4.4.2 Engineering Assessment

(1) Suitability for Aggregates

Results of aggregate tests showed that the Kiteto samples were slightly outside the standard range for soundness, but that the other samples were in the range usable as aggregates. However, results of tests for absorption, unit weight, voids, and clay lumps indicate that the materials - especially from T.P.C. and R. Karanga - contain large quantities of fines of (0.075 mm and below). Removal of fines by washing will, therefore, be necessary before the materials are used.

Compressive strength tests on concrete showed that a combination of Karanga coarse aggregare and Karanga fine aggregate yielded an extremely low strength or strength less than one-half of the target. In order to use R. Karanga aggregates for actual structures, therefore, retesting and reexamination of aggregate mix proportions will be required.

(2) Available Quantities

Based on the field investigations and laboratory tests of aggregate materials, the available quantities at respective sites have been estimated as follows. The geological profiles of the test pits are shown in Fig. 4.4.2.

(a) Kiteto

This location is 7 km southeast of Kikuletwa No. 1 Hydropower Station and 2 km south (at the opposite bank) of the proposed powerhouse site for the Kikuletwa No. 2 Hydropower Project. The material is medium to coarse-grained sand mainly of Precambrian crystalline schist and gneiss origins, as it is collected from the riverbed deposits of a tributary draining into the Kikuletwa River. The available quantity, if the material is recovered from a 3-km area along the tributary, is estimated to be 1.0×10^4 m^3.

(b) Nyumba ya Mungu

The location is at the downstream part of the Kikuletwa River, approximately 90 km southeast of Kikuletwa No. 1 Hydropower Station. The hauling distance - at 100 km - will be very long. The material consists of riverbed deposits of the Kikuletwa River (which were carried down by flood water); it is medium- to coarse-grained sand mainly of Precambrian crystalline schist and gneiss origins. The available quantity is estimated to be more than $1.0 \times 10^5 m^3$.

(c) Hai

An existing crushing plant is located in Hai on the trunk road connecting Moshi and Arusha. The plant is 15 km north of the Kikuletwa No. 1 Hydropower Station, and it treats dense rock fragments, about 30 cm in diameter. These originate from basaltic rocks, the volcanic products of Mt. Kilimanjaro. The material is crushed into the following sizes: below 1/4", 1/4 to 1/2", 1/2 to 3/4", 3/4 to 1"; and above 1". The material treated is crushed rock collected from the surrounding area, including from the Kikuletwa No. 2 project site .

(d) R. Karanga

This location is 12 km northeast of the Kikuletwa No. 1 Hydropower Station. The material is sand-gravel and sand originating from basaltic rocks that are the volcanic products of Mt. Kilimanjaro.

Except for the No. 5 site, where silt predominates, the estimated quantities available for aggregates are as follows:

Location	Fine material (m^3)	Coarse material (m^3)
No. 1	2.5×10^2	6.0×10^3
No. 2	0.9×10^3	2.1×10^3
No. 3	2.8×10^2	4.8×10^3
No. 4	1.7×10^3	1.7×10^3

In view of the above-mentioned test results, however, the materials should be further screend before actual use; this could decrease the usable quantity.

(e) T.P.C.

This location is in a sugarcane field 3 km south of the R. Karanga site. The material usable as aggregates is covered by a thick (maximum 5.5 m) overburden of fine materials. The available quantity is estimated to be fairly large, but the overburden will have to be stripped to excavate the material.

Table 4.4.1 RESULT OF LABORATORY TESTS (1 of 5)

Location	Classification of Aggregate	Remarks
R. Karanga	Volcanic: alkali-ne-Basalt	
T.P.C.	Volcanic: alkali-ne-Basalt	
Hai	Volcanic: alkali-ne Basalt and grey Basalt	
Kiteto	Sedimentary: quartz/feldspar cemented by limestone	
Nyumba ya Mungu	Sedimentary: quartz/magnetite cemented by limestone	

Table 4.4.1 RESULT OF LABORATORY TESTS (2 of 5)

Sieve tests		Percentage passing through sieves (%)											Remarks
Sampling Location	Pit name	Under 0.075mm	0.150	0.300	0.600	1.200	2.360	4.750	9.500	19.00	38.10	76.00	
	No.1-2	0.1	0.7	4.3	10.0	17.0	22.0	27.8	35.0	45.0	57.0	80.0	
	No.1-3(1)	0.2	0.5	4.0	9.6	12.9	22.7	27.6	34.0	43.0	53.0	72.0	
R. Karanga	No.1-3(2)	0.1	0.2	0.8	1.8	6.0	12.0	19.0	28.0	38.0	47.9	57.0	
	No.3-3	0.1	0.4	1.7	3.8	14.9	32.0	49.9	64.0	77.0	87.0	96.0	
	No.5-1	0.1	0.5	3.0	16.7	36.0	43.0	51.0	60.0	71.9	82.0	93.0	
T.P.C.	No.1	0.1	0.8	3.0	6.8	15.4	28.0	41.9	55.0	68.6	77.8	85.0	
													(Plant name)
		0	0	0	0	0	0	0	0	0	80.0	100.0	Over 1"
		0	0	0	0	0	0	0	0	6.0	100.0		1 - 3/4"
Hai		0	0	0	0	0	0	0	1.0	83.0	100.0		3/4 - 1/2"
		0.1	0.1	0.2	0.2	0.2	0.2	1.0	18.0	100.0			1/2 - 1/4"
		2.3	4.5	7.0	12.7	24.9	54.0	94.4	99.7	100.0			Under 1/4"
	No.5	0.1	1.0	7.0	21.0	44.0	62.0	79.0	93.6	100.0			
Kiteto	No.7	0.1	0.5	2.8	15.0	35.0	63.0	87.6	96.0	100.0			
	No.8	0.1	0.7	3.0	11.7	32.4	55.0	77.0	91.0	100.0			
	No.12	0.1	0.6	4.0	8.9	29.0	55.9	81.8	94.0	100.0			
Nyumba ya Mungu	No.1	0.1	0.2	1.0	8.4	28.5	56.7	82.7	93.8	100.0			

Table 4.4.1 RESULT OF LABORATORY TESTS (3 of 5)

Fine Aggregate

Location	Kiteto						Nyumba ya Mungu	Hai	R. Karanga				T.P.C.	Maximum Allowable	
Pit name	No. 3	No. 5	No. 7	No. 8	No.10	No.12	-	1/4"	No.1-3		No.3-3	No.5-1	No.1	ASTMC33	JIS (for dam)
Grading	See Fig. 4.4.1 (1 of 6), (2 of 6) and (3 of 6)														
Specific gravity	2.62	2.60	2.63	2.65	2.73	2.71	2.71	2.57	-	-	-	-	-		
Absorption (%)	12.6	13.1	12.4	12.6	10.7	13.6	14.2	11.8	-	-	-	-	-		
Soundness (%)	6.4	13.7	-	-	-	14.1	5.2	-	5.6	4.8	7.2	4.6	5.8	less than 10.0	less than 10.0
Unit weight (kg/m^3)	1959.4	1942.2	-	1994.7	1992.2	1994.7	1890.6	1698.4	-	-	-	-	-		
Voids (%)	25.1	25.0	-	24.4	26.7	26.1	29.9	33.6	-	-	-	-	-		
Clay lumps*1 (%)	1.8	1.3	-	2.8	2.0	1.6	-	0.7	-	-	-	-	-	less than 3.0	less than 1.0
Clay lumps*2 (%)	-	4.1	-	4.6	-	-	2.5	6.3	-	-	-	-	-		less than (3.0)
Organic impurities	not present	not present	-	not present	not present	not present	not present	-	-	-	-	-	-		
Alkali-Aggregate reaction	0 *3	-	-	-	-	-	0	0	-	-	-	0	0		

*1: ASTM C142 *2: BS 812 *3: 0 is innocuous

Table 4.4.1 RESULT OF LABORATORY TESTS (4 of 5)

Coarse Aggregate

Location	Hai				R. Karanga			Maximum (Minimum) Allowable	
Pit name	1/2"	3/4"	1"	Over size	No.1-3	No.3-3	No.5-1	ASTMC33	JIS (for dam)
Grading	See Fig. 4.4.1 (4 of 6) and (5 of 6)								
Specific gravity	2.54	2.55	2.55	-	-	-	-		more than 2.5
Absorption (%)	1.9	2.9	2.8	-	-	-	-		less than 3.0
Abrasion (%)	22.8	24.8	24.9	22.3	26.7	25.2	27.2	less than 50.0	less than 40.0
Soundness (%)	2.8	3.1	3.2	2.3	2.7	3.0	-	less than 18.0	less than 12.0
Unight weight (kg/m^3)	1542.7	1542.7	-	-	-	-	-		
Voids (%)	39.0	39.2	-	-	-	-	-		
Clay lumps*1 (%)	0.5	0.8	-	-	-	-	-	less than 2.0	less than 0.25
Crushing Value (%)		22.0				15.0			
Alkali-Aggregate reaction	0*2	-	-	-	-	0	-		

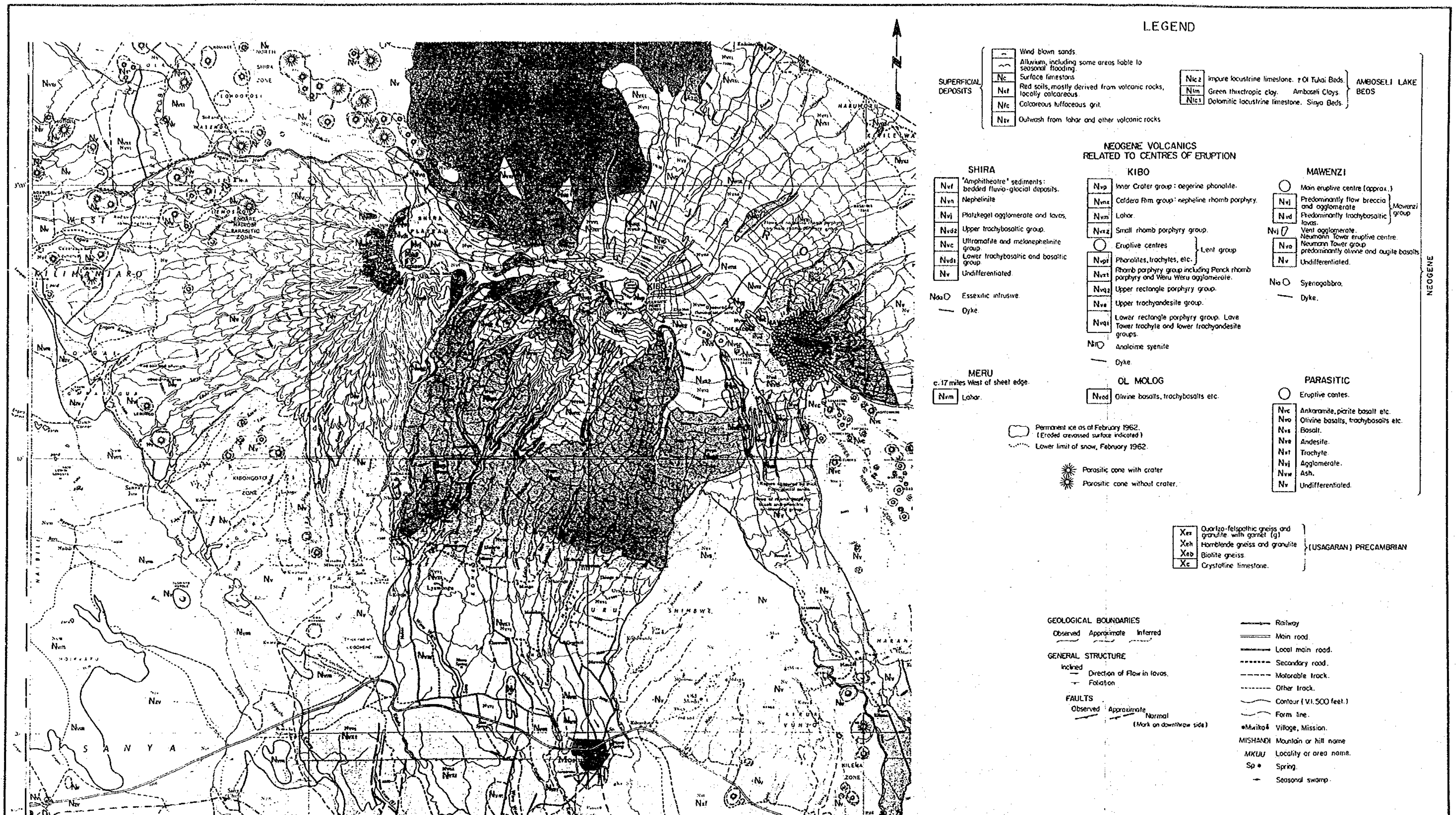
*1: ASTM C142 *2: 0 is innocuous

Table 4.4.1 RESULT OF LABORATORY TESTS (5 of 5)

Natural (fine and coarse) Aggregate

Location	R. Karanga		T.P.C
Pit name	No.3-3	No.5-1	No.1
Grading	See Fig. 4.4.1 (6 of 6)		
Specific gravity	2.46	2.43	2.52
Absorption (%)	24.1	22.1	15.2
Unight weight (kg/m^3)	1939.3	1990.5	2040.6
Voids (%)	20.8	17.7	18.7
Clay lumps*1 (%)	1.5	1.9	1.4
Clay lumps*2 (%)	-	20.6	16.9
Organic impurities	Present	Present	Present

*1: ASTM C142
*2: BS812



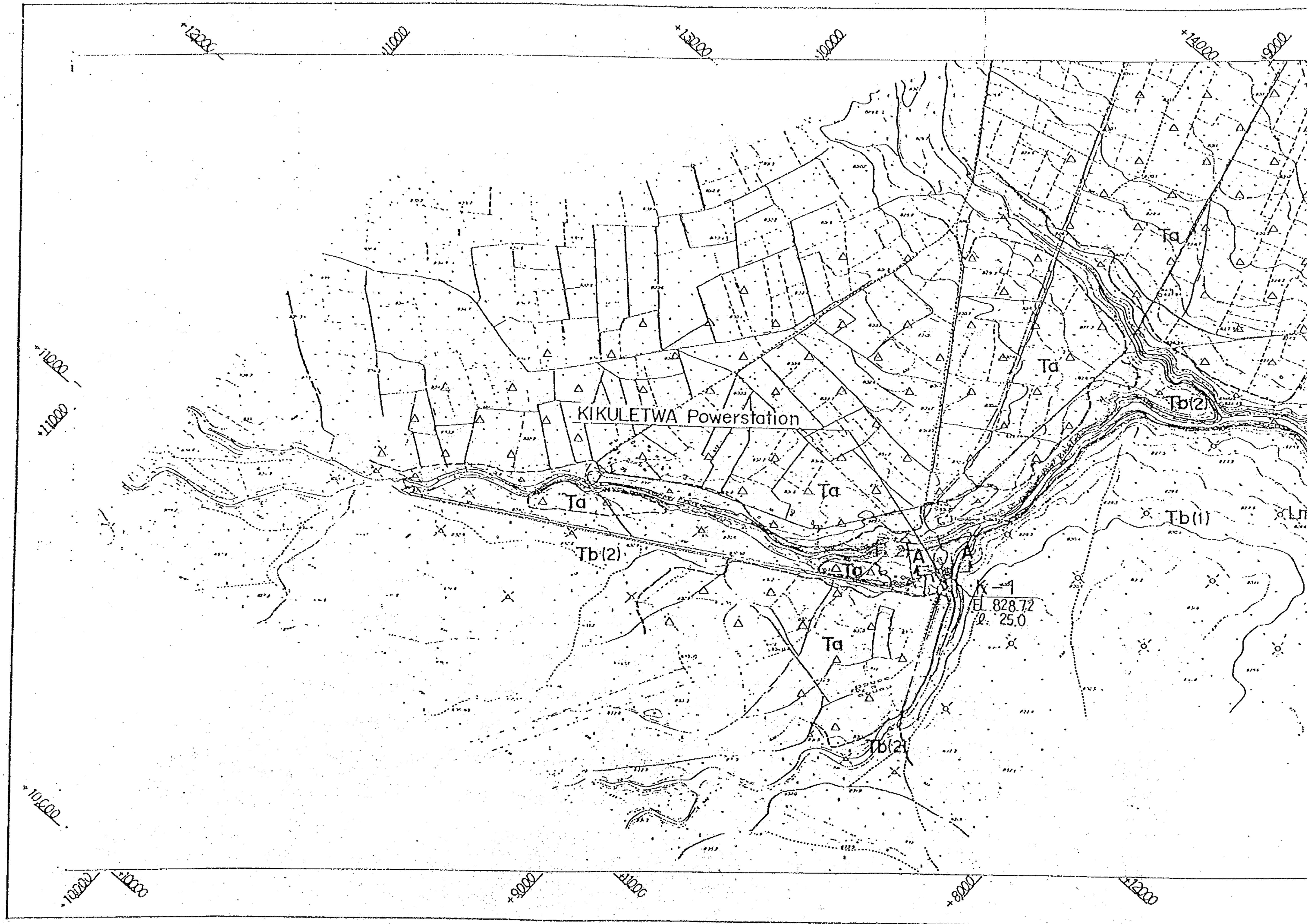
Note : The origin of this map is GEOLOGICAL MAP OF KILIMANJARO by MINISTRY OF INDUSTRIES, MINERAL RESOURCES AND POWER (GEOLOGICAL SURVEY DIVISION) 1965 (Scale of 1:125,000)

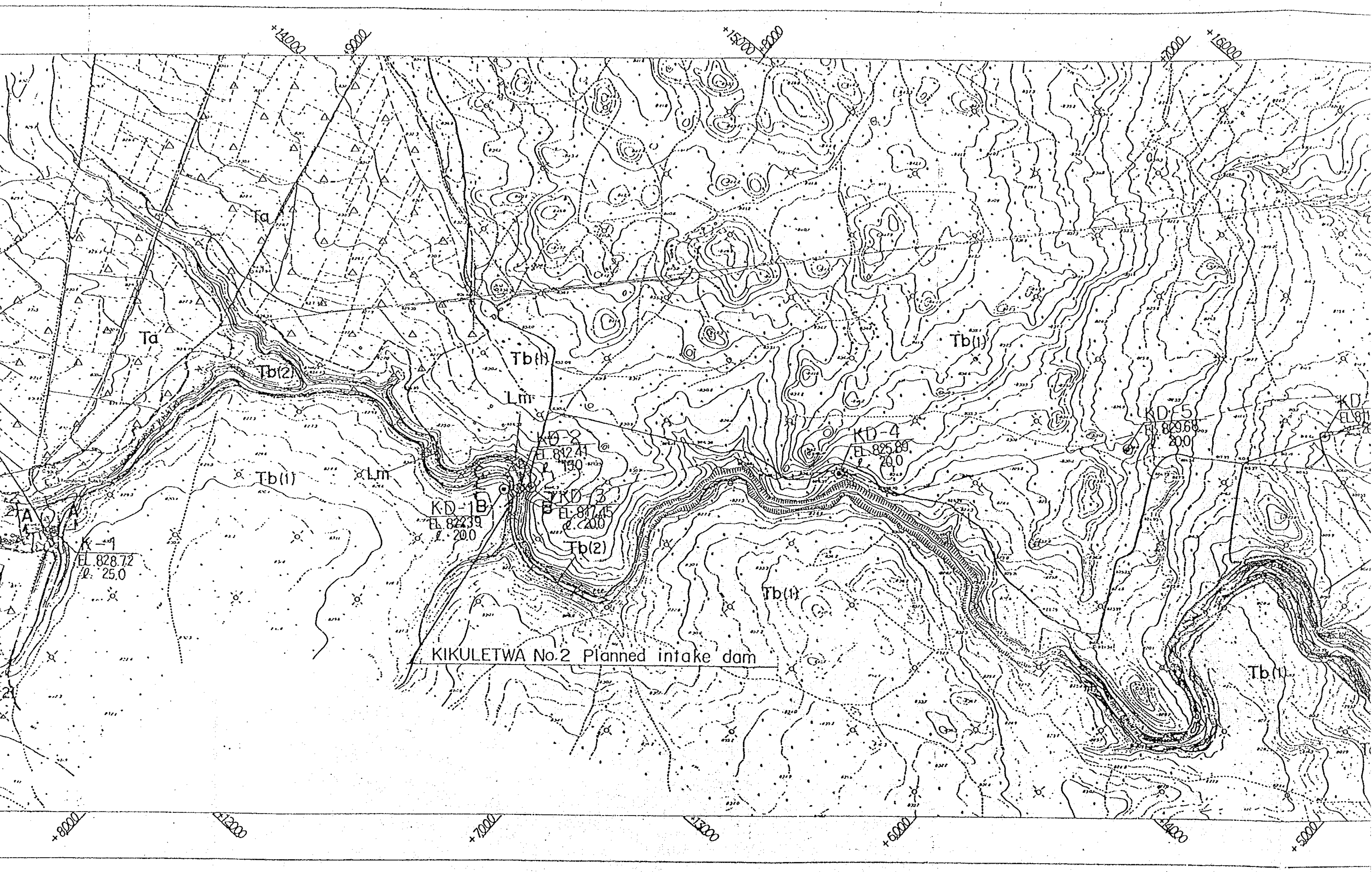
JAPAN INTERNATIONAL COOPERATION AGENCY

KIKULETWA No.1 EXISTING HYDROPOWER STATION AND KIKULETWA No.2 HYDROPOWER PROJECT

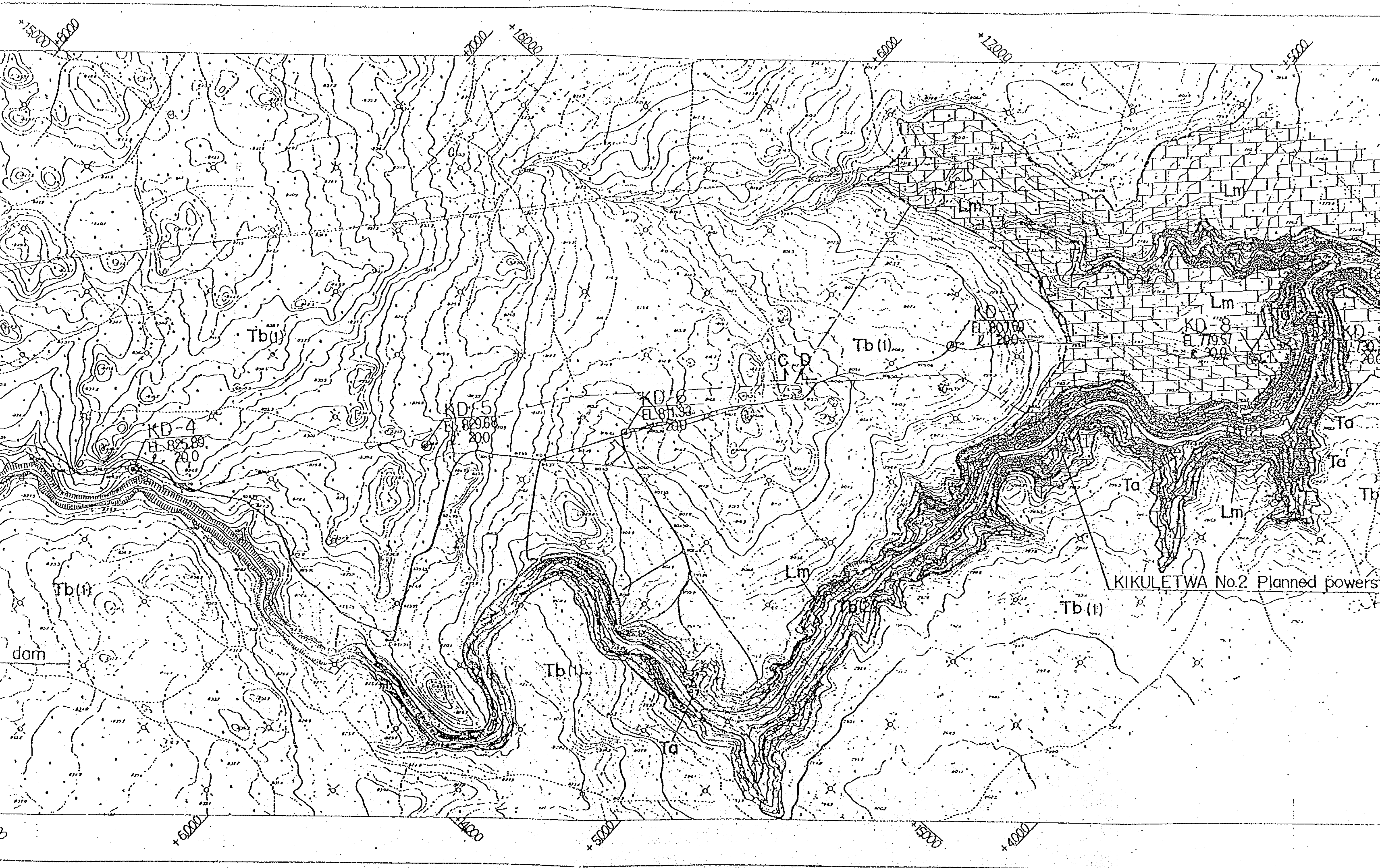
REGIONAL GEOLOGICAL MAP

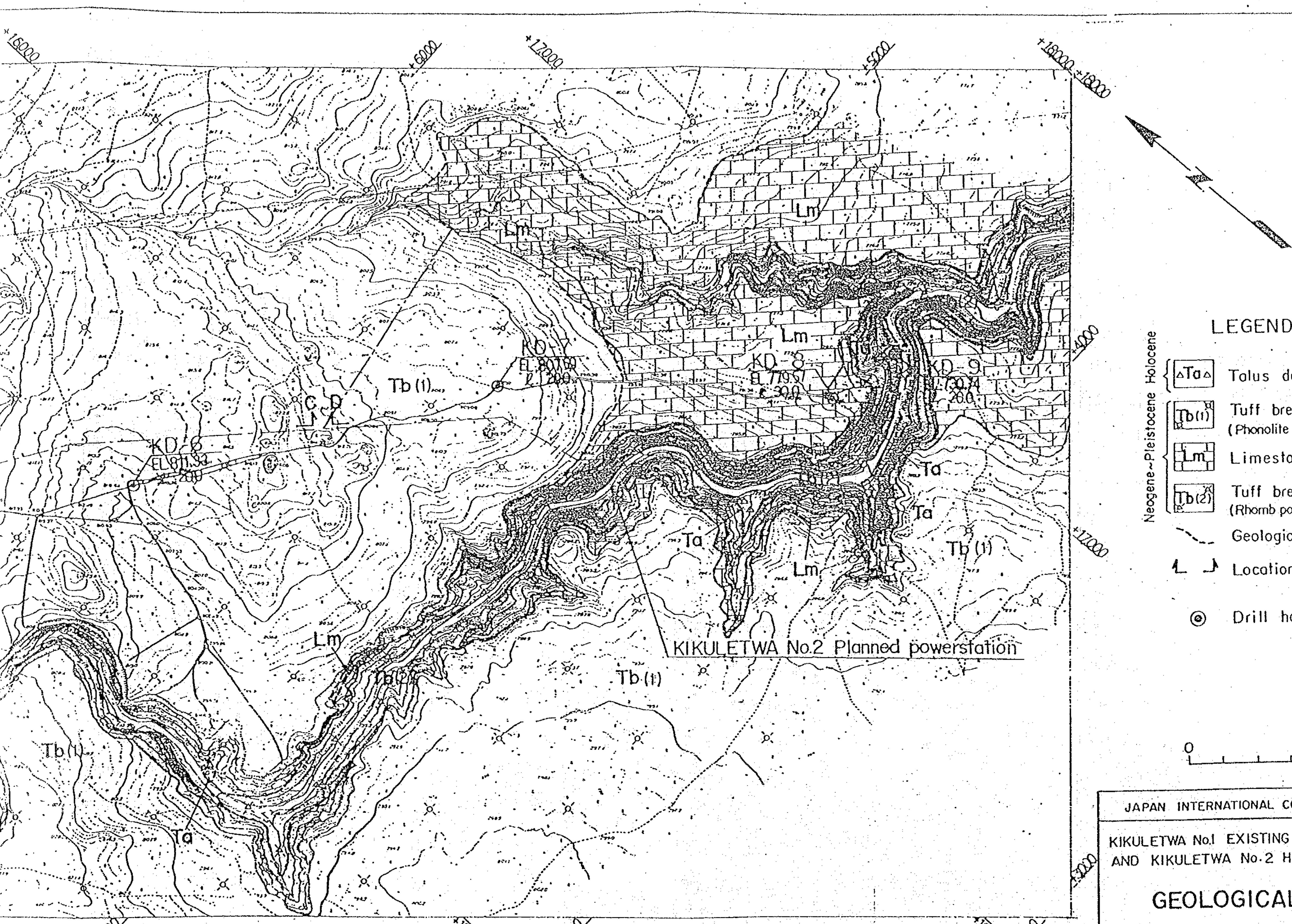
Fig. 4.1.1.


KIKULETWA Powerstation
Ta
Tb(2)
Tb(1)
K-1
EL 828.72
ℓ 25.0
+12000
+11000
+13000
+10000
+14000
+9000
+8000
+10600



+14000
+9000
+15000
+8000
+7000
+16000
Ta
Ta
Tb(2)
Tb(1)
Lm
Tb(1)
Lm
Tb(1)
KD-2
EL.812.41
ℓ 15.0
KD-3
EL.817.45
ℓ 20.0
KD-1
EL.822.39
ℓ 20.0
B
B
A
A
K-1
EL.828.72
ℓ 25.0
Tb(2)
KD-4
EL.825.80
ℓ 20.0
KD-5
EL.829.68
20.0
Tb(1)
Tb(1)
KIKULETWA No.2 Planned intake dam
+8000
+12000
+7000
+13000
+6000
+14000
+5000


KD-4
EL 825.89
20.0
KD-5
EL 829.68
20.0
KD-6
EL 811.93
20.0
EL 807.60
20.0
KD-8
EL 779.57
30.0
Tb(1)
Tb(1)
Tb(1)
Tb(1)
Tb(1)
Lm
Lm
Lm
Lm
Lm
Ta
Ta
Ta
Ta
dam
KIKULETWA No.2 Planned powers
+16000
+17000
+14000
+15000
+6000
+5000
+4000



LEGEND

Neogene~Pleistocene Holocene

Holocene	Ta	Talus deposit
Neogene~Pleistocene	Tb(1)	Tuff breccia (1) (Phonolite block rich)
	Lm	Limestone
	Tb(2)	Tuff breccia (2) (Rhomb porphyry block rich)

Geologic boundary

Location of section

Drill hole

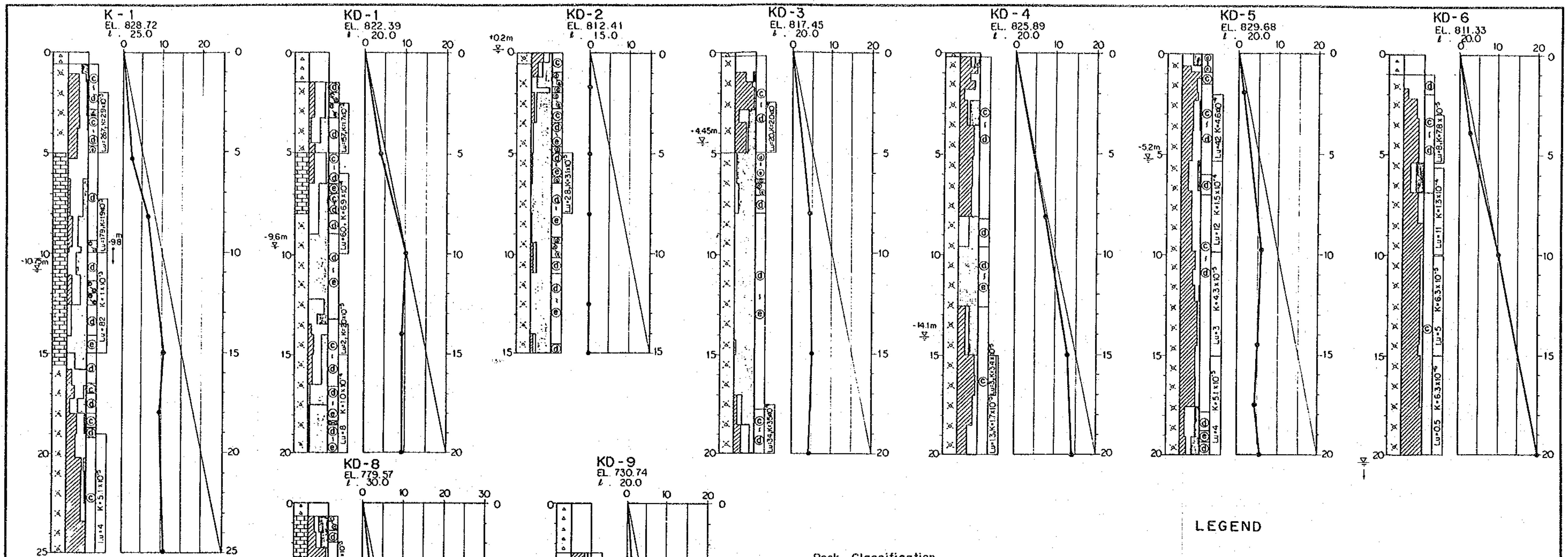
0 500 m

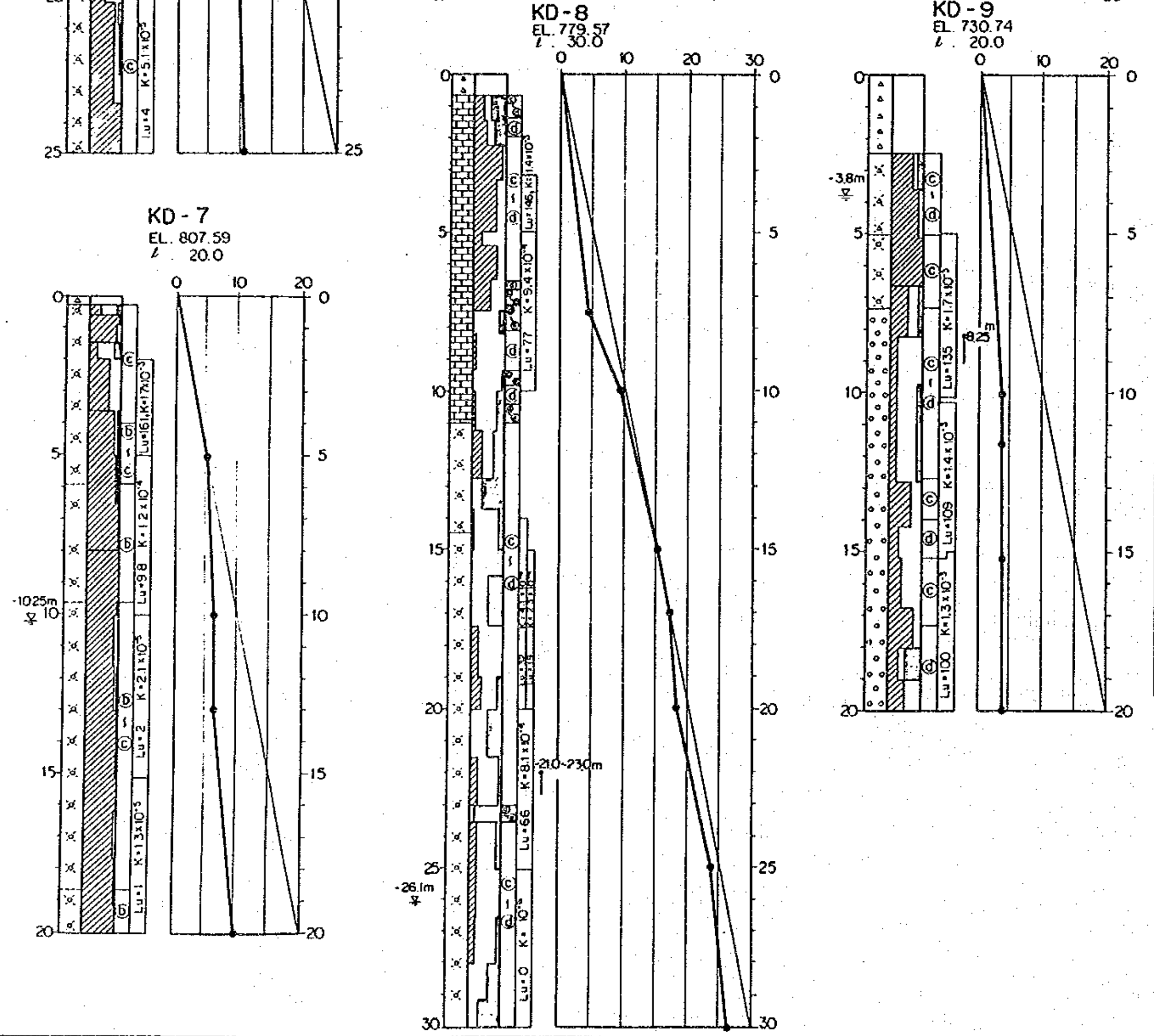
JAPAN INTERNATIONAL COOPERATION AGENCY

KIKULETWA No.1 EXISTING HYDROPOWER STATION AND KIKULETWA No.2 HYDROPOWER PROJECT

GEOLOGICAL PLAN

Fig. 4.1.2.

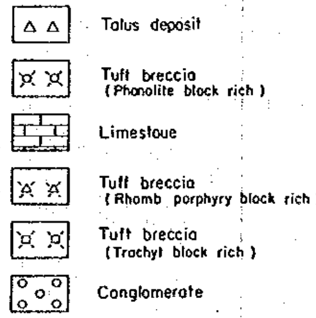


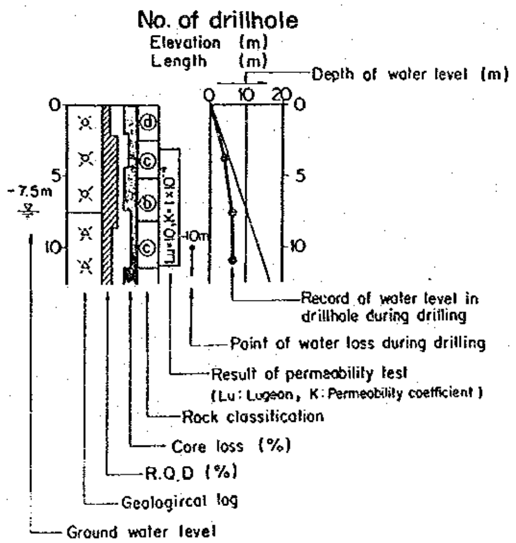


LEGEND

Rock Classification

	Description
ⓐ	The rock mass is very fresh, and the rock forming minerals and grains undergo neither weathering nor alteration.
ⓑ	The rock mass is relatively solid. The rock is contaminated by limonite, etc. Rock blocks are separated by firm hammer blow along joints.
ⓒ	The rock mass is somewhat soft. The rock forming minerals and grains are somewhat softened by weathering. Rock blocks are separated by ordinary hammer blow along the joints.
ⓓ	The rock mass is soft. The rock forming minerals and grains are softened by weathering. Rock blocks are separated by soft hammer blow along the joints.
ⓔ	The rock mass is remarkably soft. The rock forming minerals and grains are softened by weathering. The cohesion of joints and cracks is almost absent. The rock mass collapses by light hammer blow.





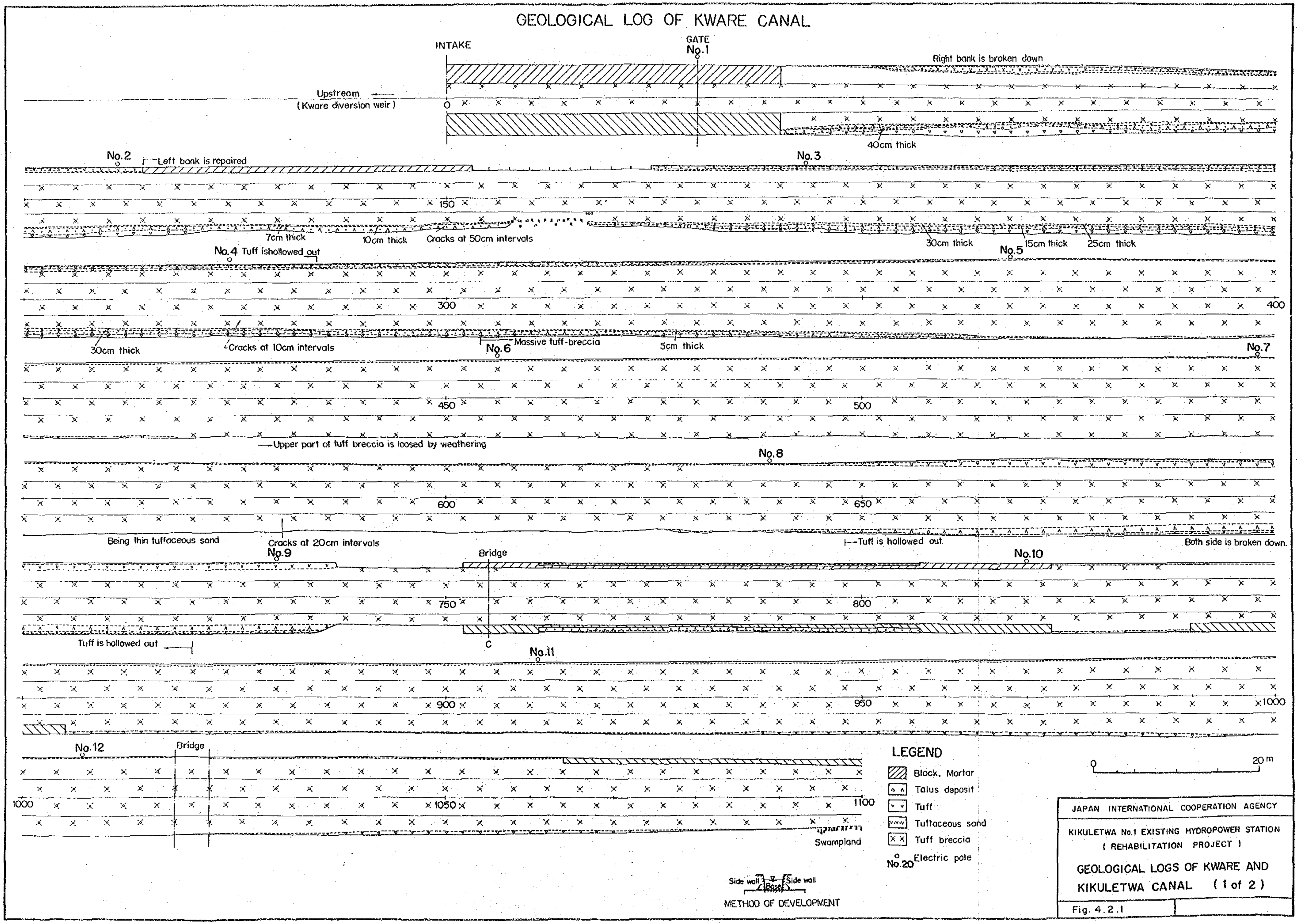
0 10 m

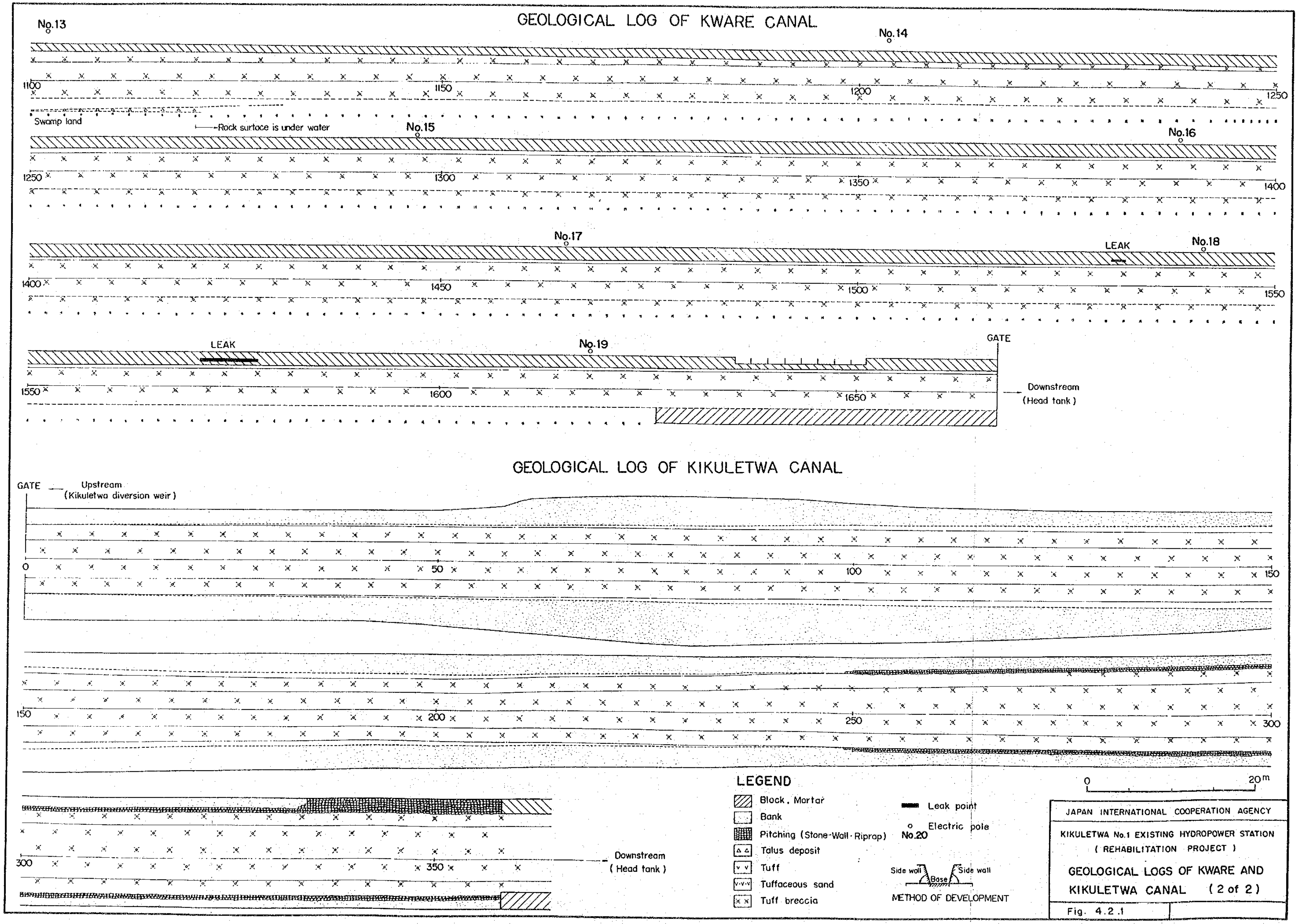
JAPAN INTERNATIONAL COOPERATION AGENCY

KIKULETWA No.1 EXISTING HYDROPOWER STATION AND KIKULETWA No.2 HYDROPOWER PROJECT

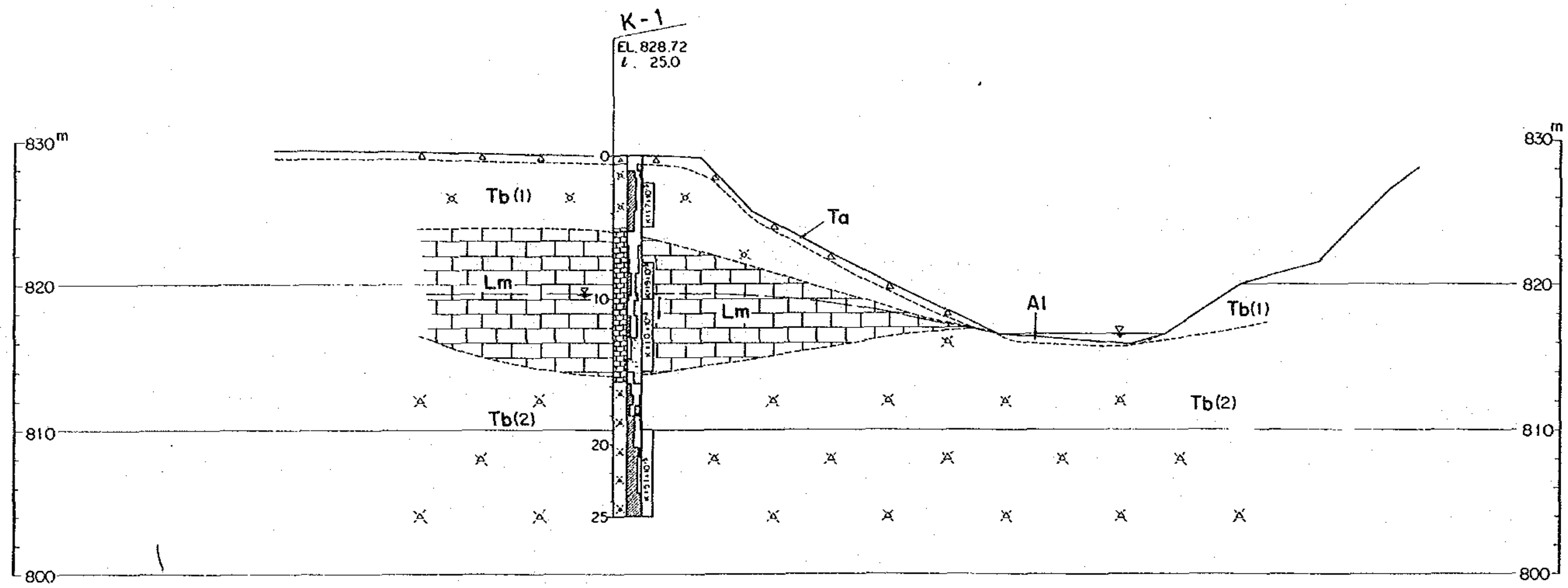
GEOLOGICAL LOGS OF DRILLHOLE

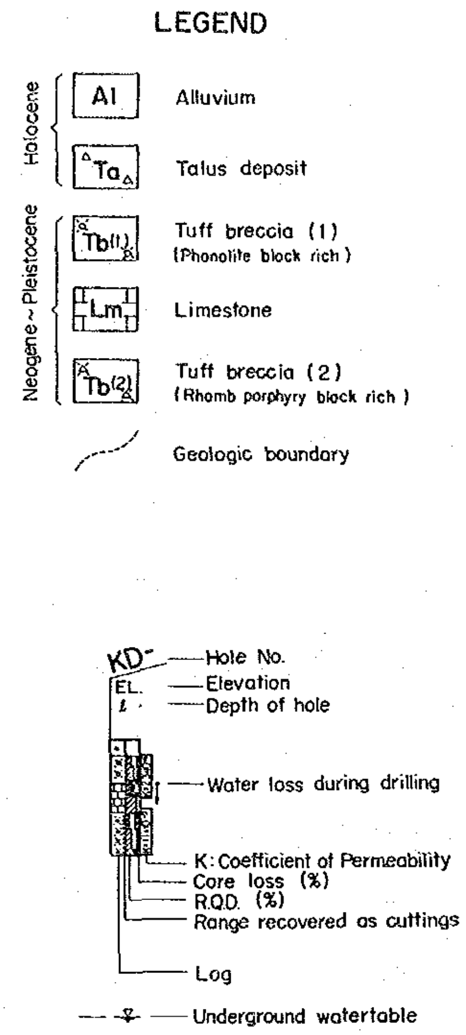
Fig. 4.1.3.


GEOLOGICAL LOG OF KWARE CANAL
INTAKE
GATE
No.1
Right bank is broken down
Upstream
(Kware diversion weir)
0
40cm thick
No.2
Left bank is repaired
No.3
150
7cm thick
10cm thick
Cracks at 50cm intervals
30cm thick
15cm thick
25cm thick
No.4 Tuff is hollowed out
No.5
300
400
30cm thick
Cracks at 10cm intervals
No.6
Massive tuff-breccia
5cm thick
No.7
450
500
Upper part of tuff breccia is loosed by weathering
No.8
600
650
Being thin tuffaceous sand
Cracks at 20cm intervals
Tuff is hollowed out.
Both side is broken down.
No.9
Bridge
No.10
750
800
Tuff is hollowed out
C
No.11
900
950
1000
No.12
Bridge
1000
1050
1100
Swampland
LEGEND
Block, Mortar
Talus deposit
Tuff
Tuffaceous sand
Tuff breccia
No.20 Electric pole
0
20 m
Side wall
Base
Side wall
METHOD OF DEVELOPMENT
JAPAN INTERNATIONAL COOPERATION AGENCY
KIKULETWA No.1 EXISTING HYDROPOWER STATION
(REHABILITATION PROJECT)
GEOLOGICAL LOGS OF KWARE AND KIKULETWA CANAL (1 of 2)
Fig. 4.2.1


GEOLOGICAL LOG OF KWARE CANAL
No.13
No.14
1100
1150
1200
1250
Swamp land
Rock surface is under water
No.15
No.16
1300
1350
1400
No.17
LEAK
No.18
1450
1500
1550
LEAK
No.19
GATE
1600
1650
Downstream
(Head tank)
GEOLOGICAL LOG OF KIKULETWA CANAL
GATE
Upstream
(Kikuletwa diversion weir)
0
50
100
150
200
250
300
350
Downstream
(Head tank)
LEGEND
Block, Mortar
Bank
Pitching (Stone-Wall·Riprap)
Talus deposit
Tuff
Tuffaceous sand
Tuff breccia
Leak point
Electric pole
No.20
Side wall
Base
Side wall
METHOD OF DEVELOPMENT
0
20m
JAPAN INTERNATIONAL COOPERATION AGENCY
KIKULETWA No.1 EXISTING HYDROPOWER STATION
(REHABILITATION PROJECT)
GEOLOGICAL LOGS OF KWARE AND
KIKULETWA CANAL (2 of 2)
Fig. 4.2.1

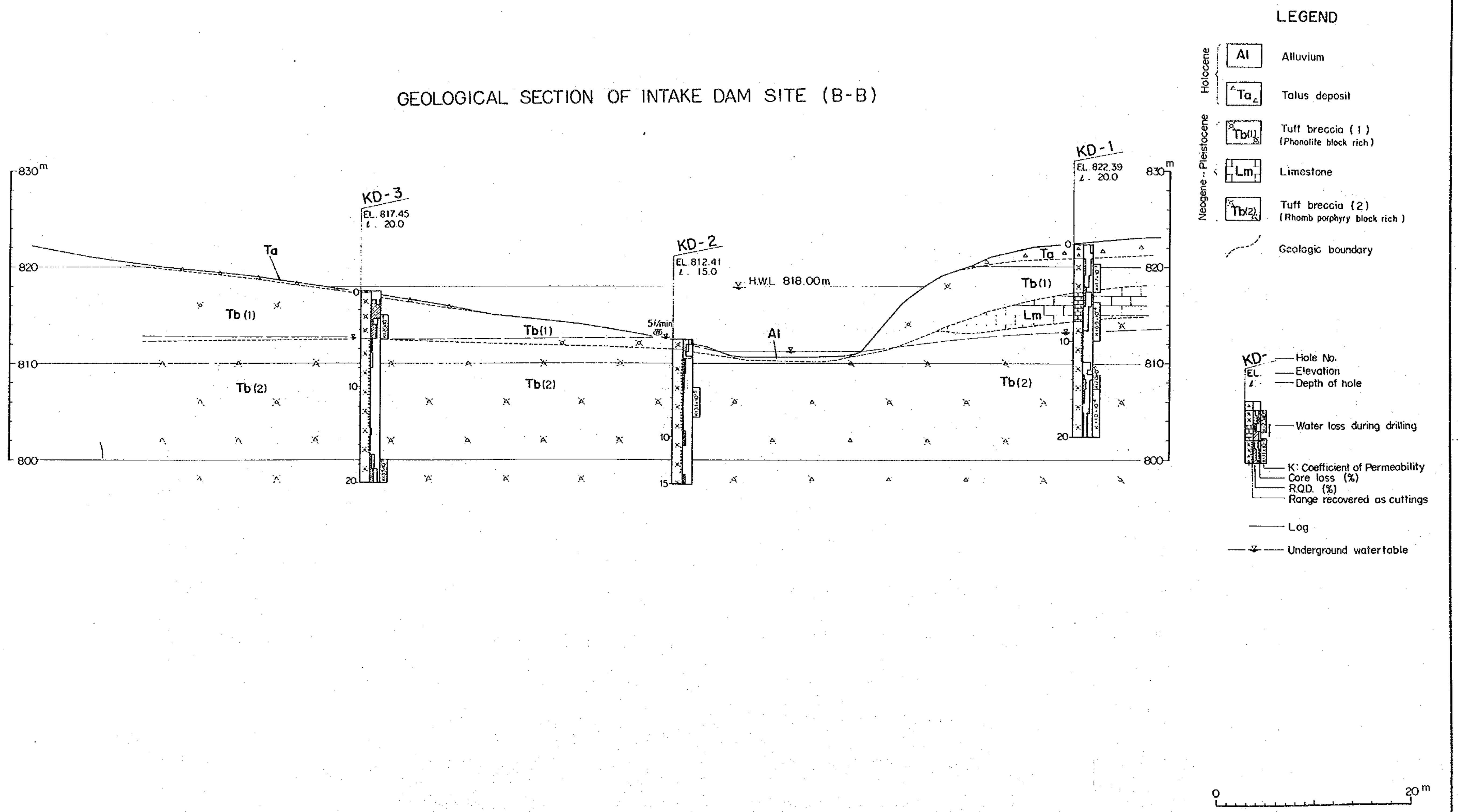
GEOLOGICAL SECTION OF POWER STATION SITE (A-A)





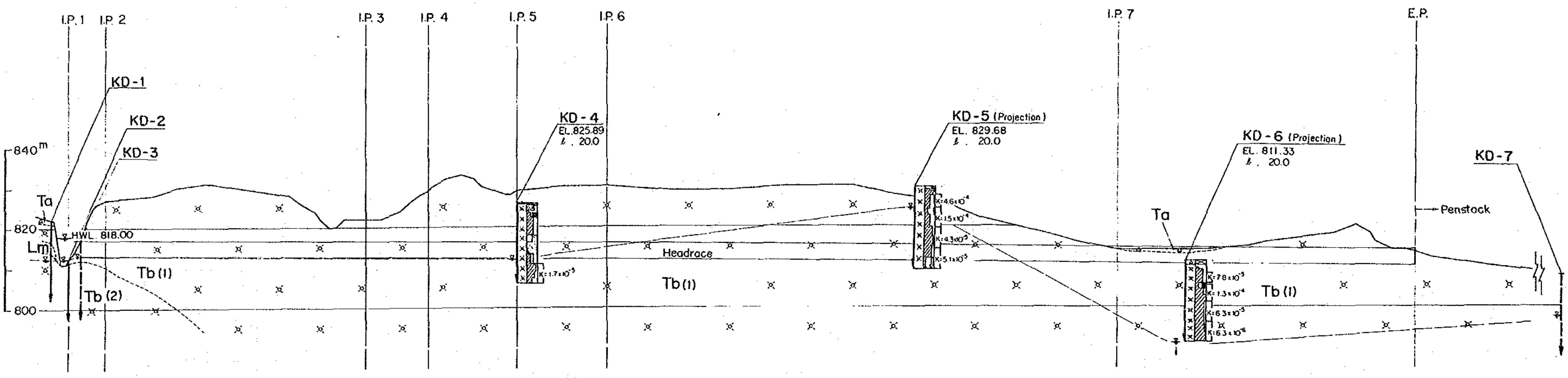
JAPAN INTERNATIONAL COOPERATION AGENCY
KIKULETWA No.1 EXISTING HYDROPOWER STATION (REHABILITATION PROJECT)
GEOLOGICAL SECTION OF POWER STATION SITE (A-A)
Fig. 4.2.2

GEOLOGICAL SECTION OF INTAKE DAM SITE (B-B)



JAPAN INTERNATIONAL COOPERATION AGENCY
KIKULETWA No.2 HYDRO POWER PROJECT
GEOLOGICAL SECTION OF INTAKE DAM SITE (B-B)
Fig. 4.3.1

GEOLOGICAL SECTION OF WATERWAY (C-C)



LEGEND

Holocene
- Ta — Talus deposit

Neogene ~ Pleistocene
- Tb(1) — Tuff breccia (1) (Phonolite block rich)
- Lm — Limestone
- Tb(2) — Tuff breccia (2) (Rhomb porphyry block rich)
- Geologic boundary

- KD- — Hole No.
- EL. — Elevation
- ℓ. — Depth of hole
- K: Coefficient of Permeability
- Core loss (%)
- R.Q.D. (%)
- Range recovered as cuttings
- Log
- Underground water table

Horizontal: 0 — 500 m

Vertical: 0 — 50 m

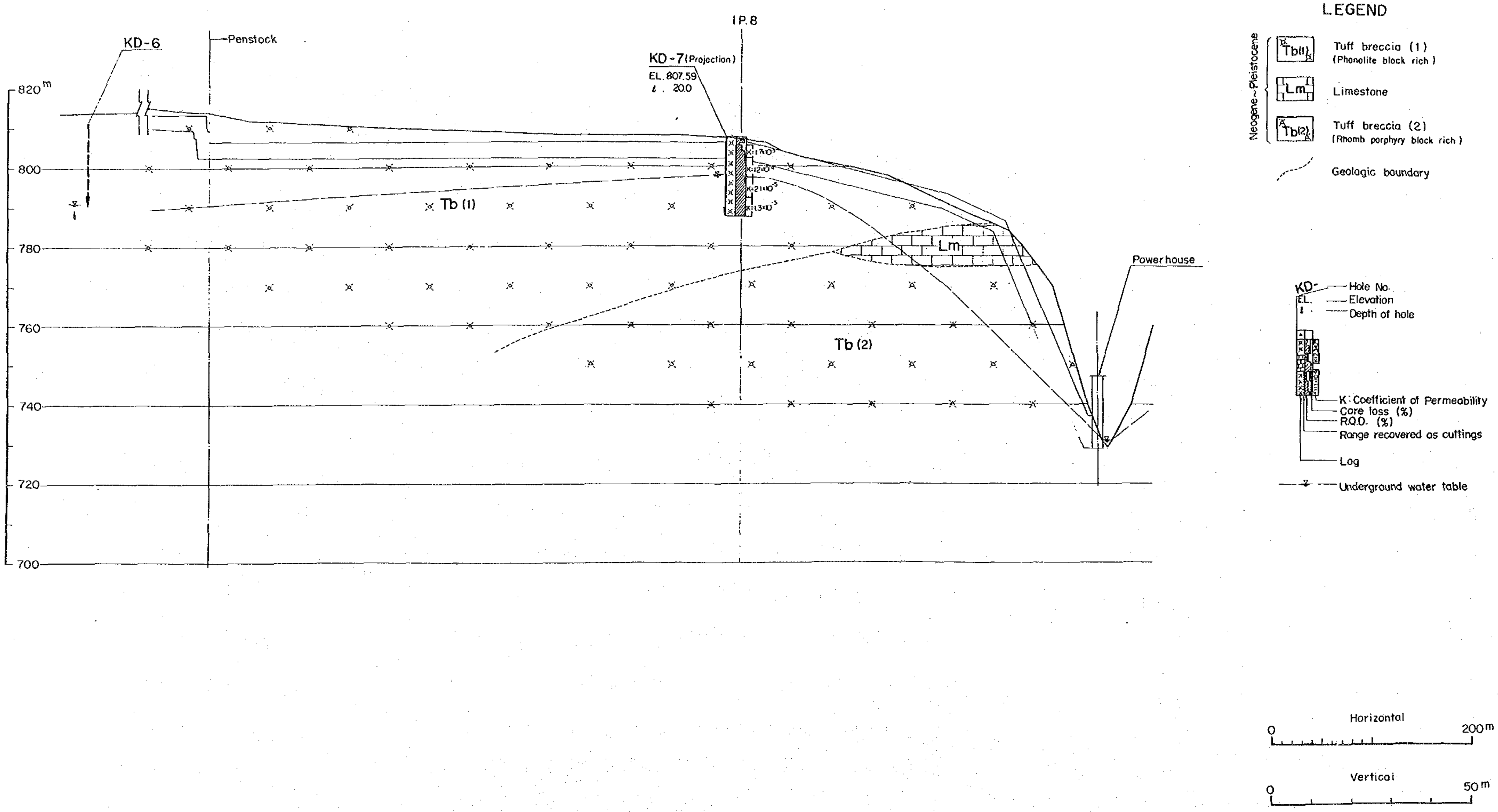
JAPAN INTERNATIONAL COOPERATION AGENCY

KIKULETWA No. 2 HYDRO POWER PROJECT

GEOLOGICAL SECTION OF WATERWAY (C-C)

Fig. 4.3.2.

GEOLOGICAL SECTION OF PENSTOCK AND POWER STATION (D-D)



JAPAN INTERNATIONAL COOPERATION AGENCY

KIKULETWA No.2 HYDRO POWER PROJECT

GEOLOGICAL SECTION OF PENSTOCK AND POWER STATION SITE (D-D)

Fig. 4.3.3.

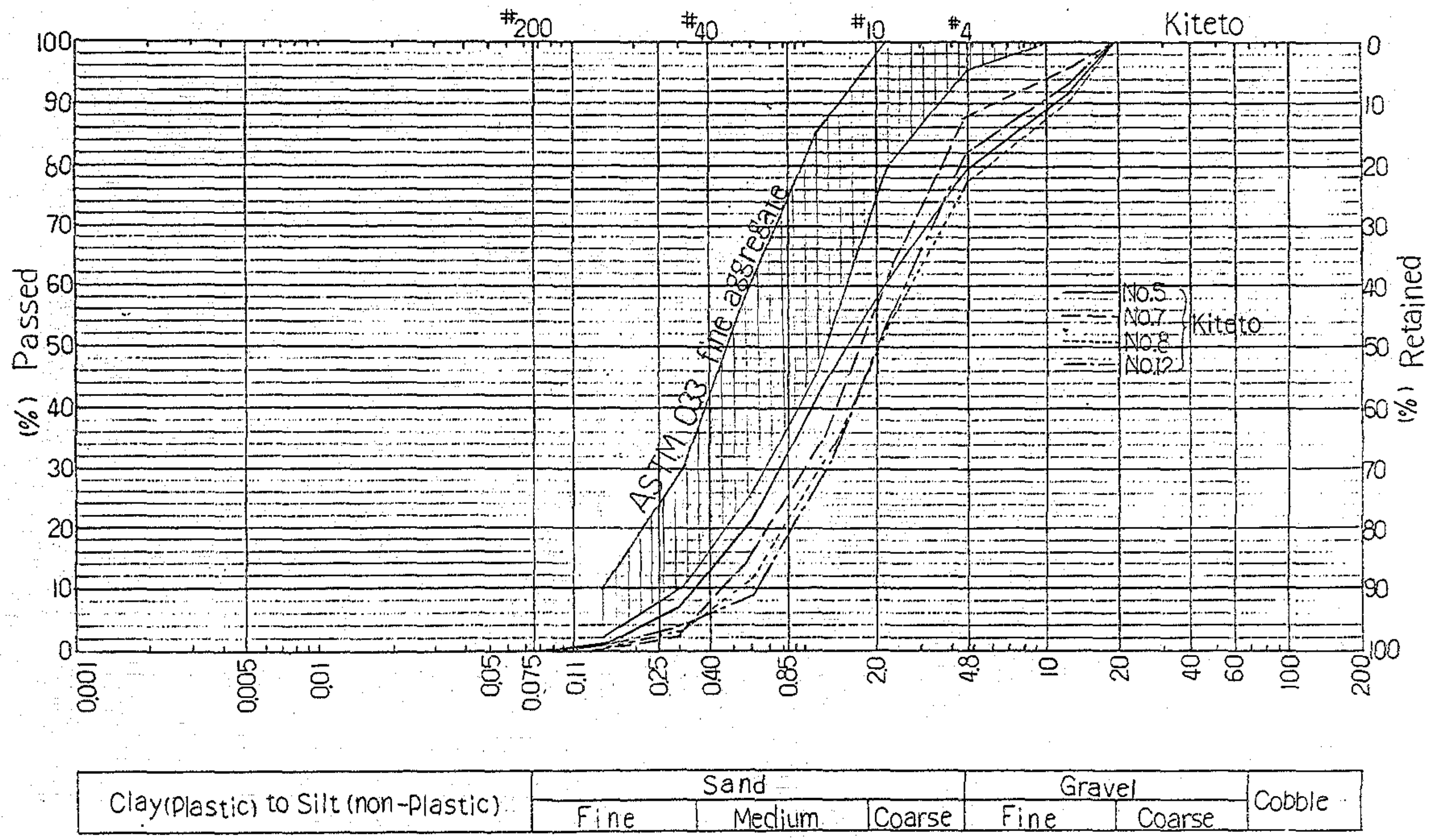


Fig. 4.4.1 DISTRIBUTION CURVE OF AGGREGATE (1 of 6)

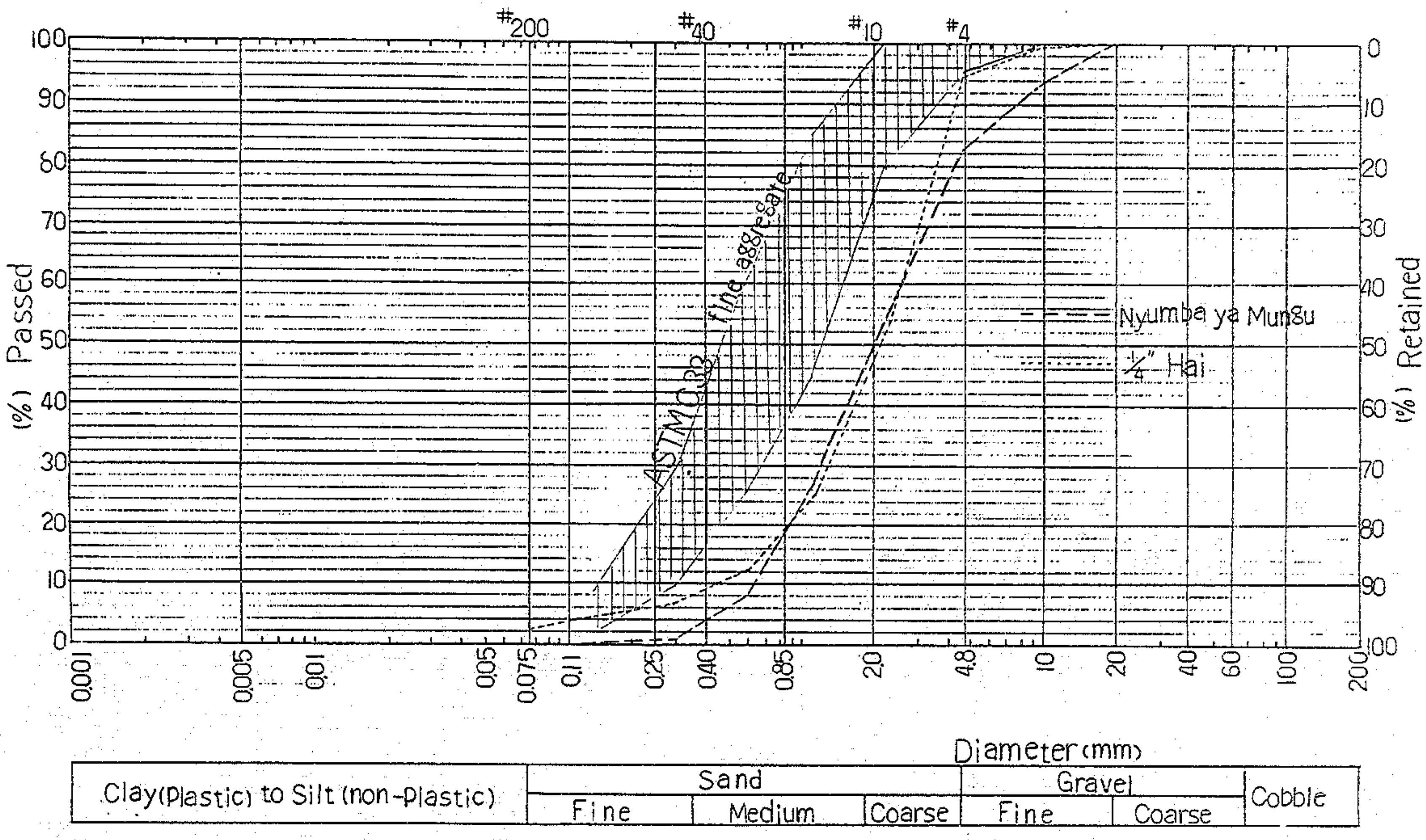


Fig. 4.4.1 DISTRIBUTION CURVE OF AGGREGATE (2 of 6)

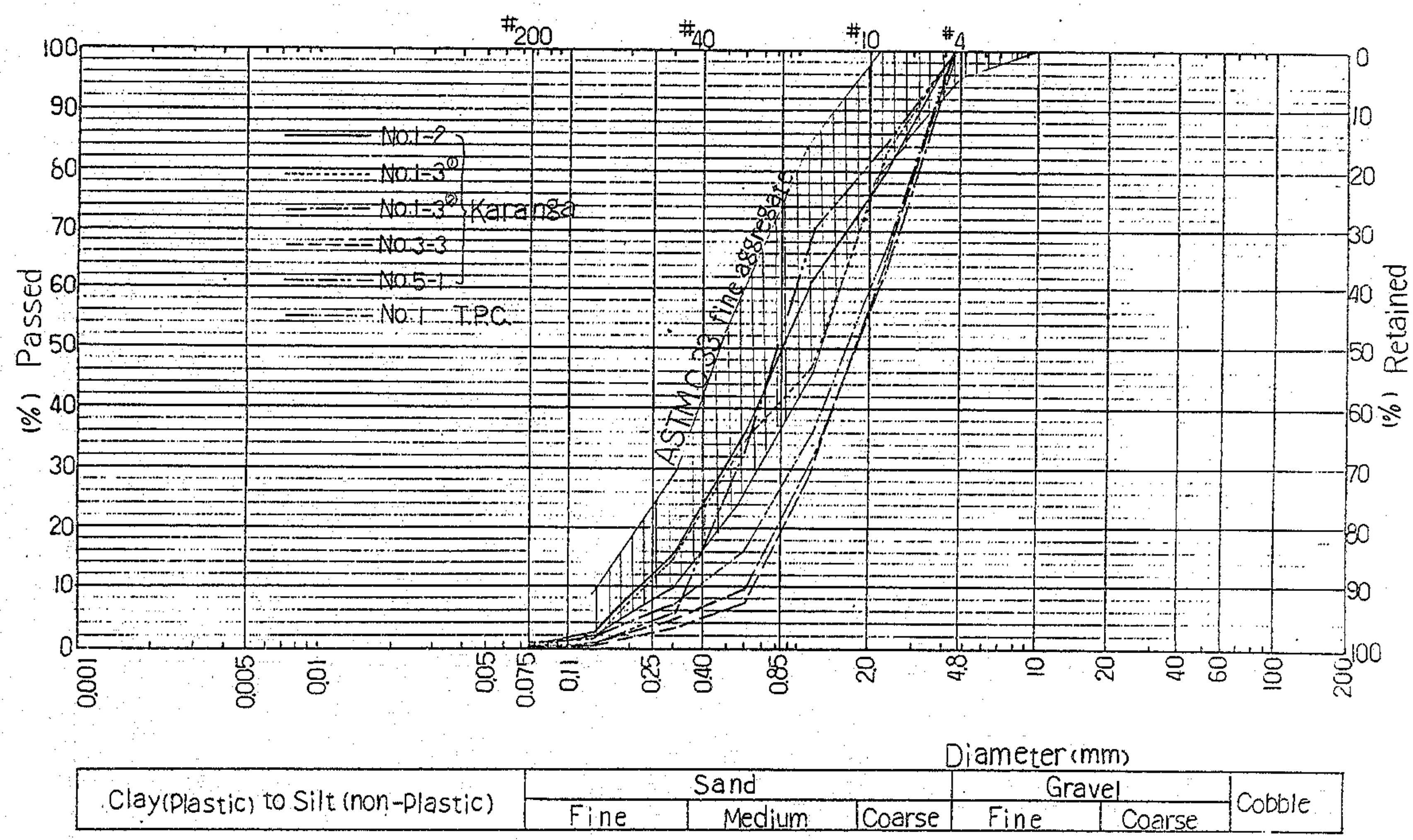


Fig. 4.4.1 DISTRIBUTION CURVE OF AGGREGATE (3 of 6)

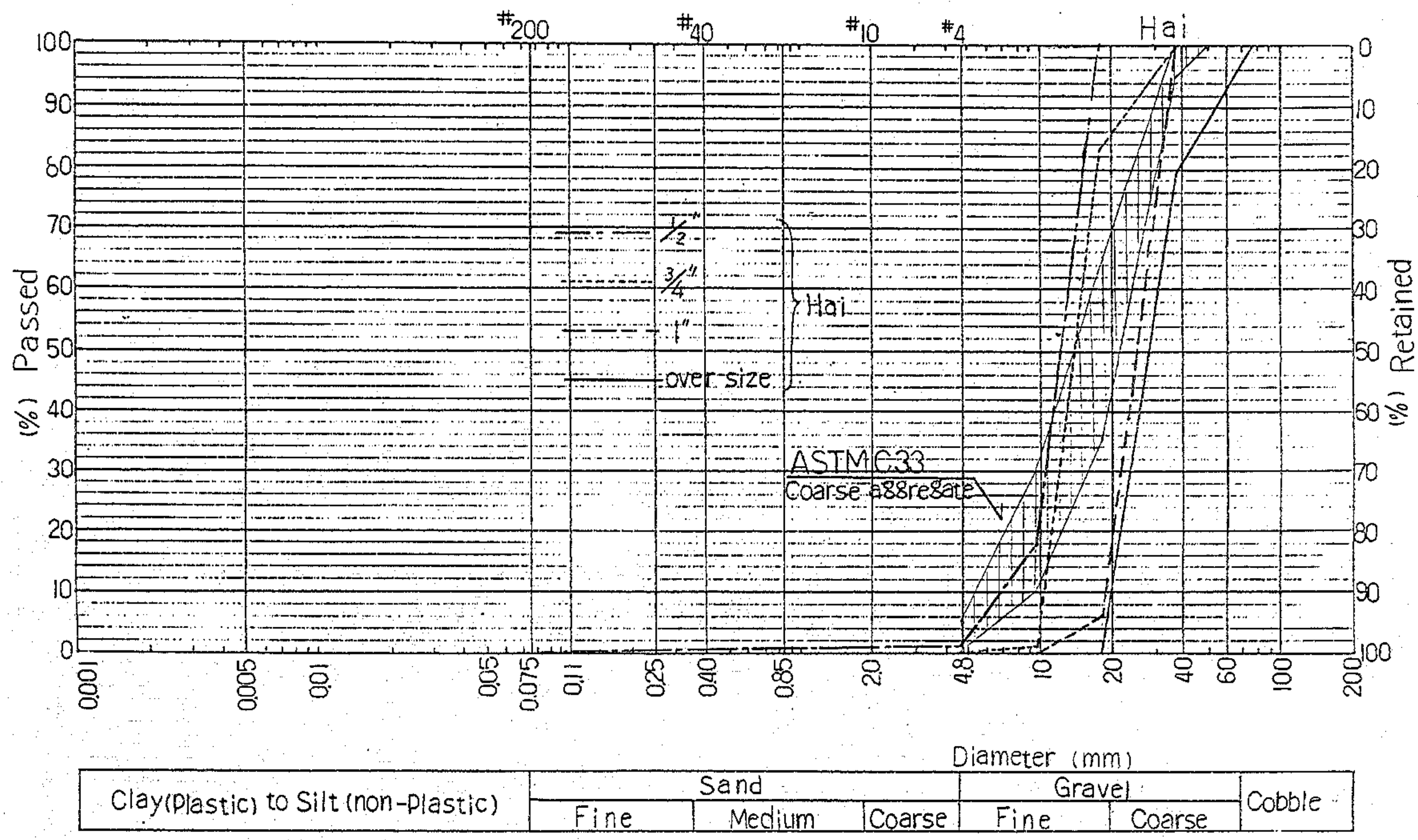


Fig. 4.4.1 DISTRIBUTION CURVE OF AGGREGATE (4 of 6)

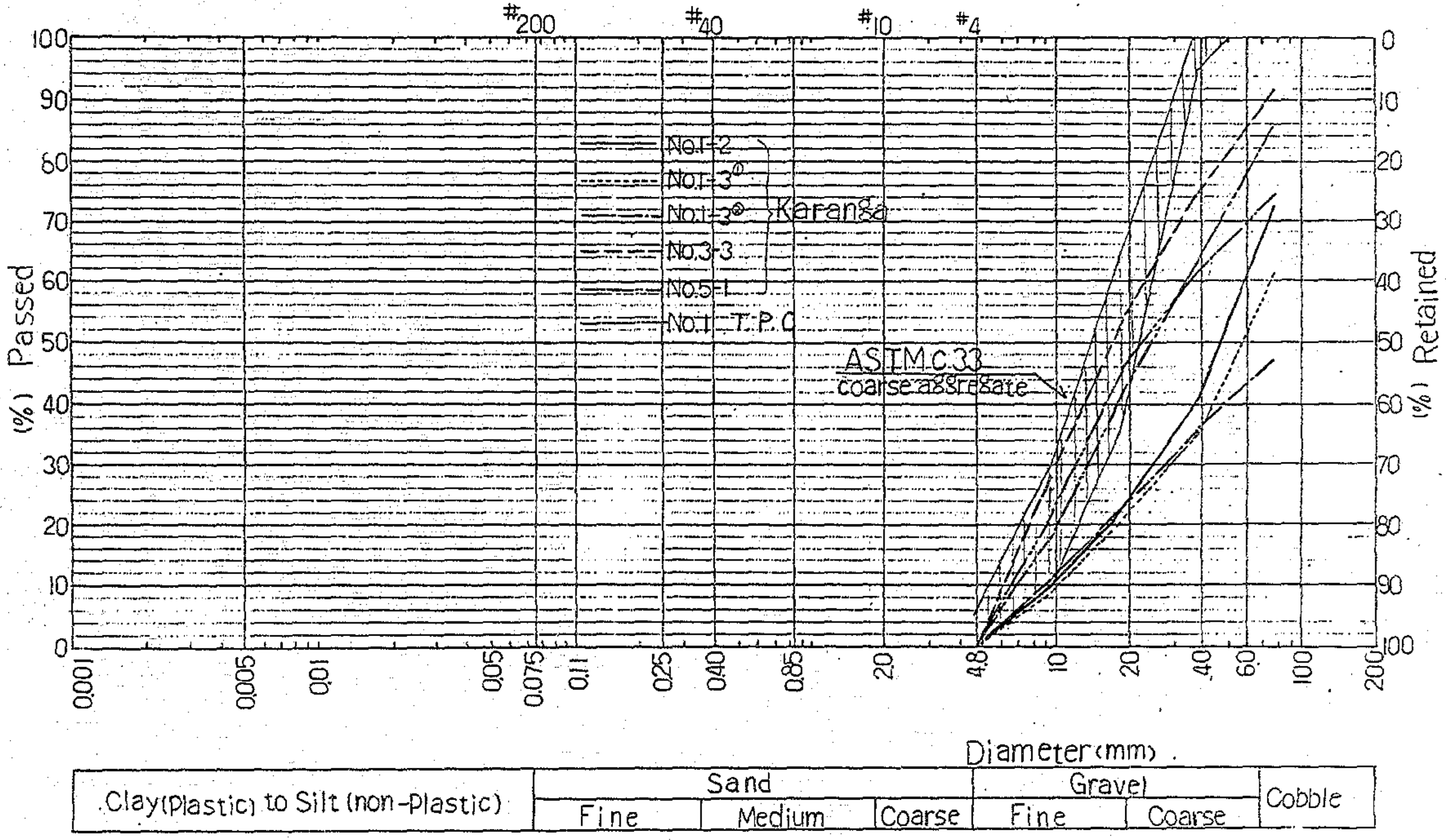


Fig. 4.4.1 DISTRIBUTION CURVE OF AGGREGATE (5 of 6)

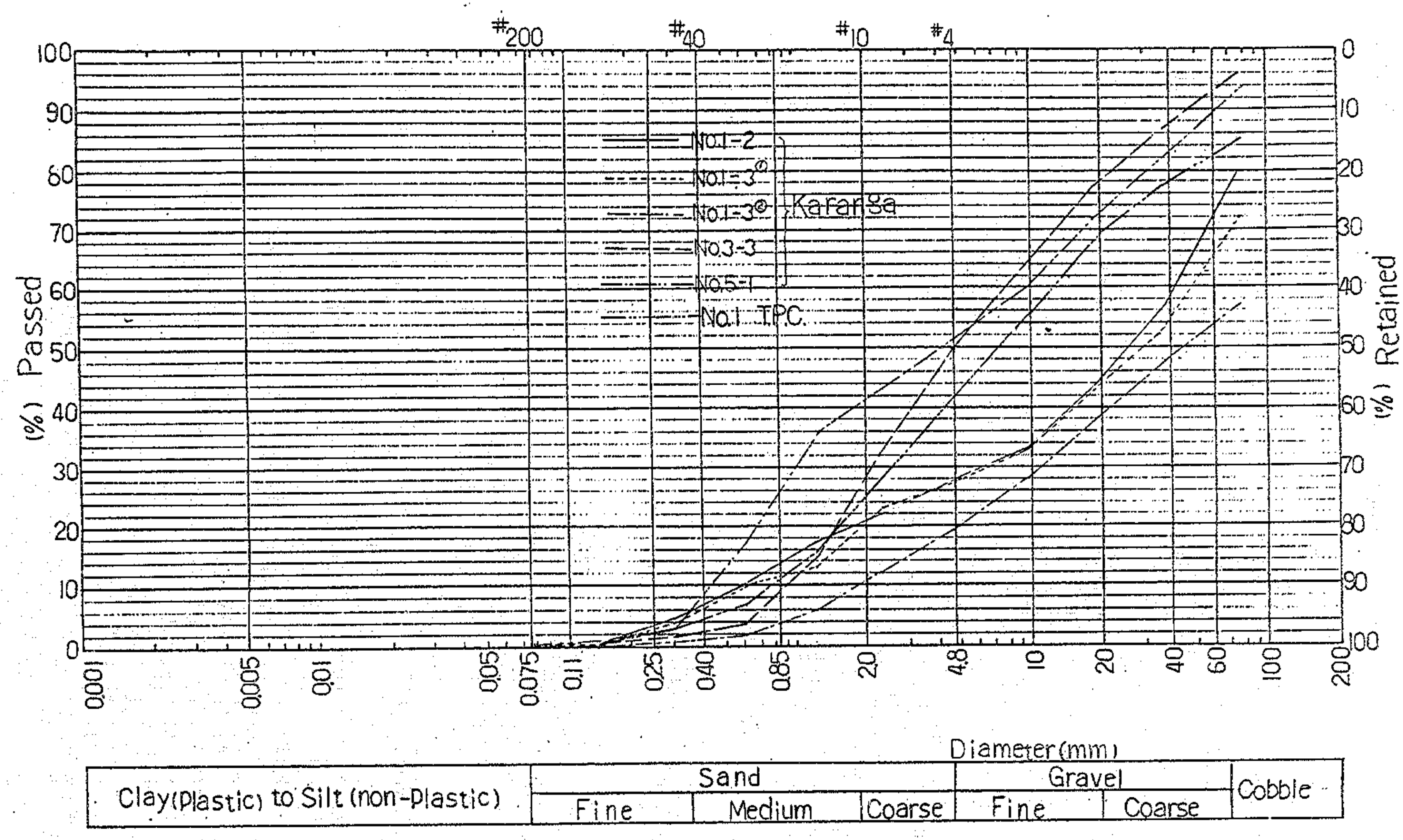
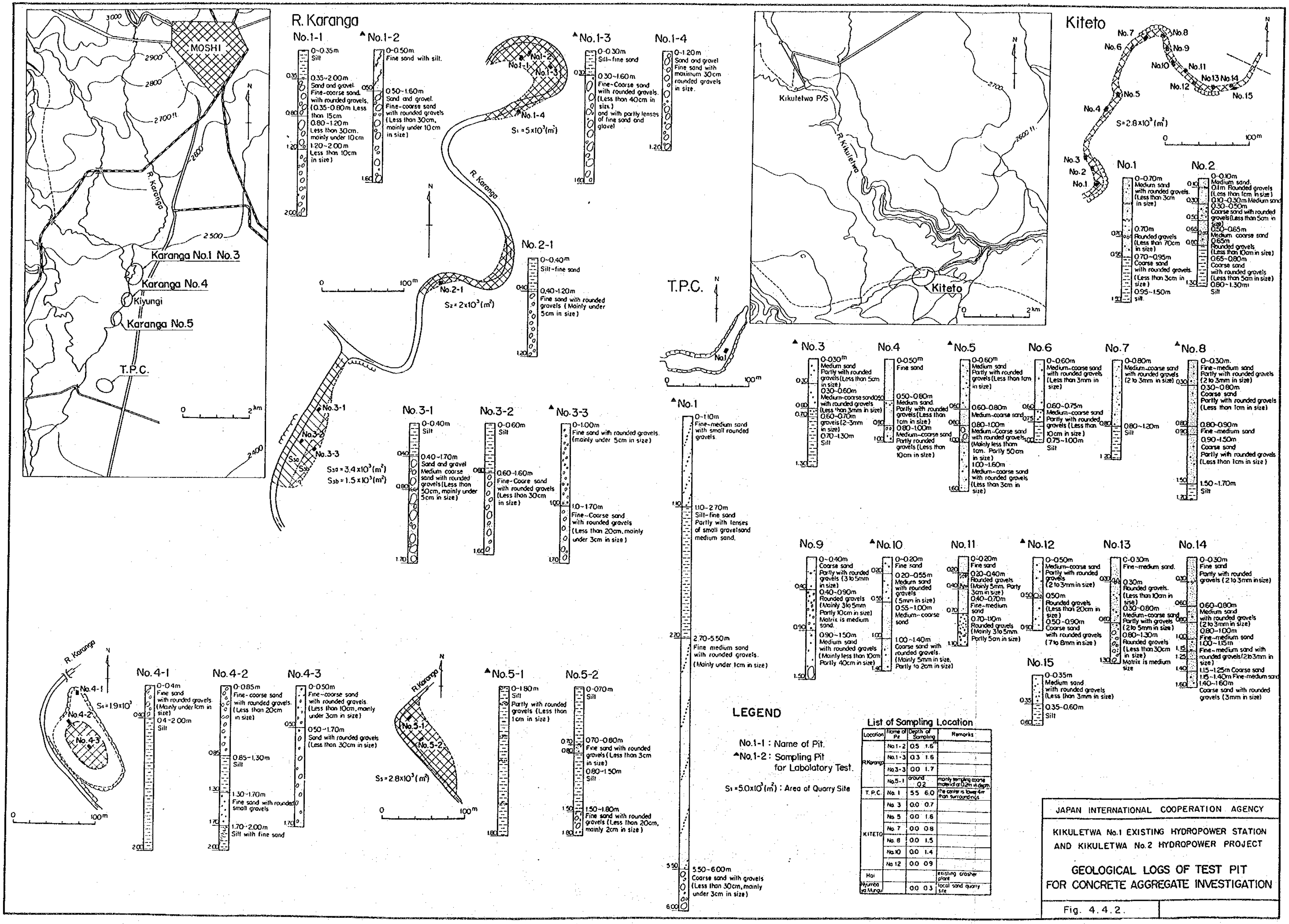


Fig. 4.4.1 DISTRIBUTION CURVE OF AGGREGATE (6 of 6)



List of Sampling Location

Location	Name of Pit	Depth of Sampling	Remarks
R.Karanga	No.1-2	0.5 1.6m	
	No.1-3	0.3 1.6	
	No.3-3	0.0 1.7	
	No.5-1	around 0.2	mainly sampling coarse material at 0.2m in depth
T.P.C.	No. 1	5.5 6.0	the center is lower 4m than surroundings
KITETO	No. 3	0.0 0.7	
	No. 5	0.0 1.6	
	No. 7	0.0 0.8	
	No. 8	0.0 1.5	
	No.10	0.0 1.4	
	No.12	0.0 0.9	
Hai			existing crosher plant
Njumba ya Mungu		0.0 0.3	local sand quarry site

JAPAN INTERNATIONAL COOPERATION AGENCY

KIKULETWA No.1 EXISTING HYDROPOWER STATION AND KIKULETWA No.2 HYDROPOWER PROJECT

GEOLOGICAL LOGS OF TEST PIT FOR CONCRETE AGGREGATE INVESTIGATION

Fig. 4.4.2.

CHAPTER 5
HYDROLOGY AND METEOROLOGY

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Page

5.1 OUTLINE OF HYDROMETEOROLOGY OF PROJECT AREA

Tanzania's Kilimanjaro Region, which borders Kenya and is situated approximately 450 km northwest of Dar es Salaam, enjoys considerably more rainfall than the semi-arid regions which make up most of the country.

At the higher elevations of Mt. Kilimanjaro's slopes, annual precipitation exceeds 1,800 mm. On the higher areas of Mt. Pare, annual precipitation exceeds 1,000 mm. Precipitation decreases at lower elevations, however, and low-lying areas receive less than 500 mm of precipitation each year. Fig. 5.3.2 shows an isohyetal map of the area, prepared based on the average annual precipitation data provided in App. I.

This region generally has a heavy rainy season from March to May, and light rainy season in November and December.

Table 5.1.1 gives the records of temperature, humidity, evaporation, and sunshine hours which were collected at the Moshi (EL. 854 m) and Same (EL. 872 m) observatories in the Kilimanjaro Region, and compiled at the Directorate of Meteorology in Dar es Salaam. The region is characterized by mild or moderate temperatures and very low relative humidities of about 40 to 60 percent. Evaporation is fairly substantial even in the rainy season (with a value of about 300 mm in March).

The Kikuletwa River is formed by the merging of numerous streams and springs, including the Usa River running down the south slope of Mt. Meru, and the Sanya River and Kware River running down the south slope of Mt. Kilimanjaro. The Kikuletwa River flows east at the south slope of Mt. Kilimanjaro, and merges with the Ruvu River flowing at the foot-hills of Kilimanjaro's southeastern slope. Immediately after merging, the rivers flow into the Nyumba ya Mungu Reservoir. Downstream of the Nyumba ya Mungu Reservoir, the river is known as the Pangani. The Pangani River flows through the foothills at the south side of Mt. Pare, reaching the Tanga Region and finally emptying into the Indian Ocean.

The potential sites in the Same District proposed for small hydro are located on the Hingilili River, the Yongoma River, and the Sesseni River, all of which flow down the steep eastern slope of Mt. South Pare. These rivers, together with streams running down the steep east watershed of the mountain, merge with the Kambaga and Mkomazi rivers. These rivers flow through the Mkomazi Valley, then spread out to the east of Mt. South Pare.

The basins of the Kikuletwa and Ruvu rivers are composed of highly permeable volcanic products from Mt. Meru and Mt. Kilimanjaro. While some of the rainfall becomes direct surface runoff into rivers and streams, the remainder is absorbed in the permeable strata, and either evaporates or becomes groundwater. Part of the groundwater emerges in springs, such as those of Rundugai and Chemka; the balance is stored in deeper aquifers. The deep underground waters are used for irrigation at low-lying areas such as the Kahe Basin.

For the Sesseni River and the Kikuletwa River, the macroscopic runoff coefficients are estimated as follows, based on the annual runoff in 1970 and the estimated annual average basin precipitation.

	Kikuletwa (1DD-54)	Kikuletwa (1DD-1)	Sesseni (1DB-24)
Catchment area (sq. km)	2,220	3,880	170
Average runoff (cu.m/sec)	13.02	23.75	2.13
Annual runoff (mm/yr)	185	193	395
Basin av. rainfall (mm/yr)	800	800	800
Av. runoff coefficient (%)	23	24	50

5.2 METEOROLOGICAL AND RUNOFF DATA

5.2.1 Meteorological Data

A ledger of meteorological data observations (precipitation, temperature, humidity, evaporation, sunshine hours, etc.) for all of Tanzania is filed at the Directorate of Meteorology in Dar es Salaam.

Precipitation data collected at 25 meteorological observatories in and near the project area (see Table 5.2.1) were obtained by the JICA Team. App. I shows the data of the individual stations.

5.2.2 Runoff Data

Runoff observations for the Kilimanjaro Region's major rivers and streams have been carried out for many years under the administration of a water resources office at Moshi. As a rule, the data are supposed to be published every 5 years by the Project Preparation Division of the Ministry of Water. The latest Hydrological Year Book, however, was published in December of 1970.

Although observations of river water levels at 8 a.m. and 4 p.m. have been continued since 1971, Hydrological Year Books giving runoff conversions have not been formally published. A list of the runoff data collected by the JICA Team is given in Table 5.2.2.

Between 1959 and 1963, the Ministry of Water closed many runoff gauging stations, and temporarily suspended observations at others. At present, the Ministry is reorganizing the observation network through the entire country.

For the study of available discharges for power generation and of design floods for a small hydroelectric development project, hydrological data from the Hydrological Year Books, together with additional supplementary data, were used.

5.3 ANALYSIS OF HYDROMETEOROLOGICAL DATA

5.3.1 Study of Precipitation Data

The monthly average rainfalls at the various observation stations, based on collected precipitation data, are shown in Fig. 5.3.1. In both the Kilimanjaro and Same areas, a heavy rainy season has been observed in March, April, and May, and a light rainy season in November and December.

Moshi and Same observatory records for maximum rainfall for a day, and for maximum hourly rainfall intensity for that day, are shown in Table 5.3.1. At the Moshi observatory, a maximum daily rainfall of 166.4 mm was recorded on April 9, 1986; the day's maximum hourly rainfall intensity was 82 mm.

An isohyetal map of the Kilimanjaro and Same areas, based on the annual average precipitations at the observation stations listed in App. I, is shown in Fig. 5.3.2. Annual precipitation exceeding 1,800 mm can be seen in the highland area of Mt. Kilimanjaro, while precipitation in the low-lying areas is below 500 mm.

The Kikuletwa River, sourced from Mt. Kilimanjaro and Mt. Meru, has a catchment area of 2,220 sq. km at gauging station No. 1DD-54, and the basin and river course stretch widely from an abundant to a sparse rainfall area.

According to the isohyetal map for the Kilimanjaro Region, the average basin rainfall at the gauging station (No. 1DD-54) immediately downstream of the existing TANESCO power station is estimated to be approximately 800 mm/yr.

5.3.2 Hydrological Cycle

Yearly variations in annual precipitation at Arusha (No. 933-633) and Kikuletwa (No. 933-769), where data collection is comparatively sufficient, are shown in Fig. 5.3.3. The graph shows that precipitation was extreme in the years 1963, 1968, and 1978 - a cycle, at both sites, first of 5 years and then of 10 years. Yearly variations in river runoffs are shown in Fig. 5.3.4. For the Kikuletwa River flowing from Mt. Meru and Mr. Kilimanjaro, the high water years were 1968 and 1974 - a cycle of 6 years. For the Sesseni River flowing from Mr. South Pare, the high water years were 1970 and 1978, showing an 8-year cycle.

It is said that a large flood occurs in the Kilimanjaro Region about once every 10 years. According to the above records, the cycle for medium-scale floods is approximately 5 years, while large-scale floods have a return period of close to 10 years.

5.4 RUNOFF CHARACTERISTICS AT POTENTIAL SITES

5.4.1 Runoff Characteristics at the Gauging Stations

As mentioned in 5.2, the daily average discharge data of the various runoff gauging stations are contained in App. II. The characteristics of discharge durations at individual gauging stations are described below.

(1) Kikuletwa River Gauging Station (No. 1DD-54)

This gauging station is located approximately 300 m downstream from TANESCO's existing Kikuletwa Hydropower Station.

In addition to the river runoffs from the watersheds of Mt. Meru and Mt. Kilimanjaro, the spring water from Chemka, Rundugai, etc. is also included in these measurements.

The water for power generation at the existing TANESCO power station is diverted from the Kikuletwa and Kware rivers, and the power discharge is released into the Kikuletwa River upstream of the point where the two rivers merge. The No. 1DD-54 gauging station therefore covers the entire runoff of the Kikuletwa and Kware rivers, including the power discharge. The annual average runoff at Gauging Station No. 1DD-54 for the 9-year period from 1967 to 1976 was 13.02 cu.m/sec.

(2) Himo River Gauging Station (No. 1DC-11A)

The runoff gauging station (No. 1DC-11A) for the Himo River is located at the Moshi-Tanga highway bridge; the catchment area is 264 sq.km. The average runoff at this point for the 8-year period from 1969 to 1976 was 2.06 cu.m/sec. The existing intake facility to be used for the Himo River Rehabilitation Project is located approximately 6 km upstream of Moshi-Taveta road bridge, and has a catchment area of 174 sq.km.

The catchment area at the proposed Himo No. 2 site, which is located approximately 2.5 km upstream from the Moshi-Taveta road bridge, is estimated to be 183 sq. km.

(3) Sesseni River Gauging Station (No. 1DB-2A)

The catchment area of this gauging station is estimated, on the basis of 1/50,000 and 1/250,000 topographic maps, to be 192 sq. km.

The average runoff for the 20-year period from 1963 to 1982 was 2.13 cu.m/sec.

The catchment areas for the planned intake sites of Ihindi (upstream power generation plan) and Gulutu (downstream power generation plan), on the Sesseni River, are estimated to be 181.3 sq.km and 190.0 sq.km, respectively.

(4) Hingilili River Gauging Station (No. 1DB-18)

The catchment area of the Hingilili River at No. 1DB-18 (Kiruka Hamlet) is given as 38 sq.km in the Hydrological Year Book (1965-70). Based on a recently completed 1/20,000 topographic map*, the catchment area at the point of transition from mountainland to plain area is estimated to be 55.8 sq. km.

It is therefore estimated that the catchment area at the intake site for the Hingilili hydropower development scheme will be 53.5 sq. km. The average runoff for the 13-year period from 1963 to 1975 was 0.63 cu.m/sec.

*The development survey study for expanded afforestation work in the Same District.

(5) Yongoma River Gauging Station (No. 1DB-3)

The gauging station (No. 1DB-3) which had been installed on the Yongoma River approximately 1 km upstream from the Gonja-Kihurio road was closed in May 1963. An automatic recording water gauge was installed in 1982, but the runoff data have not yet been published.

In regard to the hydropower development scheme for the Yongoma River, the vegetation, topography, and precipitation conditions suggest that the duration curve will be similar to that for the Sesseni River.

For the Mkomazi Irrigation Project, the catchment area of the Yongoma River at the point where the river enters the plain area is estimated at 70.5 sq.km. For the hydropower development project, the catchment area at the intake site is estimated to be 57.0 sq.km.

(6) Average Monthly Runoffs and Specific Runoffs

Table 5.4.1 shows the average monthly runoffs and specific runoffs per 100 sq.km for the five streams proposed for small hydropower development projects.

At the south slope of Mt. Kilimanjaro, the specific runoffs of the Himo River exceed those of the Kikuletwa River in April, May, June, and July, indicating that the Himo River also has larger specific runoffs in relation to average annual runoffs.

For the Hingilili and Sesseni rivers, which flow east down Mt. South Pare, the specific runoff of the former is greater than that of the latter throughout the entire year.

A hydrograph showing the monthly average runoffs at the No. 1DD-54 gauging station on the Kikuletwa River and at the No. 1DB-2A station on the Sesseni River is shown in Fig. 5.4.1. These data are important for studying small hydropower development projects in the Kilimanjaro Region.

(7) Runoff Duration Curves and Discharge Characteristics

Runoff duration curves for the Kikuletwa River, the Himo River, and the Sesseni River are shown in App. II. The duration curves of the years indicating average discharge conditions are shown in Fig. 5.4.3.

River	Year of Average Runoff Condition
Kikuletwa	1970
Himo	1970
Sesseni	1964

The runoff characteristics obtained from the duration curves of the respective rivers may be tabulated as follows:

(Unit: cu.m/sec)

River	Maximum discharge	95-day discharge	185-day discharge	275-day discharge	355-day discharge	Minimum discharge
Kikuletwa	32.28	13.22	11.89	10.95	9.43	7.16
(2,220 sq.km)	(1.45)	(0.60)	(0.54)	(0.49)	(0.42)	(0.32)
Himo	33.35	2.57	0.85	0.34	0.19	0.06
(264 sq.km)	(12.63)	(0.97)	(0.32)	(0.13)	(0.07)	(0.02)
Sesseni	175.24	2.15	1.14	0.34	0.25	0.21
(192 sq.km)	(91.27)	(1.12)	(0.59)	(0.18)	(0.13)	(0.11)

Note: Figures in parentheses are specific runoffs per 100 sq.km.

Of the nine (9) hydropower potential sites, Kikuletwa No. 1 and No. 2 Power Stations were given the highest development priority. The runoff characteristics at the gauging station (No. 1DD-54) of the Kikuletwa River, the site for these power stations, are as follows:

- Base-flow discharge is large.
- The ratio between 95-day discharge and 355-day discharge is small.
- The discharge per 100 sq.km is the smallest among the five rivers.
- The range of fluctuation in discharge through the year is small.
- Discharge conditions are, therefore, very advantageous for hydroelectric power generation.

With regard to river discharges of the Mt. South Pare basin, the runoff data (1983-1987) of the Yongoma River (shown in Table 5.4.1), and the results of a study on the Mkomazi Irrigation Project indicate that the Yongoma River's specific runoff per 100 sq.km has an annual average value of 1.67 cu.m/sec, which is fairly large when compared with the 1.11 cu.m/sec of the Sesseni River. The base-flow discharge of the Hingilili River is also larger than that of the Sesseni River, as previously mentioned.

In view of these facts, the base-flow discharges in the runoff curves of the Yongoma and Hingilili rivers are considered to be larger than the base-flow discharge of the Sesseni River.

In the hydropower study carried out in the Identification Stage, the ratio of the 355-day discharge to the minimum monthly average discharge in the Sesseni River was considered applicable in order to yield a conservative estimate of the 355-day discharges of the Yongoma and Hingilili rivers.

	Minimum Monthly Discharge in October (cu.m/sec)	355-day Discharge (cu.m/sec)
Sesseni River C.A. 192 sq.km	0.43	0.25
Yongoma River Gauging St. (C.A. 70 sq.km)	0.47	0.27
Intake Site (C.A. 57 sq.km)	0.38	0.22
Hingilili River Gauging St. (C.A. 38.0 sq.km)	0.28	0.16
Intake Site (C.A. 53.5 sq.km)	0.32	0.19

5.4.2 Runoffs of Kikuletwa No. 1 and No. 2 Intake Sites

At present, the water for generating power at the existing TANESCO power station is transported from intake facilities on the Kikuletwa River mainstream and the tributary Kware River, by means of open canals of lengths 370 m (cross-sectional area: approx. 10 sq.m) and 1,670 m (cross-sectional area: approx. 6 sq.m). The discharge is released into the Kikuletwa River mainstream.

The No. 1DD-54 runoff gauging station is located downstream of the confluence of the Kware River and the mainstream, so that the runoff records of this gauging station cover all of the discharge of the two rivers. In other words, these runoff records indicate the available discharge for Kikuletwa No. 1 and No. 2 hydropower projects.

The catchment area of the Kware River is approximately 200 sq.km, which is only 10 percent of the total catchment area of Gauging Station No. 1DD-54. Although a quantitative judgment cannot be made because runoff data for the Kware River are not available, it is thought that the springs located along the Kware River basin contribute greatly to the dry-season discharge of this tributary. The discharges of the open canal diverted from the Kware River were 3 to 4 cu.m/sec. in September-October 1987 and in February-March 1988, or roughly the same as for the canal from the Kikuletwa River. Consequently, a comparatively large discharge from the catchment area can be expected even in the dry season.

The runoff duration curve at the Kikuletwa River gauging station (No. 1DD-54) is shown in Fig. 5.4.3(2) of the preceding section. The average 355-day discharge from 1967 to 1975 was approximately 10 cu.m/sec. Such a discharge, supported by a large base flow, can provide very favorable conditions for hydroelectric power generation.

5.5 DESIGN FLOOD DISCHARGE

5.5.1 Records of Maximum Flood

As mentioned in the preceding section, the precipitation and runoff data show that the heavy flood season in the Kilimanjaro Region is in the months of March, April, and May.

The largest flood remembered by personnel at the present TANESCO power station occurred in May 1978. On the basis of high water marks and river cross section, the flood water level is estimated to have been EL. 820.80 m, and the flood discharge approximately 200 cu.m/sec.

5.5.2 Daily Maximum Discharge and Probable Flood Discharge

The daily maximum discharges per year, as taken from the runoff records (provided in App. II) of gauging station No. 1DD-54 on the Kikuletwa River, are shown in Table 5.5.1.

The flood discharge figures for 1978 to 1987, given in parentheses, are JICA Team estimates based on the river profile and the rating curve shown in Fig. 5.5.1. The data are based on the water levels observed by the Moshi Water Resources Office.

The probable flood discharges, as estimated by the logarithmic normal distribution probability method, are shown in Fig. 5.5.2, based on the daily maximum discharge record for the 16-year period. The probable Kikuletwa River flood discharges for return periods of 20, 50, 100, and 200 years are as follows:

Return Period (Yr)	Probable Flood Discharge (cu.m/sec)
20	140
50	180
100	210
200	250

The May 1978 flood discharge at the present TANESCO power station, mentioned in the preceding section, is estimated to have been from a flood with a magnitude corresponding to a 100-year return period.

5.6 CHARACTERISTICS OF RIVER WATER

5.6.1 River Water Quality

Water samples were collected from the Kikuletwa, Himo, Yongoma, Hingilili, and Sesseni rivers. Analysis carried out at the Soil & Water Laboratory in Maji Ubungo showed that water in the rivers flowing down Mt. Kilimanjaro is alkaline, with pH values slightly higher than 7.