CHAPTER 7

GEOLOGY AND CONSTRUCTION MATERIALS

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7.1 Outline of Survey

In the way of a survey on geology and construction materials concerning the Project, collection of existing data, studies thereof and field investigations were carried out.

7.1.1 Existing Data

Studies were made of the following data related to geology, collected in preliminary investigations (October 1981) and field investigations (February-March 1982 and October 1982):

Sümerman, K., (1973)

"The Geological Engineering Investigation of Köprücay Beskonak Dam Site and Grout Curtain Courses"

Karanjac, J., (1976)

"Regime of Oluk-köprü and Koca Dele Springs of Köprücay Basin Based on Hydrograph Analysis"

Energo Co., (1967)

"Oymapinar Dam and Reservoir Feasibility Study"

Coyne & Bellier, (1969)

"Oymapinar Dam and Hydroelectric Project, Second Phase Final Report"

Eroskay, S. O., (1968)

"Geological Investigation of Köprücay-Beskonak Reservoir"

Atalay, H., and Sipahi, H., (1979)

"Explanatory Notes on the Hydrogeology of Oluk-köprü Springs, Proceedings of First International Symposium on Karst Hydrogeology"

Yevjevich, V., (1981)

"Karst Waters of Southern Turkey"

Tarimci, T., (1982)

"Geological Study Report of Beskonak Project"

7.1.2 Field Investigations and Data Analyses

Field investigations were made twice by the Survey Mission, in February-March 1982 and October 1982. The main objectives of the former were confirmation in the field of data already obtained in the preliminary investigations, collection of rock samples and collection of field information for formulating an additional investigation plan, while those of the latter were confirmation of progress in additional investigations, and examination of the results in the field.

Samples collected in the field were analyzed in Japan.

Field investigations and sample analyses consisted of the following:

(1) Surface geological reconnaissances of dam site, reservoir and its vicinity

(2) Investigation in test adits at dam site

(3) Investigation of drilled core of dam site and its vicinity

(4) Investigation of water spring at reservoir and its vicinity

(5) Materials investigation at dam site vicinity

(6) Sample analyses (see Table 7.1)

Table 7-1 Sample For Analysis

Analysis	Sample No.	Formation	Locality
Chemical Analysis	BC – 1	Köprüçay Conglomerate (Pebble)	Drillhole LS-1, 162m, left bank at Damsite
	BC – 2	Köprüçay Conglomerate (Matrix)	〃
	BC – 4	Beşkonak Formation	On river bed at Beşkonak gauging station
	BC – 5	〃	In the vicinity of Secondary Damsite
Microscopic Observation	BM – 1	Köprüçay Conglomerate	Drillhole LS-1, 162m, left bank at Damsite
	BM – 2	Beşkonak Formation	Drillhole RS-20, 212m, right bank at the vicinity of Damsite
X-ray Diffraction	BX – 1	Beşkonak Formation	In the vicinity of Secondary Damsite

7.1.3 Investigation Works

In the project area, besides surface geological reconnaissances, there have been core boring, test adit, test pit and groundwater investigations carried out chiefly by EIE.

(1) Boring

Boring had been performed mainly by EIE at the dam site and its vicinity with 26 holes totalling 6,310.68 m as shown in Table 7-2, from 1967 to 1971. In all of the drillholes, permeability tests had been conducted in step with drilling. In the reservoir area, two drillholes totalling 272 m shown in Table 7-3 had been drilled by DSI during Nov. 1982 and Apr. 1983 for the Feasibility Study. In these drillholes, permeability tests had been executed. At the surrounding area of the Oluk-köprü springs in the vicinity of the upstream end of the reservoir, the three drillhoes totalling 730 m shown in Table 7-4 were made in 1977 as a part of the joint project of the United Nations Development Program and DSI with the title "Strengthening DSI Groundwater Investigation Capabilities" (UNDP/DSI Project).

(2) Test Adits

Test adits consisting of 6 adits totalling 1,073.3 m in length shown in Table 7-5 were driven by EIE at the same time that drillhole boring was done.

(3) Test Pits

Test pits consisting of 8 pits, 19.3 m, shown in Table 7-6, were excavated by EIE at a site on the left bank approximately 10 km downstream from the dam site.

(4) Groundwater Investigations

(a) Water Level Investigations

Measurements of water levels in drillholes at the dam site and in its vicinity had been carried out by EIE until 1971.

(b) Water Quality Analyses

Water quality analyses were performed by EIE and DSI on river water and spring water in the project area.

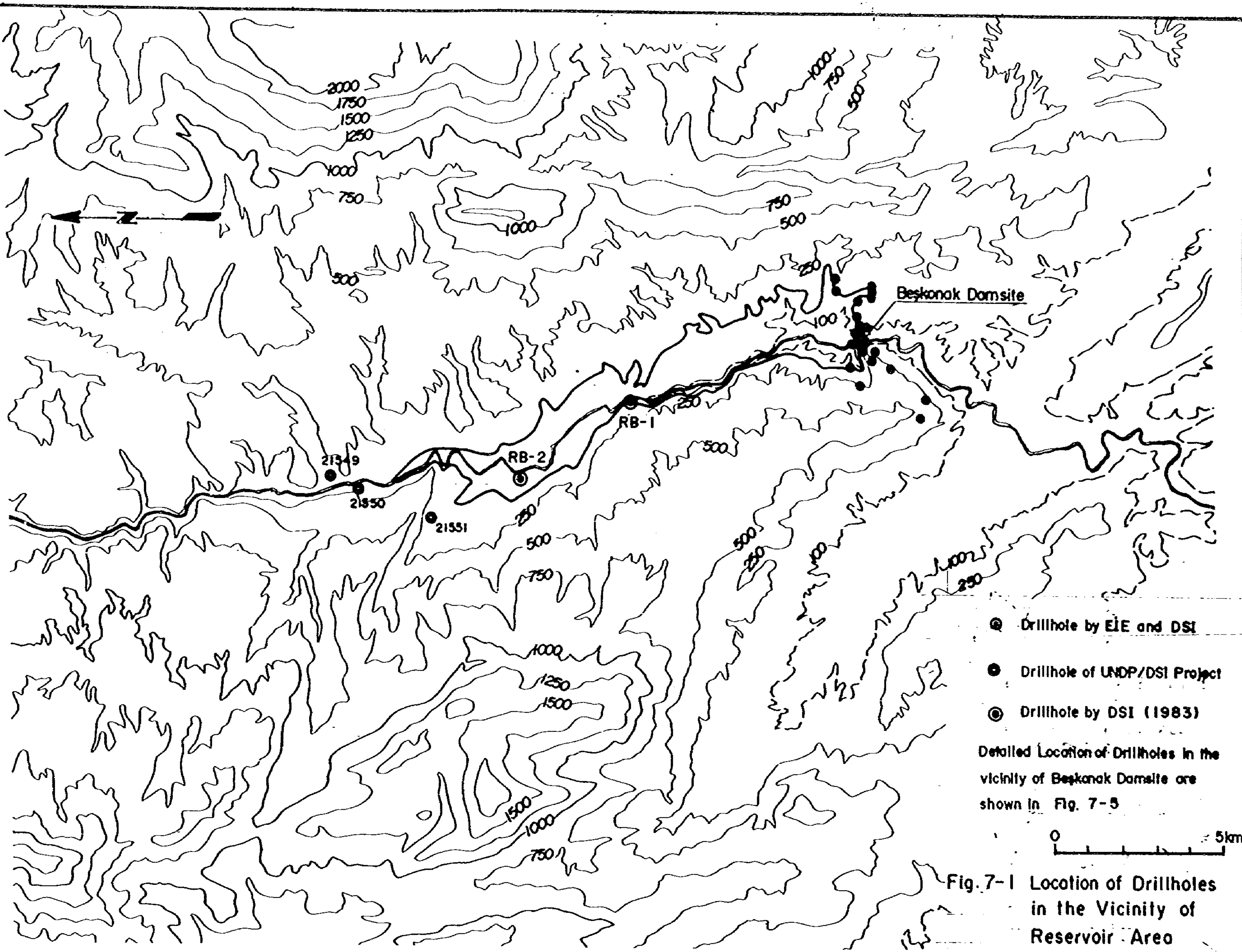


Fig. 7-1 Location of Drillholes in the Vicinity of Reservoir Area

Table 7-2 List of Drillholes at Beskonak Damsite and its Vicinity

Name	Elevation (m)	Coordination X	Coordination Y	Length (m)	Remarks
*LS-1	180.24	4,103,863.29	609,625.83	360.00	Inclined hole (53°)
*LSI-2	177.05	4,103,823.93	609,734.37	392.23	
*RS-3	89.83	4,103,891.09	609,427.18	140.10	In Adit RT-3
*LS-4	72.59	4,103,948.43	609,590.69	90.20	In Adit LT-1
*LS-5	113.73	4,103,948.84	609,656.59	125.00	In Adit LT-2
LS-6	196.74	4,103,745.98	609,894.05	400.22	
*RH-7	-	-	-	150.70	On river bed
*RH-8	-	-	-	125.00	"
RH-10	-	-	-	150.25	"
LS-11	193.22	4,103,811.40	610,193.62	300.00	
RS-12	115.40	4,104,040.99	608,722.27	150.00	
RS-13	243.90	4,103,685.95	609,225.64	353.23	
LS-14	207.62	4,103,806.20	610,569.61	330.17	
RS-15	267.71	4,103,463.14	609,051.62	314.80	
RS-16	198.86	4,103,421.63	609,264.01	230.00	
LS-17	136.75	4,103,565.07	609,903.42	190.00	
RS-18	297.64	4,102,666.64	608,592.24	371.00	
LS-19	194.14	4,104,551.58	611,376.23	431.00	
RS-20	289.52	4,101,652.78	607,867.06	375.00	
LS-21	137.94	4,104,417.59	610,852.60	228.00	
RS-22	254.70	4,103,792.75	608,257.28	260.00	
LS-23	68.68	4,104,128.61	609,744.94	152.00	
RS-24	272.20	-	-	320.00	
H1	164.79	4,103,540.21	610,709.94	100.00	Secondary damsite
H2	143.95	4,103,527.75	610,821.18	200.00	"
H3	164.05	4,103,524.00	610,960.37	65.00	"
Total		26 holes		6,310.68	

Note 1: Drillholes except RS-24, which was drilled by DSI in 1977, were drilled by EIE between 1967 and 1971.

2: Drillhoes marked with * are located at the dam site

Table 7-3 List of Drillholes Drilled by DSI for the Feasibility Study

Location	Name	Elevation (m)	Coordination X	Coordination Y	Length (m)	Remarks
Right-bank	RB-1	140.1			144.4	
"	RB-2	133.45			128.00	
Total	2 holes				272.00	

Table 7-4 List of Drillholes in the Vincity of Oluk-köprü Springs

Name	Elevation (m)	Coordination X	Coordination Y	Length (m)	Remarks
21549	200			199	
21550	162			300	
21551	198			231	
Total	3 holes			730	

Note : Drillholes belong to UNDP/DSI Project and were drilled in 1977

Table 7-5 List of Adits

Location	Name	Elevation (m)	Coordination X	Coordination Y	Length (m)	Remarks
Damsite	LT-1	69.99	4,104,028.36	609,639.52	339.00	
	LT-2	112.08	4,104,005.47	609,648.86	230.00	
	RT-3	87.15	4,103,928.92	609,471.05	189.00	
	RT-4	54.43	4,103,967.38	609,472.22	174.00	
	LA-5	146.51	4,103,926.87	609,572.73	67.00	
	RT-6	125.72	4,103,853.50	609,470.77	71.30	
Total	6 adits				1,070.3	

Table 7-6 List of Test Pits

Kind of Material	Name	Length (m)
Impervious Core Material	B-1	7.0
	B-2	1.5
	B-3	0.9
	B-4	2.0
	B-5	3.1
Sub-total	5 pits	14.5
Concrete Aggregate	A-1	1.6
	A-2	1.8
	A-3	1.4
Sub-total	3 pits	4.8
Total	8 pits	19.3

7.2 Geology of Reservoir

7.2.1 Method of Investigation

Regarding the reservoir and its surroundings, surface geological reconnaissances and core boring had been carried out, and the results were given in 1/25,000 scale geological maps by Eroskay (1968) and 1/5,000 scale geological maps by Sümerman (1973). The quantities of drilling investigations are given in Tables 7-2 to 7-4 with the locations shown in Fig. 7-1.

7.2.2 Outline of Topography

The reservoir area is located approximately 40 km upstream from the mouth of the Köprücay River. The reservoir has a length of approximately 15 km and most parts of width from 1 to 1.5 km. The topography in the surroundings of the reservoir is gentle as a whole, but dissection has progressed at the left bank side due to erosion by tributaries of the Köprücay River. The Köprücay River forms narrow gorges of 30 to 200 m in depth in the vicinity of the dam site and also in the upstream area of the reservoir. There are prominent karstic topographies developed in the neighborhoods of the watersheds at EL. 1,000 to 2,000 m above both banks of this reservoir. However, such topographies cannot be seen in the reservoir area.

7.2.3 Outline of Geology

(1) Stratification and Facies

Köprücay Conglomerate and the Beskonak Formation of the Miocene Epoch are distributed in the reservoir area. In the vicinity of the reservoir, there is Pre-Tertiary formations distributed outside the water impoundment area.

(a) Pre-Tertiary Formations

The Pre-Tertiary formations are composed of the Kirkkavak Formation, red limestones and radiolarites, ophiolite, and the Cretaceous Limestone. All of these formations belong to the Mesozoic Era, and they have complex distributions. With regard to stratification there are two opinions. One is that the order from underlying to overlying is the Kirkkavak Formation, red limestones and radiolarites, and limestone. The other is that these are formations of roughly the same age. Details have not yet been clarified.

The Kirkkavak Formation is distributed in a narrow band in the north-south direction at the skirt of the mountain at the left bank of the reservoir. On the western side it adjoins the Beskonak Formation by the Kepez Fault, while on the eastern side it is covered by the Cretaceous Limestone, and on the southern side by the Köprücay Conglomerate. The component rocks of this conglomerate are weakly metamorphosed shale and sandstone.

The red limestone and radiolarite formation outcrops locally at the right bank of the reservoir. Ophiolite is distributed from south (downstream side) of the reservoir to the west (left bank side), and is composed of gabbro and serpentine. The Cretaceous Limestone comprises the watersheds on both sides of the reservoir with wide distribution, and development of karstic topography is prominent.

(b) Tertiary Formation

The Köprücay Conglomerate belongs to the Miocene Epoch of the Neogene Period and is distributed chiefly at the reservoir right bank and the upstream area of the right bank. This formation contains large quantities of pebbles and subrounded pebbles of limestone, and the matrix is calcareous. This formation presents a bright gray to dark gray color in a fresh state, and is hard and compact but has been subjected to karstification. The formation is intercalated with thin layers of shale and sandstone at parts.

The Beskonak Formation was deposited in the same age as the Köprücay Conglomerate, and there are interfingers between the two. This formation is distributed mainly at the left bank of the reservoir. It is composed of alternations of shale and sandstone (with shale predominant), and thin layers of conglomerate intercalated at places. This formation is gray in color and compact in a fresh state, but when weathered, presents a brown color, and becomes soft.

(2) Geological Structure

In the vicinity of the Köprücay River basin, north-northwest to south-southwest geological structures such as folds and faults, are generally predominant in the Pre-Tertiary.

The Neogene formations overlie the Pre-Tertiary strata in unconformity and are distributed in a narrow band north-south along the Köprücay River. The boundary between the Neogene and Pre-Tertiary strata at the ground surface is the Kepez Fault extending north-south on the left bank of the Köprücay River, while on the right bank there is unconformity. The Köprücay Conglomerate and the Beskonak Formation comprising the Neogene rocks have an interfingered relationship, but judging by the distributions and lithofacies of the two at the ground surface, and data of the adjoining Oymapinar site, there is a tendency for the Köprücay Conglomerate to be underlying to a greater extent.

A fold structure consisting of one syncline and two anticlines is seen in the Neogene strata. The syncline is called the Köprücay Syncline, with the synclinal axis extending in a north-south direction roughly coinciding with the Köprücay River. Consequently, along the Köprücay River, the bedding planes of both the Köprücay Conglomerate and the Beskonak Formation incline toward the Köprücay River with the dip around 20 deg. At the Beskonak Formation distribution area on the left-bank side of the Köprücay River, there is the Korüdag Anticline that trends north-south, while at the Köprücay Conglomerate distribution area on the right bank side there is the Bozburum Anticline which trends northwest-southeast.

Faults cutting across the Neogene formations are either parallel to the above-mentioned fold structure or intersect it, but the number of them is small. Prominent faults parallel to the folds are the Kepez Fault and the Bucak Fault. The Kepez Fault extends north-south at the left bank of the Köprücay River, and comprises the boundary between the Beskonak Formation and Pre-Tertiary Formations (mainly Kirkkavak Formation). The Bucak Fault is located at the western wing of the Bozburum Anticline at the right bank of the Köprücay River. It extends parallel to the wing in a northwest-southwest direction and comprises part of the boundary between Köprücay Conglomerate and the Beskonak Formation. There are two prominent faults intersecting the fold structure. One is F-1 Fault extending east-west or north-northeast to south-southwest immediately upstream of the dam site (F-1 Fault), and the other extending west-northwest to east-southeast downstream of the Oluk-köprü springs and comprising part of the boundary between Köprücay Conglomerate and the Beskonak Formation.

7.2.4 Hydrogeology

(1) Rivers and Streams

The runoff of the Köprücay River has been recorded to be from 20 to 1,700 m^3/sec at the Beskonak gaging station located at roughly the center of the reservoir, the annual average being approximately 90 m^3/sec.

There are only four tributaries including the Akcay Dele and Koca Dele feeding the Köprücay River which have surface flows throughout the year, and all of these join the main stream in the vicinity of the upstream end of the reservoir. The catchment areas of these tributaries are comparatively large and all extend outside the distribution area of Köprücay Conglomerte. The tributaries other than the above have seasonal surface flow and their catchment areas are relatively small, and mostly limited to within the distribution area of Köprücay Conglomerate.

(2) Springs

The distribution of springs is shown in Fig. 7-2. Their locations may be grouped according to valley bottom, mountain foot and mountain slope. Those at the valley bottom are the Oluk-köprü springs and the group of springs downstream of the dam site.

The Oluk-köprü springs are of the largest scale in the reservoir area and its vicinity with water springing from Köprücay Conglomerate over a length of 2 km along the Köprücay River. The total discharge is at least 35 m^3/sec during the dry season, reaching two or three times this discharge in the rainy season.

The group of springs downstream of the dam is springing from the Köprücay Conglomerate 2 to 3 km downstream of the dam site throughout the year, with the total discharge apparently within about 2 m^3/sec. Springs at mountain foot (EL. 200 - 700 m) are mostly located in the Beskonak Formation distribution area at the left bank side of the Köprücay River. Springs on mountain slopes (mostly above EL. 700 m) are seen in the vicinity of the boundary between Cretaceous Limestone and the Kirkkavak Formation, and also in limestone distribution areas.

Wells may be seen in the Beskonak Formation distribution area, and hamlets exist in the vicinities.

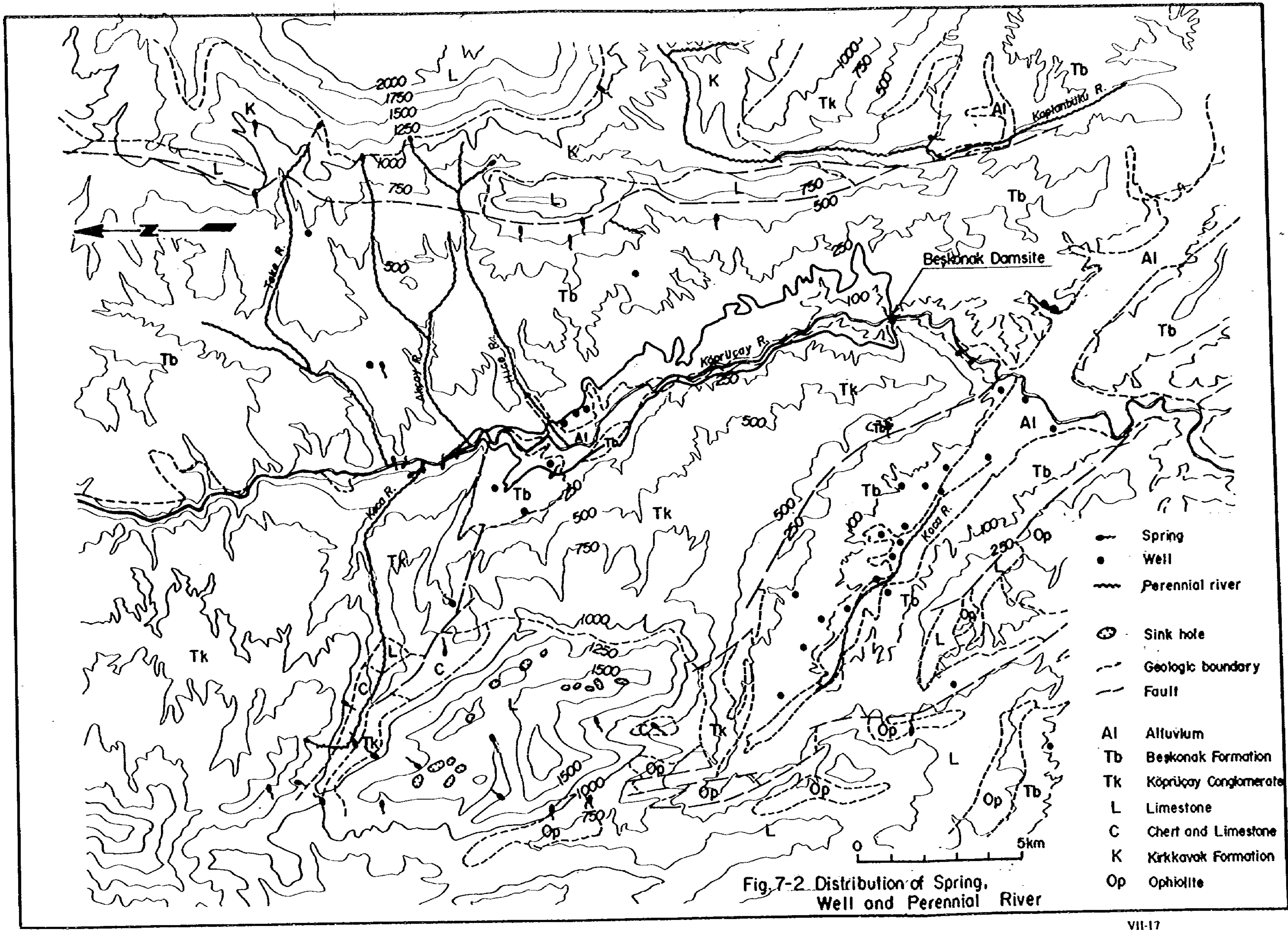


Fig. 7-2 Distribution of Spring, Well and Perennial River

(3) Permeabilities of Formations

The hydrogeological characteristics of the formations are judged as follows on the basis of the constituent rocks, whether or not karstic topography has developed, the conditions of surface water flows of rivers and streams, distributions of springs, wells, etc.

(a) Kirkkavak formation

This formation is composed of shale and sandstone, and is non-calcareous. Springs are seen at the boundary between this formation and limestone. Most streams in this distribution area have surface flows throughout the year. Therefore, this formation is judged to be impermeable.

(b) Red limestones and radiolarites

This formation is composed of red limestones and radiolarites, and because of the interbeddings of radiolarites, it will be impermeable as a whole.

(c) Ophiolite

This formation consists of gabbro and serpentine, and is judged to be not permeable.

(d) Cretaceous Limestone

This formation consists of limestone, and since development of karstic topography is prominent, permeability is judged to be high.

(e) Koprucay Conglomerate

Karstic topography is not developed in the distribution area of this formation. However, the formation has a large proportion of limestone pebbles, while the matrix is also calcareous. As a result of chemical analyses of samples collected from the dam site, the content of non-soluble constituents (SiO_2 and Al_2O_3) is 2.2% for limestone pebbles and 15.6% for the matrix (see Table 7-7).

As a result of investigations by core boring and test adits at the dam site, it has been found that Koprucay Conglomerte has been karstified, and groundwater level is lower than the river level. Springs and wells are not seen at the mountain foots and slopes of the distribution area of this formation, and there are many streams having seasonal surface flows. In view of the above, this formation is judged to be permeable.

(f) Beskonak Formation

This formation is composed of sandstone and shale. The results of chemical analyses of samples taken from the reservoir area are shown in Table 7-7. The content of non-soluble components is 30 to 40%. There are many springs and wells in the distribution area of this formation, and most streams have surface water throughout the year. Also, there are many cases of water springing seen in the vicinity of the boundary between this formation and Köprücay Conglomerate. Accordingly, although this formation is fairly calcareous, it is judged to be not permeable.

Table 7-7 Qualitative Analysis of Calcareous Rock Collected from Beskonak Area

Sample No.	Locality	Formation	Rock Name	Result of analysis		Norm calculation (1)		Norm calculation (2)	
				Composition	% (wt)	Composition	% (wt)	Composition	% (wt)
BC-1	Drillhole LS-1 on the left bank in the vicinity of Damsite	Köprüçay Cgℓ.	Cgℓ. (gravel)	CaO	36.6	$CaCO_3$	65.5	$CaCO_3$	28.5
				MgO	14.9	$MgCO_3$	31.1	$CaMg(CO_3)_2$	68.1
				SiO_2	1.9	SiO_2	1.9	SiO_2	1.9
				Al_2O_3	0.3	Al_2O_3	0.3	Al_2O_3	0.3
				Total	53.7	Total	98.3	Total	98.8
BC-2	ibid.	Köprüçay Cgℓ.	Cgℓ. (matrix)	CaO	42.4	$CaCO_3$	75.9	$CaCO_3$	68.4
				MgO	3.0	$MgCO_3$	6.3	$CaMg(CO_3)_2$	13.8
				SiO_2	14.7	SiO_2	14.7	SiO_2	14.7
				Al_2O_3	0.9	Al_2O_3	0.9	Al_2O_3	0.9
				Total	61.0	Total	97.8	Total	97.8
BC-4	Beşkonak gauging station	Beşkonak F.		CaO	29.2	$CaCO_3$	52.3	$CaCO_3$	36.8
				MgO	6.2	$MgCO_3$	13.0	$CaMg(CO_3)_2$	28.5
				SiO_2	26.6	SiO_2	26.6	SiO_2	26.6
				Al_2O_3	5.3	Al_2O_3	5.3	Al_2O_3	5.3
				Total	67.3	Total	97.2	Total	97.2
BC-5	Road-cut on the south of Hortu	Beşkonak F.		CaO	28.2	$CaCO_3$	50.5	$CaCO_3$	41.1
				MgO	3.8	$MgCO_3$	7.9	$CaMg(CO_3)_2$	17.3
				SiO_2	30.0	SiO_2	30.0	SiO_2	30.0
				Al_2O_3	6.5	Al_2O_3	6.5	Al_2O_3	6.5
				Total	68.5	Total	94.9	Total	94.9

7.2.5 Watertightness of the Reservoir

With regard to watertightness of the reservoir, the reservoir and its surrounding area were studied with four different areas.

(1) Upstream Area

This area consists of both a part of the reservoir upstream of Beskonak village and its vicinity.

(a) Geology

The Beskonak Formation and Köprücay Conglomerate are distributed in the upstream area of the reservoir.

The Beskonak Formation is distributed on the left bank of the Köprücay River. It is also distributed at mountain foot on the right bank opposite to the Beskonak village. This formation adjoins the impervious Kirkkavak Formation at the east side with the Kepez Fault.

The Köprücay Conglomerate is distributed on the right bank with its eastern side interfingered with the Beskonak Formation, while at the western side it mainly abuts Cretaceous Limestone. Therefore, permeable formations consisting of Köprücay Conglomerate and Cretaceous Limestone are widely distributed on the right bank of the upstream area.

(b) Oluk-köprü Springs

The Oluk-köprü springs comprise a group of springs emerging from the Köprücay Conglomerate over a distance of approximately 2 km along the Köprücay River bank in the vicinity of the upstream end of the reservoir, and elevations of springing are from 160 to 170 m.

According to Karanjac (1976), the hydrologic conditions of the Oluk-köprü springs are described below.

i) The total discharge in the dry season is approximately 30 m^3/sec with double to triple this volume in the rainy season.

ii) The annual discharge is approximately 1,400 x $10^6 m^3$ to make up more than 50% of the annual runoff at Beskonak gaging station located approximately 4 km downstream.

iii) As a result of water quality analyses, spring water is judged to be pure groundwater.

iv) Approximately one third of the annual runoff at Beskonak gaging station is being supplied from outside the catchment area.

v) The area underlained by pervious formations (Köprücay Conglomerate and limestone) upstream of the reservoir may be considered as the source of the spring water, but the annual discharge of spring water is approximately double the water possible to be supplied from this area.

The Köprücay Conglomerate from which the Oluk-köprü springs emerge is bounded on the eastern and southern sides by the impermeable Beskonak Formation. In order to further clarify the geological conditions in the vicinity of the Oluk-köprü springs, three drillholes totalling 742 m was drilled as a part of the UNDP/DSI Project. The results are summarized below.

i) The Köprücay Conglomerate in the vicinity of the springs is continuous down to the bottom (EL. -138 m) of one drillhole at the left bank and the bottom (EL. 1 m) of one drillhole at the right bank, and it was confirmed that there were few intercalation of impervious layer.

ii) The water levels in drillholes in Köprücay Conglomerate are slightly higher than the water level of the river.

iii) Beskonak Formation lies in fault contact with Köprücay Conglomerate, and it was confirmed that this Beskonak Formation was continuous down to the bottom (EL. -45 m) of one drillhole of 243 m long.

In view of the above, it is thought that the groundwater passing through the Cretaceous Limestone and the Köprücay Conglomerate distributed widely at the right bank side, are dammed by the Beskonak Formation distributed at the eastern and southern sides and spring at the Köprücay River. The Köprücay Conglomerate extend further to the south and there is a strong possibility that some kind of barrier hindering infiltration of groundwater exists in the vicinity of the opposite bank to the Beskonak village. Karanjac (1976) surmised that an impermeable layer (radiolarite layer) existed subjacent to the Köprücay Conglomerate.

(c) Watertightness

In the vicinity of the drainage area, what will be a problem in the aspect of watertightness of the reservoir is the Köprücay Conglomerate. Detailed conditions of karstification of the Köprücay Conglomerate have not yet been clarified. There is a possibility that karstified Köprücay Conglomerate is being hidden underlying the Beskonak Formation at the right bank of the Köprücay River.

As described above, the geological condition of the upstream reservoir area has not been adequately clarified. However, the existance of Oluk-köprü springs at EL. 160 to 170 m indicates that the groundwater level at the upstream area of the reservoir is slightly higher than the design high water level of the reservoir of EL. 155 m, and there is no possibility of leakage from the reservoir at the upstream area.

(2) Left Bank Area

This area comprises the left bank of the Köprücay River downstream from Beskonak village to immediately upstream of the dam.

The Beskonak Formation is distributed in this area. This formation is composed of alternations of shale and sandstone. The shale is not permeable predominant, while there is a very small amount of conglomerate intercalated. An anticlinal structure (Korüdag Anticline) having an axis parallel to the Köprücay River is developed in the Beskonak Formation, and the bedding planes are dipped toward the reservoir. Consequently, even if permeable layers such as conglomerate are intercalated in the Beskonak Formation, there is little possibility of leakage from the reservoir occurring through the Beskonak Formation.

Further, it has been confirmed by boring that slightly karstified Köprücay Conglomerate is distributed under the Beskonak Formation at the left bank in the vicinity of the dam site. It is imagined that Köprücay Conglomerate similarly underlies the Beskonak Formation at the entire left bank side of the reservoir. Accordingly, there is a possibility that leakage from the reservoir will reach downstream of the dam after passing by the dam vicinity through conglomerate under the Beskonak Formation. Still further, there is a possibility that the Köprücay Conglomerate subjacent to the Beskonak Formation is continuous to the Kaplanbuk valley (22 km east of the dam site) outside the catchment area. It was reported by Tarimci (1982) that there were springs above EL. 130 m in this area, indicating that the groundwater level is high. As it was also confirmed in the field investigations by the Survey Mission in October 1982, there is practically no possibility of leakage to the Kaplanbuk valley.

(3) Right Bank Area

The scope of this area is the right bank side from Beskonak village to immediately upstream of the dam site.

(a) Geology

The Köprücay Conglomerate is distributed at the right bank area of the reservoir. The width is 3 to 8 km at the ground surface and adjoins the Cretaceous Limestone and the Beskonak Formation at its western side.

Two drillholes named RB-1 and -2 were excecuted by DSI during the Feasibility Study. These drillholes were drilled in the Köprücay Conglomerate, and measurement of water level and permeability tests were executed. The results of them are shown in Figs. 7-3 and 7-4 and the following table.

Item	Unit	RB-1	RB-2
Test Section	Section	52	44
Mean Lu. Value	Lu	2.8	37
Section: injection pressure at hole top not increased to specified level	Section (%)	2 (4)	6 (14)
Water level in drillhole (June 23th, 1983)	m (Depth)	56.5	23.4

Fig. 7-3 Log of Drillholes RB-1 and 2

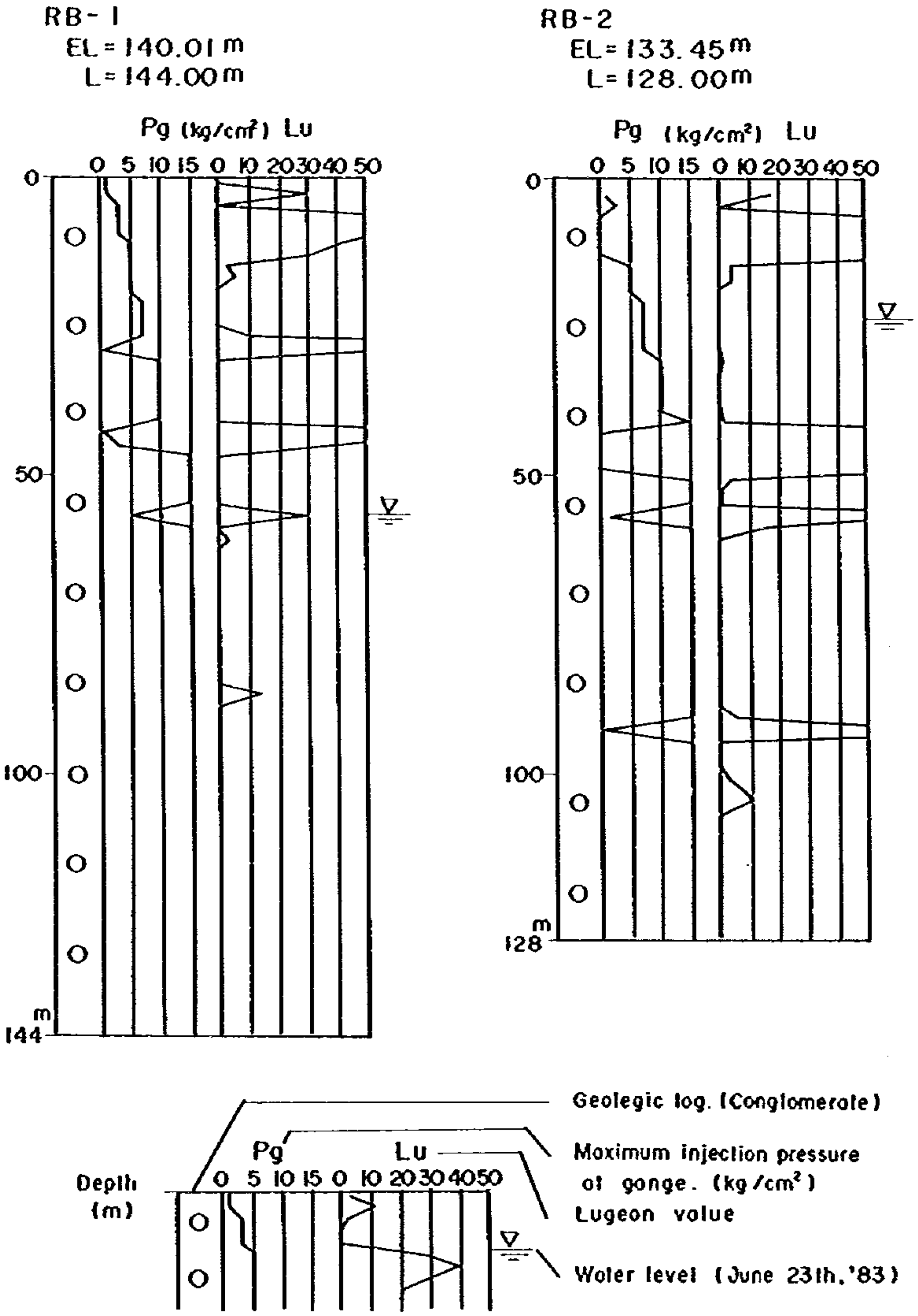
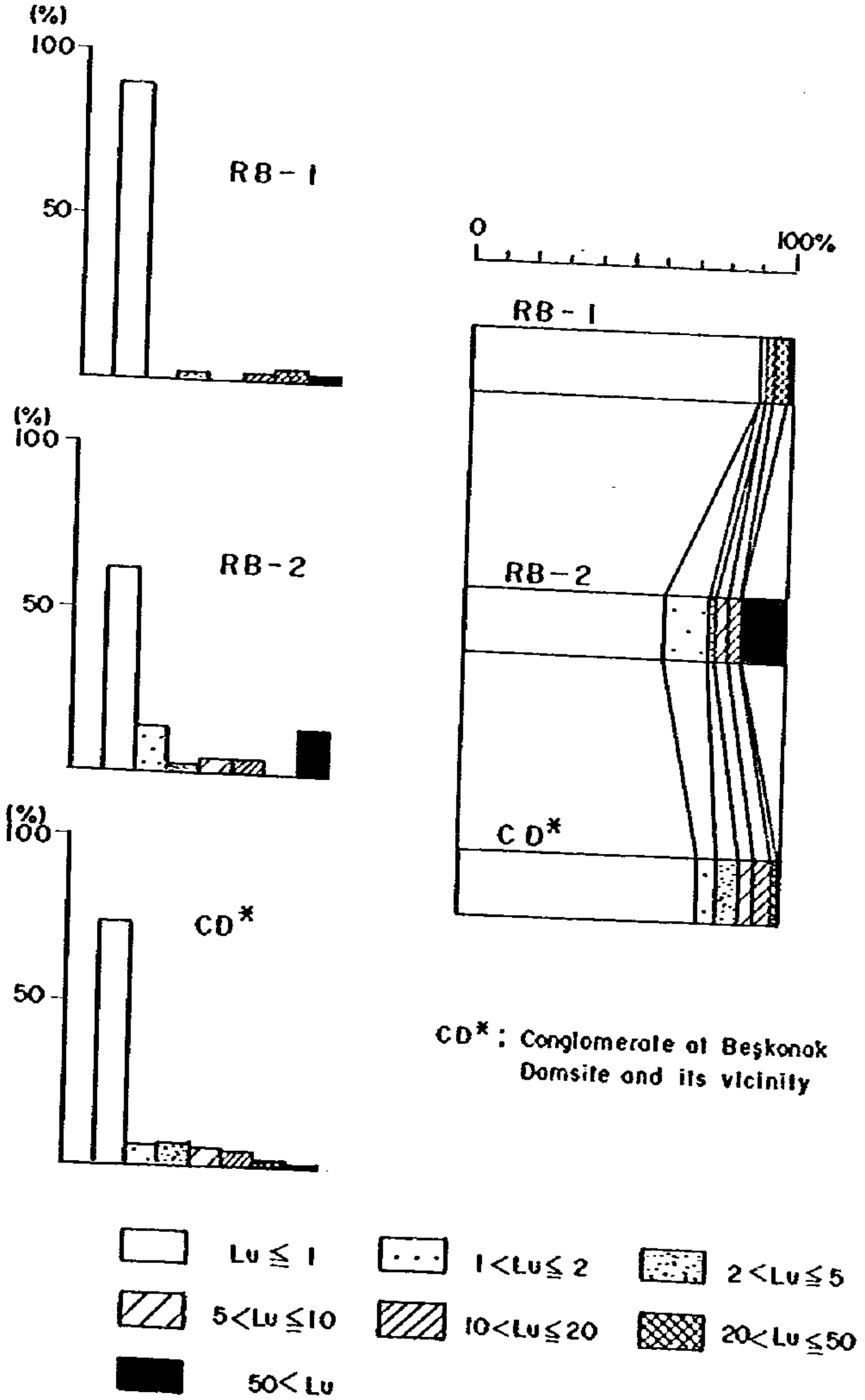


Fig. 7-4 Lugeon Value in Drillholes RB-1 and-2



They are summerised as follows.

i) Permeable surface layer is 14 m thick

ii) Below 60 m deep (EL.70 m) permeable portion are limitted and most portion (88%) are quite impermeable (0 Lu)

iii) No intercalation of shale extists in the conglomerate

iv) Water level in the drillholes are lower than river level.

Judging from the results of these drillholes and those of existing investigation works in the vicinity of the dam site, the Köprücay Conglomerate is karstified and permeable down to the elevation lower than the design high water level of the reservoir of EL.155 m

The Köprücay Conglomerate continues on by the right bank to the downstream area of the dam site, and abuts Cretaceous Limestone at the western side which shows a prominent karst topography and is estimated to have high permeability.

Meanwhile, at the south-western side next to the Bucak Fault there is the impermeable Beskonak Formation. The Beskonak Formation distributed in the vicinity of the Bucak Fault is continuous to above EL. 180 m which level is higher than the design high water level of the reservoir. It is thought that Pre-Tertiary strata headed by the Cretaceous Limestone are hidden below the conglomerate.

(b) Watertightness

From the standpoint of watertightness, what will be problems at the right bank side of the reservoir are the Köprücay Conglomerate and the Cretaceous Limestone. Probable leakage paths to downstream of the dam and other catchment area are

1) along the conglomerate distribution area to downstream area.

2) through the Cretaceous Limestone to the west.

Regarding the passage of 1), as described in 7.3, "Geology of Dam Site Vicinity," the Köprücay Conglomerate in the vicinity of the dam site has been karstified to great depth, and due to its fairly high permeability it is thought the possibility of leakage by this passage 1) is high.

With regard to the possibility of leakage by the path of 2), it should be judged by the distribution of the Cretaceous Limestone. Eroskay's (1968) 1/25,000 geological maps do not cover the Cretaceous Limestone distribution area, but when supplemented by the 1/250,000 geological map of Karanjac (1976), the outline of distribution of the Cretaceous Limestone is described below.

i) The Cretaceous Limestone, in the western side, adjoins ophiolite which extends in a north-northwest to south-southwest direction in the Aksu River basin. This ophiolite comprises the western boundary of the permeable strata (Cretaceous Limestone and Köprücay Conglomerate) in the Köprücay River basin.

Details of the relationship between the Cretaceous Limestone and ophiolite are unknown, but from the fact that ophiolite is approximately 5 km wide, it is thought that an effective impervious layer is comprised.

The elevations of the boundary between the Cretaceous Limestone and ophiolite are almost all above EL. 300 m which is higher than the design high water level of the reservoir.

ii) The Cretaceous Limestone is unconformably overlain by the Köprücay Conglomerate at the northern side. This Köprücay Conglomerate extends to the right bank side of the upstream reservoir area and bounded by the ophiolite described in i). Consequently, the groundwater in the Köprücay Conglomerate distribution area either springs at the Oluk-köprü springs (EL. 160 - 170 m) or reaches the interior of the Cretaceous Limestone on the southern side.

iii) The Cretaceous Limestone is unconformably overlain by the Beskonak Formation at the southern side in the Koca Dele basin (joining with the Köprücay River downstream of the dam site), and the elevation of the boundary appears to be above EL. 200 m which is higher than the design high water level of the reservoir.

Judging from the outline of distribution of the Cretaceous Limestone, there is little possibility of leakage through this limestone.

(4) Dam Site Vicinity

Details of watertightness of this area are described in 7.3.

(5) Problematic Points Regarding Watertightness of Reservoir

The problematic points regarding watertightness of the reservoir are indicated below.

(a) There is a possibility of leakage from the reservoir occurring through the Köprücay Conglomerate.

(b) The probable leakage passages are the four cases below.

i) A path going through the right bank Köprücay Conglomerate to reach downstream of the dam site

ii) A path going from the right bank Koprucay Conglomerate through the Köprücay Conglomerate underlying the left bank Beskonak Formation to reach downstream of the dam site

iii) A path leading from the right bank Köprücay Conglomerate through Cretaceous Limestone distributed at the western side to reach another basin

iv) A path going through the Köprücay Conglomerate in the vicinity of the dam site to reach downstream of the dam site.

(c) Of the passages described above, there is little possibility for the path of iii), while the paths of i) and ii) would join with that of iv). Consequently, evaluation of the permeability of the Köprücay Conglomerate distributed in the vicinity of the dam site is of greatest importance in examining the watertightness of the reservoir.

7.2.6 Stabilities of Slopes in the Vicinity of the Reservoir

Topography in the vicinity of the reservoir is generally relatively gentle and landslide have not been found so far. Also, there are no places where surface deposits are seen to be thick. Accordingly, it is thought there is little possibility of large-scale landslides or collapses occurring.

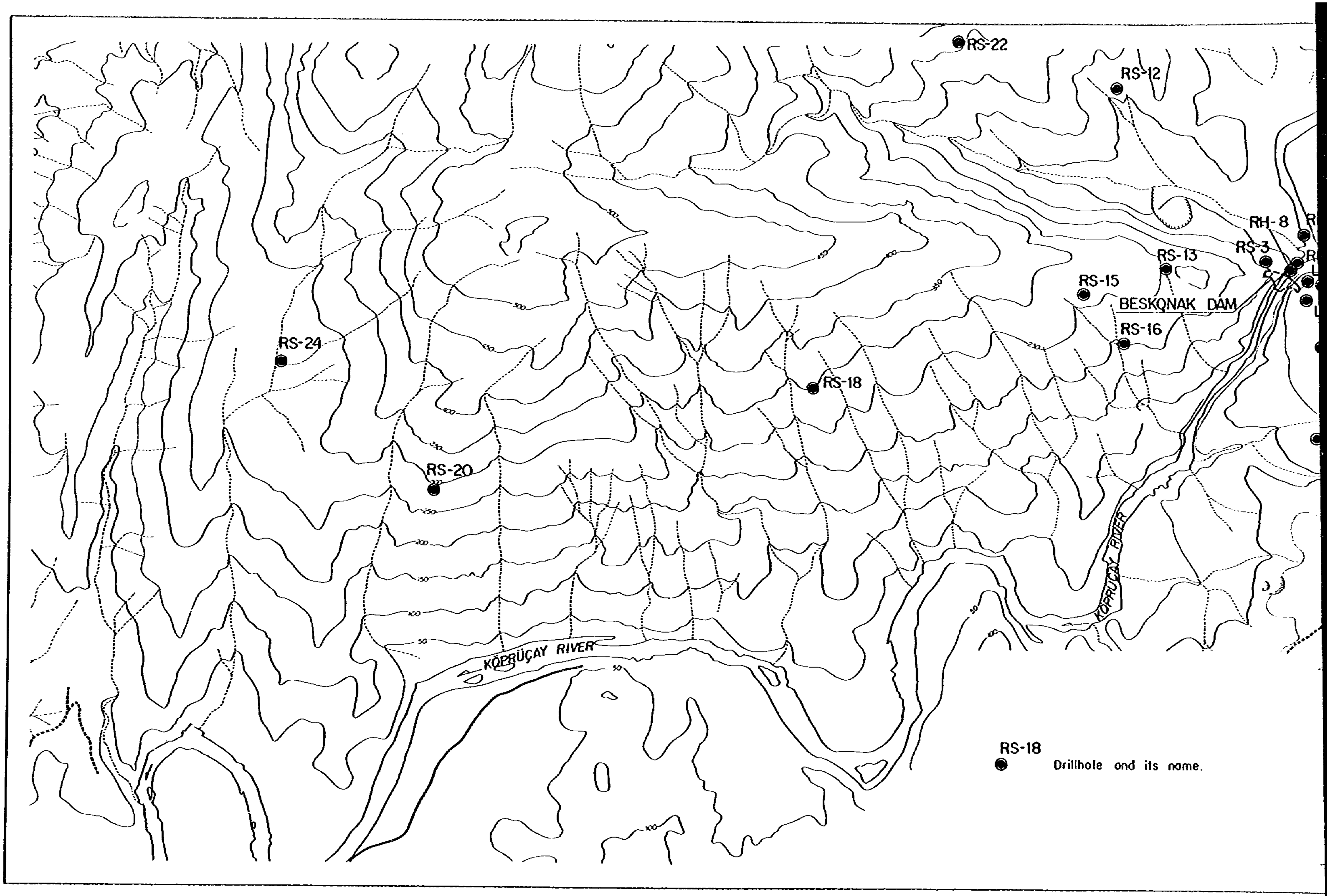
7.3 Geology of the Dam Site Vicinity

7.3.1 Method of Investigation

Surface geological reconnaissances, core boring and driving test adit had been carried out in the vicinity of the dam site. The results of these investigations were compiled by Sumerman (1973). The results of surface reconnaissances were compiled in geological maps of 1/5,000 scale.

Drilling was performed with 26 holes, totalling 6310.68 m (including the dam site), the locations and quantities are shown in Fig. 7-5 and Table 7-4. The average length of drillholes is approximately 240 m, while the longest hole is LS-6 with 400.22 m, and the lowest elevation reached is -236.86 m of LS-19. The elevations investigated by core boring are shown in Fig. 7-7, and a range between EL.200 m and -120 m has been examined extensively. The drillholes most distant from the dam site are LS-19 (1.9 km) on the left bank and RS-24 (3.5 Km) on the right bank. Further, permeability tests were performed in the drillholes.

A total of six test adits, 1,070.3 m, had been excavated within a range of 200 m from the dam site. The locations and quantities are shown in Fig. 7-6 and Table 7-5. The elevations of adits are between 54 and 150 m and their distribution are limited rather than that of core boring (see Fig. 7-7).


RS-22
RS-12
RH-8
RS-3
RS-13
RS-15
BESKONAK DAM
RS-16
RS-24
RS-18
RS-20
KÖPRÜÇAY RIVER
KÖPRÜÇAY RIVER
RS-18
Drillhole and its name.

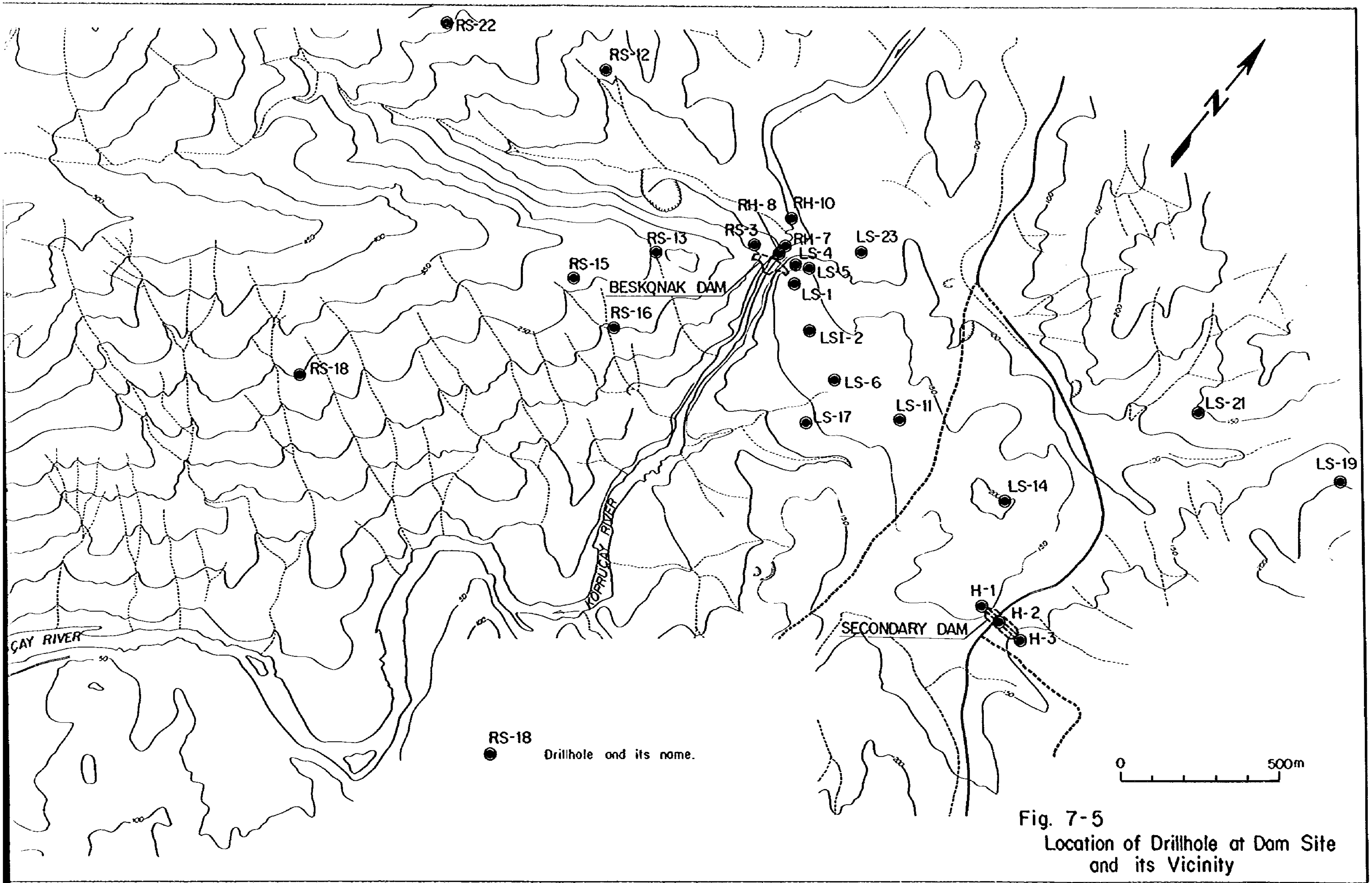


Fig. 7-5
Location of Drillhole at Dam Site and its Vicinity

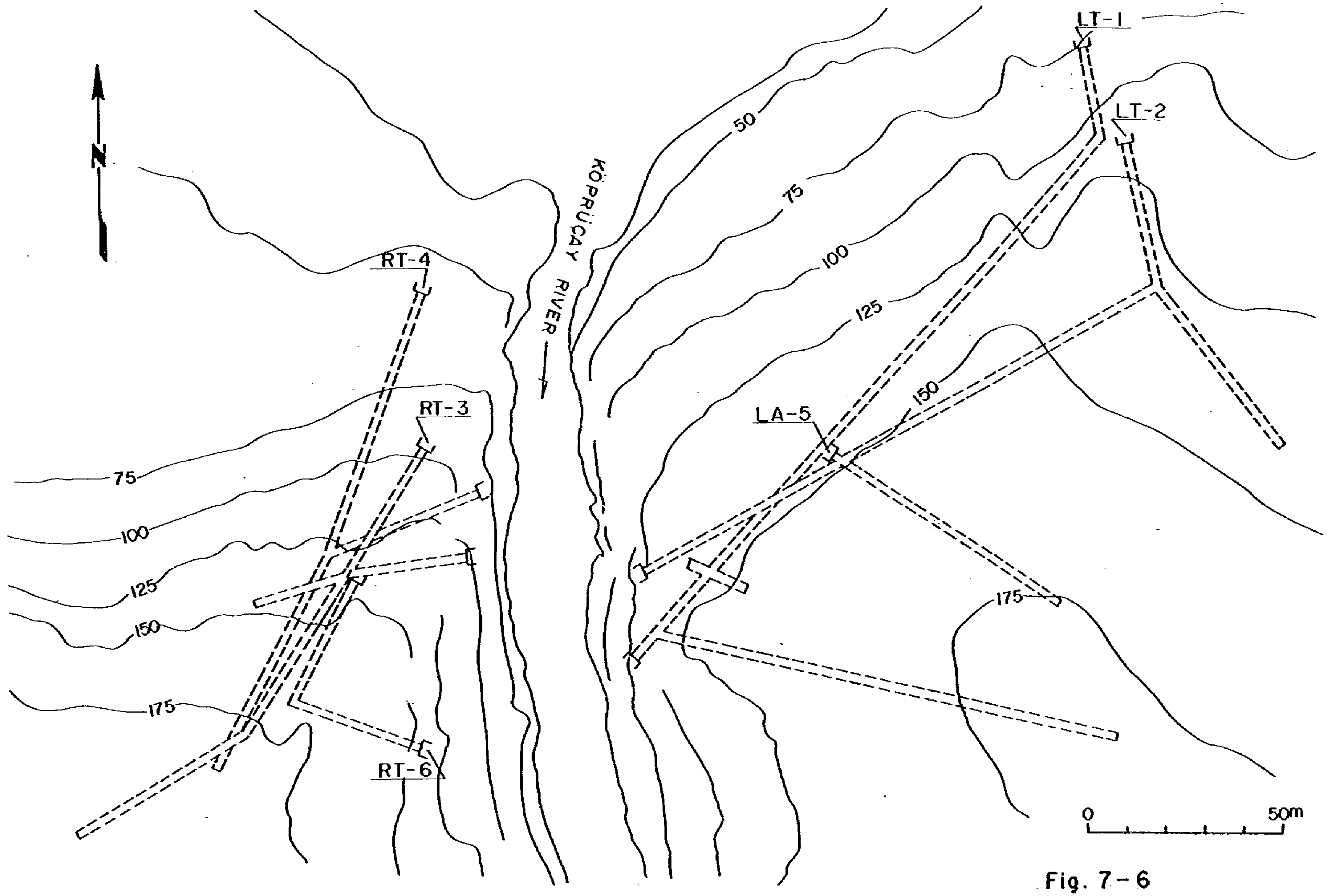
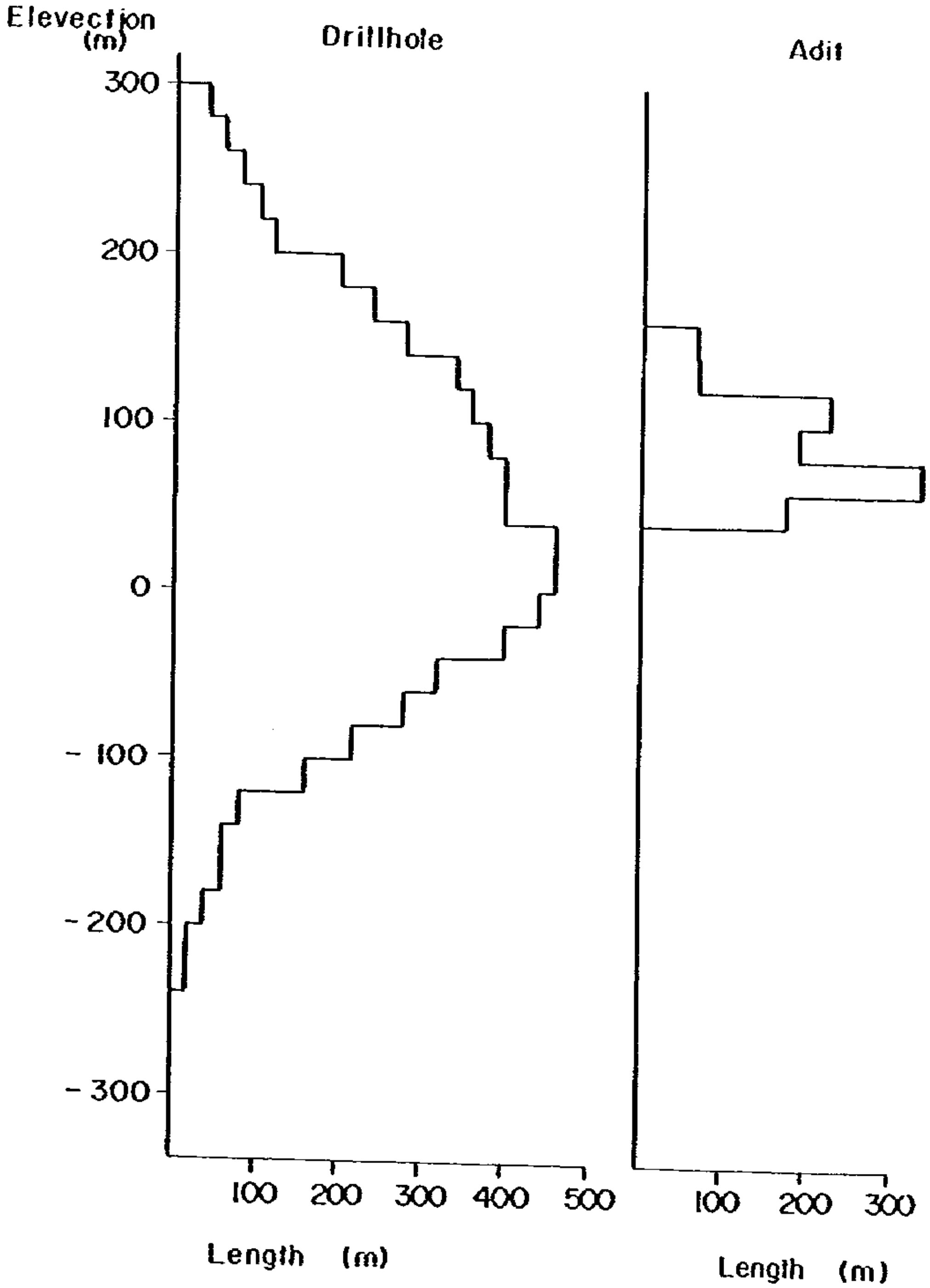


Fig. 7-6
Location of Adit at Dam Site

Fig. 7-7 Investigation Work-Elevation in the vicinity of Dam Site



7.3.2 Outline of Topography

The Köprücay River flows southward meandering slightly in the vicinity of the dam site. A section of approximately 700 m in the vicinity of the dam site forms a narrow gorge reaching a depth of 150 m and the valley is 15 to 40 m wide at bottom. At the upstream and downstream of the gorge, valley bottom is 100 to 300 m wide and the inclinations of both banks are 20 to 40 deg. On the left bank, the Hortu Dele joins with the main stream approximately 700 m downstream of the dam site and cuts a deep valley. The ridge extending continuously from the dam site to the secondary dam is thin in general, and at the design high water level of 155 m, this ridge is generally 100 m to 250 m wide. The secondary dam site is located on a saddle at EL.144 m, with a gentle topgraphy spread out in the vicinity.

On the right bank, there is a ridge of which the upstream side slope is more than 60 deg., but the downstream side slope is 20 to 30 deg. and comparatively gentle to comprise an adequately wide mountain body.

7.3.3 Outline of Geology

(1) Distributions of Rocks

The Köprücay Conglomerate and the Beskonak Formation are distributed in the vicinity of the dam site. The Köprücay Conglomerate is mainly outcropped on the right bank and the Beskonak Formation on the left bank, with the boundary between the two running roughly along the Köprücay River. Further, with the fault (F-1) crossing the Köprücay River upstream of the dam site as the borderline, the boundary between the two becomes irregular and the Köprücay Conglomerate extends to the left bank. In other words, the Köprücay River flows through the Köprücay Conglomerate distribution area in the downstream of the F-1 Fault, and the dam site was selected in the vicinity of the upstream end of a gorge cut by the Köprücay River.

The Köprücay Conglomerate is mainly outcropped on the right bank in the vicinity of the dam site. The Köprücay Conglomerate to the Bucak Fault is approximately 3.5 km distant from the dam site, and the conglomerate adjoins the Beskonak Formation through this fault. The lower limit of the conglomerate at the right bank has not been confirmed even at a drillhole (RS-13) with its bottom at EL. -109 m. The Beskonak Formation is also distributed on the right bank, but restricted to a small area below EL.100 m of Goyal Yulu Canyon at the upstream side of the F-1 Fault.

On the left bank, the Beskonak Formation is exposed over a wide area and reaches to the Kepez Fault approximately 4.5 km distant from the dam site to contact the Kirkkavak Formation or the Köprücay Conglomerate by this fault. The Köprücay Conglomerate is outcropped in the vicinities of the dam site and the Hortu site, and underlies the Beskonak Formation.

The boundary between the Beskonak Formation and the Köprücay Conglomerate has been confirmed partly by several drillholes. At the upstream side of the F-1 fault the boundary is confirmed at EL. -90 m of a drillhole LS-21, 1,440 m away from the Köprücay River, and at EL. -193 m of LS-19, 1,900 m away, and is clarified to dip eastward. On the other hand, at the downstream side of the F-1 fault, the boundary has been confirmed at EL. 20 m of a drillhole LS-14, 970 m distant from the Koprucay River.

As for the conglomerate outcropped in a narrow strip at the Hortu saddle, it has been confirmed to be continuous down to the bottom of a drillhole H-2 (mouth of hole at EL.143.96 m, length 200 m), showing that it is not an intercalation in the Beskonak Formation. As stated above, the boundary between the Beskonak Formation and the Köprücay Conglomerate is higher on the downstream side than on the upstream side with the F-1 fault as the boundary.

It might be added that the lower limit of distribution of the Köprücay Conglomerate and information on underlying strata have not been obtained.

(2) Lithofacies and Lithological Character

The Köprücay Conglomerate is mainly composed of round or subround pebbles of sandstone and a calcareous matrix (see Table 7-7), and it is stratified with most individual strata being 3 m or more in thickness. In the vicinity of the dam site and at the right bank, there are few intercalations of sandstone and shale in the Köprücay Conglomerate, but at locations close to the Beskonak Formation on the left bank, it has been found from drillholes LS-1, LSI-2, LS-6, LS-11 and LS-16 that thin layers chiefly of sandstone are interbedded.

In the vicinity of the Bozburum Anticline at the right bank, it has been confirmed by surface reconnnaissances and a drillhole RS-20 that shale is intercalated. Köprücay Conglomerate is hard and compact, is comparatively massive, jointed in part, but karstified along joints.

The Beskonak Formation is composed mainly of alternations of sandstone and shale, with shale predominant. The rock is quite tight where fresh, but parts near the ground surface are brown in color and weathered to be soft. This formation has a fairly high lime content (see Table 7-7), but is rarely karstified.

(3) Geological Structure

(a) Folding

The Köprücay Conglomerate and the Beskonak Formation distributed in the vicinity of the dam site are together folded with an axis in the north-south direction roughly parallel to the Köprücay River. The fold structure is comprised of one syncline and two anticlines sandwiching the former, and has gentle folds with dips of strata at fold wings 30 deg. or under.

The synclinal axis roughly coincides with the Koprucay River and extends in the north-south direction so that the dam site is located roughly on the synclinal axis.

The anticline at the right bank (Bozburum Anticline) is located one-sidedly in the west ward of the conglomerate distribution area. The anticlinal axis located at approximately 3 km southwest extending in the northwest-southeast direction, and crosses the Köprücay River at about 2 km downstream of the dam. The anticline at the left bank (Korudag Anticline) is located approximatley 2.5 km east of the dam site in the Beskonak Formation distribution area with its axis extending in the north-south direction.

Accordingly, the strata in the vicinity of the dam site show a strike of north-south on the whole, and dip gently toward the Köprücay River with inclinations of 30 deg. or under.

(b) Faults

Prominent faults existing in the vicinity of the dam site are F-1 and F-7 faults.

The F-1 fault crosses the above-mentioned fold structure, and goes across the Köprücay River approximately 150 m upstream of the dam site. In this vicinity it comprises the boundary between the Beskonak Formation and the Köprücay Conglomerate over a distance of about 1.5 km.

The extension of the fault to the left bank side can be pursued for approximately 1 km along the Degirmenlik River to the Beskonak Formation distribution area, but further extension to the east is indistinct. Toward the right bank side, the fault can be pursued for about 2 km through the conglomerate distribution area to the Bucak Fault.

The F-1 fault trends east-west on the left bank and east-west to northeast-southwest on the right bank and dips 50 to 60 deg. to the upstream side. This fault has been confirmed at drillholes RH-10 and LS-18 as a sheared zone of 10 to 20 m wide comprising the boundary between the Beskonak Formation and the Köprücay Conglomerate.

In the conglomerate next to the fault, secondary faults are developed in a zone of approximately 40 m wide. These secondary faults are seen in the vicinities of the portals of test adits LT-1 and LT-2 on the left bank of the dam site.

The F-7 fault is located at a distance of approximately 1 km from the dam site. It extends to the southwest from the vicinity of the eastern end of the F-1 fault, reaches the Köprücay River approximately 1.2 km downstream of the dam site, then runs further along the right bank of the Köprücay River until it reaches the Bucak Fault. The F-7 fault has a nearly vertical dip and its sheared zone of 10-40 m wide is observed at the ground surface on the left bank of the dam site.

Other than the above faults, there are relatively continuous faults developed in the conglomerate distribution area. All of these have their upstream ends in the vicinity of the F-1 fault and extend toward the south-southeast. They have roughly vertical dips and sheared zones of widths not exceeding 1 m.

(c) Minor Faults and Joints

In the Köprücay Conglomerate there are minor faults and joints. Minor faults are accompanied by sheared zones less than 20 cm wide and are less continuous than faults described in (b). These minor faults and joits, in the vicinity of the dam site, according to results of investigations at test adits, predominantly strike N70°E-EW roughly orthogonal to the synclinal axis, or N10°-30°E crossing the synclinal axis diagonally, and dip close to vertical. In the vicinity of the Bozburum Anticline, as a result of surface reconnaissance, minor faults and joints trend northwest-southeast or northeast-southwest and dip close to vertical.

On the other hand, in the distribution area of the Beskonak Formation, faults and joints are indistinct on the whole.

7.3.4 Karstification in the Vicinity of the Dam Site

Of the rocks distributed in the vicinity of the dam site, the Beskonak Formation is alternating beds of sandstone and shale and is not karstified, whereas the Köprücay Conglomerate is composed of calcareous conglomerate and is karstified. The Köprücay Conglomerate, as described previouly, is widely distributed on the right bank in the vicinity of the dam site, while on the left bank, it also underlies the Beskonak Formation. In the area of distribtution of the Köprücay Conglomerate in the surroundings of the dam site, extreme karst topography such as sinkholes are not found. In a 1/5,000 scale geological map by Sümerman (1973), only one cave is shown with the entrance at EL.200 m on the right bank 800 m downstream of the dam site. However, as a result of drillhole and test adit investigations carried out at the vicinity ofonne dam site, it has been clarified that solution cavities* and solution channels* are developed in the Köprücay Conglomerate.

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* Here, solution cavities are of nearly circular cross-sectional shapes, whereas solution channels are of cross-sectional shapes which are long and narrow. Further, the two categories together are called solutions.

The geologic characteristics in drillholes and test adits were recorded by Sümerman (1973) as 1/100 scale boring logs and 1/50 and 1/100 scale test adit developments. The study results of karstification in the Köprücay Conglomerate are described as follows. In these records, solution channels of widths 0.5 cm and under and solution cavities of diameters of 1 cm and under are not indicated.

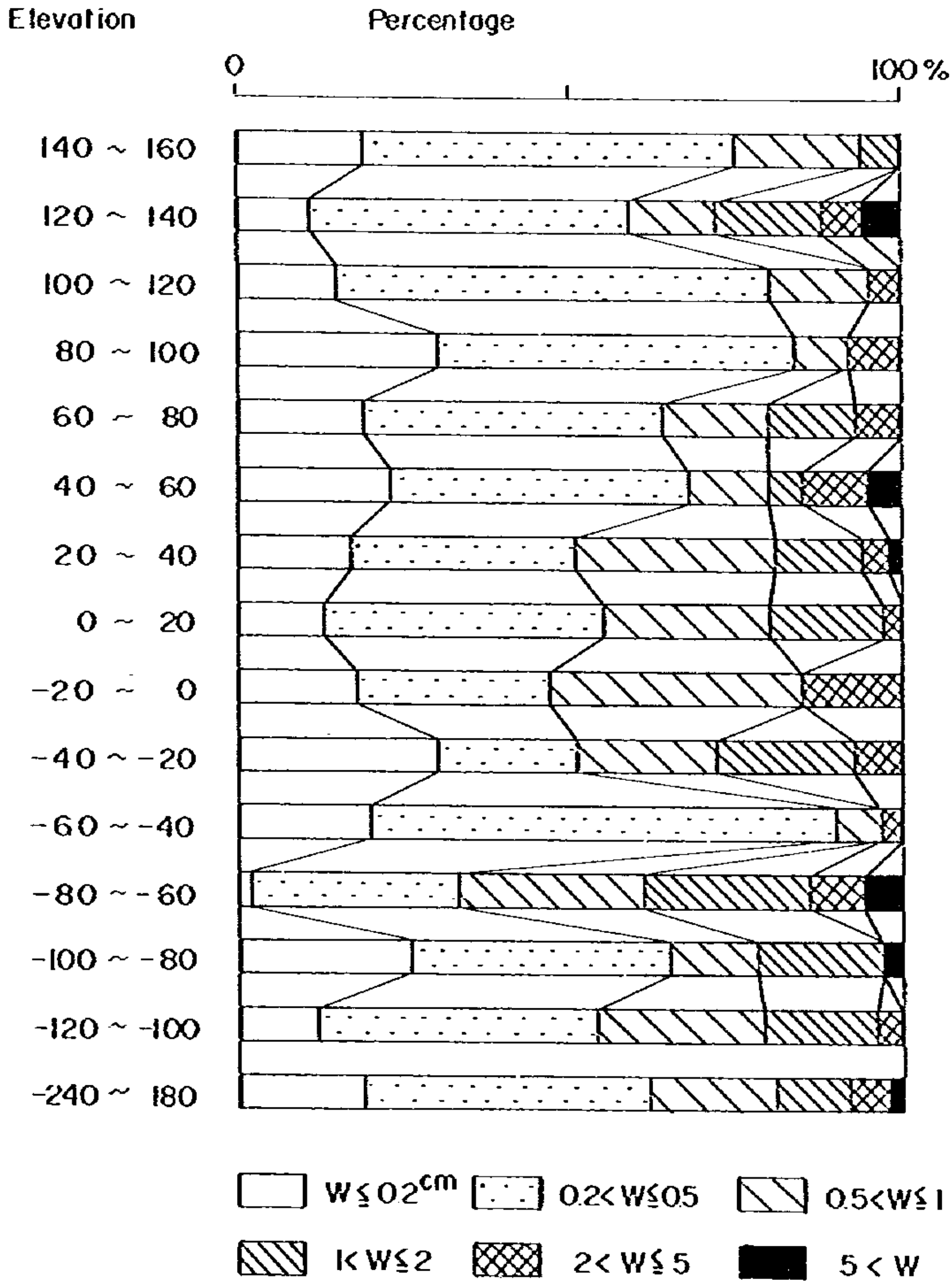
(1) Sizes of Solutions

The relations between widths and elevations of solutions confirmed by core boring are shown in Fig.7-8. Most of solutions are supposed to be filled with clay or calcite, as observed in test adits in the vicinity of the dam site. Their widths are not effective void widths. The width of solutions averages 0.9 cm, the maximum being 4 m in a drillhole LS-11 at a depth of 260 m. Solutions of 0.2 to 0.5 cm wide are largest in number, making up 42% of the whole, while those of 5 cm wide or larger make up only 1%, and on the whole the solutions are of small sizes.

Further, according to Fig.7-8, although there is variation deeper than EL.0 m in the ratio of composition regarding the sizes of solutions, it may be said that as a whole, they are roughly uniform. Also, it was confirmed by core boring that practically no solutions of width larger than 1 cm can be recognized under EL. -120 m.

The widths of solution cavities in test adits average 1.1 to 3.4 cm with the largest being 80 cm at 46 m in main adit of LT-1. Solution channels of widths 2 cm or less make up 70% of the whole, and those of widths of 10 cm or more make up 7% of the whole. The diameters of solution caves average 25 to 60 cm, the maximum being 150 x 300 cm in the vicinity of 43 m in the entrance adit RT-4. Solution cavities of diameters 10 to 50 cm make up 58% of the whole, with those of diameters of 1 m or more make up about 5% (4 cavities).

Fig. 7-8 Width of Solution in Drillhole



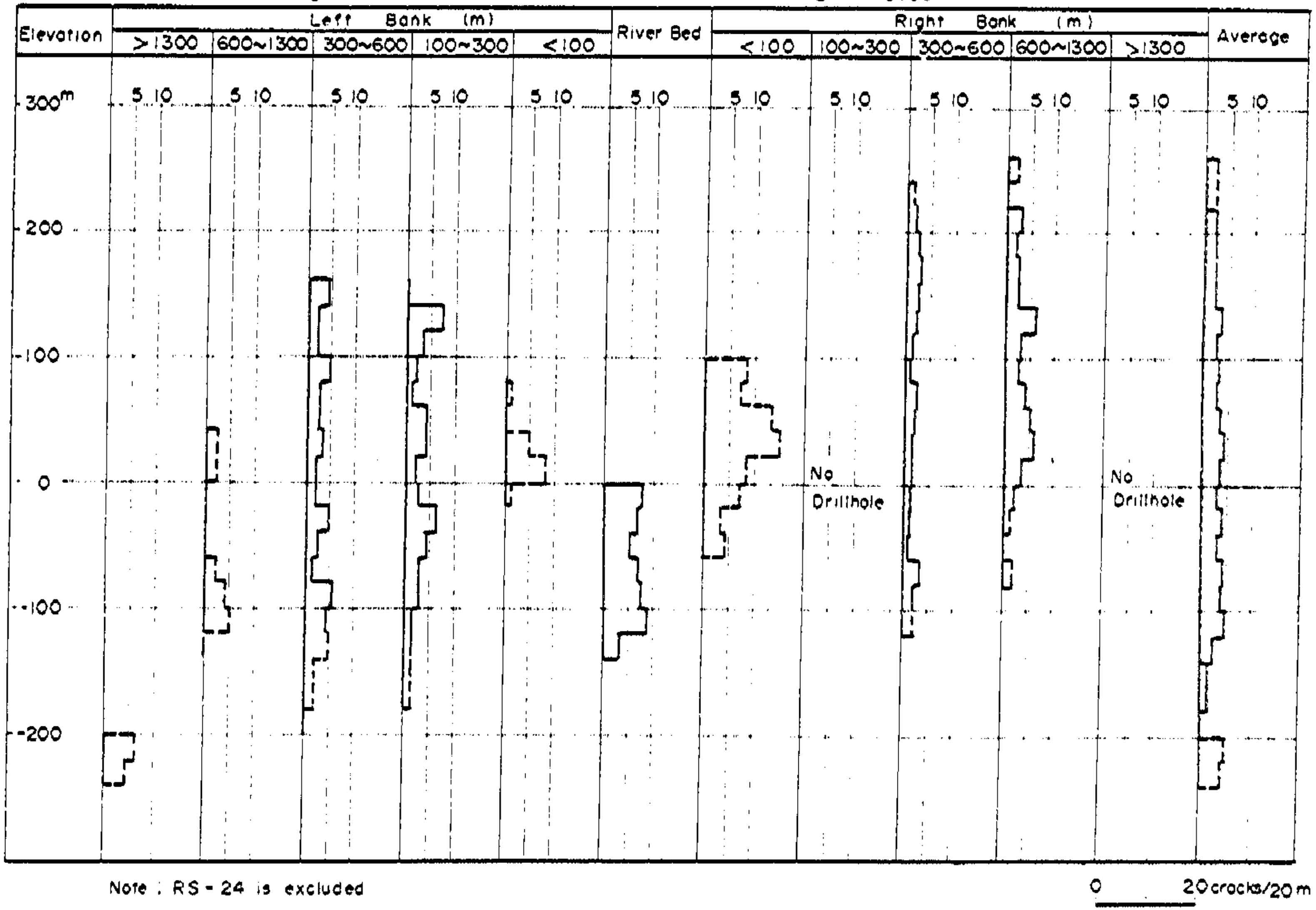
(2) Distribution Frequency of Solution

Since drillholes have the purpose of making investigations for dam construction and curtain grouting, they are located in a long, narrow area extending in the norhteast-southwest direction. Fig. 7-9 shows drillholes grouped according to distance from the Köprücay River and the distribution of solutions in the Köprücay Conglomerate by elevation. Solutions exist even in the vicinity of the bottom (EL.-236.86 m) of a drillhole LS-19 drillhole reaching the lowest elevation. The lower limit of karstification has not yet been confirmed.

The distribution frequency of solutions shows a high occurrence (approximately 0.5 per meter) particulary at the river bed and within 100 m far from the river bed. By elevation, there is slightly high occurrence at elevations of 120 to 140 m, 20 to 40 m, and -40 to -20 m. Below EL.-120 m, though there are few drillholes going down to this depth, it appears that the distribution frequency becomes smaller. For the whole dam site vicinity, it may be considered that the distribution frequency of solutions in the Köprücay Conglomerate is approximately uniform and the average is 0.13 per meter (7.8 m spacing).

Meanwhile, test adits have been excavated in a range within 200 m far from the dam site and between elevations of 54 and 150 m. Solution channels were found to be distributed at a frequency averaging 0.33 per meter, and solution cavities at 0.01 per meter, which are higher than the frequency of solutions in drillholes near the test adits.

Fig. 7 - 9 Distribution of Solution in Drillholes



Note : RS - 24 is excluded

(3) Directions of Solutions

Practically all of the solution channels observed at the test adits have developed along faults and joints, while 87% of the solution cavities have developed along faults and joints. In other words, 93% of faults and continuous joints are accompanied by solution channels or solution cavities.

Accordingly, it may be said that karstification of the Köprücay Conglomerate has progressed along faults and joints in the bedrock. As described in 7.3.3(3), faults and joints having strikes of N70°E-EW, N10-30°E, and dips close to vertical are fairly predominant. It is considered that the direction of development of solution channels roughly coincide with these faults and joints.

(4) Continuity of Solutions

Since the groundwater level in the vicinity of the dam site is lower than the river water level and quickly follows its fluctuation, it is estimated that there are interconnected channels developed in the conglomerate. In addition, since there is a tendency for joints and faults to be developed in two directions in the conglomerate, it is considered that the solution channels and solution cavities are interconnected to comprise a three-dimensional network.

(5) Previous Groundwater Table and Elevation of Solution

It is generally said that solution due to groundwater progresses most in the vicinity of the groundwater table. The groundwater level in the vicinity of the dam site coincides roughly with the water level of the Köprücay River (approximately EL. 38 m). The distribution frequency of solutions is slightly high at elevations of 20 to 40 m near the river level.

Accordingly, there is a possibility that solution channels and cavities were formed concentrated at river water levels in the past.

It will be possible to estimate the past river water levels in the dam site vicinity judging from the topography of the surroundings as follows (see Fig. 7-10):

(a) EL. 0 m : Bottom elevation of alluvium at river bed of the dam site

(b) EL. 70 m : Elevation in case the plane of the terrace distributed in the vicinity of the confluence with the Koca Dele is extended to the dam site parallel to the present river gradient

(c) EL. 90 m : Elevation in case the gently river gradient near Beskonak village is extended to the dam site

(d) EL. 220 m : Elevation in case the plane of the fan (Duzaguc Formation) distributed at the left bank upstream of the dam is extended to the dam site

Meanwhile, elevations with peaks in distribution frequency of solutions, although indistinct, are seen at 120 to 140 m, and -20 to -40 m. Of these, it appears that -20 to -40 m corresponds to EL. 0 m of (a). It is difficult to discern the correspondence for the others, but this is thought to be a matter for further consideration. Also, it is said that the Mediterranean Sea level was approximately 100 m lower during the Würm Glacial Age than the present sea level.

In the vicinity of the dam site, there appears to be a tendency for the degree of karstification to become weak deeper than EL. -120 m. It is reported that at the site of Oymapinar dam, which is under construction in the Hanavgat River adjacent on the east to the Köprücay River, prominent karstification cannot be seen deeper than EL. -100 m. These phenomena may be common over a wide area, and may have a relation to the sea level during the Würm Glacial Age.

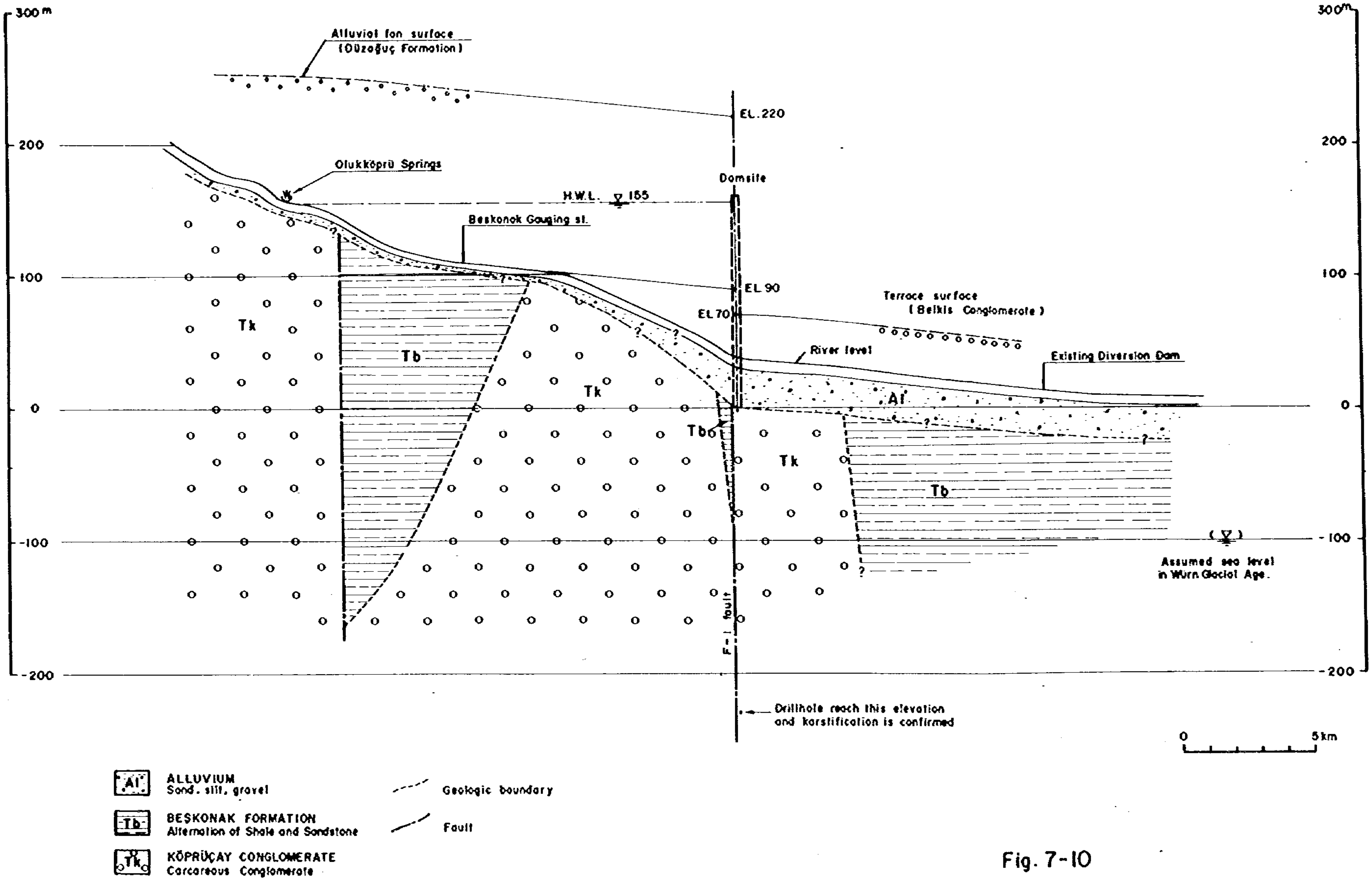


Fig. 7-10
Topography along Köprüçay River

7.3.5 Groundwater in the Vicinity of the Dam Site

(1) Groundwater Level

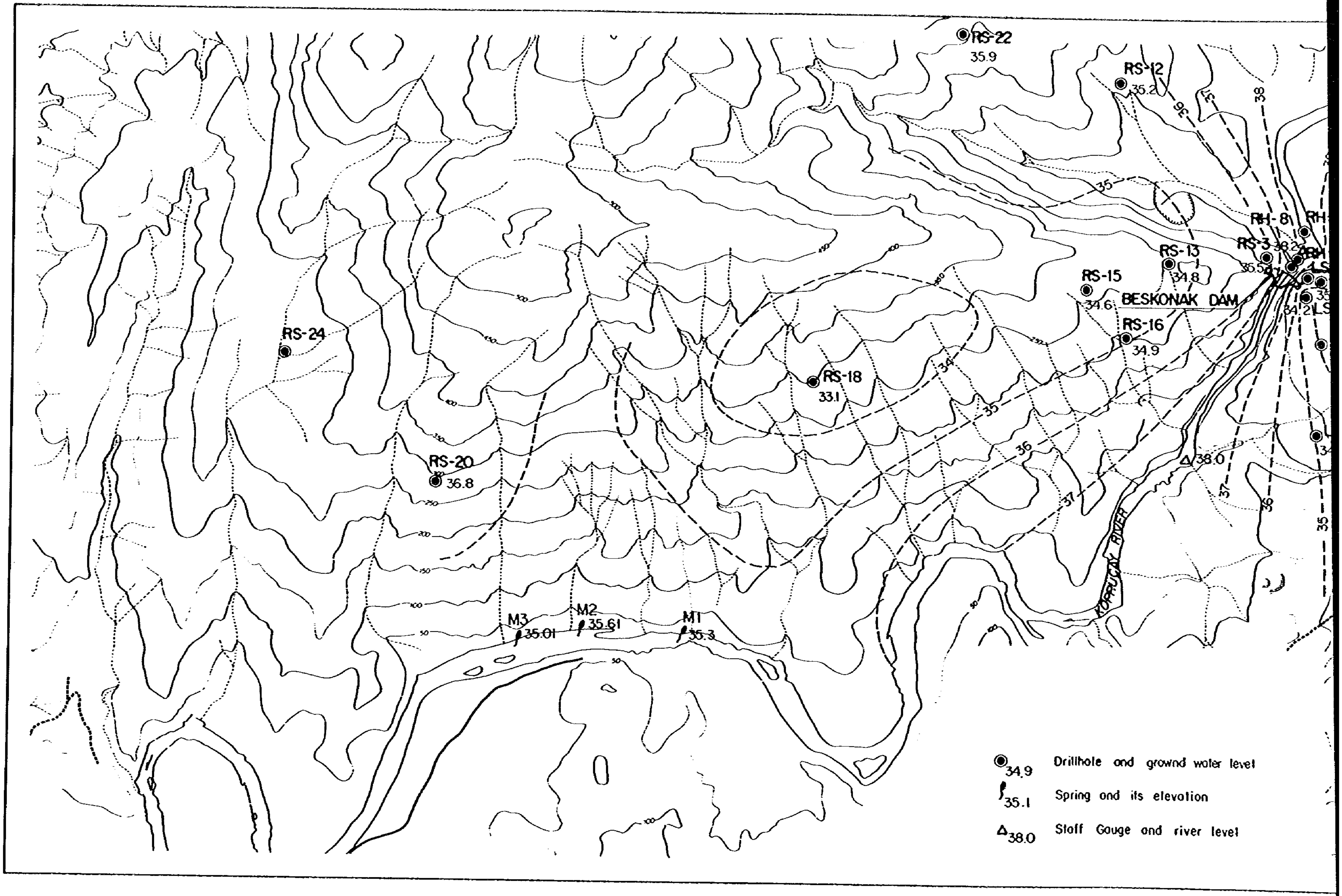
The groundwater level in the vicinity of the dam site can be clarified by the measurement records of Sümerman (1973) on river water levels and water levels in drillholes. These records are obtained by almost daily measurements of water levels in drillholes at the dam site vicinity and the water levels of the Köprücay River over a 3-year period from 1969 to 1971. These results are shown in graph form. According to the results, water levels in drillholes sometimes become higher than river water level in the rainy season from December to May, but are all lower than the river water level during the remaining period. Exceptionally, drillholes H-1 and H-3 at the Hortu Saddle on the left bank side of the dam site show water levels (EL. 100 m and higher) considerably higher than the river water level, because they were drilled in the Beskonak Formation or the Köprücay Conglomerate having numerous intercalations of sandstone and shale.

Fig. 7-11 shows the groundwater tables in the vicinity of the dam site in the dry season. Groundwater level becomes lower with increased distance from the Köprücay River. At the left bank, there is a concave portion of the groundwater table 3 to 4 m lower than the river level in a direction extending southeast through a drillhole LS-6. On the other land, at the right bank, there is a concave portion 4 to 5 m lower than the river level at and around RS-18.

That the groundwater level in the dam site vicinity is lower than the river level, is thought to be due to the Köprücay Conglomerate widely distributed at the dam site being karstified to be reduced to the watertightness.

Fig. 7-12 shows the differences between river level and water levels in drillholes in the dry season. The water levels in drillholes show comparatively sharp declines (gradients 3/100 and steeper) from the Köprücay River to about 100 m away, and as described in 7.3.4, this appears to have relations with high distribution frequency of solutions in this portion.

Fig. 7-13 indicates a portion of the records of measurements on river levels and drillhole water levels of Sümerman (1973). It shows that water levels in many drillholes quickly follow fluctuations in river level. This phenomenon is thought to suggest that interconnected voids are generally developed in the bedrock in the vicinity of the dam site.


RS-22
35.9
RS-12
35.2
RS-24
RS-13
34.8
RS-15
34.6
BESKONAK DAM
RS-16
34.9
RS-18
33.1
RS-20
36.8
RH-8
RS-3
35.5
38.2
M3
35.01
M2
35.61
M1
35.3
38.0
KÖPRÜÇAY RIVER
34.9 Drillhole and grownd water level
35.1 Spring and its elevation
38.0 Staff Gauge and river level

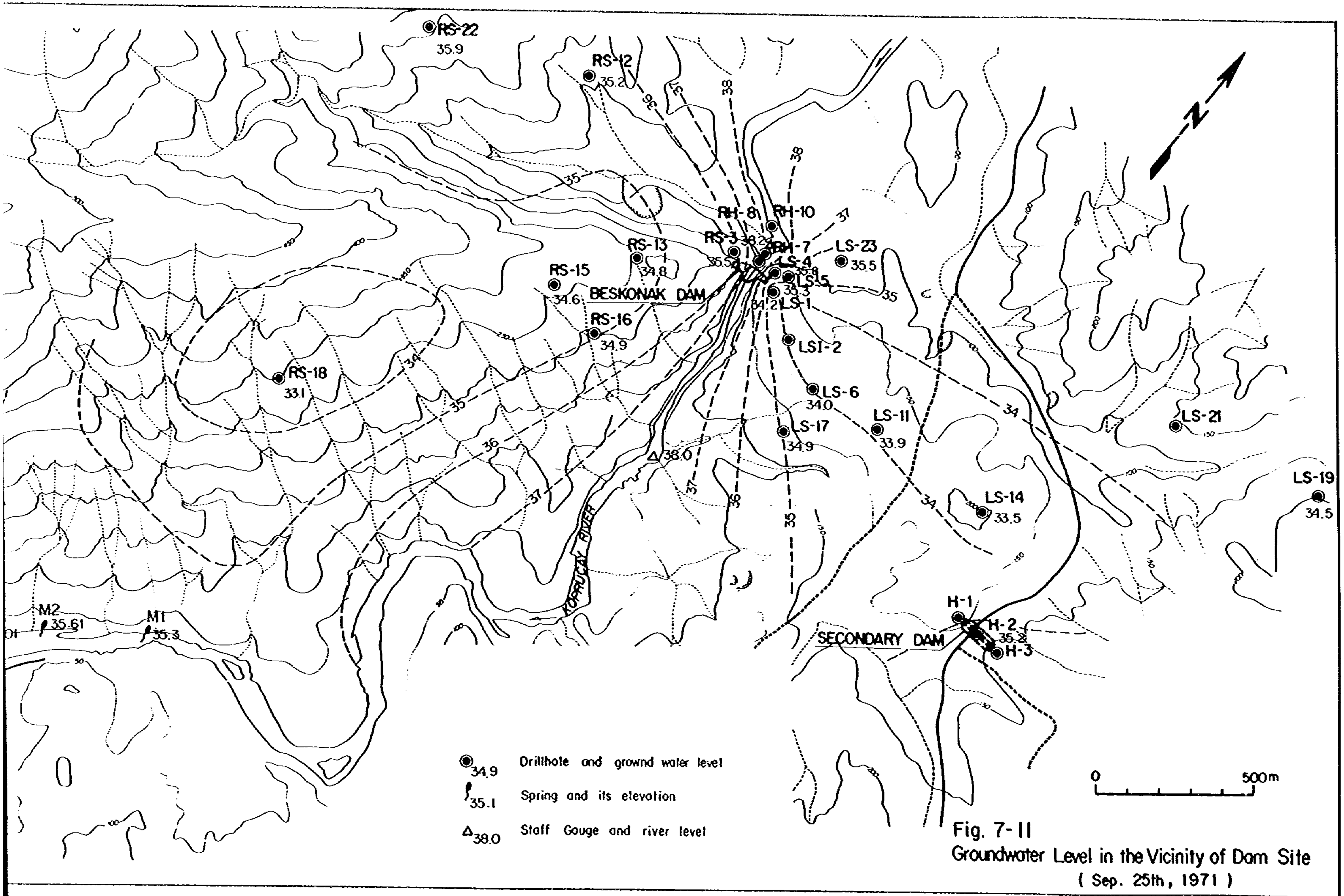


Fig. 7-11
Groundwater Level in the Vicinity of Dam Site
(Sep. 25th, 1971)

Fig. 7-12 Elevation Head Between River Level and Water Level in Drillhole

(Sept: 25th, 1971)

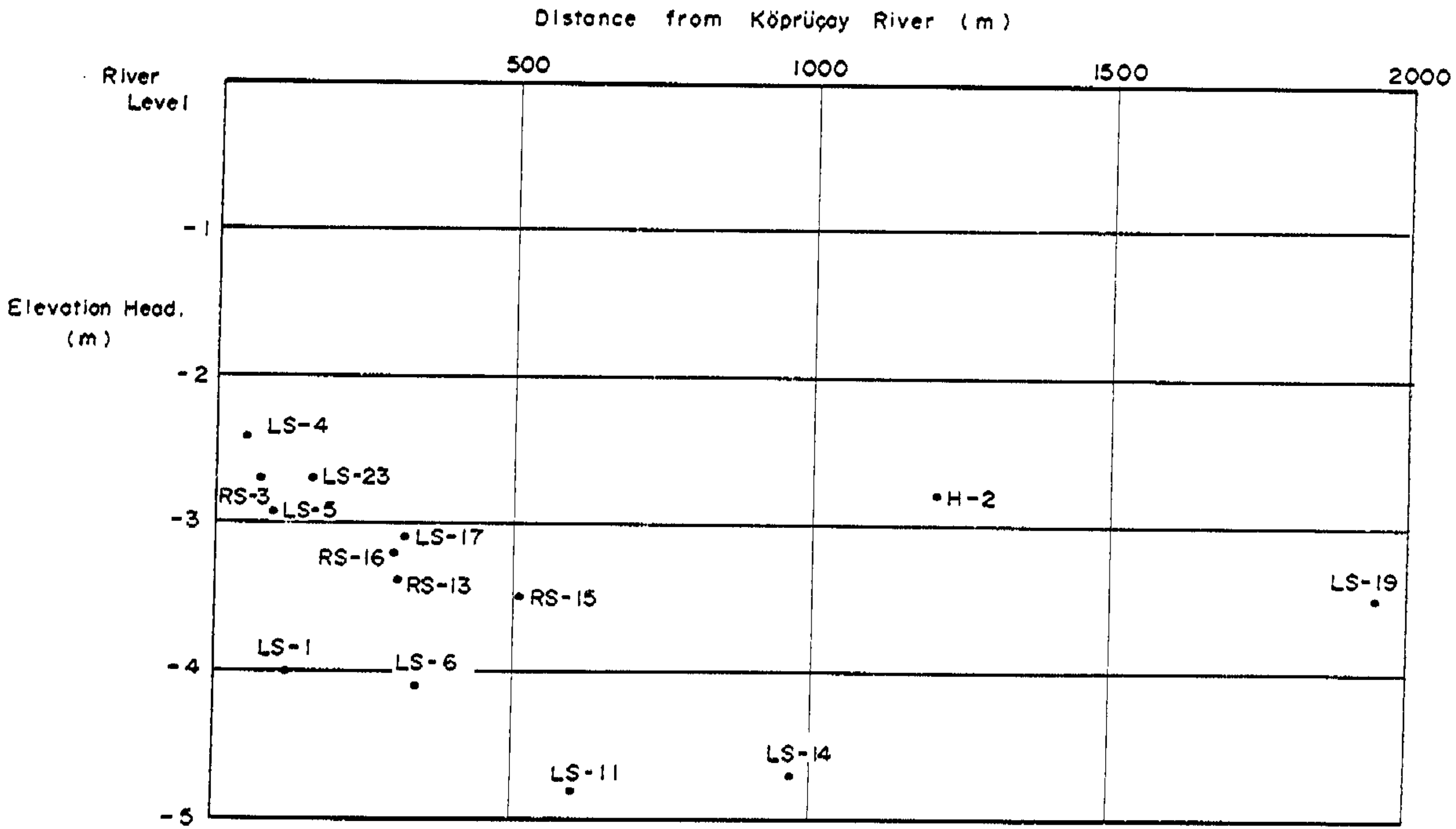
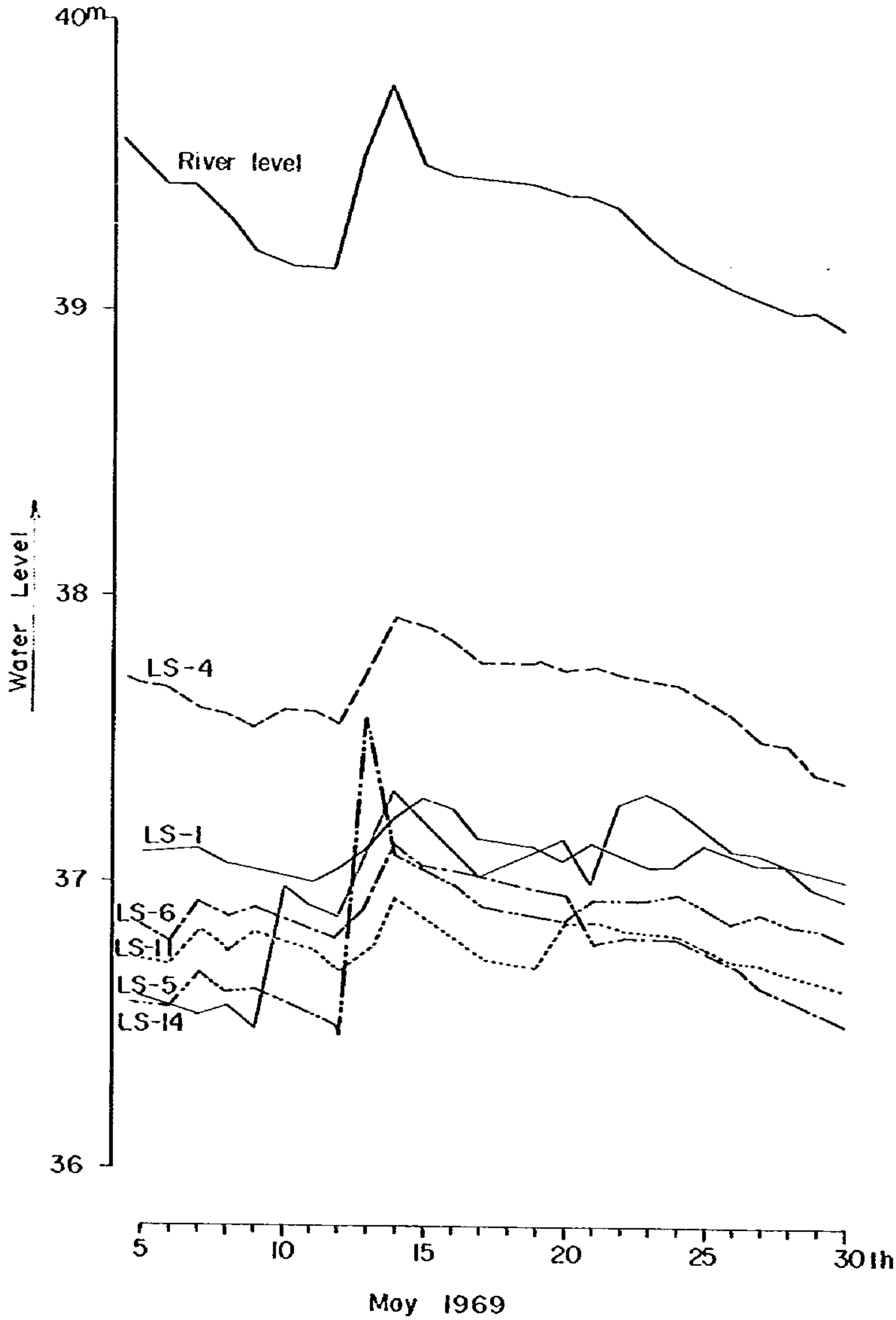


Fig. 7-13 Fluctuation of Groundwater Level in Drillholes in the Vicinity of Dam Site



(2) Springs Downstream of the Dam Site

Springs are seen approximately 3 km downstream from the dam site at the right bank of the Köprücay River. Major springs named M1 to M3 emerge through the conglomerate at the river bank at elevation of 35 - 36 m.

The results of runoff measurements carried out by DSI in 1982 are shown in Table 7-8 (Tarimci, 1982). According to the flow measurement (see Fig. 7-14), river flow at No.5 site is 0.8 - 11.4 m^3/sec. larger than that at No.4 site upstream of No.5 site. This phenomena would indicate that the river water infiltrates to the river bed or both banks between two sites. Since all tributaries in the vicinity of the dam site dry up in July, the downstream increase (approximately 3 m^3/sec) in runoff is thought to roughly indicate the volume of water springing from M1 to M3.

These springs are situated on the northeast flank of the Bozburum Anticline which trends northwest-southeast where shale and sandstone intercalated in the conglomerate toward the upstream side. Accordingly, it is thought that the groundwater in the conglomerate are hindered from moving downstream by the intercalated layers of shale and sandstone, and emerged at the bank of the Köprücay River.

As a result of water quality analysis of the M1 and M2 springs, the Oluk-köprü springs and the Köprücay River at the dam site, the following is reported in Sümerman (1973).

(a) The dissolved ingredients of these water samples were approximately the same, but according to chlorine concentrations, M1 and M2 are intermediate between the Oluk-köprü springs and the Köprücay River.

(b) According to seasonal variations in water temperature, part of the water of the M1 and M2 springs is supplied from the Köprücay River.

Further, the Survey Mission, judging from simplified water quality investigations carried out in October 1982, did not obtain any results to refute these observations. The results of water quality test performed by DSI are shown in Table 7-9.

Table 7-8 Results of River Flow Measurement

(Unit: m^3/sec)

Site No.	Apr. 27,	May 10,	June 29,	July 28,	Sept 3,
1	-	-	17.119	8.039	2.785
2	94.512	94.784	52.228	42.015	33.616
3	5.395	6.350	13.645	2.493	2.476
4	-	118.994	67.360	51.189	-
5	-	107.586	60.667	50.410	36.620
6	-	117.310	66.525	53.498	40.681
7	-	107.961	54.000	53.000	37.000

Locations of measurement sites are shown in Fig. 7-14

Table 7-9 Water Quality Analysis

Locality No.	Temp. (°C)	PH	EC	DO (ppm)	Ca^{2+} (ppm)	Mg^{2+} (ppm)	HCO_3^- (ppm)	Cl^- (ppm)	SO_4^{2-} (ppm)
B-1	14	7.2	435	6.64	72	10.8	268.4	7.1	12.0
B-2	14	7.1	440	6.56	68	12.0	268.4	7.1	4.8
B-3	14	7.2	365	6.80	42	16.8	225.7	6.4	5.8
B-4	14	7.0	375	7.25	40	8.4	164.7	7.1	7.7
B-5	14	7.1	365	6.80	52	2.4	219.6	6.4	7.7
B-6	14.5	7.0	390	7.38	62	7.2	231.8	7.1	13.0
B-8	14.5	6.9	390	6.76	56	12.0	231.8	7.4	14.9
B-9	14.5	7.1	435	7.60	64	12.0	262.3	7.1	13.0
O-1	14	7.2	375	6.92	56	9.6	225.7	6.4	13.0
O-2	14	7.1	375	7.08	56	9.6	244.0	7.1	6.7
K-1	17	7.1	480	6.64	72	8.4	256.2	20.9	17.3
KD-1	17	7.3	485	6.76	46	10.8	195.2	20.6	7.7
River	18	7.4	345	7.20	52	7.2	195.2	12.4	13.0

Sampled on June 23th, 1982 and analyzed by DSI

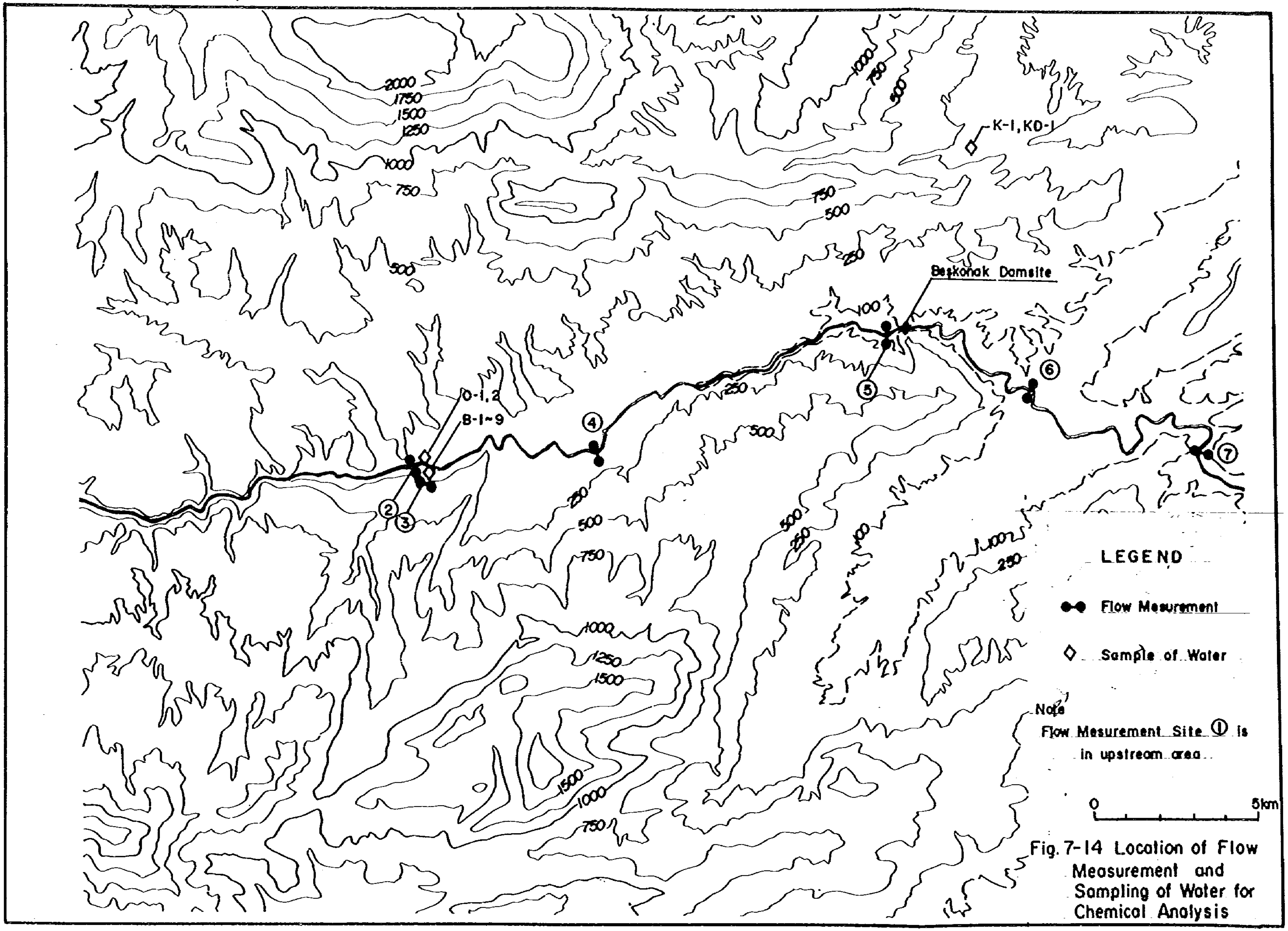


Fig. 7-14 Location of Flow Measurement and Sampling of Water for Chemical Analysis

7.3.6 Permeability in the Vicinity of the Dam Site

(1) Permeability Tests

Permeability tests were performed during drilling holes in the vicinity of the dam site. According to Sümerman (1973), the tests were carried out in bedrock deeper than 4 m with lengths of sections 2 m, injection pressures were set at tops of drillholes 1-10 kg/cm^2 in sections to a depth of 42 m and 10 kg/cm^2 beyond 42 m. Injected water volume during 10 minutes under these pressures were measured. The test results were shown in boring logs.

Lugeon values were calculated based on these test values, and the studies below were made concerning permeability of bedrock in the vicinity of the dam site.

(a) Distribution of Lugeon Values of the Köprücay Conglomerate

The Köprücay Conglomerate generally comprises surface layers which are 20 to 40 m thick with high permeability of 10 to 70 Lu. Deeper than 40 m, the permeability is an average of 5.9 Lu, with sections of 1 Lu or under making up 74% of the whole, and sections of 10 Lu and higher 7% (see Fig. 7-15).

The distribution of Lugeon values of the conglomerate at depths greater than 40 m is shown in Fig. 7-16 in terms of relation between distance from the Köprücay River and elevation. As shown in this figure, parts of especially high Lugeon values are not recognized seen from the standpoint of distance from the Köprücay River. From the standpoint of elevaton, peaks of Lugeon values are indistinct at the left bank, but from the river bed to the right bank, peaks are seen fairly clearly at elevations of 120 to 140 m, 20 to 60 m, and -60 to -80 m. As a whole, at elevations of 40 to 60 m and -60 to -80 m, there are indistinct peaks. At elevations below -100 m, it may be acceptable that permeability is low although the number of test sections is small.

Further, Lugeon values of the conglomerate in the vicinities of faults are generally high. As a result of tests at drillholes RH-10 and LS-23, the range of 20 to 50 m wide in the vicinity of the F-1 fault show around 40 Lu. Other major faults are mostly accompanied with 5 to 20 m wide zones which permeability are 4-30 Lu.

(b) Distribution of Lugeon Values of the Beskonak Formation

The Beskonak Formation is generally weathered down to 40 m from the surface, but most sections have not been tested or are of less than 20 Lu. At deeper than 40 m, the mean Lugeon value is 1.6, sections of 1 Lu or under make up 88% of the whole, and sections of 10 Lu or higher 2%, so that permeability are much lower compared with the conglomerate (see Fig. 7-15). Further, with regard to the Beskonak Formation, permeable zones are not found in the vicinities of faults.

Fig. 7-15 Frequency of Lugeon Value at the depth deeper than 40m

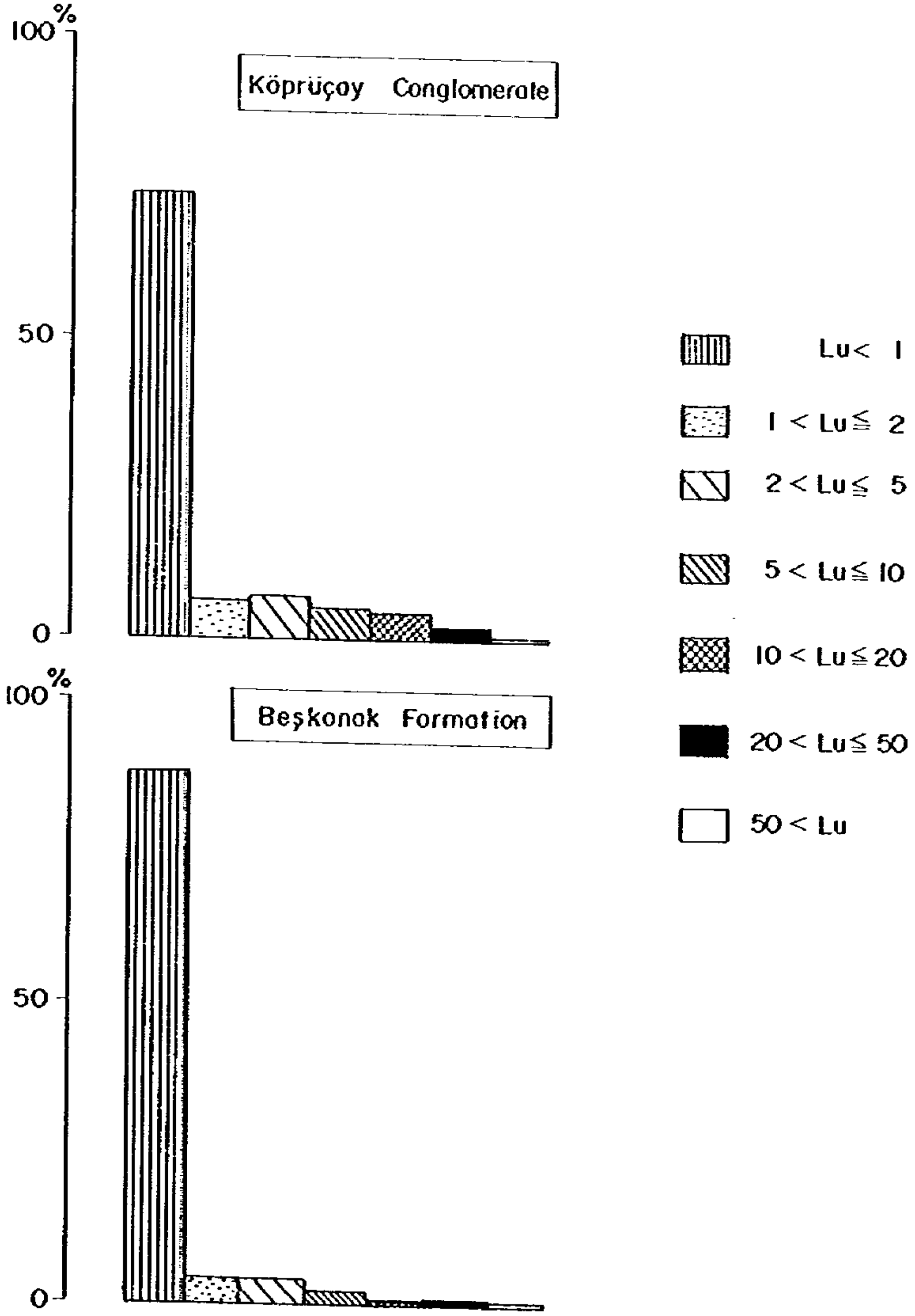
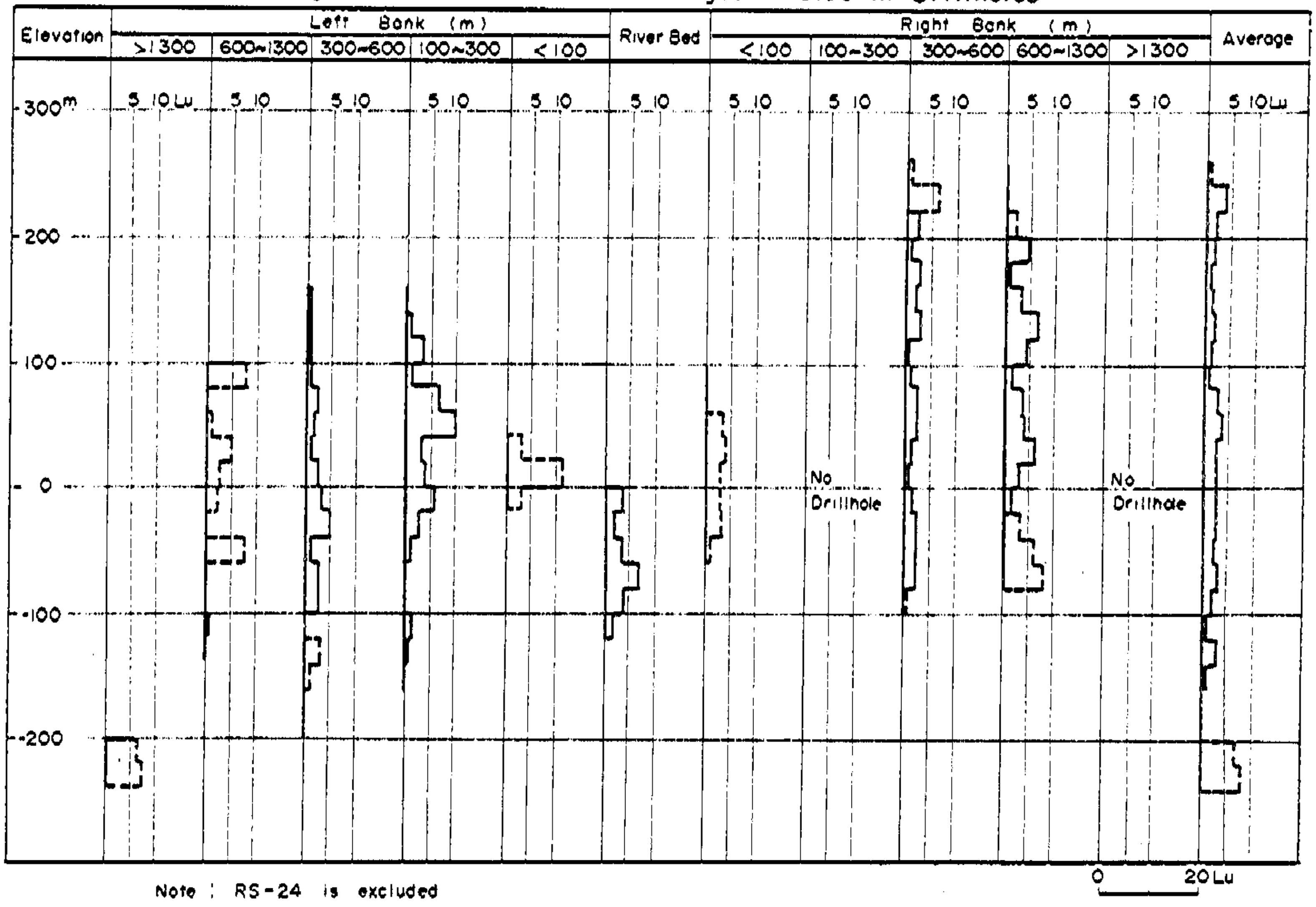


Fig. 7-16 Distribution of Lugeon Value in Drillholes



Note : RS-24 is excluded

(2) Examination of Permeability Test Results

(a) Solutions and Lugeon Values

The Köprücay Conglomerate has been karstified, and it is expected that the distribution of solutions in the bedrock will have influence on the results of permeability tests. In fact, at the individual permeability test sections, solutions often exist where Lugeon values are high. At the right abutment of the dam site, Lugeon values and the distribution frequency of solutions show comparatively good agreement.

However, at the vicinity of the river bed and at the left bank, hardly any agreement can be seen between the two (see Fig.7-9 and Fig. 7-16), that is, at individual permeability test secitons, in case of existence of solutions, the Lugeon values are not necessarily high. This is thought to be due to the solutions being filled with clay or calcite seen in test adits, or certain of the solutions lacking in continuity.

(b) Section with Injection Pressure Less than 10 kg/cm^2

In permeability tests, it is prescribed for injection pressures at drillhole tops to be set at 10 kg/cm^2 for depths exceeding 42 m, and of sections tested in the conglomerate deeper than 42 m there were 7.9% not reaching the required 10 kg/cm^2.

The Lugeon values in these sections are high averaging 24.7 Lu, with sections of 20 Lu and higher making up 45%. The reason why the specified pressure is not reached is thought to be that the pump capacity is exceeded since there would be continuous solutions in the test section and the volume of water injected is large. Accordingly, it is thought permeability is under-evaluated for these sections. Especially, it is thought that permeability is extremely high at sections for which any pressures cannot be obtained at the mouths of drillholes.

Sections where injection pressures do not reach the required 10 kg/cm^2 are encountered at intervals averaging 25.2 m. On the other hand, solutions in conglomerate appear at intervals averaging 7.8 m. Consequently, it can be roughly estimated that approximately 30% of the solutions cannot maintain injection pressure at 10 kg/cm^2 in permeability tests and these solutions are supposed to be continuous.

(c) Groundwater Level and Lugeon Value

The two features below can be recognized in regard to groundwater level in the vicinity of the dam site as described in 7.3.5.

1) The groundwater level is lower than the river water level.

2) The groundwater level quickly follows fluctuations in the river level.

Such phenomena are due to the Köprücay Conglomerate having been karstified to become poor in watertightness. It is thought this poor watertightness suggests that solution cavities or channels formed in the bedrock have developed to join with each other. Two phenomena of 1) and 2) could not be explained by the average Lugeon value (5.9 Lu) of the conglomerate obtained in permeability tests. Accordingly, the state of the groundwater level, as described in (b), "Section with Injection Pressure Less than 10 kg/cm^2," substantiates the possibility that the Lugeon value is under-evaluating the permeability of the bedrock.

(3) Evaluation of Permeability of the Köprücay Conglomerate

The following summarization will be made concerning the Köprücay Conglomerate distributed in the vicinity of the dam site:

(a) The distribution width is 3.5 km on the right bank side and 1.5 km on the left bank side with the elevation of the lower limit below -200 m.

(b) The Köprücay Conglomerate has been karstified and the lower limit has not yet been confirmed, but below EL. -120 m both distribution frequency and size of karstification tend to become smaller.

(c) The sizes of solutions in the Köprücay Conglomerate are small, and above EL. -120 m the distribution is more or less uniform.

(d) The majority of solutions has grown along joints and faults.

(e) Almost all of the solutions are filled with clay or calcite.

(f) As a result of permeability tests, the Lugeon values of the Köprücay Conglomerate show a more or less uniform distribution above EL. -120 m and the average is 5.9 Lu.

(g) In permeability tests, the specified injection pressure cannot be obtained for 7.9% of the sections tested in the Köprücay Conglomerate, and the Lugeon values for these sections underestimate the permeability of the bedrock.

(h) The groundwater level in the Köprücay Conglomerate is lower than the river water level, and quickly follows fluctuations in the river water level.

To recapitulate the above matters, it may be considered that small-scale solutions have developed uniformly and have been connected three-dimensionally above EL. -120 m in the Köprücay Conglomerate. Therefore, in studying the matter of leakage from the reservoir expected in the vicinity of the dam site, the Köprücay Conglomerate above EL. -120 m can be considered macroscopically as a homogeneous medium with regard to permeability.

However, the Köprücay Conglomerate is widely distributed in the surroundings of the dam site, and existing data cannot completely deny the existence of large-scale continuous solutions. The Oluk-köprü springs in the upstream area of the reservoir indicate that a considerable number of connected cavities or channels exist in the Köprücay Conglomerate. The phenomenon of low groundwater level in the vicinity of the dam site has not yet been thoroughly explained and requires further investigations.

The Köprücay Conglomerate indicates 5.9 Lu on the average as a result of permeability tests, and this value includes test sections for which injection pressures do not reach the specified value. It is necessary to keep in mind that this value underestimates the permeability of the Köprücay Conglomerate.

7.4 Geologies of the Dam Site and Various Structure Sites

7.4.1 Dam Site

(1) Method of Investigation

With regard to the dam site, there were surface reconnaissances, core borings and test adit excavations carried out.

The results of surface reconnaissances were summarized in geological maps of 1/1,000 scale.

Boring was performed with seven drillholes totalling 1,383.23 m (see Table 7-2), and permeability tests were carried out at the holes. As for test adits, there were six excavated, totalling 1,070.3 m (see Table 7-5).

(2) Topagraphy

The dam site is located about 50 m downstream from the upstream end of a gorge carved by the Köprücay River. The gorge at the dam site presents a deep, narrow V-shape. The valley width at the bottom (EL. 38 m) is 15 to 25 m, with the left bank below EL. 150 m and the right bank below EL. 200 m being steep cliffs of more than 70 deg, while the valley width at the design high water level (EL. 155 m) is 70 to 100 m. Above the cliffs on both sides the slopes are approximately 30 deg.

(3) Geology

(a) Surface Deposits

Practically all of the dam site has exposed rock with thin overburden only filling depressions at the surface of the bedrock.

The thickness of the alluvium is 33.54 m at a drillhole RH-8 on the dam axis, 19.15 m at RH-7 upstream of the dam axis, and 14.98 m at RH-10 upstream of the entrance of the gorge. The alluvium is composed of sand and gravel, and at RH-8 calcareous conglomerate boulders of maximum size of 3.2 m were recognized in addition.

(b) Foundation Rock

The foundation rock of the dam site is composed of the Köprücay Conglomerate only. This conglomerate consists mainly of round and subround gravels of limestone and a calcareous matrix, and is intercalated with few thin shale and sandstone layers.

The Köprücay Conglomerate is massive and hard judging from the recovered core which is 1 m and more long in general. Classifying the bedrock according to the standards given in Table 7-10, they are:

Weathering	:	2 or 3
Hardness	:	B
Interval of Cracks	:	I or II

Table 7-10 Standard of Rock Evaluation

Weathering		Hardness		Interval of Cracks	
1	Very fresh. No weathering of mineral component	A	Very hard. Broken into Knifeedged pieces by strong hammer blow.	I	Over 100 cm
2	Fresh. Some minerals are weathered slightly. Usually no brown crack.	B	Hard. Broken into pieces by strong hammer blow.	II	40 - 100 cm
3	Fairly fresh. Some minerals are weathered. Cracks are stained and with weathered material.	C	Brittle. Broken into pieces by medium hammer blow.	III	20 - 40 cm
4	Weathered. Fresh portions still remain partially.	D	Very brittle. Easy broken into pieces by medium hammer blow	IV	5 - 20 cm
5	Strongly weathered. Most minerals are weathered and altered to second minerals.	E	Soft. Able to dig with hammer	V	Under 5 cm

(c) Structural Geology

The structural geology at the dam site is described below.

i) The dam site is located near the axis of a gentle syncline (Köprücay Syncline) along the Köprücay River, and bedding planes generally strike N30°E-80°E parallel to or diagonally intersecting the dam axis, and dip 4-11°toward the downstream side.

ii) The prominent faults distributed in the vicinity of the dam site are listed in Table 7-11. Although there are other faults distributed in the vicinity of the dam site, these all have sheared zones of widths not more than 1 m, and are not very continuous.

iii) Faults and joints having strikes of N70°E-EW and N10-30°E, and dips all close to vertical are fairly prominent.

(d) Karstification

The general trends of karstification of the Köprücay Conglomerate at the dam site and its surroundings are described in 7.3.4. At the dam site there are the following trends in addition:

i) Regarding the distribution frequency of solutions, it has been found to be high at the river bed and the right bank by drillholes RH-7, RH-8 and RS-3. The distribution frequency is high above elevation of 100 m, while a trend of decrease is not indicated above EL. -120 m (see Fig. 7-17).

ii) The width of solution is increased at EL. 60 - 80 m. But below EL. -40 m, hardly any can be seen which are of widths 2 cm or more (see Fig. 7-18).

Table 7-11 Major Faults in the Vicinity of the Dam Site

Name of Fault*	Sheared Zone Width (cm)	Strike, Drip	Location	Chief Location Confirmed
F-1	400	EW-57°N	At 120 m upstream from upstream end of dam foundation. Minor faults are numerous in a range to approximately 40 m downstream of this fault, but the dam foundation is outside the range of influence.	RH-10: 122.0 - 129.5 m LS-23: 83.9 - 89.4 m
F-3	10-50	N5-15°E 65-71°NW	At left abutment of dam foundation. The fault has a strike in the upstream downstream direction, and dips toward the mountain side.	Adit RT-3: left lateral adit 25 m Adit RT-4: left lateral adit 18 m
F-4	50-100	N15°E 76-81°NW	At left bank side of dam site in roughly upstream-downstream direction. Distance from dam site is approximately 60 m, and crosses Kopru-cay River approximately 180 m downstream of dam site.	Left bank upstream slope Adit LT-1: middle adit 45.5 m Adit LT-2: 42 m Adit LA-5: 39 m

* Names of faults according to Sumerman (1973)

Fig. 7-17 Distribution of Solution at Dam Site

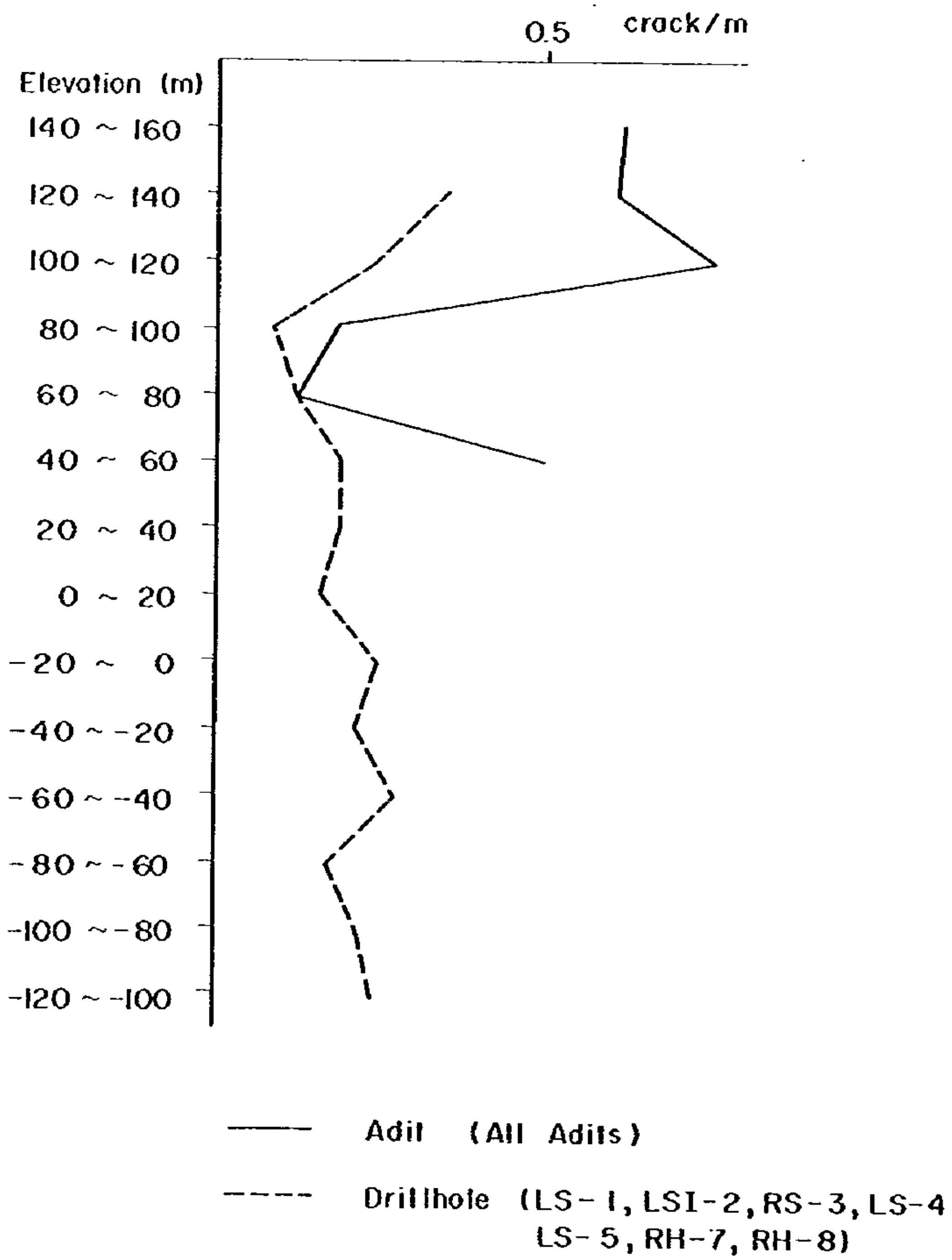
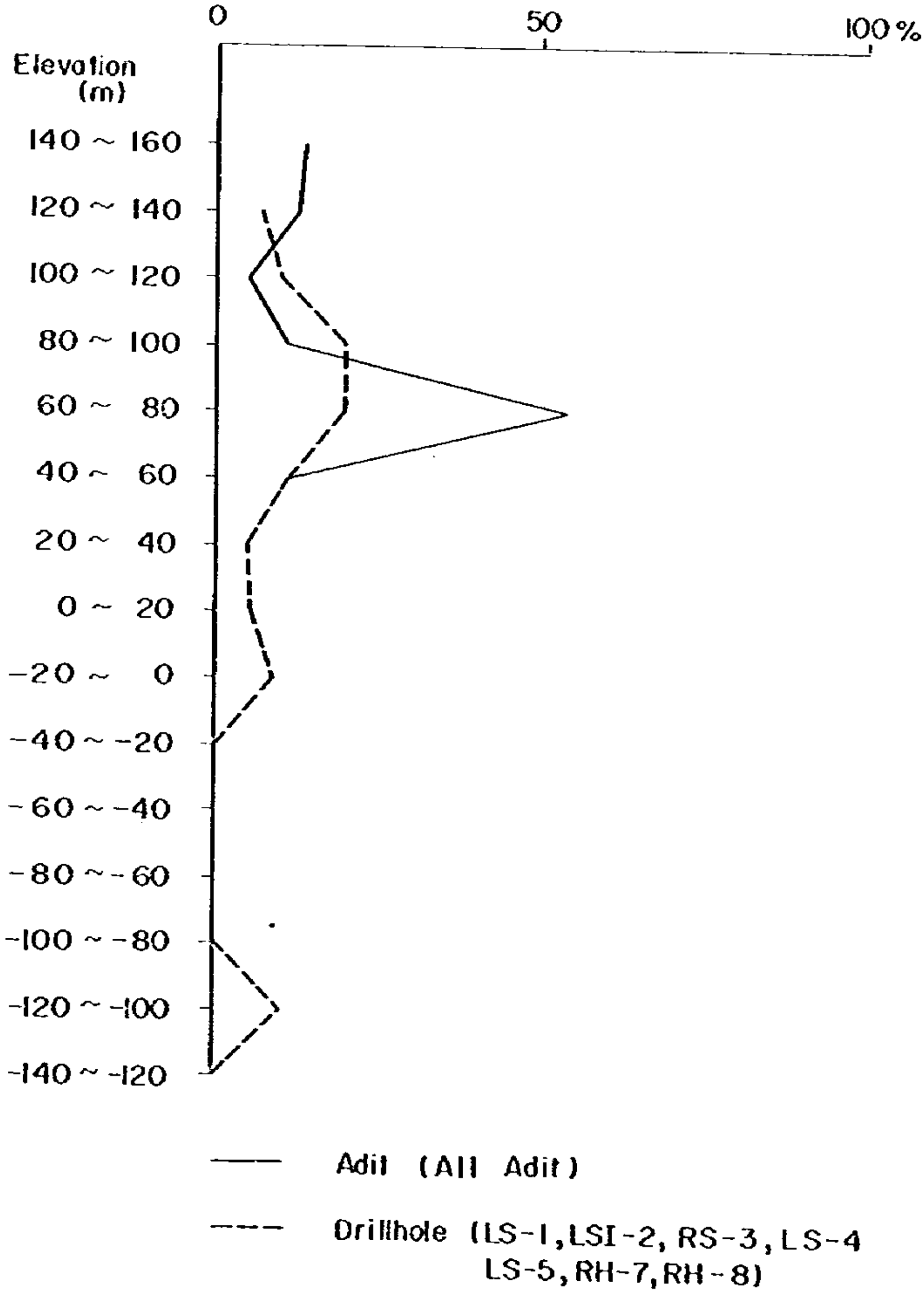


Fig.7-18 Width of Solution at Dam Site
(Percentage of solution which is more than 2 cm wide)



(e) Groundwater

The condition of groundwater in the surroundings of the dam site is described in 7.3.5.

(f) Permeability

The general trend of permeability of the Köprücay Conglomerate in the surroundings of the dam site is descrived in 7.3.6, and it is the same at the dam site. In essence, the Köprücay Conglomerate has solutions distributed more or less uniformly above EL. -120 m, and macroscopically, it may be considered as a homogeneous medium regarding permeability, and that permeability according to test results is fairly high averaging 5.9 Lu.

Further, in addition, the following has been clarified as a result of permeability tests in drillholes at the dam site.

i) The thickness of the zone of high permeability (20 Lu or higher) at the surface layer of the Köprücay Conglomerate is 45 m at LS-1, while at LS-4, LS-5 and RS-3, there are many sections indicating more than 20 Lu from the ground surface to near the groundwater level at depths of 90 to 100 m.

ii) In RH-7 and RH-8 at the river bed, permeability is high at parts within a depth of 10 m from the surface of the bedrock and in the vicinity of EL. -60 m.

iii) In the surroundings of the faults the sections where permeabilities are more than 10 Lu are at the depths of 166 to 200 m in LS-1 (EL. 14 to -20 m, details of direction unknown), 60 to 70 m in LS-4 (EL. 14 to 4 m, F-4 Fault), and 78 to 102 m in RH-7 (EL. -50 to 74 m, F-2 fault crossing river immediately upstream of the dam site, and dipping to upstream side).

(4) Engineering Geology

(a) Strength

The Köprücay Conglomerate comprising the dam site is massive and hard, and weathering of the surface layer is slight. Furthermore, prominent faults or other weak lines such as to affect the stability of a dam structure cannot be recognized. Therefore, this rock is judged to have ample strength and stability as the foundation for the structures planned at the dam site.

(b) Permeability

The Köprücay Conglomerate comprising the dam foundation rock is widely distributed in the surroundings of the dam site, and the permeability in this area is described in 7.3.6. In effect, the Köprücay Conglomerate at the dam site and its surroundings is of high permeability, and there is much possibility of leakage from the reservoir occurring through this rock. Accordingly, it is necessary to study over a wide area concerning improvement of watertightness of the dam foundation rock including the surroundings of the dam site.

7.4.2 Other Structure Sites

(1) Power Intake Sites

The power intakes are located on the left bank slope upstream of the dam site. The inclination of the slope is 20 to 30 deg. There are numerous outcrops at the slope and surface deposits are thin. The left lateral adit of LT-2 extends to the intake sites. The foundation rock is comprised of the Köprücay Conglomerate. This Köprücay Conglomerate has numerous minor faults and is slightly sheared at the left lateral adit of LT-2, but there is no section in the adit driven with supports, and it is a fairly stable bedrock.

Judged from the above, it is thought the bedrock of the intake sites possess no problem as the foundation for the structures planned.

(2) Headrace and Penstock Sites

The headrace and penstock are located at the left bank side of the dam site. Drillholes and test adits have not been provided at these sites. The ground surface along these sites is a gentle slope of not more than 30 deg. The cover thicknesses for the projected structures are 30 to 90 m at the headrace site and 30 to 70 m at the penstock site. The foundation rock is composed of the Köprücay Conglomerate, the same as that distributed at the dam site.

The Köprücay Conglomerate of the headrace and penstock sites is judged to be massive and hard from the results of the investigation works. Prominent faults have not been confirmed at these sites, and the planned structures are located above the groundwater table. Therefore, it is thought there will be practically no geological problems at these sites.

(3) Power Station

The power station is located on the left bank at the downstream end of the gorge approximately 600 m downstream of the dam site. Investigation works have not been performed at this site. Since there is outcropping of hard, massive Köprücay Conglomerate at the ground surface, it is judged that the bed rock is strong enough as the foundation for the power station, and that there are few problems with regard to stability of excavated slopes.

(4) Secondary Dam Site

The secondary dam site is located at the left bank side of the main dam site. The distance from the main dam site is

1,400 m. The three drillholes totaling 365.0 m, shown in Table 7-2, have been provided at this site.

The secondary dam site is on a saddle at EL. 144 m (11 m lower than high water level), and the vicinity presents a topography of gentle relief. Surface geological reconnaissances and drillholes have revealed the geology of the secondary dam site as described below.

(a) Surface deposits are thin and only overburden of not more than 1 m in thickness is distributed.

(b) The foundation rock is composed of the Beskonak Formation and the Köprücay Conglomerate.

(c) The Beskonak Formation is widely distributed at the ground surface in the vicinity of the secondary dam site, and is composed of sandstone and shale alterations with shale predominant. There are few cracks, while karstification has not occurred.

(d) The Köprücay Conglomerate is distributed on the left abutment of the secondary dam and extends in a narrow strip in a direction roughly orthogonal to the dam axis. This conglomerate is confirmed by H-2 to be continuous for the 200 m from hole-top to hole-bottom (EL.-56.04 m) and is thought not to be an intercalation in the Beskonak Formation, but a continuation of the conglomerate distributed in the vicinity of the main dam site. At the surface portion of the Köprücay Conglomerate at the secondary dam site, intercalations of sandstone and shale are prominent. The Köprücay Conglomerate is generally massive and hard, but is karstified along joints.

(e) Prominent faults have not been confirmed in the vicinity of the secondary dam site.

(f) The thickness of the strongly weathered portion at the surface of the foundation rock is 8 m (drillhole H-1) at the Beskonak Formation and 4 to 5 m (drillholes H-2 and H-3) at the Koprucay Conglomerate.

(g) The Köprücay Conglomerate, as a result of permeability tests at drillholes H-1, H-2 and H-3, indicates low Lugeon values, with hardly any sections above 10 Lu. However, the water level in H-2 is lower than the water level of the Köprücay River and it is thought the permeability of this conglomerate cannot be said to be low as indicated by the abovementioned permeability test results.

It is judged to be as follows concerning the secondary dam site from the standpoint of engineering geology.

(a) The thickness of the weathered portion of the Beskonak Formation which would be problematic strength-wise as the foundation rock at the secondary dam site is not more than 8 m.

(b) There is a possibility that the Köprücay Conglomerate at the secondary dam site is high in permeability, but since the area of its distribution is narrow and there are numerous intercalations of sandstone and shale at the surface portion of the dam foundation, while the water pressure which will act during water impoundment will be low, it is judged that large-scale leakage will not occur.

7.5 Construction Materials

7.5.1 Outline

It is planned for the Beskonak dam to be a concrete dam, with the volume of dam concrete approximately 488,000 m^3. Besides this dam, if the waterway structures and power station are included, the total volume of concrete will be approximately

632,000 m^3.

On the other hand, it is planned for the cofferdams and secondary dam to be rockfill dams, of which impervious core materials will amount to approximately 68,000 m^3, filter materials approximately 61,000 m^3, and rock materials approximately 350,000 m^3.

Regarding borrow areas and quarries for these materials and qualities of the materials, an investigation was made by EIE in 1967, and the suitable collection sites described in the following section were discovered. The Survey Mission, in addition to investigating the sites in the field, also evaluated the results of tests. Also, investigations were made of weathered shale of the Beskonak Formation distributed at the surroundings of the secondary dam site of the Hortu Saddle. Further, investigations were made of borrow areas and quarries for filter materials and rock materials to be used for construction of diversion dams and the secondary dam.

The results of tests on materials performed by DSI and EIE are shown in Tables 7-12 and 7-13, and Figs. 7-19 to 7-21.

7.5.2 Concrete Aggregates

As pits for collection of concrete aggregates, the deposits spread out along both banks of the Sagirin River approximately 10 km downstream from the dam site were selected as shown in Dwg. 1-2 and Fig. 7-19. Test pits were made by EIE at three locations to investigate the properties of the materials and samples were tested in the laboratory. The evaluation of the test results is as follows:

(1) The unit weight of sand ranges between 1,669 and 1,803 kg/m^3 which is standard.

(2) The specific gravities and absorptions of sand and gra-

vel are both good.

(3) The contents of fines and clay are slightly high and thorough washing will be required before using.

(4) The content of organic matter is low and there is no special problem.

(5) The soundness of sand and gravel is good.

(6) With regard to gradation of gravel, it is thought sizes of 40 mm and larger are slightly deficient, but since there is an adequate quantity of deposits, it is considered there will be no problem in particular.

(7) Examining gradation of sand by fineness modulus, the material from test pit A-2 is slightly coarse, and adjustments will be necesssary for actual use.

(8) The material is harmless from the standpoint of alkali resistance.

As a whole, these concrete aggregates are of good physical properties, but since fines (passing 0.074 mm) and clay contents are high, it is desirable for both sand and gravel to be used upon washing.

It is estimated that approximately 1,200,000 m^3 of material are available in this area, and it is judged there is an adequate amount of aggregates for the total volume of concrete.

7.5.3 Impervious Core Materials

Regarding borrow areas for impervious core materials, areas adjoining the concrete aggregate pits have been selected by EIE as shown in Dwg. 1-2 and Fig. 7-19.

Test pits were provided at five locations in order to investigate the characteristics of materials in these areas and necessary tests were performed in the field and in the laboratory. The evaluation of test results is as follows:

(1) Of the five samples, those of A-2, A-3, B-2 have high contents of fines (0.074 mm and under) at 89-97%, and use by themselves is not desirable.

(2) The samples A-1 and B-1 have contents of fines (0.074 mm and under) of 40 to 50%, and although it is thought they can be used by themselves, they are materials somewhat low in plasticity.

(3) Organic matter contents average 0.5 to 1% and are very low.

(4) Permeability coefficients are from 5.7×10^{-7} to 9.0×10^{-8} cm/sec, and imperviousness can be amply looked forward to.

As described above, the content of fine soil is high as a whole, and in addition, the material is of low plasticity, so that it is desirable for improvement to be made by blending with a coarse-grained material.

Meanwhile, it has been found as a result of investigations that shale and spoiled shale of Beskonak Formation, widely distributed adjacent to these borrow areas, can be used as impervious core materials.

This type of shale is distributed in large quantities at the left bank side of the dam site, especially the vicinity of the secondary dam site, and it is thought it will be more advantageous from the standpoints of both material quality and economy rather to use this shale for the impervious core of the secondary dam. Furthermore, it is desirable for the above-mentioned weathered shale to be used as impervious core materials for cofferdams, and further detailed investigations should be made.

7.5.4 Filter Materials

It is planned for a total of 61,000 m^3 of filter materials to be used for cofferdams and the secondary dam.

The plan is for river-bed gravel deposited upstream of the Beskonak dam site to be used as the filter materials. It is necessary for further investigations to be made in the future regarding the gradations and available quantities of these materials.

7.5.5 Rock Materials

It is planned for a total of 350,000 m^3 of rock materials to be used for the cofferdams and the secondary dam.

Of these materials, the rock for cofferdams would consist mainly of excavation muck from the diversion tunnels and power intakes. The muck will consist entirely of Köprücay Conglomerate and is suitable as rock material.

As for rock material for the secondary dam it is planned to divert excavation muck from the power station and switchyard sites.

Table 7-12 Test Results of Impervious Core

Sample No.	Specific Gravity	Compaction max. (t/m^3)	Compaction Wopt (%)	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	Permeability Coefficient (cm/sec)	Triaxial Shear C (kg/cm^2)	Triaxial Shear °	Clasification Symbol
A-1	2.68	1.87	14.5	26.1	18.0	8.1	2.90×10^{-7}			CL
A-2	2.70	1.66	19.2	45.8	24.2	21.6	0.90×10^{-7}			CL
A-3	2.68	1.62	19.1	50.5	24.3	26.2	3.40×10^{-7}			CL-CH
A-4	2.70	1.89	13.6	23.6	-	-	1.80×10^{-7}			GM
A-5	2.70	1.79	16.4	31.9	19.8	14.1	0.90×10^{-7}			CL
	2.70	1.76	18.2	36.3	23.2	13.1	5.70×10^{-7}	1.10	19°30'	CL-ML

Table 7-13 Test Results of Concrete Aggregate

Sample No.	Unit Weight (kg/m^3) Sand	Unit Weight (kg/m^3) Gravel	Specific Gravity & Absorption Sand	Specific Gravity & Absorption Gravel	Percent Passing from #200	Clay Amount Sand	Clay Amount Gravel	Frost Action Sand	Frost Action Gravel	Rattler Test Sand	Rattler Test Gravel
A-2	1803	-	2.62 2.0%	2.64 0.9%	4.8	6.1	0.6	4.4	3.5	3.8	19.5
A-1	1669	-	2.62 2.1%	2.67 0.7%	3.2	0.7	0.65	3.95	2.8	3.8	18.9
A-3	1740	-	2.62 2.1%	2.65 1.0%	4.6	1.8	0.5	4.20	3.1	3.6	

Fig. 7-19 Location of Borrow Area

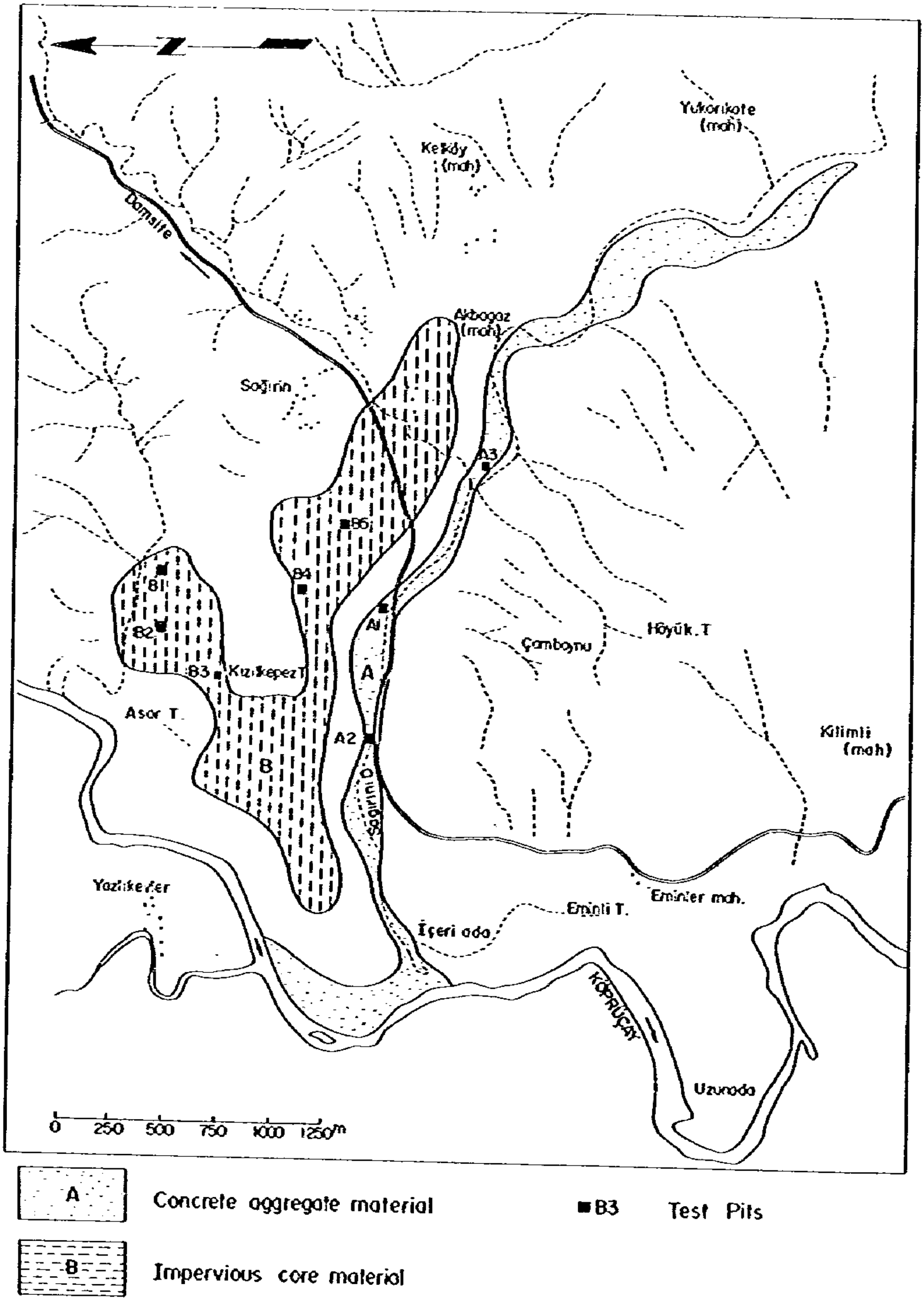
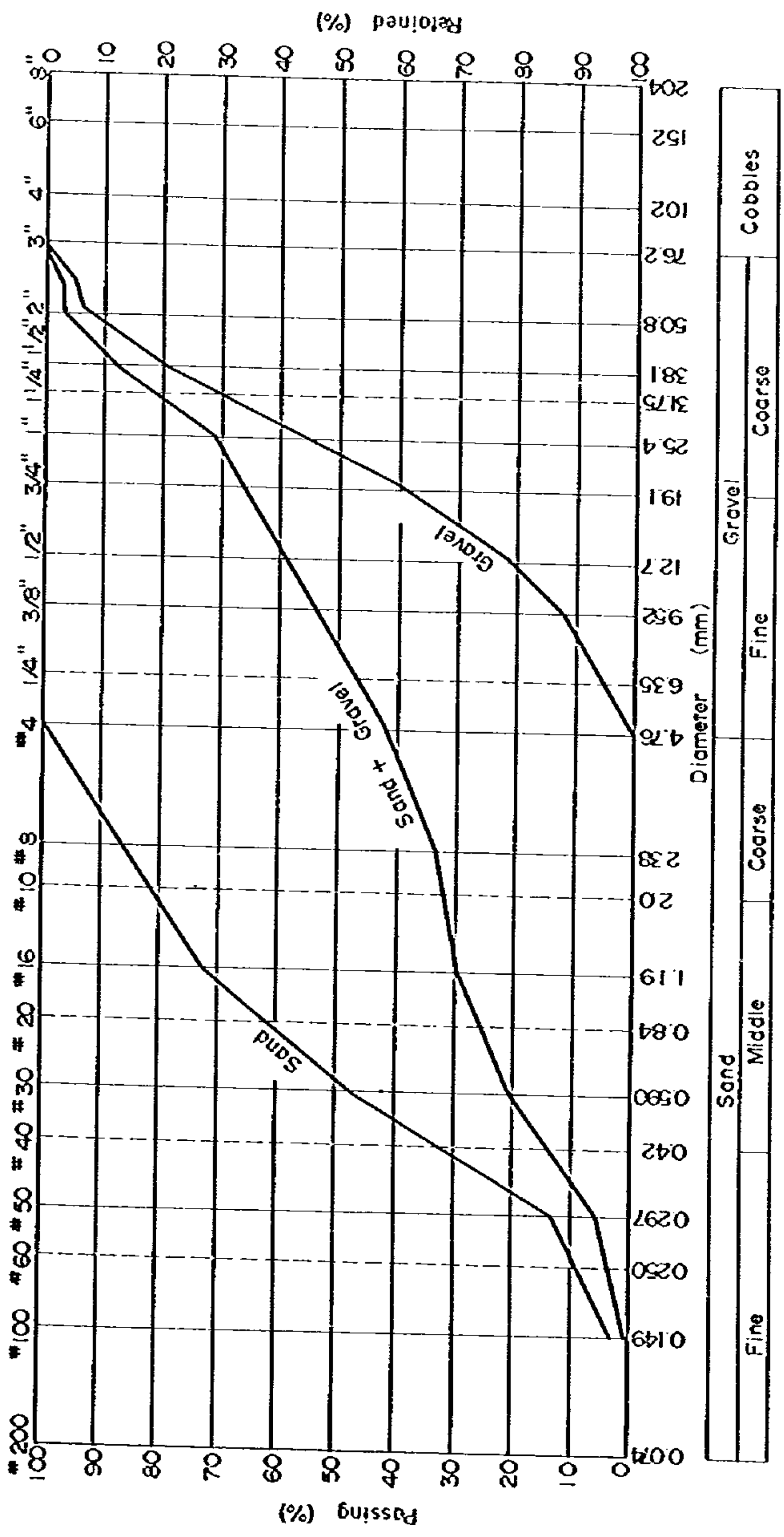
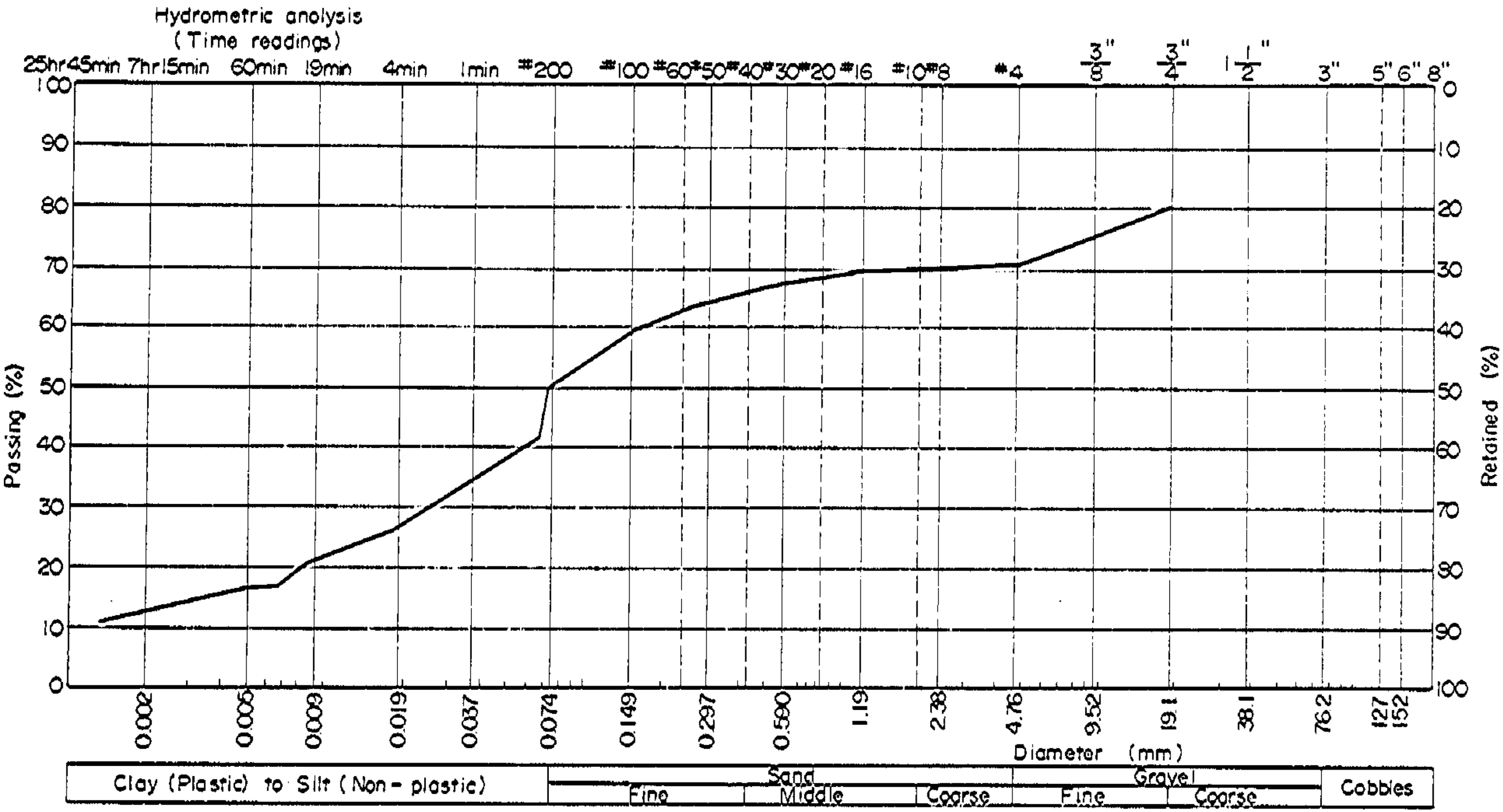


Fig.7- 20 Distribution Curve of Concrete Aggregate



Note : A - I Test Pits

Fig. 7-21 Distribution Curve of Impervious Core



Note ; B-1

7.6 Problematic Points and Recommendations for Additional Investigations

7.6.1 Problematic Points

The problematic points concerning this Project are all in relation to watertightness of the reservoir, and are the following:

(1) There is a strong possibility for leakage from the reservoir to occur by a passage through the karstified Köprücay Conglomerate in the vicinity of the dam site to reach downstream of the dam site.

(2) The Köprücay Conglomerate in the vicinity of the dam site is distributed in widths of more than 1.5 km at the left bank side of the dam site and 3.5 km at the right bank side, and permeability is high above EL. -120 m. Accordingly, the range of possible leakage occurrence is wide.

7.6.2 Matters for Clarification

In studying measures against leakage from the reservoir, it is of greatest importance to correctly grasp the permeability of the Köprücay Conglomerate in the vicinity of the dam site, and it is necessary to clarify the condition of karstification of the conglomerate for this purpose. Regarding this conglomerate, as described in 7.3.6, there is a more or less uniform development of small-scale solution cavities and channels above EL. -120 m, and the rock can macroscopically be considered as a homogeneous medium with regard to permeability. However, the state of karstification of the Köprücay Conglomerate widely distributed in the vicinity of the dam site cannot be said to have been suficiently clarified in the investigations in the past, while regarding permeability also, it is thought not to have been adequately grasped in permeability tests performed so far.

Accordingly, it is necessary for further additional investigations to be made and the following matters clarified.

(1) Parts of the Köprücay Conglomerate which cannot be considered macroscopically to be homogeneous with regard to permeability, in effect, ascertainment of existence or the range of distribution of parts of relatively large-scale solution.

(2) Average permeability of the part of Köprücay Conglomerate which macroscopically can be considered to be homogeneous.

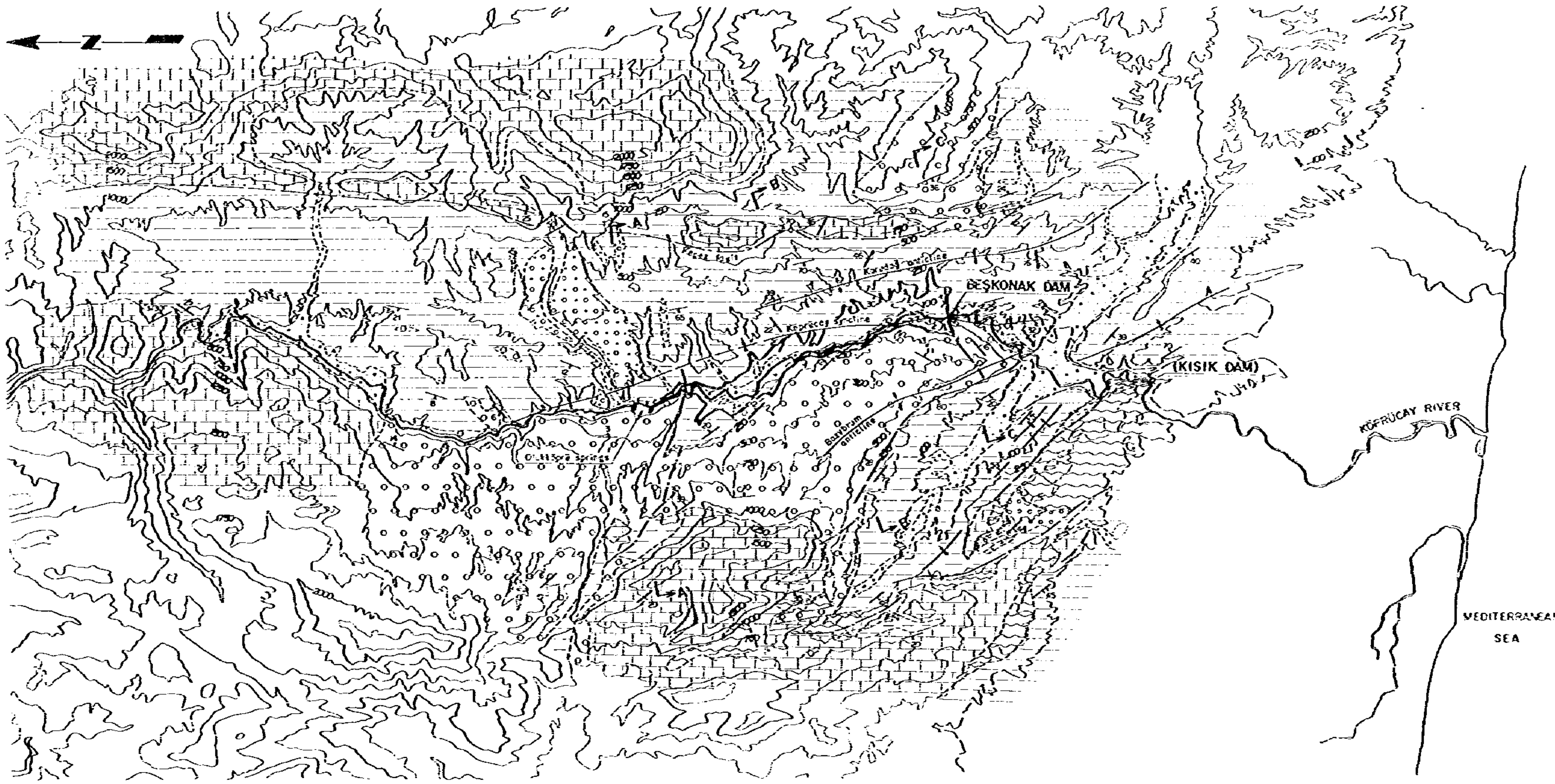
Further, in clarification of these matters, it is necessary to give thorough consideration to phenomena concerning groundwater, the fact that groundwater level becomes lower with increased distance from the river, and the fact that the groundwater level quickly varies following fluctuations in the river water level.

7.6.3 Recommendation of Additional Investigation

It is recommended that the additional investigations listed in Table 7-14 be carried out in order to clarify the matters pointed out in 7.6.2.

Table 7-14 Additional Investigations

Type	Location	Purpose	Approximate Quantity	Method
Core boring	Damsite vicinity	Clarification of state of karstification of Köprücay Conglomerate in damsite vicinity	6-8 holes, total 2,000 m	To be inclined about 60 deg in direction perpendicular to strike of predominant joints. Hole-bottom elevation to be about -100 m Part of these holes to be provided at concave portion of groundwater table
	Damsite vicinity	Confirmation of boundary between Köprücay Conglomerate and Beskonak Formation at left aboutment of damsite	2 holes, total 300 m	Vertical direction. Hole bottom elevation to be about 0 m
Permeability test	Damsite vicinity	Accurate grasping of permeability of Köprücay Conglomerate in damsite vicinity	12-15 holes	To be performed along with drilling of abovementioned holes, including some of existing holes Injection pump to be of enough capacity
Test pit	Adit RT-4, at right abutment of damsite	Clarification of detailed distribution of solutions in vicinity of groundwater table	1 pit, 20 m	
Pumping test	Adit RT-4	Grasping of permeability, Grasping of continuity of solutions		Pump-up of water at the abovementioned vertical shaft and observation of water level fluctuation in surrounding drillholes
Temperature measurement in drillhole	Damsite vicinity	Detection of groundwater passages from variations in water temperature distributions in drillholes		Periodic measurements from end of dry season to early part of rainy season
Dye test	Damsite vicinity	Confirmation of groundwater passages and grasping of permeability		Estimation of groundwater passages from results of past or above additional investigations. Dye introduced at drillhole or the pits, with detection attempted at projected locations



LEGEND

Quaternary	ALLUVIUM	Geologic boundary
	DÜZAĞAÇ FORMATION	Strike and dip of strata
Tertiary	BEŞKONAK FORMATION	Fault
	KÖPRÜÇAY CONGLOMERATE	Assumed fault
	TAŞAĞIL CONGLOMERATE	Strike and dip of fault
Mesozoic	(LIMESTONE)	Anticlinal axis
	(OPHIOLITE)	Synclinal axis
	(CHERT AND RED LIMESTONE)	Large spring
	KIRKKAVAK FORMATION	

0 — 10

BEŞKONAK PROJECT	
GEOLOGY PLAN OF RESERVOIR AREA AND ITS VICINITY	
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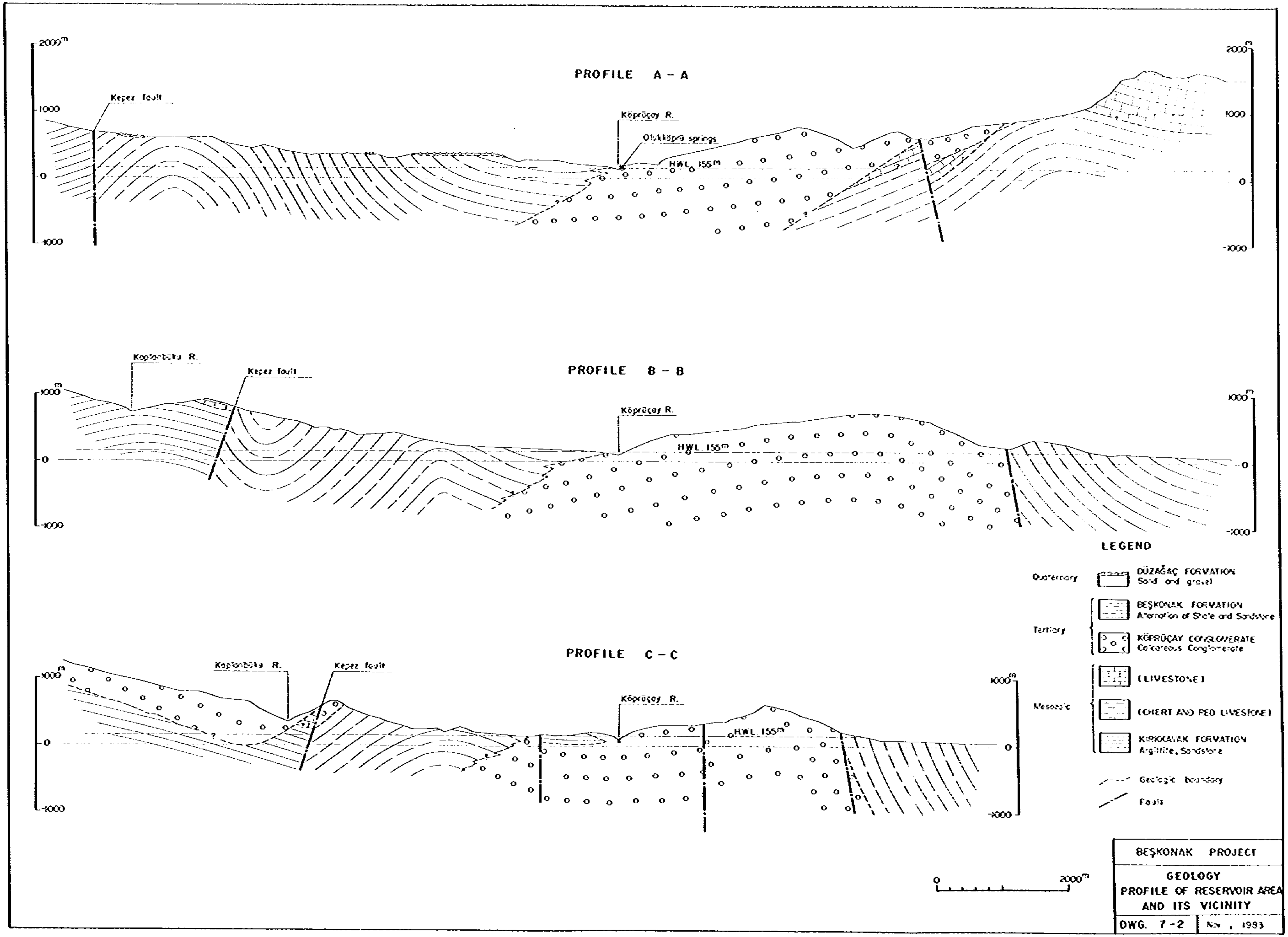
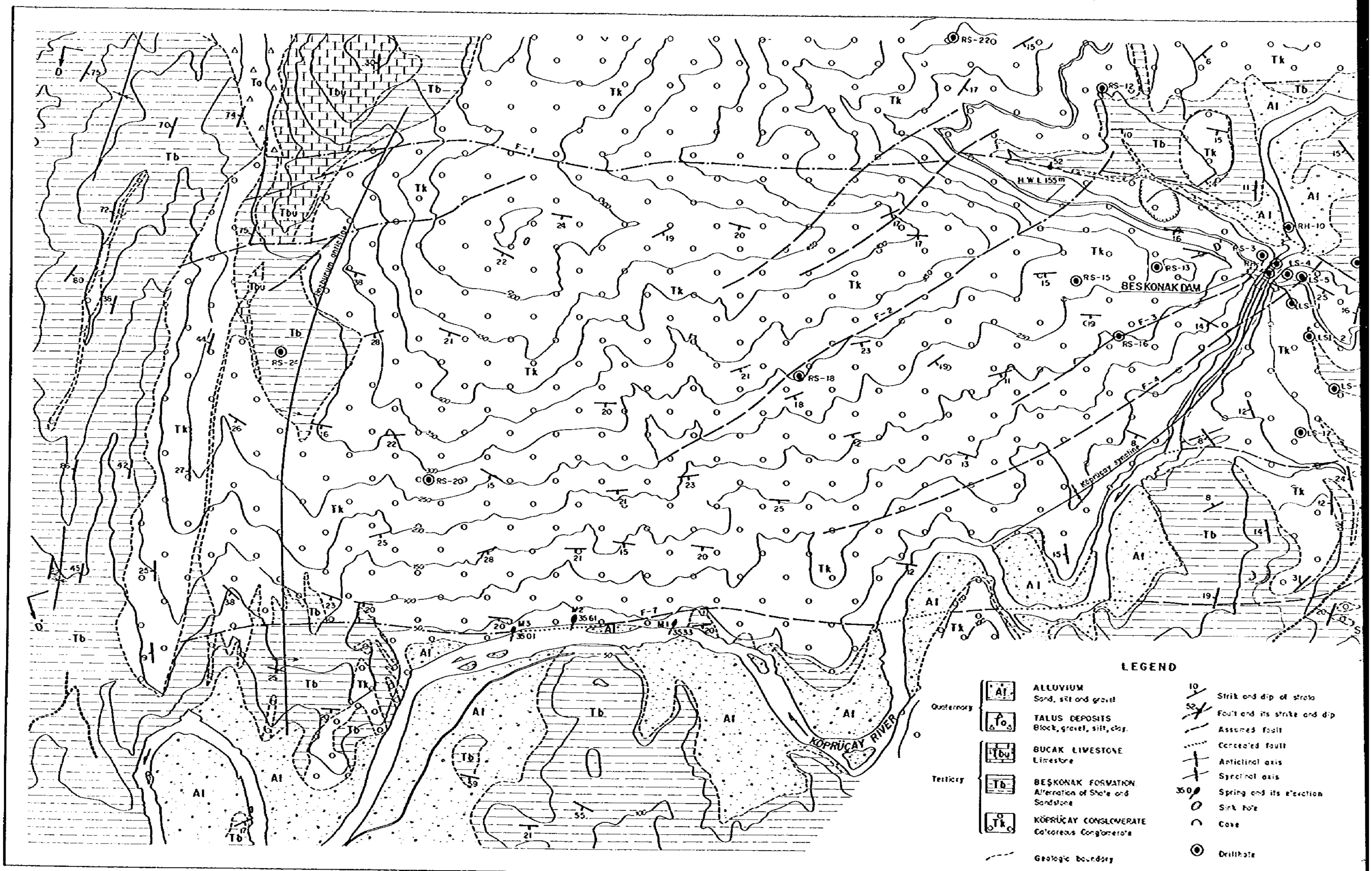
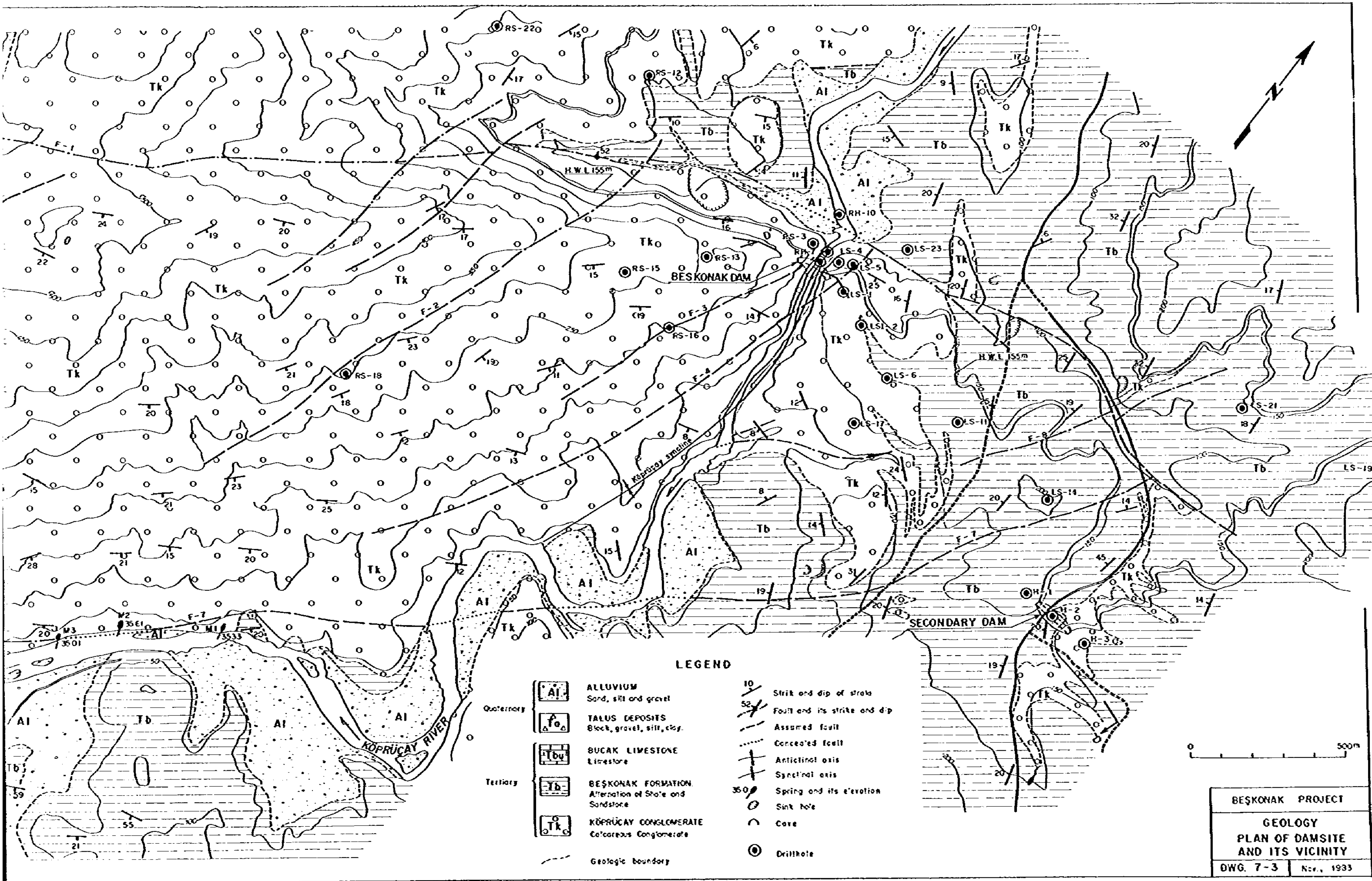

PROFILE A - A
Kepez fault
Köprüçay R.
Olukköprü springs
HWL 155m
PROFILE B - B
Kaplanbükü R.
Kepez fault
Köprüçay R.
HWL 155m
PROFILE C - C
Kaplanbükü R.
Kepez fault
Köprüçay R.
HWL 155m
LEGEND
Quaternary
DÜZAĞAÇ FORMATION
Sand and gravel
Tertiary
BEŞKONAK FORMATION
Alternation of Shale and Sandstone
KÖPRÜÇAY CONGLOMERATE
Calcareous Conglomerate
Mesozoic
(LIMESTONE)
(CHERT AND RED LIMESTONE)
KIRKKAVAK FORMATION
Argillite, Sandstone
Geologic boundary
Fault
BEŞKONAK PROJECT
GEOLOGY
PROFILE OF RESERVOIR AREA
AND ITS VICINITY
DWG. 7-2
Nov., 1993


LEGEND
Quaternary
ALLUVIUM
Sand, silt and gravel
TALUS DEPOSITS
Block, gravel, silt, clay.
Tertiary
BUCAK LIMESTONE
Limestone
BEŞKONAK FORMATION
Alternation of Shale and Sandstone
KÖPRÜÇAY CONGLOMERATE
Calcareous Conglomerate
Geologic boundary
Strike and dip of strata
Fault and its strike and dip
Assumed fault
Concealed fault
Anticlinal axis
Synclinal axis
Spring and its elevation
Sink hole
Cave
Drillhole
BEŞKONAK DAM
KÖPRÜÇAY RIVER
Köprüçay syncline
H.W.L.155m
F-1
F-2
F-3
F-4
F-7
RS-22
RS-12
RS-13
RS-15
RS-16
RS-18
RS-20
RS-24
RS-3
RH-10
LS-4
LS-5
LS-17
M1
M2
M3
Tk
Tb
Tbu
Al
To


BEŞKONAK DAM
SECONDARY DAM
KÖPRÜÇAY RIVER
Köprüçay syncline
H.W.L 155m
LEGEND
Quaternary
Al ALLUVIUM
Sand, silt and gravel
Ta TALUS DEPOSITS
Block, gravel, silt, clay.
Tertiary
Tbu BUCAK LIMESTONE
Limestone
Tb BEŞKONAK FORMATION
Alternation of Shale and Sandstone
Tk KÖPRÜÇAY CONGLOMERATE
Calcareous Conglomerate
Geologic boundary
Strike and dip of strata
Fault and its strike and dip
Assumed fault
Concealed fault
Anticlinal axis
Synclinal axis
Spring and its elevation
Sink hole
Cave
Drillhole
0 500m
BEŞKONAK PROJECT
GEOLOGY
PLAN OF DAMSITE AND ITS VICINITY
DWG. 7-3
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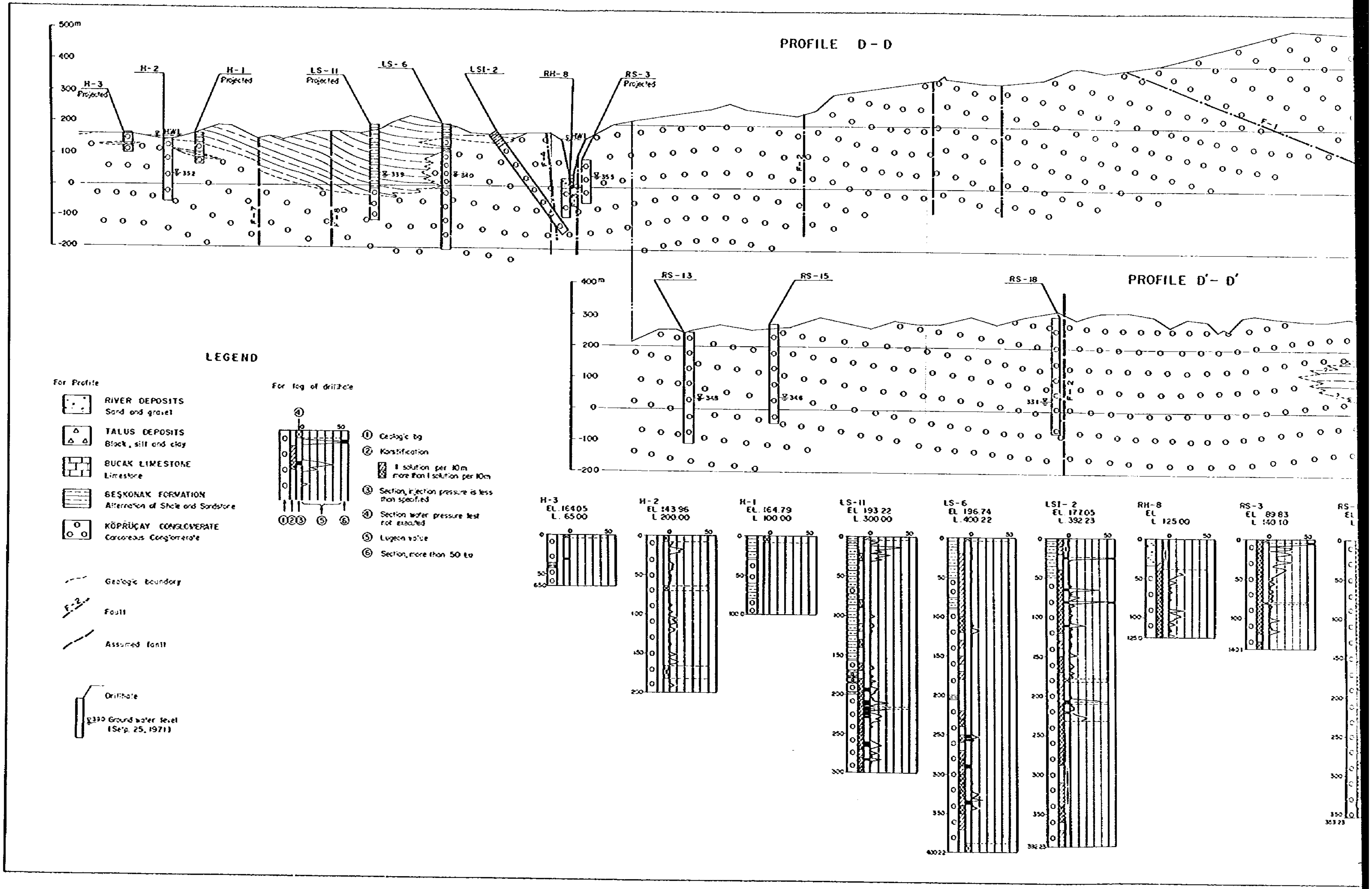
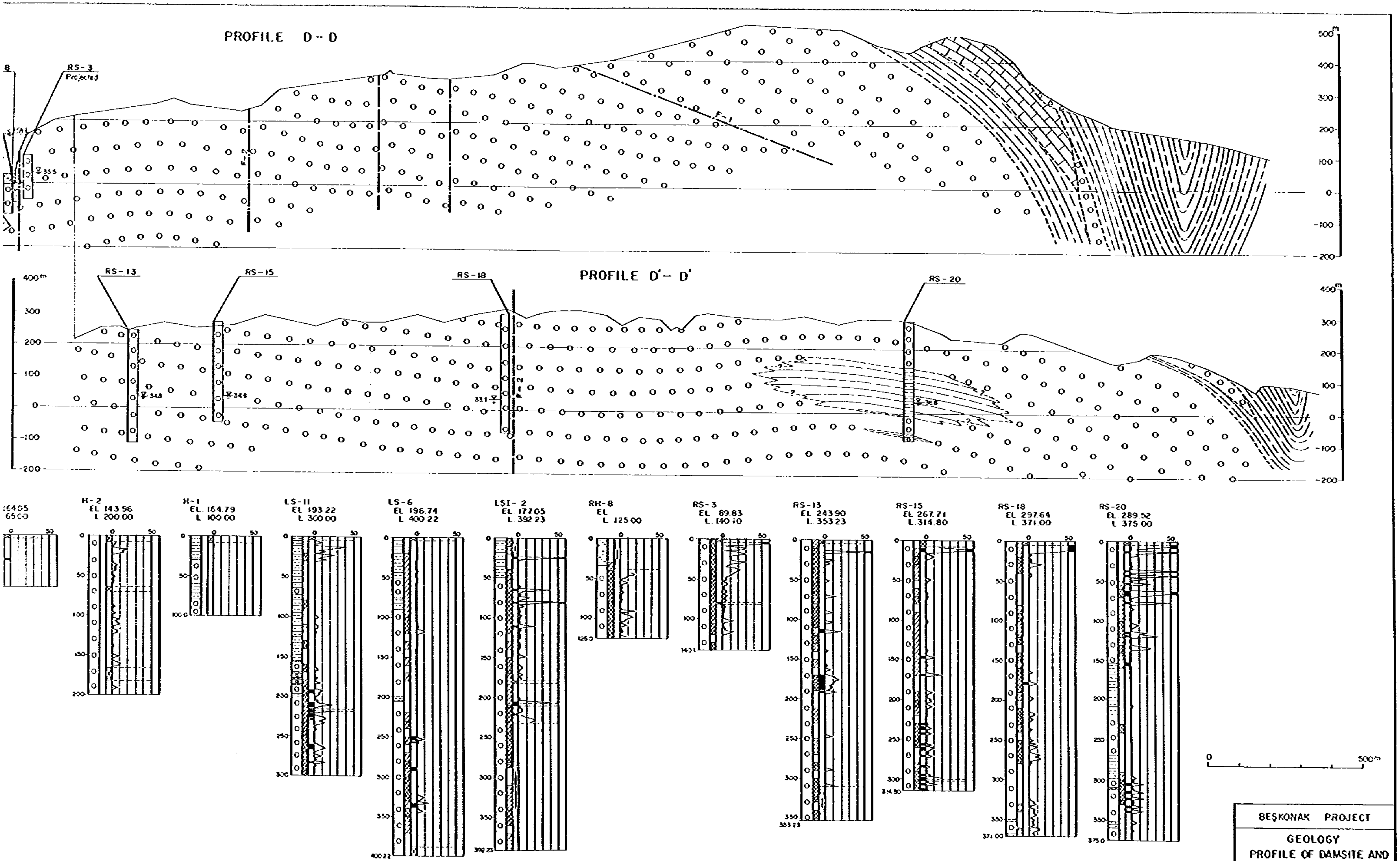


PROFILE D - D
PROFILE D' - D'
H-3 Projected
H-2
H-1 Projected
LS-11 Projected
LS-6
LSI-2
RH-8
RS-3 Projected
RS-13
RS-15
RS-18
500m
400
300
200
100
0
-100
-200
LEGEND
For Profile
RIVER DEPOSITS
Sand and gravel
TALUS DEPOSITS
Block, silt and clay
BUCAK LIMESTONE
Limestone
BEŞKONAK FORMATION
Alternation of Shale and Sandstone
KÖPRÜÇAY CONGLOMERATE
Calcareous Conglomerate
Geologic boundary
Fault
Assumed fault
Drillhole
330 Ground water level
(Sep. 25, 1971)
For log of drillhole
① Geologic log
② Karstification
1 solution per 10m
more than 1 solution per 10m
③ Section, injection pressure is less than specified
④ Section water pressure test not executed
⑤ Lugeon value
⑥ Section, more than 50 Lu
H-3 EL 164.05 L 65.00
H-2 EL 143.96 L 200.00
H-1 EL 164.79 L 100.00
LS-11 EL 193.22 L 300.00
LS-6 EL 196.74 L 400.22
LSI-2 EL 177.05 L 392.23
RH-8 EL L 125.00
RS-3 EL 89.83 L 140.10



BEŞKONAK PROJECT

GEOLOGY
PROFILE OF DAMSITE AND
ITS VICINITY

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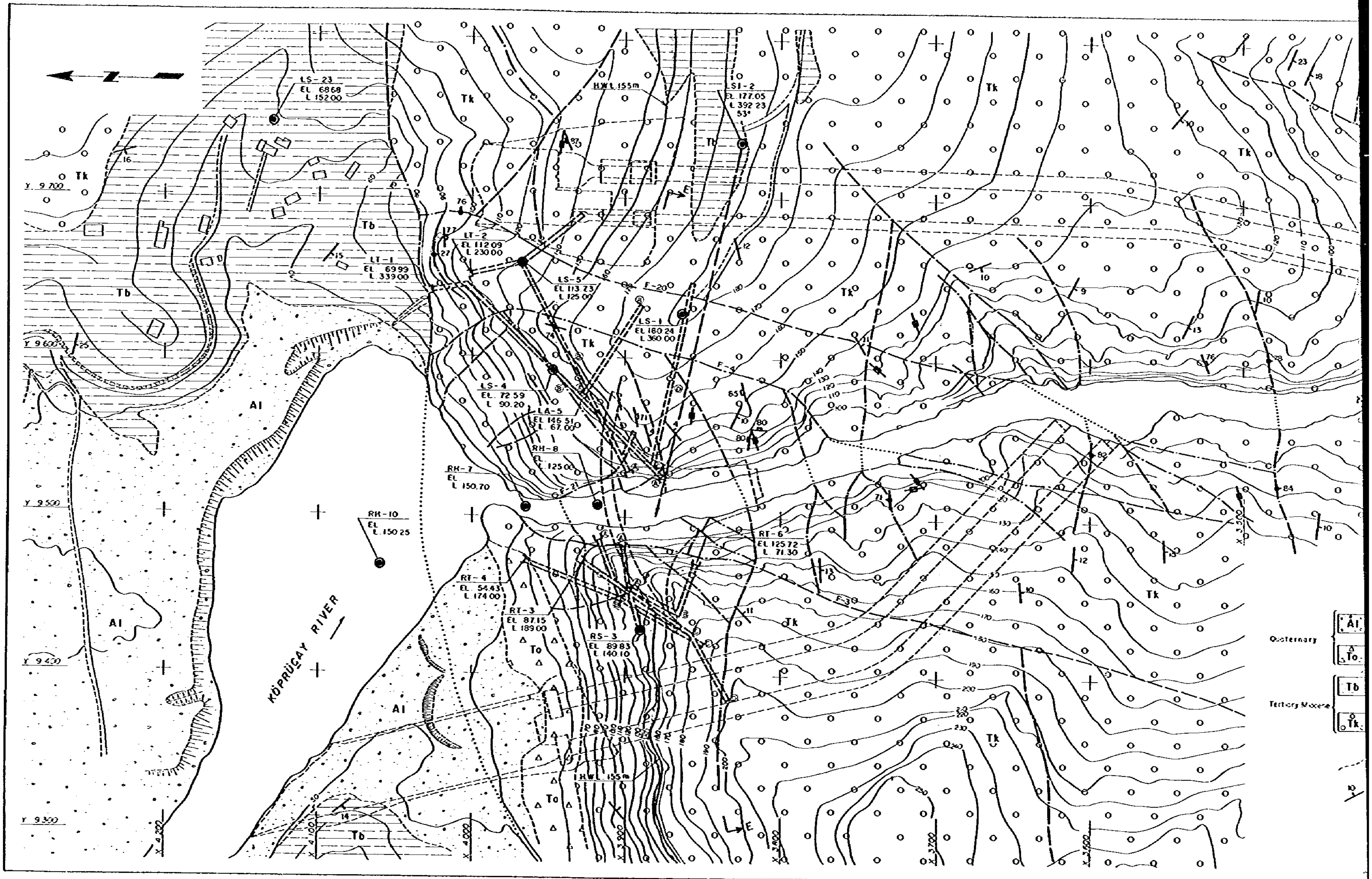
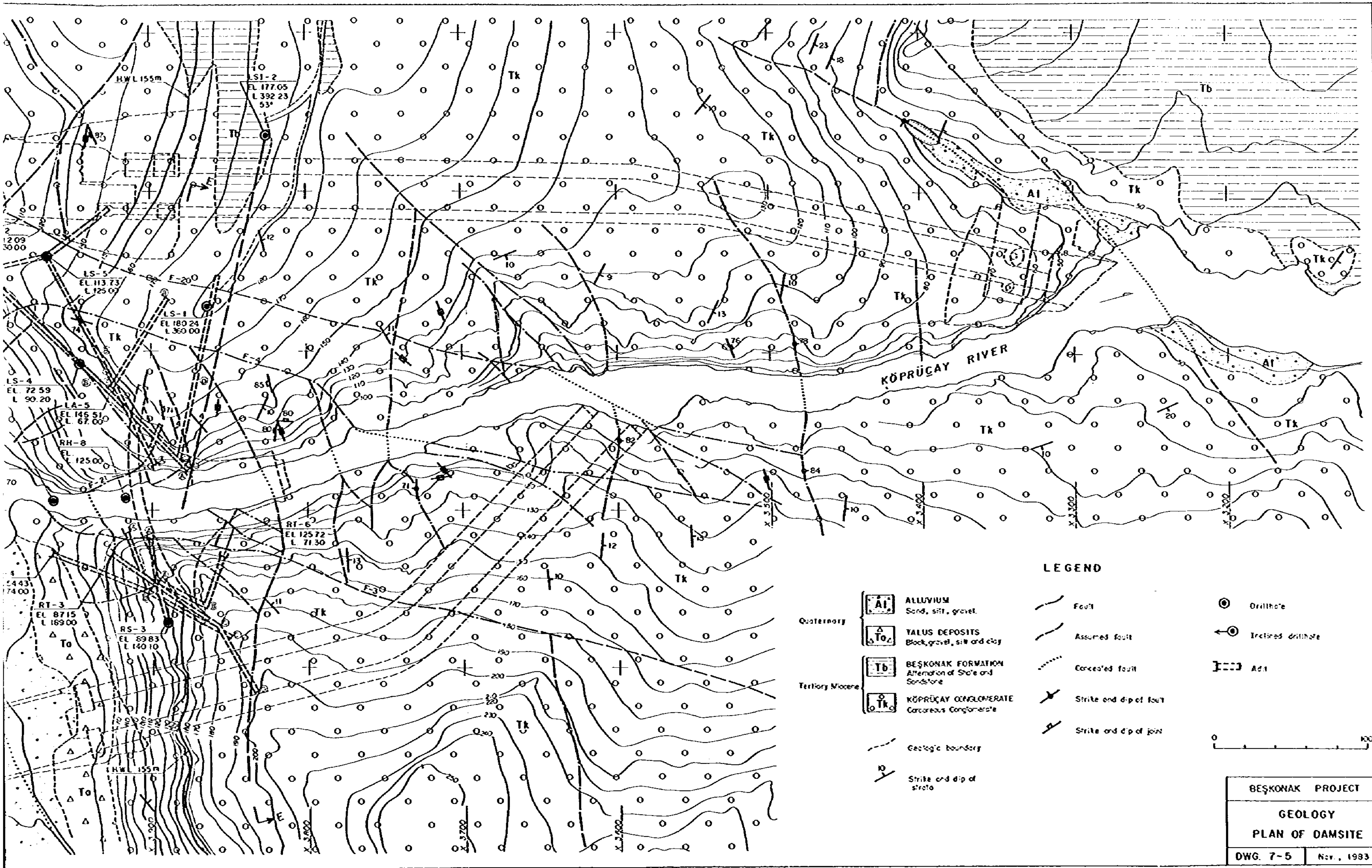

N
LS-23
EL 68.68
L 152.00
LT-1
EL 69.99
L 339.00
LT-2
EL 112.09
L 230.00
LS-5
EL 113.23
L 125.00
LS-1
EL 180.24
L 360.00
SI-2
EL 177.05
L 392.23
53°
HWL 155m
LS-4
EL 72.59
L 90.20
LA-5
EL 146.51
L 67.00
RH-8
EL
L 125.00
RH-7
EL
L 150.70
RH-10
EL
L 150.25
RT-6
EL 125.72
L 71.30
RT-4
EL 54.43
L 174.00
RT-3
EL 87.15
L 189.00
RS-3
EL 89.83
L 140.10
HWL 155m
KÖPRÜÇAY RIVER
F-20
F-8
F-21
F-3
Tk
Tb
To
Al
Y 9700
Y 9600
Y 9500
Y 9400
Y 9300
X 4200
X 4100
X 4000
X 3900
X 3800
X 3700
X 3600
Quaternary
Tertiary Miocene



H.W.L 155m
LSI-2
EL 177.05
L 392.23
53°
LS-5
EL 113.73
L 125.00
LS-1
EL 180.24
L 360.00
LS-4
EL. 72.59
L 90.20
LA-5
EL 145.51
L 67.00
RH-8
EL
L 125.00
RT-6
EL 125.72
L 71.30
RT-3
EL 87.15
L 169.00
RS-3
EL 89.83
L 140.10
F-20
F-4
F-21
F-3
Tk
Tb
Al
To
Tkc
KÖPRÜÇAY RIVER
LEGEND
Quaternary
ALLUVIUM
Sand, silt, gravel
TALUS DEPOSITS
Block, gravel, silt and clay
Tertiary Miocene
BEŞKONAK FORMATION
Alternation of Shale and Sandstone
KÖPRÜÇAY CONGLOMERATE
Calcareous Conglomerate
Geologic boundary
Strike and dip of strata
Fault
Assumed fault
Concealed fault
Strike and dip of fault
Strike and dip of joint
Drillhole
Inclined drillhole
Adit
0
100m
BEŞKONAK PROJECT
GEOLOGY
PLAN OF DAMSITE
DWG. 7-5
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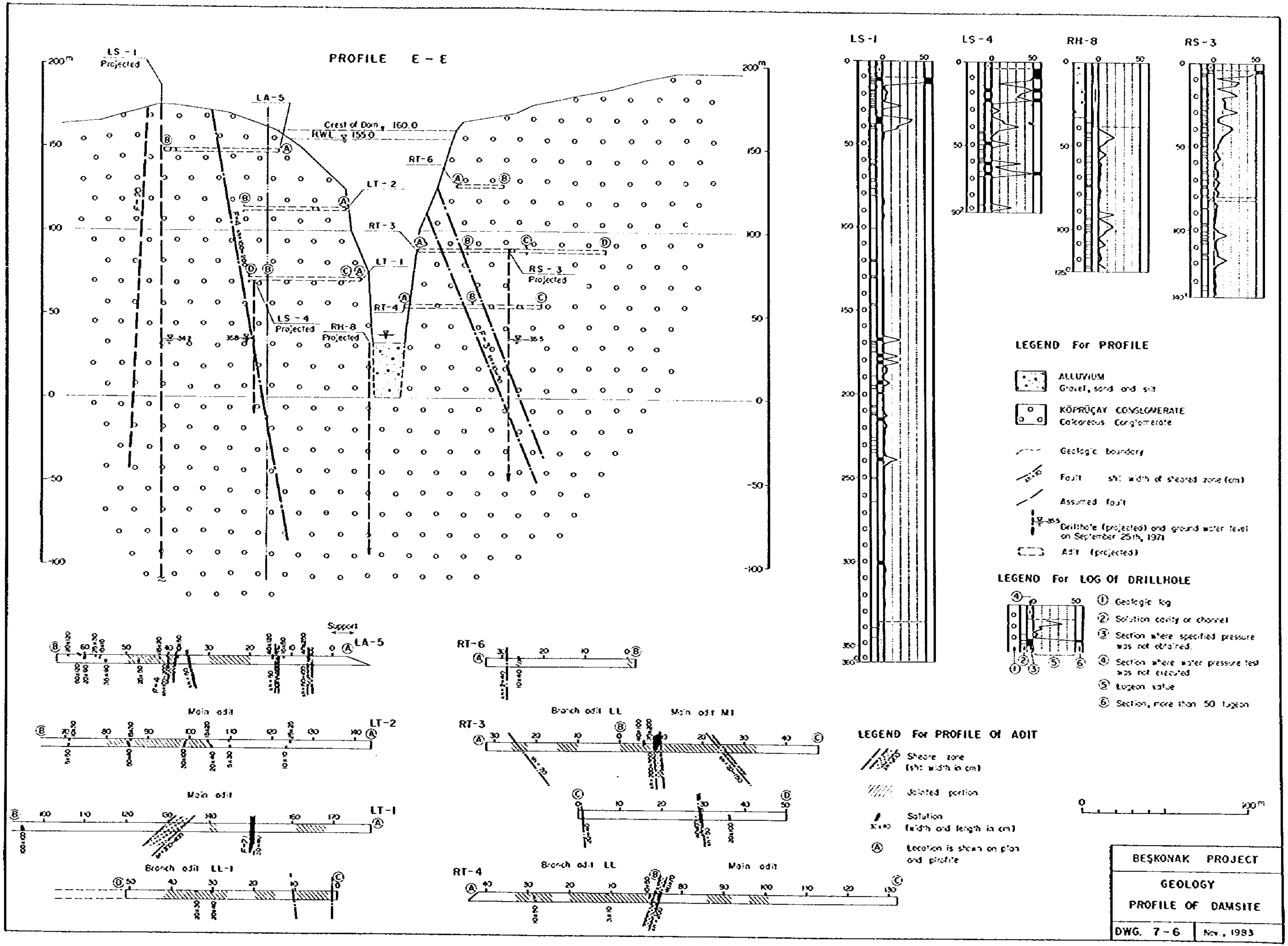
PROFILE E - E
LS - 1 Projected
LA-5
Crest of Dam 160.0
RWL 155.0
RT-6
LT - 2
RT - 3
LT - 1
RS - 3 Projected
RT-4
LS - 4 Projected
RH-8 Projected
LS-1
LS-4
RH-8
RS-3
LEGEND For PROFILE
ALLUVIUM
Gravel, sand and silt
KÖPRÜÇAY CONGLOMERATE
Calcareous Conglomerate
Geologic boundary
Fault sh: width of sheared zone (cm)
Assumed fault
Drillhole (projected) and ground water level on September 25th, 1971
Adit (projected)
LEGEND For LOG Of DRILLHOLE
① Geologic log
② Solution cavity or channel
③ Section where specified pressure was not obtained.
④ Section where water pressure test was not executed
⑤ Lugeon value
⑥ Section, more than 50 lugeon
Support
Main adit
Branch adit LL
Main adit M1
Branch adit LL-1
LEGEND For PROFILE Of ADIT
Sheare zone (sh: width in cm)
Jointed portion
Solution (width and length in cm)
Ⓐ Location is shown on plan and profile
BEŞKONAK PROJECT
GEOLOGY
PROFILE OF DAMSITE
DWG. 7 - 6
Nov., 1983

CHAPTER 8

SEEPAGE FLOW ANALYSIS OF DAM SITE VICINITY AND CURTAIN GROUTING

CHAPTER 8 SEEPAGE FLOW ANALYSIS OF DAM SITE VICINITY AND CURTAIN GROUTING

LIST OF FIGURES

LIST OF TABLES

LIST OF DRAWING

CHAPTER 8 SEEPAGE FLOW ANALYSIS OF DAMSITE VICINITY AND CURTAIN GROUTING

8.1 Seepage Flow Analysis of Dam Site Vicinity

8.1.1 Basic Considerations

With regard to watertightness of the reservoir, as described in 7.2.5, there is little possibility of leakage from the reservoir occurring at the upstream part, but there is a likelihood of leakage in the downstream direction through the Köprücay Conglomerate of high permeability distributed at the right bank. Therefore the vicinity of the dam site is an area requiring study of greatest importance.

At the right bank side of the dam site, the Köprücay Conglomerate is distributed over a width of approximately 3.5 km and contacts the impermeable Beskonak Formation. On the other hand, at the left bank side, the Köprücay Conglomerate is distributed underlying the Beskonak Formation and extends eastward for 1.5 km from the dam site, but the boundary between the Beskonak Formation and the Köprücay conglomerate is indistinct.

It would be impossible to completely prevent leakage through the Conglomerate which is distributed over a wide area, but it is judged that this leakage could be reduced with a grout curtain. However, enormous amounts of cost and time would be required to provide a grout curtain over the entire section of the Conglomerate (L ≒ 5 km). Moreover, it would be difficult to completely prevent leakage even with the grout of 5 km long. Therefore, it is considered realistic for the grout curtain not necessarily made to extend to an impermeable stratum, but for grouting to be performed limited to a zone in the vicinity of the dam site where it is considered leakage from the reservoir is concentrated, allowing some leakage to occur at other zones.

Generally speaking, it is impossible to completely prevent leakage from a reservoir in an area of calcareous rock distributed, but it is said the reservoir could be constructed even though there is some leakage so long as the safety of major structures is not impaired, and moreover, unless the adjoining and downstream areas are affected. In this case, it is necessary for leakage from the reservoir to be allowed to some extent, the allowable maximum leakage determined from an economic and technical viewpoint, and leakage prevention works for holding leakage below that level to be planned.

In view of the above, a numerical analysis was attempted on the problem of leakage through the bedrock of the dam site vicinity which is recognized qualitatively to exist, including a study on the range of the grout curtain. In the numerical analysis the results of permeability tests obtained in past investigations and data on solution cracks, etc., were taken, rearranged and analyzed, coefficients of permeability were set, and calculations were made as follows:

(1) Seepage flow in case of assuming the bedrock in the vicinity of the dam site to be macroscopically a homogenous continuum.

(2) Seepage flow in case of assuming existence of prominent joints (solution cracks) in the bedrock.

In the analysis here, study was made chiefly of the case of (1) above, while for the case of (2), studies of certain cross section was made.

Since hypotheses were set up for the calculation conditions and techniques in the numerical analysis, the analysis results are handled strictly as reference data.

Detailed data regarding seepage flow analysis are given in Appendix A-4. Further, since this analysis is a basic study, there are partial discrepancies from the dimensions given in the preliminary design described in Chapter 11.

8.1.2 Method of Analysis

Darcy's law was applied in calculations in seepage flow analysis. Seepage phenomena inside bedrock are governed by joints and cracks which are distributed irregularly and complicatedly, and also by the shapes and scales of faults and sheared zones.

There is some question, especially, about undiscriminatingly applying Darcy's law to seepage flow analysis of bedrock having solution cracks and solution holes such as at the Beskonak dam site where calcareous rocks have been subjected to solution action for a great length of time. However, the following have been clarified concerning the geology of the dam site surroundings, based on investigation works such as boring and test adits:

(1) Boundary conditions are distinct with regard to the aspects of topography and geology.

(2) The calcareous conglomerate is isotropic as a whole.

(3) The zone considered is amply large for the scales of cavities such as solution cracks.

(4) Small-scale cracks exist sufficiently and seepage paths together make multi-connected structure,

and macroscopically, the bedrock may be regarded as a homogeneous continuum so that it is thought Darcy's law could be applied.

In performing the analysis, a computerized analysis program of two-dimensional seepage flow was used. The program is based on the finite element method developed for studying the behavior of seepage flow inside bedrock by numerical analysis.

8.1.3 Permeability Coefficient of Dam Site Vicinity Bedrock

The permeability coefficient of the bedrock in the vicinity of the dam site was determined based on the results of the study described in 7.3.6, a summary being as follows:

(1) The correlations between Lugeon values obtained by permeability tests at the various drillholes and elevations, were estimated with distances from the river as a parameter. The results are shown in Fig. 7-16.

(2) The correlations between the distribution of solution cracks and elevations, were estimated with distances from the river as a parameter. The results are shown in Figs. 7-17 and 7-18.

(3) The results of permeability tests near the ground surface and in the vicinities of faults were arranged separately from (1) and (2).

Based on the above results, the following were made clear regarding the permeability of the bedrock in the vicinity of the dam site:

(1) Of the Köprücay Conglomerate, the surface layer portion (to a depth of approximately 40 m), the F-1 fault portion (sheared zone of 40 m wide) and fault portions other than the F-1 fault (sheared zone of 30 m wide) have respectively high permeability.

(2) The facies of the Köprücay Conglomerate has a permeability about five times higher than the part of alternations of shale and sandstone.

(3) There are parts of high permeability locally in the Köprücay Conglomerate.

(4) The Köprücay Conglomerate in the surroundings of the dam site generally shows a high permeability especially in the vicinities of streams and in sections of river water level variation.

(5) Solution cracks in the Köprücay Conglomerate are prominent in the range from EL. 60m to EL. -120 m.

In view of the above considerations the permeability coefficients (Lugeon values) used in calculations were set in Table 8-1. In performing the calculations, conversions to the coefficients were made on the basis of 1 Lugeon = 1 x 10^{-5} cm/sec. For the reasons described in 7.3.6, since it is conceivable that the coefficient of the bedrock of Köprücay Conglomerate might be underevaluated, K1 is extended to K2 (= 5 K1) and K3 (= 10 K1).

Table 8-1 Lugeon Values Adopted for the Analysis

Unit: Lugeon

Item		Measured Average Value	Adopted Values		
			K1	K2	K3
Surface (Depth 40 m)	Köprüçay Conglomerate	35.2	40	200	400
	Shale and Sandstone	13.3	20	100	200
Facies	Köprüçay Conglomerate	5.9	10	50	100
	Shale and Sandstone	1.6	2	10	20
Sheared zone (width 40 m F-1 Fault)	Köprüçay Conglomerate	41	40	200	400
	Shale and Sandstone	-	40	200	400
Sheared zone (width 30 m Fault except F-1)	Köprüçay Conglomerate	9.9	20	100	200
	Shale and Sandstone	-	20	100	200
Grout zone	Curtain	-	5	5	5
	Consolidation	-	1	1	1

8.1.4 Seepage Flow Analysis as Homogeneous Continuum

(1) Plane Analysis

Plane analysis was performed using permeability coefficient K1 for the two cases below.

(a) Without grout curtain

(b) With grout curtains (right bank side: L = 1,000 m,
left bank side : L = 500 m)

The analysis was made for a plane at EL. 80 m, an intermediate water level of the reservoir, with the purpose of finding behaviors such as seepage path and stream line direction of seepage flow, and plane distribution of leakage volume, thereupon to decide the calculation cross sections. Calculation models are given in Figs. 8-1 and 8-2, and the calculation results in Figs. 8-3 to 8-5. Figs. 8-3 and 8-4 indicate the flow nets of the left and right banks when grout curtains are not provided, while Fig. 8-5(a) shows the plane distribution of seepage flow at the upstream face inflow portion. The greater part of the leakage from the reservoir occurs in the vicinity of the dam site, and approximately 90% of the total amount flows out in the range of 800 m from the dam on the right bank side and 400 m on the left bank side. More or less the same trend is seen regardless of whether or not there is grout. Further, the seepage flow is governed by the path length, and there is little influence of faults and geological boundaries.

Based on the above results, as the cross sections to be analyzed in the following (2), dam site and five cross sections, where ratios to the total leakage volume are 50%, 70%, and 90% at the right bank, and 70% and 90% at the left bank, were selected and are shown in Fig. 8-3 and Fig. 8-4.

Also, calculations were made for the two cases of

(a)	Grout lengths:	right bank	L =	1,100 m
		left bank	L =	500 m
(b)	Grout lengths:	right bank	L =	550 m
		left bank	L =	250 m

using K3 to study the range of grouting. The results are shown in Fig. 8-5(b). The considerations with regard to range of grouting are described in 8.2.

Fig. 8-1 Calculation Model of Right Bank (Slice Section EL.80m)