alteration present a light yellowish brown to grayish white color and have become brittle. A typical outcrop of such strong hydrothermal alteration may be seen at the upstream part of a gully at the right bank downstream of the dam. The hydrothermal alterations along joints and minor faults are also observed on the road at the left bank of the dam, but strong hydrothermal alteration is seen at more than 400 m downstream from the dam axis and the degree of hydrothermal alteration at the dam site is low.

Rhyolite shows a light greenish gray to a light reddish gray color and is intruded into the volcanic breccias. The rhyolite is a hard rock, and intrusive planes are generally tight.

b) Faults and Joints

Large scale faults of great length accompanied by wide sheared zones are not distributed in the surroundings of the damsite. Faults seen at the damsite have sheared widths of 10 to 40 cm, and strike N-S, dip 60-80°E, roughly parallel to the dam axis. They are chiefly distributed at the left bank of the dam. These faults generally have not prominent fault clay or fault breccia, but faults strongly subjected to hydrothermal alteration seen 400 to 500 m downstream of the dam axis are accompanied by embrittled and clayey parts.

Joints are developed at intervals of 20 to 50 cm at both banks. Of these joints, the ones, which strike NE-SW dip 75° to 85°SE, are most prominent, and these are followed by joints which strike NW-SE and dip almost vertical.

c) Weathering and Alteration

The surfaces of bed rock are mostly weathered and discolored brown near the ground surface. Cracky and strongly weathered zone is 3 to 5 m from the ground surface at both banks. Weathering discoloration along cracks may be seen from the ground surface to a depth of approximately 50 m at the left abutment and to 70 to 90 m at the right abutment.

The dam foundation rock has been slightly subjected to hydrothermal alteration as a whole, and has chlorite and epidote as altered minerals, but strength of the rock has not been lowered, and it is hard on the whole. Pyrite formed by hydrothermal alteration is often seen along crack planes.

(b) Surface Deposits

a) Alluvial Fan Deposits

Alluvial fan deposits are distributed at the mouth of a gully at the right bank immediately downstream of the dam, and consist of gravel, sand, and silt.

b) River Deposits

The thickness of river deposits is 60 m at maximum according to three drillholes bored at the river bed. River deposits are mainly composed of gravels of 5 to 10 cm diameter and coarse-grained sand.

Standard penetration tests are performed at 30 points in Drillhole Ni-109 and at 4 points in Drillhole NiA-108 every 1.5 m in depth. According to the results, N = 14 to 19 are indicated at five points in Ni-109, but these small N-Value points are scattered and all the others are N = 20 to 50.

c) Talus Deposits

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

(c) Ground Water

The final water levels in drillholes bored at the dam site are as shown in Fig. 7-9. The groundwater levels are low on the whole at both banks, but rise going from the river bed toward the mountain sides even though slightly. The groundwater level in the left bank rises about 11 m at the point approximately 100 m to the mountain side from the river, and that in the right bank rises about 4 m at the point approximately 150 m to the mountain side from the river.

(d) Permeability

Lugeon tests utilizing drillholes at the dam site are carried out on a total of 7 holes, amounting to 317 stages and a length of 634 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 method below.

The Lugeon values (Lu) which are the results of tests are all quantities injected (unit ℓ/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 kgg/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. 7-9. According to the results, permeabilities at the dam site are summarized as follows:

- Left Bank of Dam

  At the lower part of the slope, permeability is low to a depth of 52 m, with Lu = 0.5 to 4 indicated except for the surface portion where tests are not carried out. On the other hand, at deeper than 52 m, there are scattered places where permeability is high, with Lu = 4 to 50.

From the middle part of the slope and above, permeability is high to around a depth of 30 m from the ground surface with Lu = 10 to 30 indicated, but deeper than 30 m, although there are parts of Lu = 20 to 30 at places, most parts indicate Lu = 0 to 3.

- River Bed

Although a slightly high permeability of Lu = 6 to 30 is indicated from the surface of the basement rock to a depth of approximately 10 m, permeability is low with Lu of 0 to 3 at deeper than this.

- Right Bank of Dam

The portion indicating high permeability of Lu $\geq$ 20 to 30 is at a depth from the ground surface of around 30 to 35 m. Deeper than 30 to 35 m, permeability is generally low, and although Lu = 5 to 10 is indicated at parts and Lu $\geq$ 20 is indicated at sections of depths 100 to 118 m and 128 to 138 m of Drillhole SG-102, most parts are Lu = 0 to 4.

3) Geological Engineering Assessments

Judging by the geological conditions of the ground surface and the results of drilling including permeability tests, the following geological engineering assessments may be made of the damsite:

(a) The volcanic breccia, tuff breccia, tuff, and rhyolite have been slightly subjected to hydrothermal alteration on the whole, but the strengths of the rocks have not been lowered, and the rocks are hard as a whole. Therefore, it is judged that these rocks possess ample bearing capacity as the foundation for the fill dam of 175 m height presently planned, except for cracky and strongly weathered zone near the ground surface. This cracky and strongly weathered zone is from the ground surface to 3 to 5 m at both right and left banks.

(b) As discontinuous planes in the foundation rock, there are faults, joints, and intrusive planes of rhyolite. As previously mentioned, faults confirmed at the damsite are all of small scale and less continuity, and prominent fault clay and fault breccia are not contained.

Joints are comparatively well developed and weathering discoloration along joints is seen to a depth of 50 m from the ground surface at the left bank and to depths of 70 to 90 m at the right bank.

(c) According to the results of Lugeon tests, at the left bank of the dam, it is Lu = 10 to 30 from the ground surface to around a depth of 30 m at the middle and higher part of the slope, and Lu = 4 to 50 at deeper than 52 m at the lower part of the slope for a high permeability, but elsewhere, it is Lu = 0 to 4 for low permeability except in part.

On the other hand, at the right bank of the dam, the section from the ground surface to a depth of around 30 to 35 m has high permeability of Lu ≥ 20 to 30, but deeper than this, the permeability is a low Lu = 0 to 4 except in part.

The bedrock at this site consists of hard volcanic breccias, and there is no water permeating through between mineral grains of the rock, and permeability is governed by the previously mentioned discontinuities such as joints. Consequently, it is thought ample water cut-off treatment can be provided, including sections of high permeability seen at parts, by the generally used type cement grouting.

(d) A part of the foundation for the rock zones of the dam will consists of a river deposit approximately 60 m thick. This river deposit is composed chiefly of gravel and coarse-grained sand. N-values in standard penetration tests are N = 20 to 50 at the greater part, indicating that the constituent material is well consolidated.

(3) Tailrace Tunnel

1) Topography

The tailrace tunnel extends in a direction to the east from the damsite roughly parallel to the Oltu river, and the total length is approximately 9,300 m.

Since the tailrace tunnel passes near the foot of the mountain situated at the south side of the Oltu River, the earth cover for the tunnel is comparatively thin, being 130 to 500 m at the upstream part, 80 to 20 m at the midstream part, and 70 to 400 m at the downstream part.

Of gullies crossing the tunnel route, there are two at the upstream part of the tunnel and two at the downstream part seen which are prominent, and of these, the Anzav Valley located at the downstream part of the tunnel is the largest.

2) Geology

As shown in Fig. 7-10, the Ayvalı Volcanic Rocks and the Pügey Formation are distributed around the tailrace tunnel route. The Ayvalı Volcanic Rocks comprise acidic and basic lava, rhyolite, tuff, and volcanic breccia and are distributed widely from the upstream to midstream part of the tailrace tunnel. These rocks are all hard excepting embrittled parts resulting from the hydrothermal alteration. Hydrothermal alteration parts have been confirmed at gullies at the left bank downstream of Ayvalı Dam, and at the Bulanik valley.

The Pügey Formation consists of hard limestone and marl is distributed at the downstream part of the tailrace tunnel. This formation has an axis of syncline in the vicinity of the Anzav Valley, and strike N-S dip 40-80°E or W, crossing more or less perpendicularly with the tunnel route.

The Pügey Formation and the Ayvalı Volcanic Rocks contact each other by a fault, which strike N-S dip 70°E, approximately 1 km upstream of the Anzav Valley. Although the width of the sheared zone of this fault is not clearly known, it has embrittled parts caused by hydrothermal alteration along the fault as seen at the Bulanik valley.

Although prominent faults crossing the tailrace tunnel route other than the abovementioned fault comprising the boundary between the Pügey Formation and Ayvalı Volcanic Rocks have not been confirmed, there are several lineaments interpreted to exist diagonally intersecting the tunnel at angles of 40 to 50 deg in aerial photos.

Several small scale landslides are distributed around the tailrace tunnel route, but these are not located at places where earth covers of the tunnel are thin or in the neighborhoods of the tunnel portals.

3) Geological Engineering Assessments

Judging by the geological conditions of the ground surface, the results of aerial photo interpretations, the results of exploratory drillings and the results of seismic prospectings, the following geological engineering assessments can be made regarding the tailrace tunnel route.

(a) The acidic and basic lava, rhyolite, tuff, and volcanic breccia of the Ayvalı Volcanic Rocks, and the alternation of limestone and marl of the Pügey Formation are all hard rocks, and are considered not to hinder excavation of the tunnel.

(b) A conspicuous fault crossing the tailrace tunnel route is the one comprising the boundary between the Pügey Formation and Ayvalı Volcanic Rocks. An embrittled part caused by hydrothermal alteration is confirmed along this fault at the Bulanik valley, and there is a possibility that such an embrittled part will be found along the fault at the tunnel route also. However, since this fault crosses the tunnel route almost perpendicularly, and also dips steeply, even in the event there are such embrittled parts, the tunnel can cut through with the shortest distance. Accordingly, this fault is not thought to make tunnel excavation difficult over a great length.

(c) The tailrace tunnel passes the comparatively large Anzav Valley at its downstream part. The depth from the ground surface to the projected tunnel location at this point is approximately 70 m. At this Anzav Valley, Drillhole SL-112 is bored and seismic prospecting is carried out on three traverses in order to confirm the depth of the bedrock. According to the results of Drillhole SL-112 and seismic prospectings, the thickness of river deposits of the Anzav Valley along this tunnel route is 36 to 40 m, and the thickness of bedrock above the tunnel location is from 30 to 34 m. The bedrock around the tunnel route consists of alternations of hard limestone and marl, so it is judged that there will be no geological problem in tunnel excavation under the Anzav Valley.

(d) The groundwater conditions at the tailrace tunnel route are considered to be as described below. In the Ayvalı Volcanic Rocks distribution area, the rising of the groundwater level from the river to the mountain side is very gradual as seen at the damsite. And from the results of Lugeon tests carried out at the damsite, the permeability is generally very low at the part deeper than 30 to 35 m at the slopes and deeper than 10 to 15 m at the river bed. As mentioned above, the groundwater level is generally low along the tailrace tunnel and the tunnel will pass the rock mass of low permeability.

Therefore, it is estimated that there will not be very much springing of water inside the tunnel.

On the other hand, at areas of Pügey Formation, it is thought the groundwater level is high in general as seen from the abundant flow of water in the Anzav Valley. However, there are no prominent solution cavities in the alternations of marl and limestone of the Pügey Formation, while joints are not developed very much. According to the results of Lugeone tests carried out at the Sakartepe Damsite, which was planned in the Pügey formation area, permeability is low Lu $\leq$ 5 at the part deeper than 20 to 40 m at the slopes of both banks and deeper than 10 m at the river bed. Therefore it is thought there will not be large amounts of water springing inside the tunnel.

(4) Powerhouse

1) Topography

The powerhouse is planned as an underground type at the left bank immediately downstream of the Ayvalı dam.

The underground powerhouse would be located in a ridge extending in a southeast-northwest direction at the left bank of the dam, and the depth from the ground surface to the powerhouse would be 350 to 500 m.

2) Geology

Tuff breccia, volcanic breccia, and rhyolite of the Ayvalı Volcanic Rocks are distributed in the surroundings of the powerhouse site.

These rocks, as described in 7.3 (2), "Geology of Dam Site," are slightly subjected to hydrothermal alteration as a whole, but almost no deterioration of ligholological characters has occurred and the rocks are hard.

No prominent fault has been confirmed at the surroundings of the powerhouse site. Joints, which strike NE-SW dip 75-85° SE, are most prominent similarly to the dam site, following which there are joints of strike NW-SE which are almost vertical.

3) Geological Engineering Assessments

Judging by the geological condition of groundsurface and the results of Drillhole SL-103 made in the vicinity of the powerhouse site, the geological engineering assessments below can be made on the powerhouse site:

- Prominent faults are not distributed in the surroundings of the powerhouse site.

- According to the results of Drillhole SL-103 (drillhole mouth elevation 997 m, hole length 185 m), rock mass from the ground surface to a depth of 55 m consists of rhyolite with weathering discoloration along cracks, but rock mass deeper than 55 m consists of hard volcanic breccia in which there is hardly any weathering seen along cracks. There are few cracks at deep parts, and the average

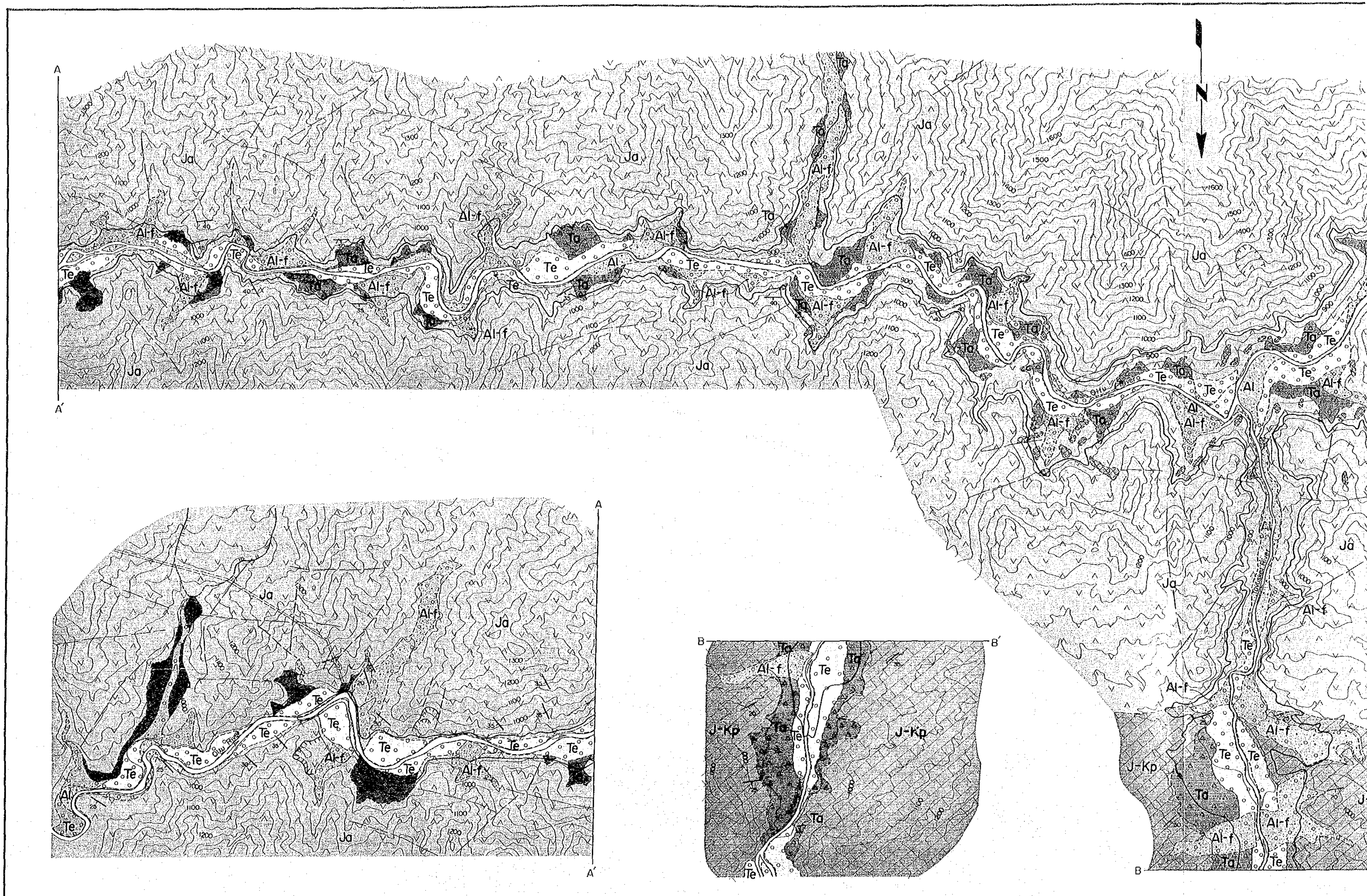
RQD from the ground surface to a depth of 90 m is approximately 42%, whereas from 90 to 185 m, the average RQD is approximately 61%.

The underground powerhouse would be located more than 100 m farther down than the hole-bottom elevation of 812 m of Drillhole SL-103, and the condition of the surrounding rock is estimated to be the same as the above or even better.

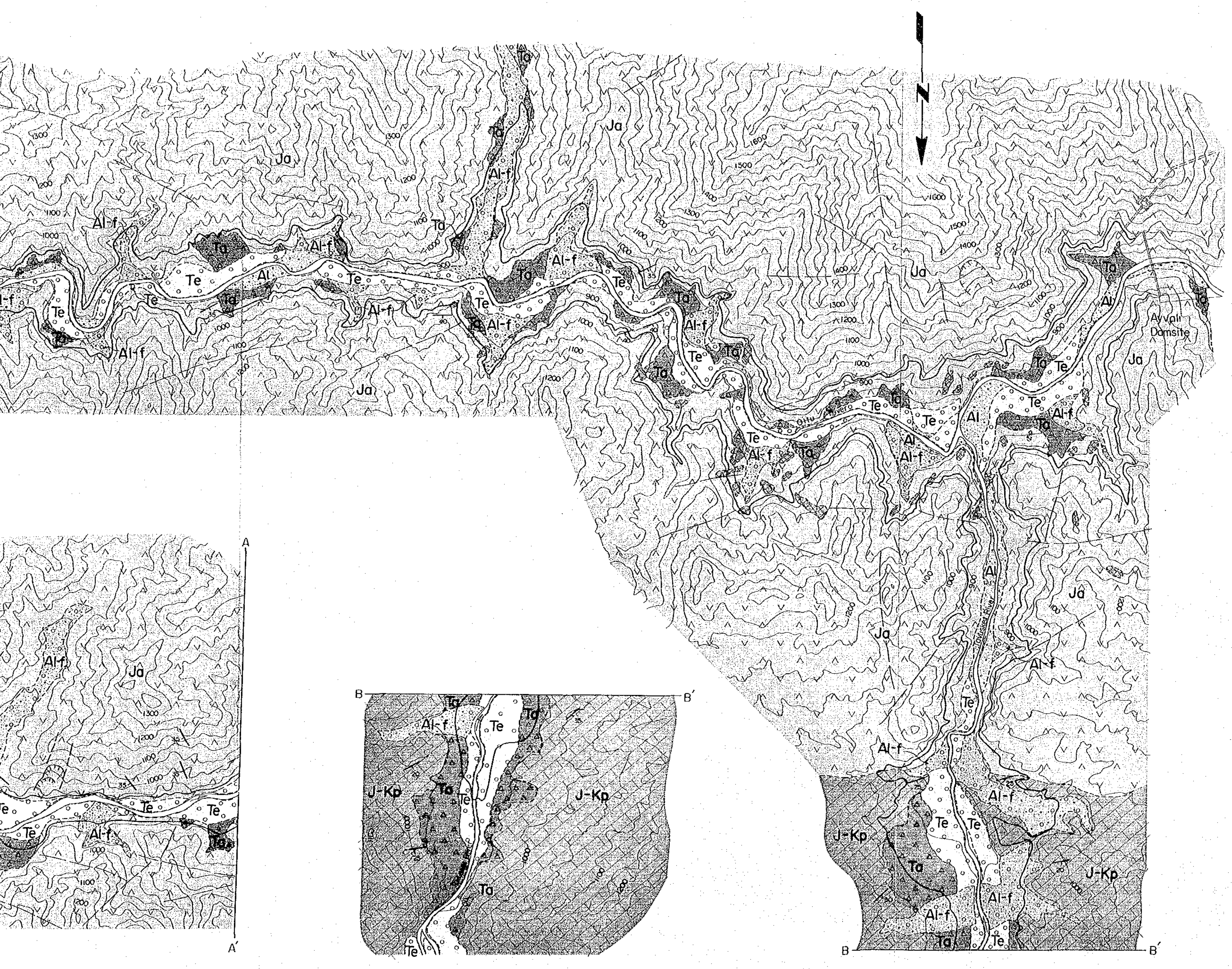
Considered from such a condition of the bedrock, it is judged that there is no great geological problem which would make construction of an underground powerhouse difficult at this site.

- According to the results of Lugeon tests carried out at Drillhouse SL-103, permeability is high at Lu ≥ 20 from the ground surface to the vicinity of a depth of 25 m. However, from 25 m to 90 m in depth, most parts are Lu = 0 to 4, with parts which are Lu ≥ 10 to 20, while deeper than 90 m, permeability is very low at Lu = 0 to 3. Consequently, permeability of surrounding rocks of the underground powerhouse is assumed to be very low. Therefore, it is thought the amount of ground water which would spring inside the underground cavern would be small.

- At the underground powerhouse site, only one drillhole, SL-103 of length 185 m, has been bored. Therefore, it is necessary for drilling investigations and exploratory adit investigations to be carried out before starting the final design to make clear the bedrock conditions, permeability, and hydrogeological conditions around the elevation of the powerhouse.



A
A′
B
B′
N
Ja
Jâ
Al-f
Al
Te
Ta
J-Kp



LEGEND

- Ta — Talus deposit
- Al — Alluvial deposit
- Al-f — Alluvial fan deposit
- Te — Terrace deposit
- J-Kp — Pügey formation (Alternation of marl and limestone)
- Ja — Ayvalı volcanic rocks (Acidic and basic lava, rhyolite, tuff and Volcanic breccia)
- Hydrothermal alterlation
- Strike and dip of strata
- Strike and dip of fault
- Assumed fault
- Aerialphoto lineament
- Geologic boundary
- Landslide
- Probable landslide interpreted by aerial photograph

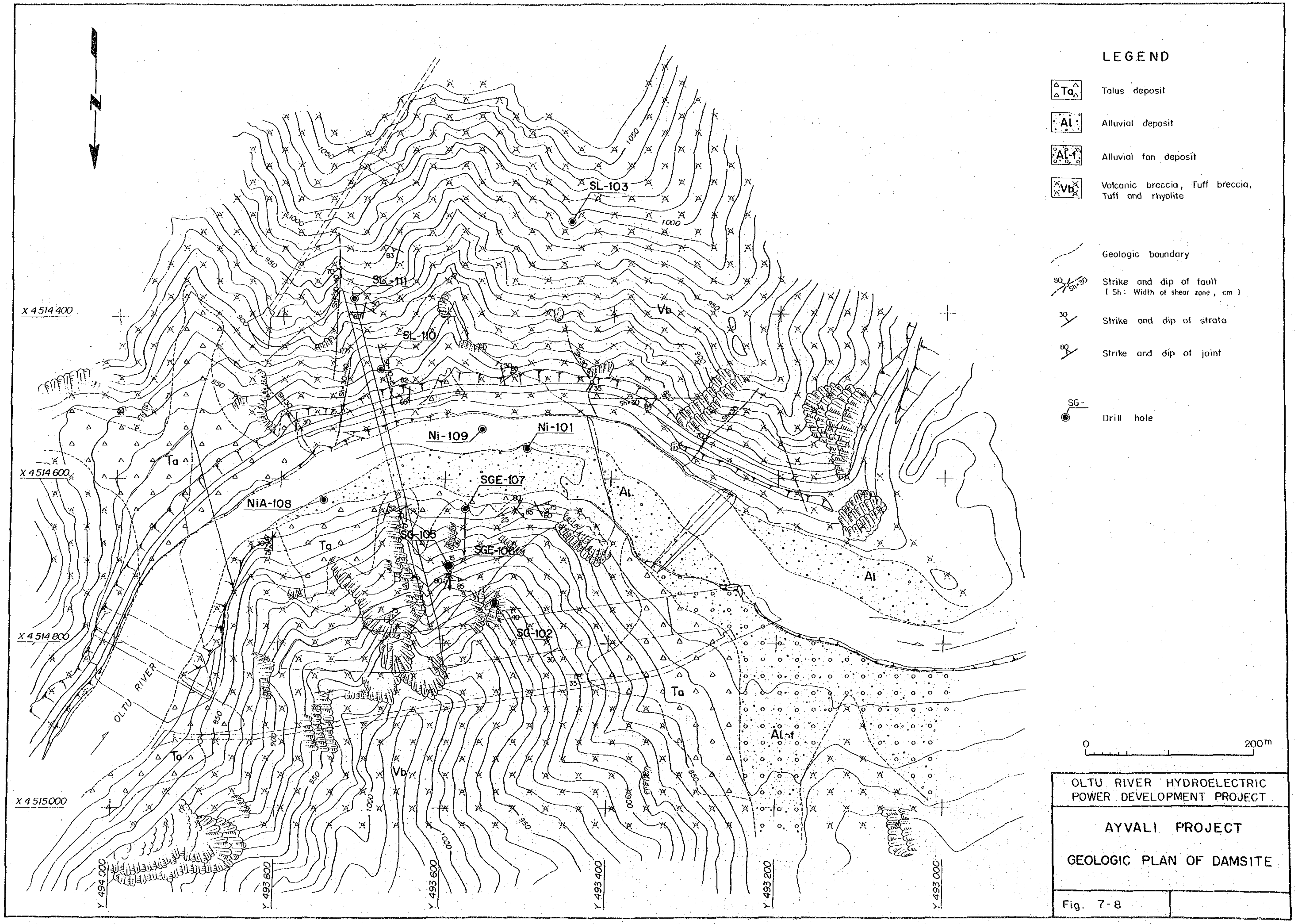
0 1000m

OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

AYVALI PROJECT

GEOLOGIC PLAN OF RESERVOIR AREA

Fig. 7-7

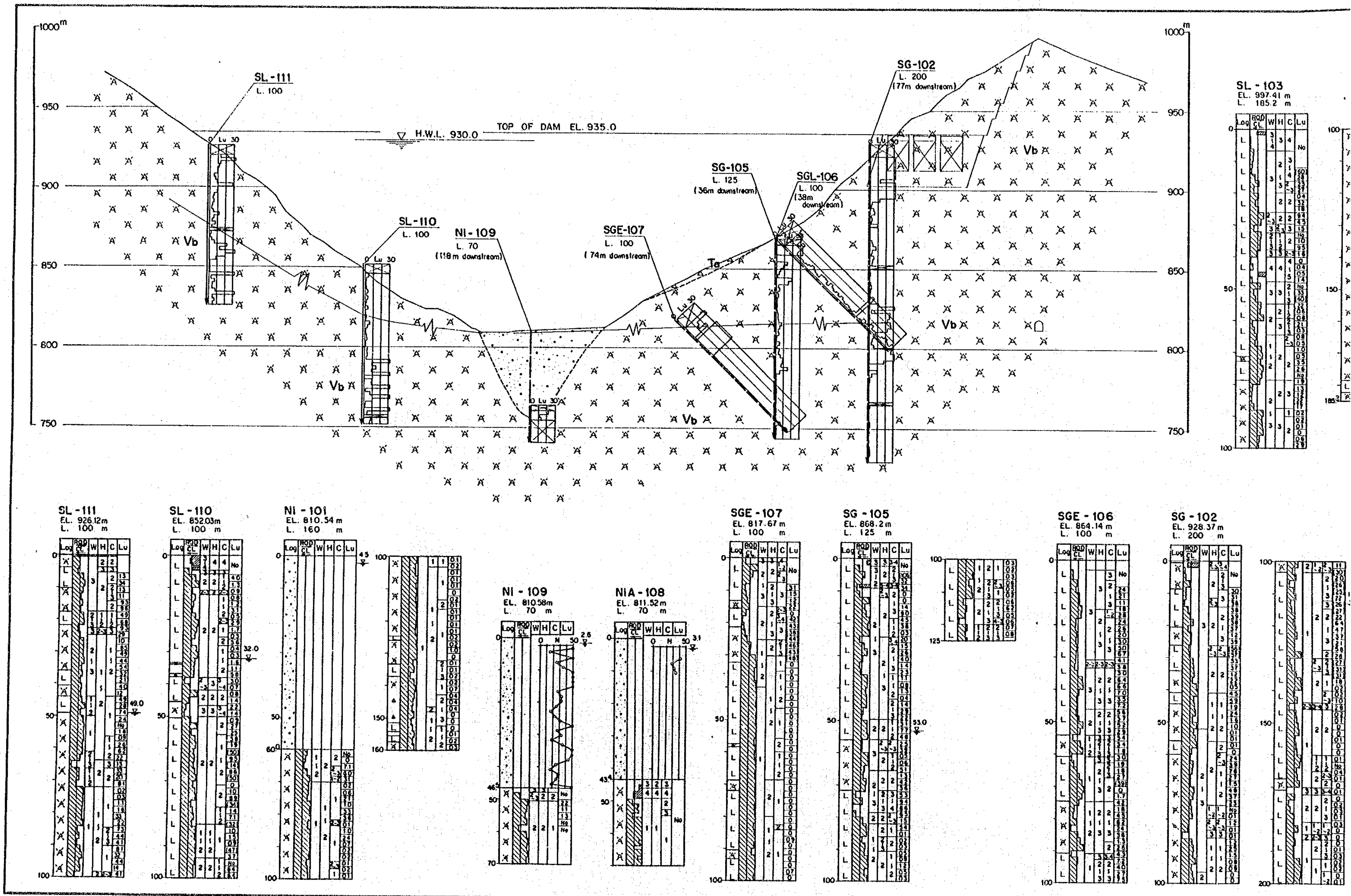


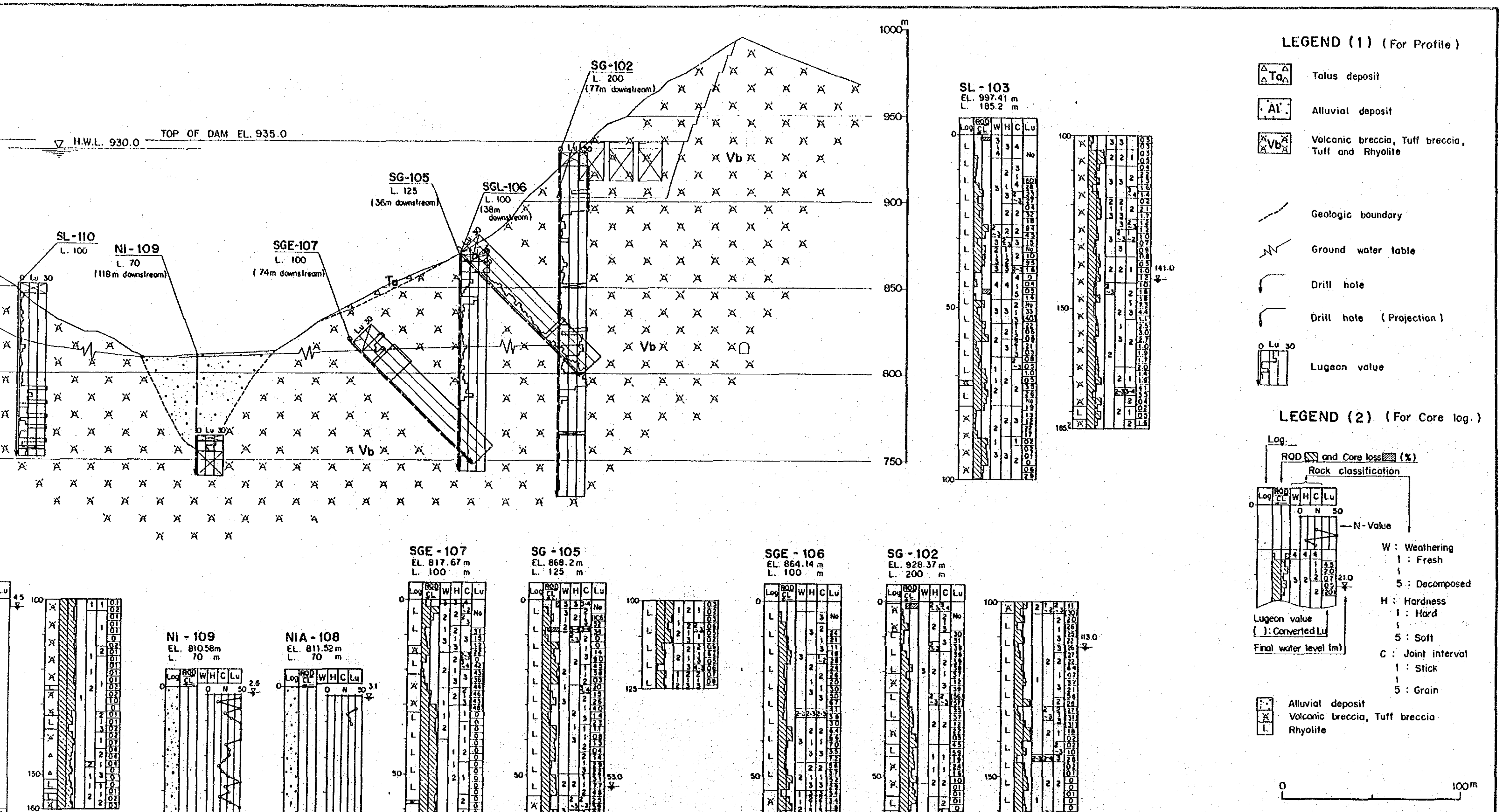
OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

AYVALI PROJECT

GEOLOGIC PLAN OF DAMSITE

Fig. 7-8


SL-111
L. 100
SL-110
L. 100
NI-109
L. 70
(118m downstream)
SGE-107
L. 100
(74m downstream)
SG-105
L. 125
(36m downstream)
SGL-106
L. 100
(38m downstream)
SG-102
L. 200
(77m downstream)
H.W.L. 930.0
TOP OF DAM EL. 935.0
Vb
Ta
SL-103
EL. 997.41 m
L. 185.2 m
SL-111
EL. 926.12m
L. 100 m
SL-110
EL. 852.03m
L. 100 m
NI-101
EL. 810.54 m
L. 160 m
NI-109
EL. 810.58m
L. 70 m
NIA-108
EL. 811.52m
L. 70 m
SGE-107
EL. 817.67 m
L. 100 m
SG-105
EL. 868.2 m
L. 125 m
SGE-106
EL. 864.14 m
L. 100 m
SG-102
EL. 928.37 m
L. 200 m
Log RQD CL W H C Lu



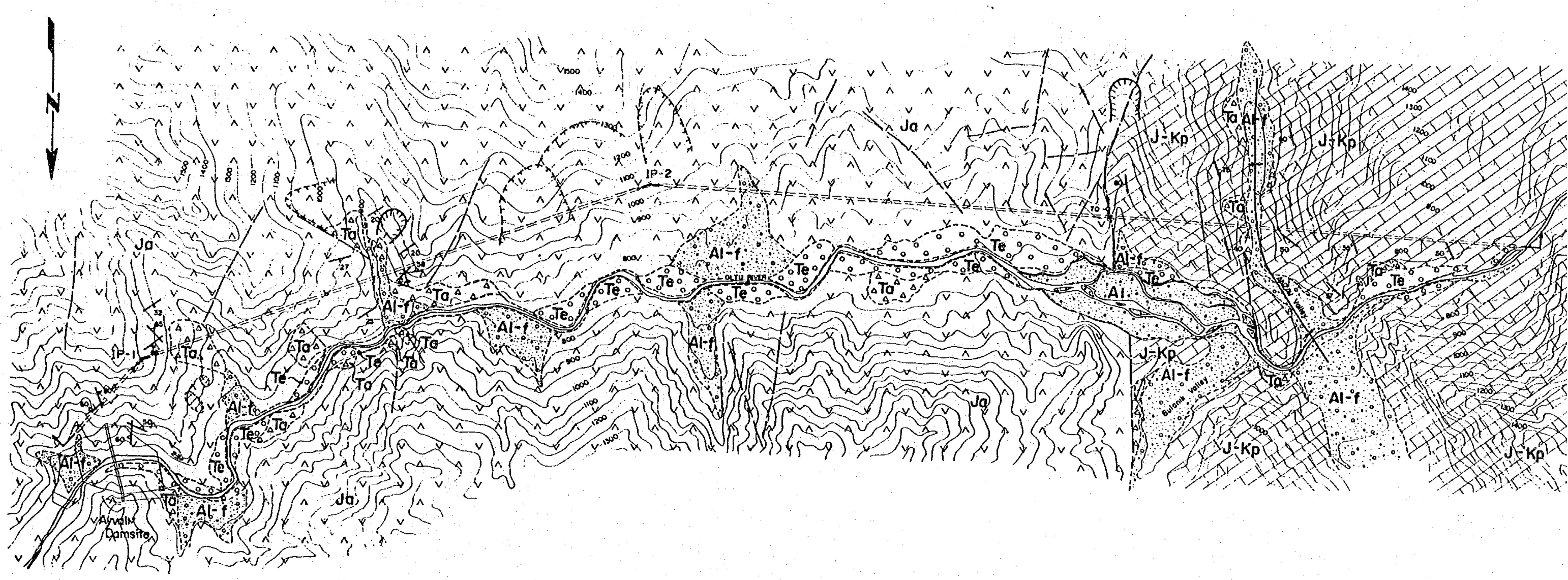
OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

AYVALI PROJECT

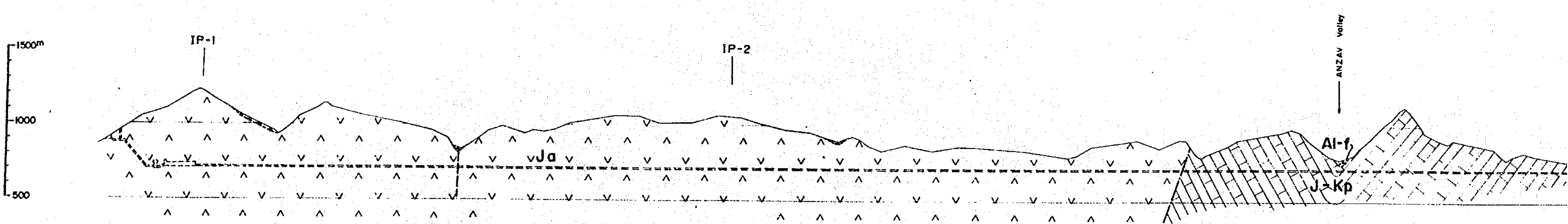
GEOLOGIC PROFILE OF DAMSITE

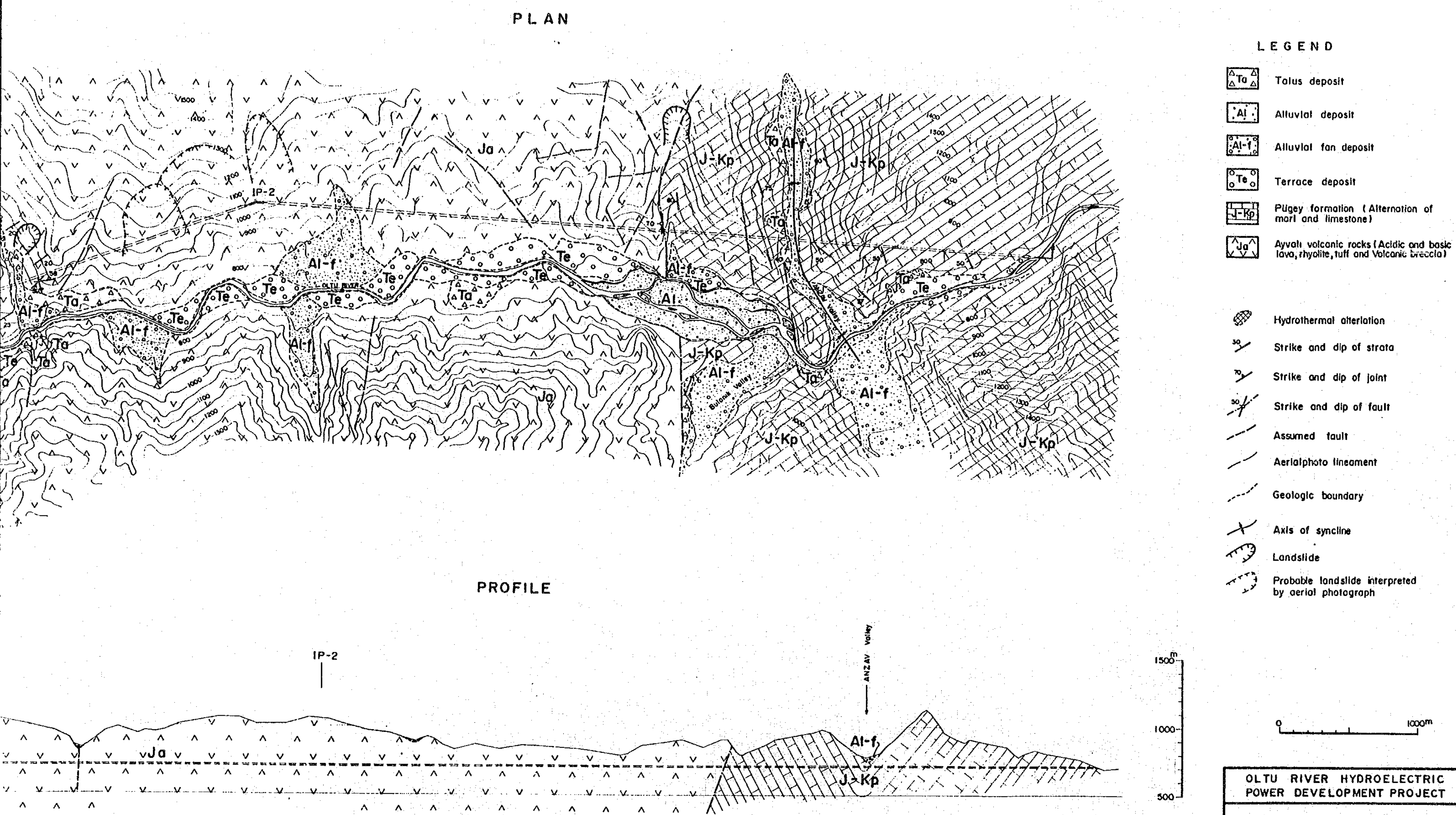
Fig. 7-9

PLAN



PROFILE





OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

AYVALI PROJECT
GEOLOGIC
PLAN AND PROFILE OF WATERWAY

Fig. 7-10

7.4 Materials

7.4.1 Impervious Core Materials

(1) Impervious Core Materials for the Olur Dam

The total quantity of impervious core material to be used for the rockfill dam is approximately 600 x 10^3 m^3.

As a result of investigations carried out by EİE and the JICA Survey Team, the borrow area around the Kaledibi village approximately 3.0 km upstream from the damsite (left bank) was selected as the first candidate site, and the borrow area at Yolboyu village further 11 km upstream (right bank) as the second candidate site.

The borrow area at Kaledibi selected as the first candidate site is very close to the damsite, has a large area from which borrowing can be done, while there is a large quantity available for collection, and this is the most promising borrow area from the point of view of construction cost. But according to the results of laboratory tests, since it is judged not to be favorable necessarily in the aspect of permeability, further investigations will be required.

The results of laboratory tests on material from the borrow area at Yolboyu selected as the second candidate site are good, but because the transportation distance will be too long, this is not necessarily favorable from the viewpoint of construction cost.

The candidate site for impervious core material at Kaledibi is located at the alluvial fan spread out at the mouth of a gully feeding the Oltu River. This alluvial fan deposit is mainly composed of gravels of Ayvalı Volcanic Rocks several to several tens of centimeters in diameter, sand, silt, and clay. According to visual inspection at the site, the content of 3-inch-plus gravels is very high at 20% to 45%.

The candidate site for impervious core material at Yolboyu is located at an old landslide area in the Oltu Formation. This landslide deposit consists mainly of sand, silt, and clay originating from mudstone, marl, and sandstone of the Oltu Formation, and also contains gravels several to several tens of centimeters in diameter. According to visual inspection at the site, the content of 3-inch-plus gravels is 10% to 15% and very low compared with that at Kaledibi.

The quantity available for collection at the Kaledibi borrow area which is the first candidate site is estimated at more than 2.0×10^6 m^3, while the Yolboyu borrow area which is the second candidate site is also vast, and collection of more than 2.0×10^6 m^3 is amply feasible.

The pits listed in Table 7-3 (b) were excavated with the abovementioned two candidate sites as the objects. The locations of the pits are shown in Fig. 7-11 and 7-12. The samples collected were tested at the laboratories of EIE and DSI.

1) Laboratory Test Items and Quantities

The laboratory test items and quantities are as given in Table 7-4.

Table 7-4 Items and Quantities of Test of Olur Project

Items	Quantities		Remarks
	Kaledibi	Yolboyu	
Specific Gravity	8	4	
Moisture Content	8	4	
Grain Size Analysis	8	4	
Liquid Limit and Plastic Limit	8	4	
Compaction	8	4	
Permeability	8	1	
Direct Shear	4	1	
Absorption	8	4	

The depths of the individual pits at the soil borrow areas of Kaledibi and Yolboyu and the classifications of the soil materials are given in Appendix.

2) Test Results

The results of tests on impervious core materials are given in Table 7-5, Fig. 7-13 and 7-14. Summaries of the test results are given below for the Kaledibi and Yolboyu impervious core materials.

- Specific gravities are 2.66 to 2.71 for Kaledibi impervious core materials and 2.61 to 2.68 for Yolboyu impervious core materials, almost the same for the two.

- Regarding unified soils classification system (ASTM D 2487), the soil material of Kaledibi belongs to clayey gravel (GC) and the soil material of Yolboyu to clayey sand (SC) or inorganic clay (CH) according to gradation tests and Atterberg tests.

- Optimum water contents obtained by compaction tests were from 8.8% to 11.5% for Kaledibi impervious core material, and the maximum dry densities were 1.99 t/m^3 to 2.12 t/m^3. Regarding differences between natural water contents and optimum water contents, natural water contents were on the wet side with the exception of MK-1, and the differences were from 0.2% to 4.2%. The optimum water contents of Yolboyu impervious core material were 11.0% to 16.7% with maximum dry densities 1.76 t/m^3 to 2.07 t/m^3. The differences between natural water contents and optimum water contents were from 3% to 8.7%, with natural water contents being higher.

- Direct shear box tests were performed unconfined and undrained, and cohesion and angle of internal friction were respectively 25 kN/m^2 to 38 kN/m^2 and 31° to 36° for Kaledibi impervious core material, and 13 kN/m^2 and 18 deg for Yolboyu impervious core material.

- With respect to grain-size distribution, the maximum size of Kaledibi impervious core material was 70 mm since blocks had been removed, with the quantities of 19.1 mm and under being from 72% to 84%, 4.75 mm and under from 40% to 56%, 0.075 mm and under from 12% to 30%, and 0.005 mm and under 6% to 14%. With Yolboyu soil materials, the maximum size was 38 mm, with the quantities of 19.1 mm and under from 94% to 99%, 4.75 mm and under from 75% to 82%, 0.075 mm and under from 25% to 58%, and 0.005 mm and under from 12% to 33%.

- Atterberg tests were performed to judge the consistency of the soil. The liquid limit (LL) of Kaledibi impervious core material was between 26.5% and 32.6%, the plastic limit (PL) between 15.0% and 19.9%, and the plasticity index (PI) between 7.8 and 15.7. For Yolboyu impervious core material, the liquid limit (LL) was between 33.6% and 54.6%, plastic limit (PL) between 17.9% and 25.1%, and the plasticity index between 14.7 and 29.5. The properties of the material from the two sites are distinctly different due to their origins.

- Permeabilities were checked by triaxial tests using 9 samples under confined and undrained conditions. As a result, Kaledibi impervious core material had from 4.62×10^{-3} cm/s to 3.96×10^{-6} cm/s for much scatter, and permeability was high on the whole. With Yolboyu impervious core material, there was only one sample, and the result was 2.67×10^{-8} cm/s.

3) Evaluation

To make assessments of the above test results, the Kaledibi impervious core material is a clayey gravel (GC) according to the unified soils classification system, while Yolboyu soil material belongs to clayey sand (SC) and to inorganic clay (CH).

Kaledibi impervious core material contains 12% to 29% of fine material (0.075 mm and under), and is thought to be good from the standpoint of gradation, but the coefficient of permeability is not necessarily suitable.

Retesting is being done at present. On the other hand, the fine material in Yolboyu impervious core material is from 23% to 60% and more than the Kaledibi material. The coefficient of permeability is 2.67×10^{-8} cm/s and also favorable.

If as a result of retesting the coefficient of permeability is not necessarily low enough, it will be necessary to consider use of blending materials from Kaledibi and Yolboyu.

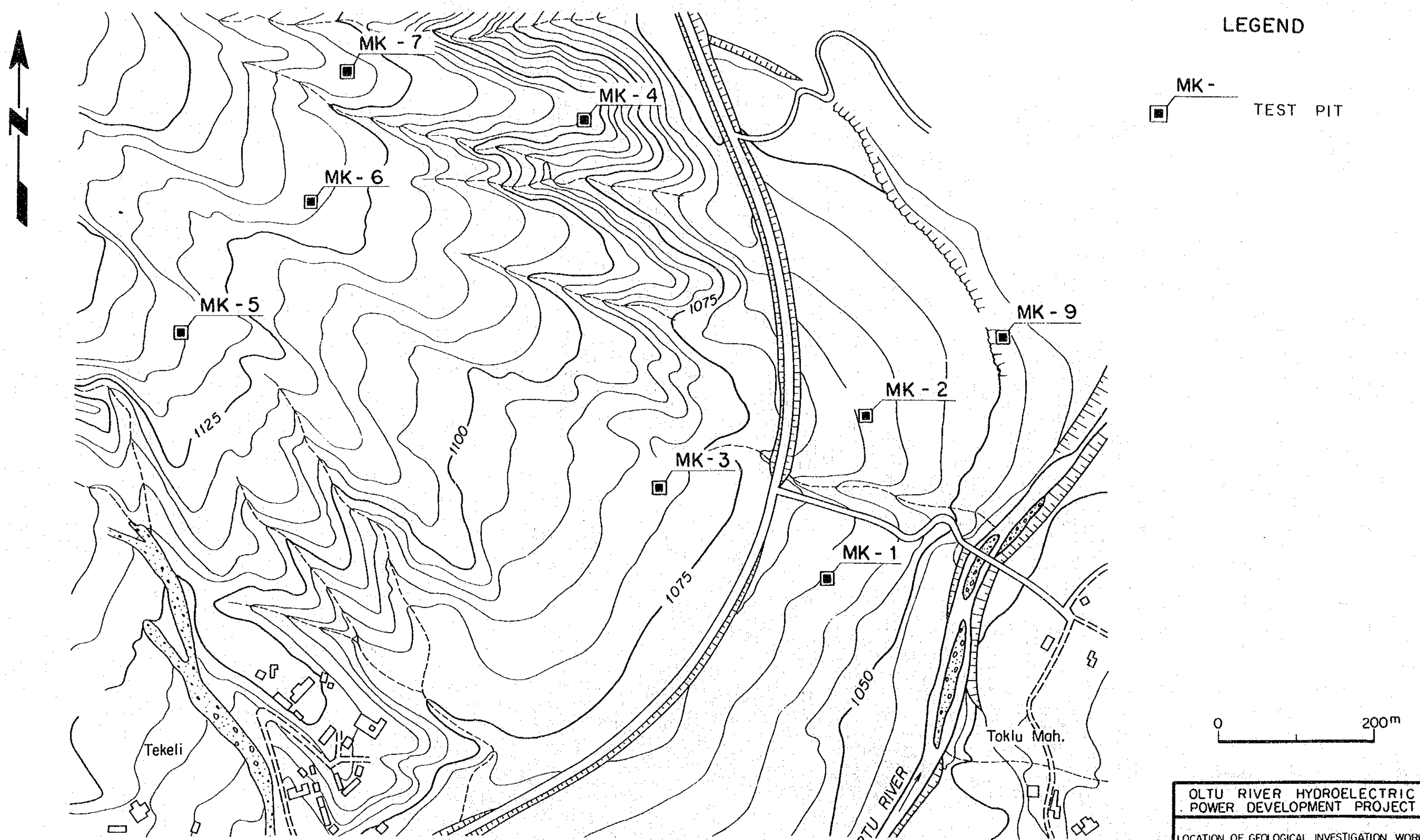
As indicated by the results of consolidation tests, the dry density of the Kaledibi soil is sufficiently high, while that of Yolboyu soil, although lower than for Kaledibi, is not so low that it will be a problem in particular. According to the results of direct shear tests, the angle of internal friction of Kaledibi soil is sufficiently large, while as for Yolboyu soil, if it were to be blended with Kaledibi soil and used upon appropriate zoning, an adequate safety factor from a structural viewpoint will be secured.

Direct shear tests and permeability tests of Yolboyu soil have been made only on a single sample and additional tests will be necessary prior to detailed designing.

More detailed investigations and testing would be desirable for definite design and construction.

Quantity-wise, adequate materials are available at both the borrow areas of Kaledibi and Yolboyu.

KALEDİBİ BORROW AREA



OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

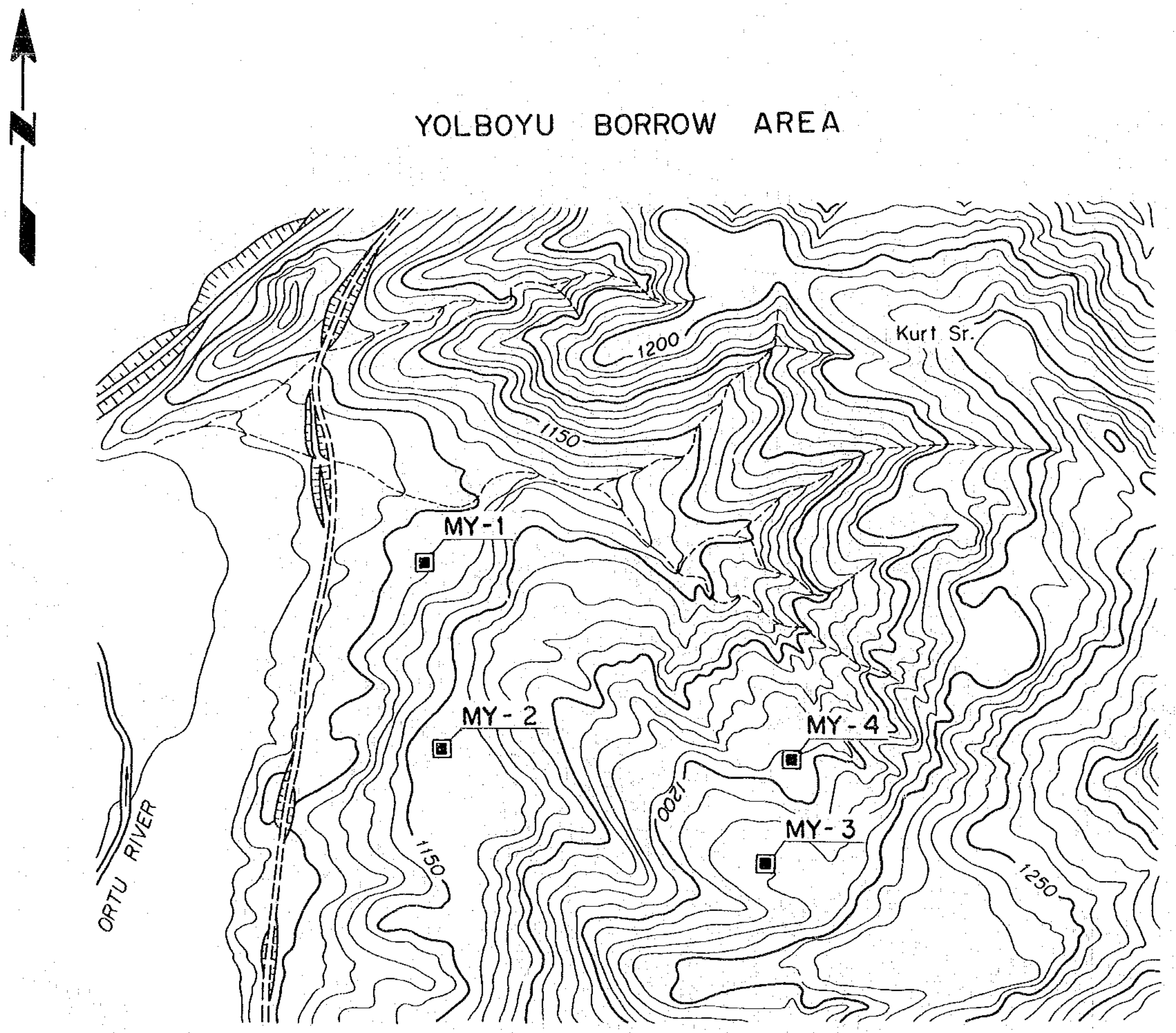
LOCATION OF GEOLOGICAL INVESTIGATION WORKS

OLUR BORROW AREA-PLAN

Kaledibi Area

Fig. 7-11

YOLBOYU BORROW AREA



LEGEND

MY- TEST PIT

0 200 m

OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOCATION OF GEOLOGICAL INVESTIGATION WORKS

OLUR BORROW AREA-PLAN

Yolboyu Area

Fig. 7－12

Table 7-5 Results of Test (Soil Material) of Olur Project

Name of Dam	Name of Pit	Depth of Sample	Soil Classification	Specific Gravity	Natural Moisture Content	Atterberg Limit LL	Atterberg Limit PL	Atterberg Limit PI	Grain Size Analysis of Sample: Max Grain Size (mm)	mm -76.2 (%)	mm -19.1 (%)	mm -4.76 (%)	mm -0.074 (%)	mm -0.005 (%)	Average Absorption (%)	Compaction: Opt. Water Content (%)	Compaction: Max. Dry Density (t/m^3)	Shear (Cu): c (kN/m^2)	Shear (Cu): φ (deg)	Coefficient of Permeability (cm/sec)	Block rate >3 in (%) (Visual observe)
	MK-1	2.20	GC	2.67	10	32.6	16.9	15.7	42	100	78	40	19	9	2.0	11.8	2.0	-	-	$3.45x10^{-3}$	32
	MK-2	2.50	GP GC	2.67	11	26.5	18.7	7.8	45	100	72	40	12	6	1.9	9.0	2.09	38	34	$4.22x10^{-3}$	20
	MK-3	3.50	GC	2.71	12	30.6	17.0	13.6	40	100	84	44	15	6	2.4	10.5	2.06	-	-	$4.62x10^{-3}$	25
	MK-4	3.60	GC	2.66	12	31.2	18.7	12.5	60	100	78	55	30	14	3.3	11.0	1.99	25	33	$3.96x10^{-6}$	30
	MK-5	2.50	GC	2.67	11	31.6	18.7	12.9	70	100	79	54	23	9	2.5	10.8	1.99	-	-	$1.07x10^{-4}$	45
	MK-6	3.20	GC	2.66	14	32.6	19.9	12.7	40	100	78	53	26	12	1.9	11.5	1.99	37	31	$6.10x10^{-5}$	30
	MK-7	3.00	GC	2.67	12	31.2	19.0	12.2	38	100	81	56	22	13	1.6	10.3	2.11	-	-	$2.76x10^{-3}$	40
	MK-8	4.00	GC	2.68	13	27.3	15.0	12.3	45	100	73	48	16	8	2.2	8.8	2.12	25	36	$2.40x10^{-3}$	35
	MY-1	4.00	SC	2.68	20	33.6	17.9	15.7	34	100	96	78	25	12	3.3	13.2	1.98	13	18	$2.67x10^{-8}$	15
	MY-2	3.00	CH	2.62	23	54.6	25.1	29.5	20	100	99	79	41	28	2.7	16.7	1.86	-	-	-	10
	MY-3	3.00	CL	2.61	25	47.3	23.8	23.5	30	100	95	82	58	33	4.1	16.3	1.76	-	-	-	10
	MY-4	4.00	SC	2.66	14	33.6	18.9	14.7	38	100	94	75	32	16	3.9	11.0	2.07	-	-	-	10

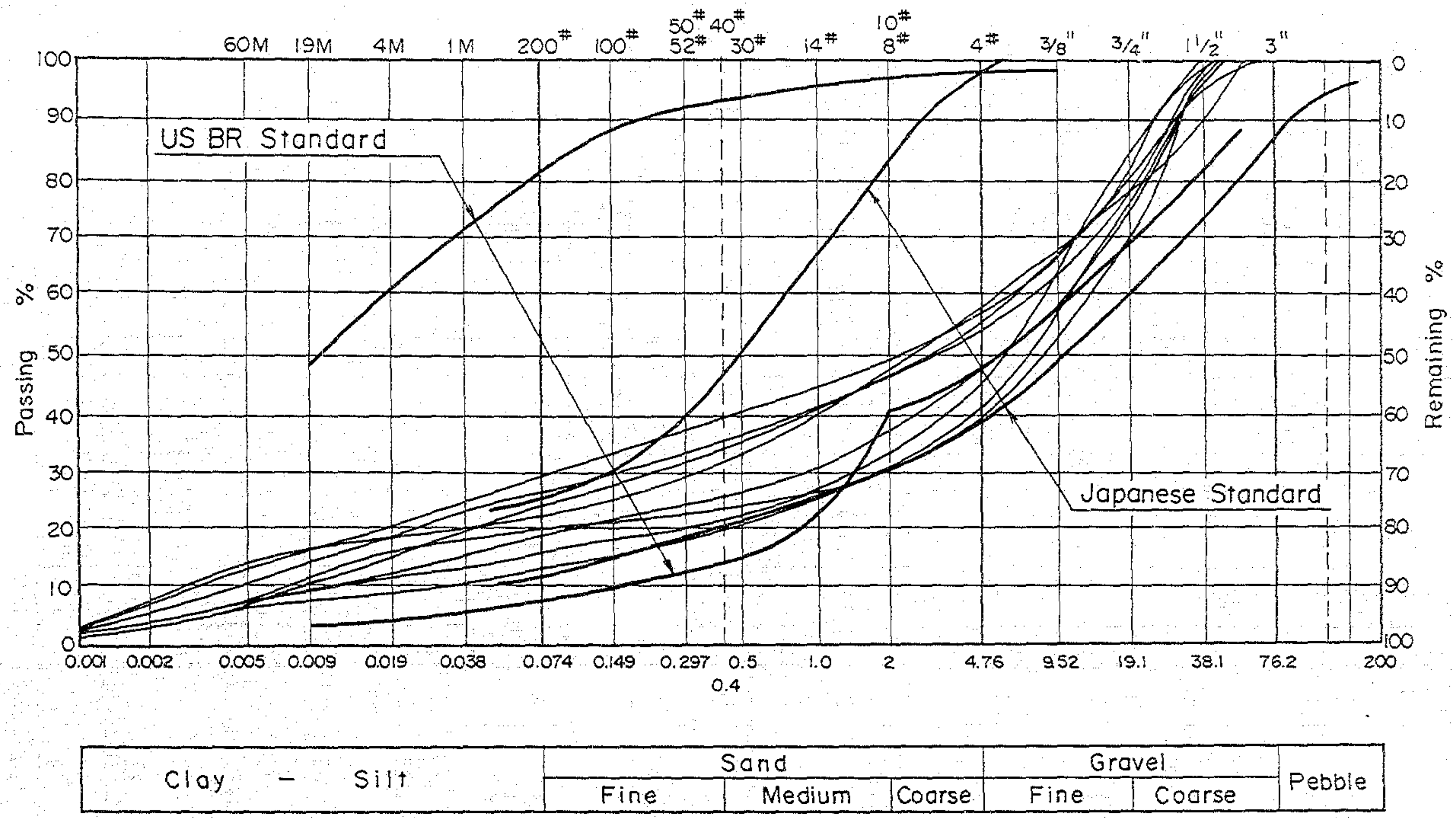


Fig. 7-13 Sieve Analysis of Kaledibi Borrow Material

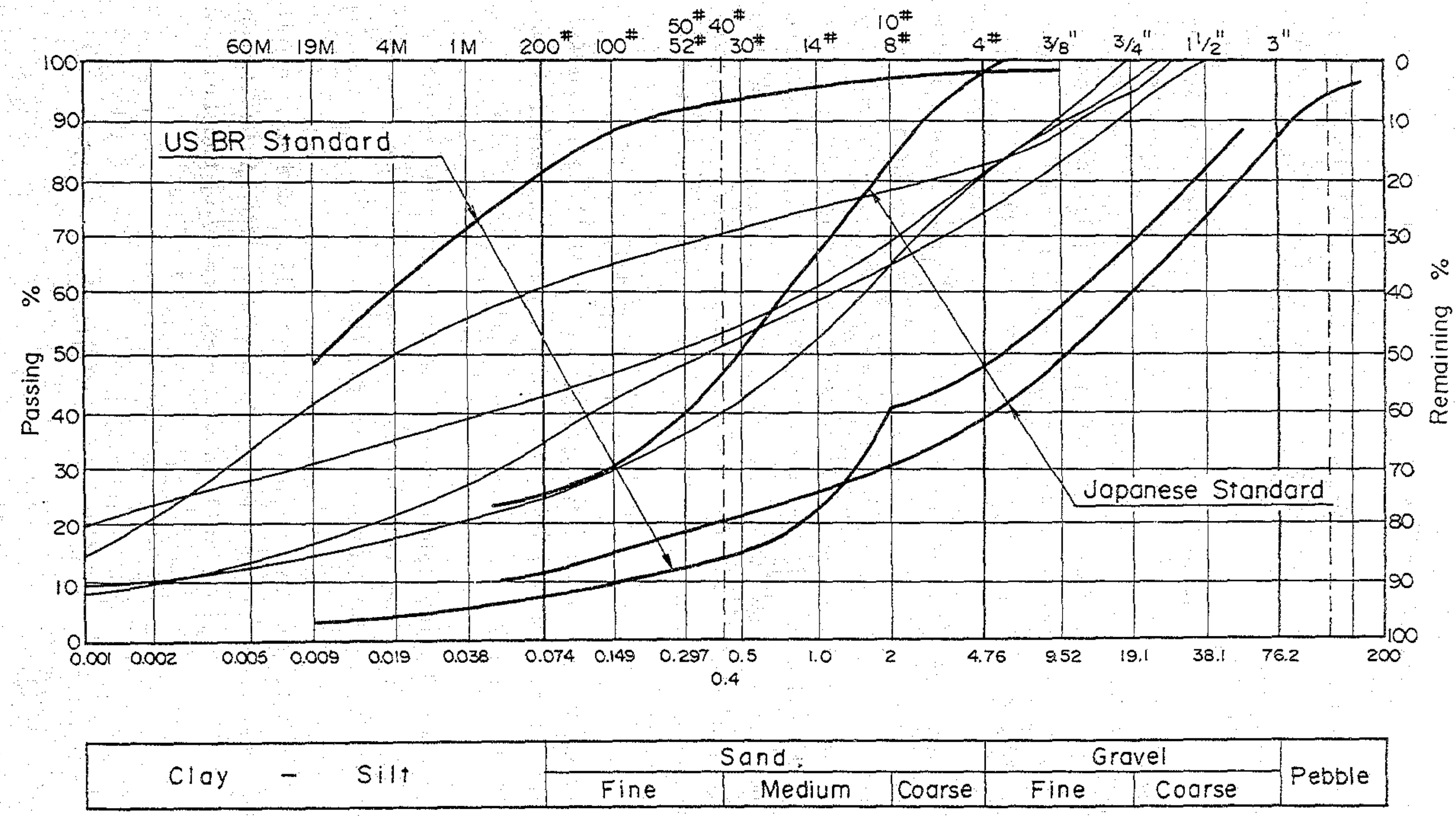


Fig. 7-14 Sieve Analysis of Yolboyu Borrow Material

(2) Impervious Core Materials for the Ayvalı Dam

The total quantity of impervious core material to be used at the impervious core zone of the rockfill dam would be approximately 1.3 x 10^6 m^3.

As a result of investigations by EIE and the JICA Survey Team, a candidate site for the borrow area was selected at the Bulanik Valley approximately 8 km downstream (right bank) of the damsite, and approximately 8 km upstream of the dam in the Tavusker Valley which joins in at the right bank, and investigation tests were carried out.

These two candidate sites are fairly distant from the dam at 8 km, while the borrow areas are not so large. The quantities available are also not very large, and there may be a case where it will be necessary for blending to be done by the stockpiling method at each of the candidate sites or for blending to be done of material from the two candidate sites in the vicinity of the dam to prepare embankment material having the proper grain-size distribution.

In designing and constructing the dam it will be necessary to devise ways of reducing the amount of soil materials to be used.

The Bulanik Valley candidate soil borrow area is located at a fan formed along the valley from the vicinity of where the Bulanik Valley merges with the Oltu River.

The deposits at this fan are composed of gravel, sand, silt, and clay of the Pugey Formation. It is estimated that 1.8 x 10^6 m^3 of soil can be borrowed from the Bulanik Valley.

The Tavusker Valley candidate soil borrow area consists of river terraces formed along the valley approximately 6.5 km upstream from the confluence of the Tavusker Valley and the Oltu River. These river-bank deposits are composed of gravel, sand, silt, and clay of the Pügey Formation. It is estimated that the amount which can be borrowed from the area investigated in the Tavusker Valley will be around 0.8 x 10^6 m^3.

The pits listed in Table 7-3(c) were excavated with the two candidate sites mentioned above as the objects. The locations are shown in Fig. 7-15 and Fig. 7-16.

The samples collected were tested at the laboratories of EIE and DSI.

1) Items and Quantities of Laboratory Tests

The items and quantities of the laboratory tests are given in Table 7-6.

Table 7-6 Items and Quantities of Test of Ayvalı Project

Items	Quantities	
	Bulanik	Tavusker
Specific Gravity	12	11
Moisture Content	12	11
Grain Size Analysis	12	11
Liquid Limit and Plastic Limit	12	11
Compaction	11	11
Permeability	22	11
Direct Shear	6	5
Soluble Salt Content	-	-
Absorption	7	-

The depths of the individual pits at the soil borrow areas of Bulanik and Tavusker and the classifications of the soil materials are given in Appendix.

2) Test Results

The results of tests on the impervious materials are given in Table 7-7. The summaries of the test results, for the Bulanik soils and for the Tavusker soils, are as described below.

- Specific gravities are 2.64 to 2.72 for Bulanik soils and 2.63 to 2.74 for Tavusker soils.

- With regard to Unified Soil Classifications (ASTM D2487), from grain-size tests and Atterberg limit tests, the Bulanik soils belong to inorganic clay (CL) to clayey gravel (GC), while Tavusker soils also belong to inorganic clay (CL) to clayey gravel (GC).

- The optimum water contents obtained from consolidation tests are 11.0% to 20.5% for Bulanik soils, and 14.5% to 22.5% for Tavusker soils, while maximum dry densities are 1.64 t/m^3 to 1.99 t/m^3 and 1.62 t/m^3 to 2.00 t/m^3, respectively, and there is considerable scattering in optimum water contents and dry densities with both soil materials. Differences between natural water contents and optimum water contents are considerably scattered depending on the place and depth, and while with Bulanik soils natural water contents are higher at places and optimum water contents higher at other places, natural water contents are all higher for Tavusker soils except at MT-9.

- Direct shear tests were carried out consolidated and undrained (CU). As a result, cohesion and angle of internal friction were 18 k/m^2 to 38 kN/m^2 and 19° to 32°, respectively, for Bulanik soils and 35 k/m^2

to 61 kN/m^2 and 12 to 28°, respectively, for Tavusker soils.

- Regarding grain-size distributions, for Bulanik soils the maximum particle size was 50 mm, the amounts of 19.1 mm and under from 72% to 100%, 4.75 mm and under 43% to 100%, 0.075 mm and under 8% to 88%, and 0.005 mm and under 6% to 56%. The number of samples tested was 12, and there was very much scatter among samples depending on place and depth of collection. For Tavusker soils, the maximum particle size was 80 mm, the amounts of 19.1 mm and under 68% to 100%, 4.75 mm and under 43% to 98%, 0.075 mm and under 18% to 87%, and 0.005 mm and under 10% to 43%. There was a fair amount of scatter depending on the place of collection.

- Atterberg limit tests were conducted on both Bulanik and Tavusker soils. The results were liquid limits (LL) of 30.9% to 55.2%, plastic limits (PL) of 16% to 22.6%, and plasticity indices (PI) of 9.9 to 30.9 for Bulanik soils. Liquid limits (LL) were 32.1% to 49.5%, plastic limits (PL) 17.1% to 22.8%, and plasticity indices (PI) 15 to 27.1 for Tavusker soils.

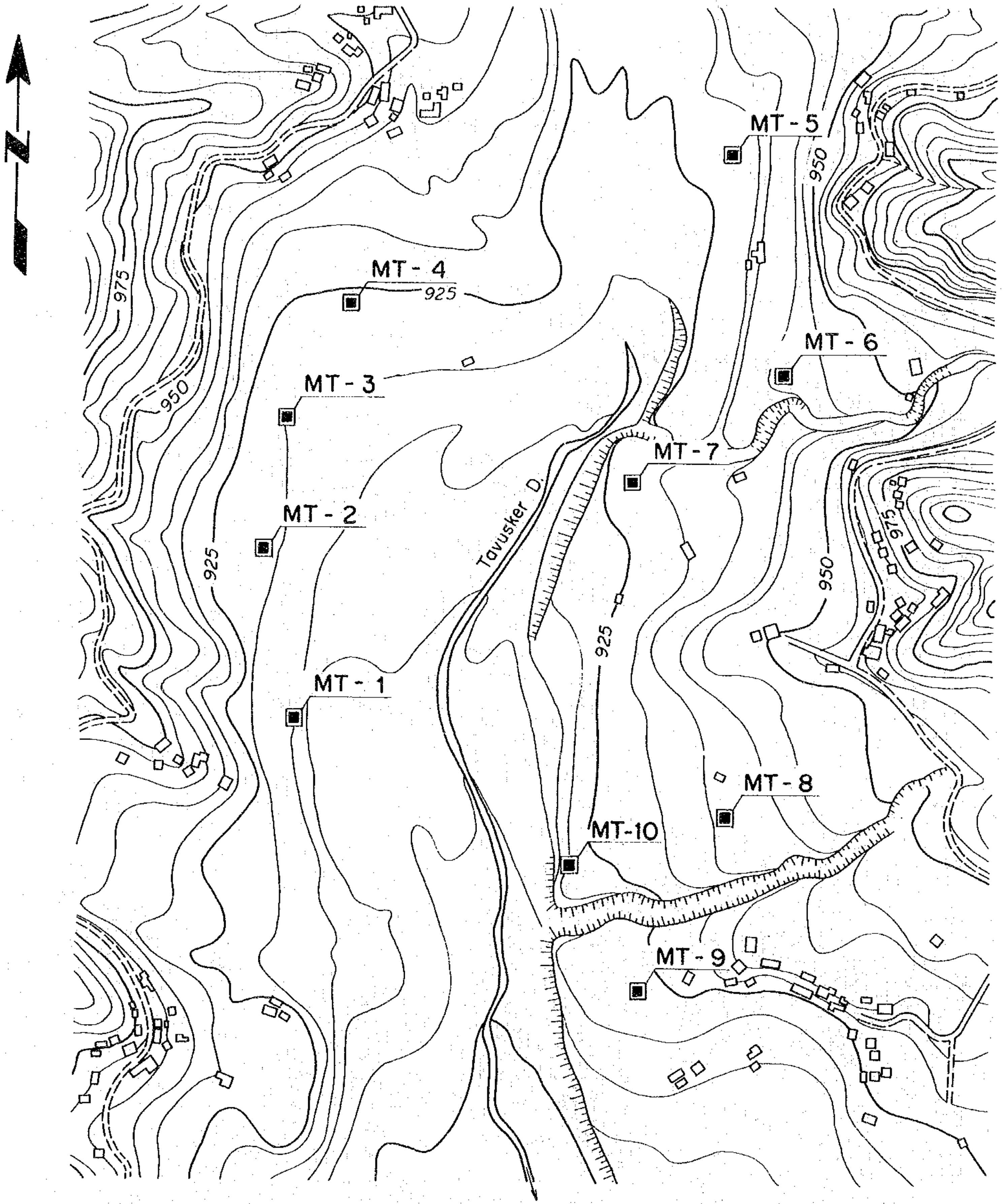
- According to permeability tests, the values for Bulanik soils were 1.58 x 10^{-8} to 2.02 x 10^{-3} cm/s for what at first glance appears like scatter, but almost all coefficients of permeability were about 10^{-8} cm/s to 10^{-7} cm/s. The coefficients were 3.2 x 10^{-7} cm/s to 4.1 x 10^{-6} cm/s for Tavusker soil. Bulanik soil material contained a considerable amount of salts so that permeability tests were continued for approximately 7 months on material from MB-3, but changes in test results were not recognized.

3) Evaluation

To evaluate the above results, the Bulanik soils are inorganic clay (GL) to clayey gravel (GC) according to the Unified Classification Method, while contents of fines (0.075 mm and under) are from 8% to 88% for great scattering, but since there is no other suitable material, it will be necessary to make up a soil possessing the required properties by suitably blending the soil materials of this valley. As for Tavusker soils, they are also inorganic clay (CL) to clayey gravel (GC) according to the Unified Classification Method with contents of fines (0.075 mm and under) 18% to 87%. Permeability test results are all around 10^{-8} cm/s to 10^{-7} cm/s, and the material can be said to be of good quality from this aspect, but it will be necessary for further investigations to be made of the aspect of quantity.

In definite designing and construction it will be desirable for more detailed investigations and testing to be carried out. Quantity-wise, it may be that the amounts available for borrowing are not necessarily very large.

TAVUSKER BORROW AREA



LEGEND

MT- TEST PIT

0 200 m

OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

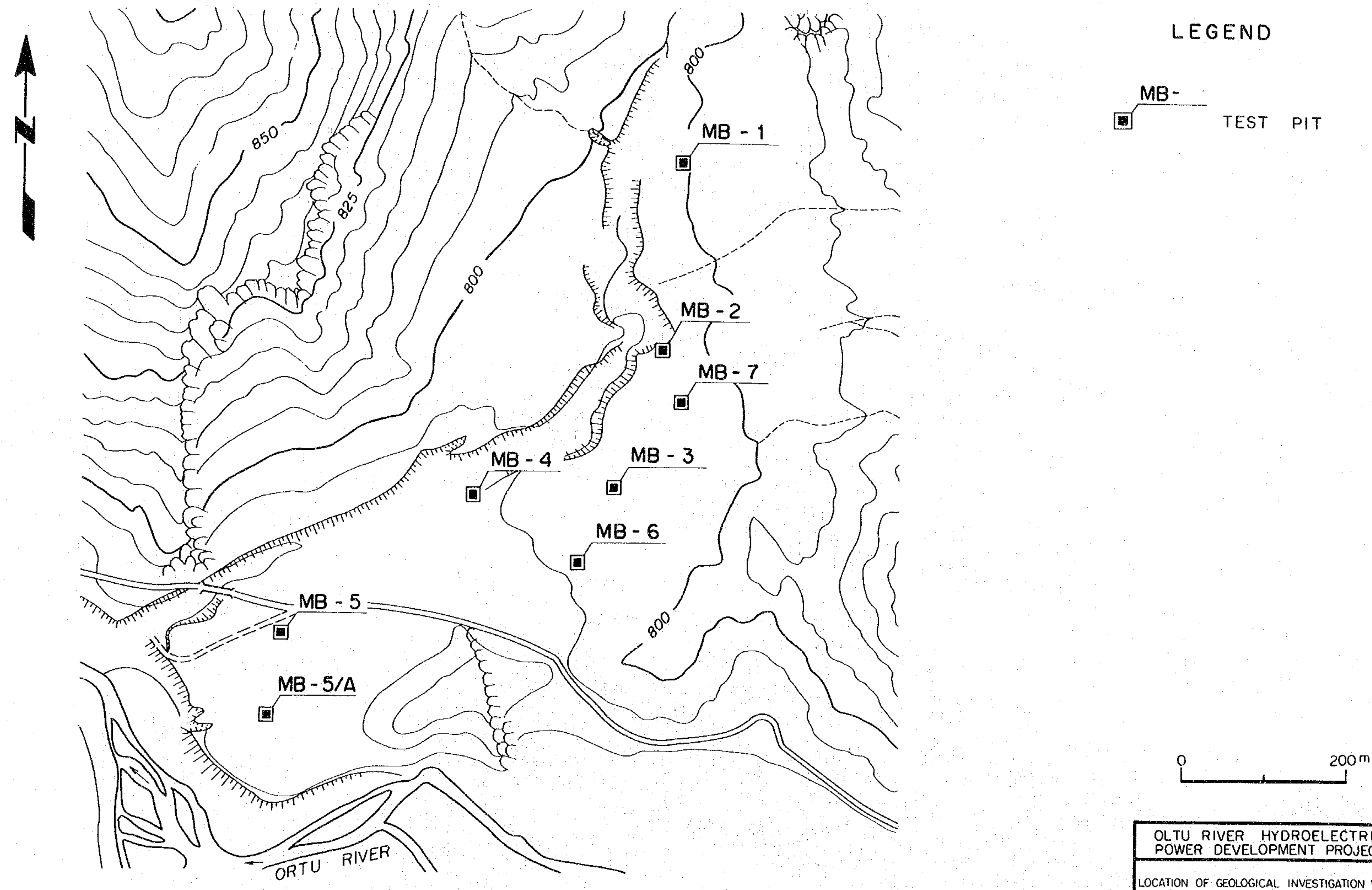
LOCATION OF GEOLOGICAL INVESTIGATION WORKS

AYVALI BORROW AREA-PLAN

Tavusker Area

Fig. 7 – 15

BULANIK DERE BORROW AREA



OLTU RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOCATION OF GEOLOGICAL INVESTIGATION WORKS

AYVALI BORROW AREA-PLAN

Bulğnık Area

Fig. 7-16

Table 7-7 Results of Test (Soil Material) of the Ayvalı Project (1)

Name of Dam	Name of Pit	Depth of Sample	Soil Classification	Specific Gravity	Natural Moisture Content	Atterberg Limit			Grain Size Analysis of Sample						Average Absorption	Compaction		Sheer (Cu)		Coefficient of Permeability	Block rate >3 in
									Max Grain Size	mm -76.2	mm -19.1	mm -4.76	mm -0.074	mm -0.005		Opt. Water Content	Max. Dry Density	c	φ		
						LL	PL	PI	(mm)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(t/m^3)	(kN/m^2)	(deg)	(cm/sec)	(%) (Visual observe)
	MB-1	4.00	CL	2.64	20	34.5	20.7	13.8	12	100	100	96	81	37	-	19.5	1.68	-	-	$1.00x10^{-7}$	-
	MB-2	0-2.00	CH	2.71	28	55.2	21.3	30.9	16	100	100	98	82	56	-	19.0	1.67	38	19	$3.21x10^{-8}$	-
		2.00-4.00	CL	2.63	10	38.0	21.6	16.4	23	100	99	92	59	34	-	15.0	1.74	-	-	$3.20x10^{-6}$	15
		4.00-6.00	GW GC	2.67	11	37.0	17.9	19.1	50	100	72	43	8	6	3.5	-	-	26	32	-	30
		6.00-12.00	SC	2.67	7	34.6	18.3	16.3	24	100	97	70	22	12	2.8	12.0	1.99	25	32	$2.02x10^{-3}$	30
	MB-3	4.00	CL	2.68	23	40.7	21.0	19.7	17	100	100	95	65	37	-	17.5	1.74	35	20	$1.00x10^{-7}$	-
	MB-4	0-2.00	CL	2.64	12	36.7	19.5	17.2	53	100	85	75	50	26	4.9	14.0	1.89	-	-	$1.00x10^{-7}$	-
		2.00-6.00	GC	2.72	12	37.5	21.3	16.2	40	100	76	48	27	16	2.5	11.0	1.91	-	-	$3.50x10^{-7}$	-
		6.00-10.00	GC	2.70	16	30.9	21.0	9.9	50	100	76	54	30	16	2.4	11.0	1.96	-	-	$8.00x10^{-7}$	25
	MB-5A	2.1	CL	2.70	16	40.3	19.0	21.3	50	100	84	64	42	24	2.7	14.0	1.86	36	21	$2.32x10^{-8}$	20
	MB-6	1.40	CH	2.72	14	50.9	22.6	28.3	5	100	100	100	88	52	-	20.5	1.64	-	-	$1.58x10^{-8}$	-
	MB-7	2.00	GC	2.64	11	35.5	16.0	19.5	42	100	82	62	28	16	2.0	13.0	1.96	18	30	$2.00x10^{-7}$	30
	MT-1	4.00	CL	2.71	18.3	45.5	21.4	24.1	25	100	98	86	55	32	-	15.0	1.72	-	-	$6.90x10^{-7}$	5
	MT-2	4.00	SC	2.71	-	32.1	17.1	15.0	19.1	100	100	77	30	14	-	14.5	2.00	37.5	28	$2.30x10^{-6}$	10
	MT-3	3.80	CL	2.73	23	49.5	22.4	27.1	9.5	100	100	98	87	43	-	22.0	1.62	-	-	$7.10x10^{-7}$	-
	MT-4	3.60	CL	2.74	23.2	43.2	22.4	20.8	19.1	100	100	97	78	37	-	20.7	1.67	35	19	$5.80x10^{-7}$	-
	MT-5	4.00	SC	2.73	21.8	38.2	20.2	18.0	19.1	100	100	88	44	20	-	17.0	1.78	-	-	$4.10x10^{-6}$	-
	MT-6	3.80	CL	2.74	20.8	38.1	21.2	16.9	15	100	100	97	64	23	-	18.0	1.74	37	20	$3.20x10^{-7}$	5

Table 7-7 Results of Test (Soil Material) of the Ayvalı Project (2)

Name of Dam	Name of Pit	Depth of Sample	Soil Classification	Specific Gravity	Natural Moisture Content	Atterberg Limit			Grain Size Analysis of Sample						Average Absorption	Compaction		Shear (Cu)		Coefficient of Permeability	Block rate >3 in
									Max Grain Size	mm -76.2	mm -19.1	mm -4.76	mm -0.074	mm -0.005		Opt. Water Content	Max. Dry Density	c (kN/m²)	φ (deg)		(%)
						LL	PL	PI	(mm)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(t/m³)			(cm/sec)	(Visual observe)
	MT-7	4.00	GC	2.67	17.6	36.3	20.9	15.4	45	100	68	43	18	10	-	15.0	1.84	-	-	2.10×10^{-6}	20
	MT-8	3.80	GC	2.64	20.8	42.0	21.6	20.4	43	100	86	68	42	24	-	15.5	1.79	60	23	3.50×10^{-6}	10
	MT-9	3.50	GC	2.64	15.3	37.8	20.8	17.0	76.2	100	76	60	42	20	-	16.7	1.78	-	-	2.90×10^{-6}	10
	MT-10	0-2.50	CL	2.72	-	43.1	22.8	20.3	19.1	100	100	97	68	32	-	18.3	1.72	-	-	5.10×10^{-7}	-
		2.50-5.00	CL	2.63	-	46.1	22.7	23.4	9.5	100	100	98	82	36	-	22.5	1.62	61	12	5.40×10^{-7}	-