DELICE ÇAYI
SULAKYURT
KALECIK
ANKARA
DELICE
KIRIKKALE
KESKIN
BALA
YOZGAT
SORGUN
YERKOY
SEFEATLI
KAMAN
KESIKKOPRU DAM
HIRFANLI DAM
KIRSEHIR
ÇAYIRALAN
FELAHIYE
HACIBEKTAŞ
TUZLA G
BUNYAN
ORTAKOY
AVANOS
GULSEHIR
NEVSEHIR
KAYSERI
INCESU
TATLARIN DAM
DAMSA DAM
TUZ GOLU
TUZ (SALT) LAKE
YESILHISAR
SULTAN SAZLIGI
DEVELI
YILDIZELI
SIVAS
HAFIK
IMRANLI
SUBAREAS OF KIZILIRMAK RIVER BASIN
(1) DRAINAGE AREA OF HIRFANLI DAM
(2) BETWEEN HIRFANLI DAM AND DELICE R
(3) ACIÇAY DRAINAGE AREA
(4) DELICE R DRAINAGE AREA
(5) DEVRES R DRAINAGE AREA
(6) BETWEEN DELICE R AND PROJECT SITE
N
10 0 10 20 30 40km
BOYABAT - KEPEZ PROJECT
SUBAREAS OF KIZILIRMAK RIVER BASIN
Fig No III-3-19 March 1979

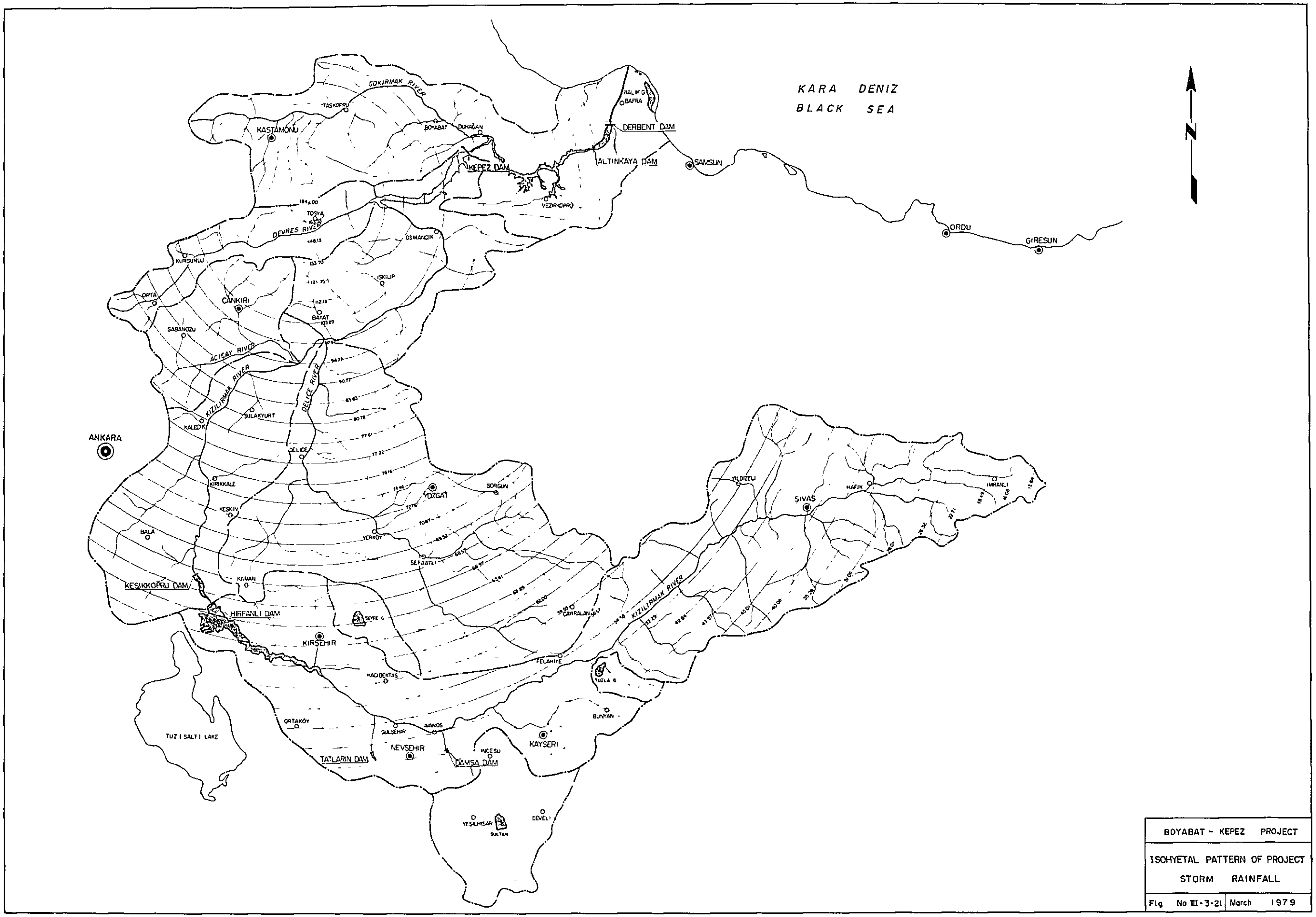


Mean depth area relation for 24 hours stormrainfall based on selected major observed storms and depth-area curve for PMP



Depth area relation for 24 Hours storm rainfall of selected major storms

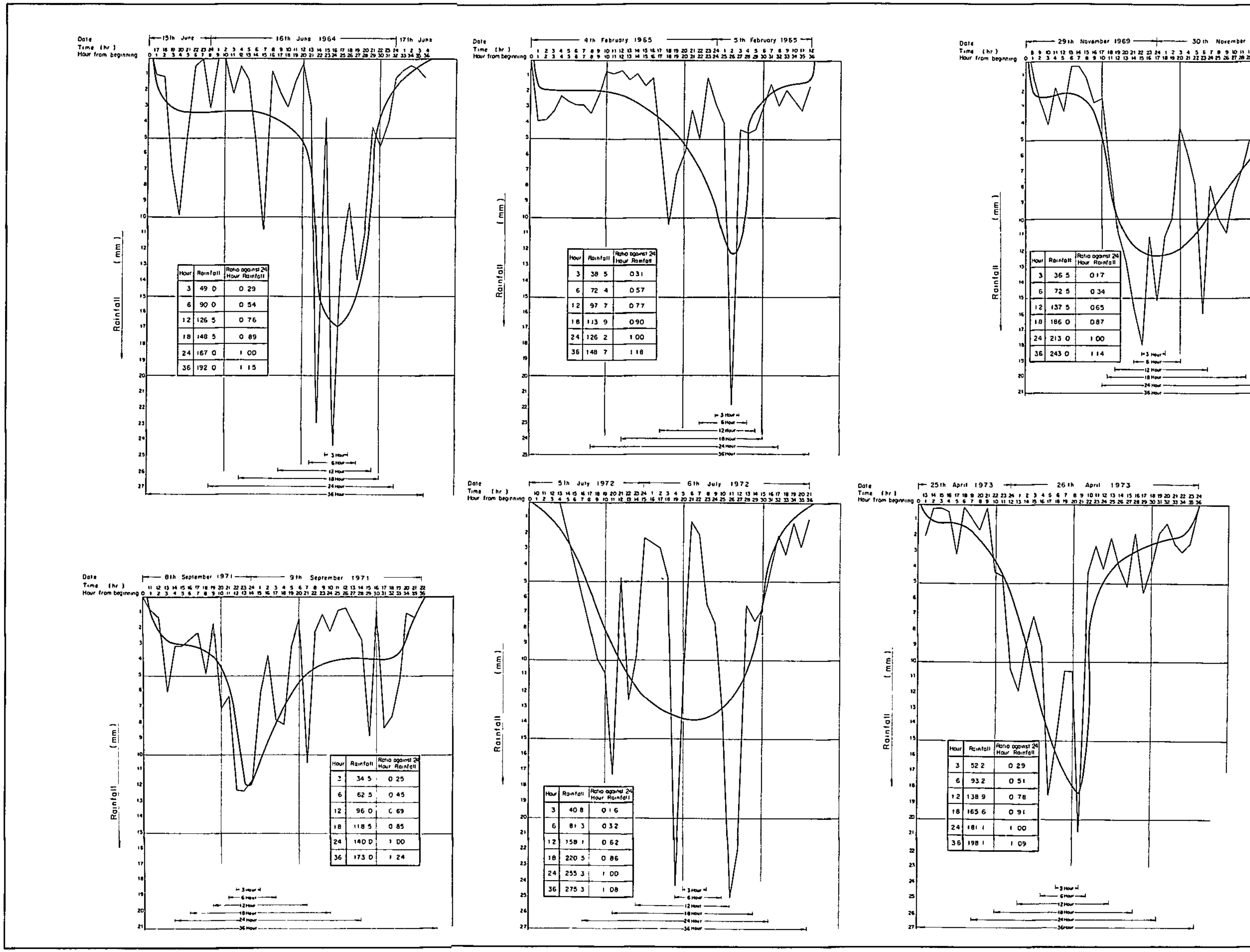
BOYABAT - KEPEZ PROJECT	
DEPTH AREA RELATION OF 24 HOUR P.M.P.	
Fig No III-3-20	March 1979



BOYABAT - KEPEZ PROJECT

ISOHYETAL PATTERN OF PROJECT STORM RAINFALL

Fig No III-3-21 March 1979



15th – 17th June 1964

Hour	Rainfall	Ratio against 24 Hour Rainfall
3	49 0	0 29
6	90 0	0 54
12	126 5	0 76
18	148 5	0 89
24	167 0	1 00
36	192 0	1 15

4th – 5th February 1965

Hour	Rainfall	Ratio against 24 Hour Rainfall
3	38 5	0 31
6	72 4	0 57
12	97 7	0 77
18	113 9	0 90
24	126 2	1 00
36	148 7	1 18

29th – 30th November 1969

Hour	Rainfall	Ratio against 24 Hour Rainfall
3	36 5	0 17
6	72 5	0 34
12	137 5	0 65
18	186 0	0.87
24	213 0	1 00
36	243 0	1 14

8th – 9th September 1971

Hour	Rainfall	Ratio against 24 Hour Rainfall
3	34 5	0 25
6	62 5	0 45
12	96 0	C 69
18	118 5	0 85
24	140 0	1 00
36	173 0	1 24

5th – 6th July 1972

Hour	Rainfall	Ratio against 24 Hour Rainfall
3	40 8	0 16
6	81 3	0 32
12	158 1	0 62
18	220 5	0 86
24	255 3	1 00
36	275 3	1 08

25th – 26th April 1973

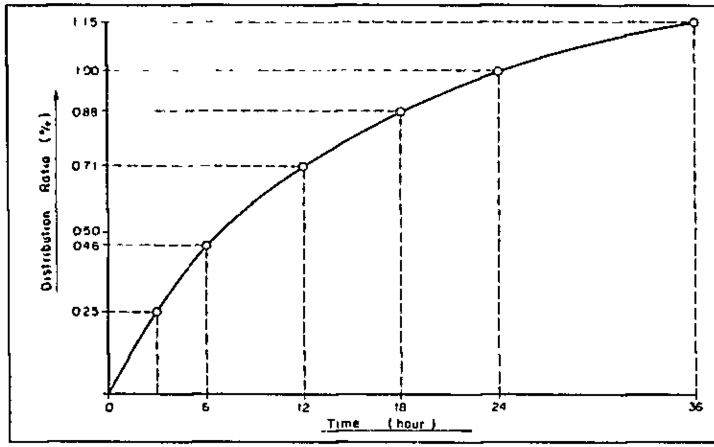
Hour	Rainfall	Ratio against 24 Hour Rainfall
3	52 2	0 29
6	93 2	0 51
12	138 9	0 78
18	165 6	0 91
24	181 1	1 00
36	198 1	1 09

BOYABAT - KEPEZ PROJECT

THE TIME DISTRIBUTION OF 36 HOUR MEAN RAINFALL FOR MAJOR STORMS

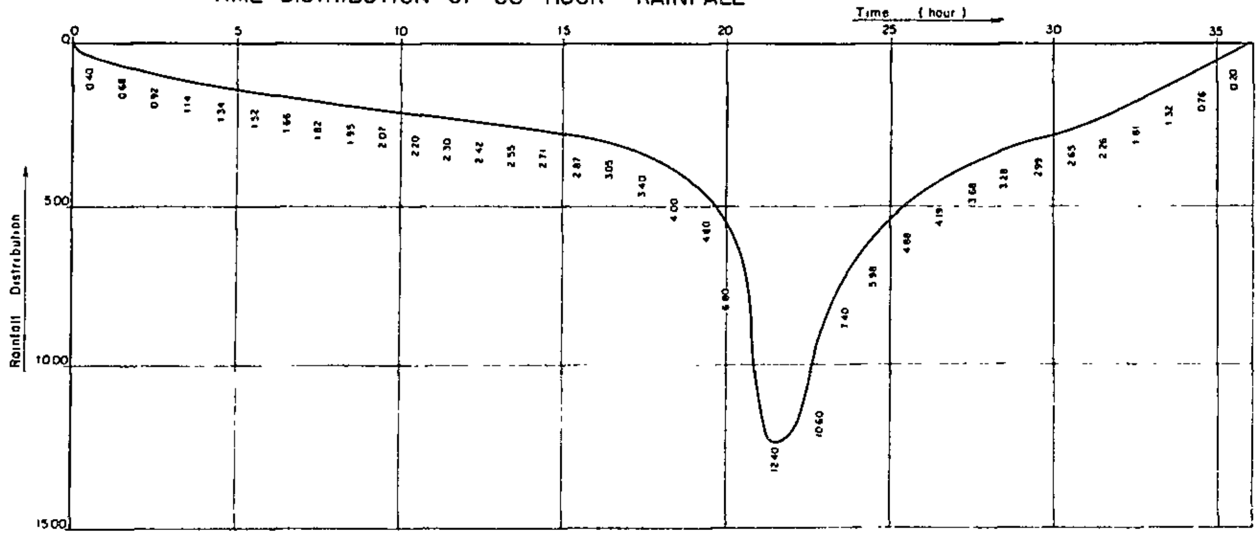
Fig No III-3-22 | March 1979

TIME DISTRIBUTION OF CLASIFIED RELATIVE RAINFALL ACCORDING TO 24 HOUR RAINFALL

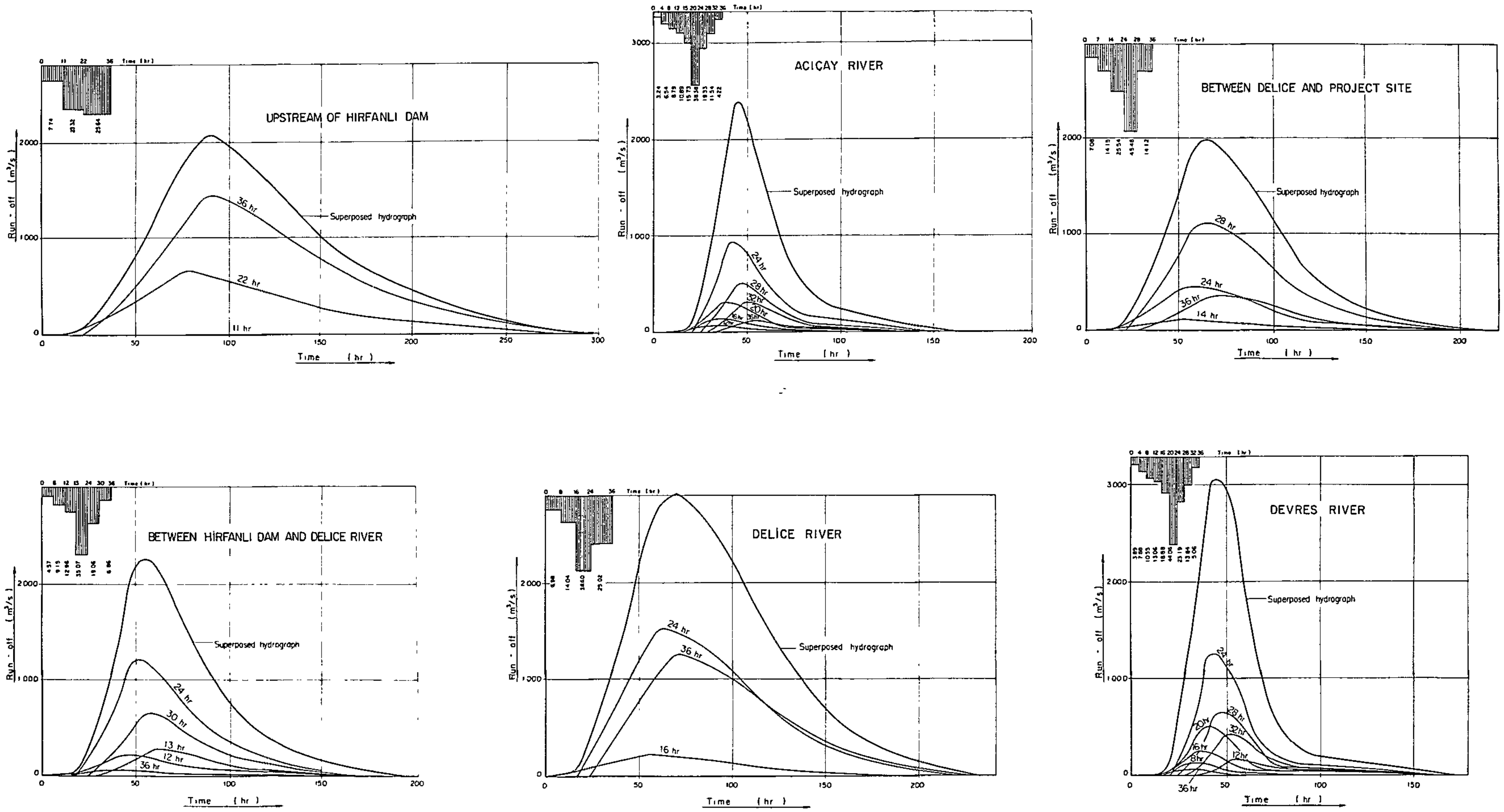


Rainfall / YEAR	3 hr	6 hr	12 hr	18 hr	24 hr	36 hr
1964	0.29	0.54	0.76	0.89	1.00	1.15
1965	0.31	0.57	0.77	0.90	1.00	1.18
1969	0.17	0.34	0.65	0.87	1.00	1.14
1971	0.25	0.45	0.69	0.85	1.00	1.24
1972	0.16	0.32	0.62	0.86	1.00	1.08
1973	0.29	0.51	0.78	0.91	1.00	1.05
TOTAL	1.47	2.73	4.27	5.28	7.00	6.88
Average	0.25	0.46	0.71	0.88	1.00	1.15

TIME DISTRIBUTION OF 36 HOUR RAINFALL



BOYABAT - KEPEZ PROJECT	
THE DERIVATION OF TIME DISTRIBUTION OF 36 HOUR RAINFALL	
Fig No III-3-23	March 1979

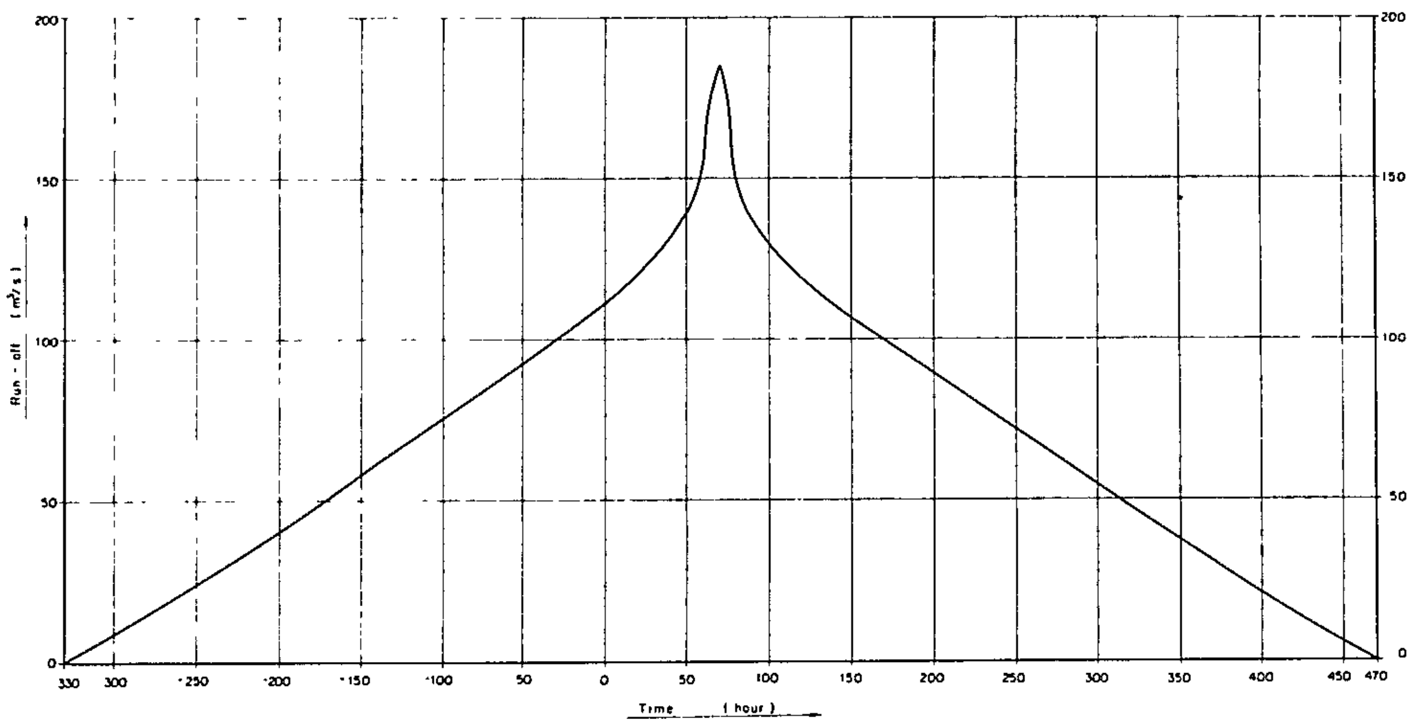


BOYABAT - KEPEZ PROJECT

SUPERPOSITION OF RUNOFF HYDROGRAPHS OF 6 SUBBASINS RESULTED FROM PROJECT DESIGN STORM

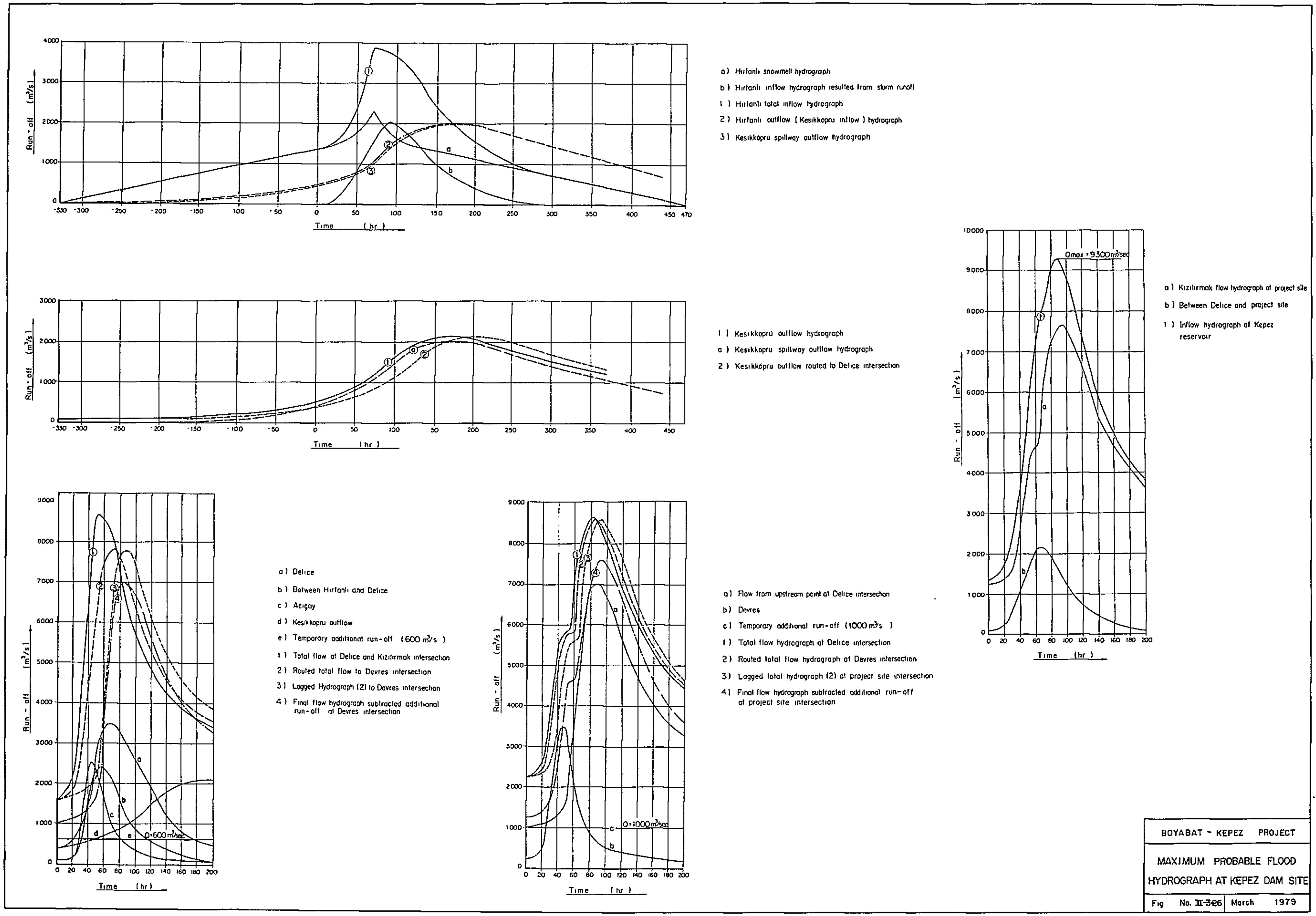
Fig No. III-3-24 | March 1979

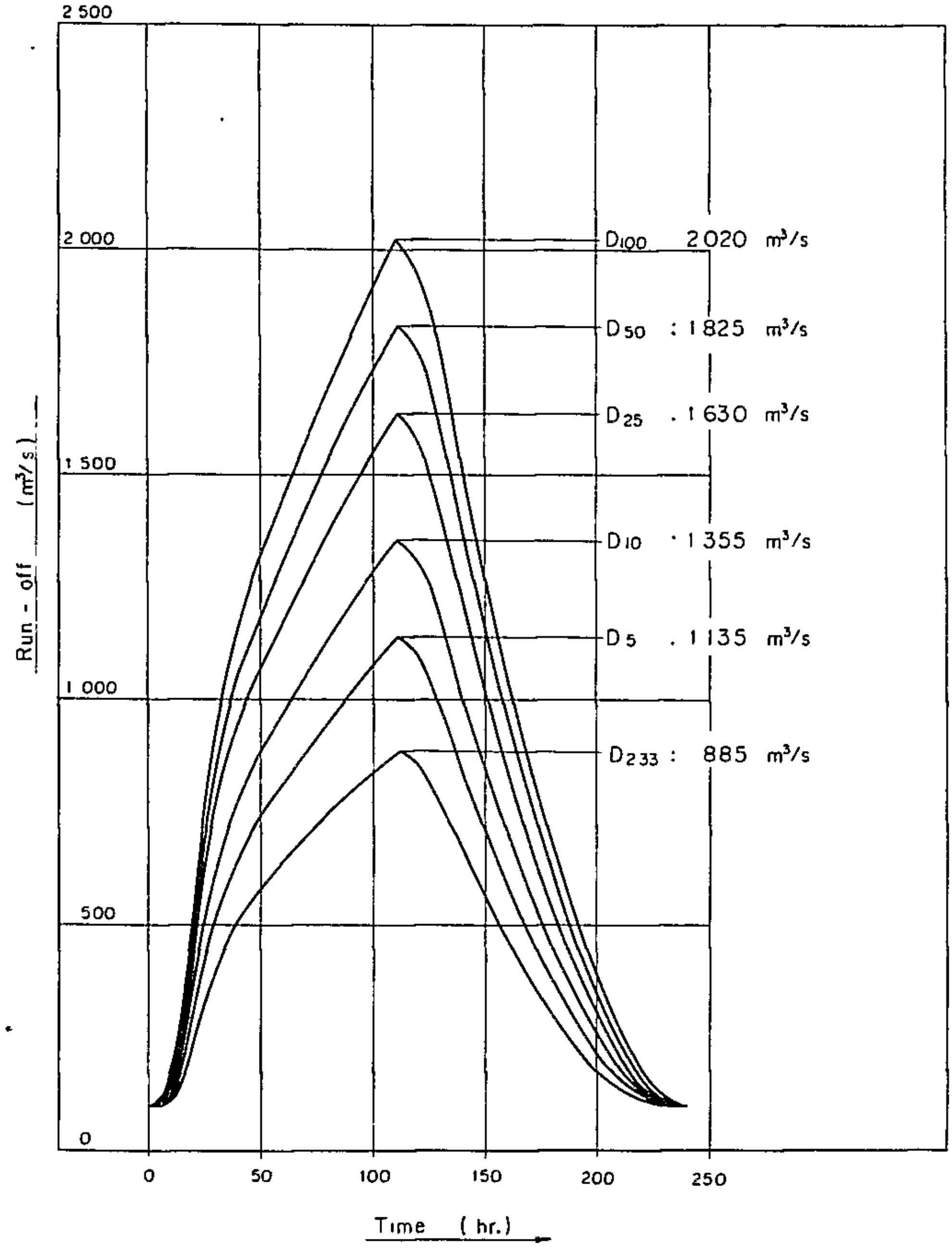
SNOWMELT RUNOFF HYDROGFAPH FOR 1000 km²



NOTICE Peak values of Delice River hydrograph and snowmelt hydrograph are superposed

BOYABAT - KEPEZ PROJECT	
SNOWMELT RUNOFF HYDROGRAPH FOR 1000 km²	
Fig No III-3-25	March 1979


a) Hirfanlı snowmelt hydrograph
b) Hirfanlı inflow hydrograph resulted from storm runoff
1) Hirfanlı total inflow hydrograph
2) Hirfanlı outflow (Kesikkopru inflow) hydrograph
3) Kesikköprü spillway outflow hydrograph
Run - off (m³/s)
Time (hr)
1) Kesikköprü outflow hydrograph
a) Kesikkopru spillway outflow hydrograph
2) Kesikköprü outflow routed to Delice intersection
a) Kızılırmak flow hydrograph at project site
b) Between Delice and project site
1) Inflow hydrograph of Kepez reservoir
Qmax = 9300 m³/sec
a) Delice
b) Between Hirfanlı and Delice
c) Acıçay
d) Kesikkopru outflow
e) Temporary additional run-off (600 m³/s)
1) Total flow at Delice and Kızılırmak intersection
2) Routed total flow to Devres intersection
3) Lagged Hydrograph (2) to Devres intersection
4) Final flow hydrograph subtracted additional run-off at Devres intersection
Q = 600 m³/sec
a) Flow from upstream point at Delice intersection
b) Devres
c) Temporary additional run-off (1000 m³/s)
1) Total flow hydrograph at Delice intersection
2) Routed total flow hydrograph at Devres intersection
3) Lagged total hydrograph (2) at project site intersection
4) Final flow hydrograph subtracted additional run-off at project site intersection
Q = 1000 m³/sec
BOYABAT - KEPEZ PROJECT
MAXIMUM PROBABLE FLOOD HYDROGRAPH AT KEPEZ DAM SITE
Fig No. III-3-26 March 1979



BOYABAT - KEPEZ PROJECT

FLOOD FREQUENCY CURVE AT KEPEZ DAM SITE

Fig. No.III-3-27 March 1979

3.8 SEDIMENTATION

Measurement of the concentration of suspended load of the Kızılırmak River was made by DSI for a total of 332 days from September 18, 1962 to June 30, 1973 at Çetınkaya Bridge at Bafra.

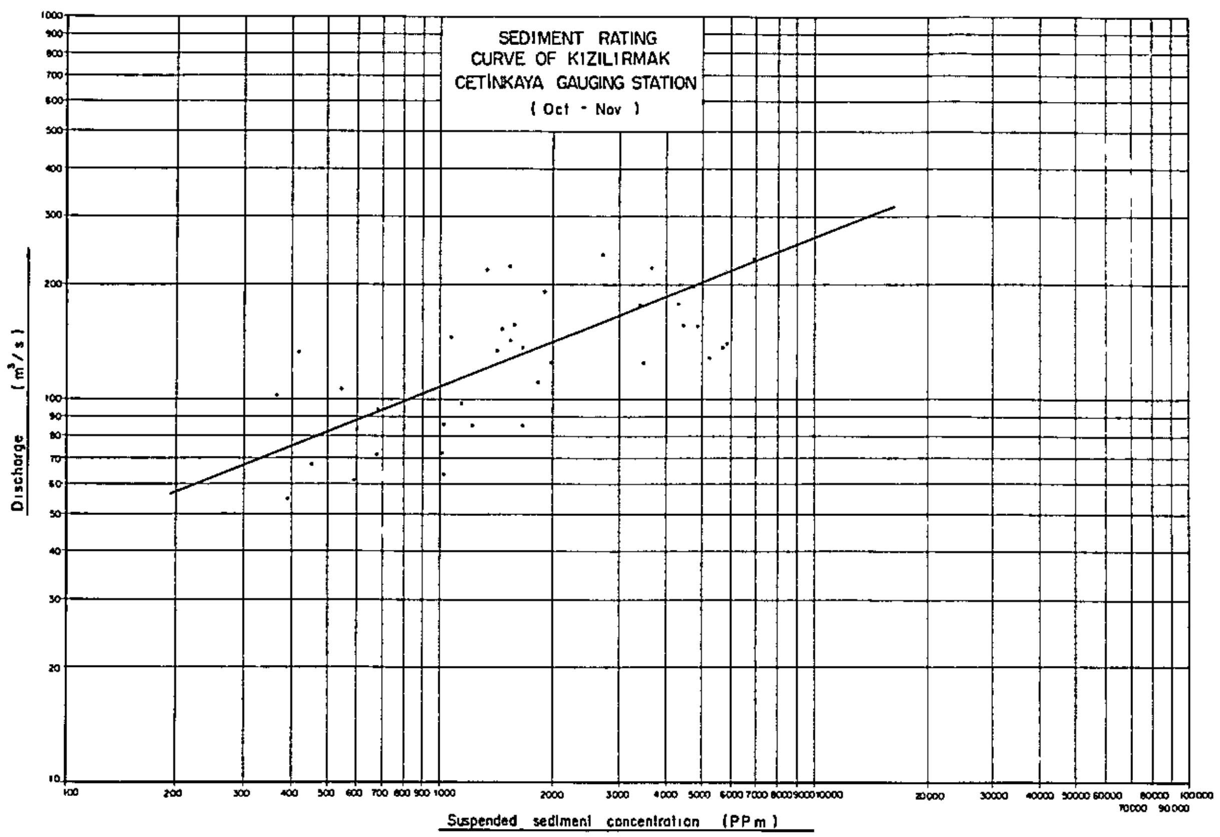
Also, similar measurements were made by EİE at the Inözü Gauging Station for a total of 89 days between March 28, 1967 to May 16, 1974. As results of analyses of these data, the suspended load of the Kızılırmak River consists 26% of sand and 74% of silt and clay with the average concentration being 6,600 ppm.

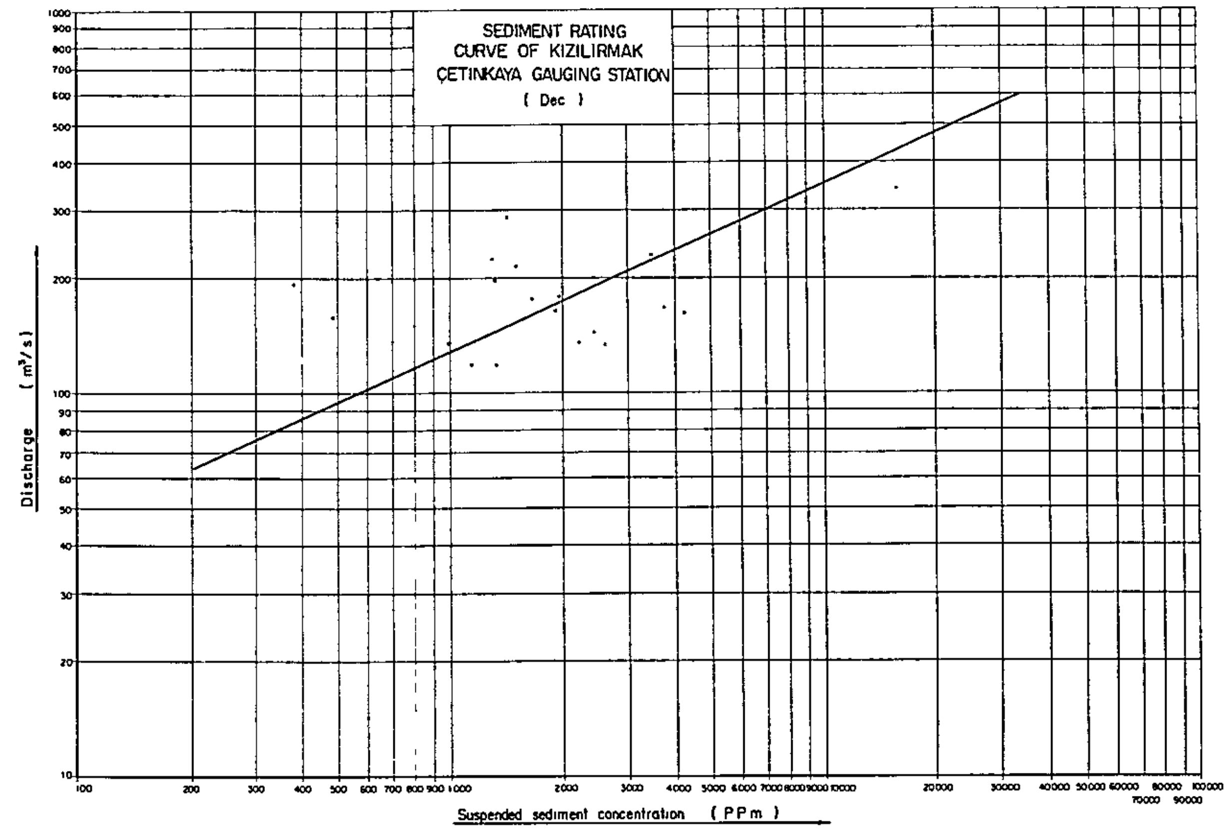
Since the distance between Inozü Gauging Station, that is, the Altınkaya dam site, and Çetinkaya Bridge is approximately 25 km and short, the run-offs are considered to be roughly equal. The relation between suspended load concentration and run-off at the Altınkaya dam site by month expressed as logarithms are as indicated in Fig. III-3-28.

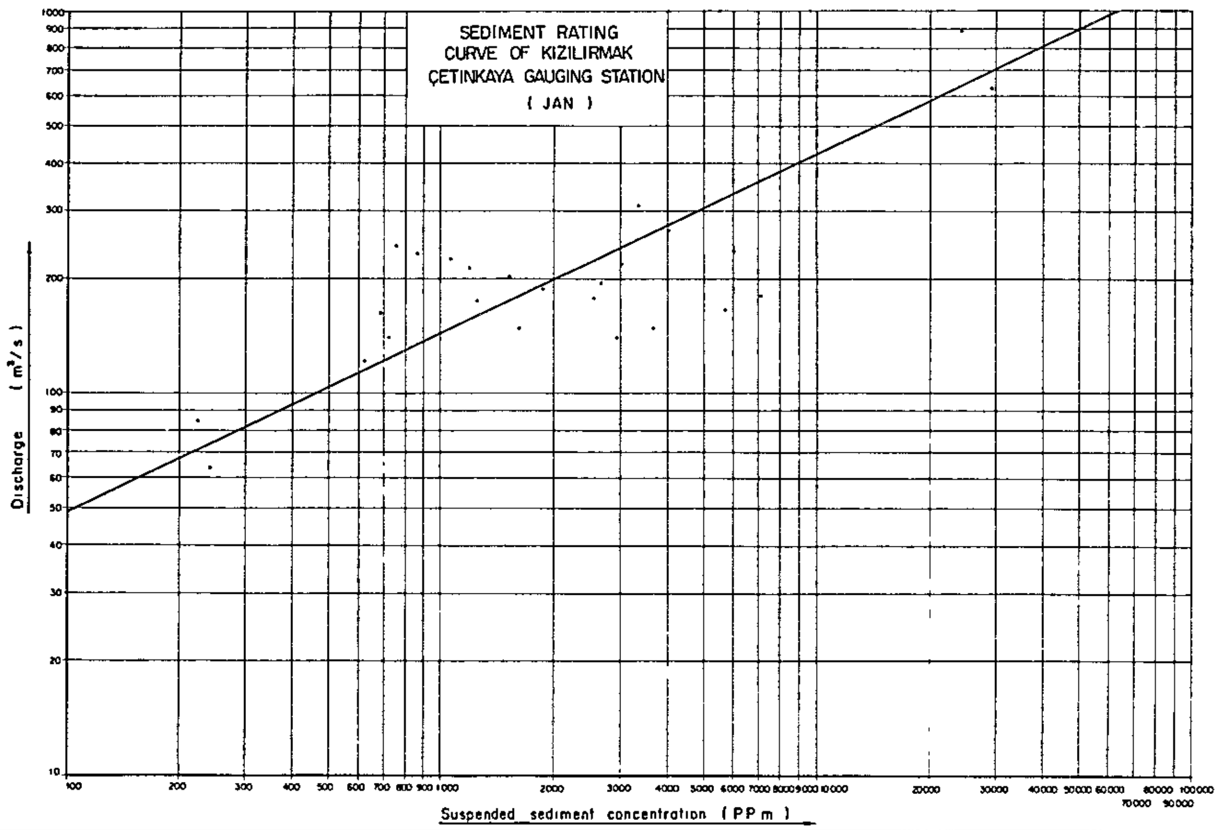
Considering the suspended load concentrations at the Altınkaya dam site and the Kepez dam site to be the same, the suspended load concentration at the Kepez dam site is calculated based on the monthly average present run-offs previously calculated for the 37 years. The run-off duration curves of the monthly averages of the Altınkaya dam site present run-offs and the Kepez dam site present run-offs for 37 years are indicated in Fig. III-3-29.

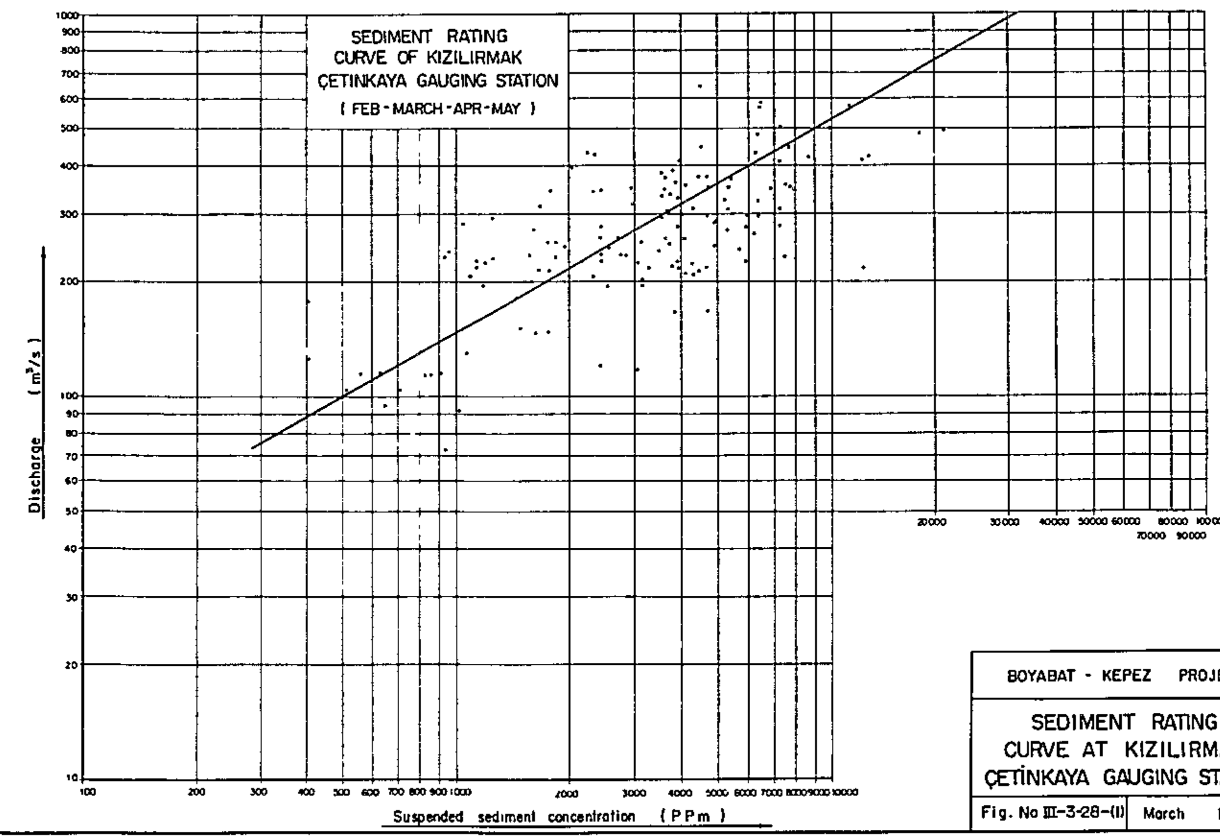
The unit weight of the sedimentation settling in the reservoir calculated by the method proposed by the USBR will be W = 1.193 t/m^3 in 50 years. Calculating the sedimentation of each year using the above, the result will be 25.2 x 10^6 m^3 and with this considered as the bed load and taking account of 20% as suspended material, the sedimentation each year will be 30.2 x 10^6 m^3.

A period of 50 years will be required for the surface of the sedimentation to reach the base elevation of the intake and it is judged that problems of sedimentation will not arise during the service life of the power station.









BOYABAT - KEPEZ PROJECT

SEDIMENT RATING
CURVE AT KIZILIRMAK
ÇETİNKAYA GAUGING STATION

Fig. No III-3-28-(I) March 1979

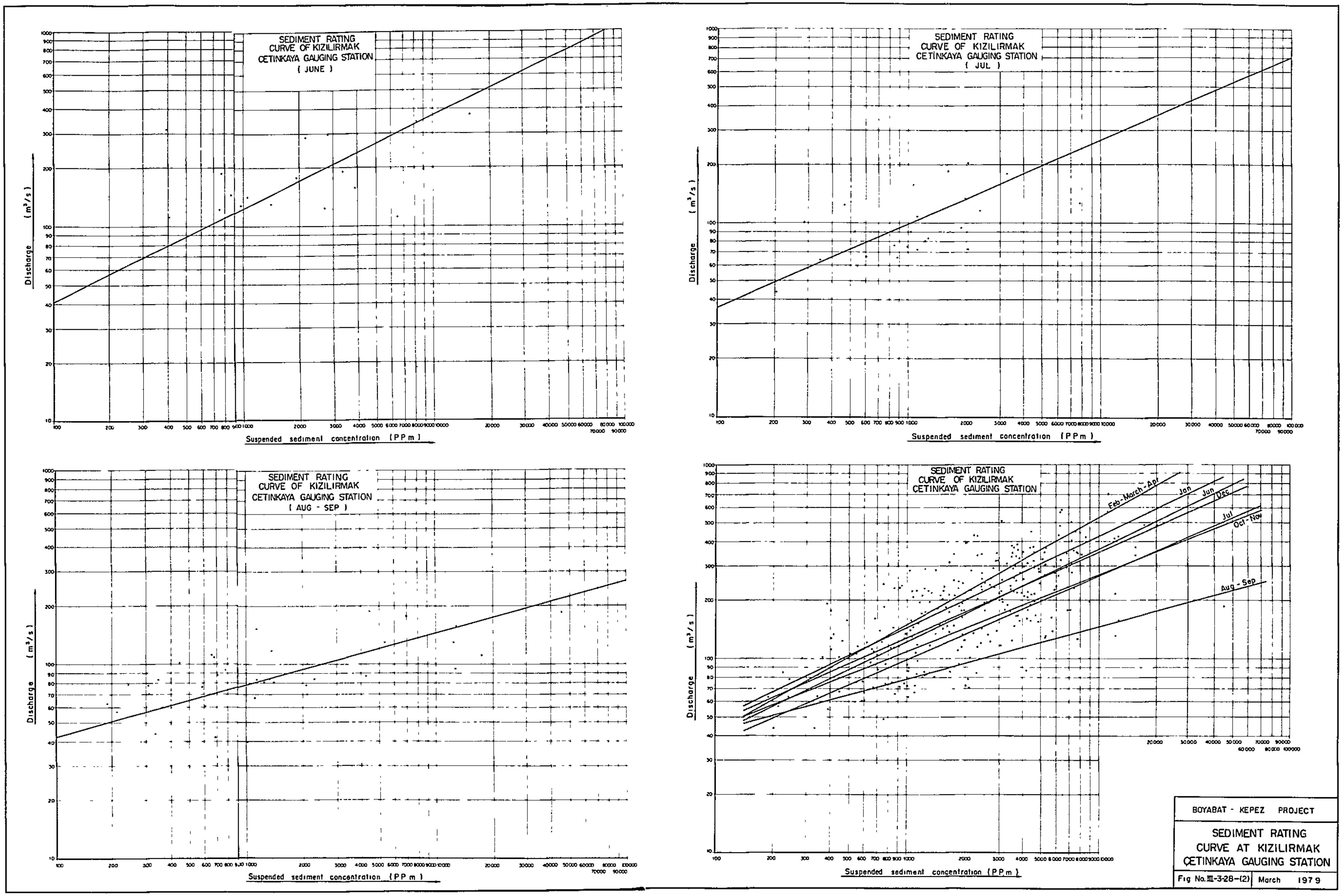
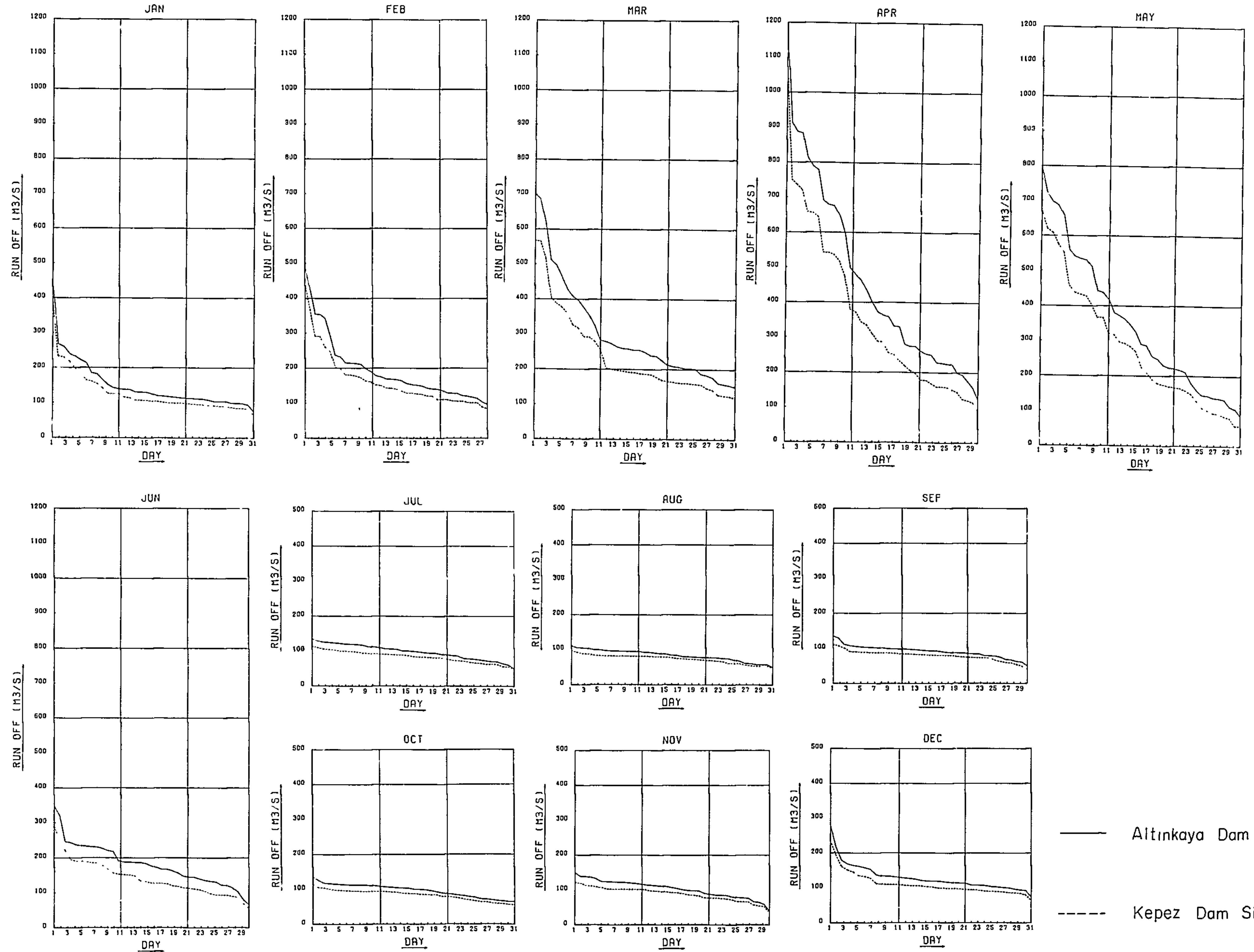

SEDIMENT RATING CURVE OF KIZILIRMAK ÇETİNKAYA GAUGING STATION (JUNE)
SEDIMENT RATING CURVE OF KIZILIRMAK ÇETİNKAYA GAUGING STATION (JUL)
SEDIMENT RATING CURVE OF KIZILIRMAK ÇETİNKAYA GAUGING STATION (AUG - SEP)
SEDIMENT RATING CURVE OF KIZILIRMAK ÇETİNKAYA GAUGING STATION
Discharge (m³/s)
Suspended sediment concentration (P P m)
Feb-March-Apr
Jan
Jun
Dec
Jul
Oct-Nov
Aug-Sep
BOYABAT - KEPEZ PROJECT
SEDIMENT RATING CURVE AT KIZILIRMAK ÇETİNKAYA GAUGING STATION
Fig No. III-3-28-(2)
March 1979

Fig. III-3-29 Run-off Duration Curves



——— Altınkaya Dam Site.

----- Kepez Dam Site.

CHAPTER 4

GEOLOGY AND CONSTRUCTION MATERIALS

CHAPTER 4 GEOLOGY AND CONSTRUCTION MATERIALS

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CHAPTER 4 GEOLOGY AND CONSTRUCTION MATERIALS

4.1 PREVIOUS STUDIES

The Kepez Dam site was selected 6 km downstream from the Boyabat site as a result of explorations in 1967-1968. During the period from 1970 to 1976, there were 28 boreholes (total length 7,743.02 m), 80 permeability tests in alluvium, 2,423 water pressure tests in rock, and 7 exploratory adits (total length 830.20 m) provided. The results of these investigations are summarized in the 3 reports indicated in Appendix. As for the details of boring and exploratory adits, the tables below should be referred to.

Table III-4-1 Exploratory Adits at Kepez Dam Site

	Elevation	Length	Direction
RA-1	187.21 m	10.4 m	
LA-2	198.35	52.2	N14°W
LA-3	218.39	296.5	N55°W (0-33 m), N40°W (33-296.5 m)
LA-3a	218.39	61.3	N35°E
RA-4	237.58	142.0	N52°W (0-80 m), N39°E (80-142 m)
RA-5	199.01	65.0	N84°W
LA-6	252.56	122.0	N62°E (0-70 m), N24°W (70-122 m)
RA-7	305.15	80.8	N77°E
Total	7 adits	830.2 m	

Table III-4-2 List of Drill Holes in Kepez Dam Site

No.	Coordinate Y	Coordinate X	Elevation	Depth	Direction Inclination
LSI-1	416153.63	4578616.30	227.89	207.45	EW, 55°
LS -2	416320.05	4578724.83	199.76	369.81	Vertical
RH -3	416301.50	4578634.00	191.60	125.65	"
LS -4	416103.97	4578596.09	212.38	189.02	"
RS -5	416379.95	4578599.54	209.95	321.54	"
LSI-6	416278.25	4578710.50	199.57	66.10	N68°W, 45°
LSI-A6	416278.25	4578710.50	199.57	252.00	N56°W, 55°
LS -7	416059.02	4578805.26	330.60	70.40	Vertical
RSI-8	416428.46	4578686.73	206.17	455.10	N60°W, 45°
RS -9	416428.46	4578686.73	206.17	125.00	Vertical
LSI-10	416318.30	4578725.56	199.60	100.00	N60°W, 45°
RH -11	416353.30	4578694.30	190.26	342.00	Vertical
RH -12	416370.50	4578685.00	189.26	100.00	"
RH -13	416390.08	4578674.85	188.26	100.00	"
LSI-14	416268.65	4578708.22	199.87	580.50	EW, 45°
RH -15	416380.25	4578679.75	189.15	101.00	Vertical
RH -16	416343.06	4578697.56	190.60	101.00	"
LSI-17	416319.41	4578725.76	199.84	343.50	N73°W, 65°
RSI-18	416503.84	4578714.03	201.12	398.50	N80°E, 55°
RSI-19	416396.11	4578634.45	196.02	289.00	N3°W, 45°
RSI-20	416379.55	4578585.26	210.01	266.20	N13°E, 60°
RSI-21	416393.68	4578593.29	210.20	311.20	N45°W, 70°
LSI-22	416273.89	4578755.55	218.89	219.50	N65°W, 30°
RS -23	416566.28	4578667.16	239.02	482.50	Vertical
LS -24	415712.50	4579269.13	586.87	726.50	"
LS -25	416224.74	4578824.67	211.71	357.00	"
LSI-26	416149.75	4578926.73	224.01	334.00	N40°W, 85°
LSI-27A	416149.75	4578926.73	224.01	68.55	EW, 70°
Total	28 holes			7743.02 m	

4.2 GENERAL GEOLOGY

4.2.1 Geomorphology

The Kızılırmak, with the length of its mainstream 1,355 km, is the largest river of Turkey entirely within the confines of the country's borders. The project site is at the downstream part of the river approximately 100 km upstream from its mouth. The river rises at a point approximately 240 km southeast of Samsun and flows west to the vicinity of Sivas from where it meanders sweepingly and flows southwest - west - northwest and north. The reservoir of Hirfanlı Dam is located part way down. From there, it flows roughly in a northeasterly direction to flow through the Bafra Plain which is a vast delta and then empties into the Black Sea. In the stretch from Osmancık to Durağan, the river is forced to meander at sharp angles due to the nature of the geological structure. The average river gradient from Kargı near the design backwater end to the mouth of the river is 1:580.

Mountain ranges generally run east-west being from the north the Black Sea Coastal Mountains, the North Anatolian Mountains (Ilgaz Mountains, Ak Mountains) and the Central Anatolian Mountains.

The Black Sea Coastal Mountains are north of the Gokırmak River and run parallel to the Black Sea coast comprising a mountain range having peaks of 1,000 to 2,000 m.

The North Anatolian Mountains are separated into the Ilgaz Mountains on the west and the Ak Mountains on the east with the Kızılırmak River as the dividing line. The Ilgaz Mountains are a mountain range in the SWW-NEE direction bounded by the Gökırmak River on the north and the Kızılırmak River and Devrez Creek on the south. The direction of this mountains is controlled by geological structure and corresponds with the direction of North Anatolian Fault Zone. Both the dam site and the reservoir of the Project subject to this morphologic province.

There is a mountain range in the SW-NE direction on the south side of the North Anatolian Mountains which runs parallel to the Kızılırmak and is the watershed between Devrez Creek and the Kızılırmak. There is another mountain range in the SW-NE direction on the east of this one also.

To the south of this mountain range tower the Central Anatolian Mountains which extend in an E-W direction.

4.2.2 Geology

(1) Stratigraphy

In the surrounding area of the Kızılırmak from Kalecik to the mouth of the river, a metamorphic series of the Paleozoic Era, limestone, an ophiolitic series, flysch and a volcanic series of the Mesozoic Era, and flysch of the Cenozoic Tertiary Period are mainly distributed, and these basal rocks are covered with Quaternary deposits.

Metamorphic Series

This series is distributed mainly in the North Anatolian Mountains.

Green schist, epidote-chlorite schist, graphite schist, quartzite schist, sericite schist, phyllite, marble and quartzite are intermixed and a distinct identification has not been made.

There is a gradual transition to Mesozoic flysch, and the boundary is indistinct. There is also interfingering with the ophiolitic series.

Tertiary sandy limestone directly covers the metamorphic series at some areas. Examples of this are seen in the surrounding area of the Kepez dam site and at a high elevation on the left bank of the Boyabat dam axis.

Mesozoic Limestone

This limestone exists scattered at various places and is covered by the ophiolitic series. The age is considered to be Jurassic-Cretaceous.

Mesozoic Ophiolitic Series

This series is distributed in the North Anatolian Mountains, south of Devrez Creek and in the surroundings of Çoram. The lithofacies consist of limestone, spilite, diabase, basalt, pillow lava, marl, radiolarite, and serpentine, and the series is considered to be the product of a typical geosyncline orogenic movement characterized as a "mixed tectonic series" in which sedimentary rocks and igneous rocks are intermixed.

The age is considered to be Upper Cretaceous.

Mesozoic Flysch

This flysch is considered as being Upper Cretaceous and consists of sandstone, argillaceous rock, marl, and sandy limestone. It is mainly distributed in the Black Sea Coastal Mountains.

Mesozoic Volcanic Series

This series is found at scattered locations in the North Anatolian Mountains. There are interfingers of marl, sandy limestone, tuff and andesite lava. The age is considered to be Upper Cretaceous.

Tertiary Flysch

This flysch, besides being widely distributed south of the North Anatolian Mountains, is also found along the Gökırmak River and in the vicinity of Bafra.

(2) Structural Geology

This region has a history of two orogenies, the Variscan Orogeny, beginning with the Variscan Geosyncline and the Alps Orogeny beginning with the Alps Geosyncline, and sedimentation, diagenesis, regional metamorphism (the product of which is the metamorphic series), and intrusion of igneous rocks (ophiolitic series) are seen, and the region thus is complex both in terms of lithofacies and geological structure.

In general, the major geological structures have an orientation of roughly E-W, and fold axes and faults are mostly in this direction.

Folds

In general, fold axis in the E-W direction are predominant, but in the Ilgaz Mountains and southwest of Devrez Creek there are axis that are in the NE-SW direction with some in the N-S direction.

Symmetrical folds, asymmetrical folds and overturned folds are formed, but recumbent folds do not exist, and the folding structure is not complex.

Faults

Faults are formed in large number in areas where the metamorphic series and ophiolitic series are distributed. Faults having strikes in the E-W direction with right handed slip are generally predominant. Especially prominent faults run parallel in the North Anatolian Mountains, and one of them runs from Kamıl in the reservoir area to Kargı.

At Inebolu on the Black Sea coast and in the vicinity of Kalecik at the upstream part of the Kızılırmak, there are faults formed with strikes in the NS direction.

There is overthrusting west of Kalecik where Tertiary flysch is covered by an Upper Cretaceous ophiolitic series.

4.2.3 Seismicity

Turkey is situated on the Alpine Earthquake Belt and a fair amount of earthquakes has occurred.

The country can be divided into three predominant earthquake zones, which are

North Anatolian Zone along the Black Sea
Southeastern Zone the area surrounding Antakya
Western Zone the area surrounded by the Aegean Sea and the Marmara Sea

The study area is situated at the immediate north of the North Anatolian Zone which corresponds to the North Anatolian Fault Zone.

According to data in "Earthquake Catalogue of Turkey and Surroundings" prepared by I.T.U. and "Map of Earthquake Regions of Turkey" prepared by the Ministry of Reconstruction and Settlement, the earthquakes which have occurred within a radius of 50 km from the projected dam site are as indicated on the Seismic Map (DWG. III-4-1).

4.3 GEOLOGY AT DAM SITE

4.3.1 Topography

The Kızılırmak River in the vicinity of the projected dam axis has a channel on a roughly straight line in the SSW-NNE direction for a stretch of approximately 1 km, while upstream and downstream of this section the direction of flow is E-W. The projected dam axis is located roughly at the middle of the section in the SSW-NNE direction which forms a limestone-distributed gorge of width of 80 to 100 m, whereas schist is predominantly distributed in the surroundings of the E-W direction channels upstream and downstream and the valleys are opened wide.

The river-bed elevation at the projected dam axis is 190 m with the abutments at both banks comprising extremely rugged terrain peculiar to limestone and the slope gradients are 70 to 80°. The mountaintop at the left-bank side is at an elevation of 510 m while that at the right-bank side is at 577 m. At the backs of both there is distribution of schist and relatively open gullies are formed. The gorge width is 110 m at El. 200 m, 185 m at El. 250 m, 220 m at El. 300 m, 250 m at El. 330 m (N.W.L.), 306 m at El. 400 m, and from the river-bed up to El. 200 m the slope gradient is slightly gentle. The ratio between height and valley width at El. 330 m (N.W.L.) is approximately 1:1.4.

Gullies joining the mainstream are mostly of small scale. The gully at the left bank upstream of the dam axis is estimated to run along a fault with schist distributed above El. 300 m, while the branch gully extending in a direction NNE-SSW from El. 300 m has been formed along a fault at the boundary between limestone and schist. There is a gully in the SEE-NWW direction upstream of the dam axis at the right bank also, and this is again an area with distribution of schist. Further, back of the right-bank dam abutment there is a wide gully formed, and this, too, is a schist area.

Based on the above, it may be seen that development of gullies is of low degree in areas where limestone is distributed, whereas gullies are well-developed where there are distributions of schist. The areas where limestone is distributed present steeply-sloped topographical features while the areas of schist show comparatively gentle features, and thus the correlations of lithofacies and geological structure with topography are well-displayed.

4.3.2 Stratigraphy

The basal rocks in the vicinity of the Kepez dam site consist of limestone and schist with the greater part made up of limestone. According to "Geological Map of Turkey 'SINOP,' 1/500,000", the limestone and schist are considered to comprise an undifferentiated metamorphic series.

These basal rocks are covered by small-scale slope wash, while at the river bed, a sand-gravel layer is deposited to a thickness of approximately 45 m.

Slope Wash

Slope wash is distributed on the left-bank side at the gully where Drill Hole LS-4 is located and at the portion of change in topography (comprising a gully topography) on the right-bank side upstream of the dam axis.

The slope wash at the left-bank is clayey sand intermixed with breccia of schist (weathered and friable) and limestone (relatively fresh and hard), while that on the right-bank side is mostly breccia of limestone (fresh, hard) and there is practically no content of fine particles.

The thickness of these slope wash deposits are around 5 m.

Alluvium

Judging by the result of boring investigations, the thickness of the layer is around 45 m.

The deposit is a sand layer containing clay and has an intermixture of gravel of pebble to cobble size. The quantity of gravel is in the range of 20 to 40% on the whole with parts where the quantity reaches up to around 70%.

Schist

Schist is distributed at the back of the dam abutment, from the ground surface to a depth of 300 to 500 m underground. There are epidote-chlorite schist and graphite schist, and exposures of these repeatedly alternate in a complex pattern. And although not observable at the ground surface, as a result of boring, it has been found there is calcareous schist underground at the left-bank side, while underground on the right-bank side upstream of the dam axis there is distribution of metaconglomerate.

Schistosity is extremely developed on the whole with weathering at the surface layer and the rock is easily exfoliated and friable, while also at parts the schist has become clayey. The schist is weak against mechanical shocks such as from drilling, and cores are mostly in poorer condition than the original, and from this fact also it is estimated that the schist distributed at this dam site is slightly crushed as a whole. As an exception, the metaconglomerate is comparatively massive and hard.

Limestone

The color of limestone is white to gray to blackish-gray and rock close to a white color is siliceous while that close to blackish-gray is pelitic. The former is mostly distributed from the vicinity of drill holes (RH-11 - RH-16) at the river bed to the downstream side, while the latter is mostly distributed at the upstream side. The rock is generally microcrystalline with advanced recrystallization, and calcite has been formed.

The limestone is fresh and hard on the whole with spacings between cracks 50 to 200 cm, and the condition is good as the foundation for a structure. Weathering can be seen at the vicinity where the F-1 fault and F-3 fault intersect, the vicinity where the F-2 fault and F-3' fault intersect, the vicinity of the boundary with schist between 225 and 275 m in Exploratory Adit LA-3, between 65 m and 88 m of Exploratory Adit LS-6, and along specific faults and seams. However, weathering has not progressed to the extent that the rock is softened, the degree being that of crack surfaces being discolored.

As described above, the limestone is good strength-wise, but there are cavities and small caves existing here and there due to dissolution by water. The cavities and small caves are formed along faults and seams, but are discontinuous and the individual caves are opened in the form of lenses. Prominent caves exist along the F-1 fault, and in the vicinity under Exploratory Adit RA-7, there is one which is of width of approximately 150 cm, height of approximately 20 cm, and depth of more than 100 cm. Along the F-5 fault there are caves of openings of 20 to 30 cm at places. Inside exploratory adits, there are caves formed at two places, the vicinity of 170 m in LA-3 (width 50 cm, height 10 cm, depth unknown), and at the part of RA-4 along the F-1 fault (opening 5 - 10 cm). According to the results of investigations up to this time, the caves along the F-1 fault are the largest, with others being small.

Judging by the results of investigations by geological explorations and of observation of exploratory adits, it is surmised that the limestone in this area has little formation of large caves compared with others.

Parts in DWGs. III-4-3 to III-4-6 where traces of caves are seen are identified by asterisks.

4.3.3 Structural Geology

On looking at the geologic plan, the greater part is made up of limestone, but considered from a widened viewpoint, the limestone is intercalated by schist in the forms of lenses and blocks. Considered from the projected dam site, the distance from the middle of the river to where schist is distributed at both sides is around 300 m, and is 300 to 500 m deep underground. The distance to the upstream side is 400 m and to the downstream side 600 m.

The boundary between limestone and schist is a fault (F-5) with a brittle section of more than 20 m including weathered portions. The boundary on the right-bank side is estimated the existence of fault.

Prominent faults developed at the dam site are F-1 to F-7, but they are not such as to be problems with regard to structural stability.

A list of the faults is indicated in Table III-4-3.

Table III- 4-3 List of Faults at Kepez Dam Site

	Strike and Dip	Sheared Zone	Note
F-1	N15-52°W, 30-48°SW	cl + sh = 10-100 cm	Dipped in upstream direction at strike roughly orthogonal to river
F-2	N45°W, 55°SW	cl + sh = 20-30 cm	Dipped in upstream direction at strike roughly orthogonal to river
F-3	N5-12°W, 40-42°NE	cl + sh = 10 cm	Dipped in right-bank direction intersecting river diagonally at gentle angle
F-4	NS, 40°W	cl + sh = 30 cm	Roughly parallel to river, dipped in left-bank direction
F-5	N20°E, 78°NW	cl + sh = 100 cm	Roughly parallel to river, boundary of limestone and schist
F-6	N27°E, 40°SE	cl + sh = 20 cm	Parallel to river, dipped in right-bank direction
F-7	N8°W, 52°NE		

Note : cl = clay, sh = sheared zone

It is further estimated that faults exist at the boundary between limestone and schist at the right-bank side previously mentioned and the gully where Drill Hole LS-4 is located.

There are few joints in schist, but joints are well-developed in limestone. Thoroughgoing studies have been made by EIE regarding joints. The greater part of joints at the ground surface and in exploratory adits have been measured, projected on "Schmidt Equal Area Nets," and statistically processed (DWG. III-4-7). The results are as indicated below.

	Number Measured	Predominant Joint	Next Predominant Joint
Right-bank adits	2829	N30°W, 46°SW	
Right-bank ground surface	1446	N27°W, 46°SW	
Left-bank adits	4726	N21°E, 60°NW	N48°E, 41°SW
Left-bank ground surface	1365	N50°W, 48°SW	N22°E, 60°NW

Note) Right-bank adits : RA-4, RA-5, RA-7

Left-bank adits : LA-2, LA-3, LA-6

Regarding treatment with grout which can be considered based on the above results, especially consolidation grout, the following can be said in general.

The directions effective for filling the greatest number of cracks is one close to being N60°E, 50°NE at the right-bank, and boring in the horizontal direction in consideration of topographical conditions at the left-bank.

4.3.4 Rock Soundness

The locations where the dam proper and appurtenant structures are to be situated all lie in the limestone distribution area.

Detailed values regarding the limestone are unknown since foundation rock tests have not been carried out, but based on the results of surface reconnaissance and observations of exploratory adits and drilling cores, it is considered to possess adequate strength for construction of a concrete gravity dam.

In the investigations of the present study, rock soundness classifications were made in exploratory adits on a trial basis and the results was that the greater part belongs to ② or ②-① (see DWG. III-4-8 for rock soundness classifications). With these classifications ② and ②-① as tentative criteria, the following values can be looked forward to.

- o Unconfined compressive strength of test piece: not less than 800 kg/cm^2
- o Static modulus of elasticity of foundation rock: not less than 5 x 10^4 kg/cm^2
- o Modulus of deformation of foundation rock : not less than 3 x 10^4 kg/cm^2
- o Shear strength of foundation rock : not less than 30 kg/cm^2

4.3.5 Watertightness of Foundation Rock and Cavities in Limestone

The results of water pressure tests are as indicated in DWG. III-4-5 and DWG. III-4-6. According to these, many of the sections from the present ground surface down to depths of around 100 m generally exceed 25 lugeons and are permeable. The limestone along the F-5 fault is also permeable. Other than the above and with some local exceptions the watertightness is good as a whole.

Various reasons may be considered for the high permeability and cavities formed in the limestone can be cited as one of them. On scrutiny of drilling cores there is evidence seen at places of limestone having been dissolved by water, and in many cases these parts and sections of high permeability coincide.

Studying the parts permeable due to cavities in limestone by a section drawing, the following can be said.

(1) Zone of Ground Surface Line to Around 100 m

There are many parts where large amounts of water are swallowed at zero pressure to 2 to 3 kg/cm^2, and considered together with evidence of dissolution in drilling cores it is estimated that cavities exist in large number.

(2) Portion along F-5 Fault at Left-Bank Side

On inspecting Exploratory Adit LA-3 the limestone in the section from the F-5 fault to around 40 m beyond is weathered along crack surfaces and there is interjection of clay. This suggests that water permeates along the F-5 fault from the ground surface and the limestone is in a state where cavities are liable to be formed. On inspection also of the drilling core of Drill Hole LSI-26 bored along the F-5 fault from within Exploratory Adit LA-3 there are many traces of dissolution, and at depths of 50 to 70 m (El. 170 - 150 m) large quantities of water were swallowed at zero pressure in water pressure tests, while at a part of the section 225 to 220 m (El. 0 - -25 m) in depth the pressure would not rise above 6 kg/cm^2 and a level of 25 lugeons was exceeded.

Based on the above, it may be presumed that cavities are developed.

(3) Scattered Local Occurrence Deep Underground

High lugeon values were indicated as results of water pressure tests in the vicinities of El. 0 m in LSI-6A, El -50 m and El. -100 m in LSI-14, El. -100 m in LS-2, El. -80 m in RH-11, and El. -165 m in RS-23, and drilling cores show evidence of dissolution.

(4) Boundary between Limestone and Schist Deep Underground

Although at some distance from the projected dam site, there are extremely permeable sections near the boundary between limestone and schist in LS-1, RSI-20, and RSI-21. Although fewer in drill holes closer to the dam axis, permeable parts must be paid attention.

Of the above, it is estimated the amounts of leakage will be great at (1) and (2), whereas leakage will be localized in the cases of (3) and (4) and it is estimated the amounts will be smaller compared with (1) and (2).

In general, the problem of leakage with regard to limestone cannot be discussed in terms of creep length, but must be considered from the standpoint of pipe flow. Consequently, in water cut-off treatment, the continuity of caves must be severed at some part without fail.

Permeability tests have been carried on alluvium. The results were that coefficient of permeability is in the range of 1×10^{-4} to 1×10^{-3} cm/sec as a general trend. However, there are parts which are locally high in permeability.

On looking at the results of measurements on the ground water table, it is at El. 190 m which is practically the same as the surface of the river, and even though at a distance from the river, the water table does not rise above El. 200 m. The fact that there are few places inside exploratory adits where water springs or drips substantiates this fact.

4.4 GEOLOGY IN RESERVOIR AREA

4.4.1 Topography

The Kızılırmak River flows roughly west to east for the 20 km from the vicinity of Kargı at the end of the backwater of the reservoir to the vicinity of Kamıl, and from Kamıl it flows down from the southwest to the northeast.

The valley which is broad at 500 to 1,000 m from Kargı to Asıkbuku (immediate downstream of Kamıl), downstream of which for approximately 4 km it is 200 to 300 m, and then down to the vicinity of the projected Boyabat dam axis 500 to 700 m.

Although there are numerous tributaries and gullies joining the Kızılırmak, there are few perennial creeks with water flowing throughout the year, and the majority consists of ephemeral creeks with water only in the wet season and when it rains.

Gullies in the entire reservoir area are developed in a dendritic pattern reflecting well the geological state of wide distribution of schist. There are extremely few gullies where limestone is distributed with only small-scale ones formed along some faults and sheared zones. Alluvial fans are developed at mouths of gullies.

4.4.2 Geology

In the reservoir area there are Kepez Schist classified under the metamorphic series and Delikbek limestone both of which are Paleozoic and thrusting through them are intrusions of diabase and serpentine belonging to the Mesozoic Cretaceous ophiolitic series, and further, these old basement rocks are covered in unconformity with Tertiary sedimentary rocks.

Table III-4-4 Stratigraphic Sequence of Reservoir Area

Era Period Epoch	Series	Symbol	Lithology
Cenozoic			
Quaternary	Alluvium	Al	
	Fan deposite	Fd	
	Slope wash	Sl	
	Travertine	ktv	
	Terrace dt	kt	
Tertiary			
Pliocene	Karaboya fm	Tkb	sandstone, conglomerate
Eocene-Oligocene	Akbelen fm	Ta	flysch
Eocene	Kuzköy fm	Tkz	volcanic flysch
	Sarıyar fm	Ts	conglomerate
	Boztepe fm	Tb	flysch
Paleocene-Eocene	Karımca fm	Tk	sandstone, limestone
Mesozoic			
Cretaceous	Ophiolitic	Mo	serpentine, diabase
Paleozoic	Metamorphic	Pk	schist (Kepez Sch)
		Pb	limestone (Delikbek lm)

Kepez Schist, Pk

Delikbek Limestone, Pd

These rocks are distributed most widely throughout the reservoir area.

The schist may be classified as chlorite schist, epidote-chlorite schist, calcareous schist, graphite schist (phyllite) which alternate frequently in a complex manner at places. Schistosity of E-W orientation is predominant while bedding is indistinct. Micro-folding is also developed at various places.

Delikbek limestone is distributed in the form of blocks or lenses with intercalations of Kepez schist. The limestone is fresh and hard and has high weathering resistance. Part of it has turned into calcareous schist near the boundary with schist. Although of small scale, caves have been formed as a result of dissolution by water.

Karımca Formation, Tk

This formation is distributed at various places in scattered form overlying the Paleozoic schist and limestone in unconformity. The lower part is sandstone which gradually changes over to limestone as higher elevation is approached.

The sandstone is fine- to medium-grained and generally speaking is a relatively hard and dense rock, but is loose in localized parts.

The limestone generally presents a yellowish-gray color, is massive and hard, but weathered material is interjected along crack surfaces and is weak as original ground. Compared with Delikbek limestone, there are many caves formed due to dissolution.

Boztepe Formation, Tb

This formation is distributed only southwest of Köprübası Village. This formation is flysch of thickness of approximately 100 m consisting of alternations of marl, claystone, siltstone and mudstone.

Sarıyar Formation, Ts

This conglomerate is distributed between Maksutlu and Kamıl at the right-bank of the Kızılırmak. This is conglomerate which has a mixture of ill-sorted, subrounded to rounded limestone gravel. The gravel particles average 15 to 25 cm in size with the maximum 80 cm. As a whole, this conglomerate is loose and easily separated.

The thickness of the layer is approximately 150 m.

Kuzköy Formation, Tkz

This formation is distributed overlying the Sarıyar conglomerate.

The formation consists of andesitic lava, basaltic lava, tuff, agglomerate and flysch.

Many landslides have occurred in the area where this formation is distributed, but fortunately, these landslides have all occurred at elevations higher than the reservoir water level.

Akbelen Formation, Ta

This formation is distributed at parts of high elevation northeast of Fakılı Village. It consists of sandstone, conglomerate and siltstone. The types of gravel in the conglomerate are schist, limestone, serpentine, quartz and radiolarite, and the particle sizes range from 0.5 to 2 cm.

Karaboya Formation, Tkb

This formation is distributed on the upstream side from the vicinity of Kamıl. The formation consists of alternations of sandstone and conglomerate. The types of gravel in the conglomerate are schist and diabase, with infrequent limestone and quartz, and the components are well-sorted.

Terrace Deposit, Kt

These deposits are deposited at the vicinities of Saraycık and Aşıkbükü, and the surroundings of Yayladuzu. The bottom surfaces are at elevations of approximately 300 m with layer thicknesses 10 to 30 m.

Rounded to subrounded gravels of schist, serpentine, limestone and radiolarite are contained and these are ill-sorted.

Travertine, Ktv

This travertine is distributed underlying the vicinity of the boundary between the limestone and schist north of Kışla Village. Plant matter is intermixed.

Slope Wash, Sl

Although of small scale, numerous slope washes are distributed at the bottoms of steep slopes in the entire reservoir area.

Fan Deposite, Fd

Alluvial fans are developed at mouths of gullies at various places. The greater part consists of ephemeral creeks, and the fans are the results of sand and gravel eroded and transported during rainfall being deposited at the vicinities of confluences with the mainstream where grades become gentle, and the ratios of coarse particles are higher the closer to the gullies with those of fine particles higher the farther away.

The consistuent gravels depend on the lithofacies of the surroundings.

Alluvium, Al

These deposits are deposited at the Kızılırmak and large tributaries. The thicknesses are approximately 45 m at the Kepez dam site and approximately 40 m at the Boyabat dam site, while upstream of Aşıkbükü it is estimated the thicknesses are even greater.

The gravels comprising the deposits are of schist, limestone, diabase and radiolarite. These deposits are ill-sorted on the whole.

Diabase and Serpentine

These rocks are distributed between Hacıçay and Asağızeytin. These intrude Paleozoic schist with a strike oriented roughly E-W. These rocks are massive as a whole with schistosity developed at parts.

The Kızılırmak has a channel oriented east-west from Kargı to Kamıl and a river width of 500 to 1,000 m, and this is because one of the North Anatolian faults exists along the river. The faults existing north of Kışla have vertical displacements as much as 100 m. There are many other faults, but there is no fault other than the above which has a large-scale sheared zone.

4.4.3 Watertightness

Limestone is also distributed in this reservoir area and the form of this distribution is that of Kepez schist intercalated in blocks and lenses of limestone. There is little limestone which would be submerged below N.W.L. 330 m. The places where submergence will occur described in order from upstream to downstream are the following. There are several places downstream of the vicinity of Kargı, but these are rock bodies of diameters between 100 to 200 m and there is no continuity. There are four locations in the vicinity of Karapurcek where these are rock bodies in the form of lenses extending NWW-SEE. There are distributions of limestone at two locations in the vicinity of Makusutlu, one at the mouth of Tekkesin Creek, immediately downstream of Aşıkbükü, several places at Aşağızeytin, the vicinity of Aydin, and frequently downstream of the Boyabat dam site. Among the above, there is no limestone body which reaches up to the watershed with another river except at the surrounding area of the Kepez dam site, and all have orientations continuing in the upstream-downstream direction of the river.

4.4.4 Slope Stability

The dissertation here is based on a 1/25,000 reservoir area geological map prepared by EIE. With regard to the landslides and slope collapses distributed in the west reservoir area, and to landslides and slope collapses which may occur during water impoundment, the following principles are supported:

(1) Items Requiring Attention:

Landslides and slope collapses occurring at places where damage will be inflicted on densely populated areas, principal roads, and structures related to the dam. Also, large-scale landslides which would suddenly raise the reservoir water level.

(2) Items to be Left Untouched:

Landslides, slope collapses, or small-scale collapses at other than the above.

The many landslides in the Kuzköy Formation distributed to 5 km southwest of Kamıl are of relatively large-scale but are 1 to 2 km distant from the reservoir surface and do not directly affect the reservoir. Since there are no dwellings either, they will be no problem.

The landslide which has occurred at the left bank southwest of Hacıçay is approximately 3 km distant from the reservoir surface and there will be no problem.

There are small-scale collapses of slopes downstream of Kamıl, but they are not of the category of 1) above, and also will be no problem.

4.5 CONSTRUCTION MATERIALS

Regarding aggregate for concrete it was judged economically advantageous as a result of field reconnaissance to collect the river deposits widely distributed upstream of the project site and to manufacture aggregate by crushing and classifying at an aggregate plant. Accordingly, the borrow areas A, B and C as shown in DWG. III-6-1 are selected in consideration of the available quantity of river deposits, quality, gradation, hauling distance to the aggregate plant and collecting conditions.

Borrow Area A is located at the confluence with Mosum Gully joining the Kızılırmak River at the left-bank 2.0 km upstream from the dam site and is a deposit brought down from the upstream parts of Mosum Gully consisting chiefly of limestone and schist with limestone making up the greater part. The quantity of the deposit is estimated to be 2.0 million m^3.

Borrow Area B is located 2.0 to 4.0 km upstream of the dam site at the left-bank side of the mainstream and is covered by 2 to 3 m of topsoil. The material consists of limestone and green schist as at Borrow Area C described below. The gradation also is the same as at Borrow Area C. Regarding available quantity it is thought 1.0 million m^3 will be the limit considering that it will not be economical to collect material from deep under water.

Borrow Area C is mainly a deposit at the left-bank side of the mainstream 4.0 to 7.0 km upstream of the dam site, and there is practically no topsoil. The material and gradation are the same as at Borrow Area B although there is somewhat higher content of coarse particles. The results of preliminary tests on samples collected from this borrow area are shown in Table III-4-5 and gradation in Fig. III-4-1.

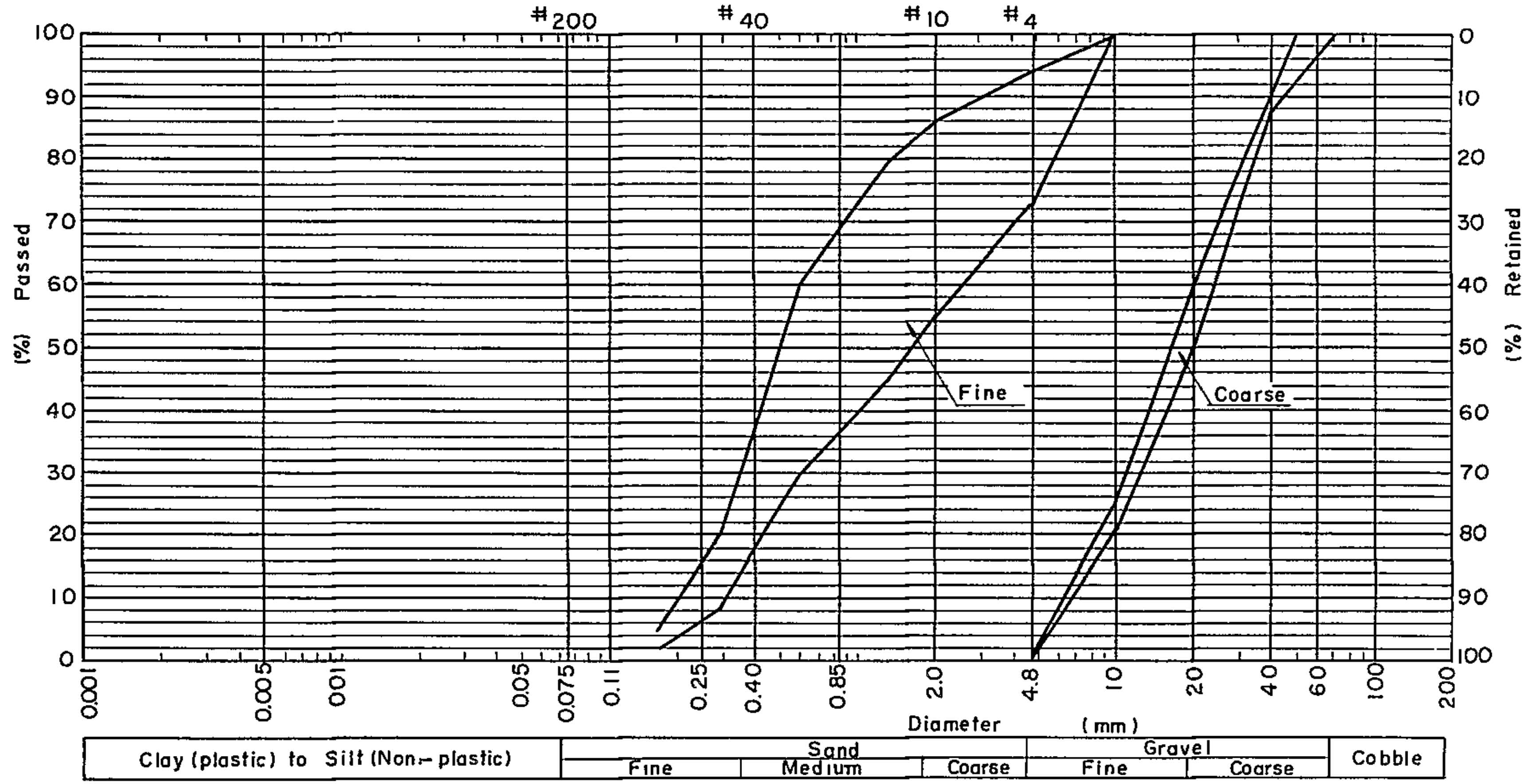
Based on the above table and figure it is judged that the physical properties and gradations of the river deposits are satisfactory and the material can be used as aggregate for concrete.

With respect to Borrow Area B, it has the merit of shorter hauling distance than Borrow Area C, but as previously mentioned, the topsoil is thick, the available quantity is limited, and the area will be submerged after completion of the cofferdam so that it is judged advisable to consider it merely as an auxiliary for Borrow Areas A and C.

Table III-4-5 Test Results of Concrete Aggregate

Borrow Area	Group Symbol	Unit Weight (t/m^3)		Specific Gravity		Passing No. 200 Sieve (%)		Absorption (%)		Coating (%)		Los Angeles Test (%)	
		Sand	Gravel	Sand	Gravel	Sand	Gravel	Sand	Gravel	Sand	Gravel	100 cycle	500 cycle
C	SP - GP	1.68 - 1.80	1.82 - 1.87	2.70 - 2.71	2.75 - 2.78	2.5 - 3.8	0.2 - 0.4	0.4 - 0.6	0.3 - 0.5	0.8 - 2.8	0.3 - 0.6	2.8 - 3.4	18.6 - 19.5

Fig. III – 4 – 1 Distribution Curve of Aggregate



4.6 CONCLUSIONS AND RECOMMENDATIONS

4.6.1 Conclusions

(1) Kepez Dam Site

(a) Rock Soundness : The foundation rock is limestone and has adequate strength as a dam foundation. Weathering of the surface layer and creep will not be problem.

(b) Faults : No fault exists which would be a problem for stability of the dam. The brittle portion including weathered parts of the F-5 fault at the left-bank side is of large-scale, but is outside the stress field of the dam. Rather, the faults at the dam site of this Project should be given attention as developed portions of cavities.

(c) Watertightness : The limestone has cavities formed along faults and seams, and there are portions which are permeable. These are, (i) the zone of about 100 m from the ground surface including the faults F-1 to F-7, (ii) the zone along the F-5 fault to deep underground, (iii) localized zones deep underground, and (iv) although no more than a guess, the boundary between limestone and schist deep underground.

Grouting should be done for the zones of (i) and (ii) which are expected to show prominent leakage. Judged from the results of investigations up to this point, permeable parts of the zones of (iii) and (iv) are localized, and much leakage cannot be considered. It is desirable for judgments to be made regarding treatment of the zones of (iii) and (iv) to await the results of further investigations.

(2) Reservoir Area

There is no problem in particular with regard to either watertightness or slope stability.

(3) Construction Materials

The plan would call for aggregate to be collected from the vicinity of Mosum Gully entering the river at the left-bank 1.5 km upstream from the dam site and the river deposit at the mainstream 4.0 to 7.0 km upstream.

4.6.2 Recommendations

(1) Kepez Dam Site

As a result of the feasibility study, the dam axis has been selected approximately 200 m downstream from the previously investigated dam axis, and hereafter, it is necessary for the additional investigations described below to be carried out to ascertain the geological structure and permeability of the area including the two dam axes (DWG. III-4-4).

(a) Geological Exploration : Geological explorations should be carried out for the surroundings of the dam site to ascertain in detail the geological structure, the continuity of the limestone rock body, and the state of distribution of caves.

(b) Exploratory Adit : The boundary between limestone and schist should be confirmed and karstification of limestone investigated. Adits are also necessary for carrying out drill hole when limitations are placed topographically on drill hole from the surface.

Table III-4-6 List of Exploratory Adits Proposed

	Elevation (m)	Length (m)	Direction
LA-10	200.0	300.0	N78°W
LA-11	250.0	150.0	"
LA-12	300.0	100.0	"
RA-13	200.0	300.0	S78°E
RA-14	250.0	100.0	"
RA-15	300.0	150.0	"
Total	6 adits	1,100.0	

(c) Drill Holes : The boundary between limestone and schist should be confirmed and various tests performed.

Table III-4-7 List of Drill Holes Proposal

	Elevation (m)	Depth (m)	Direction and Inclination	Water Pressure Test	Dye Test	Investigation of Water Flow
LD-1	200.0	350.0	Vertical	o		
LD-2	200.0	170.0	"	o		
LD-3	200.0	300.0	N78°W, 80°	o		
LD-4	200.0	100.0	N78°W, 50°	o		
LD-5	300.0	60.0	Vertical	o	o	
LD-6	302.0	50.0	" (U)	o		
LD-7	302.0	60.0	" (U)	o	o	
RB-8	190.0	350.0	Vertical	o		
RB-9	190.0	400.0	"	o		o
RD-10	200.0	400.0	"	o		o
RD-11	200.0	350.0	S78°E, 75°	o		o
RD-12	300.0	80.0	Vertical	o		
RD-13	302.0	50.0	" (U)	o		
RD-14	300.0	90.0	"	o		
RD-15	301.0	100.0	Horizontal	o		
RB-101		200.0	Vertical	-		
RB-102		200.0	"	-		
Total	17 holes	3,310.0				

Note) (U) means Upper.

RB-101 and RB-102 are to be drilled to investigate the continuity of the limestone in the downstream area.

(d) Dye Test : When carrying out water pressure tests on sections where faults and seams are encountered, dye or fluorescence soda is to be added to the water and the condition of emergence at the ground surface and inside exploratory adits is to be observed.

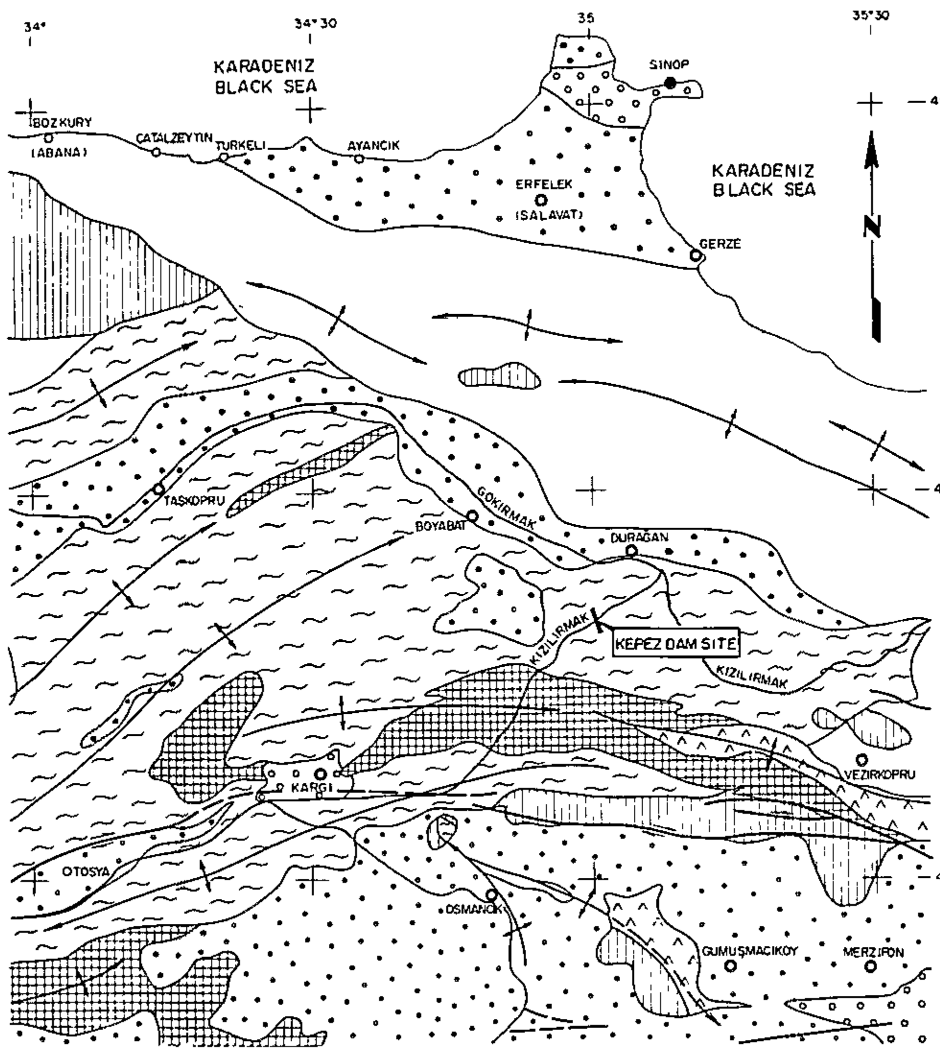
(e) Investigation of Ground Water Flow : There are various methods of ascertaining the flow of ground water such as the tracer and electric resistibility methods,but the latter is convenient. It would also be a good idea to employ micromoulients.

Further, if possible, it would be desirable to investigate continuities of limestone caves by introducing tracers at parts where leakage is extreme.

The ground water level should be measured at all drill holes, existing and planned this time.

(2) Construction Materials

Since the properties of aggregate for dam concrete will greatly affect design of the dam body and concrete mix proportions, grids of 150 m should be plotted for Borrow Areas A and C, and pits dug at all intersections (partly to be drill holes to ascertain the available quantities). It is necessary for representative samples to be collected from these pits and further tests to be made on physical porperties and gradation.

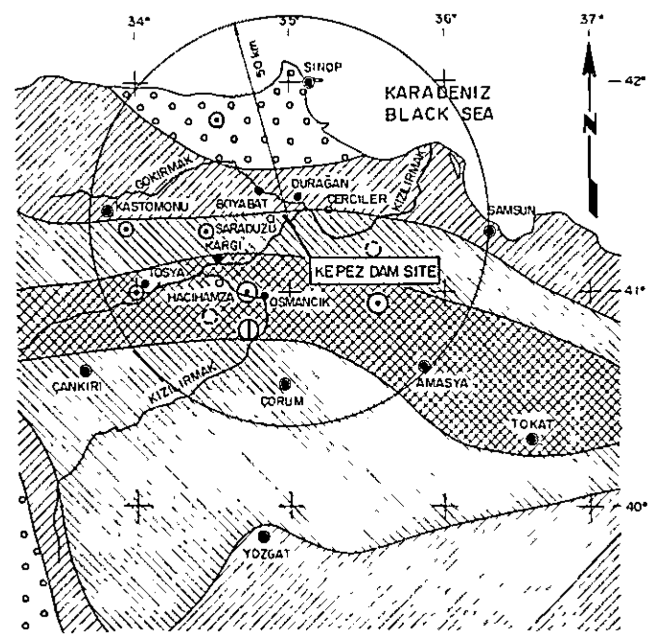


TECTONIC MAP

0 5 10 30 km

LEGEND

- Quaternary
- Tertiary
- Upper Cretaceous Flysch and Volcanics
- Mesozoic Ophiolitic Series
- Mesozoic Limestone
- Metamorphic Series
- Fold Axis
- Fault



SEISMIC MAP

0 17 34 51 km

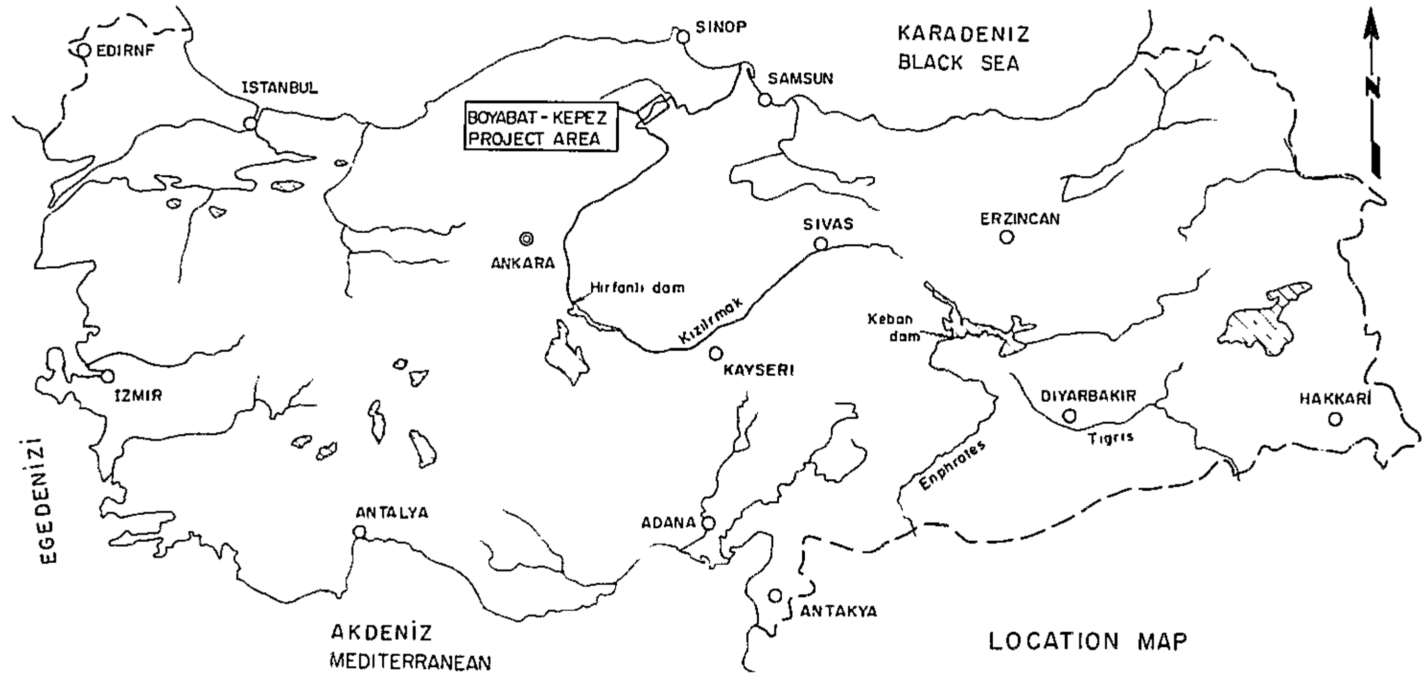
LEGEND

- Primary Degree Earthquake Region
- Secondary Degree Earthquake Region
- Third Degree Earthquake Region
- Fourth Degree Earthquake Region

M S 11 - 1964 arası

Shallow Earthquakes

- Earthquakes of Unknown Magnitude
- Macroseismic Epicenters: Moderate 4 ≤ M ≤ 5.4; Severe Destructive 5.5 ≤ M ≤ 6.9
- Instrumental Epicenters



LOCATION MAP

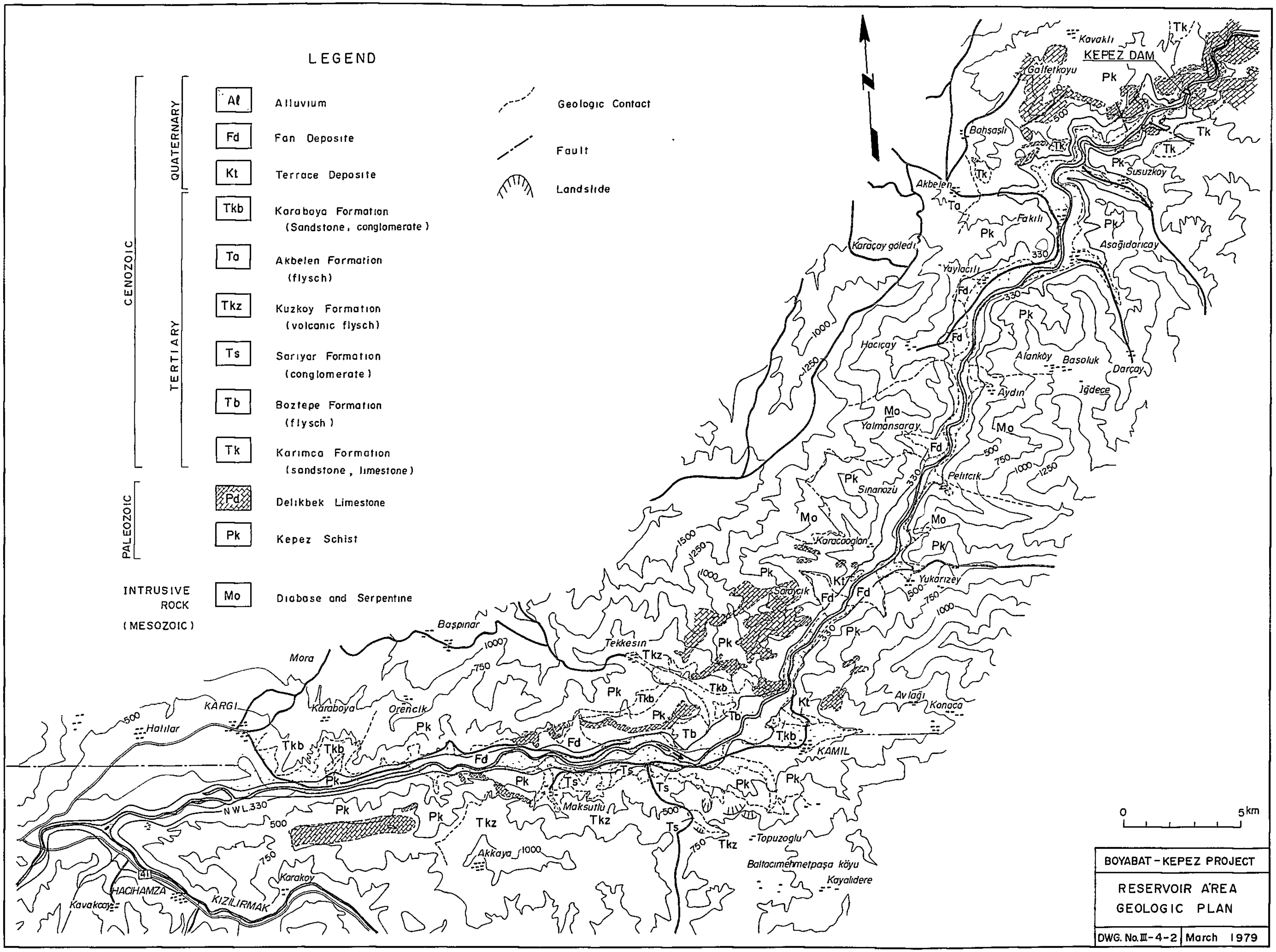
References cited

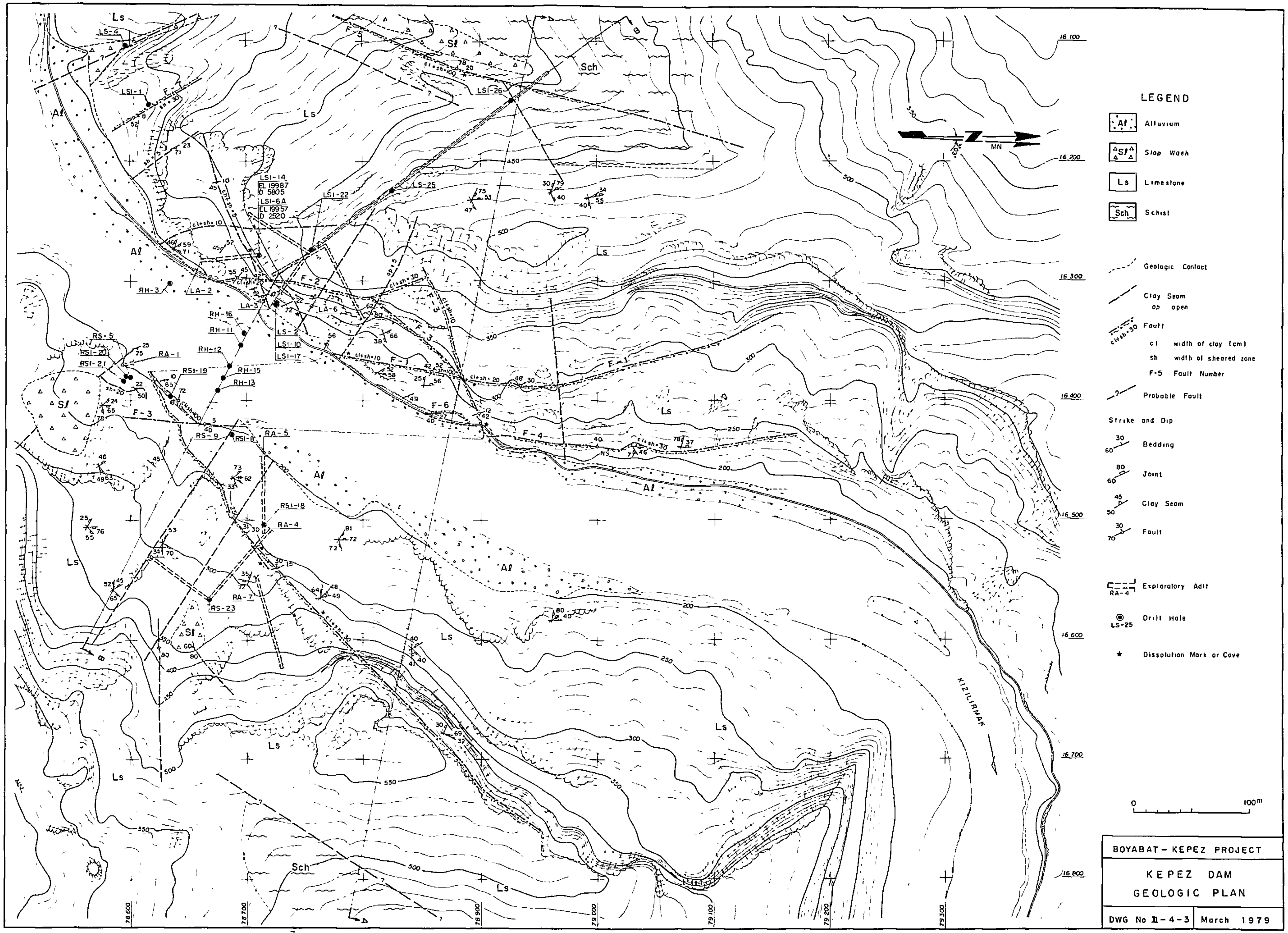
1 Geological Map of Turkey, Scaled 1/500000 (M T A Puplication)

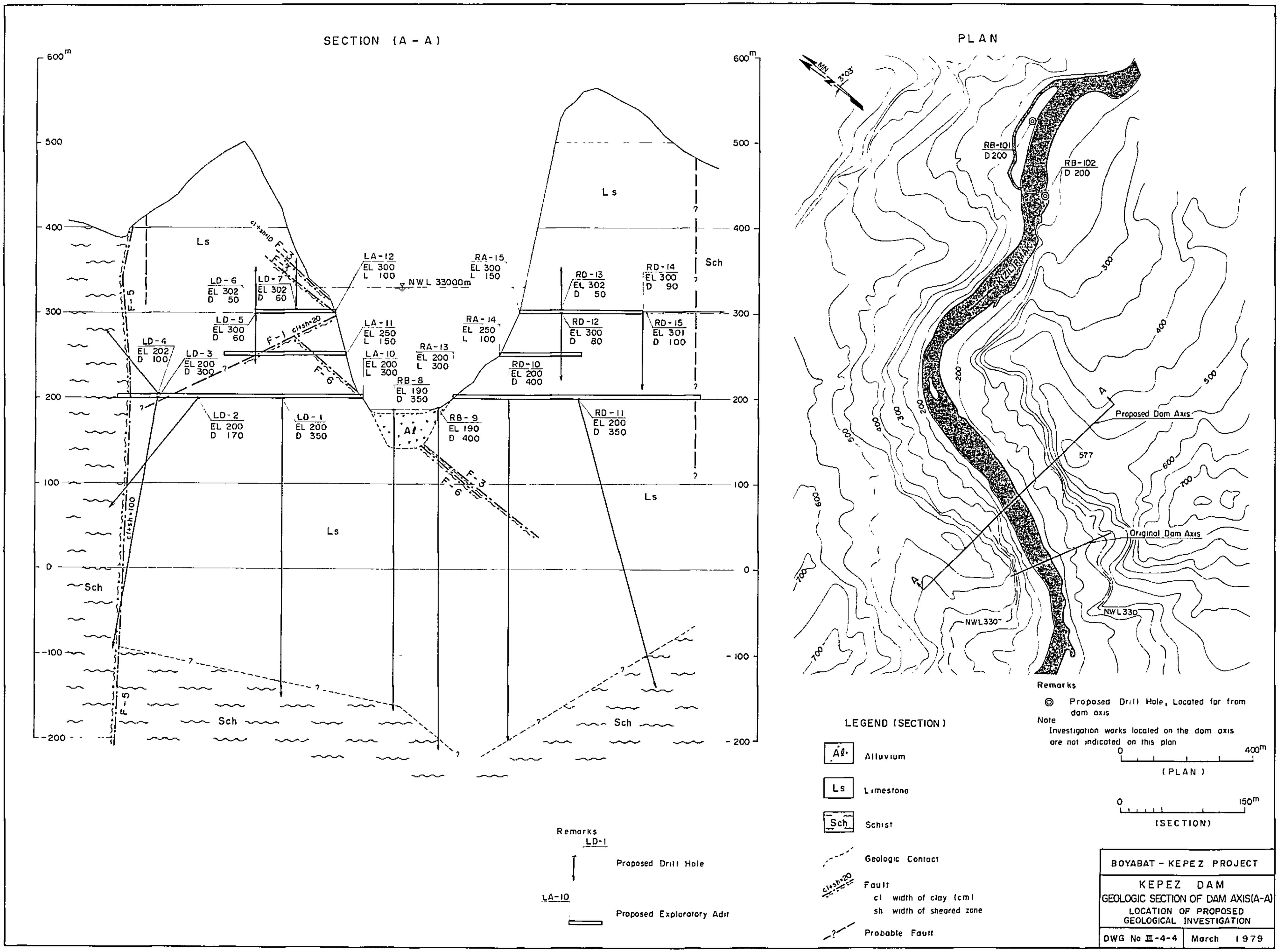
2 Earthquake Catalogue of Purkey & Surroundings (Ist Tech Uni Pub)

3 Map of Earthquake Regions of Turkey (Ministoy of Reconstruction and Settlment)

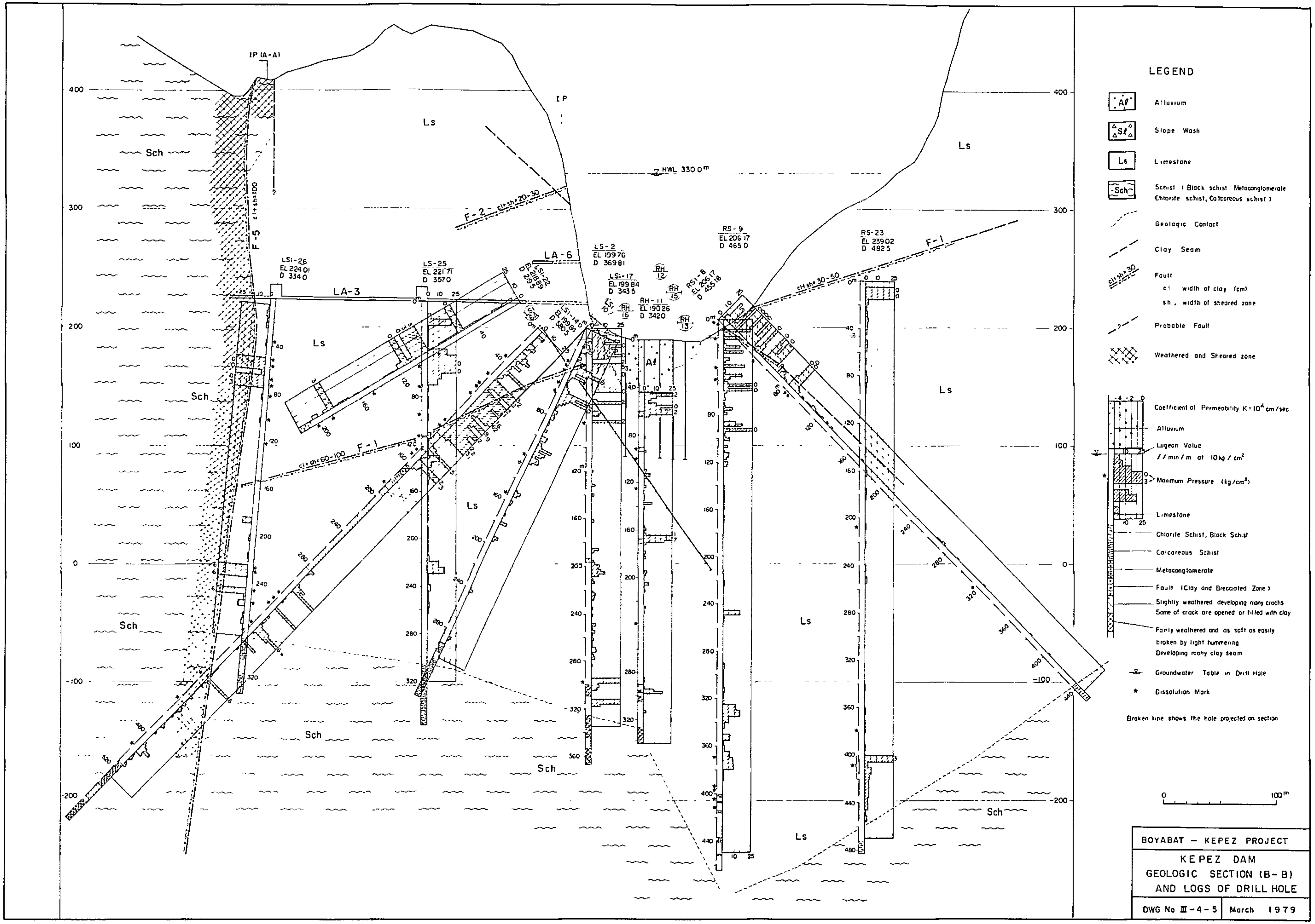
BOYABAT - KEPEZ PROJECT	
LOCATION, TECTONIC AND SEISMIC MAP	
DWG No III-4-1	March 1979

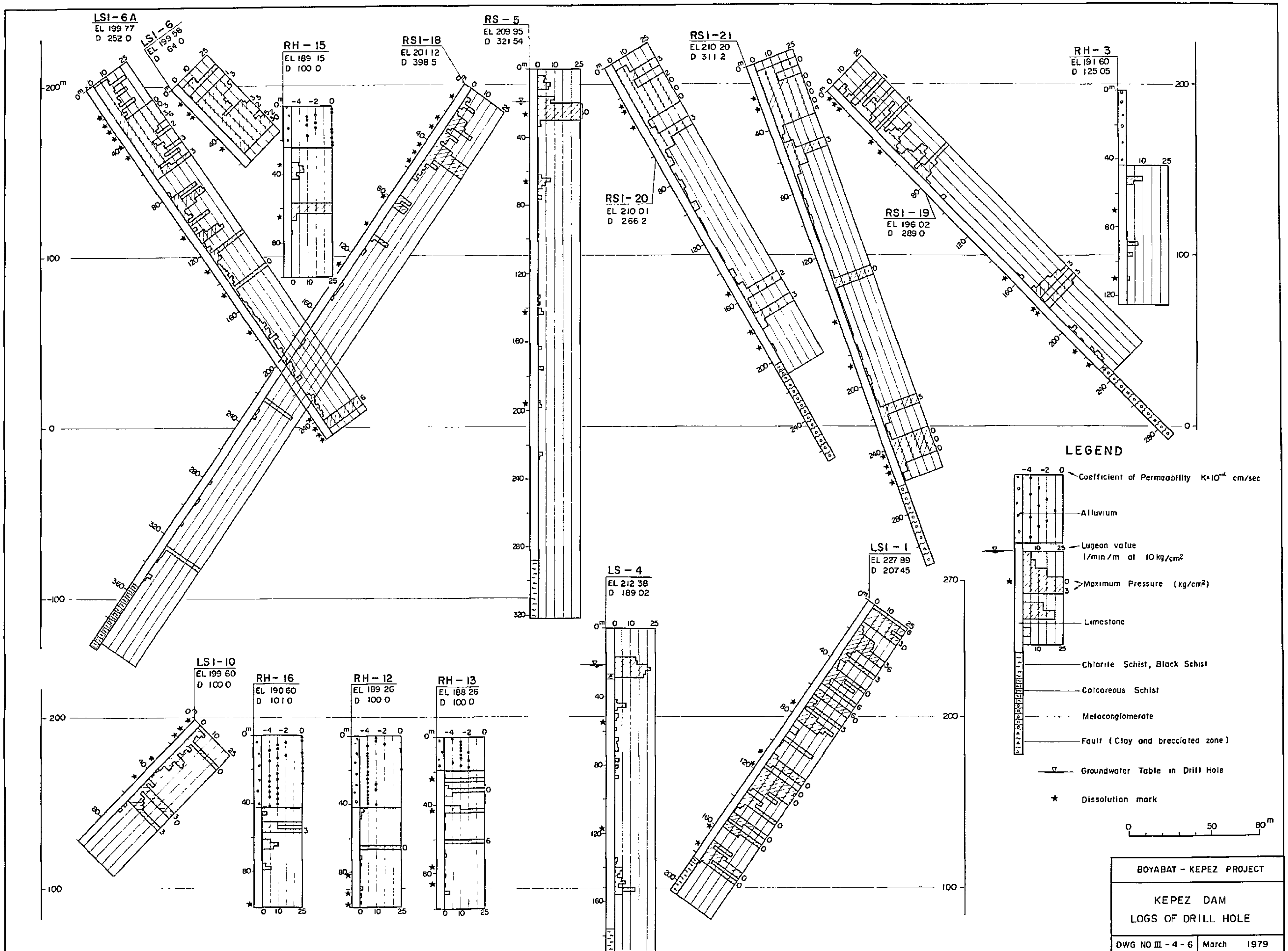

LEGEND
CENOZOIC
QUATERNARY
Al Alluvium
Fd Fan Deposite
Kt Terrace Deposite
TERTIARY
Tkb Karaboya Formation (Sandstone, conglomerate)
Ta Akbelen Formation (flysch)
Tkz Kuzkoy Formation (volcanic flysch)
Ts Sarıyar Formation (conglomerate)
Tb Boztepe Formation (flysch)
Tk Karımca Formation (sandstone, limestone)
PALEOZOIC
Pd Delikbek Limestone
Pk Kepez Schist
INTRUSIVE ROCK (MESOZOIC)
Mo Diabase and Serpentine
Geologic Contact
Fault
Landslide
N
KEPEZ DAM
KIZILIRMAK
NWL.330
0 5km
BOYABAT - KEPEZ PROJECT
RESERVOIR AREA GEOLOGIC PLAN
DWG. No.III-4-2
March 1979


LEGEND
Alluvium
Slop Wash
Limestone
Schist
Geologic Contact
Clay Seam
op open
Fault
cl width of clay (cm)
sh width of sheared zone
F-5 Fault Number
Probable Fault
Strike and Dip
Bedding
Joint
Clay Seam
Fault
Exploratory Adit
Drill Hole
Dissolution Mark or Cave
MN
KIZILIRMAK
BOYABAT - KEPEZ PROJECT
KEPEZ DAM
GEOLOGIC PLAN
DWG No III-4-3
March 1979



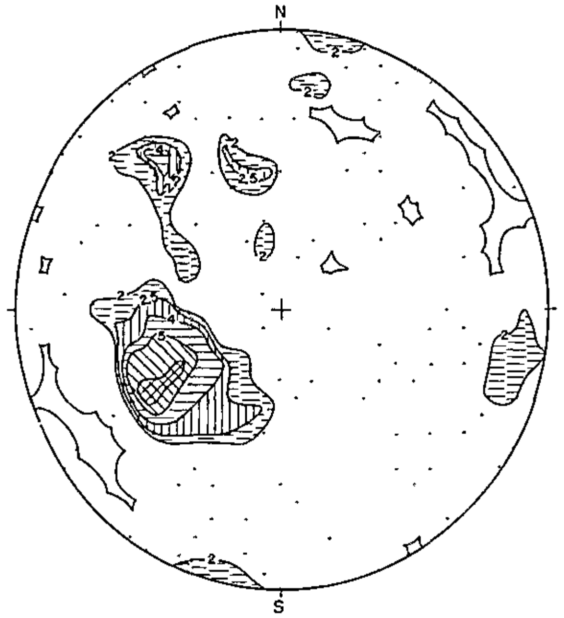
SECTION (A - A)
PLAN
NWL 330.00m
Ls
Sch
Al
LD-1 EL 200 D 350
LD-2 EL 200 D 170
LD-3 EL 200 D 300
LD-4 EL 202 D 100
LD-5 EL 300 D 60
LD-6 EL 302 D 50
LD-7 EL 302 D 60
LA-10 EL 200 L 300
LA-11 EL 250 L 150
LA-12 EL 300 L 100
RB-8 EL 190 D 350
RB-9 EL 190 D 400
RA-13 EL 200 L 300
RA-14 EL 250 L 100
RA-15 EL 300 L 150
RD-10 EL 200 D 400
RD-11 EL 200 D 350
RD-12 EL 300 D 80
RD-13 EL 302 D 50
RD-14 EL 300 D 90
RD-15 EL 301 D 100
F-1 cl+sh=20
F-3
F-5 cl+sh=100
F-6
RB-101 D 200
RB-102 D 200
KIZILIRMAK
Proposed Dam Axis
Original Dam Axis
NWL330
577
Remarks
Proposed Drill Hole
Proposed Exploratory Adit
LEGEND (SECTION)
Alluvium
Limestone
Schist
Geologic Contact
Fault
cl width of clay (cm)
sh width of sheared zone
Probable Fault
Remarks
Proposed Drill Hole, Located far from dam axis
Note
Investigation works located on the dam axis are not indicated on this plan
(PLAN)
(SECTION)
BOYABAT - KEPEZ PROJECT
KEPEZ DAM
GEOLOGIC SECTION OF DAM AXIS(A-A)
LOCATION OF PROPOSED GEOLOGICAL INVESTIGATION
DWG No III-4-4
March 1979


LEGEND
Alluvium
Slope Wash
Limestone
Schist (Black schist Metaconglomerate Chlorite schist, Calcareous schist)
Geologic Contact
Clay Seam
Fault
cl width of clay (cm)
sh, width of sheared zone
Probable Fault
Weathered and Sheared zone
Coefficient of Permeability K×10⁻⁴ cm/sec
Alluvium
Lugeon Value
l/min/m at 10kg/cm²
Maximum Pressure (kg/cm²)
Limestone
Chlorite Schist, Black Schist
Calcareous Schist
Metaconglomerate
Fault (Clay and Brecciated Zone)
Slightly weathered developing many cracks Some of crack are opened or filled with clay
Fairly weathered and as soft as easily broken by light hummering Developing many clay seam
Groundwater Table in Drill Hole
Dissolution Mark
Broken line shows the hole projected on section
HWL 330.0m
Ls
Sch
Al
F-1
F-2
F-5
LA-3
LA-6
BOYABAT - KEPEZ PROJECT
KEPEZ DAM
GEOLOGIC SECTION (B-B)
AND LOGS OF DRILL HOLE
DWG No III-4-5
March 1979

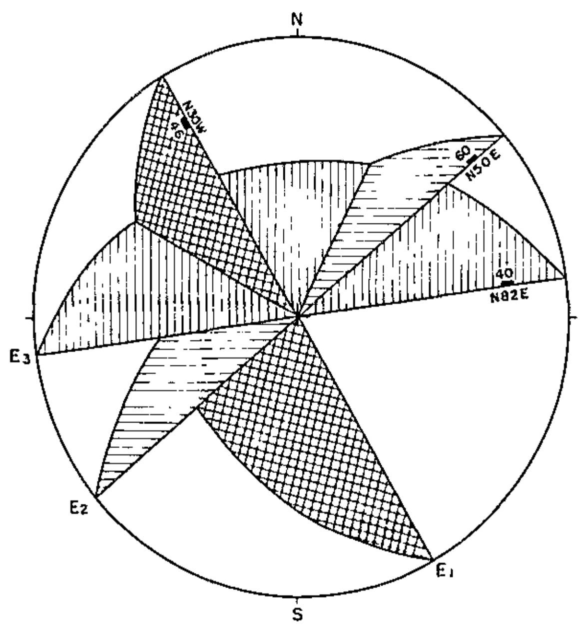


BOYABAT - KEPEZ PROJECT	
KEPEZ DAM LOGS OF DRILL HOLE	
DWG NO III - 4 - 6	March 1979

Contour Diagram of 2829 Joints
which were measured at the right bank adits
(RA-4, RA-5, RA-7) and
Stereographic Projection of Major Joints
(Prepared by projecting on upper semisphere)

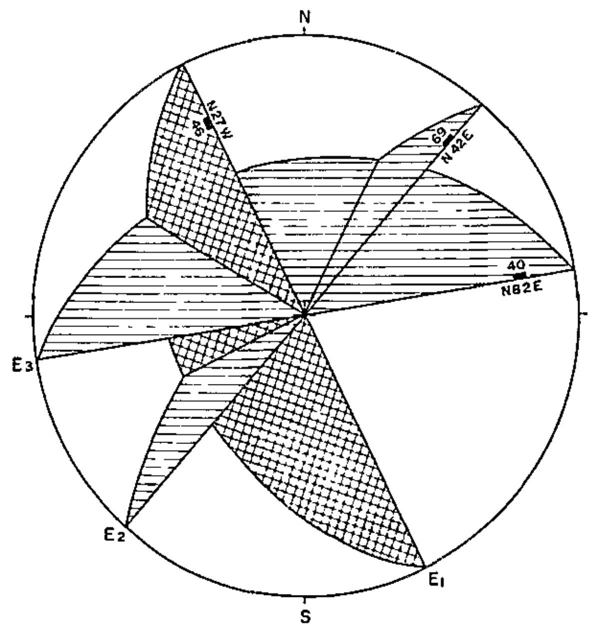


% Percentage	> 9	9 - 5	5 - 4	4 - 2,5	2,5 - 2	2 - 0	0
Symbol	E1		E2	E3			
Attitude	N30W46SW		N50E60NW	N82E40NW			
Numbers	279 253	141	115 112	77 70	56	0	



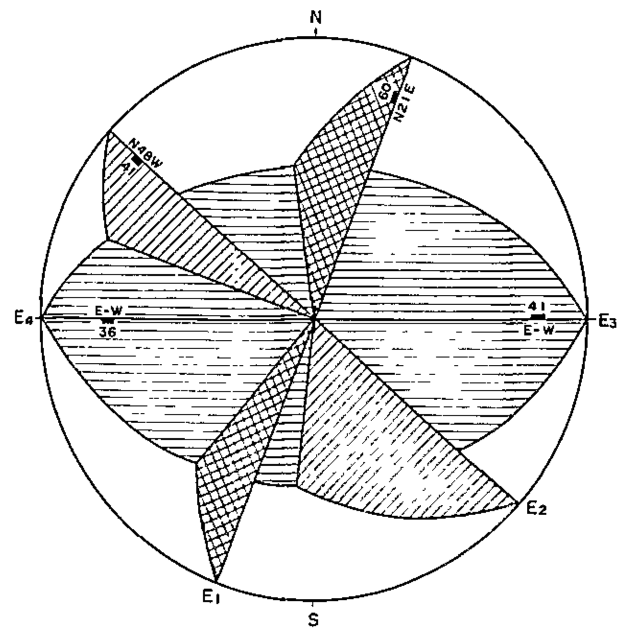
Contour Diagram of 1446 Joints
which were measured at the right bank and
Stereographic Projection of Major Joints
(Prepared by projecting on upper semisphere)

% Percentage	> 5	5 - 4	4 - 3	3 - 2	2 - 1	1 - 0	0
Symbol	E1		E2 — E3				
Attitude	N27W46SW		N42E69NW N82E40NW				
Numbers	79 72	57	46 43	42 28	14	0	



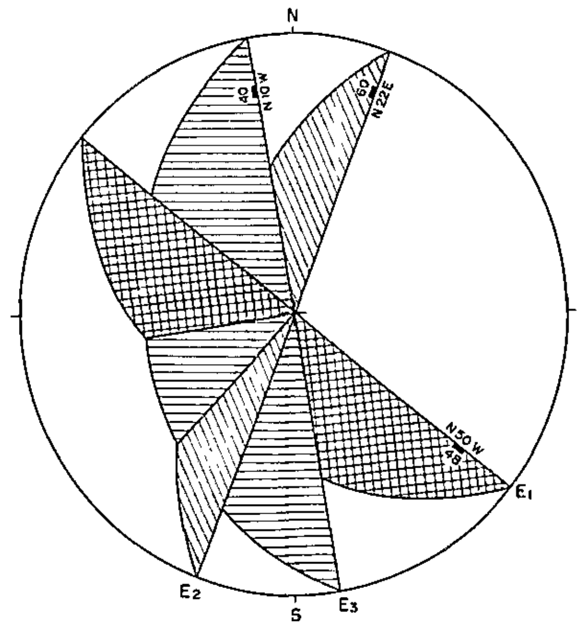
Contour Diagram of 4726 Joints
which were measured at the left bank adits
(LA-2, LA-3, LA-6) and
Stereographic Projection of Major Joints
(Prepared by projecting on upper semisphere)

% Percentage	> 5	5 - 3,5	3,5 - 2	2 - 1,5	1,5 - 1	1 - 0	0
Symbol	E1	E2	E3 — E4				
Attitude	N21E60NW	N48W41SW	E-W41N S-W36S				
Numbers	240 236	165	94	72	47	0	



Contour Diagram of 1365 Joints
which were measured at the left bank and
Stereographic Projection of Major Joints
(Prepared by projecting on upper semisphere)

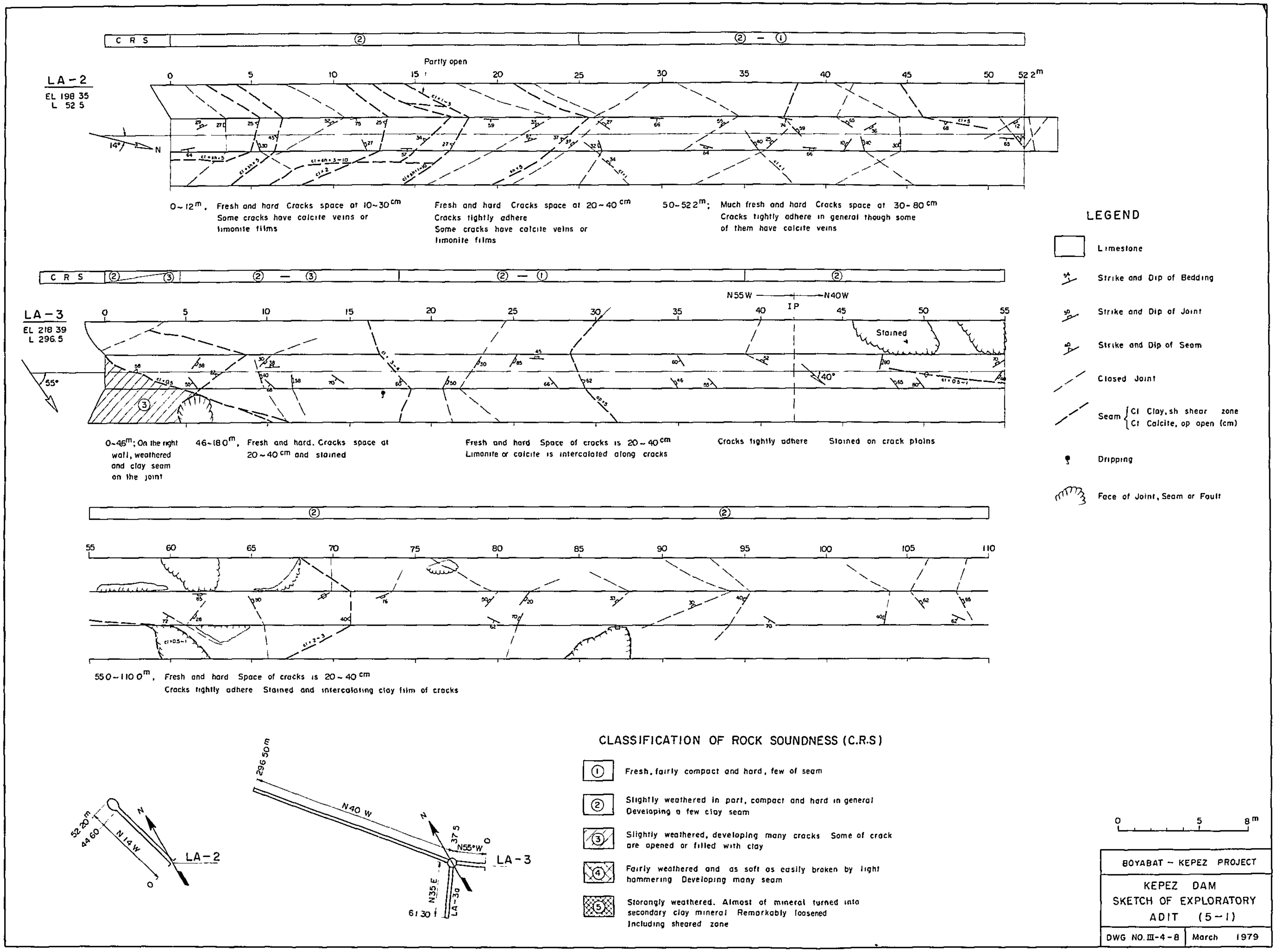
% Percentage	>4,5	4,5 - 3,5	3,5 - 3	3 - 2	2 - 1	1 - 0	0
Symbol	E1	E2	E3				
Attitude	N50W48SW	N22E60NW	N10W40SW				
Numbers	65 60	47	40	27	13	0	

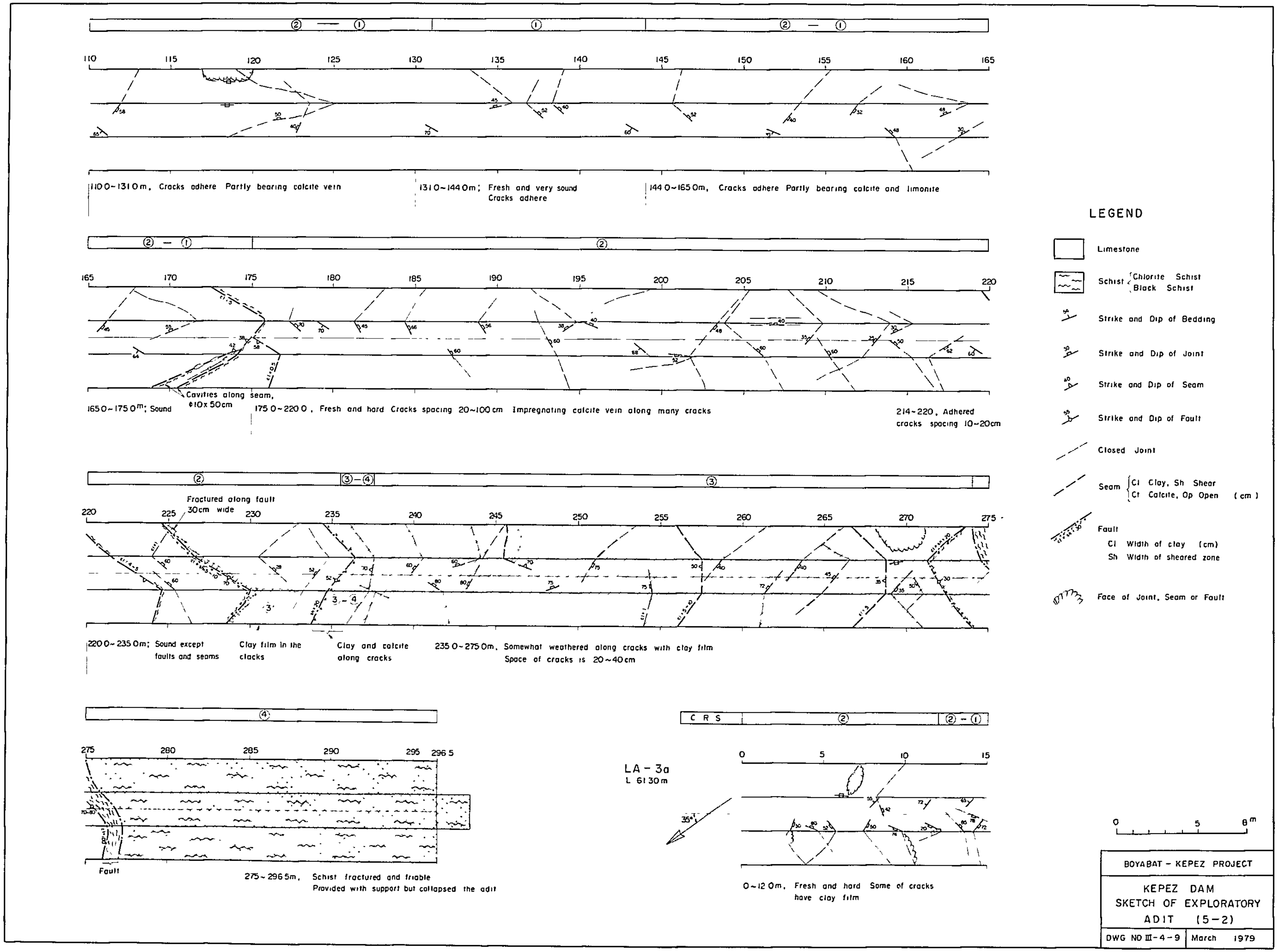


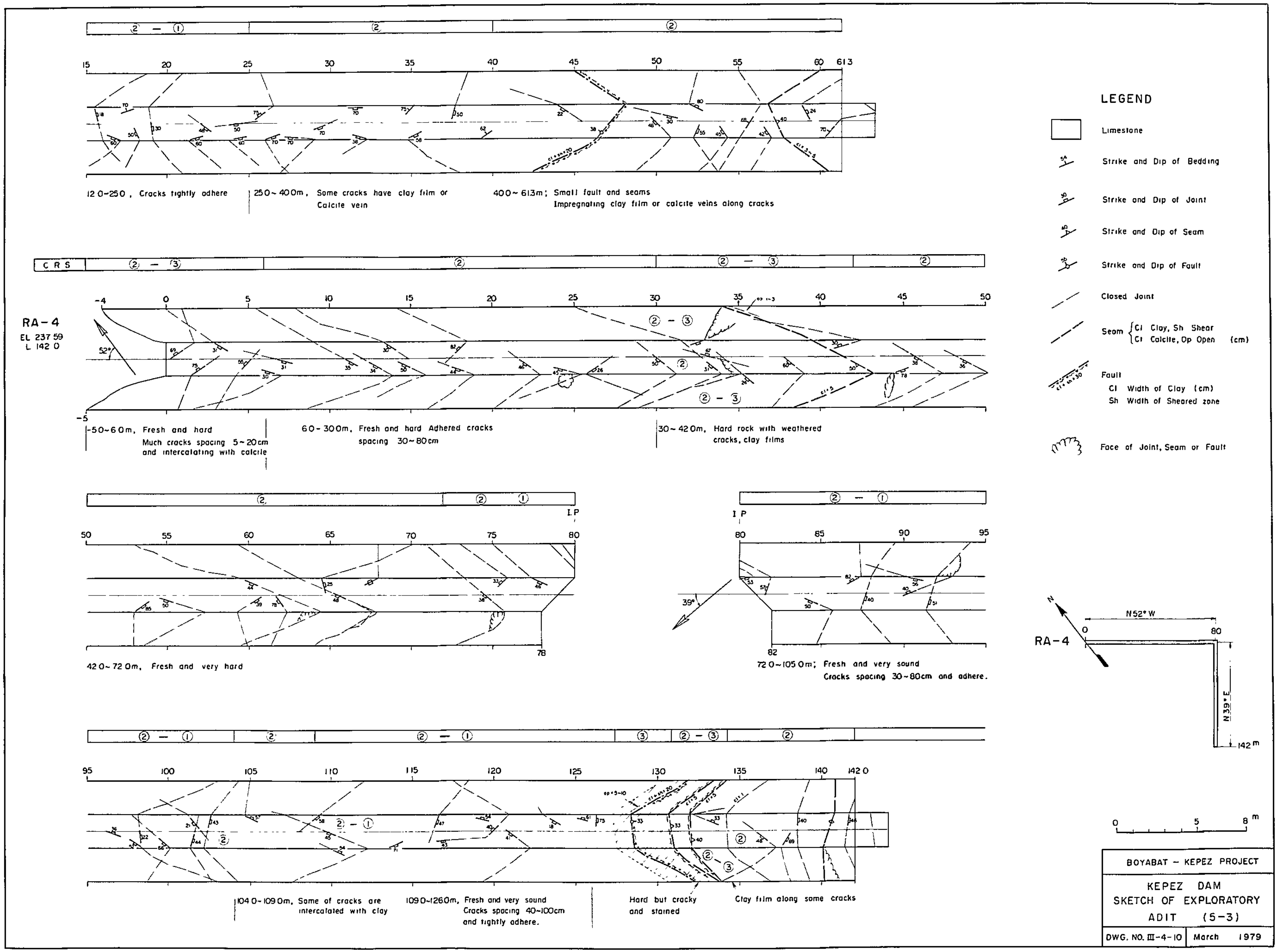
BOYABAT - KEPEZ PROJECT

KEPEZ DAM
JOINT DENSITY DIAGRAM

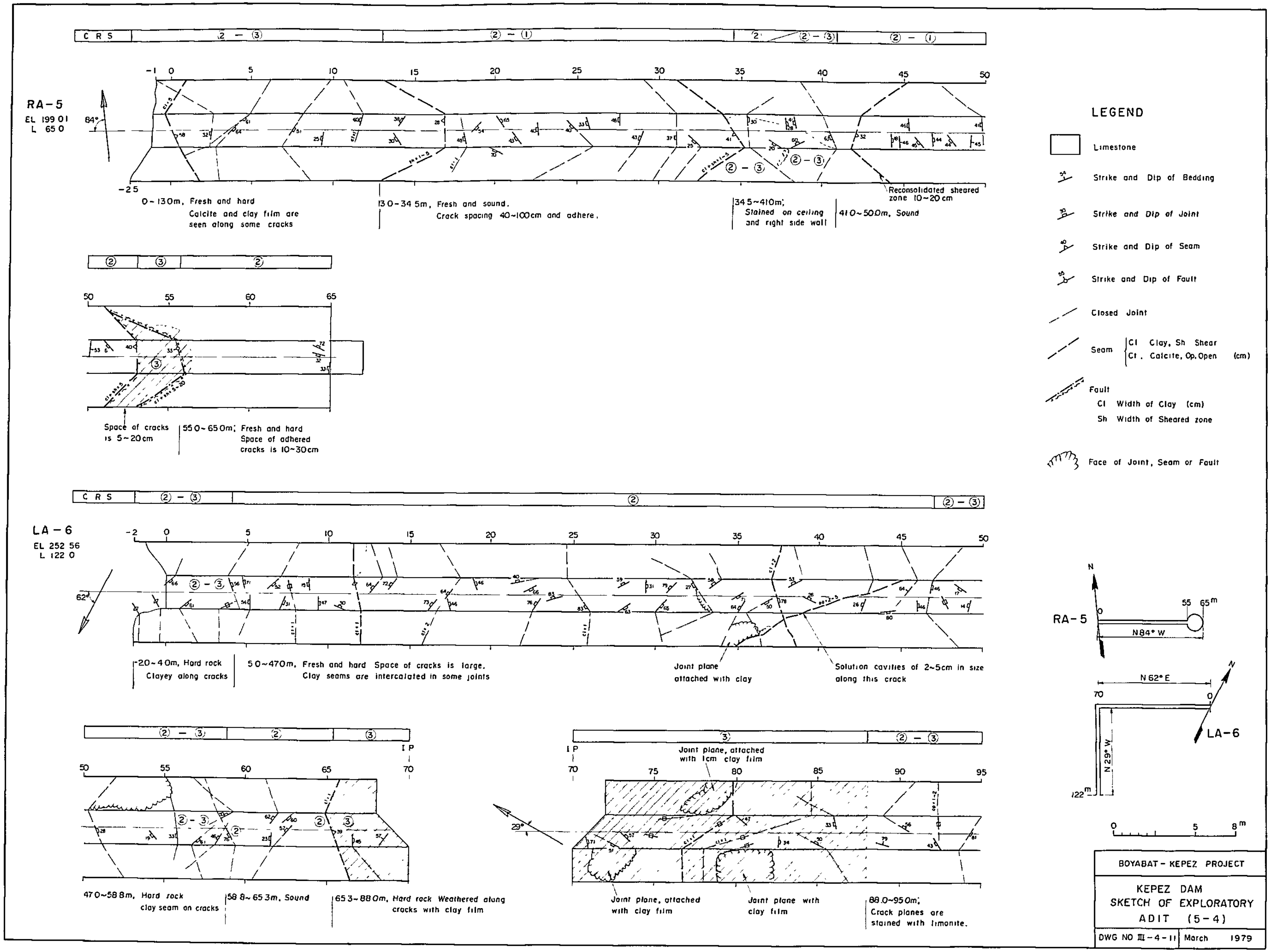
DWG No. III-4-7	March 1979

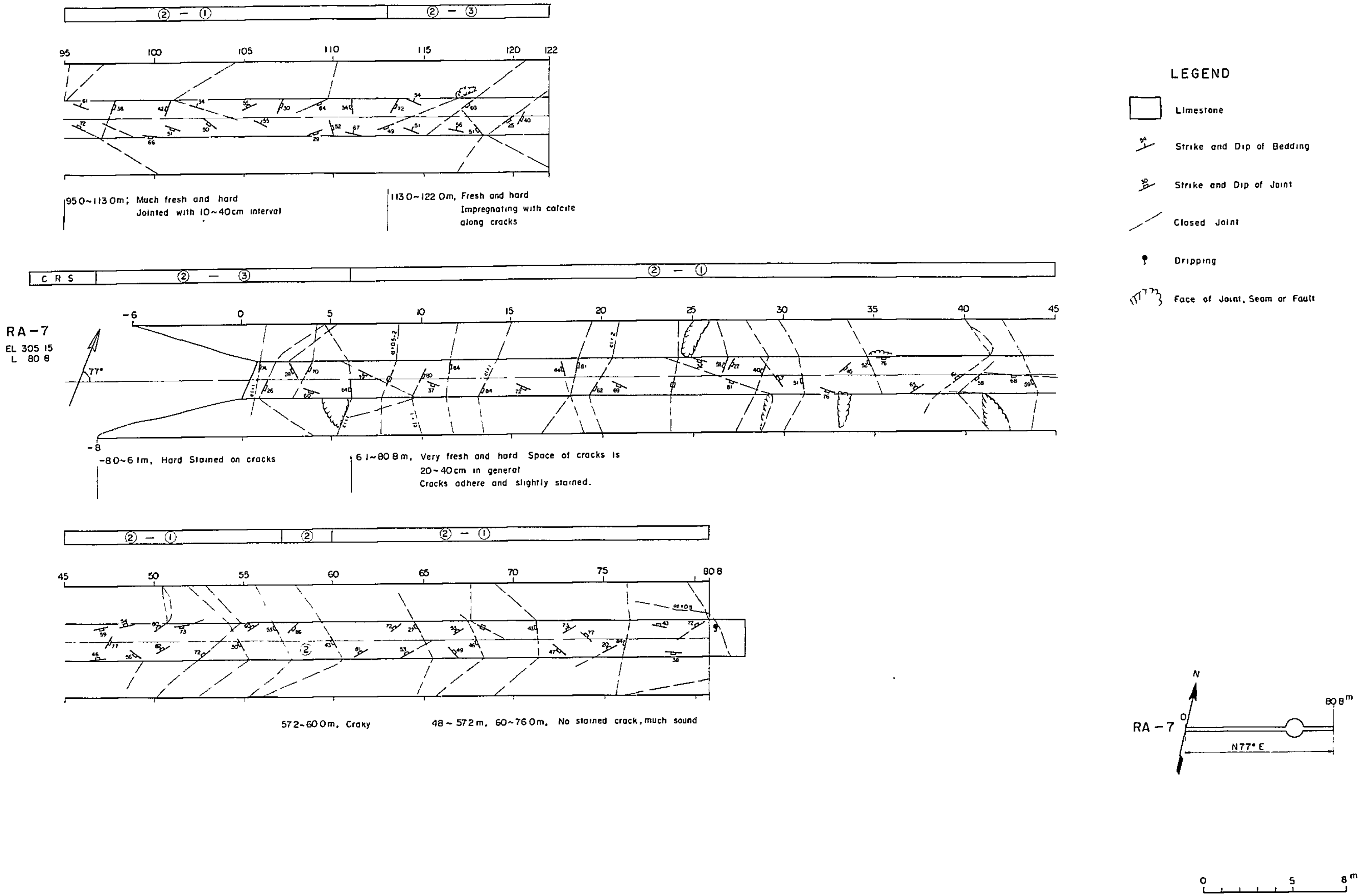

LA-2
EL 198 35
L 52 5
C R S
Partly open
0~12 m, Fresh and hard Cracks space at 10~30 cm
Some cracks have calcite veins or limonite films
Fresh and hard Cracks space at 20~40 cm
Cracks tightly adhere
Some cracks have calcite veins or limonite films
50~52 2 m; Much fresh and hard Cracks space at 30~80 cm
Cracks tightly adhere in general though some of them have calcite veins
LA-3
EL 218 39
L 296.5
N55W
N40W
IP
Stained
0~4.6 m; On the right wall, weathered and clay seam on the joint
4.6~18.0 m, Fresh and hard. Cracks space at 20~40 cm and stained
Fresh and hard Space of cracks is 20~40 cm
Limonite or calcite is intercalated along cracks
Cracks tightly adhere
Stained on crack plains
55.0~110.0 m, Fresh and hard Space of cracks is 20~40 cm
Cracks tightly adhere Stained and intercalating clay film of cracks
LEGEND
Limestone
Strike and Dip of Bedding
Strike and Dip of Joint
Strike and Dip of Seam
Closed Joint
Seam { Cl Clay, sh shear zone / Cl Calcite, op open (cm)
Dripping
Face of Joint, Seam or Fault
CLASSIFICATION OF ROCK SOUNDNESS (C.R.S)
① Fresh, fairly compact and hard, few of seam
② Slightly weathered in part, compact and hard in general. Developing a few clay seam
③ Slightly weathered, developing many cracks. Some of crack are opened or filled with clay
④ Fairly weathered and as soft as easily broken by light hammering. Developing many seam
⑤ Storongly weathered. Almost of mineral turned into secondary clay mineral. Remarkably loosened. Including sheared zone
52.20 m
44.60
N 14 W
LA-2
296.50 m
N 40 W
37.5
N55°W
LA-3
N35 E
LA-3a
61.30
0 5 8 m
BOYABAT - KEPEZ PROJECT
KEPEZ DAM
SKETCH OF EXPLORATORY ADIT (5-1)
DWG NO. III-4-8
March 1979


110~131.0m, Cracks adhere Partly bearing calcite vein
131.0~144.0m; Fresh and very sound Cracks adhere
144.0~165.0m, Cracks adhere Partly bearing calcite and limonite
Cavities along seam, ϕ10x50cm
165.0~175.0m; Sound
175.0~220.0, Fresh and hard Cracks spacing 20~100cm Impregnating calcite vein along many cracks
214~220, Adhered cracks spacing 10~20cm
Fractured along fault 30cm wide
220.0~235.0m; Sound except faults and seams
Clay film in the cracks
Clay and calcite along cracks
235.0~275.0m, Somewhat weathered along cracks with clay film Space of cracks is 20~40cm
Fault
275~296.5m, Schist fractured and friable Provided with support but collapsed the adit
LA-3a
L 61.30m
C R S
0~12.0m, Fresh and hard Some of cracks have clay film
LEGEND
Limestone
Schist Chlorite Schist Black Schist
Strike and Dip of Bedding
Strike and Dip of Joint
Strike and Dip of Seam
Strike and Dip of Fault
Closed Joint
Seam Cl Clay, Sh Shear Ct Calcite, Op Open (cm)
Fault Cl Width of clay (cm) Sh Width of sheared zone
Face of Joint, Seam or Fault
0 5 8m
BOYABAT - KEPEZ PROJECT
KEPEZ DAM
SKETCH OF EXPLORATORY ADIT (5-2)
DWG NO III-4-9
March 1979



12.0~25.0, Cracks tightly adhere
25.0~40.0m, Some cracks have clay film or Calcite vein
40.0~61.3m; Small fault and seams
Impregnating clay film or calcite veins along cracks
CRS
RA-4
EL 237.59
L 142.0
-5.0~6.0m, Fresh and hard
Much cracks spacing 5~20cm and intercalating with calcite
6.0~30.0m, Fresh and hard Adhered cracks spacing 30~80cm
30~42.0m, Hard rock with weathered cracks, clay films
I.P
42.0~72.0m, Fresh and very hard
72.0~105.0m; Fresh and very sound
Cracks spacing 30~80cm and adhere.
104.0~109.0m, Some of cracks are intercalated with clay
109.0~126.0m, Fresh and very sound
Cracks spacing 40~100cm and tightly adhere.
Hard but cracky and stained
Clay film along some cracks
LEGEND
Limestone
Strike and Dip of Bedding
Strike and Dip of Joint
Strike and Dip of Seam
Strike and Dip of Fault
Closed Joint
Seam {Cl Clay, Sh Shear
{Ct Calcite, Op Open (cm)
Fault
Cl Width of Clay (cm)
Sh Width of Sheared zone
Face of Joint, Seam or Fault
N
N52°W
RA-4
N39°E
142m
BOYABAT – KEPEZ PROJECT
KEPEZ DAM
SKETCH OF EXPLORATORY
ADIT (5-3)
DWG. NO. III-4-10
March 1979


RA-5
EL 199.01
L 65.0
0~13.0m, Fresh and hard Calcite and clay film are seen along some cracks
13.0~34.5m, Fresh and sound. Crack spacing 40~100cm and adhere.
34.5~41.0m; Stained on ceiling and right side wall
41.0~50.0m, Sound
Reconsolidated sheared zone 10~20 cm
Space of cracks is 5~20cm
55.0~65.0m; Fresh and hard Space of adhered cracks is 10~30cm
LA-6
EL 252.56
L 122.0
-2.0~4.0m, Hard rock Clayey along cracks
5.0~47.0m, Fresh and hard Space of cracks is large. Clay seams are intercalated in some joints
Joint plane attached with clay
Solution cavities of 2~5cm in size along this crack
47.0~58.8m, Hard rock clay seam on cracks
58.8~65.3m, Sound
65.3~88.0m, Hard rock Weathered along cracks with clay film
Joint plane, attached with 1cm clay film
Joint plane, attached with clay film
Joint plane with clay film
88.0~95.0m; Crack planes are stained with limonite.
LEGEND
Limestone
Strike and Dip of Bedding
Strike and Dip of Joint
Strike and Dip of Seam
Strike and Dip of Fault
Closed Joint
Seam
Cl Clay, Sh Shear
Ct. Calcite, Op. Open (cm)
Fault
Cl Width of Clay (cm)
Sh Width of Sheared zone
Face of Joint, Seam or Fault
RA-5
N84° W
N 62° E
N 29° W
LA-6
BOYABAT - KEPEZ PROJECT
KEPEZ DAM
SKETCH OF EXPLORATORY ADIT (5-4)
DWG NO III-4-11
March 1979



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KEPEZ DAM
SKETCH OF EXPLORATORY
ADIT (5－5)

DWG NO III－4－12	March 1979