Chapter 7 GEOLOGY AND CONSTRUCTION MATERIAL

Chapter 7

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7.1 Regional Geology

7.1.1 Topography

The Oltu river is the longest tributary of the Çoruh river which is located in the north-eastern area of Turkey. The basin of the Oltu river is surrounded by the Aras river basin at the east, by the Çoruh river basin at the west and the north and by the Murat river basin at the south. The elevations of mountains surrounding the Oltu river basin are generally 2,000 m to 3,000 m at Karadağ (EL. 2,399 m) and Mescit (EL. 3,255 m).

The Oltu river originates from the Kargapazari mountain and flows to the north-east direction; however, the course of the river changes to the north at the junction point with the Penek river (a tributary from the right bank side) and then changes again to the north-west direction at the proposed Olur powerhouse site.

The topography in the basin can be divided into two areas, one is the downstream area from the proposed Olur damsite and the other is the upstream area. The former area consists of volcanic rocks or sedimentary rocks belonging to lower Cretaceous, to Jurassic, or older period; accordingly, the slopes in this area form steep mountainous topography and the narrow flat plains are merely developed along the river bank, the latter one consists of sedimentary rocks including carbonate rocks belonging to Tertiary or younger period; therefore gentle mountains and wide flat plains are characteristic in this area.

7.1.2 Geology

(1) Outline

The basin of the Oltu river is the area which suffered Hercinian orogeny in Paleozoic and Alpine orogeny from Mesozoic to Cenozoic. The geology distributed, as shown in Table 7-1 and Fig. 7-1 is comprised of Quaternary sediments, Oltu formation of Tertiary, Pügey formation, Ayvalı volcanic rocks and Yusufeli formation of Mesozoic. The relation between each formation is contacted with angular unconformity.

Explanations of each formation are following:

(2) Description of Each Formation

1) Yusufeli Formation

Typical outcrops of Yusufeli formation are found at the area from Yusufeli village to the Deriner proposed damsite located downstream of the Oltu project area, and in the Oltu project area, small outcrops are seen at the left bank of middle stretch of the reservoir.

The formation is comprised of ophiolite, green schist, greywacke, basic tuff, etc. They are quite hard; accordingly, the topography in the area which the Yusufeli formation distributes, is characterized by very steep mountains. Fold and fault were also formed remarkably and Ikizdere granitic rocks intruded into the Yusufeli formation complexly.

2) Ayvalı Volcanic Rocks

The volcanic rocks which widely distribute from the proposed Olur damsite up to the end of Ayvalı tailrace tunnel are named generically as Ayvalı volcanic rocks. Therefore, the sites for the Olur dam, tunnel, powerhouse, the Ayvalı dam and tunnel are located in the Ayvalı volcanic rock area.

Ayvalı volcanic rocks are comprised of rhyolite, acidic and basic lava, tuff, agglomerate and granite as intrusive rock.

Ayvalı volcanic rocks have a clinounconformable relationship with the underlying Yusufeli formation and overlying Pügey formation in general.

3) Pügey Formation

The boundary between the Pügey formation and the Ayvalı volcanic rocks is found at the left bank of the Bulanik river (a tributary of the Oltu river) and it extends to the valley on the left bank of the Oltu river, about 1 km upstream from the Sakartepe damsite. The Pügey formation is made up largely of fine alternation of marl and limestone and contains partially intercalated sandstone and conglomerate. Some parts of the Pügey formation suffered sever folding; however, as a whole, very clear bedded outcrops continue widely in this area, especially in the downstream area from the proposed Ayvalı powerhouse site.

4) Oltu Formation

The Oltu formation, of Tertiary, distributes at both banks near the backwater of the proposed Olur reservoir and the formation is made up of semi consolidated claystone, marl, sandstone, conglomerate, etc.

Since the rocks comprising the Oltu formation are semi-consolidated continental sediments, the topography in this area shows gentle and roundish hilly slopes.

5) Terrace Deposit

The sizes of Terraces in the project area are comparatively small and they are developed in places of river banks. Gravels are normally 20 to 50 cm size and they are largely of volcanic rocks or igneous rocks.

6) Alluvium

According to the drilling results of the proposed damsite, the depth of alluvium is approximately 50 to 60 m. However, it is deeper than 80 m at the Sakartepe damsite near the boundary between the Pügey formation and the Ayvalı volcanic rocks. Gravels are mainly 10 to 20 cm size of volcanic rocks and they contain fine sand or silt layers as investigated at the Olur damsite.

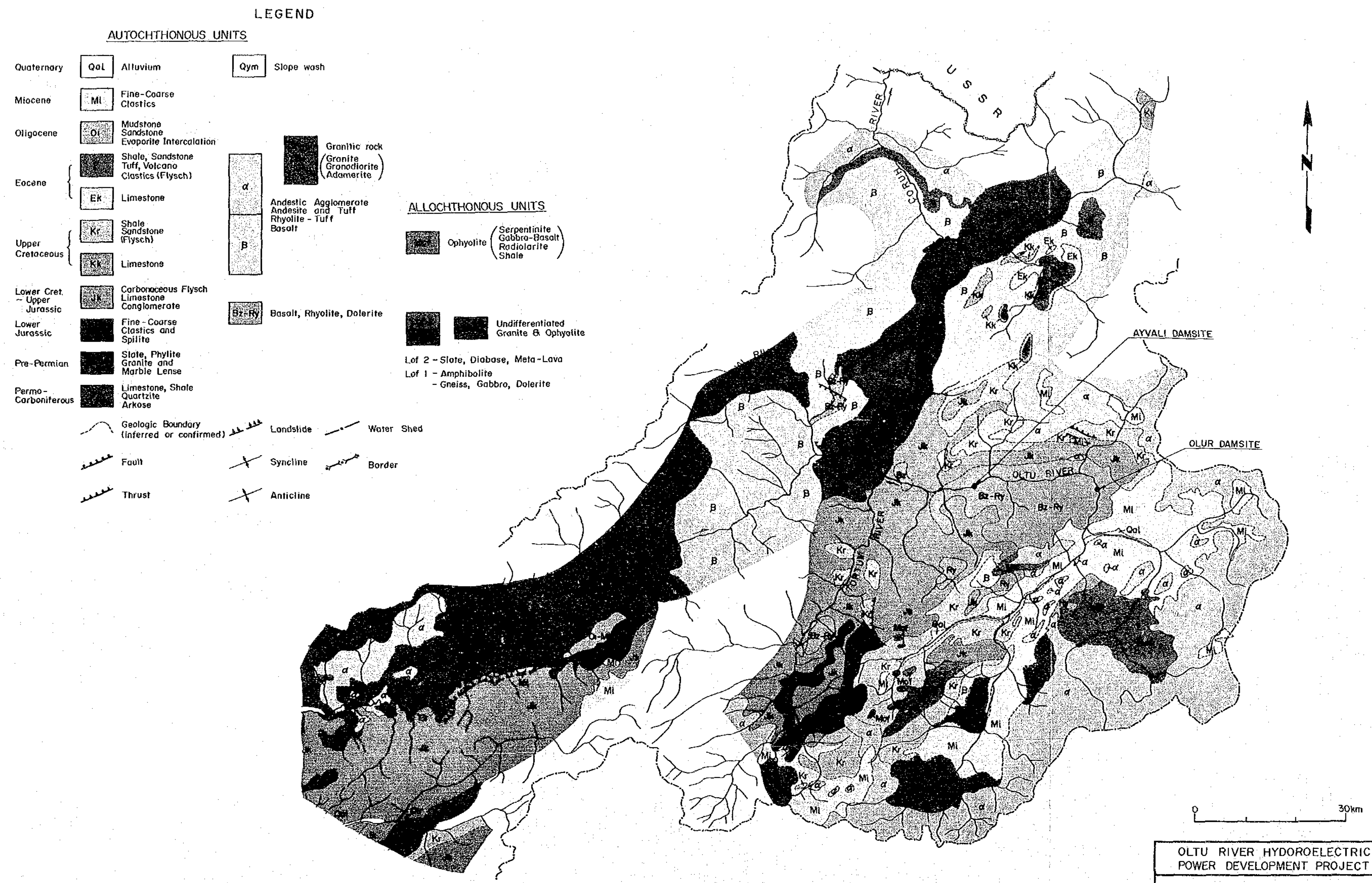
(3) Geologic Structure

1) Folding

The formation which is strongly folded in the project area is the Pügey formation; however, the folding does not continue so long, rather it is mainly local. In the Oltu formation, gentle undurations are seen, but severe folding like in the Pügey formation can not be found.

Table 7-1 Geologic Sequence

GEOLOGIC TIME			Regional Geology of Çoruh-Oltu River (EİE June, 1990)		
Era	Period		Formation	Lithology	Distribution
CENOZOIC	Quaternary		Quaternary System	Terrace deposit Alluvium	
CENOZOIC	Tertiary		Oltu F. (To)	Claystone, Marl, Sandstone, Conglomerate, Impure Limestone	Midstream & Upstream part of Olur Reservoir Area
MESOZOIC	Cretaceous	Late	Berta F. (kb)	Mudstone Marl Limestone Sandstone, Conglomerate Alternation of Spilitic Basalt, Rhyolite & Dacite IKIZDERE Granitic Rocks intruded	
MESOZOIC	Cretaceous	Early	Pügey F. (J-Kp)	Up: Alternation of Limestone & Marl with Silexite Low: Basal conglomerate, Alternation of Sandstone & Marl	Ayvalı Tailrace Tunnel
MESOZOIC	Jurassic	Late (Malm)			
MESOZOIC	Jurassic	Mid (Dogger)	Ayvalı Volcanics (Ja)	Rhyolite, Acidic and Basic lava, Volcanoclastics, Tuff, Aglomerate, Granite	Almost all project area
MESOZOIC	Jurassic	Early (Lias)	Yusufeli F. (jy)	Up: Greywacke, Slate, Phyllite Mid: Spilite (pillow lava), Metalava, Green Schist Low: Gabbro, Amphibolite	Midstream part of Olur Reservoir Area
PALEOZOIC	Permo-Carboniferous Pre-Permian			IKIZDERE Granitic Rocks intruded	



Note : This map is Compiled and Simplified from Geological Map of Çoruh River prepared by JICA in 1986 and Geological Map of Turkey 「Trabzon」, 「Kars」 (1/500,000) prepared by MTA in 1961.

OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

REGIONAL GEOLOGICAL PLAN

Fig. 7-1

2) Fault

Prominent fault in the project area is only one which strikes roughly N-S and steeply dips east, and being the boundary between Ayvalı volcanic rocks and Pügey formation.

Several lineaments assumed to be fault are interpreted by aerial photographs. One in the direction of N-S to NE-SW is most prominent and one in the NNW-SSE direction is secondary remarkable. However, these lineaments are not continuous to much length.

7.2 Outline of Investigation

7.2.1 Existing Data

The geological data used as references in writing this report are as listed in Table 7-2.

7.2.2 Geological Investigation Works

The outline of the geological investigation works carried out in the Olur Project and Ayvalı Project is as indicated below. Details are shown in Tables 7-3(a), 7-3(b) and 7-3(c).

Olur Project

Drilling		
Dam Site	10 Holes	Total 869.6 m
Powerhouse site	1 Holes	Total 30 m
Headrace tunnel	4 Holes	Total 390 m
Test pit for impervious core material	12 Pits	Total 38.5 m
Test pit for concrete aggregate	7 Pits	Total 13.5 m
Surface geological survey		
Dam site	1:1,000	map
Reservoir, Tunnel Route	1:5,000	map
Powerhouse	1:2,000	(enclargement from 1:5,000 map)
Aerial photo Interpretation	Reservoir and Tunnel route	

Ayvalı Project

Drilling		
Dam Site	10 Holes	Total 1,210.2 m
Tailrace tunnel	1 Hole	Total 70 m
Test pit for impervious core materil	18 Pits	Total 79.2 m
Test pit for concrete aggregate	8 Pits	Total 17.65 m
Surface geological survey		
Dam site	1:1,000	map
Reservoir, Tunnel route	1:5,000	map
Powerhouse	1:5,000 and 1:2,000	(enlargement from 1:5,000)
Aerial photo Interpretation	Reservoir and Tunnel route	

Table 7-2 Reference Data

	Items	Notes
1.	Intermediate Geotechnical Report for Olur, Ayvalı, Ayvalı-A, Ormanagzi and Şakartepe Damsites.	EIE, 1988
2.	Summary Report for Çoruh-Oltu river development project.	EIE, 1989
3.	Çoruh-Oltu river master plan report.	EIE, 1990
4.	Geological Map of Turkey (1:500,000) TRABZON	MTA, 1962
5.	Geological Map of Turkey (1:500,000) KARS	MTA, 1974
6.	Geological Map of Turkey (1:500,000) ERZURUM	MTA, 1963
7.	Geological Map of Turkey (1:500,000) VAN	MTA, 1964

Table 7-3(a) List of Drill Holes

Name of Hole	Location	Length	Dip	Note
Olur Project				
SK-214	Dam, river bed	99.5m	90°	
NiA-218	Dam, river bed	52.6m	90°	
Ni-219	Dam, river bed	62m	90°	
SK-210	Dam, left bank	127m	90°	
SK-212	Dam, left bank	160m	90°	
SKE-216	Dam, left bank	50m	45°	(*)
SK-211	Dam, right bank	150m	90°	
SKE-213	Dam, right bank	50m	45°	(*)
SK-215	Dam, right bank	80m	90°	
DSA-217	Spillway	81.4m	90°	
SY-220	Powerhouse	72m	90°	
DB-1	Headrace tunnel (Bahçecik)	90 m	90°	
DB-2	" "	100 m	90°	
DB-3	" "	100 m	90°	
DB-4	" "	100 m	90°	
Total	15 holes	1,374.5 m		
Ayvalı Project				
Ni-101	Dam, river bed	160m	90°	
NiA-108	Dam, river bed	70m	90°	
Ni-109	Dam, river bed	70m	90°	
SG-102	Dam, right bank	200m	90°	
SG-105	Dam, right bank	125m	90°	
SGE-106	Dam, right bank	100m	45°	(*)
SGE-107	Dam, right bank	100m	45°	(*)
SL-110	Dam, left bank	100m	90°	
SL-111	Dam, left bank	100m	90°	
SL-103	Left bank, P/S	185.2m	90°	
SL-112	Tailrace tunnel (Anzav valley)	70m	90°	
Total	11 hole	1,280.2 m		

(*) Direction of hole is perpendicular to the river.

Table 7-3(b) List of Test Pits for Impervious Material

Pit No.	Location	Length	Pit No.	Location	Length
Ayvalı Project			Olur Project		
MB-1	Bulanik Valley	4.0m	MK-1	Kaledibi	2.2m
MB-2	Bulanik Valley	12.0m	MK-2	Kaledibi	2.5m
MB-3	Bulanik Valley	4.0m	MK-3	Kaledibi	3.5m
MB-4	Bulanik Valley	10.0m	MK-4	Kaledibi	3.6m
MB-5	Bulanik Valley	1.2m	MK-5	Kaledibi	2.5m
MB-5A	Bulanik Valley	2.1m	MK-6	Kaledibi	3.2m
MB-6	Bulanik Valley	1.4m	MK-7	Kaledibi	3.0m
MB-7	Bulanik Valley	2.0m	MK-8	Kaledibi	4.0m
Sub Total	8 Pits	36.7m	Sub Total	8 Pits	24.5m
MT-1	Tavusker	4.0m	MY-1	Yolboyu	4.0m
MT-2	Tavusker	4.0m	MY-2	Yolboyu	3.0m
MT-3	Tavusker	3.8m	MY-3	Yolboyu	3.0m
MT-4	Tavusker	3.6m	MY-4	Yolboyu	4.0m
MT-5	Tavusker	4.0m			
MT-6	Tavusker	3.8m			
MT-7	Tavusker	4.0m			
MT-8	Tavusker	3.8m			
MT-9	Tavusker	3.5m			
MT-10	Tavusker	8.0m			
Sub Total	10 Pits	42.5m	Sub Total	4 Pits	14m
Grand Total	18 Pits	79.2m	Grand Total	12 Pits	38.5m

Table 7-3(c) List of Test Pits for Concrete Aggregate

Pit No.	Location	Length
Olur Project		
FM-1	Oltu river bed	1.75m
FM-2	Oltu river bed	2.2m
FM-3	Oltu river bed	1.9m
FM-4	Oltu river bed	1.5m
FM-5	Oltu river bed	2.5m
FM-6	Oltu river bed	2.1m
FM-7	Oltu river bed	1.4m
Total	7 Pits	13.35m
Ayvalı Project		
FM-1	Oltu river bed	1.75m
FM-2	Oltu river bed	1.8m
FM-3	Oltu river bed	1.7m
FM-4	Oltu river bed	3.0m
FM-5	Oltu river bed	2.5m
FM-6	Oltu river bed	2.3m
FM-7	Oltu river bed	2.5m
FM-8	Oltu river bed	2.1m
Total	8 Pits	17.65m

7.2.3 Geophysical Investigation Works

The outline of geophysical investigation works carried out in the Olur Project and Ayvalı Project is as indicated below. Details are shown in Table 7-3(d) and 7-3(e).

Olur Project

(a) Seismic Prospecting

Penstock and Powerhouse Site	4 Lines	1.240 m
Spillway Site	3 Lines	1.530 m
Headrace Tunnel	3 Lines	1.950 m

(b) Electrical Prospecting

Borrow Area	37 Points
Headrace Tunnel	600 m

Ayvalı Project

(a) Seismic Prospecting

Tailrace Tunnel	3 Lines	1,050 m
Access Tunnel for P/S	2 Lines	1,210 m

(b) Electrical Prospecting

Borrow Area	20 Points

Table 7-3(d) List of Seismic Prospecting

Line No.	Location	Length
Olur Project		
SP-1	Penstock, Powerhouse	420 m
SP-2	Penstock, Powerhouse	330 m
SP-3	Penstock, Powerhouse	240 m
SP-4	Penstock, Powerhouse	250 m
A	Spillway	630 m
B	Spillway	420 m
C	Spillway	480 m
H	Headrace Tunnel (Bahcecik)	550 m
I	Headrace Tunnel (Bahcecik)	700 m
J	Headrace Tunnel (Bahcecik)	700 m
Total	10 Lines	4,720 m
Ayvalı Project		
SAT-1	Tailrace Tunnel (Anzav valley)	390 m
SAT-2	Tailrace Tunnel (Anzav valley)	390 m
SAT-3	Tailrace Tunnel (Anzav Valley)	420 m
A	Access Tunnel for Powerhouse	560 m
B	Access Tunnel for Powerhouse	650 m
Total	5 Lines	2,260 m

Table 7-3(e) List of Electrical Prospecting

Location	Method	Quantity
Olur Project		
Kaledibi Borrow Area	Resistivity Method (Vertical)	37 points
Headrace Tunnel (Bahcecik)	Resistivity Method	600 m
Ayvalı Project		
Bulanik Borrow Area	Resistivity Method (Vertical)	20 points

7.3 Site Geology

7.3.1 Olur Project

(1) Reservoir

1) Topography

The reservoir would be formed along the Oltu River which flows from south-southwest to north-northeast and a tributary, the Penek River, which flows from east to west. The length of the reservoir will be approximately 10 km along the Oltu River and approximately 5 km along the Penek River.

The mountain masses surrounding the reservoir are of elevations from 1,400 m to 1,800 m, and they are gently sloped on the whole except for immediately upstream of the dam site and the vicinity of the confluence of the Penek River and the Oltu River. The slopes at the banks of the Oltu and the Penek are inclined at 20 to 30 deg. on average, but in the vicinity of the upstreammost part of the reservoir, the slopes are less than 20 deg.

Terrace and alluvial fans are developed along the Oltu River and the Penek River so that the width of the reservoir is wide as a whole, and the valley width at high water level EL. 1,105 m) is from 800 to 1,500 m.

2) Geology

The Yusufeli Formation and Ayvalı Volcanic Rocks of the Mesozoic Period, the Oltu Formation of the Cenezoic Tertiary Period, and Quaternary sediments mainly consisting of terrace deposits and alluvial fan deposits are distributed in the surroundings of the reservoir as shown in Fig. 7-2.

The Yusufeli Formation is constituted of basic igneous rocks such as gabbro and spilite, and by green schist and graywacke. This formation is mainly distributed in the vicinity of EL. 1,100 to 1,300 m at the left bank of the middle stretch of the reservoir, but is also distributed in small scale at the right bank. They strike roughly N-S and dip 50-80° W.

The Ayvalı Volcanic Rocks consist of basic and acidic lava, rhyolite, tuff, and tuff breccia. The Ayvalı Volcanic Rocks is the formation distributed most widely in the reservoir area. They may be found at both banks of the downstream part of the reservoir including the dam site, above EL. 1,300 m at the middle stretch of the reservoir, and at the upstream part of the reservoir.

The Oltu Formation is composed mainly of reddish brown to light green, poorly consolidated mudstone, marl, sandstone, and conglomerate, with limestone intercalated at upper parts. This formation is distributed in the vicinity of EL. 1,100 to 1,300 m at the midstream right bank of the reservoir and at the upstreammost part, with strikes in the northeast to southwest direction, and dips to the east of 30 to 70 deg.

The terrace deposits consist of cobble and boulder of diameters from 20 to 50 cm, sand, and silt, and exist scattered at both banks of the Oltu River and of the Penek River.

Alluvial fan deposits are distributed at mouths of gullies feeding the Oltu River with typical distributions seen in the vicinities of Kaledibi and Tekeli village at the right bank approximately 2 km upstream of the dam site. They consist of angular to subangular gravels of diameters from 10 cm to several tens of centimeters, sand, and silt.

Recent river deposits consist mainly of gravels of diameters from 10 to 20 cm, and medium to coarse-grained sand, but they may have intercalations of fine sand and silt several meters in thickness in some places. The deposits have been confirmed to be 44 m in thickness at the Olur dam site.

Talus deposits are distributed only in small scale at parts below the projected high water level.

Prominent faults do not exist in the surroundings of the reservoir. According to the aerialphoto interpretations, lineaments in the NW-SE direction and NE-SW direction are seen, but neither is continuous to very much length.

Landslides of small scale are seen at three places on the left-bank from the midstream part to the upstream part of the reservoir, but all are located 100 m or more above high water level.

3) Geological Engineering Assessments

(a) Watertightness

The basic igneous rocks, green schist, and graywacke of the Yusufeli Formation, the basic and acidic lava, tuffs of the Ayvalı Volcanic Rocks making up the reservoir area are all impermeable rocks.

The Oltu Formation distributed at the up-stream part of the reservoir also consists mainly of impermeable mudstone, marl, sandstone, etc. Although limestone is intercalated at the upper part of the Oltu Formation, this limestone is distributed only at parts considerably higher up than high-water level.

Topographically also, there are no scraggy ridges or saddles where leakage would be of concern.

Judging by these topographical and geological conditions, it is considered that watertightness of the reservoir will be amply assured.

(b) Stability of Slope

As landslides seen at the slopes around the reservoir are of small scale and located at places more than 100 m above high water level, they may be judged as not harming the stability of the reservoir.

Distributions of talus deposits are of small scale, and are considered not to endanger stability of reservoir slopes.

(2) Dam

1) Topography

The dam site is located near EL. 1,020 m at the bed of the Oltu River approximately 7 km upstream from the confluence of the Oltu River and its tributary Olur River. The Oltu River flows down in a south-southwest to north-northeast direction while meandering, but the course changes to south-southeast to north-northwest from the vicinity of the dam site.

The slope at the right bank of the dam site is inclined at approximately 40°. On the other hand, the inclination of the slope at the left bank is approximately 25° from the vicinity of the river bed to around EL. 1,050 m, and is about 40° above EL. 1,050 m. Both banks have almost no vegetation, and there are many outcrops of basement rock.

The river width at the dam site is approximately 60 m, and the valley width at high water level elevation of 1,105 m is approximately 300 m. On the other hand, the width of the valley upstream of the dam site suddenly becomes wide, while just downstream of the dam site, there is an alluvial fan of width about 300 m developed along a gully joining in from the right bank.

2) Geology

Granite porphyry, rhyolite, and diabase, and terrace deposits, river deposits, and talus deposits partially covering them are distributed at the dam site as shown in Figs. 7-3 and 7-4.

(a) Foundation Rock

a) Constituent Rocks

The foundation rock of the dam is composed of granite porphyry, rhyolite, and diabase. The granite porphyry is a massive rock of gray color tinged with light red, and is distributed chiefly from the right abutment of the dam to the river bed. Tight hair cracks are developed in many parts of the granite porphyry, but it is very hard as a rock mass.

The rhyolite and diabase, which intrude in units of widths from 1 m to 30 m, are mainly distributed at the left bank of the dam and both banks of the upstream coffer dam. Both rocks are hard, and extreme differences in lighological characters are not seen according to rock types. Intrusive planes strike N40-50°E and dip 45-75°E in general, namely they cross the dam axis obliquely and incline toward the left bank side. The intrusive planes are perfectly tight at places, but a cracky zone of 20 to 30 cm in width is developed in some places. However, clay and fine breccia are not intercalated in these zones.

b) Faults and Joints

Large scale faults of great lengths accompanied by wide sheared zones are not distributed in the neighborhood of the dam site. The faults recognized at the dam site are not accompanied by fault clay and fault breccia, and there are only cracks developed parallel to the fault planes, these not being very continuous.

Several such faults of widths from 40 cm to 1 m are distributed at the left bank of the dam. Some of them strike N50-80W and dip 60°-70°SW, and the others strike N60E dipping 60-70SE or NW.

Joints are developed at both banks at spacings of 20 to 30 cm on average. Predominant joints strike NE-SW dipping roughly vertical and strike NW-SE dipping 40 to 50°NE and SW.

(c) Weathering

The surface of bedrock is weathered and discolored brown near the ground surface at many places. At the left-bank abutment, a cracky and highly weathered zone is 3 to 8 m from the ground surface. Weathering discoloration along cracks can be seen prominently to the vicinity of a depth of 40 m from the ground surface.

On the other hand, at the right-bank abutment, a cracky and highly weathered zone is 3 to 4 m from the ground surface, while weathering discoloration along cracks can be seen from the ground surface to around a depth of 85 m.

(b) Surface Deposits

a) Terrace Deposits

Terrace deposits are distributed on the left bank of the upstream coffer dam and consist of cobble and boulder 10 to 50 cm in diameter, sand, and silt.

b) Alluvial fan Deposits

Alluvial fan deposits are distributed at the mouth of a gully at the right bank just downstream of the dam. According to the results of seismic prospecting and drilling

DSA-217, the thickness of the alluvial fan deposits ranges from 20 to 60 m in general and is 57 m at the spillway stilling basin site. The constituents are mainly silt and coarse-grained sand from the ground surface to a depth of 20 m, while deeper than 20 m consists of gravels several centimeters in diameter, coarse-grained sand, and silt.

c) River Deposits

The thickness of river deposits is 44 m at maximum according to the results of three drillholes made at the river bed. River deposits consist mainly of gravels of diameter 5 to 10 cm and coarse grained sand, but a layer of thickness approximately 15 m consisting of fine-grained sand and silt is confirmed between depths of 25.5 m and 39.7 m at Drillhole SK-214 bored downstream of the dam. On the other hand, such a layer consisting of fine material is not confirmed at Drillhole Ni-219 bored at the downstream of SK-214 and Drillhole NiA-218 bored at the upstream part of the dam.

Standard penetration tests are not performed at Drillhole SK-214, but are carried out at Drillhole NiA-218 and Ni-219 at every 1.5 m in depth. According to the results, N-values are all from 20 to 50, except for one location.

d) Talus Deposits

Talus deposits are distributed in small scale only at the foots of the slopes at both banks.

(c) Ground Water

The final water levels in the drillholes at the dam site are as shown in Fig. 7-4. The groundwater tables rise although gently at both banks according to the topography.

(d) Permeability

Lugeon tests utilizing drillholes at the dam site are carried out on a total of 6 holes, amounting to 278 stages and a length of 556 m. These tests are carried out in the foundation rock excluding surface deposits and river deposits with stages at 2-m intervals.

The results of Lugeon tests are analyzed by the following method.

The Lugeon values (Lu) which are the results of tests are all quantities injected (unit $\ell/m/min/10\ kgf/cm^2$) at injection pressure of 10 kgf/cm^2).

Therefore, with regard to a case where the injection pressure can not be raised to 10 kgf/cm^2 for some reason, a value converted by the following equation is used.

$$Lu = \frac{10Q}{P.L}$$

where, Q: quantity injected (ℓ/min)
L: length of test section (m)
P: injection pressure (kgf/cm^2)

The results of Lugeon tests are shown in Fig. 7-4. According to the results, permeabilities at the dam site are summarized as follows:

. Left Bank of Dam

High permeability zone with Lu≥20-30 is approximately 35 m thick from the ground surface above the mid-height portion of the slope, and approximately 15 m thick from the ground surface at the lower part of the slope. At deeper than 35 m at parts higher than the middle portion of the slope, the permeability is low with Lu of 0 to 3 indicated. On the other hand, at deeper than 15 m at the lower part of the slope, Lu values of 4 to 10 are indicated.

. River Bed

From the surface of the basement rock to a depth of approximately 16 m, a slightly high permeability of Lu = 6 to 20 is indicated, but the permeability is low at deeper than this, and Lu = 0 to 3 is indicated.

. Right Bank of Dam

High permeability zone with Lu ≥ 20 to 30 is from the ground surface to a depth of 30 to 40 m. At deeper than 30 to 40 m, a low permeability of Lu = 0 to 3 is generally indicated, but at the sections of depth 98 to

104 m and 116 to 128 m in Drillhole SK-211, values of Lu ≥ 20 are indicated.

3) Geological Engineering Assessments

Judging by the geological condition of the ground surface and the results of drillings including permeability tests, the following geological engineering assessments may be made concerning the dam site.

(a) It is judged that the granite porphyry, ryholite and diabase distributed at the dam site possess enough load bearing capacity as the foundation for the fill dam of 136 m height presently planned, except for cracky and strongly weathered zone near the ground surface.

These cracky and strongly weathered portions are from 3 to 8 m from the ground surface at the left abutment and 3 to 5 m at the right abutment.

(b) As planes of discontinuity in the foundation rock, there are faults, joints, and intrusive planes of igneous rocks. As previously mentioned, the faults confirmed at the dam site are all of small scale with little continuity, and they are not accompanied by prominent fault clay or fault breccia.

Joints are comparatively well-developed, and weathering discoloration along joint planes is seen to a depth of about 40 m from the ground surface at the left bank, and to around 85 m from the ground surface at the right bank.

Regarding intrusive planes of igneous rocks, there are cases in which they are perfectly tight and cases in which they are accompanied by cracky zones of 20 to 30 cm in width, but clay and fine breccia are not intercalated.

(c) According to the results of Lugeon tests, both banks indicate high permeability of Lu ≥ 20 to 30 from the ground surface to depths of 30 to 40 m, but deeper than 30 to 40 m, permeability is low at Lu = 0 to 3 except for parts at the right bank. As for the river bed, permeability is low at Lu = 0 to 3 when depth from the surface of the basement rock becomes deeper than approximately 16 m.

The bedrock at this site consists of hard igneous rocks. There is no water permeating between mineral particles of rock, and permeability is governed by discontinuous planes such as joints. Therefore, it is thought possible for ample water cut-off treatment to be provided by the generally-used type of cement grounting.

(d) Part of the foundation for the rock base of the dam consists of river deposits of thickness approximately 44 m. These river deposits consist mainly of gravel and coarse-grained sand, but a layer of fine-grained sand and silt has been confirmed at a section of approximately 15 m between depths of 25.5 m and 39.7 m in Drillhole SK-214.

However, thick layer of fine-grained sand and silt has not been observed in the Drillhole NiA-218 and Ni-219. It is thought that such a layer is not widely continuous. The N-values in standard penetration tests are from 20 to 50, which indicate that the constituent matter is well consolidated.

(3) Headrace Tunnel

1) Topography

The headrace tunnel extends in the west-northwest direction from the dam site and its total length is approximately 9,600 m.

The route of the headrace tunnel consists of rugged mountainland as a whole, and the middle part of the tunnel passes a ridge of El. 1,800 to 2,000 m extending in a direction from southwest to northeast. As for the upstream part of the tunnel, it passes a ridge branching in the southeast direction from the main ridge while the downstream part passes a ridge branching in a northerly direction.

There are three gullies crossing the downstream part of the headrace tunnel route, of which the one extending toward the Bahcecik village is the largest.

The earth cover for the tunnel is 400 to 950 m in the upstream part to the middle part of the tunnel, while it is 70 to 250 m at the downstream part.

2) Geology

The Ayvalı Volcanic Rocks of acidic and basic lava, rhyolite, tuff, and volcanic breccia are distributed at the headrace tunnel route as shown in Fig. 7-5. These rocks are all very hard except for the embrittled parts caused by hydrothermal alteration. The hydrothermal alteration zones are confirmed along faults in the vicinity of the Oltu River which flows north of the headrace tunnel.

Although there is no prominent fault intersecting the headrace tunnel, several lineaments crossing the tunnel at obtuse angle are interpreted in aerial photographs.

Some landslides are distributed along the valley crossing the downstream part of the headrace tunnel. Headrace tunnel passes under the end portion of the landslide at the Bahçecik village.

3) Geological Engineering Assessments

Judging by the geological condition of the ground surface and the results of aerial photo interpretations, the following geological engineering assessments may be made of the headrace tunnel route.

(a) The headrace tunnel route consists of the Ayvalı Volcanic Rocks of the Mesozoic Era. As the acidic and basic lava, rhyolite, tuff, and volcanic breccia comprising the Ayvalı Volcanic Rocks are all hard and dense rocks, it is considered they will not be obstacles to tunnel excavation.

(b) No prominent fault crossing the headrace tunnel has been confirmed. However, several lineaments crossing the tunnel are confirmed by aerial photo interpretations, and there is a possibility that these comprise weak lines in the bedrock. Since there are cases of hydrothermal alteration parts along weak lines in the Ayvalı Volcanic Rocks, it will be necessary for care to be exercised in tunnel excavation at places where weak lines are expected.

(c) The downstream part of the headrace tunnel passes under the end portion of the land-slide at the Bahçecik village. The depth from the ground surface to the projected tunnel location at this site is approximately 80 m. According to the results of the seismic prospecting carried out along the tunnel route, thickness of the landslide mass is 63 m, and minimum thickness of bedrock from the bottom of landslide to tunnel location is 17 m. This thickness of rock of a minimum 17 m will not be a problem in tunnel excavation, but a careful study will be required concerning the method of lining when considering the fact that this is to be a pressure tunnel.

Although, one traverse of seismic prospecting has been carried out on this landslide, four exploratory drillings, additional seismic prospectings and electrical prospecting are doing now to clarily the thickness and shapes of the landslide mass.

(4) Penstock and Powerhouse Site

1) Topography

For the penstock and powerhouse site, OPK Plan and OPT Plan, which is located at a approximately 400 m upstream of OPK Plan Site, are examined. As the result of examination, OPK Plan site is finally selected as penstock and powerhouse site judging from the economical point of view.

The penstock route of the OPK Plan is located at a ridge extending in a direction from southwest to northeast. The slope of the penstock route forms steep cliffs at parts, but on average, it is approximately 30° at the upper part and approximately 35° at the lower part. Bedrock is exposed at other than the vicinity of the river bed.

On the other hand, the penstock route of the OPT Plan comprises a slightly opened-up gully-like topography of width 100 to 150 m. The section from the surge tank to approximately 250 m downstream is a slope of inclination 30° to 40° where bedrock is exposed, while on the powerhouse side from this is a gentle slope of inclination 10° to 15° covered by surface deposits.

2) Geology

As shown in Fig. 7-6, Ayvalı Volcanic Rocks, and overlying terrace deposits and talus deposits, are distributed at the penstock and powerhouse site.

The Ayvalı Volcanic Rocks comprise the basement rocks at this site and consist of hard acidic and basic lava, tuff, and tuff breccia. Prominent joints in the Ayvalı Volcanic Rocks are one which strikes SE-NW and dips 60° to 80° SW and one which strikes SW-NE and dips 40° to 80° SE.

Terrace deposits are distributed in a width of 100 to 150 m from the vicinity of the powerhouse site in the OPT Plan to immediately upstream of the powerhouse site in the OPK Plan. The thickness of terrace deposits is from 40 to 60 m according to the results of seismic prospecting and Drillhole SY-220.

Talus deposits are distributed in the vicinity of the powerhouse in the OPK Plan and from the vicinity of the powerhouse site to the middle part of the penstock in the OPT Plan. According to the results of seismic prospecting, the thickness of talus deposits in the vicinity of the OPT Plan powerhouse is 10 to 15 m. The thickness of talus deposits in the vicinity of the OPK Plan powerhouse is estimated to be a maximum of 10 m from the condition of distribution.

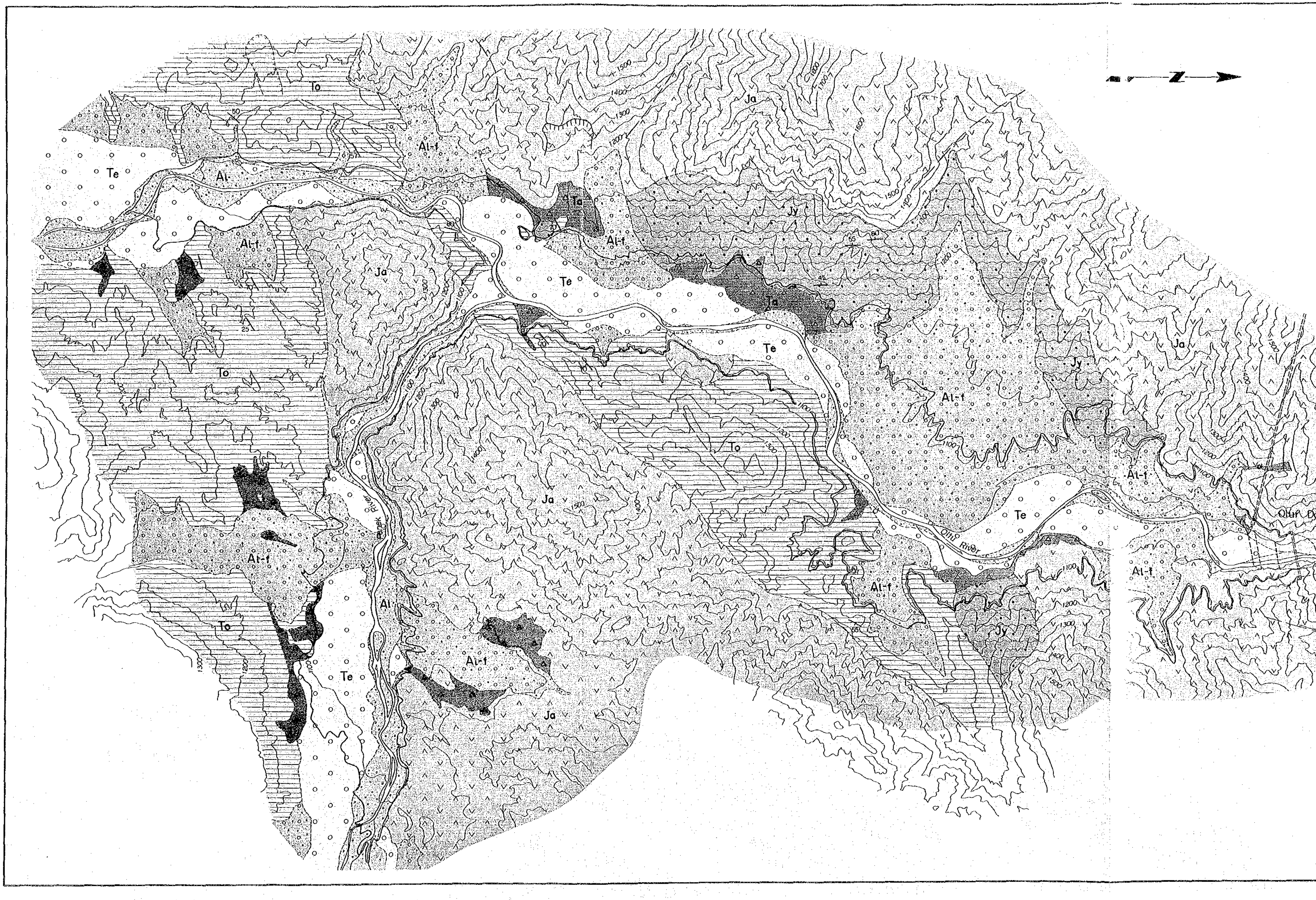
Large scale faults and landslides are not recognized at this site.

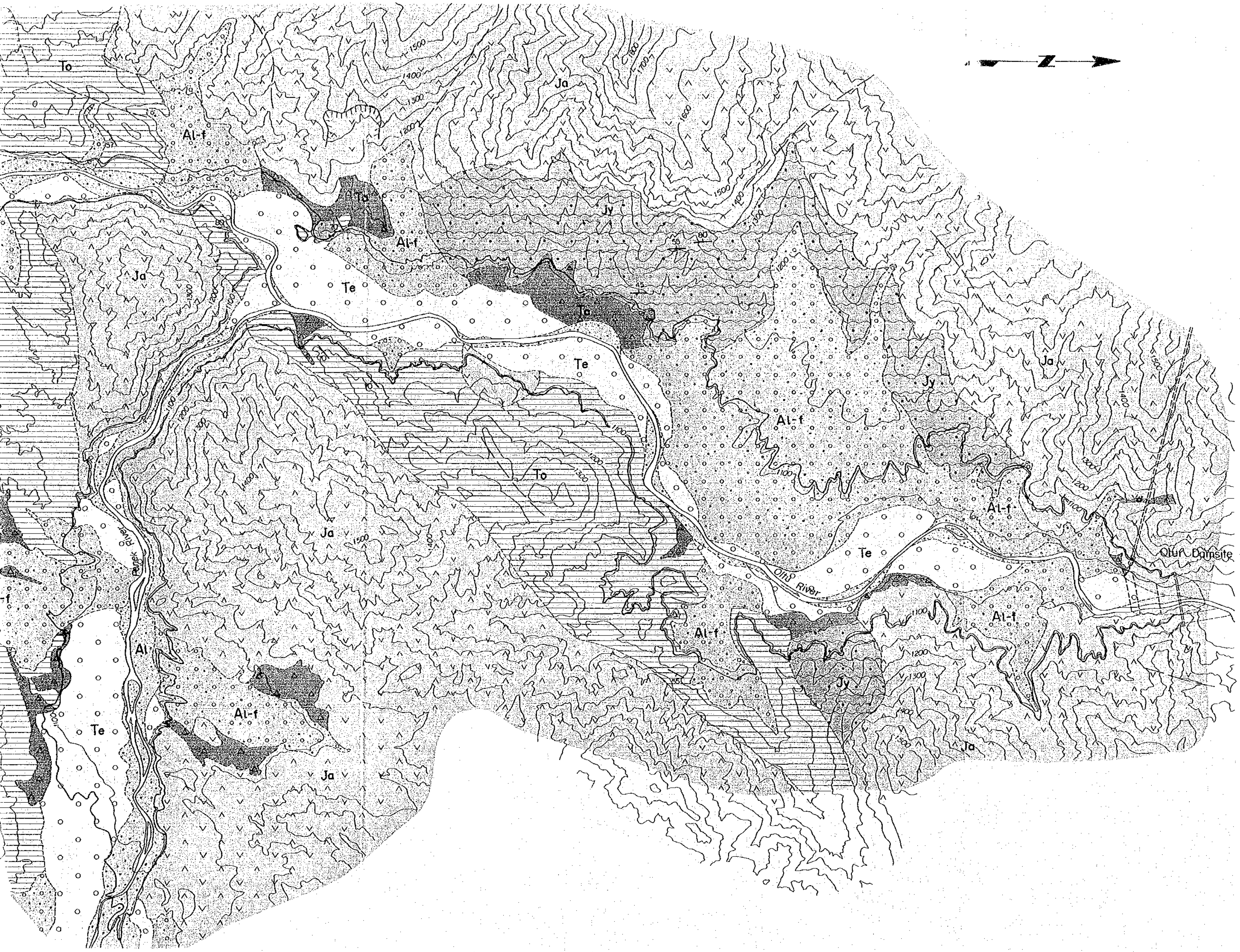
3) Geological Engineering Assessments

The following geological engineering assessments are made of the penstock and powerhouse site based on the geological condition of the ground surface and results of seismic prospecting.

- Talus deposits are distributed at the powerhouse sites in the OPK and OPT Plans. As their thicknesses are 10 to 15 m, the powerhouse foundation is thought to consist of hard Ayvalı Volcanic Rocks.

- The penstock route in the OPK Plan consists of hard Ayvalı Volcanic Rocks. On the other hand, there is a distribution of talus deposits at parts of low elevation at the penstock route in the OPT Plan, but the thickness of it is 10 to 15 m at maximum.


N
To
Te
Al
Al-f
Ja
Jy
Ta
Te
To
Olur D
Tortum Riv
Oltu River
Al
Al-f
Te
To
Ja
Jy
Ta



LEGEND

Ta	Talus deposit
Al	Alluvial deposit
Al-f	Alluvial fan deposit
Te	Terrace deposit
To	Oltu formation (Claystone, marl, Sandstone, Conglomerate and limestone)
Ja	Ayvalı volcanic rocks (Acidic and basic lava, rhyolite, tuff and Volcanic breccia)
Jy	Yusufeli formation (Gabbro, spilite, greenschist and greywacke)

30	Strike and dip of strata
	Aerialphoto lineament
	Geologic boundary
	Landslide
	Probable landslide interpreted by aerial photograph

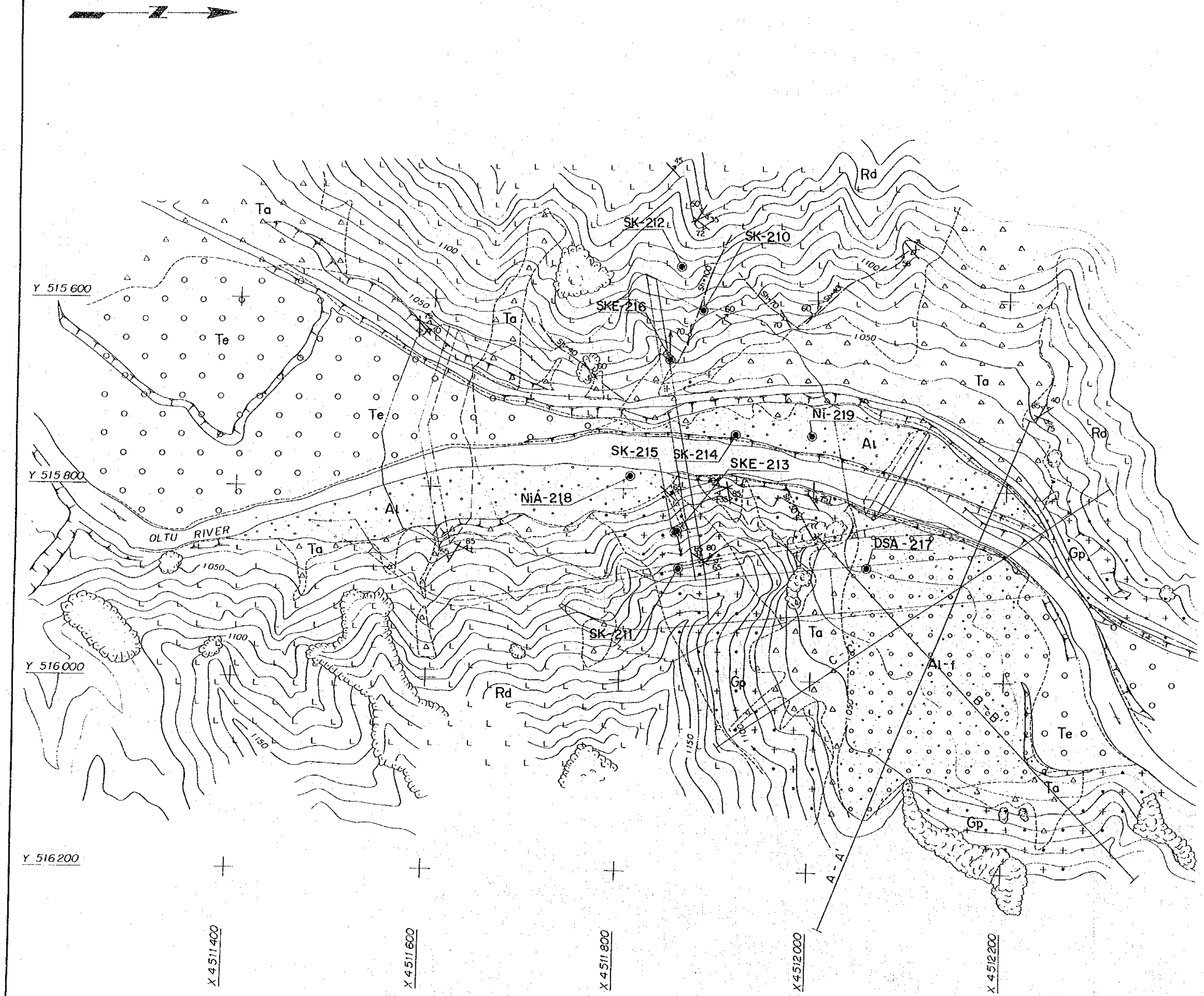
0 1000 m

OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

OLUR PROJECT

GEOLOGIC PLAN OF RESERVOIR AREA

Fig. 7-2



LEGEND

- Ta — Talus deposit
- Al — Alluvial deposit
- Al-f — Alluvial fan deposit
- Te — Terrace deposit
- Gp — Granite porphyry
- Rd — Rhyolite and Diabase
- Geologic boundary
- Strike and dip of fault (Sh : Width of shear zone, cm)
- Strike and dip of joint
- Strike and dip of igneous contact
- SK- Drill hole
- A - A' Seismic prospecting line

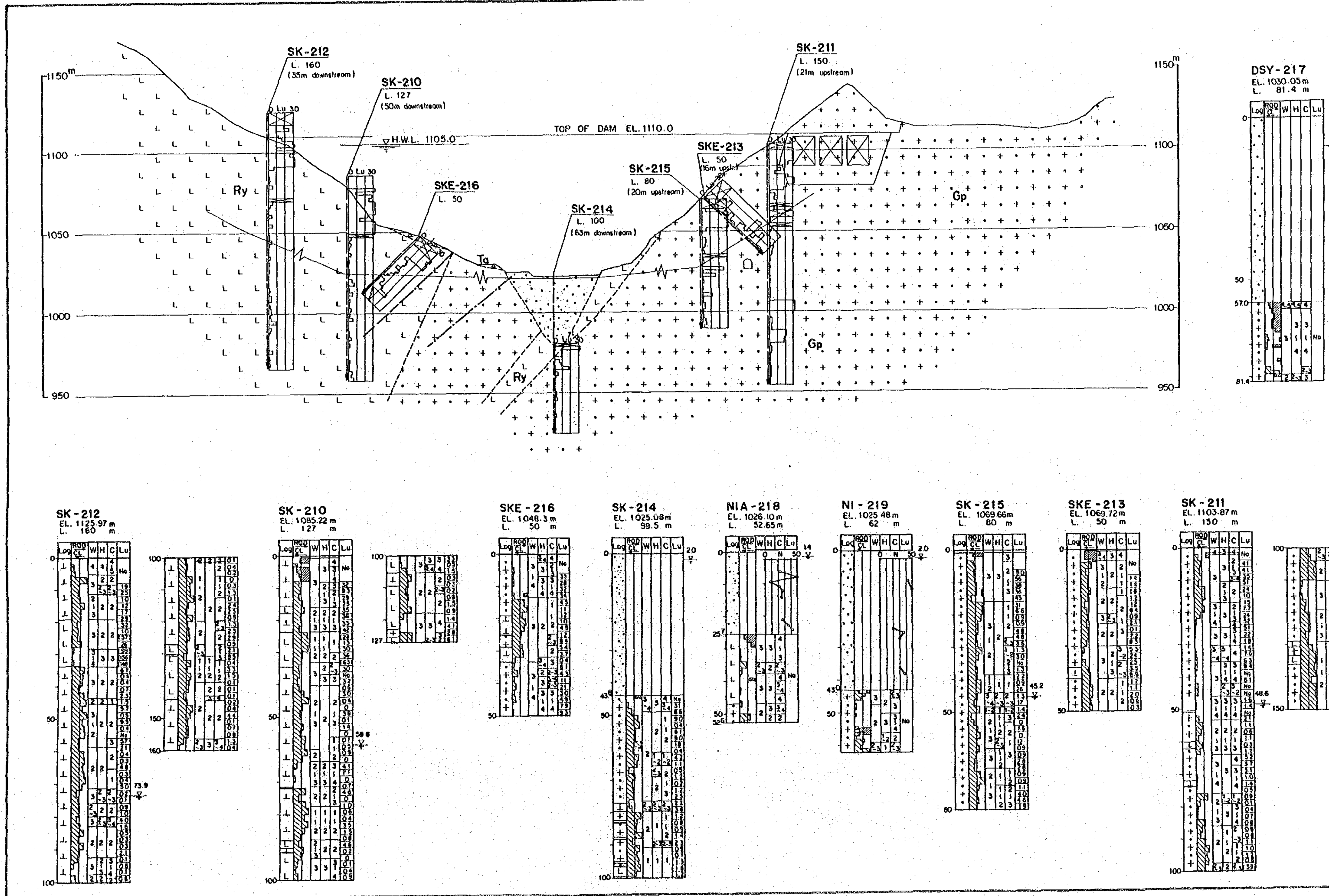
0 200m

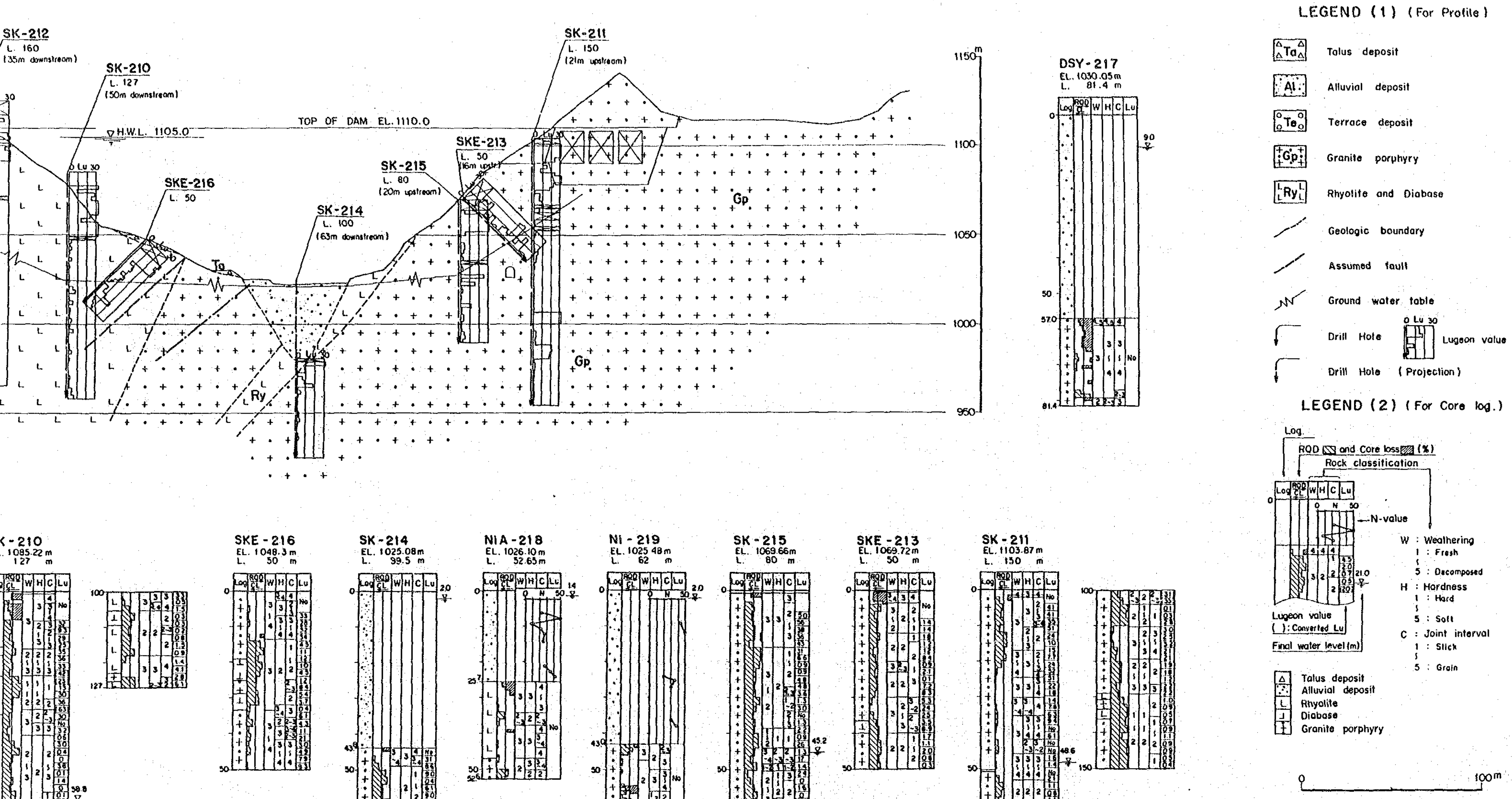
OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

OLUR PROJECT

GEOLOGIC PLAN OF DAMSITE

Fig. 7 - 3


SK-212
L. 160
(35m downstream)
SK-210
L. 127
(50m downstream)
SKE-216
L. 50
SK-214
L. 100
(63m downstream)
SK-215
L. 80
(20m upstream)
SKE-213
L. 50
SK-211
L. 150
(21m upstream)
TOP OF DAM EL. 1110.0
H.W.L. 1105.0
Ry
Tg
Gp
1150m
1100
1050
1000
950
DSY-217
EL. 1030.05 m
L. 81.4 m
SK-212
EL. 1125.97 m
L. 160 m
SK-210
EL. 1085.22 m
L. 127 m
SKE-216
EL. 1048.3 m
L. 50 m
SK-214
EL. 1025.08 m
L. 99.5 m
NIA-218
EL. 1026.10 m
L. 52.65 m
NI-219
EL. 1025.48 m
L. 62 m
SK-215
EL. 1069.66 m
L. 80 m
SKE-213
EL. 1069.72 m
L. 50 m
SK-211
EL. 1103.87 m
L. 150 m
Log
RQD
CL
W
H
C
Lu

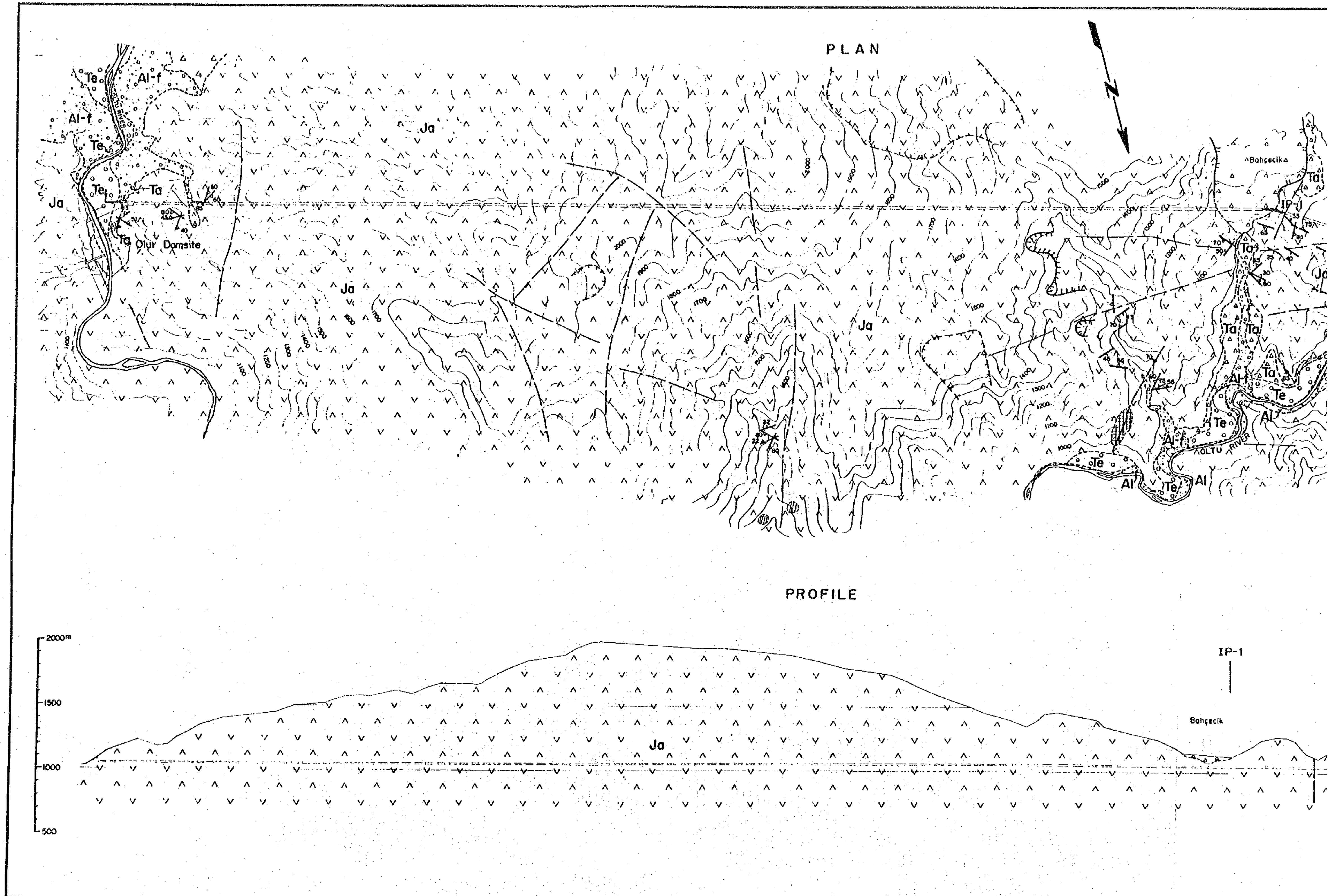


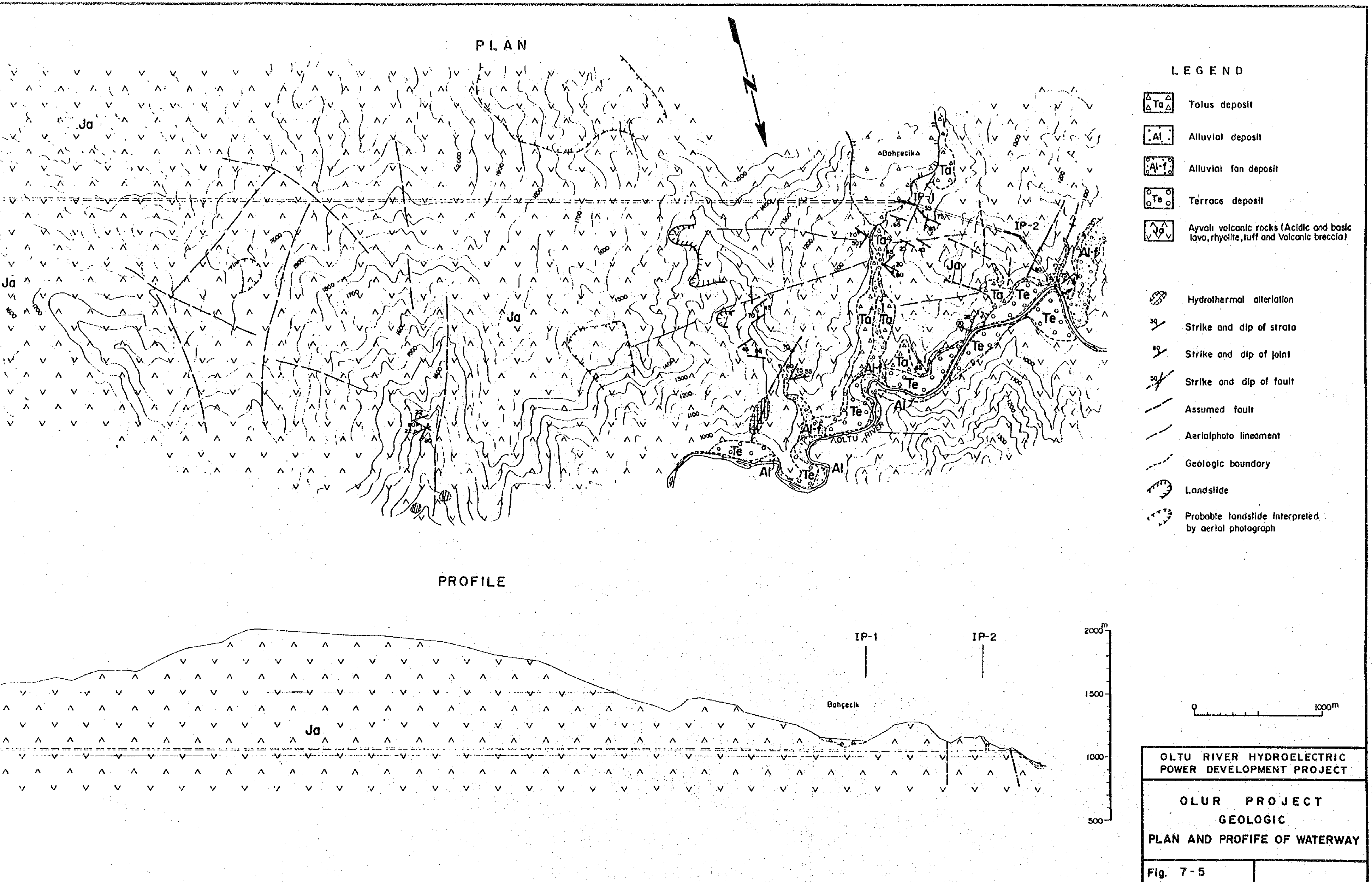
OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

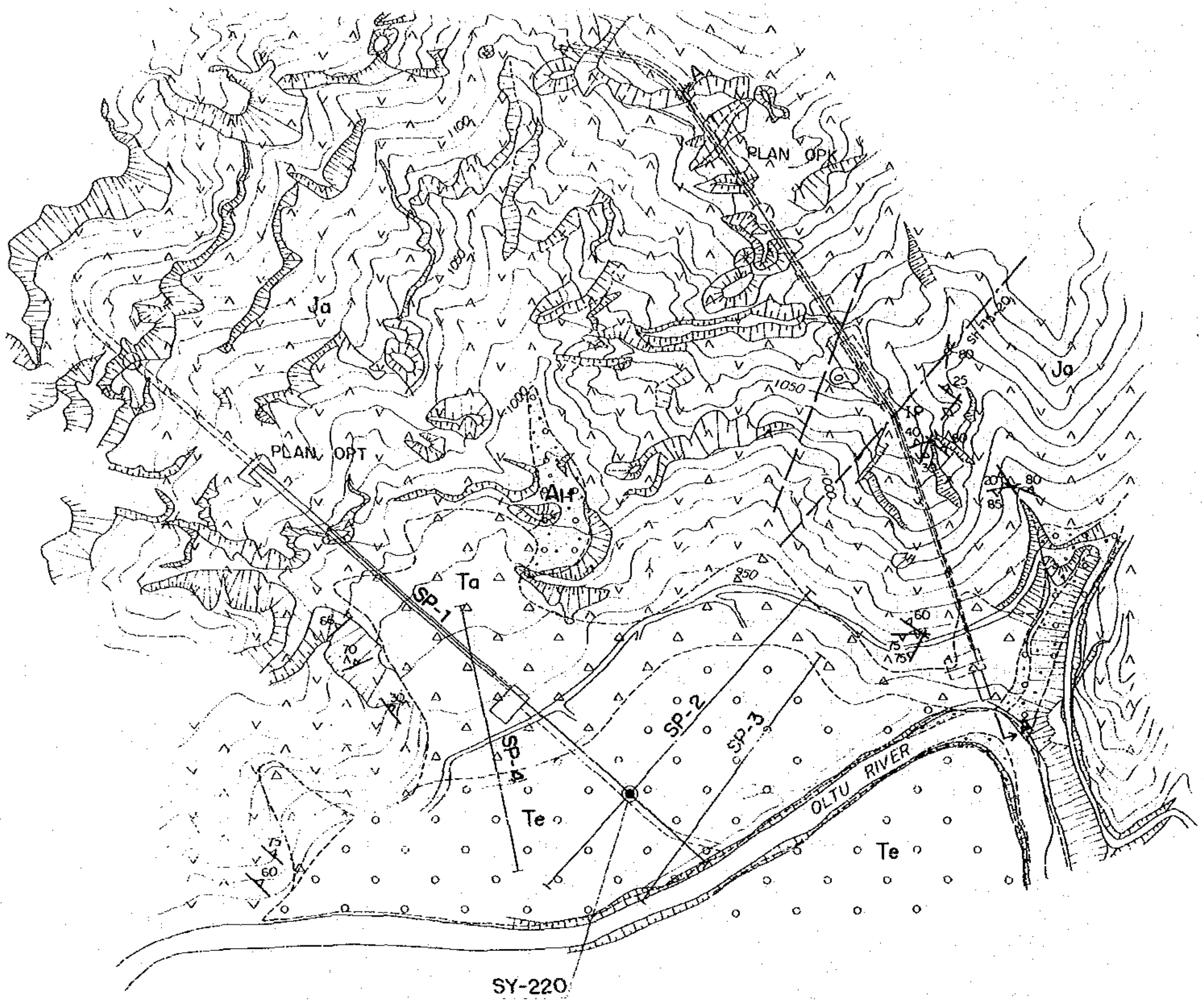
OLUR PROJECT

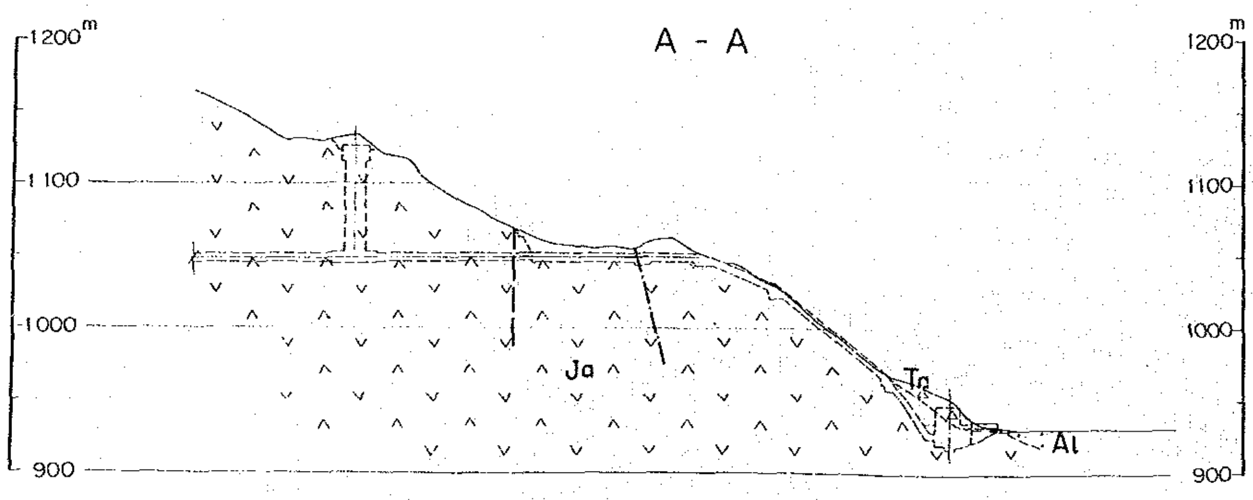
GEOLOGIC PROFILE OF DAMSITE

Fig. 7-4

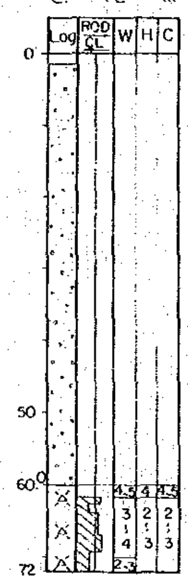

PLAN
PROFILE
Ja
Ta
Te
Al-f
Al
Olur Damsite
OLTU RIVER
Bahçecik
IP-1
2000m
1500
1000
500


PLAN
LEGEND
Talus deposit
Alluvial deposit
Alluvial fan deposit
Terrace deposit
Ayvalı volcanic rocks (Acidic and basic lava, rhyolite, tuff and Volcanic breccia)
Hydrothermal alteration
Strike and dip of strata
Strike and dip of joint
Strike and dip of fault
Assumed fault
Aerialphoto lineament
Geologic boundary
Landslide
Probable landslide interpreted by aerial photograph
Bahçecik
IP-1
IP-2
OLTU RIVER
Ja
Ta
Te
Al
Al-f
PROFILE
IP-1
IP-2
Bahçecik
Ja
2000m
1500
1000
500
0
1000m
OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT
OLUR PROJECT
GEOLOGIC
PLAN AND PROFIFE OF WATERWAY
Fig. 7-5





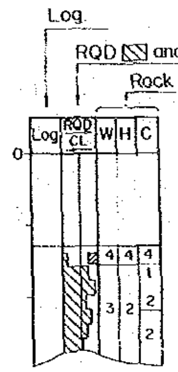
SY - 220
EL. 934.69 m
L. 72 m



LEGEND (1) (For Plan and Profile)

- Ta — Talus deposit
- Al — Alluvial deposit
- Al-f — Alluvial fan deposit
- Te — Terrace deposit
- Ja — Ayvali volcanic rocks (Acidic and basic lava, rhyolite, tuff and Volcanic breccia)
- Geologic boundary
- 50 — Strike and dip of fault
- Assumed fault
- 30 — Strike and dip of strata
- Drill hole
- SP- — Seismic prospecting line

LEGEND (2) (For Core log.)



W : Weathering
1 : Fresh
5 : Decomposed
H : Hardness
1 : Hard
5 : Soft
C : Joint interval
1 : Stick
5 : Grain

- Alluvial deposit
- Volcanic breccia, Tuff breccia

0 250m

OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

OLUR PROJECT

GEOLOGIC PLAN OF PROFILE OF PENSTOCK AND POWERHOUSE

Fig. 7-6

7.3.2 Ayvalı Project

(1) Reservoir

1) Topography

The reservoir is formed along the Oltu River which flows from east to west and along the Tavusker River, a tributary, which flows from north to south and merges with the Oltu River at about 1.8 Km upstream of the dam site. The length of the reservoir is approximately 13 km along the Oltu River and approximately 4 km along the Tavusker River.

The mountain masses surrounding the reservoir area are of elevations from 1,300 m to 1,700 m, and present comparatively steep appearances with average slope inclinations of 30 to 40 deg.

There are terrace and alluvial fans developed somewhat at the upstream stretch of the Tavusker River and the vicinity of the confluence of the Tavusker River and the Oltu River so that the valley width at the high water level (EL. 930 m) is large at 800 m to 900 m, but elsewhere, the width of the reservoir is narrow, the valley width being 300 to 600 m.

2) Geology

The Ayvalı Volcanic Rocks and Pugey Formation of the Mesozoic Era, and Quarternary deposits mainly consisting of terrace deposits and alluvial fan deposits are distributed in the reservoir area as shown in Fig. 7-7.

The Ayvalı Volcanic Rocks consist of basic and acidic lava, rhyolite, tuff, tuff breccia, and volcanic breccia are distributed throughout the entire reservoir area except for the upstream part of the Tavusker River. The rocks making up the Ayvalı Volcanic Rocks are generally hard, but have been embrittled at parts which have been strongly subjected to hydrothermal alteration. Such hydrothermal alteration parts present light yellowish brown to grayish white, and are scattered at both sides of the Oltu River from approximately 1 km to approximately 4 km upstream from the Ayvalı dam site.

According to the results of X-ray analyses, these hydrothermal alteration parts contain pyrophyllite, quartz, kaolin, pyrite, and gypsum thought to have been formed by oxidation of sulphide minerals such as pyrite near the ground surface.

The Pügey Formation is mainly composed of alternations of marl and limestone, with sandstone and conglomerate interbedded at places. This formation is distributed at the upstream part of the Tavusker River with a roughly east-west strike and gentle dip to the north at 20 to 30 deg. It contacts the underlying Ayvalı Volcanic Rocks in unconformity.

Terrace deposits consist of cobble and boulder of diameters from 20 to 50 cm, sand, and silt, and are distributed in small scale at the banks of both the Oltu River and Tavusker River.

Alluvial fan deposits consist of angular to subangular gravels of several centimeters to several tens of centimeters in diameter, sand, and silt, and are distributed in small scale at the mouths of gullies joining the Oltu River.

River deposits consist mainly of cobbles of diameters 10 to 20 cm and medium- to coarse-grained sand, but there are places where fine sand and silt are intercalated. A thickness of 60 m has been confirmed at the Ayvalı dam site for the deposits.

Talus deposits are only distributed in small scale at the foots of the slopes at right and left banks of both the Oltu River and the Tavusker River.

Prominent faults are not distributed in the surroundings of the reservoir. According to the aerialphoto interpretations, lineaments in the east-west direction are seen in the distribution area of the Ayvalı Volcanic Rocks, but all are short and not continuous.

Landslides are seen at two places near the end of the reservoir, but both are of small scale, and are located at high places above high water level.

3) Geological Engineering Assessments

(a) Watertightness

The basic and acidic lava, and tuffs of the Ayvalı Volcanic Rocks are all impervious rocks. Meanwhile, the Pügey Formation distributed at the upstream part of the Tavusker River mainly consists of thin alternations of marl and limestone, of which the limestone shows a weak solution property. However, as the limestone forms thin alternations with non-soluble marl, continuous solution cavities have not been formed, so that the Pügey Formation is an impermeable rock mass as a whole.

Topographically, there are no scraggy ridges or saddles to cause concern about leakage.

Judging by these topographical and geological conditions, it is considered that watertightness of the reservoir will be amply assured.

(b) Stability of Slope

Landslides seen at the slopes around the reservoir are of small scale and located at places higher than high water level so that it is judged they are not at all harmful to the stability of the reservoir.

As for hydrothermal alteration portions seen at the downstream part of the reservoir, since only small-scale spots are distributed and most of them are below high water level, they are not considered to adversely affect the stability of reservoir slopes.

Surface deposits such as talus deposits are distributed in small scale, and are judged not to make the reservoir slopes unstable.

(2) Dam

1) Topography

The dam site is located near EL. 810 m at the bed of the Olut River approximately 13 km downstream of the Olur powerhouse site. The Oltu River, which is in an approximately south-north direction in the Olur reservoir area, changes its course at roughly a right angle at about 4 km downstream of the Olur Dam, and in the vicinity of the Ayvalı damsite, it flows eastward while meandering. Since the damsite is located at a point where the Oltu River meanders stretching out in a broad arc to the south, the Oltu River flows in a northeast direction just upstream of the dam, while immediately downstream, it flows in a northwest direction.

The right-bank slope at the damsite is inclined at approximately 30 deg from the river bed to around EL. 880 m, while it is inclined at approximately 40 deg. above 880 m. The left-bank slope is inclined at approximately 40 deg. Both banks have almost no vegetation and basement rocks are exposed.

The river-bed width at the damsite is approximately 80 m, and the valley width at high water level elevation of 930 m is approximately 430 m.

2) Geology

Volcanic breccia, tuff breccia, tuff, rhyolite, and alluvial fan deposits, river deposits, and talus deposits overlying these rocks at parts are distributed at the dam site as shown in Figs. 7-8 and 7-9.

(a) Foundation Rock

a) Constituent Rocks

The foundation rock of the dam consists of volcanic breccia, tuff breccia, and tuff, and rhyolite intruding these rocks.

The volcanic breccias are greenish gray in color,and are hard at fresh parts, but portions subjected to hydrothermal