CHAPTER VIII

GEOLOGY

8.1 OUTLINE OF PROJECT AREA

A. Topography

The project site is located about 10 km northwest of the city of Popoyan. The storage reservoir is to be constructed on the Rio Sate, which is a tributary of the Río Cauca. The project is located on the foot of Cordillera Central in the basin between Cordillera Central and Occidental.

General topography around the project site is of volcanic origin, represented by the undulated wide plateau which was formed by volcanic product composed of lava flow, volcanic ash and agglomerate.

The Rio Cauca has deeply eroded this volcanic plateau and flow through a gorge about 100 m high. On the other hand, streams draining into the Rio Cauca frequently forms waterfalls at the confluence because of the different degree of erosion between the Río Cauca and the streams.

The proposed three dam sites are located at the middle stream of the Rio Sate around Julumito Village.

No. 2 dam site which is the best is located in the middle of the three proposed sites. The elevation of river bed is about 1645 m and the width of the river is about 7 m.

The topography above the tunnel route between the left bank of the Río Sate and the right bank of the Río Cauca is an undulated plateau. The deepest cover above the tunnel is about 80 m if the elevation of the tunnel is 1680 m.

All of the possible powerhouse sites are on the right bank of the Río Cauca, and at each site the natural ground profile along the penstock is a very steep wall. The elevation of the Rio Cauca water surface varies from 1615 to 1580 at the different powerhouse sites. The elevation at the top of the valley wall is about 1715.

B. General geology

The geology of the project site consists of volcanic products as described in the foregoing paragraph. As a whole, a wide and thick lava flow which is considered as basalt is distributed below and about elevation 1700 m and this lava flow forms the lava plateau. Volcanic ash or agglomerate accumulates on this lava plateau.

The detail system of volcanic activity at this area is not clear, but the period of ejection is considered as Quaternary. The thickness of lava flow is not confirmed clearly, but judging from the banks of the Rio Cauca at the project site, it must be thicker than 100 m. The lava flow is of grayish color, somewhat coarse grain and porous at the surface, but dense and hard at the lower part. Horizontal and vertical joints are comparatively remarkable.

Volcanic products accumulated on the lava mainly consist of uncemented volcanic ash that covers the whole of the project area. This ash is weathered and changed to clayey soil. The color of this ash is orange to orange-brown at the weathered part and is pinky at the fresh part. The maximum depth of ash in the project site is presumed to be about 60 m.

An outline of talus and terrace deposits at the project site is as follows:

Talus deposit

The distribution is mainly found at the foot on the banks of the Rio Cauca. The talus contains blocks of rock which have fallen from the wall of lava flow. The elevation of the top of this deposit is about 1650 m.

Terrace deposit

The distribution is mainly found around the sites of the diversion dam and canal. Besides these sites, the newest terrace can be found at the banks of the Rio Cauca. The elevation of the former site is roughly from 1725 m to 1700 m and the latter is one or two meters higher than the elevation of the river.

8.2 DAM SITE

A. General

As described in paragraph 8-1, the geology distributed at the project site consist of mainly lava flow and tuffaceous clay. This geologic condition is almost the same at the dam site.

From the civil engineering point of view, No. 2 dam site is superior than the other two sites, and also geologically, No. 2 dam site is better than the others as judged from surface investigation. Consequently, investigations by trench and permeability test were executed at the No. 2 dam site.

B. No. 2 dam site

The slopes of the banks for elevations lower than 1690 m are parallel and stable, but the zone above elevation 1710 m is forming a comparatively narrow ridge at the banks, and for instance, the width of the ridge at right bank is about 14 m at the elevation about 1718 m.

The slopes of the valley walls is about 35°, the elevation of river bed is about 1645 m, the width of river about 7 m and the ratio of height of dam at the crest (1717 m) to width of valley is about 1 : 4.

The geology consist of lava flow and tuffaceous clay covering the lava.

From observation of outcrop, lava flow is distributed at the banks lower than elevation about 1700 m and it is presumed that top of lava is comparativly flat.

At the downstream of the proposed dam axis, the banks are covered with overburden having a presumed thickness of 2 m to 5 m. Although base rock should be confirmed by means of drill holes and adits, it is presumed that lava flow must be distributed below elevation 1700 m approximately.

At the upstream of the dam axis, the thickness of overburden at the banks is comparatively thin.

Lava is remarkably weathered at the outcrops, specially at the right bank. The color of rock has changed to brownish-gray. The rock is hard but does not give a high sound by hammer blow. Weathered rock is well consolidated and it has sufficient bearing power as foundation rock for an embankment dam. There are some joints in the direction of NS 90°, EW 90° and horizontal with irregular cracks at outcrops.

Tuffaceous clay covering the lava is orange-brown, fine grained and uncemented, but is compacted. The permeability of this soil is about $K = 10^{-4}$ cm/sec according to field tests.

A detailed engineering geologic interpretation of this dam site should be prepared according to the results of investigations by drilling and adit, but the following judgements can be made by the present preliminary investigation:

(1) The surface of the lava is weathered and is somewhat soft, but the foundation rock below 2 to 3 m from the surface of the lava flow will be adequate for the foundation of a fill type dam.

(2) As joints and cracks are developing in the lava flow, consolidation grouting and curtain grouting are necessary at the impervious core zone. The grouting should be designed by the results of future investigations, but it is considered that only conventional methods of grouting will be required.

(3) The overburden at the dam site should be excavated and its depth should be confirmed by future investigation.

(4) The permeability of tuffaceous clay is about $K = 10^{-4}$ cm/sec.

C. No. 1 dam site

The ratio of height of dam to width of valley at elevation 1717 m is 1 : 4. The left abutment is stable, but the ridge along the right abutment is comparatively narrow. Therefore it is necessary to confirm the elevation and the width of this ridge.

The banks at the dam site are covered with overburden and tuffaceous clay as described already and outcrops of rock could not be found.

The bottom of the valley, about 100 m upstream of the dam sxis, is of brown and gray color, compacted and uncemented clay. The basement rock of this site must be deeper than No. 2 dam site.

D. <u>No. 3 dam site</u>

The ratio of height of dam to width of valley at elevation 1717 m is about 1 : 4. The ridge at the right abutment is narrow and low as at the two others dam sites.

Geology consist of lava and tuffaceous clay. Some outcrops of lava were found below elevation 1650 m. The rock character of the outcrop is the same as at No. 2 dam site.

8.3 TUNNEL AND POWERHOUSE SITE

A. <u>Tunnel routes</u>

Two alternative routes for the tunnel were studied. The topography along these tunnel routes was described in paragraph 8. 1. The geology consist of lava flow and tuffaceous clay accumulated over lava flow as mentioned before.

Tuffaceous clay is uncemented and the groundwater table is high. In view of the fact that the structure will be a pressure tunnel, the tunnel should be aligned to pass in the rock formation.

According to the present plan, the elevation of the tunnel is about 1680 m and it is presumed that it will pass through the lava flow, but, as there are some joints and cracks in the lava flow, seepage of water might be encountered during the tunnel excavation. There is a narrow ridge in part of the tunnel route and through the lava flow near the surface. Therefore it is presumed that this part of tunnel will have not enough rock coverage and should be carefully designed.

B. Powerhouse site

Two alternatives of powerhouse were studied: An underground and above ground structures.

The geologic condition for an underground structure can not be estimated only by the geological conditions of the surface outcrops and it is necessary to obtain sufficient data by drilling or other methods.

According to observations of outcrops, there are some joints and cracks in the lava flow of this site, but the geologic condition is worth investigating for an underground powerhouse.

Two sites for above ground powerhouse were considered on the right bank of the Rio Cauca. Uncemented terrace and talus deposit are distributed at the proposed sites. The depth of terrace deposit must be confirmed by drilling, but it is presumed that is more than 5 m deep. Below the uncemented deposit, a relatively cemented deposit can be found at site No. 3. Judging from the outcrops, this cemented deposit is suitable for the foundation of powerhouse. The distribution and depth of this cemented deposit must be confirmed by drilling, if No. 3 site is selected.

All of the proposed penstock sites for a surface powerhouse are located on very steep wall of the Rio Cauca. Between elevation 1650 m and elevation 1700 m, the wall slope is 80°. Below elevation of about 1650 m, the talus deposit is distributed along the wall. The wall consist of lava flow that is suitable for the penstock foundation.

8.4 DIKE SITE

The dike site, which is located near Julumito Village, is lower than the proposed high water surface of the reservoir, therefore a small dike should be constructed.

The topography of this site is hilly land, gently undulated. The geology is not clear because of the covering by black cultivated soil, but, according to partial outcrops of marsh, it is presumed that sand and gravel layer belonging to terrace deposit must be distributed beneath the black cultivated soil.

Engineering geologic interpretations of this site are as follows:

Groundwater level is very high and it is encountered at about 1707 m elevation. When water is stored in the reservoir, the groundwater level will rise at the opposite side of the reservoir. Therefore, for the protection of cultivated land, some treatment against the rising of groundwater level will be necessary. Also treatment is necessary against leakage of water from the reservoir and the other technical problems, e.g. piping action, etc.

8.5 DIVERSION DAM AND CHANNEL SITE

A. Outline

The geology of the channel site generally consists of terrace deposit and tuffaceous clay.

Terrace can be divided in two stages: lower terrace and higher terrace. The lower terrace is locally formed where the Rio Cauca meanders and the higher terrace can be found roughly at places lower than elevation 1725 m.

The zone above elevation 1725 m consists of tuffaceous clay which is covering the whole of the project area.

The terrace deposit is compact and is formed by sand somewhat tuffaceous and gravelly. The diameter of gravel varies from 10 cm to 70 cm.

B. Geology of site

Diversion dam and sedimentation pond will be located on the lower terrace deposit which appears to be relatively deep. Therefore grouting or blanketing using tuffaceous clay would be necessary for prevention of leakage of water.

The geology along the channel and the short tunnel at the end of the channel are composed of tuffaceous clay. Structures built on this type of clay should have underdrains.

8.6 BORROW AREA, QUARRY SITE AND CONCRETE AGGREGATES

A. Borrow area

Impervious core material available around the project site is tuffaceous clay. This soil is orange to grayish orange color, very fine and silty, and also, it has high natural water content. The result of field permeability test is $K = 10^{-4}$ cm/sec approximately.

The proposed sampling places for laboratory soil test are shown in Fig. 8-1 and Fig. 9-3.

B. Quarry site

The rock material for the dam will be obtained from the lava flow which is distributed on the right bank of the Río Cauca.

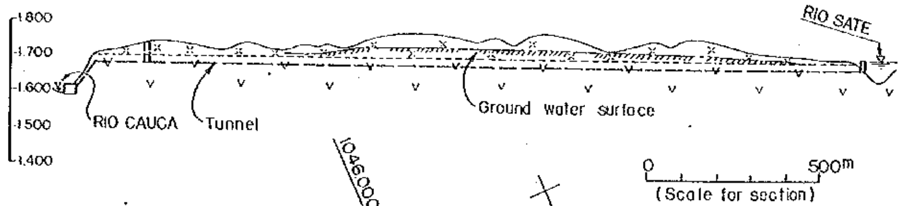
This lava is somewhat porous and it has comparatively low specific gravity at the surface, but below the surface it is dense and usable as rock-fill material. The quarry site which should be investigated is shown on Fig. 8-1 and Fig. 9-3.

C. Concrete aggregate

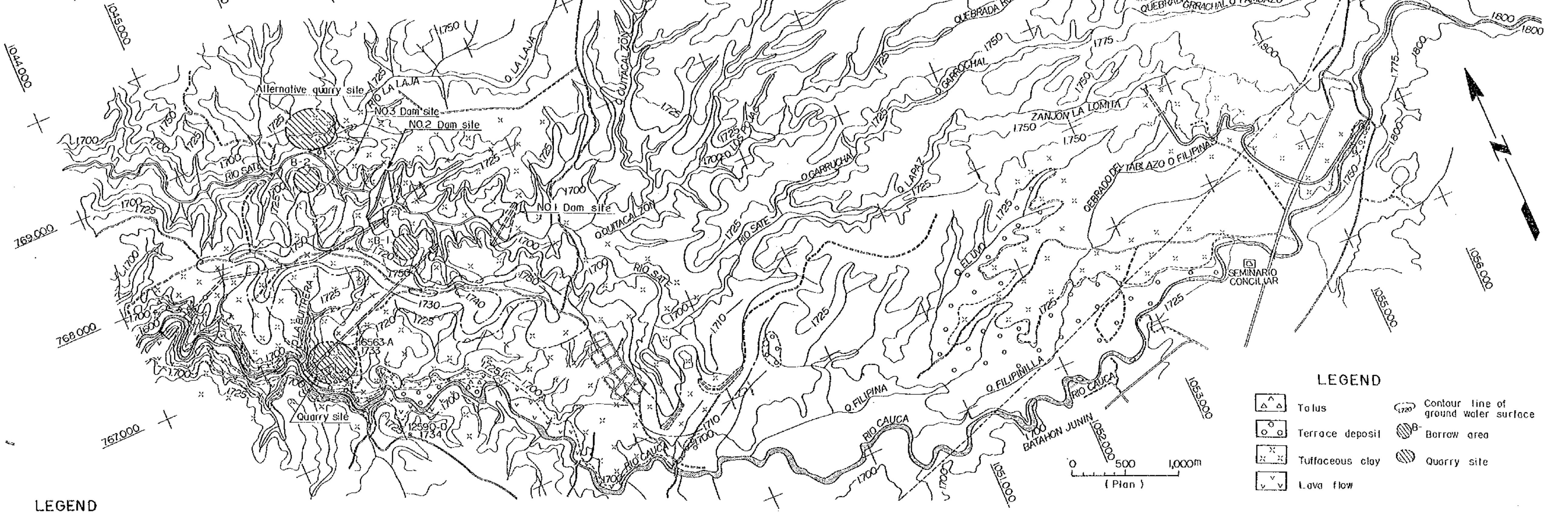
As the dam will be an embankment structure, concrete aggregates will be mainly used for the tunnel and powerhouse. Natural deposit can not be found around the sites of tunnel and powerhouse. A proposed site for aggregate is located near the site of the channel and it is about 12 km away from the tunnel site shown in Fig. 8-1. This site is formed by a terrace deposit of the Río Cauca, but generally, the sand includes tuffaceous material and good quality material can not be anticipated along the Rio Cauca.

It is recommended that sand and aggregate for concrete be collected from the Río Timbio as in the case of Florida II project which is under construction.

SECTION A–A



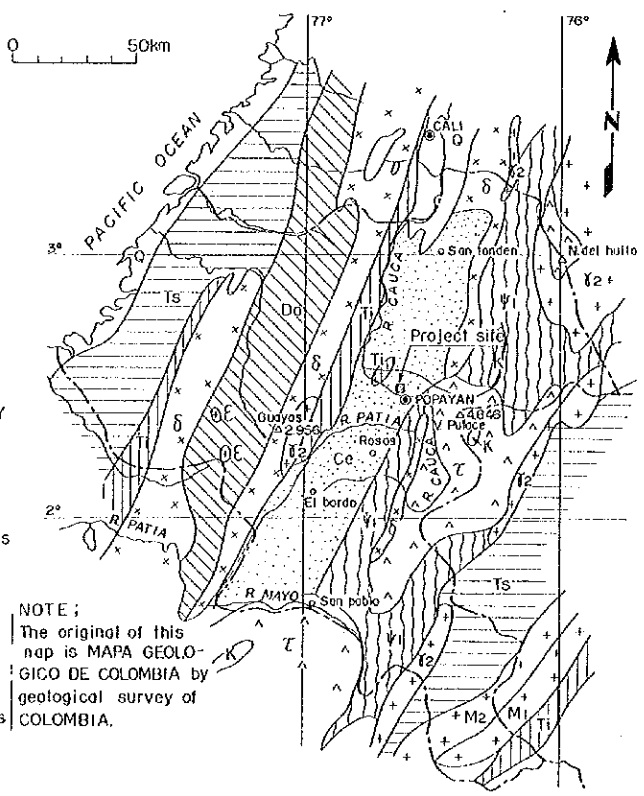
GEOLOGIC PLAN OF PROJECT AREA



LEGEND

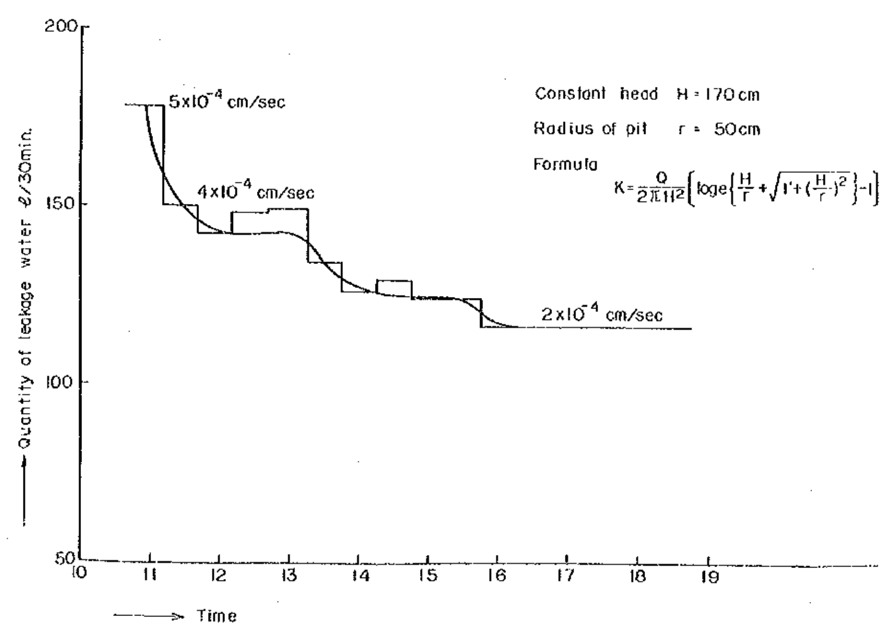
Ce	Cenozoico no diferenciado
Q	Cuaternario
Ts	Terciario superior
Ti	Terciario inferior
K	Cretaceo
Dd	Roca principalmente mesozoicas
ψ1	Ectinitas
M2	Migmaticas homogeneas Y heterogeneas
M1	Granitos de anatexia
τ	Andesitas, basaltas Y sus tobas de edad cenozoica
δ	Formaciones diabasicas
γ2	Granitos Y granodioritas
ε	Tonalitas Y rocas intrusivas mas basicas

GENERAL GEOLOGIC PLAN OF CAUCA



NOTE ; The original of this map is MAPA GEOLOGICO DE COLOMBIA by geological survey of COLOMBIA.

FIELD PERMEABILITY TEST IN NO.2 DAM SITE



OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO – JAPAN
CENTRALES ELECTRICAS DEL CAUCA S.A.
JULUMITO HYDROELECTRIC PROJECT
GEOLOGIC MAP OF PROJECT AREA
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO – JAPAN
FIG. 8-1 DATE

CHAPTER IX

FIELD INVESTIGATION REQUIRED FOR FEASIBILITY STUDY

9.1 PREPARATION OF TOPOGRAPHICAL MAP

A. Preparation of drainage area map

Map covering whole drainage area of the project including the Rio Palacé to scale: 1/50,000 - 1/100,000.

B. Field check of existing aerial topographic maps

Area: reservoir area, route along diversion channel (Rio Cauca, Rio Palacé, Rio Blanco) and waterway routes.

Scale and contour line interval: 1/10000 and 5 m

C. Preparation of topographical maps of stracture sites

Place	Scale	Contour Line Interval (m)	Area (km^2)
No. 2 Dam site (extend existing survey)	1/500	2	0.4
No. 1 Dam site (extend existing survey)	1/500	2	0.25
No. 3 Powerhouse site	1/500	2	0.5
Dike site (No. 1) (No. 2)	1/500	2	0.5
Diversion dam site (Rio Cauca)	1/500	2	0.2
Diversion dam site (Rio Palacé, Rio Blanco)	1/500	2	0.2

D. River profile and leveling

(1) River profile

Rio Cauca: From the confluence of the Rio Sate to elevation 1750 m along the river.

(2) Leveling

Rio Palacé, Rio Blanco.

9.2 HYDROLOGIC AND METEOROLOGIC INVESTIGATION

A. Hydrologic investigations

As hydrologic information is the most important basic data necessary in the future feasibility study of Julumito project, adequate run-off records must be obtained as follows.

(1) Continuous recording of daily run-off at Julumito Gauging Station.

(2) Observation of daily run-off of the Rio Sate.

(3) Daily run-off of the Rio Palacé and the Rio Blanco.

(4) Daily run-off of the Laguna San Rafael.

B. Meteorologic investigations

(1) Daily precipitation records of the Rio Cauca catchment area (Popayan, Puracé, Coconuco and others)

(2) Daily precipitation records of the Rio Palacé, Rio Blanco and Laguna San Rafael catchment areas.

(3) Observation of evaporation at Popayán.

Daily temperature (max. min. and average)

Humidity (max. min. and average).

9.3 GEOLOGIC INVESTIGATION

The locations of geologic investigations are shown in Fig. 9-3 and also, these are listed in Table 9-1.

A. No.2 dam site

Drill hole and adit

All drill holes have to be drilled by core borings of BX size and core samples in tuffaceous clay have to be recovered for every 2 m, but after reaching basement rock, the core recovery should be 100 %. The ground-water level in the hole should be measured.

The cross section of adit should be 1.2 m x 1.6 m x 2.0 m as shown in Fig. 9-3.

B. No. 1 dam site

Four drill holes are necessary and their location are aligned along the proposed dam axis. The method of drilling is the same as for No. 2 dam site.

C. Tunnel and powerhouse site

Four drill holes are proposed at the powerhouse and tunnel sites. These sites are shown in Fig. 9-3 and Table 9-1, but as detailed topographic map are not available, the location of each hole should be determined by rough surveying. Drilling should to be executed by BX size bits. Core recovery of tuffaceous clay accumulated on the basement rock should be made for every 10 m. After reaching bedrock, 100 % core recovery should be attempted.

D. Quarry site

One drill hole is proposed at the quarry site. The size of the bit is BX.

Core recovery of the surface deposit is not necessary, but the depth of the deposit should be confirmed. After reaching rock, 100 % core recovery should be attempted.

E. Borrow area

Two proposed area for impervious core material are selected as shown in Fig. 9-3. Investigations of both area should be executed by test pit and drilling. Soil samples for laboratory test should be taken from the bottom of each pit (3 m) and the items of laboratory test are explained in Table 9-2.

Drilling at the borrow areas should be executed by NX size bit and soil samples taken every 1 m.

F. Dike site

Two NX size drill holes are proposed at this site. The core should be recovered from every 1 m. Measurement of groundwater level in the drill hole is necessary and if possible, permeability tests should be executed by using the holes. (For the execution of the test reference is made to Design of Small Dams, U.S.B.R.)

G. Laboratory test for soil material

All samples for laboratory test should be taken from the bottom of each pit in both areas. The items of tests are given in Table 9-2.

Table 9-1 List of Geologic Investigation

Site	Investigation	NO.	Length (m)	Location	(m)	Coordination
NO. 2 dam	Drill hole	DH-201	25	Left bank.	EL. 1720	Detail location shown in Fig. 9-3.
		DH-202	15	Left bank.	EL. 1710	
		DH-203	10	Left bank.	EL. 1646	
		DH-204	15	Right bank.	EL. 1654	
		DH-205	25	Right bank.	EL. 1720	
		Sub. T	90			
NO. 1 dam		DH-101	25	Left bank.	EL. 1720	
		DH-102	15	Left bank.	EL. 1690	
		DH-103	15	Right bank.	EL. 1690	
		DH-104	25	Right bank.	EL. 1720	
		Sub. T	80			
Tunnel and powerhouse		DH- 1	160	Under ground powerhouse		X=767 830 Y=1 046 370
		DH- 2	35	End of q. la buitrera		X=767 760 Y=1 045 850
		DH- 3	35	Bottom of queb.		X=767 865 Y=1 045 165
		DH- 4	20	NO. 3 powerhouse		X=767 730 Y=1 044 560
		Sub. T	250			
Quarry		DH- 5	60	Right bank of CAUCA		X=767 000 Y=1 045 700
		Sub. T	60			
Borrow NO. 1		DH- 6	55			X=767 500 Y=1 046 840
Borrow NO. 2		DH- 7	30			X=768 430 Y=1 046 135
		Sub. T	85			
Dike NO. 1		D. DH-1	20	EL. 1714.65		X=765 130 Y=1 048 950
Dike NO. 2		D. DH-2	20	EL. 1712.35		X=765 000 Y=1 048 380
		Sub. T	40			
Total			605			
NO. 2 dam	Adit	A - 1	30	Left bank.	EL. 1690	Detail location shown in Fig. 9-3.
		A - 2	15	Left bank.	EL. 1660	
		A - 3	20	Right bank.	EL. 1660	
		A - 4	20	Right bank.	EL. 1690	
		A - 5	20	Left bank.	EL. 1670	
		A - 6	20	Right bank.	EL. 1680	
Total			125			
Borrow NO. 1	Test pit	TP-101	3			X=767 615 Y=1 046 790
		TP-102	3			X=767 525 Y=1 046 975
		TP-103	3			X=767 440 Y=1 046 700
		TP-104	3			X=767 350 Y=1 046 885
		Sub. T	12			
Borrow NO. 2		TP-201	3			X=768 570 Y=1 046 080
		TP-202	3			X=768 480 Y=1 046 265
		TP-203	3			X=768 385 Y=1 046 000
		TP-204	3			X=768 305 Y=1 046 180
		Sub. T	12			
Total			24			
SUM.	Drill hole	18	605			
	Adit	4	125			
	Test pit	8	24			

Table 9-2 Items for Soil Test

1. General character
   - 1.1 Water content
   - 1.2 Density (g/cm^3)
   - 1.3 Dry density (g/cm^3)
   - 1.4 Specific gravity
2. Gradition analysis
3. Consistency
   - 3.1 Liquid limit (W_L) (%)
   - 3.2 Plastic limit (W_p) (%)
4. Compaction test
   - 4.1 Field water content (F.M) (%)
   - 4.2 Optimum water content (Wop) (%)
   - 4.3 Maximum dry density (t/m^3)
5. Triaxial test
   - 5.1 Cohesion (kg/cm^2)
     - (1) Optimum water content
     - (2) Optimum water content + 2%
   - 5.2 Angle of internal friction (ϕ)

     Shear test

     Unconfined compression test

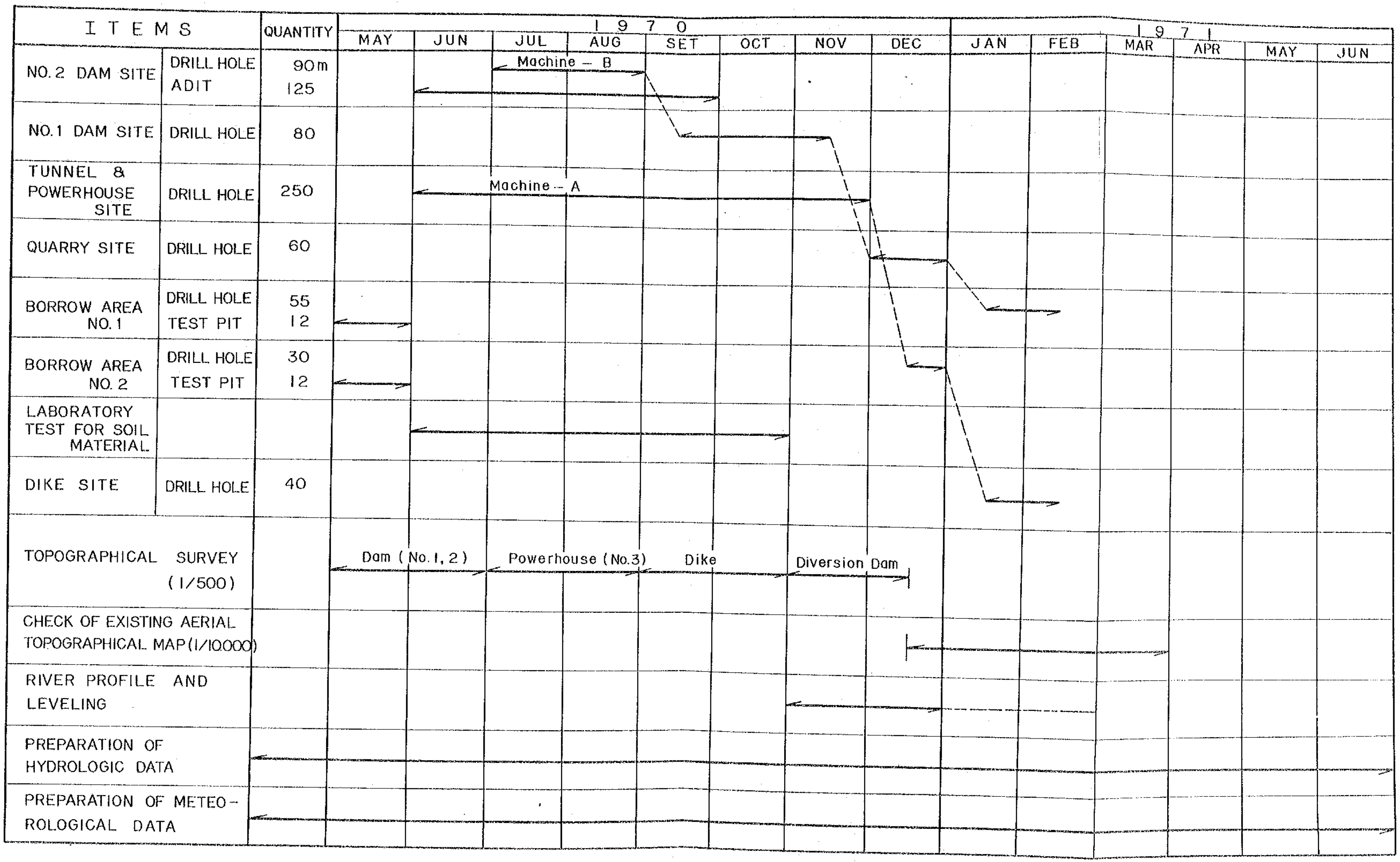
     (undisturbed)

     Unconfined compression strength (qu) (Kg/cm^2)

     Strain at failure (_) (%)

     (repeated) .... (qu) and ($\mathcal{E}$)
6. Consolidation test
   - 6.1 Disturbed sample (Optimum water content and optimum water content + 2%)
     - (1) Consolidation (unsaturated)
     - (2) Consolidation after saturated
   - 6.2 Undisturbed sample (Natural water content)
     - (1) Consolidation (unsaturated)
     - (2) Consolidation after saturated
7. Permeability test for impervious material
8. Field permeability test for foundation

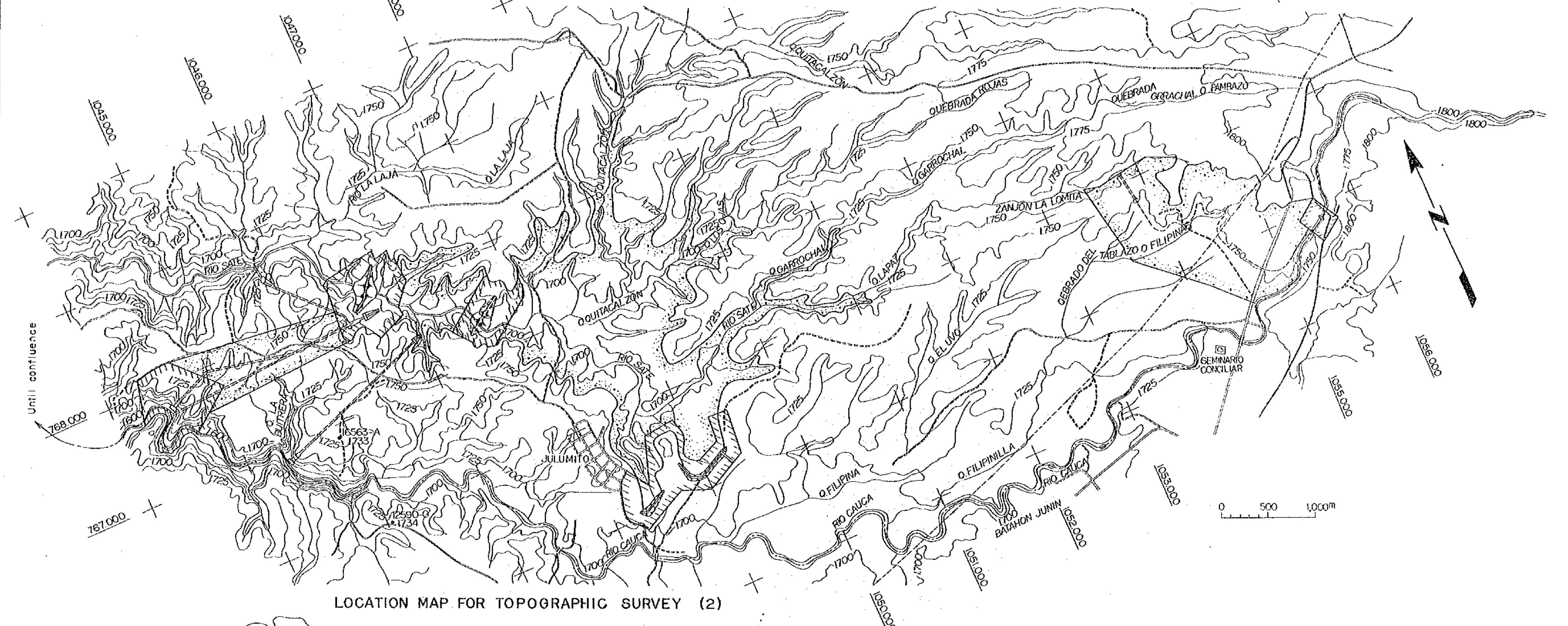
Fig: 9-1 Schedule of Field Investigations for Feasibility Study



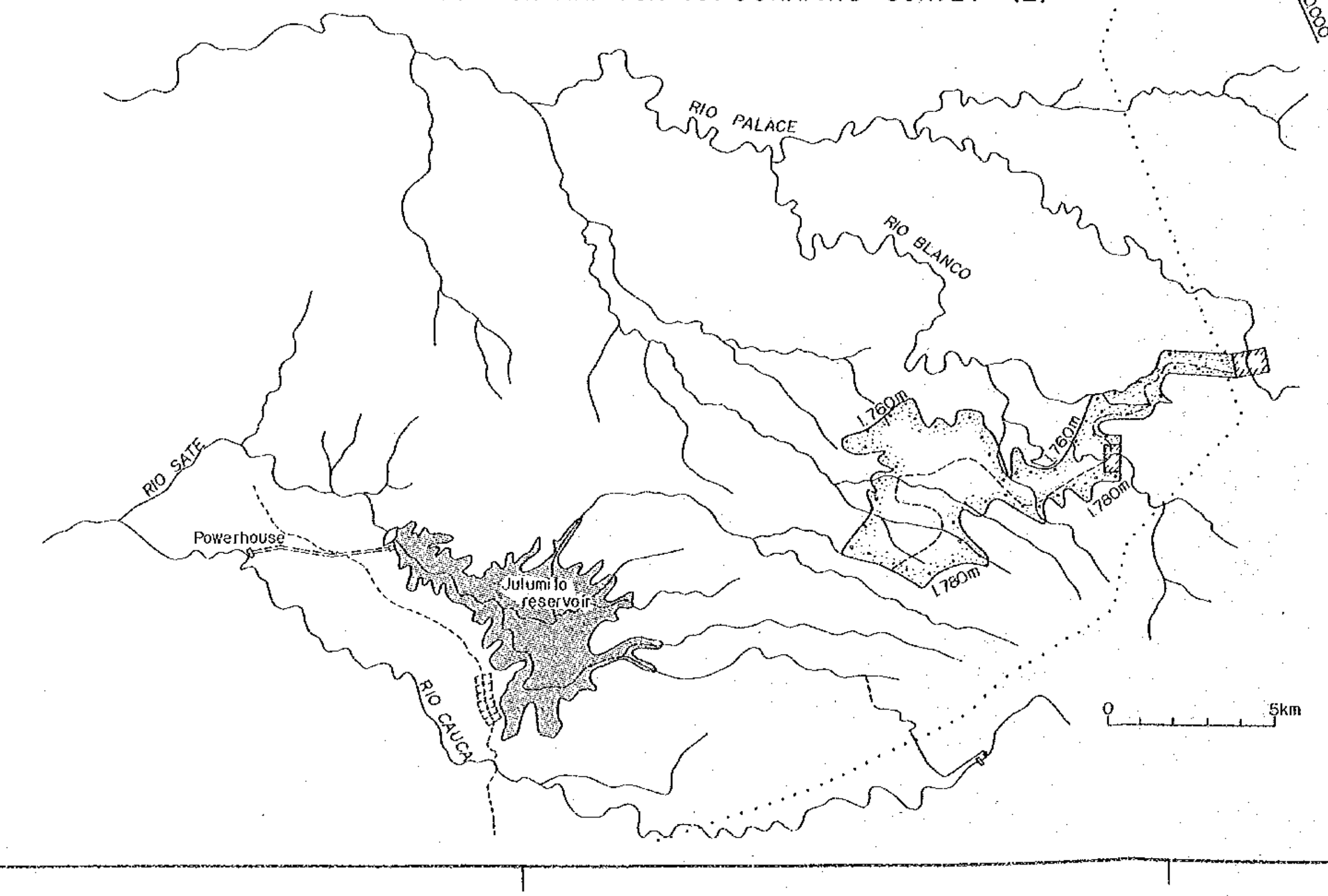
NOTE

Program of drill hole is planned by using two machines

LOCATION MAP FOR TOPOGRAPHIC SURVEY (1)



LOCATION MAP FOR TOPOGRAPHIC SURVEY (2)



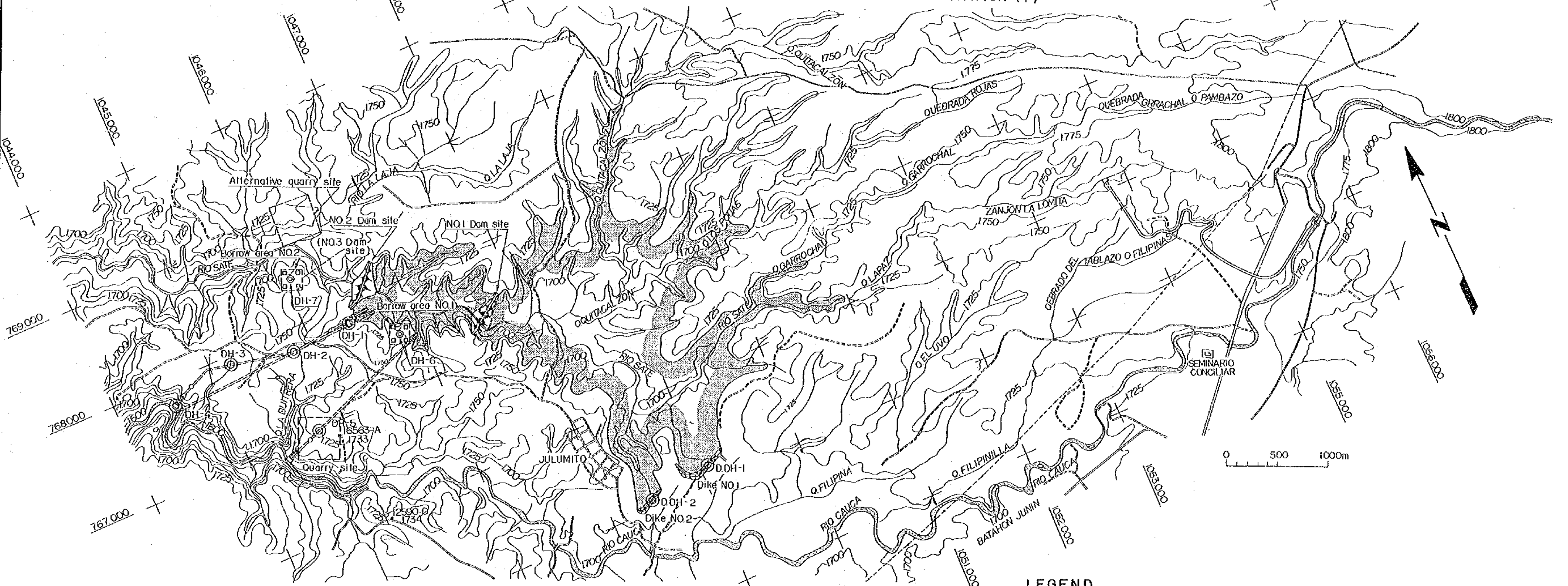
LEGEND

TOPOGRAPHIC SURVEY

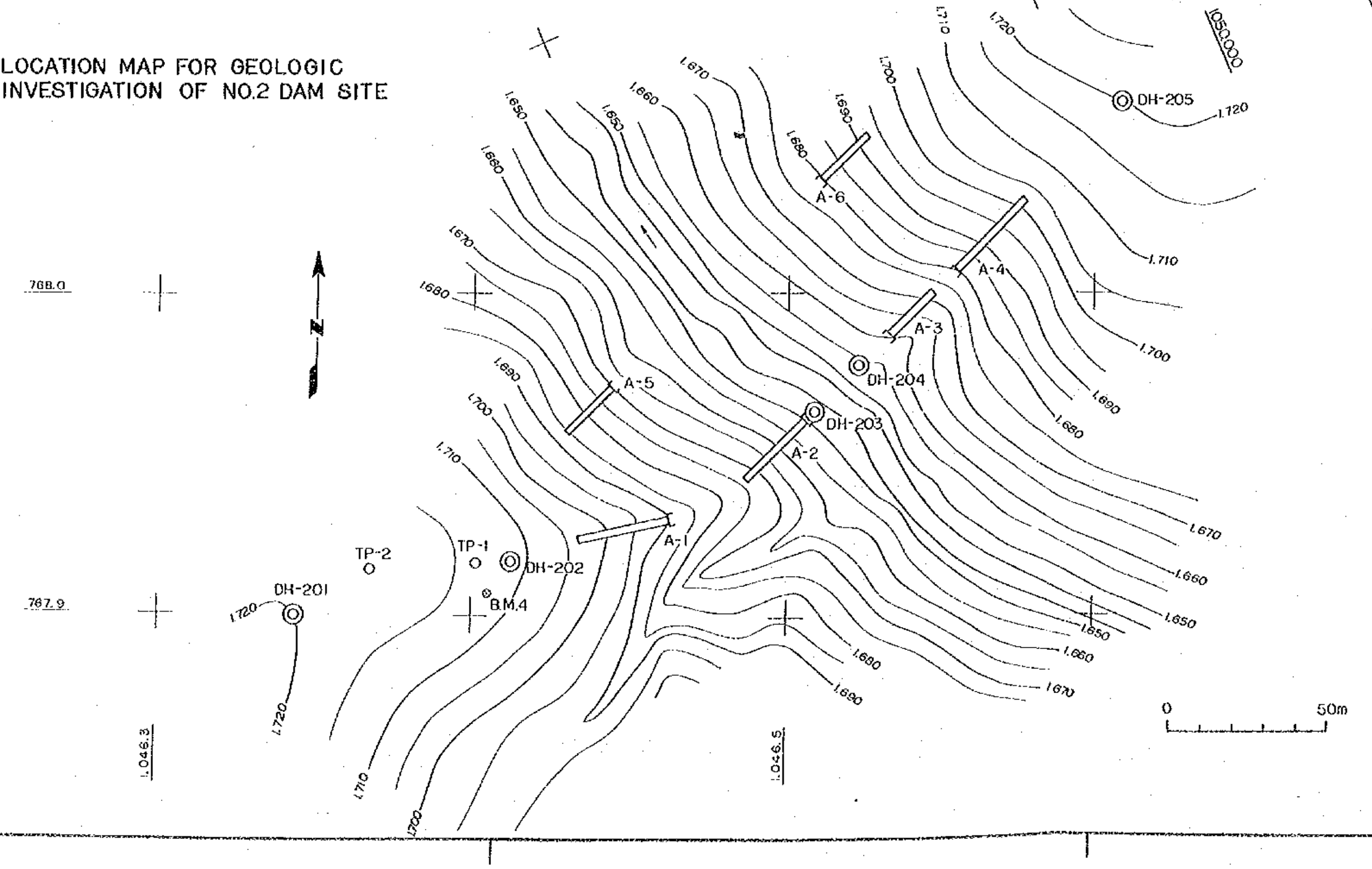
- River profile survey
- Topographic survey (Scale 1:500)
- Area necessary to be checked by field survey (addition of contour line, 5m interval)

OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO – JAPAN
CENTRALES ELECTRICAS DEL CAUCA S.A
JULUMITO HYDROELECTRIC PROJECT
LOCATION MAP FOR TOPOGRAPHIC SURVEY
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO – JAPAN
FIG. 9-2 | DATE

LOCATION MAP FOR GEOLOGIC INVESTIGATION (1)



LOCATION MAP FOR GEOLOGIC INVESTIGATION OF NO.2 DAM SITE



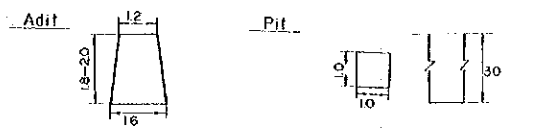
LEGEND

- ◎ DH- Drill hole
- □ Test pit
- A- Adit

Note:

(1) The location of each investigation is shown on Table 9-1.

(2) The standard size of adit and test pit are shown below.

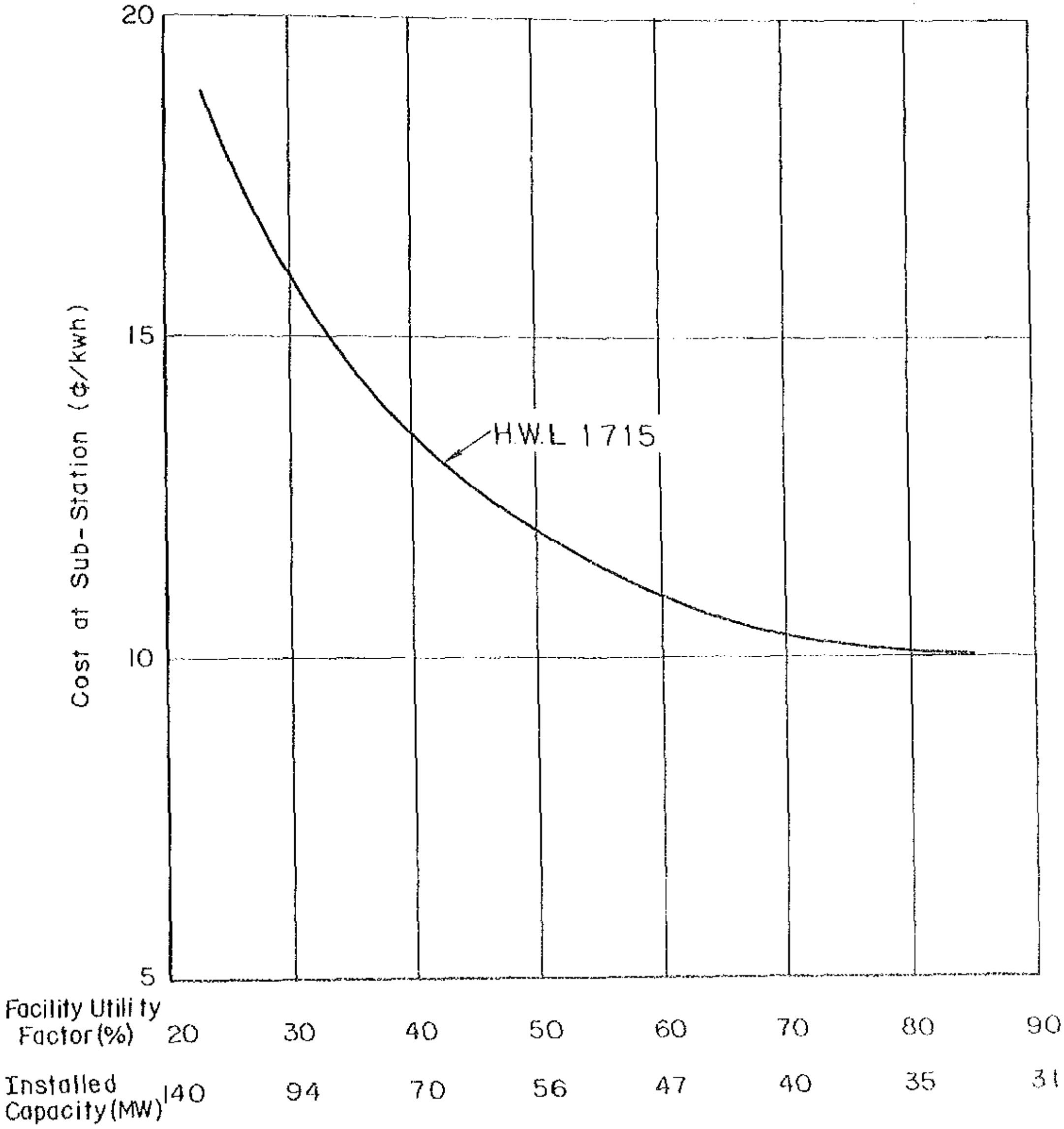


OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO - JAPAN
CENTRALES ELECTRICAS DEL CAUCA S.A.
JULUMITO HYDROELECTRIC PROJECT
LOCATION MAP FOR GEOLOGIC INVESTIGATION
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO - JAPAN
FIG. 9-3 / DATE

APPENDIX

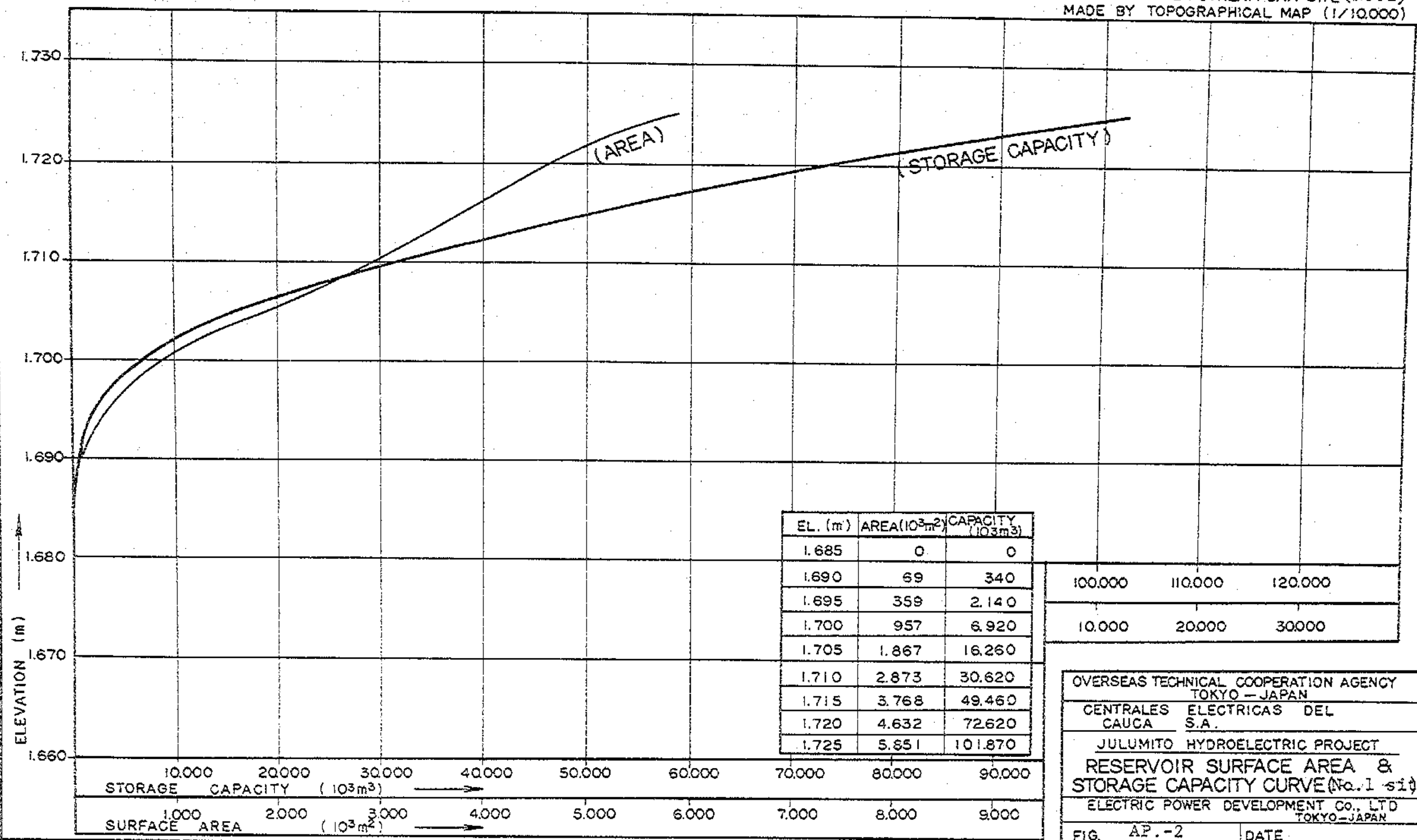
Fig. AP-1

Relation Between Cost and Facility Utility Factor



Note, This diagram shows the relation between cost and facility utility factor in the case of H.W.L 1715m

(NOTE) : UPPER STREAM DAM SITE (No. 1)
MADE BY TOPOGRAPHICAL MAP (1/10,000)



EL. (m)	AREA ($10^3 m^2$)	CAPACITY ($10^3 m^3$)
1.685	0	0
1.690	69	340
1.695	359	2.140
1.700	957	6.920
1.705	1.867	16.260
1.710	2.873	30.620
1.715	3.768	49.460
1.720	4.632	72.620
1.725	5.851	101.870

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO – JAPAN

CENTRALES ELECTRICAS DEL CAUCA S.A.

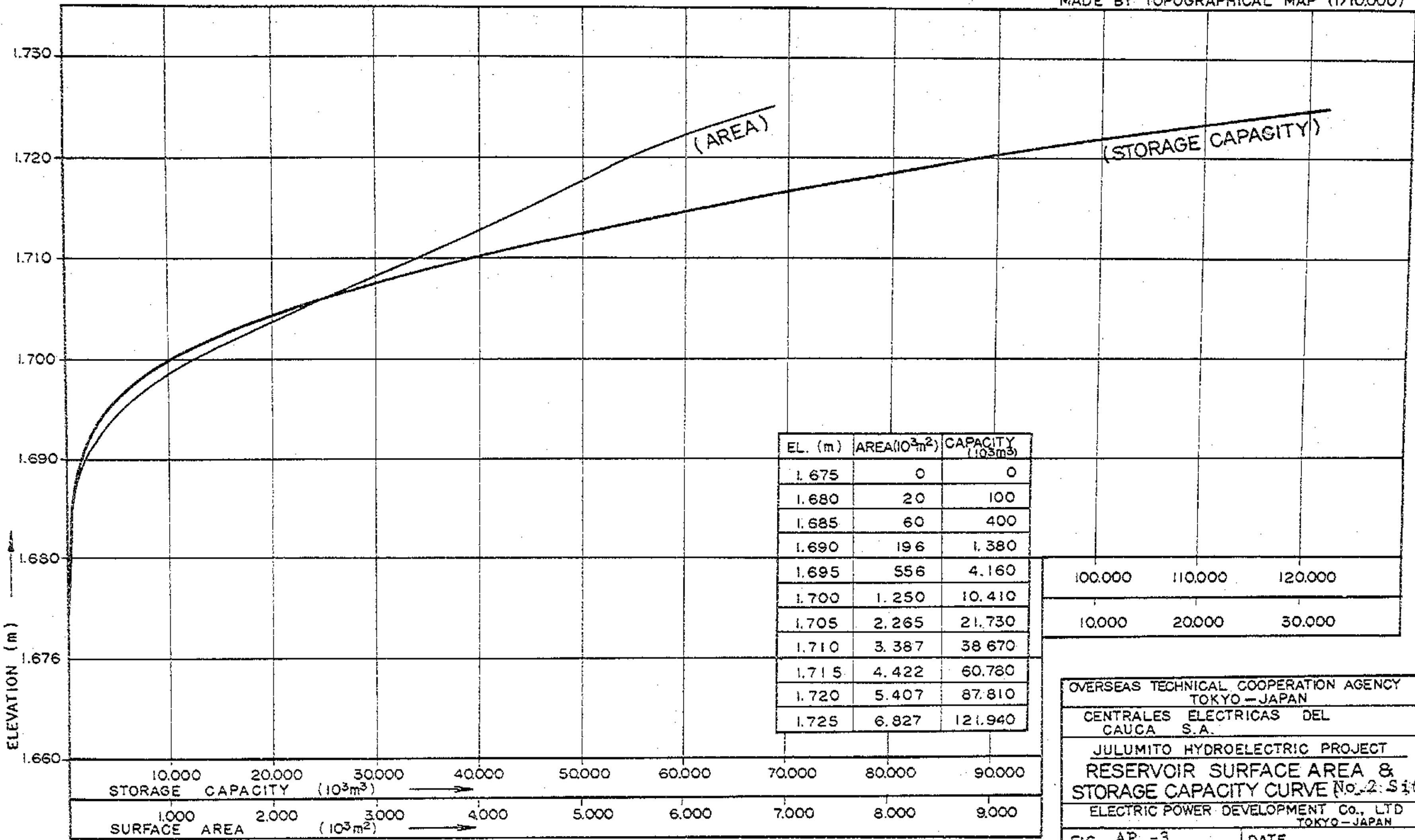
JULUMITO HYDROELECTRIC PROJECT

RESERVOIR SURFACE AREA & STORAGE CAPACITY CURVE (No. 1 site)

ELECTRIC POWER DEVELOPMENT Co., LTD
TOKYO–JAPAN

FIG. AP.-2 | DATE

(NOTE) : MIDDLE STREAM DAM SITE (No.2)
MADE BY TOPOGRAPHICAL MAP (1/10,000)



EL. (m)	AREA(10^3m^2)	CAPACITY (10^3m^3)
1.675	0	0
1.680	20	100
1.685	60	400
1.690	196	1.380
1.695	556	4.160
1.700	1.250	10.410
1.705	2.265	21.730
1.710	3.387	38 670
1.715	4.422	60.780
1.720	5.407	87.810
1.725	6.827	121.940

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO—JAPAN

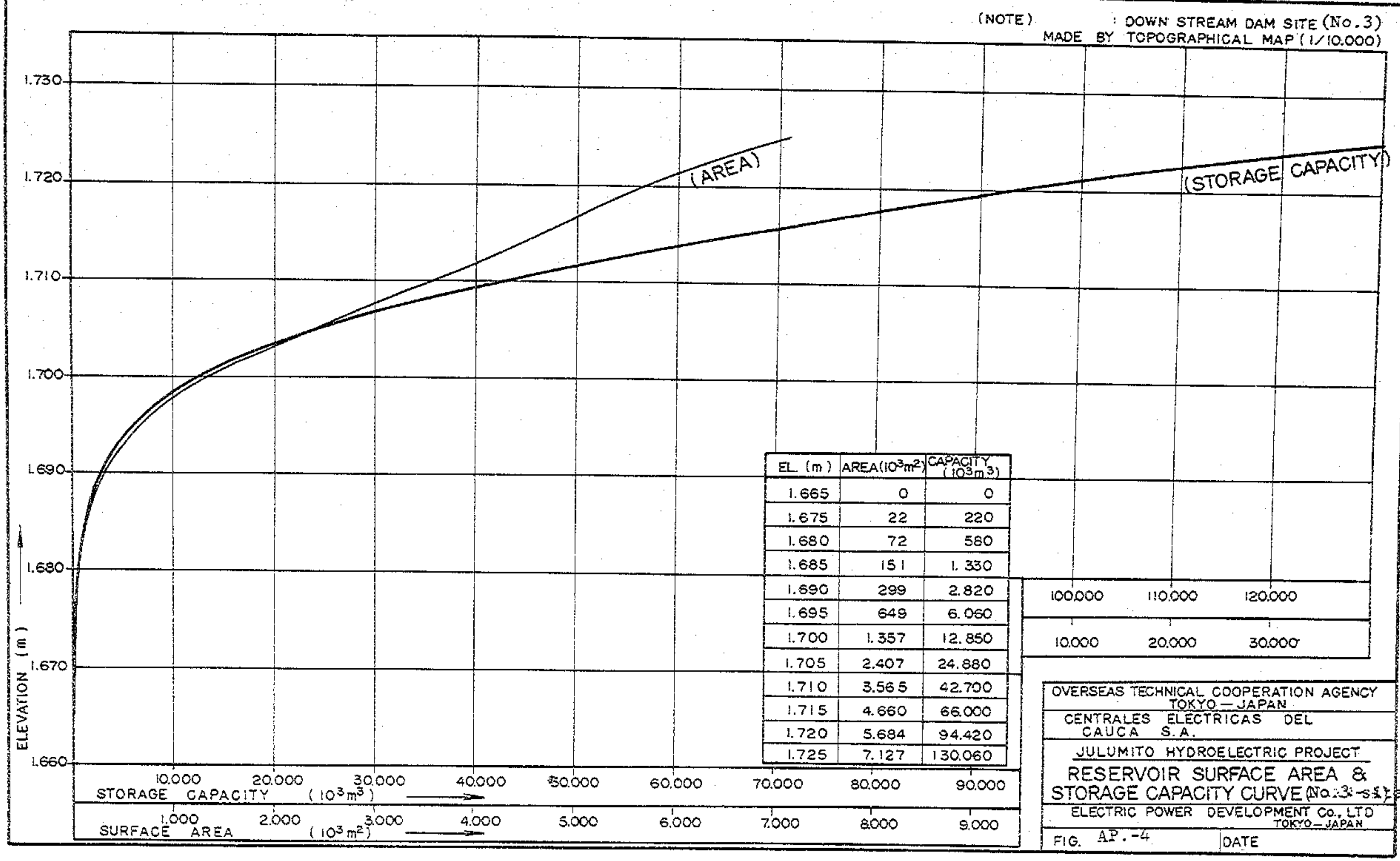
CENTRALES ELECTRICAS DEL CAUCA S.A.

JULUMITO HYDROELECTRIC PROJECT

RESERVOIR SURFACE AREA & STORAGE CAPACITY CURVE No.-2 Site

ELECTRIC POWER DEVELOPMENT Co., LTD
TOKYO—JAPAN

FIG. AP.-3 | DATE



EL. (m)	AREA ($10^3 m^2$)	CAPACITY ($10^3 m^3$)
1.665	0	0
1.675	22	220
1.680	72	580
1.685	151	1.330
1.690	299	2.820
1.695	649	6.060
1.700	1.357	12.850
1.705	2.407	24.880
1.710	3.565	42.700
1.715	4.660	66.000
1.720	5.684	94.420
1.725	7.127	130.060

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO — JAPAN

CENTRALES ELECTRICAS DEL CAUCA S.A.

JULUMITO HYDROELECTRIC PROJECT

RESERVOIR SURFACE AREA & STORAGE CAPACITY CURVE (No.3)

ELECTRIC POWER DEVELOPMENT Co., LTD
TOKYO — JAPAN

FIG. AP.-4 DATE

DISCHARGE STATION JULUMITO

Table AP-1-(1)

CAUCA RIVER, IN THE BASIN OF JULMITO ELEVATION UNIT YEAR 1964

DATE	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1					17.4	17.0	21.8	21.6	19.4	17.8	22.9	21.6	1
2					17.2	20.2	18.0	24.2	20.7	17.7	20.1	15.5	2
3					18.2	21.4	20.0	30.4	36.1	19.7	24.5	13.1	3
4					15.3	25.5	31.6	36.0	48.0	24.5	18.5	18.0	4
5					16.7	24.2	30.1	30.8	24.1	30.9	21.8	47.5	5
6					16.9	23.9	18.9	35.3	23.1	60.7	37.5	46.1	6
7					15.7	23.9	18.6	33.8	21.8	53.1	35.0	30.4	7
8					15.2	19.5	19.8	36.9	24.1	50.5	21.8	18.0	8
9					16.4	20.0	25.7	29.8	20.0	40.2	13.9	13.6	9
10					19.9	21.6	31.7	25.8	21.6	37.6	15.3	28.7	10
11					17.0	19.1	32.0	37.5	19.0	29.1	17.9	22.6	11
12					15.9	18.8	27.0	57.9	17.8	24.5	22 3	28.5	12
13					25.1	18.1	29.9	63.7	27.7	22.4	26.6	24.4	13
14					30.5	17.1	28.4	51.3	28.6	20.3	17.8	15.2	14
15					24.8	21.1	23 0	60.8	20.7	18.2	14.5	38.4	15
16					19.4	18.9	19.6	53.8	20.8	16.7	16.3	15.6	16
17					16 6	17.6	18.3	49.2	18.2	20.8	23.0	29.8	17
18					23.5	22 0	18.2	45.9	17.9	38.8	35.6	71.2	18
19				16.8	25.1	30.8	18.2	43.2	23.9	75.3	30.5	44.7	19
20				16.7	21.0	26.5	19.1	42.9	22.0	68.7	28.3	35.7	20
21				16.4	17.3	30.9	17.7	47.6	18.2	43.9	21.6	46.9	21
22				15 8	17.1	31.9	16.8	46.1	20.3	19.4	14.2	35.7	22
23				15.5	20.8	27.9	18.5	49.0	18.4	19.6	19.4	38.9	23
24				16.6	21.0	26.1	19.6	52.7	18.4	16.5	17.7	32.1	24
25				16.9	27.1	20.6	19.5	41.4	33.4	16.0	15.1	14.3	25
26				30.9	17.9	20.7	21.6	40.3	33.8	15.3	14.1	51.3	26
27				26.1	16.2	23.9	20.5	40.3	20.2	16.4	16.8	45.0	27
28				20.1	17.4	22.2	32.7	34.4	19.4	15.4	20.8	50.8	28
29				16.8	16.2	18.9	33.1	29.4	18.9	47.3	31.6	55.4	29
30				17.4	16.8	22.5	18.3	27.1	17.9	40.3	25.7	32.0	30
31					19.1		17.7	22.5		26.1		18.7	31
Sum					594.7	672.9	705.9	1241.6	694.4	963.7	661.1	999.7	
Ave.					19.2	22.4	22.8	40.0	23.1	31.1	22.0	32.2	

Annual Total ( )

Table AP-I-(2)

DISCHARGE STATION JULUMITO

CAUCA RIVER, IN THE BASIN OF JULUMITO ELEVATION UNIT YEAR 1965

DATE	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	12.7	16.6	45.1	16.9	48.3	30.0	16.0	19.8	18.4	13.7	16.4	37.6	1
2	11.4	16.9	30.5	17.5	46.7	27.3	19.4	19.3	16.7	13.7	23.5	24.7	2
3	27.4	14.4	23.3	15.1	52 2	25.1	18.9	16.5	24.7	13.6	17.4	18.5	3
4	23.3	11.8	14.8	14.6	52.0	24.5	35.7	14.9	19.9	13.0	37.8	29.3	4
5	18.4	29.0	14.9	17.5	38.5	20.7	31.8	22.2	16.3	13.7	18.1	26.4	5
6	16.6	73.9	16.7	17.4	36.3	17.0	20.5	20.7	16.5	16.3	31.1	27.8	6
7	14.5	51.8	20.2	24.5	25.9	16.0	26.7	64.0	18.9	18.6	32 0	35.7	7
8	13.8	45.3	24.8	17.6	26.1	19.1	36.8	53.8	15.1	14.2	18.7	45.6	8
9	12.2	40.4	23.7	16 7	28.2	43.9	28.2	38.2	19.6	14.3	45.9	26.0	9
10	13.3	37.5	19.5	17.3	43.7	23.6	21.6	22.6	20.1	15.7	22.2	34.9	10
11	13.6	41.7	23.1	19.8	44.0	23.1	18.3	19.5	16.1	12.5	16.0	20.1	11
12	18.3	44.3	19.1	16.8	38.8	22.0	14.1	19.5	16.2	13.3	55.9	27.1	12
13	18.6	33.2	12.8	17.5	46.8	21.3	12.8	20.2	20.4	14.0	43.5	23.5	13
14	20.1	24.1	14.4	21.5	50.4	15 9	25.2	24.1	19.9	14.7	28.7	18.7	14
15	23.4	18.8	14.0	22.6	45.3	15.4	20.0	14.4	19.3	15.3	30.4	27.7	15
16	18.6	16.0	16.5	21.9	41.4	32.3	18.0	24.7	14.5	15.9	45 7	27.9	16
17	17.4	18.6	18.1	31.1	37.8	48.9	15.3	62.1	12.9	17.1	64.1	25.6	17
18	12.7	16.4	17.1	29.2	35.9	45.7	54.3	52.8	12.6	41.0	40.2	25.3	18
19	48.1	16.1	13.9	18.9	29.3	42.4	44.5	42.5	23.2	31.5	35.7	21.8	19
20	40.1	12.5	12.2	64.2	28.1	60.4	26.1	38.3	17.7	23.1	57.7	22.6	20
21	33.5	20.3	13.2	57.9	27.5	43.6	44.8	26.1	19.6	18.4	42.2	23.7	21
22	48.9	17.4	12.6	58.8	25.6	34.7	32.5	23.0	16.3	15.9	34.2	21.6	22
23	25.3	20.8	13.1	46.7	25.2	34.5	26.9	19.0	14.3	25.4	48.1	18.7	23
24	24.6	23.0	12.8	37.0	17.7	35 6	22.8	15.9	12.2	28.5	27.1	33.3	24
25	50.4	76.8	16.5	34.0	29.7	31.5	17.3	19.0	13.7	47.6	43.7	28.9	25
26	31.2	59.4	16.1	22.9	31.9	26.1	25.9	17.7	14 8	20.7	47.3	20.1	26
27	42.9	41.2	16.5	20.6	29.3	22.5	24.8	22.3	12.3	16.5	64.3	20.5	27
28	19.2	38.2	17.1	18.8	29.7	20.3	20.6	15.8	11.6	16.0	51.7	21.3	28
29	22.9		17.7	19.4	26.6	19.0	19.5	13.3	15.4	13.3	43.2	21.0	29
30	17.6		17.2	49.2	27.0	17.4	20.9	18.3	15.0	12.7	48.4	21.8	30
31	23.7		14 5		25.8		18.7	20.9		14.1		20.8	31
Sum	734.7	876.4	562.0	803.9	1,091.7	859.8	778.9	821.4	504.2	574.3	1,131.2	798.5	
Ave.	23.7	31.3	18.1	26.8	35.2	28.7	25.1	26.5	16.8	18.5	37.7	25.7	

Annual Total ( )

DISCHARGE

STATION JULUMITO

CAUCA RIVER, IN THE BASIN OF JULUMITO ELEVATION ______ UNIT ______ YEAR 1966

Table AP-1-(3)

DATE	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	22.2	16.9	13.9	25.3	15.7	23.6	58.7	22.4	15.2	29.5	16.3	-	1
2	23.3	19.7	14.0	22.4	16.7	19.1	44.2	24.5	16.0	26.9	14.9	-	2
3	21.9	15.5	13.9	46.2	17.5	18.3	25.0	17.6	14.1	28.0	17.0	-	3
4	17.9	12.9	14.6	34.6	15.5	16.5	19.4	14.9	14.6	18.2	25.0	-	4
5	17.2	14.2	12.8	33.2	15.6	18.7	19.5	20.0	14.7	14.7	15.5	-	5
6	17.9	16.4	15.9	15.0	14.6	18.9	29.8	24.5	17.6	16.9	16.3	-	6
7	23.3	14.5	17.6	14.7	15.8	17.8	20.1	24.4	14.4	18.9	32.6	-	7
8	18.8	17.2	16.4	17.7	15.2	14.8	21.0	20.0	15.2	14.0	23.7	-	8
9	17.8	22.7	21.7	15.7	17.5	14.6	21.9	26.5	21.7	15.3	35.0	-	9
10	18.8	21.6	50.1	36.0	22.0	26.5	22.7	19.9	27.3	19.2	21.9	-	10
11	16.2	19.5	26.3	23.1	23.6	25.7	21.6	18.4	19.7	20.4	27.2	-	11
12	13.2	15.4	29.5	17.3	19.5	23.1	28.4	17.1	17.2	16.4	24.7	-	12
13	13.9	14.2	23.7	16.0	17.5	18.8	24.6	19.8	25.2	18.7	37.7	-	13
14	16.2	15.9	50.0	18.3	21.2	20.2	25.8	24.3	22.4	17.9	51.1	-	14
15	12.8	14.1	36.6	22.0	15.7	14.0	29.0	25.7	19.2	16.7	52.7	-	15
16	14.3	13.7	16.9	21.4	15.2	14.0	22.8	20.0	16.5	17.2	57.0	-	16
17	18.6	13.8	21.9	16.9	17.4	15.0	19.2	18.2	15.5	16.5	36.5	-	17
18	18.4	18.2	19.6	20.7	16.1	18.9	23.3	19.4	18.2	17.6	44.8	-	18
19	22.2	13.5	20.0	29.1	17.3	20.1	17.3	17.2	16.1	15.9	31.8	-	19
20	19.9	12.4	24.8	24.3	15.4	17.3	16.6	24.5	17.3	23.6	27.7	-	20
21	17.5	13.7	24.7	23.2	17.8	16.8	23.7	23.0	15.3	18.4	27.6	-	21
22	13.1	12.4	33.6	21.9	23.6	15.7	20.7	18.2	15.4	23.4	23.2	-	22
23	15.6	12.5	21.2	21.4	18.5	18.9	16.6	21.4	14.6	24.2	24.5	-	23
24	18.6	12.6	18.9	24.2	15.9	33.2	16.5	22.4	18.7	21.3	29.9	-	24
25	15.6	13.6	40.3	19.3	20.3	28.3	30.3	21.7	23.4	19.7	28.2	-	25
26	23.2	17.5	25.2	17.2	18.1	19.6	35.0	21.8	18.2	20.7	33.2	-	26
27	17.4	16.8	21.2	15.9	17.4	17.0	28.8	23.9	14.7	18.6	32.7	-	27
28	16.9	13.7	19.6	17.4	18.6	17.6	22.6	17.4	14.0	17.5	28.8	-	28
29	14.4	- -	39.5	16.8	20.7	16.7	16.9	15.4	14.0	17.4	60.0	-	29
30	18.5	-	19.8	20.5	20.6	23.3	22.2	14.6	15.7	16.3	45.4	-	30
31	14.1	-	18.3	-	18.3	-	20.0	15.0	-	16.9	-	-	31
SUM	549.7	435.1	742.5	667.7	554.8	583.0	764.2	634.1	522.1	596.9	942.9		
AVE.	17.7	15.5	24.0	22.2	17.9	19.4	24.6	20.4	17.4	19.2	31.4		

Annual Total ( )

Table AP-1-(4)

DISCHARGE STATION JULUMITO

CAUCA RIVER, IN THE BASIN OF JULUMITO ELEVATION ______ UNIT ______ YEAR 1967

DATE	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1					18.7	20.9							1
2					18.5	23.9							2
3					18.8	24.1							3
4					20.0	28.3							4
5					16.4	44.1							5
6					14.7	27.9							6
7					14.9	22.4							7
8					17.4	20.8							8
9					17.6	27.1							9
10					17.0	26.7							10
11					17.4	21.7							11
12					16.8	18.9							12
13					15.0	19.5							13
14					15.1	25.1							14
15					19.4	23.4							15
16					25.8	20.3							16
17					24.9	21.5							17
18					24.0	19.1							18
19					20.4	19.6							19
20					16.9	23.6							20
21					19.4	30.6							21
22					22.2	44.9							22
23					21.8	51.5							23
24					16.5	51.5							24
25					22.6	52.1							25
26				18.1	25.2	47.4							26
27				20.2	26.0	48.2							27
28				19.4	23.7	57.0							28
29				21.9	28.2	70.1							29
30				19.9	22.8	61.0							30
31					23.4								31
Sum				995.0	621.5	993.4							
Ave.				19.9	20.0	33.1							

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Annual Total (   )

DISCHARGE STATION JULUMITO

CAUCA RIVER, IN THE BASIN OF JULUMITO ELEVATION ____ UNIT ____ YEAR 1968

Table AP-1-(5)

DATE	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	16.0	11.9	16.4	18.4	13.6	18.9	18.0	21.3	15.0	14.6	25.7	27.9	1
2	15.2	11.9	20.6	17.5	13.8	23.8	19.8	21.4	14.1	13.0	19.4	24.6	2
3	13.1	15.0	17.9	15.1	17.3	20.6	24.8	17.1	13.4	12.1	19.6	23.4	3
4	12.4	16.9	18.5	14.3	19.6	21.4	19.8	14.7	14.5	13.1	20.5	24.5	4
5	12.1	15.4	18.4	14.0	17.7	21.2	20.4	13.4	14.2	16.2	23.7	27.1	5
6	11.1	14.6	15.2	12.9	16.8	17.5	15.2	14.6	20.9	29.6	27.9	24.0	6
7	12.7	16.7	13.4	14.5	19.3	15.5	15.4	15.4	15.1	35.0	26.8	30.6	7
8	15.3	11.1	38.6	17.7	12.9	44.5	12.8	20.3	14.9	25.7	22.5	32.3	8
9	33.8	11.0	43.9	39.0	12.6	49.3	14.0	19.7	13.8	19.4	61.3	23.7	9
10	52.2	15.2	39.3	60.2	17.5	42.9	17.9	13.5	16.6	23.0	36.1	21.3	10
11	52.1	18.0	23.2	60.1	20.9	26.8	16.4	12.9	16.9	27.3	54.4	22.0	11
12	45.2	14.9	17.6	52.0	17.2	20.4	14.7	18.8	14.7	23.4	27.8	25.6	12
13	38.5	30.6	15.2	44.4	35.2	17.5	14.8	14.4	14.8	33.8	54.0	26.6	13
14	20.8	19.8	27.9	24.1	22.9	32.2	17.7	16.6	13.9	22.1	48.8	23.0	14
15	11.5	13.2	51.5	13.3	15.2	59.3	21.2	16.7	13.0	22.9	65.0	25.7	15
16	11.9	11.9	32.4	13.7	13.6	37.4	47.2	18.1	14.9	23.0	54.7	25.7	16
17	12.7	10.4	20.8	14.6	12.0	24.1	62.1	18.0	14.7	23.0	27.9	20.2	17
18	14.9	11.5	16.5	17.2	13.3	19.0	47.2	16.7	14.7	27.8	30.2	19.7	18
19	11.0	13.9	16.6	12.6	16.0	19.1	31.7	17.0	14.9	42.2	40.6	19.6	19
20	12.1	11.5	17.1	14.0	13.3	19.8	37.3	15.3	16.8	25.7	61.8	26.7	20
21	11.1	11.1	13.4	12.8	12.7	15.3	71.0	18.8	15.6	22.0	38.4	24.6	21
22	12.1	16.4	11.9	14.0	18.8	13.6	59.2	16.4	14.8	25.0	34.8	25.1	22
23	19.4	18.4	11.9	22.4	21.2	13.7	46.7	15.5	14.2	21.4	30.3	28.7	23
24	18.8	15.9	26.4	21.7	18.4	30.5	31.9	13.7	15.9	22.6	26.6	27.8	24
25	15.3	19.4	20.8	21.1	22.4	24.1	23.9	13.6	15.4	41.2	58.0	25.1	25
26	26.1	18.4	19.4	30.1	21.2	22.4	21.4	12.3	15.7	45.4	59.0	22.6	26
27	27.1	16.1	14.4	31.3	18.6	16.7	56.7	12.7	16.1	24.5	53.0	17.8	27
28	20.4	14.0	14.2	23.4	18.6	16.4	81.3	14.2	16.5	70.0	29.3	20.1	28
29	14.6		14.3	18.8	16.2	16.6	61.2	13.2	16.4	26.0	49.2	25.0	29
30	13.7		14.3	15.2	22.5	18.8	45.1	14.0	16.6	25.8	45.9	21.4	30
31	13.7		14.3		20.8		31.3	16.0		36.5		16.7	31
Sum	616.9	425.1	656.3	698.4	552.1	737.0	1,018.1	497.3	450.1	833.5	1,172.2	749.1	
Ave.	19.9	15.2	21.2	23.3	17.8	24.6	52.8	16.0	15.3	26.9	39.1	24.2	

Annual Total (   )

DISCHARGE STATION JULUMITO

Table AP-1-(6)

CAUCA RIVER, IN THE BASIN OF JULUMITO ELEVATION ______ UNIT ______ YEAR 1969

DATE	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	22.1												1
2	20.2												2
3	18.2												3
4	20.2												4
5	16.5												5
6	12.2												6
7	13.2												7
8	13.7												8
9	14.0												9
10	14.9												10
11	13.7												11
12	12.1												12
13	13.9												13
14	19.2												14
15	24.2												15
16	25.7												16
17	23.0												17
18	18.4												18
19	27.9												19
20	25.9												20
21	20.7												21
22	54.6												22
23	23.5												23
24	39.3												24
25	32.2												25
26	24.4												26
27	17.5												27
28	24.4												28
29	22.6												29
30	29.8												30
31	25.5												31
Sum	683.7												
Ave.	22.0												

Annual Total (   )

MONTHLY AVERAGE DISCHARGE OF RIO CAUCA

Gauging Station: Salvajina

Catchment Area (sq.km): 3,830

Table AP-2

(Unit : cu.m/s)

Year \ Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1946	100.5	217.7	197.8	164.9	107.4	122.9	125.5	144.5	88.9	62.1	83.8	38.3	121.2
1947	51.6	121.1	144.0	128.7	106.3	74.6	61.0	72.6	94.6	94.1	77.1	73.6	91.6
1948	211.5	254.8	139.8	94.5	77.2	143.9	201.3	134.9	117.3	72.0	59.8	38.6	128.8
1949	92.6	135.1	122.9	149.1	150.6	119.6	126.5	160.1	120.9	98.0	78.8	63.5	118.1
1950	122.4	287.9	255.8	196.6	378.7	372.6	317.2	374.8	293.5	201.8	128.9	79.7	250.8
1951	126.7	268.7	335.6	224.3	207.8	184.1	130.0	145.0	124.9	118.5	72.9	65.2	167.0
1952	90.2	201.6	199.8	163.0	159.4	124.7	124.6	172.9	116.2	92.2	71.7	49.8	130.5
1953	62.2	147.0	240.9	150.8	124.8	100.0	126.9	127.9	106.1	81.6	59.1	54.2	115.1
1954	159.8	284.1	332.3	153.5	143.2	125.2	219.6	144.2	124.2	135.3	118.4	52.0	166.0
1955	164.3	257.3	343.6	233.6	122.4	210.3	213.8	193.2	164.8	147.3	92.7	84.2	185.6
1956	181.1	259.8	340.0	310.5	205.5	172.2	121.4	147.6	200.2	117.8	98.3	89.4	187.0
1957	168.0	187.1	238.5	183.5	95.7	130.9	136.1	195.6	164.9	90.4	63.6	46.2	141.7
1958	64.5	103.6	182.0	112.4	85.5	67.8	94.2	108.7	91.3	76.4	71.3	41.6	91.6
1959	56.2	133.2	160.7	138.9	83.7	62.9	77.5	119.6	127.8	104.7	59.3	52.1	98.0
1960	87.9	128.7	175.8	240.5	193.1	120.7	129.5	119.5	86.9	88.2	64.7	51.5	123.9
1961	80.1	172.6	229.5	111.1	90.9	77.7	141.8	88.8	119.1	101.2	71.7	41.9	110.4
1962	62.3	205.6	149.1	118.1	129.6	145.8	108.9	147.0	161.6	87.6	74.1	53.1	120.2
1963	94.2	161.7	267.3	121.1	218.4	152.4	227.7	209.3	132.1	93.9	82.2	49.4	150.8
1964	59.7	213.1	153.0	130.3	92.1	69.5	142.1	140.6	191.3	117.0	97.6	87.6	124.5
1965	120.8	189.5	226.3	162.5	106.0	77.7	126.5	141.6	74.1	77.4	55.4	45.0	116.9
1966	95.1	207.9	239.7	127.6	76.6	80.5	89.1	129.8	108.4	103.1	76.2	59.3	116.1
1967	112.6	274.0	605.5	195.3	199.0	187.9	132.0	137.4	160.0	120.6	91.9	50.2	188.9
1968	76.9	246.1	164.1	115.5	156.1	134.5	177.0	125.3	132.6	136.6	74.1	68.0	133.9
Average	106.1	202.5	236.6	162.0	143.9	132.9	145.6	151.3	134.8	105.1	79.2	58.0	138.2