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CHAPTER 3 HYDROLOGY

3.1 TOPOGRAPHY AND CLIMATE

The Chira and Piura Rivers are located in the coastal region of northern Peru and spring in the western slopes of the Andes to flow down to the Pacific Ocean. The topographies and climates of the two river basins are similar. The upstream parts of both rivers consist of a mountain range of elevations from 1,500 to 3,000 m and the terrain is steep and rugged. From midstream parts to downstream parts the topography changes from hills to desert and the river gradients are gentle at approximately 1:500.

The climate is hot and dry being close to the equator and influenced by the Niño Current (warm current).

3.2 PRECIPITATION

The Andes runs down the South American continent longitudinally from north to south and is the most distant from the Pacific Ocean coast in Peru. This causes humid air rising from the Pacific Ocean and transported by northwest winds to pass over the plain area of the Pacific Ocean coast and to be cooled on the western sllpes of the Andes resulting in rainfall. Because of this, there is hardly any precipitation seen in the Pacific Ocean coastal area of Peru which has been turned into a desert. The desert area on the Pacific Ocean coast of Piura Departament, where the two projects sites are located, corresponds to the northern end of this desert running north-south, and rainfall is less than 100 mm annually.

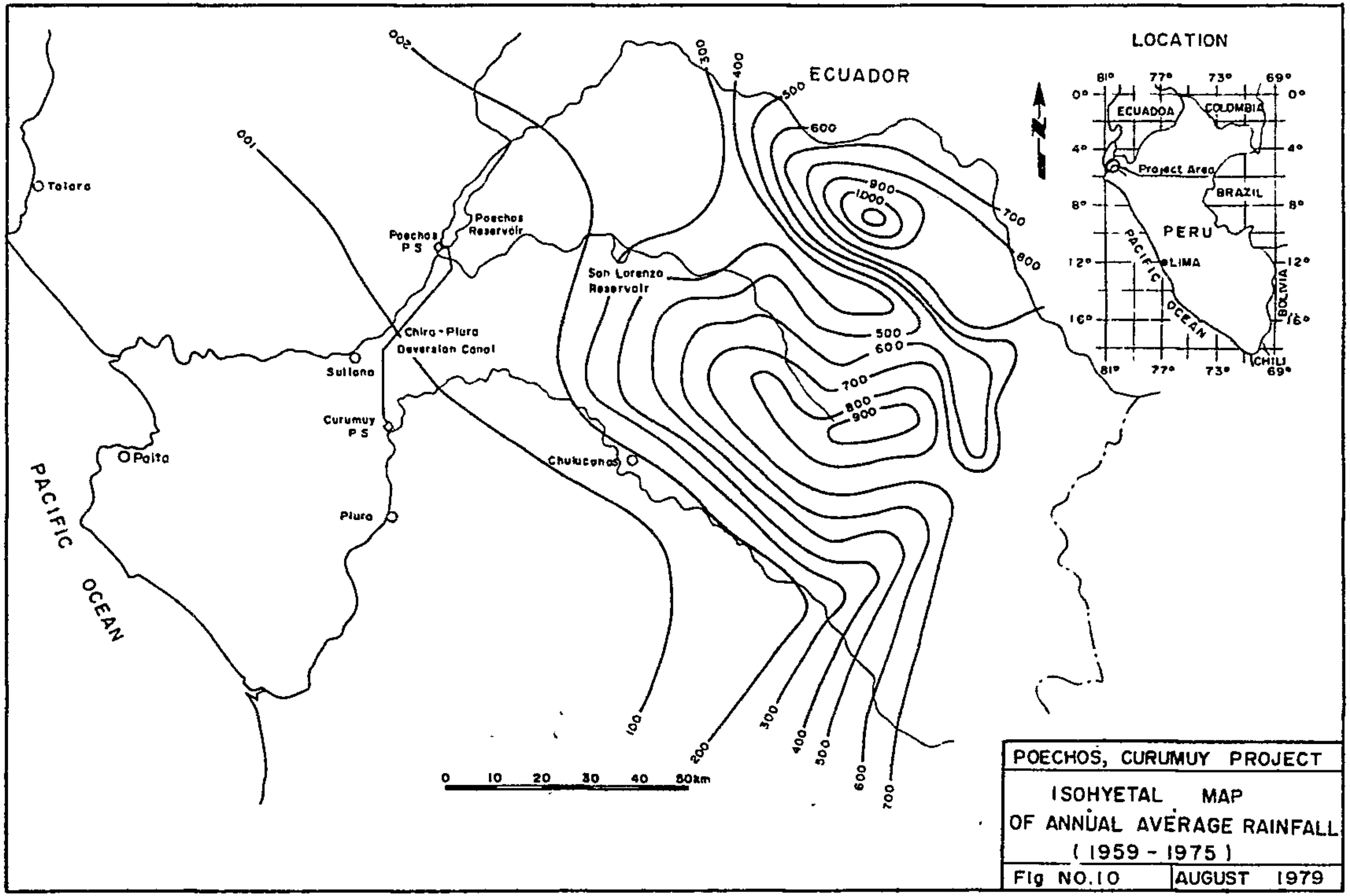
On the other hand, the foothills of the western slopes of the Andes Mountain Range receive approximately 1,000 mm of rainfall annually.

An isohyetal map based on annual average rainfall from 1959 to 1975 is shown in Fig. 10.

The annual average rainfalls of various hydroelectric power project sites are shown in Table II-3-1.

Table II-3-1 Annual Average Rainfalls at Hydroelectric Power Project Sites

Power Station	Annual Average Rainfall (mm)
Culqui	340
Yuscay	200
Poechos	130
Curumuy	60



POECHOS, CURUMUY PROJECT

ISOHYETAL MAP
OF ANNUAL AVERAGE RAINFALL
(1959 - 1975)

Fig NO.10 AUGUST 1979

The maximum daily rainfall measured during the past 5 years at San Joaquin Rainfall Gauging Station neighboring the Curumuy hydroelectric power project site was 46.9 mm.

3.3 EVAPORATION

The evaporation from the existing Poechos and San Lorenzo reservoirs estimated by Direction Ejecutiva del Proyecto Especial Chira-Piura (DEPECHP) of the Ministry of Agriculture is shown in Table II-3-2.

Table II-3-2 Evaporation from San Lorenzo and Poechos Reservoirs

Unit: mm

Month	J	F	M	A	M	J	J	A	S	O	N	D	Total
Evaporation	121	94	76	75	106	113	121	142	153	162	154	161	1478

The monthly maximum evaporation measured at Miraflores Observation Station near the Curumuy hydroelectric power project site was 220 mm.

The effects of evaporation must be examined for the two hydroelectric power projects in Poechos Reservoir and Curumuy Regulating Pondage.

With regard to Poechos Reservoir, examinations and analyses have been made by DEPECHP and an irrigation discharge plan based on the available water storage taking into consideration the effects of evaporation has been formulated and is being implemented.

As for Curumuy Regulating Pondage, the surface area is as small as 30,000 m^2, and even if the 220 mm/month measured at the Miraflores Observation Station were to be applied, the evaporation would be 220 m^3/day, and since seeing from the entire regulating capacity the evaporation loss would be only 0.2%, it was judged it would be unnecessary to consider evaporation in planning of the project.

3.4 TEMPERATURE

Temperatures at representative meteorological observation stations selected from those in the surroundings of the two hydroelectric power project sites which have long periods of observation enough to show temperatures by elevation in the respective areas are given in Table II-3-3.

Table II-3-3 Annual Average Temperature

Observation Station	Period	Elevation (m)	Annual Average Temperature (°C)
Curvan	1963 - 1975	80	25.1
Chilaco	1960 - 1976	90	24.1
Morropon	1963 - 1977	130	24.6
El Alto	1934 - 1976	295	21.1
La Tina	1963 - 1977	427	24.3
Sausal de Calucan	1963 - 1976	900	22.2
Ayaboca	1964 - 1976	2709	12.8

Further, the maximum temperature in the records of Miraflores Observation Station near the Curumuy project site is 37°C and the minimum 10°C.

3.5 GENERAL CONDITIONS OF THE CHIRA AND PIURA RIVERS

The Chira River is the most important river for the projects and its entire catchment area is 17,800 km^2. Of this area, 7,950 km^2 is in the Ecuadorian territory in the upstream part of the Chira River. The remaining 9,850 km^2 is in the Peruvian territory. The Chira River starts from the confluence of the Catamayo River and the Matara River, runs along the border with Ecuador for a short distance, after which it is joined by the Quiros River having a catchment area of 3,020 km^2 and the Chipillico River with a catchment area of 1,176 km^2 and flows down inside Peru.

The Piura River is located to the south of the Chira River and starts from the confluence of the Chigna River and the Huarmoco River. The major tributaries are the Bigote, Carral del Medio, La Gallega, Charanal and Yapate Rivers, including also, the Quebrada San Francisco into which surplus water from irrigation for San Lorenzo. The total of these catchment areas is approximately 7,100 km^2.

The major hydraulic structures to be provided in the Chira River basin are the following:

- San Lorenzo Reservoir on the Chipillico River
- Diversion Canal from the Quiros River to San Lorenzo Reservoir
- Canal of the San Lorenzo Irrigation Project including Yuscay Canal
- Poechos Reservoir for regulating irrigation water for Chira Valley and Bajo Piura Valley
- Chira-Piura Diversion Canal and large and small canal for utilizing water of Poechos Reservoir

Works to be completed in addition to the above for conducting water to cultivated land in the Chira-Piura valleys or to make improvements are the following:

- Catacaos Intake them to be provided on the Piura River and Sullana Intake Dam on the Chira River
- Improvements of Catacaos-Sechura Canal and of water distribution facilities of Piura Valley
- Improvements of Miguel Checa Canal and water distribution facilities of Chira Valley
- San Lorenzo Reservoir Phase II Project (increase of present capacity of 200×10^6 m^3 to 300×10^6 m^3)

The hydroelectric power projects in Piura Departament presently under study by the Peruvian Government are the following:

- Culqui Project
  Utilization of existing facilities for conducting water from the Quiros River to San Lorenzo Reservoir (25,000 kW)
- Yuscay Project
  Utilization of the chute of Yuscay Canal (2,500 kW)
- Poechos Project
  Planned immediately below Poechos Dam (7,600 kW)
- Curumuy Project
  Utilization of the chute at end of Chira-Piura Diversion Canal (9,000 kW)

The available discharges of the objects of the present study, the Poechos and Curumuy hydroelectric power projects, are entirely determined by the demand for irrigation water in the Piura Valley and the Chira Valley and DEPECHP determines the demand for irrigation water and the operating plan for Poechos Reservoir.

3.6 DEMAND AND SUPPLY OF IRRIGATION WATER

Agricultural land in Piura Departament presently is 28,000 ha in the Chira Valley, 30,000 ha in the Piura Valley, and 30,000 ha at San Lorenzo. These are the major areas of demand for irrigation water from the Chira River and the Piura River, while in the near future it is scheduled for 7,000 ha of farmland to be added in the Chira Valley.

The demands for irrigation water at the Chira and Piura valleys are indicated in Table II-3-4.

The demand areas supplied from Poechos Reservoir are the following:

- Chira Valley
  Downstream area of Poechos Reservoir
- Bajo Piura Valley
  Irrigation improvement area using water conducted by Chira-Piura Diversion Canal

Table II-3-4 The Demand for Irrigation Water at the Chira and Piura Valley

Month	Chira Valley		Piura Valley	
	(10^6 m^3)	(m^3/s)	(10^6 m^3)	(m^3/s)
Jan.	70	26.1	77	28.75
Feb.	70	28.9	65	26.87
Mar.	81	30.2	68	25.39
Apr.	73	28.2	108	41.67
May	69	25.8	138	51.52
Jun.	51	19.7	97	37.42
Jul.	37			
Aug.	34	12.7	46	17.17
Sep.	58	22.4	41	15.82
Oct.	69	25.8	72	26.88
Nov.	73	28.2	96	37.04
Dec.	55	20.5	77	28.75

- El Tablazo District
  District scheduled to be developed using water conducted by Chira-Piura Diversion canal

The projected supply quantities from Poechos Reservoir to meet the above demands are as shown in Table II-3-5 and Table II-3-6. The monthly average water levels of Poechos Reservoir in past years are given in Table II-3-7.

Table II-3-5 Monthly Average Discharge from Poechos Reservoir for China Valley and Poechos P.S.

Unit: m^3/sec.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1957				25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1958	24.27	26.87	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1959	24.27	26.87	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1960	24.27	25.94	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1961	24.27	26.87	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1962	24.27	26.87	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1963	24.27	26.87	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1964	24.27	25.94	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1965	24.27	26.87	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1966	24.27	26.87	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1967	16.43	18.19	19.04	17.36	16.05	12.35	8.59	7.84	13.89	16.05	17.75	13.07
1968	16.43	18.19	19.04	17.36	16.05	12.35	8.59	7.84	13.89	16.05	15.82	3.73
1969	20.91	26.87	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04
1970	24.27	26.87	28.00	25.85	23.89	18.13	12.69	11.57	20.83	23.89	26.23	19.04

Table II-3-6 Monthly Average Discharge from Poechos Reservoir for Piura Valley and Curumuy P.S.

Unit: m³/sec.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1957				25.46	51.90	33.57	27.26	15.68	10.03	20.54	29.71	23.15
1958	24.27	21.08	8.59	34.72	38.46	29.71	22.78	15.68	10.03	20.54	29.71	23.15
1959	22.41	16.12	10.08	53.63	45.56	31.64	25.39	15.68	10.03	20.54	29.71	23.15
1960	22.41	21.91	51.90	28.55	45.56	33.57	25.39	15.68	10.03	20.54	29.71	23.15
1961	22.41	19.42	17.55	34.34	45.56	31.64	25.39	15.68	10.03	20.54	29.71	23.15
1962	22.41	21.50	19.79	35.49	45.56	31.64	25.39	15.68	10.03	20.54	29.71	23.15
1963	22.41	21.50	19.79	35.49	45.56	31.64	25.39	15.68	10.03	20.54	29.71	23.15
1964	13.82	11.58	10.08	20.83	28.40	20.45	16.43	10.46	10.03	12.32	18.52	14.56
1965	22.41	19.43	10.08	14.28	28.40	30.09	24.27	15.68	10.03	20.54	29.71	23.15
1966	24.27	21.50	17.92	35.88	45.56	31.64	25.39	15.68	10.03	20.54	29.71	18.67
1967	13.82	11.58	10.08	20.83	28.38	20.45	16.43	10.46	7.33	12.32	18.52	14.56
1968	13.82	11.58	10.08	20.83	28.38	20.45	16.43	10.46	7.33	12.32	0.00	0.00
1969	0.00	11.58	9.71	19.68	28.38	20.45	16.43	10.46	10.42	12.32	18.52	14.56
1970	24.27	21.50	13.07	28.94	45.56	38.58	25.39	15.68	10.03	20.54	29.71	23.15

Table II-3-7 Monthly Average Water Level of Poechos Reservoir

Unit: m

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1958	97.35	99.35	102.00	103.00	103.00	103.00	102.85	101.20	100.90	101.55	100.05	98.20
1959	96.30	95.15	99.00	103.00	103.00	102.55	102.55	102.85	102.40	101.45	100.05	98.20
1960	96.55	98.25	101.75	103.00	102.95	102.70	102.40	101.95	101.50	100.40	98.25	95.90
1961	94.00	93.25	95.20	98.20	100.15	100.85	100.65	100.30	99.70	98.60	96.50	94.25
1962	94.35	97.75	101.60	103.00	103.00	102.95	102.80	102.80	102.80	102.55	100.95	98.90
1963	97.90	97.90	99.75	101.70	101.70	100.95	100.05	99.05	98.00	96.55	94.25	92.50
1964	92.10	92.20	92.75	94.15	95.30	95.80	95.95	95.80	96.35	96.50	95.30	93.25
1965	90.55	88.45	95.50	103.00	103.00	103.00	103.00	103.00	102.85	102.05	100.80	99.45
1966	99.00	99.70	101.50	102.95	102.60	101.55	100.60	99.90	99.10	97.80	95.15	92.05
1967	94.60	90.05	92.15	93.35	92.40	91.50	91.95	93.25	93.60	92.80	90.85	88.90
1968	87.55	86.80	88.65	90.10	88.10	85.30	85.50	86.90	86.55	85.45	84.35	84.00
1969	84.00	84.85	89.20	96.30	99.75	94.35	93.90	92.40	92.25	97.70	96.20	95.45
1970	96.50	99.80	102.55	103.00	103.00	103.00	102.85	102.80	102.55	101.70	100.40	99.75

3.6.1 Available Discharge for Diversion to the Piura River Basin

According to studies by DEPECHP the available discharge for diversion from Poechos Reservoir to the Piura River basin is as shown in Table II-3-8.

This available discharge is the quantity of flow which can be utilized for power generation at Curumuy Hydroelectric Power Station.

Table II-3-8 Available Discharge for Diversion to the Piura River

Persistence (%)	Discharge (m^3/s)
5	45.0
10	34.0
20	29.0
50	21.0
75	14.0
95	10.0
98	7.0

3.6.2 Available Discharge for Supply to the Piura River

The available discharge for supply to the Chira Valley, in effect, the discharge which can be utilized for the Poechos Hydroelectric Power Project, is as shown in Table II-3-9.

Table II-3-9 Available Discharge for Supply to the Chira River

Persistence (%)	Discharge (m^3/s)
5	28.0
10	27.6
20	26.0
50	22.8
75	17.1
95	11.9
99	8.0

3.7 MAXIMUM FLOOD DISCHARGE

Since Poechose Power Station is to be provided at the vicinity of the bottom outlet of the right-bank side of Poechos Dam, the flood discharge of this Project will be the same as that of the Chira River. The maximum flood discharge of the Chira River in the past was 4,800 m^3/sec. The design flood discharge is 5,500 m^3/sec., and the water level of the tailrace outlet of Poechos Power Station during the maximum flood will be El. 63.80 m. If the design flood discharge were to be exceeded, there is an emergency fuse-type earth dam (height 6.2 m, length 400 m), and it will be possible to discharge up to 10,000 m^3/sec. In addition, the bottom outlet can discharge a maximum of 300 m^3/sec.

The Curumuy Hydroelectric Power Project is based on conducting water from Poechos Reservoir by the Chira-Piura Diversion canal, and since the maximum capacity of this diversion canal is 70 m^3/sec, the power generation facilities will be provided with a spillway adequately capable of handling the excess even if 70 m^3/sec, were to come down. The tailrace outlet of Curumuy Power Station will be provided at the Piura River.

Consequently, the effects of flooding of the Piura River must be considered in planning of the power station. The water-level rise is estimated to reach El. 31.60 m during a 1,000-year return period flood of 4,600 m^3/sec estimated from the past maximum flood discharge of the Piura River in the vicinity of the tailrace outlet.

3.8 SEDIMENTATION

Since all of the water to be utilized in the Projects will first be stored in Poechos Reservoir, practically all of the sediment brought down from upstream of Poechos Dam will settle in the reservoir and water can be supplied without causing troubles to the turbines of the two power stations.

In the feasibility study for the Chira-Piura Irrigation Project it was estimated that the inflow of sediment would be about an annual 3×10^6 m^3 and to cope with this the reservoir possesses a capacity for sediment of approximately 170×10^6 m^3. However, according to recent measurements of the sediment inflow of the Chira River, a possibility has arisen that the measured values are considerably larger than the values estimated at the time of the feasibility study, and studies of the matter are presently being carried out by DEPECHP.

Poechos Power Station will utilize the bottom outlet, but it is possible that sediment will be removed through this conduit in the future. However, sand flushing is not of continuous nature and will not cause major hindrance to power generation.

Meanwhile, in the case of Curumuy Power Station, water will be conducted from Poechos Reservoir by the 54-km Chira-Piura Diversion Canal the route of which runs through a desert area. Because of this, it is thought that sand will enter the canal when winds are strong, but sand transported by wind will be fine-grained and the quantity will not be large, while the head at Curumuy Power Station will be as low as 40 m so that it is considered the effect on turbines will be small. Further, it is conceivable that sand brought in by winds and fine particles contained in the water coming down from Poechos Reservoir will settle in the regulating pondage, but the pondage will be made of such a structure that sediment can be removed eventually without great hindrance to power generation.

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APPENDIX - 2 Examination of Design Seismic Coefficients for Poechos and Curumuy Hydroelectric power Project Sites

CHAPTER 4 GEOLOGY

4.1 OUTLINE

4.1.1 Past Surveys

The survey below having relevance to the Poechos and Curumuy Hydroelectric Power Projects was made in the past.

In connection with implementation of the Chira-Piura Irrigation Project planned by the Ministry of Agriculture of Peru, the Yugoslavian consultant firm ENERGOPROJEKT compiled the results of a geological survey of the project area in 1974. In particular, detailed geological maps were prepared on the Poechos Dam and appurtenant facilities sites. Regarding the Curumuy project site a geological plan was prepared.

INIE, in view of the results of the above survey, published an interim report on the two power development projects in 1978. In this report, it is considered that there are no major problems from the standpoint of geology regarding the Poechos site since hard strata are deposited, while on the other hand, regarding the Curumuy site, because the foundations of major structures will be on deposits of a young age and the powerhouse site will be close to the Chira-Piura Diversion Canal, INIE has carried out permeability and other tests in order to study water springing which may occur during excavation work for the powerhouse and to consider measures for handling the water springing.

4.1.2 Present Survey

With regard to the geological conditions of the sites of the penstock, powerhouse and tailrace which are the principal structures in the Poechos Hydroelectric Power Project, judging from the conditions disclosed at the time of construction of the existing Poechos Dam, it was assumed there would be no major problems in carrying out the Project.

On the other hand, Curumuy Power Station is planned to be constructed on unsolidified sand and it was judged that special considerations would be needed regarding bearing capacity and permeability at the powerhouse site.

Consequently, in the present Study, an arrangement was made with a local contractor to carry out boring and standard penetration test works on this site, and data required for geological clarification of the foundation were collected.

The present Study therefore lays more emphasis on the Curumuy power station site as described below.

(1) Existing geological data on the Poechos and Curumuy Hydroelectric Power Project areas were collected and studied.

(2) Surface geological investigations of the vicinities of the principal structures of the Poechos and Curumuy Hydroelectric Power Projects were made.

(3) Four boreholes totalling 140 m were drilled in the Curumuy project area to find the composition of the ground strata, and standard penetration tests were performed to examine the bearing capacity of the ground. Further, based on the results of grain-size distribution tests on boring cores, coefficient of permeability was estimated and some study was made on liquefaction of sand.

(4) Representative samples were collected and examined with regard to aggregates for concrete.

4.2 CONCLUSIONS - ENGINEERING GEOLOGICAL CONSIDERATION

4.2.1 Poechos Hydroelectric Power Project

(1) A comparison was made of the left and right banks of the existing discharge channel as alternative sites for the powerhouse. At both sites the geology of the powerhouse foundation consists of Neogene shale, and judging from geological reconnaissances of the surroundings and existing data, there are no brecciated zones and gouge, or deterioration due to actions such as weathering, and bearing capacity will not be a problem.

(2) The facilities for branching from the bottom outlet and part of the penstock will be located at places where debris was backfilled during construction of the dam so that it will be necessary to make slope gradients during excavation as gentle as possible, but since shale is distributed at the foundation, there will be no problem from the standpoint of bearing capacity.

(3) The tailrace will pass through shale and there will be no problems regarding bearing capacity and excavation.

4.2.2 Curumuy Hydroelectric Power Project

(1) The project site is located in an unsolidified Quarternary diluvial sand deposit area.

(2) The foundations of both the regulating pondage and the penstocks are sand layers, but judged from the results of boring during the present Study, there will be no problem concerning bearing capacity. It is to be noted, however, that design and construction of the structures must consider the settlements and their effects on the structures.

(3) The foundation for the powerhouse site shows no problem about bearing capacity and occurrence of quick sand phenomenon because it has fairly compacted silt and clay layers, with more than 70 N values expected, according to the borings, although the foundation consists of sand layer as those for the regulating pondage and the penstock. It is necessary, however, to execute additional borings and

collect as many data as possible for further study of the foundation, because only two borings were executed for this study and there are places which showed small N values under the foundation level. It is also necessary to make permeability and grain-size distribution test in order to prepare a plan for water interception and drainage during construction.

(4) Embankment materials for the regulating pondage will be sand to be excavated for the pondage and it will be necessary to perform compaction tests on this sand.

4.2.3 Concrete Aggregates

Regarding concrete aggregates, both fine and coarse aggregates will be available from sand-gravel deposited relatively close to the two power station sites.

4.3 GENERAL TOPOGRAPHY AND GEOLOGY OF PROJECT AREAS

4.3.1 Topography

The topography of Peru, as shown in Fig.-11, may be divided into a number of characteristic morphologic provinces. With the Andes running through the national territory from northwest to southeast and occupying the western half of the land as the watershed, there are on the western side narrow coastal mountains (Cordillera de la Costa) and a plain belt (Llannura y depresiones constaneras) along the Pacific Ocean coast, and on the eastern side Sub-Andes range (Cordillera Subandina) extending in the upstream basin of the Amazon and the Amazon plains (Llanura Amazonica). The Andes is a huge range topped by peaks of 7,000m-class and having a succession of peaks higher than 5,000 m. The range is divided into the Cordillera Oriental and the Cordillera Occidental by the Interandes Trough which runs generally through the middle parallel to the axis of the range to reach the Titicaca Basin. Between the Cordillera Oriental and the Llanura Amazonica there is the Cordillera Subandina.

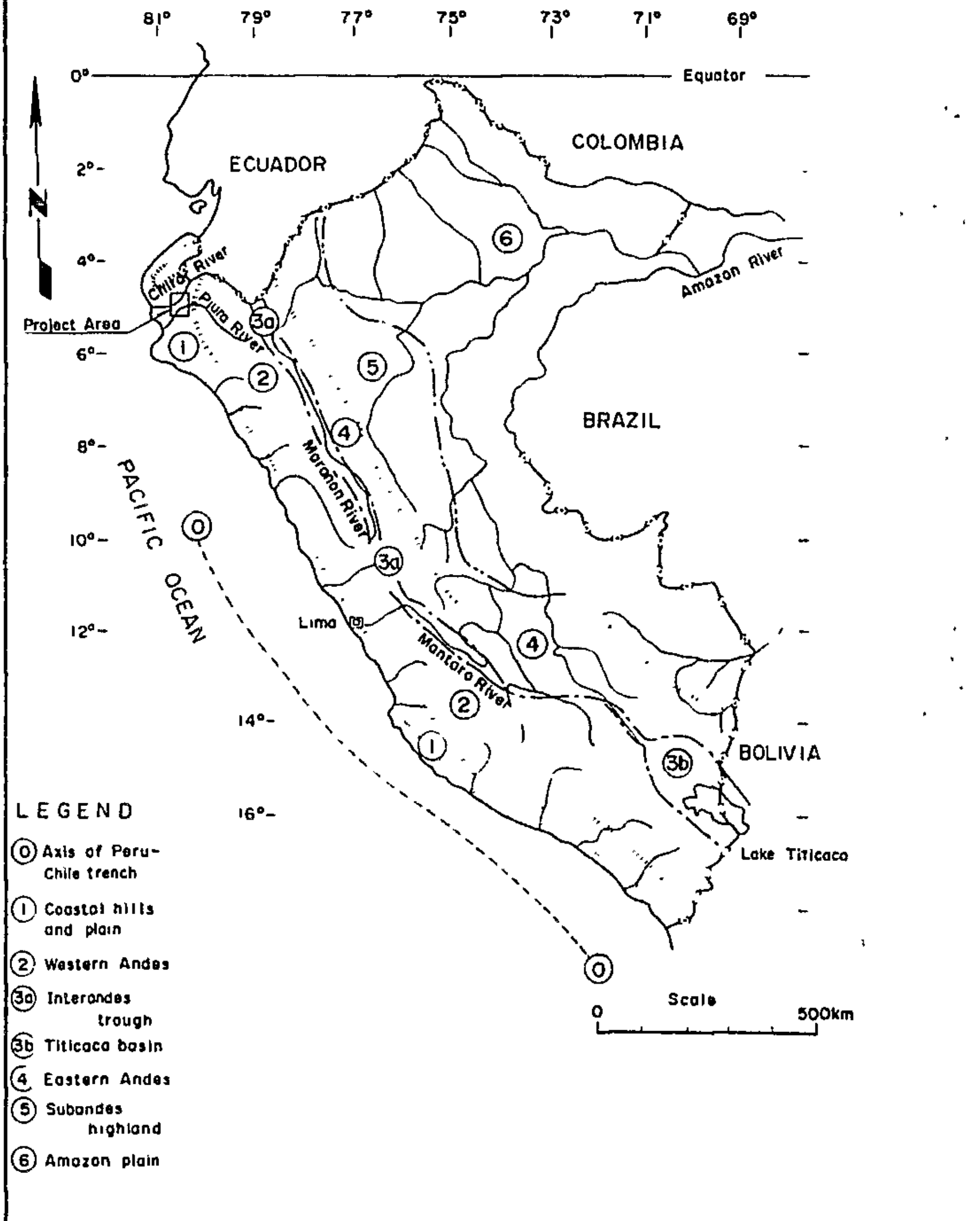
The present project area are located slightly to the east of the coastal belt along the Pacific Ocean approximately 900 km distant to the north-northwest of Lima, the capital city of the Republic of Peru.

This area is a desert divided by the Chira River and the Piura River.

The elevations of the project sites are several tens of meters above sea level, the land being flat, and there are farmlands and shrubbery spread along the river.

4.3.2 Geology

The rocks forming the national territory are sedimentary, metamorphic and igneous rocks, the geological ages being from Precambrian to Neogene, while the overlying Quarternary deposits are of diverse origins such as marine, lacustrine, aeolian and glacial.



POECHOS, CURUMUY PROJECT

MORPHOLOGICAL
PROVINCE OF PERU

Fig NO 11 | AUGUST 1979

The geology of the northwestern part of Peru in which this project area is located consists of Cenozoic formations (see Fig.-12). The north part (Poechos site) of the project area is made up of numerous formations reaching in age to Tertiary Eocene, and generally consists of shale, sandstone, lutite and conglomerate. Some boundaries of formations are in conformity with gradual transition from one age to the next, while others show remarkable unconformity due to erosion.

On the other hand, at the south part (Curumuy) site of the project area, there are thick deposits of unsolidified marine and continental Quarternary strata.

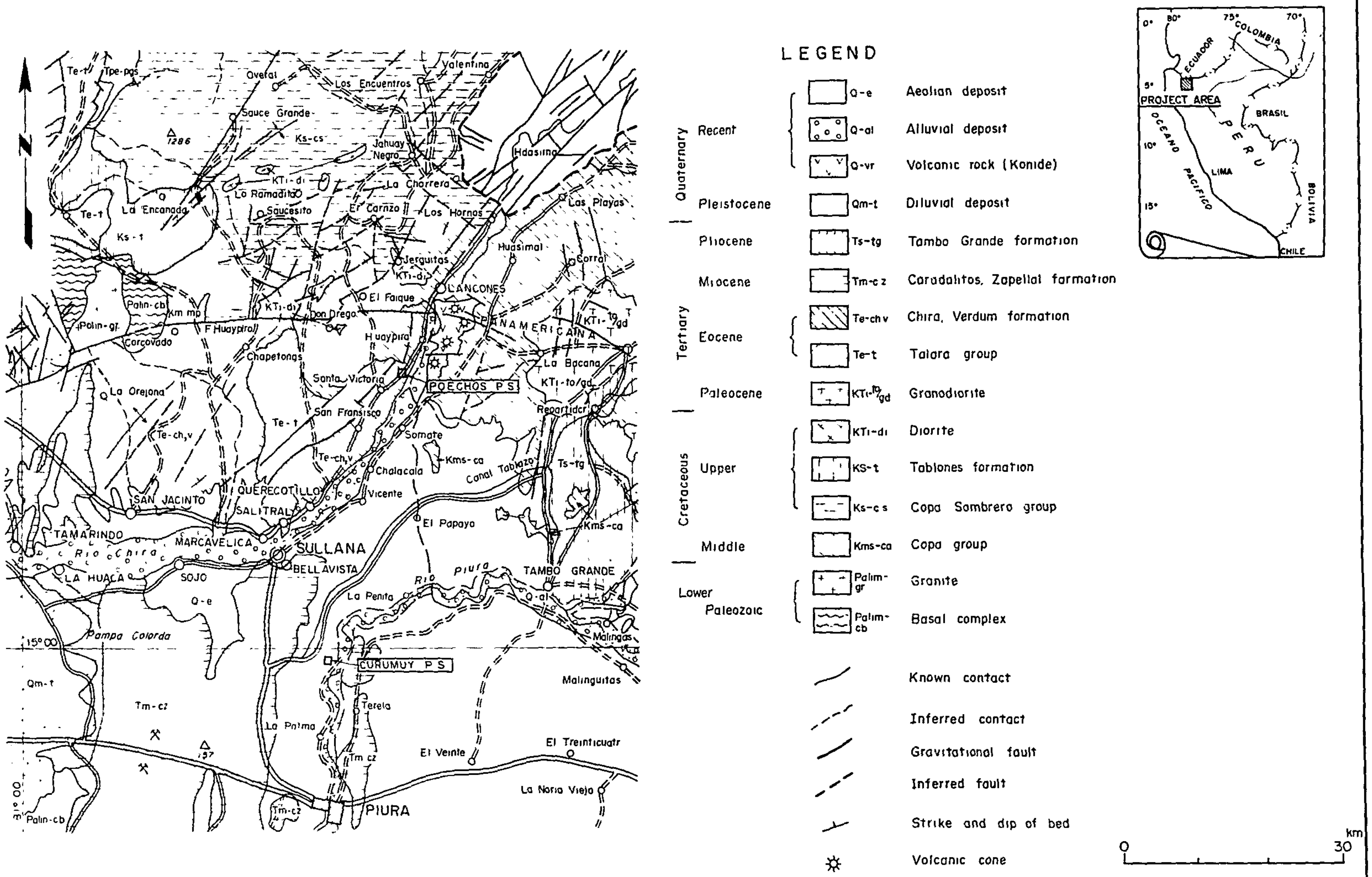
4.3.3 Earthquakes

Peru occupies a part of the Circum-Pacific Earthquake Belt surrounding the Pacific Ocean, and is one of the most earthquake-prone countries of the world. Fig.-13 shows epicenters of earthquakes within a radius of 100 km from the project area plotted from earthquake observation records for the 10-year period from 1962 through 1971 referring to data compiled by INIE.

The total number is 65, of which 50 were of magnitude 4 or stronger.

Although the epicenter of a major earthquake is not seen near the Poechos project site, there is a concentration of epicenters 50 km to the north of the project site in the vicinity of the border with Ecuador. However, earthquakes exceeding magnitude 6 have not been recorded.

Hypocenters of earthquakes of magnitudes from 4 to 6 are concentrated to the west of the Curumuy project site. Since the geology of this project site consists of unsolidified deposits, it will be necessary to make design giving thorough consideration to earthquakes. (See Appendix-2)



Note Cited from ' Geological Map , of Northwestern Peru and Southwestern Ecuador 1978 prepared by Sector Energia y Mineria, Instituto de Geologica y Mineria

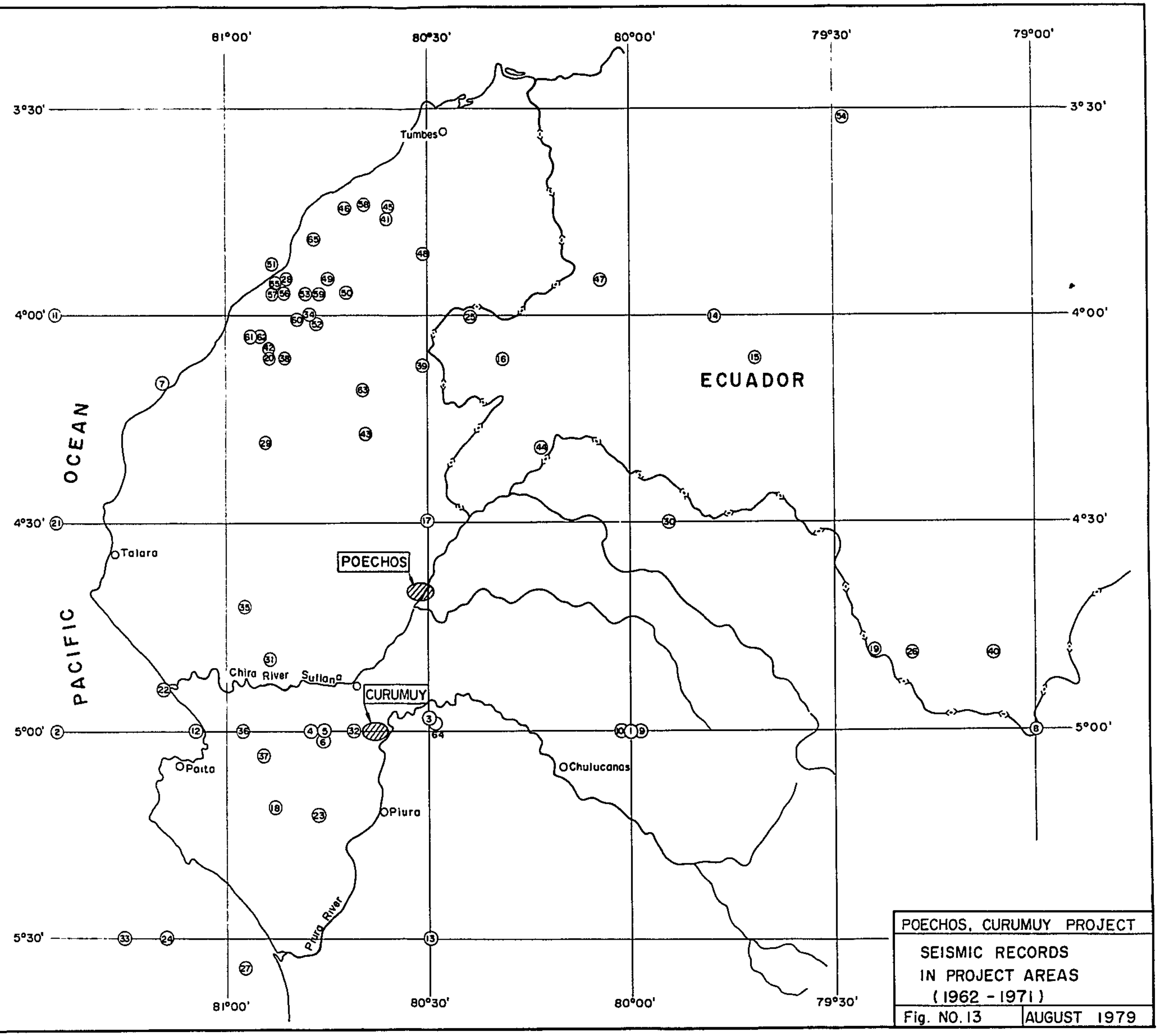
POECHOS, CURUMUY PROJECT

GENERAL GEOLOGICAL MAP OF PROJECT AREA

Fig NO 12 | AUGUST 1979

	Lat	Long
Poechos	4 40'	80 30
Curumuy	5 00'	80 40

D M Y	Lat	Long	Prof (km)	Mag (C G S)	Poechos D_1 (km)	Curumuy D_2 (km)	No
09.09 23	5 0	80 0	N	4 8	67	74	1
29 12 33	5 0	31 5	–	5 18	116	92	2
15 09 37	5 0	80 5		4 98	37	18	3
08 02 45	5 0	80 8	–	4 92	50	16	4
20 02 48	5 0	80 7		4 23	50	13	5
16 10 50	5 0	80 7	54	3 94	50	13	6
20 09 51	4 2	81 2	N	4 21	95	111	7
19 08 54	5 0	79 0	-	4 78	170	183	8
14 06 55	5 0	80 0		3 95	70	75	9
17 08 56	5 0	80 0	-	5 0	65	71	10
07 02 59	4 0	81 5	–	7 25	133	145	11
04 05 61	5 1	81 0	49	5 51	78	50	12
23 11 61	5 5	80 5	60	5 94	93	58	13
08 11 62	4 0	79 8	84	5 11	108	118	14
26 07 62	4 1	79 7	110	5 50	110	147	15
12 10 62	4 1	80 3	195	5 31	67	108	16
20 09 62	4 5	80 5	17	5 92	19	60	17
26 07 62	4 7	80 9	13	5 8	74	36	18
17 08 62	4 7	79 4	96	5 3	121	140	19
04 08 63	4 1	80 9	34	4 7	80	104	20
05 07 63	4 5	81 5	22	5 6	110	108	21
21 06 63	4 9	81 2	4	4 1	81	60	22
20 12 63	5 2	80 8	55	5 2	68	26	23
26 05 63	5 5	81 2	33	4 7	120	81	24
04 02 64	4 0	80 4	164	4 0	75	116	25
29 11 64	4 8	79 3	81	4 6	133	151	26
19 09 64	6	81 0	33	4 8	118	76	27
20 05 65	3 9	80 8	38	4 5	93	124	28
13 08 65	4 32	80 9	31	5 1	60	84	29
05 12 65	4 [illegible]	79 9	89	4 5	66	102	30
01 08 65	4 89	80 9	66	4 0	50	90	31
18 06 6	5 0	80 7	102	4 2	13	5	32
14 01 65	5 [illegible]	81 3	72	[illegible] 3	110	89	33
28 03 66	4 0	80 81	20	5 5	81	113	34
10 66	4 75	80 97	4	4 4	43	44	35
28 03 67	4 98	80 94	64	4 4	64	33	36
28 03 67	5 06	80 91	81	4 4	63	28	37
18 10 68	4 09	80 86	73	4 3	75	103	38
07 11 68	4 12	80 [illegible]	65	4 8	60	100	39
07 06 68	4 80	79 10		4 1	130	171	40
01 09 69	3 76	80 60	7	4 7	100	178	41
04 07 69	4 09	80 92	N	4	80	106	42
30 03 69	4 28	80 66	69	4 [illegible]	40	81	43
19 09 69	4 35	80 22	82	4 [illegible]	37	90	44
03 07 69	3 37	80 91	71	4 4	103	141	45
11 12 70	3 74	80 [illegible]	14	4 7	105	141	46
25 04 70	3 90	80 07	84	4 7	96	138	47
30 12 70	3 86	80 [illegible]	N	4 7	90	130	48
10 12 70	3 91	80 80	11	5 0	89	122	49
11 12 70	3 9[illegible]	80 72	37	5 7	83	118	50
29 12 70	3 89	80 90	47	4 8	88	128	51
10 12 70	3 98	80 72	33	5 4	79	113	52
15 12 70	4 02	80 8	12	7	87	119	53
07 0[illegible] 70	3 53	79 47	81	4 8	170	210	54
18 08 71	3 90	80 9	30	5 1	94	124	55
28 10 71	3 90	80 7	41	5 2	91	121	56
06 11 71	3 87	80 81	41	4 9	92	[illegible]	57
09 07 71	3 80	80 67	[illegible]	4 7	10	132	58
01 02 71	3 4[illegible]	80 8	66	4 9	[illegible]	118	59
17 07 71	4 01	80 83	3[illegible]	4 8	81	117	60
25 01 71	4 0[illegible]	80 94	31	4 9	8[illegible]	111	61
31 05 71	4 09	80 87	N	4 8	84	11	62
11 06 71	4 17	80 66	43	4	38	9[illegible]	63
25 04 72	01	79 92	18	4 9	89	134	64
12 05 72	3 87	80 71	40	4 8	101	134	65



POECHOS, CURUMUY PROJECT

SEISMIC RECORDS
IN PROJECT AREAS
(1962 - 1971)

Fig. NO. 13 | AUGUST 1979

4.4 GEOLOGY OF PROJECT SITES

4.4.1 Poechos Hydroelectric Power Project Site

(i) Topography

Since the Poechos hydroelectric power project is located immediately below the existing Poechos Dam the original topography has been altered, but as a whole it is a gentle hill area of elevations from 50 m to 100 m. The powerhouse site is at the entrance of a small valley which originally faced the Chira River. The powerhouse is planned at the left bank of the stilling basin (El. 52 m, width 24 m) of the Poechos Dam bottom outlet. Back of the concrete wall of the stilling basin there is a flat surface of about 10 m wide (El. 62 m), from which extends an excavated slope of approximately 30° up to around El. 75 m. Above this slope a vast gentle hill spread.

The depth of excavation to the powerhouse foundation will be a maximum of 25 m.

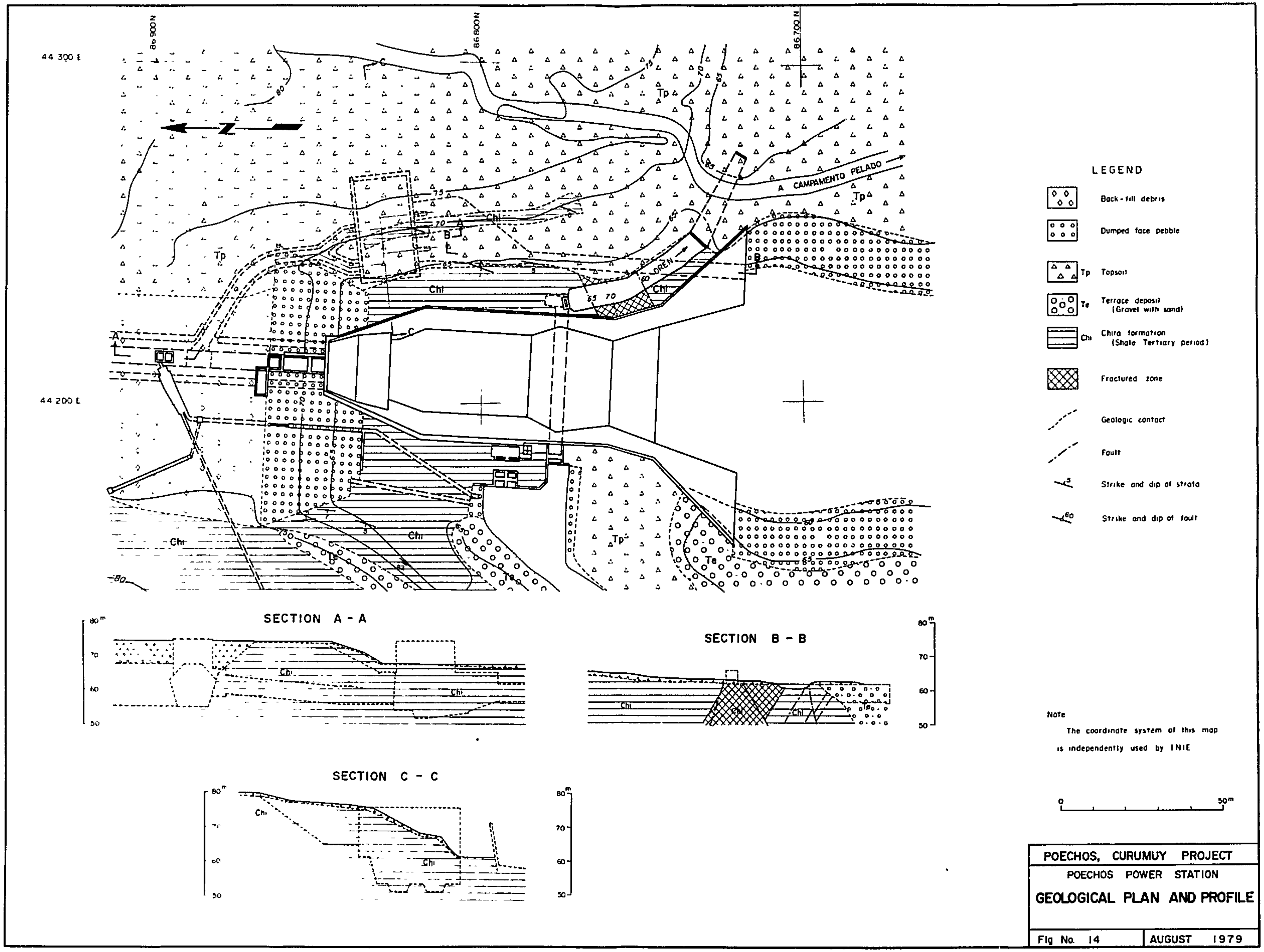
(ii) Geology

The geology of the project site, as shown in Fig.-14, consists of rock belonging to the Chira Vendum Formation correlated to Tertiary Eocene, partially covered by Quarternary terrace deposits and present alluvial deposits.

The Tertiary formation is a thick stratified formation made up of alternate beds from 10 m to 30 m in thickness of mudstone of high silt content, shale and sandstone. The strike of the strata is N20°E and the dip 5°NW. The terrace deposits are chiefly made up of cobbles of granites 10 cm or more in diameter with interstices filled by silt and fine sand. The alluvial deposits are mostly made up of gravels of granites containing also a small amount of andesite gravels.

The rock outcrop occurring in the vicinity of the powerhouse site is shale with the same strike and dip of the strata as the above-mentioned. The surface of the rock has been weathered and presents a reddish-brown color. There is a tendency to exfoliation along bedding planes into small fragments. However, according to data (boring cores, boring logs and geological profiles) of investigations made for construction of Poechos Dam, weathering has not extended very deeply, and fresh rock presents a grayish-green color and is hard and dense. The terrace deposits are seen above El. 80 m and thicknesses are up to a maximum of about 10 m.

At the powerhouse site shale is distributed covered by a thin layer of topsoil. This shale is fresh and hard at the powerhouse foundation and there will not be any problem only about bearing capacity, but also about excavated slope surface. The branching facilities from the bottom outlet and the penstock will also have shale as their foundations so that there will be no problem from the standpoint of bearing capacity, but since there are parts which were backfilled with debris, it



POECHOS, CURUMUY PROJECT
POECHOS POWER STATION
GEOLOGICAL PLAN AND PROFILE
Fig No. 14
AUGUST 1979

will be necessary to exercise care regarding safety of excavated slopes during construction.

The tailrace is also located in shale and there is no problem from the standpoint of geology.

(iii) Concrete Aggregates

It is estimated that the volume of concrete aggregates necessary for construction of Poechos Power Station will be approximately 7,300 m^3. Three areas are cited below as possible borrow areas, among which the Chira River aluvial deposit downstream of Poechos Dam will require the shortest hauling distance and is the most advantageous.

(1) Gravel is widely deposited at the Chira River downstream of Poechos Dam. This consists mainly of gravel, porphyry and andesite of uniform grain size from fist- to egg-size, and the content of sand is low. This gravel was used as aggregate for the construction of Poechos Dam also, and it is thus thought there will be no problem about quality, and it will be economical to sieve this gravel into coarse and fine aggregates for the construction of Poechos Power Station also.

(2) The terrace deposits are extracted at a place approximately 11 km south of Sullana City and sold as aggregate. The drawback in this case is that the distance of approximately 40 km is far from the Poechos Power Station site.

(3) Fine aggregate (medium-grained sand) is being produced for business at the right bank of the Chira River approximately 4 km north of Sullana City.

4.4.2 Curumuy Hydroelectric Power Project Site

(i) Topography

The project area is in the Cordillera de la Costa and Llanura y depresiones costaneras among the morphologic provinces of Peru described in 4.3.1, roughly in the middle between the sea coast and the Cordillera Occidental, where a gently undulating tableland spreads at elevations around 65 m. The Piura River has eroded this tableland to a depth of approximately 30 m and flows south meandering at amplitudes from two to several kilometers.

The regulating pondage site of this Project is located on the tableland of the right bank of the Piura River, while the powerhouse site is located on a flood plain at elevations about 30 m formed by the Piura River.

(ii) Geology

The project area consists mainly of Quaternary diluvial sand deposits which form a base of thick, unsolidified layers interspersed with silt-clay layers.

The ground surface is covered widely by an aeolian sand layer. Besides the above, alluvial deposits are distributed along the Piura River. As shown in Table II-4-1, one borehole was drilled each at the regulating pondage and penstock sites and two holes at the powerhouse site, and standard penetration tests utilizing these holes were performed.

Table II-4-1 List of Boring and Standard Penetration Tests at Curumuy Project Site

Hole	Location	Elevation (m)	Depth (m)	Standard Penetration Test (N.value)
1	Regulation pond	64.26	36.18	8
2	Powerhouse	29 37	40.00	17
3	Powerhouse	30.54	40.00	20
4	Penstock	55.37	23.82	8
Total			140.00	53

Borehole locations are shown in Fig.-15, the geological profile in Fig.-16, and boring logs in Fig.-17.

Judging from the results of boring, silt to clay layers between 22.2 m and 30.7 m in depth from the ground surface, or at 42.00 m and 33.56 m in elevation at Borehole B-1 and between 12.9 m and 16.8 m in depth from the ground surface, or between 42.47 m - 38.57 m in elevation at Borehole B-4 correlate to each other; and also other silt to clay layers found near the bottoms of the above-mentioned B-1 and B-4 seeing to be their continuance. The silt-clay layers seen at 32.2 m (El. -2.83 m) and 29.7 m (El. 0.84 m) from the ground surface at Borehole B-2 and Borehole B-3, respectively, and the above-mentioned layer seen near the bottoms of B-1 and B-4 sandwich between them a sand layer from 25 m to 30 m in thickness. The thickness of the silty flood plain deposits seen at the surface of the powerhouse site is about 3 m.

The results of penetration tests show that at B-1 (regulating pondage site) and B-4 (penstock site) N-values are from 20 to 50 in a range from the ground surface to 8 - 9 m in depth, with values higher than 50 in depths above 11 - 12 m. N-values show much variation at B-2 and B-3 (powerhouse site), and the values of about 25 at 28.5 m and 30.5 m at B-2 and the 0 at 14.0 m at B-3 are abnormally low compared with the values of layers above and below.

As for the regulating pondage and the penstocks, it is thought that there will be no problem regarding bearing capacity since the loads will be small. It is judged that the powerhouse foundation also possesses adequate bearing capacity, but since there are places showing low N-values in depth, it will be necessary to investigate this by performing additional penetration tests.

It will be unavoidable to make excavated slopes for the regulating pondage, penstocks and powerhouse considerably gentle since the ground layers consist of poorly graded medium grained sand. Also, in design of the embankment part of the regulating pondage where the similar materials will be banked, it will be necessary to carry out further materials tests to find an appropriate compaction method and a suitable slope gradient.

Existing data show permeability of the sand layer in the order of 10^{-3} cm/sec. Although the regulating pondage will be faced with asphalt, design and construction must be done in such a manner that the drain system of the foundation will work effectively. In construction of the powerhouse, excavation will be required to a depth more than 10 m below the groundwater table near the Chira-Piura Diversion Canal, so that careful study will be needed regarding water cut-off and drainage during construction.

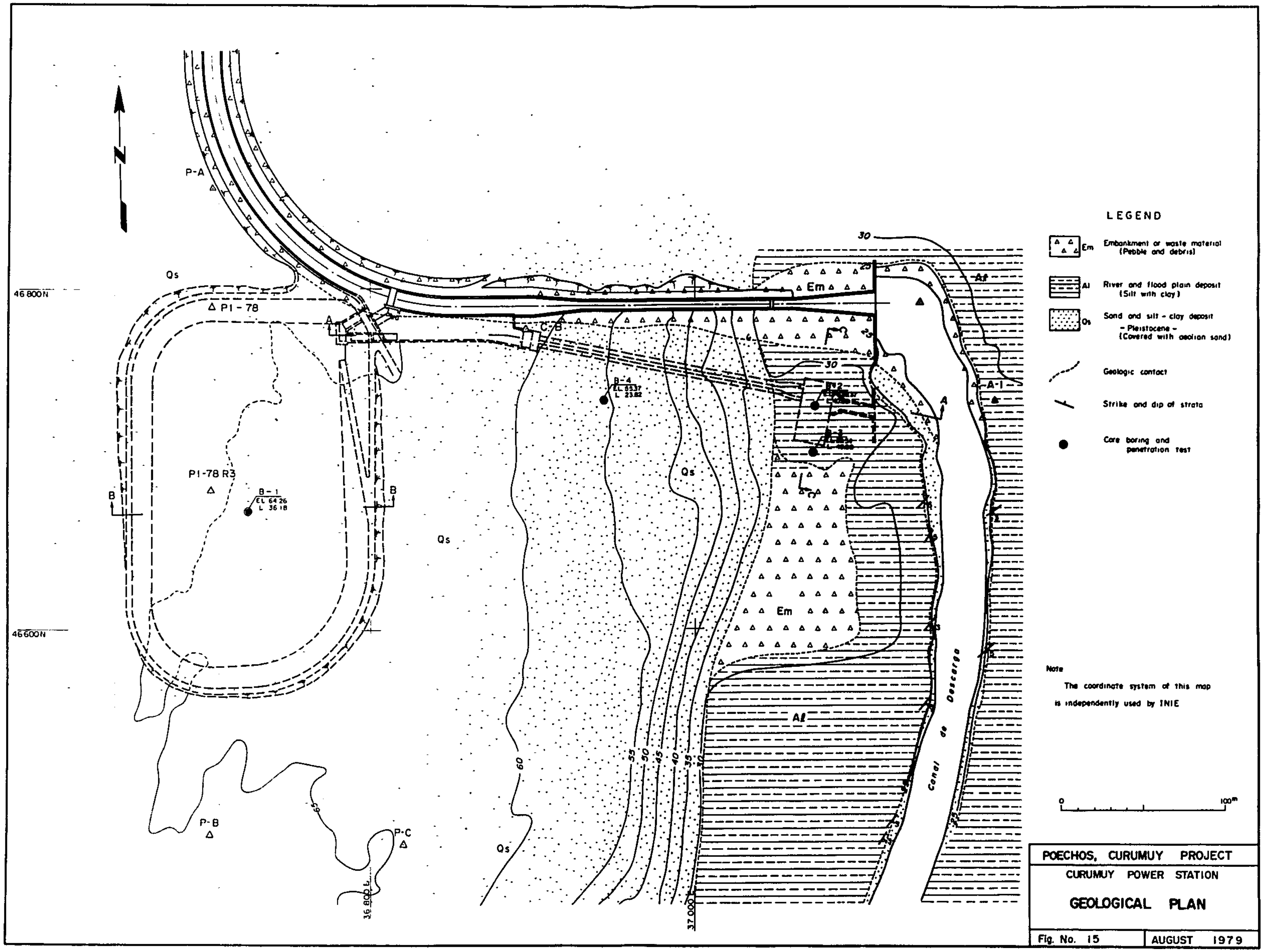
Phenomenon of liquefaction of sand during earthquake occurs when sand of uniform particle size is saturated by groundwater, and moreover, is not well-compacted. Judging from N-values, there is little possibility of occurrence of the phenomenon at the Curumuy powerhouse site, but it will be necessary to study this matter by carrying out additional penetration tests.

(iii) Concrete Aggregates

It is estimated that the volume of concrete aggregates required for construction of Curumuy Power Station will be approximately 11,000 m^3. As possible sites for borrow area, the following two may be considered, although the terrace deposits about 11 km to the west of Sullana are judged to be adequate as described for the Poechos Project.

(1) On a hill approximately 4 km west-northwest of the Curumuy power station site there is a quarry from where materials (foundation materials for irrigation waterway, subgrade materials for access roads, etc.) were obtained for works related to construction of Poechos Dam. Round gravels smaller than first-size the found mixed with fine sand and silt. The gravel has a high content of weathered sandstone in addition to granite and andesite, so there will be a problem with respect to quality.

(2) Although sand distributed widely and thickly on the hills around the regulating pondage site is poorly graded medium-grained sand, it will be possible to use this as part of fine aggregate.



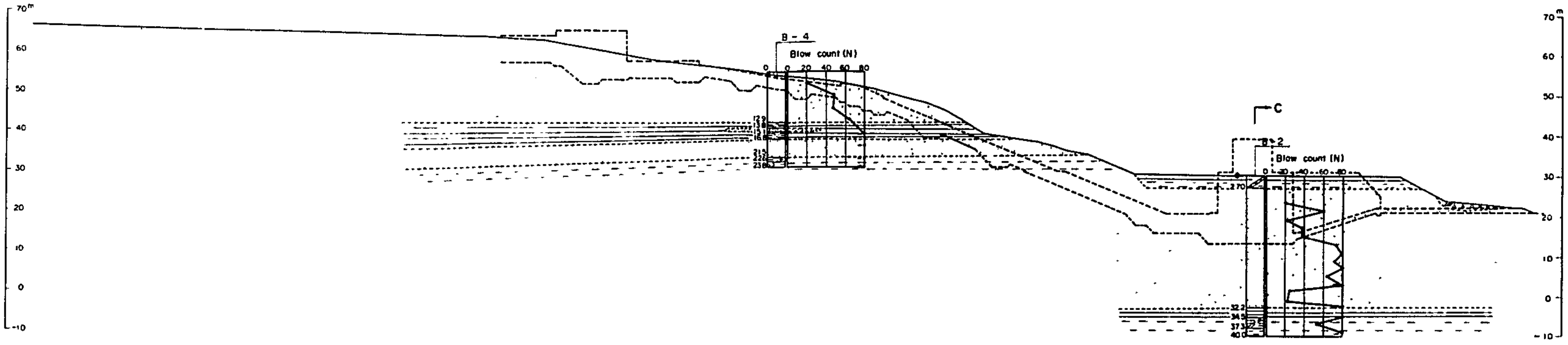
POECHOS, CURUMUY PROJECT

CURUMUY POWER STATION

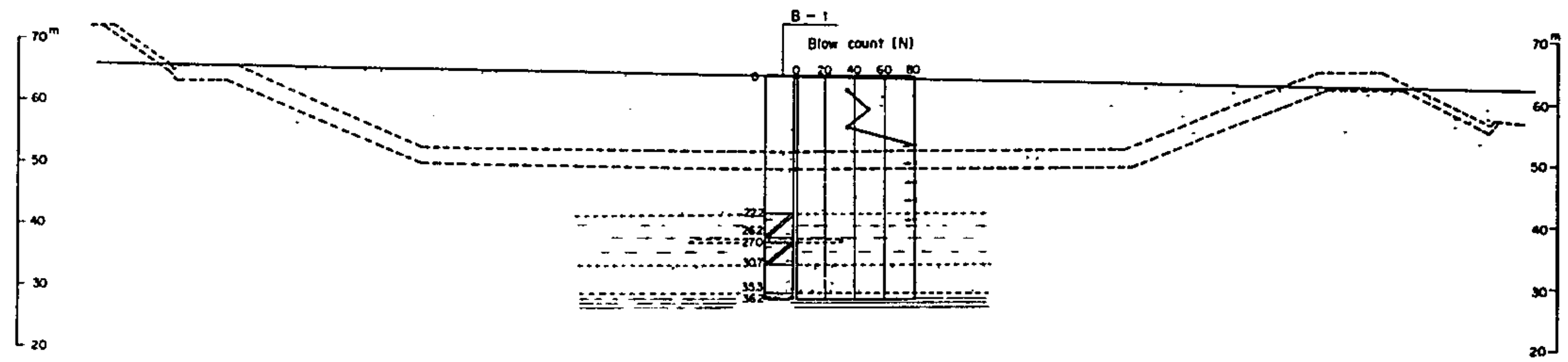
GEOLOGICAL PLAN

Fig. No. 15 | AUGUST 1979

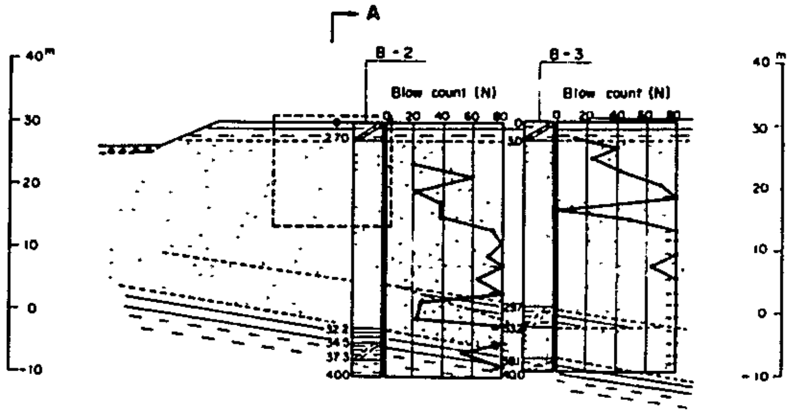
SECTION A - A



SECTION B - B



SECTION C - C



LEGEND

PROFILE

- △ Embankment or waste material (Pebble and debris)
- ▤ River and flood plain deposit (Silt and clay)
- ☐ Sand } Pleistocene
- ▤ Mainly silt } Pleistocene
- ▤ Mainly clay } Pleistocene

LOG OF BORING

- ☐ Sand
- ▤ Silt
- ▤ Clay
- ▨ Sandy
- ▨ Silty
- ▨ Clayey

0 50m

POECHOS, CURUMUY PROJECT

CURUMUY POWER STATION

GEOLOGICAL PROFILE

Fig No 16	AUGUST 1979

Fig.-17 GEOLOGIC LOG OF DRILL HOLE (1 - 8)

CURUMUY PROJECT HOLE No B - 1 (SHEET 1 OF 2)

LOCATION Regulating Pond
ELEVATION 64 26 m
COORDINATE
ANGLE FROM HOLIZONTAL 90 °
BEARING OF ANGLE HOLE

DEPTH OF HOLE 36 18 m
DEPTH OF OVERBURDEN m
LENGTH OF ROCK DRILLING m
TOTAL LENGTH OF CORE 36 18 m
CORE RECOVERY 100 %

COMMENCED 7 -Mar - '79
COMPLETED 15 -Mar - '79
DRILLED BY
LOGGED BY

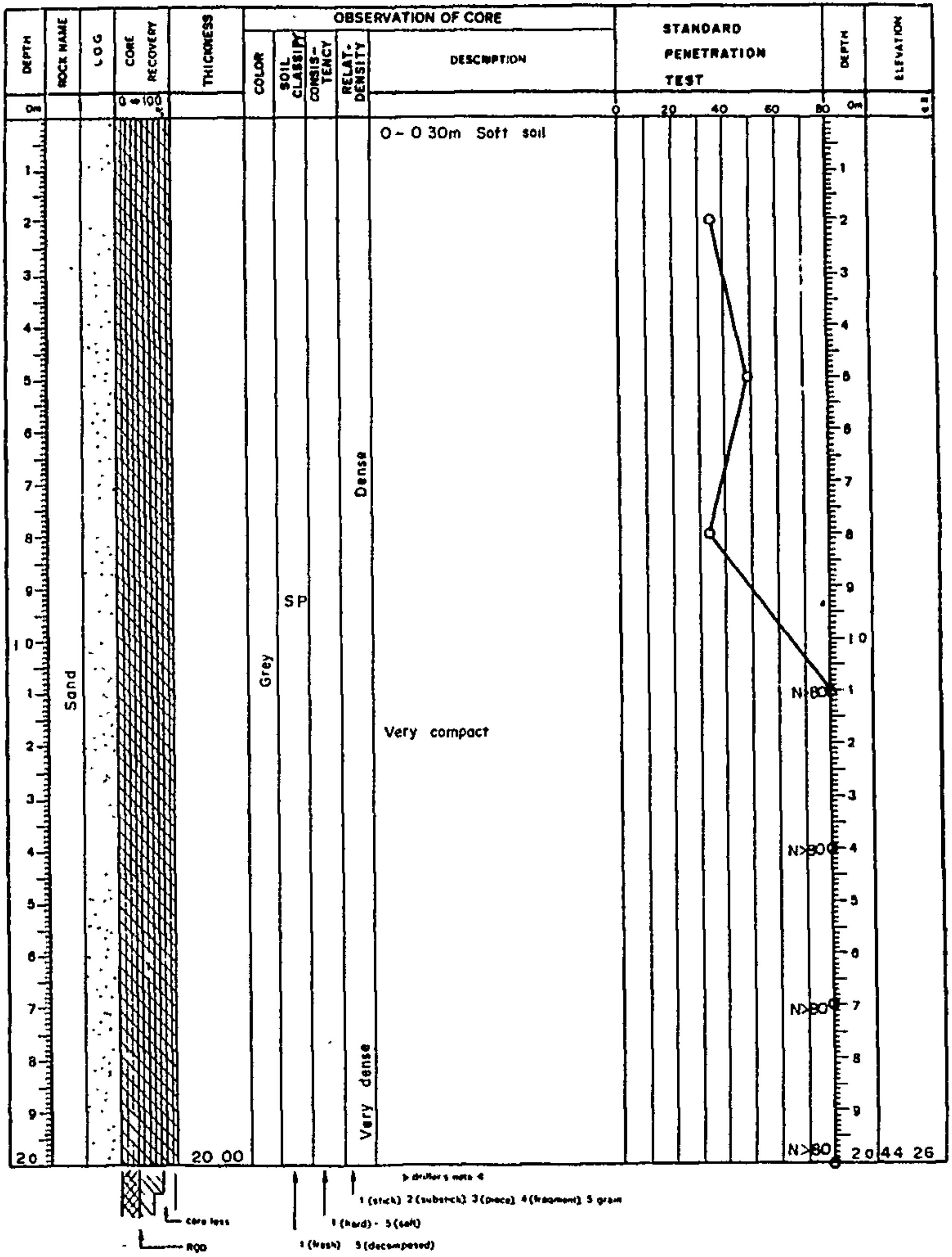


Fig - 17 GEOLOGIC LOG OF DRILL HOLE (2-8)

CURUMUY PROJECT HOLE No B - 1 (SHEET 2 OF 2)

LOCATION Regulating Pond
ELEVATION 64 26 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE
DEPTH OF HOLE 36 18 m
DEPTH OF OVERBURDEN m
LENGTH OF ROCK DRILLING m
TOTAL LENGTH OF CORE 36 18 m
CORE RECOVERY 100 %
COMMENCED 7 -Mar.- '79
COMPLETED 15 -Mar.- '79
DRILLED BY
LOGGED BY K ASANO

DEPTH 20m	ROCK NAME	CORE RECOVERY 0 – 100	THICKNESS	COLOR	SOIL CLASSIFI.	CONSIS-TENCY	RELAT. DENSITY	DESCRIPTION	STANDARD PENETRATION TEST 0 20 40 60 80	ELEVATION
2	Sand		22 20	Grey	S P		Dense	Lower cohesive soil		42 06
3	Sc		0 80		ML			With fine sand	N>80	41 26
	S		0 36		S P			Medium graded sand		40 90
	Sc		0 60		C L			No viscosity		40 30
6	Clayey silt		2 24		ML			Little viscosity		38 06
7	Sc		1 20		S M			Poorly graded		37 26
30	Clayey silt		3 50		ML			With fine sand		33 76
	Si		0 20		S M			No viscosity		33 56
	Sand		0 88		S P			Medium graded sand		32 68
2			0.52					Fine graded sand		32 16
	Sc		0 40		M L					31 76
3	Sand		0 70		S P			Medium graded sand		31 06
5			2 10					Coarse sand		28 96
6	Sc		0 88		ML			Very hard 36 18		28 08
								Bottom of hole		

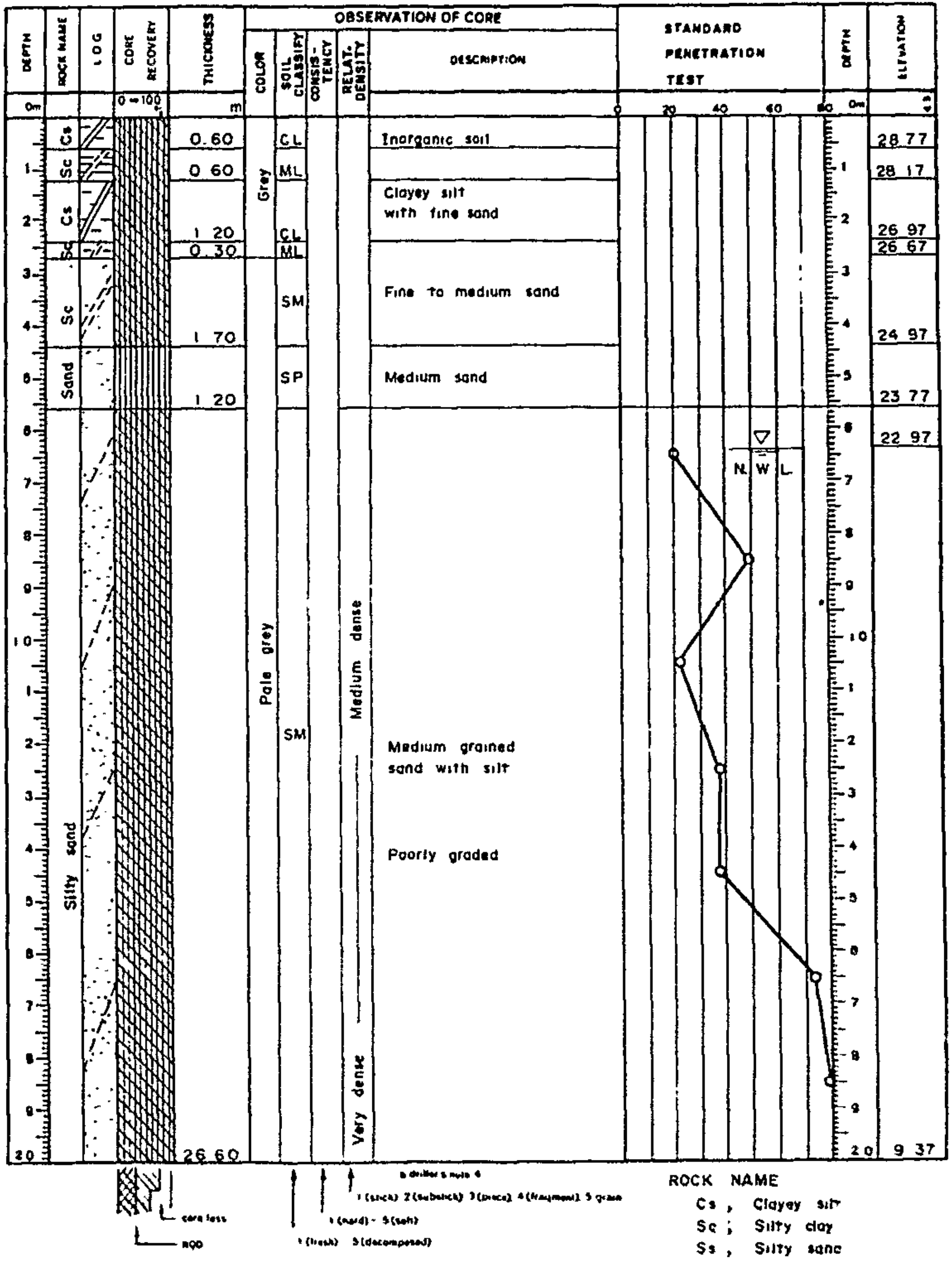
core loss
RQD
1 (fresh) 5 (decomposed)
1 (hard) – 5 (soft)
1 (stick) 2 (substick) 3 (piece) 4 (fragment) 5 grain
b driller's note 4

ROCK NAME
Sc ; Silty clay
S , Sand
Si ; Silt

Fig.-17 GEOLOGIC LOG OF DRILL HOLE (3-8)

CURUMUY PROJECT HOLE No B-2 (SHEET 1 OF 2)

LOCATION Powerhouse
ELEVATION 29 37 m
COORDINATE
ANGLE FROM HOLIZONTAL 90 °
BEARING OF ANGLE HOLE
DEPTH OF HOLE 40 m
DEPTH OF OVERBURDEN ---- m
LENGTH OF ROCK DRILLING m
TOTAL LENGTH OF CORE 40 m
CORE RECOVERY 100 %
COMMENCED 8 -Mar - '79
COMPLETED 16 -Mar - '79
DRILLED BY ------
LOGGED BY K ASANO



ROCK NAME	THICKNESS	COLOR	SOIL CLASSIFY	RELAT. DENSITY	DESCRIPTION	ELEVATION
Cs	0.60	Grey	CL		Inorganic soil	28 77
Sc	0 60		ML			28 17
Cs	1 20		CL		Clayey silt with fine sand	26 97
Sc	0.30		ML			26 67
Sc	1 70		SM		Fine to medium sand	24 97
Sand	1 20		SP		Medium sand	23 77
Silty sand	26 60	Pale grey	SM	Medium dense Very dense	Medium grained sand with silt Poorly graded	22 97 9 37

Fig.-17 GEOLOGIC LOG OF DRILL HOLE (4-8)

CURUMUY PROJECT HOLE No B-2 (SHEET 2 OF 2)

LOCATION Powerhouse

ELEVATION 29 37 m

COORDINATE

ANGLE FROM HOLIZONTAL 90°

BEARING OF ANGLE HOLE

DEPTH OF HOLE 40 m

DEPTH OF OVERBURDEN m

LENGTH OF ROCK DRILLING m

TOTAL LENGTH OF CORE 40 m

CORE RECOVERY 100 %

COMMENCED 8 - Mar - '79

COMPLETED 16 - Mar - '79

DRILLED BY

LOGGED BY K ASANO

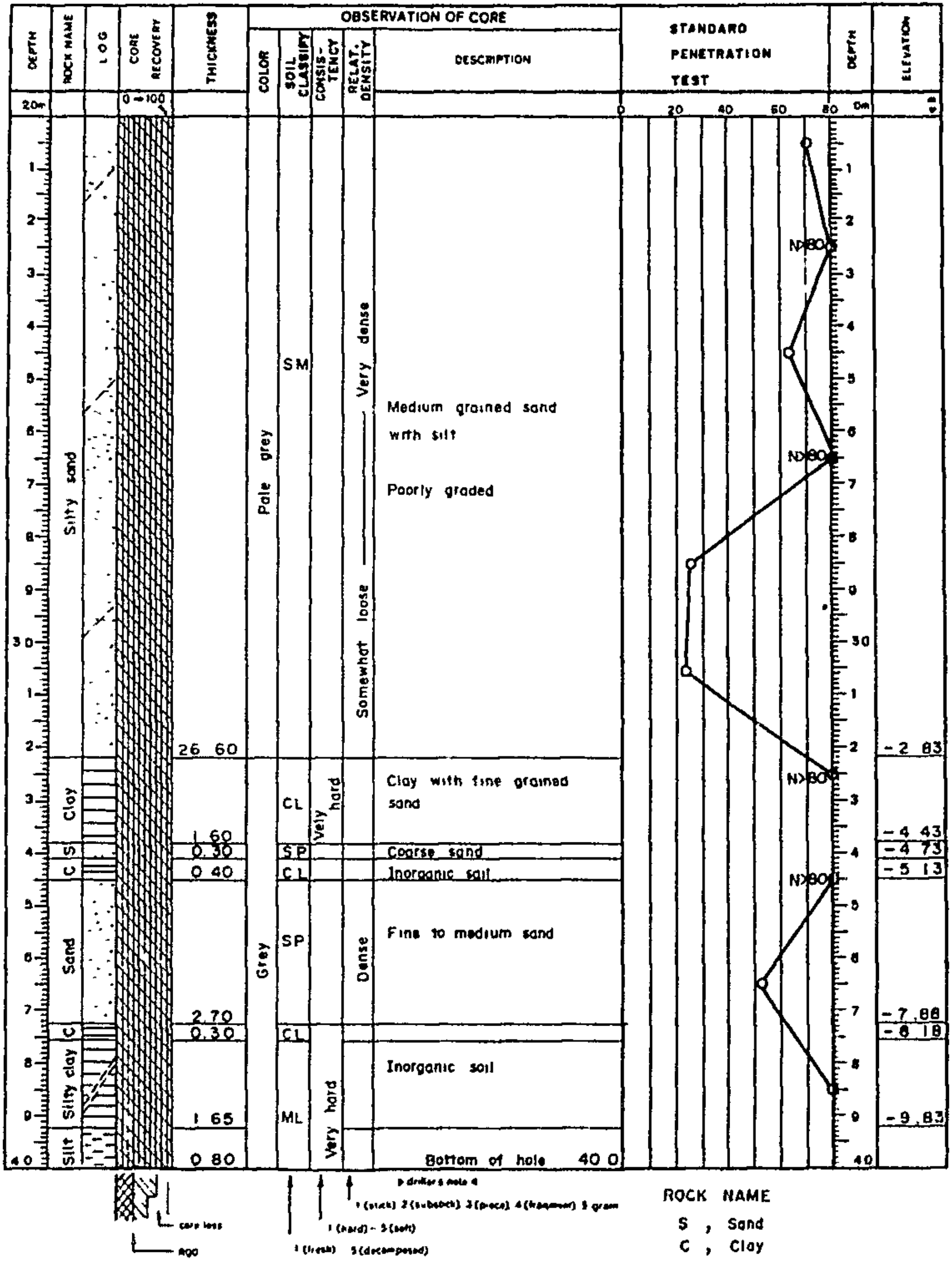


Fig.-17 GEOLOGIC LOG OF DRILL HOLE (5-8)

CURUMUY PROJECT HOLE No 8-3 (SHEET 1 OF 2)

LOCATION Powerhouse
ELEVATION 30 54 m
COORDINATE
ANGLE FROM HOLIZONTAL 90 °
BEARING OF ANGLE HOLE

DEPTH OF HOLE 40 m
DEPTH OF OVERBURDEN m
LENGTH OF ROCK DRILLING m
TOTAL LENGTH OF CORE 16 m
CORE RECOVERY 40 %

COMMENCED 16-Mar.-'79
COMPLETED 21-Mar.-'79
DRILLED BY
LOGGED BY K ASANO

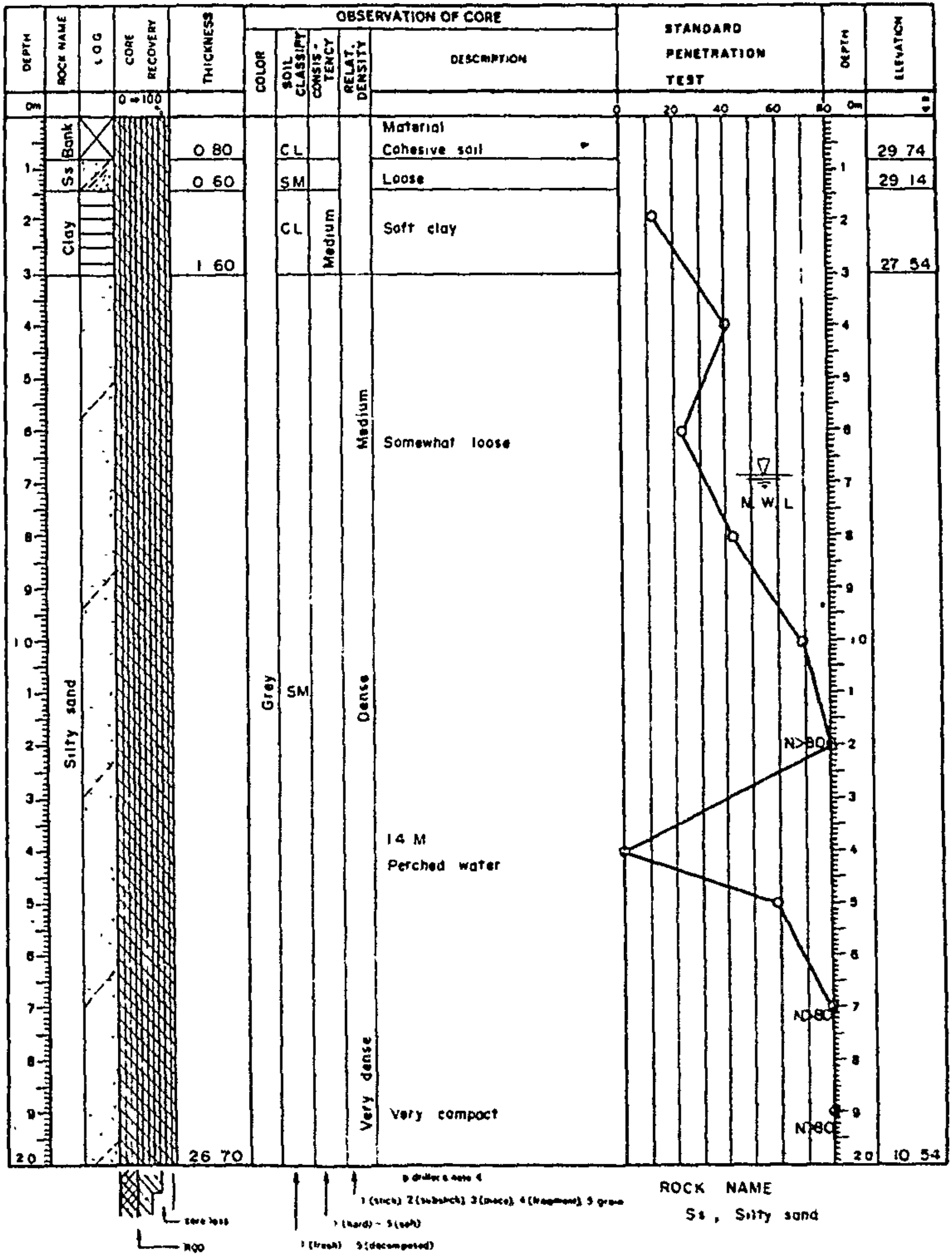


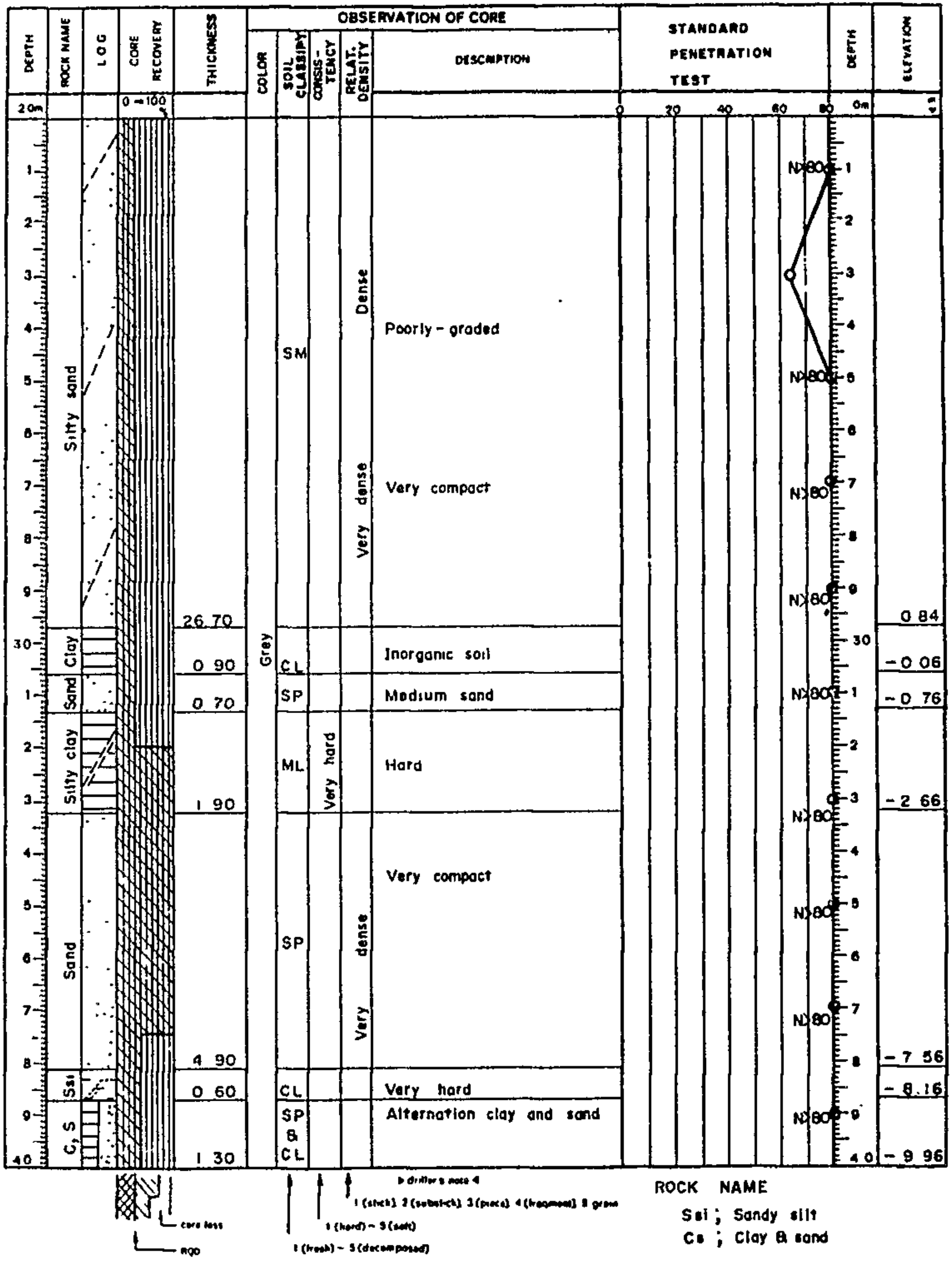
Fig.-17 GEOLOGIC LOG OF DRILL HOLE (6-8)

CURUMUY PROJECT HOLE No 8 - 3 (SHEET 2 OF 2)

LOCATION Powerhouse
ELEVATION 30 54 m
COORDINATE
ANGLE FROM HOLIZONTAL 90 °
BEARING OF ANGLE HOLE

DEPTH OF HOLE 40 m
DEPTH OF OVERBURDEN m
LENGTH OF ROCK DRILLING m
TOTAL LENGTH OF CORE 40 m
CORE RECOVERY 100 %

COMMENCED 16 -Mar - '79
COMPLETED 21 -Mar - '79
DRILLED BY
LOGGED BY K ASANO



ROCK NAME
Ssi ; Sandy silt
Cs ; Clay & sand

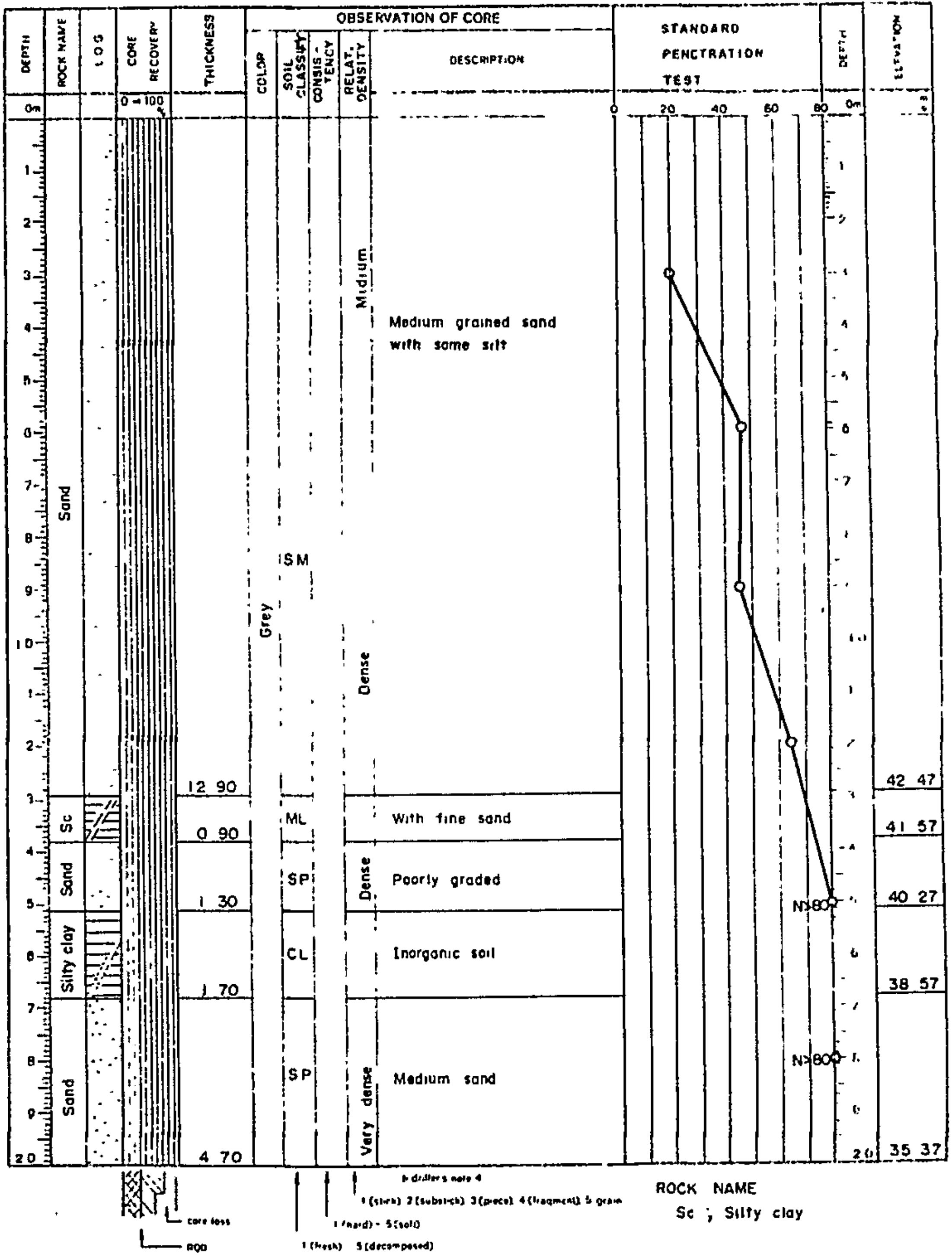
Fig.-17 GEOLOGIC LOG OF DRILL HOLE (7- 8)

CURUMUY PROJECT HOLE No B - 4 (SHEET 1 OF 2)

LOCATION Penstock
ELEVATION 55 37 m
COORDINATE
ANGLE FROM HOLIZONTAL 90
BEARING OF ANGLE HOLE

DEPTH OF HOLE 23 82 m
DEPTH OF OVERBURDEN m
LENGTH OF ROCK DRILLING m
TOTAL LENGTH OF CORE 23 82 m
CORE RECOVERY 100 %

COMMENCED 17 -Mar- '79
COMPLETED 21 -Mar- '79
DRILLED BY
LOGGED BY K ASANO



ROCK NAME
Sc ; Silty clay

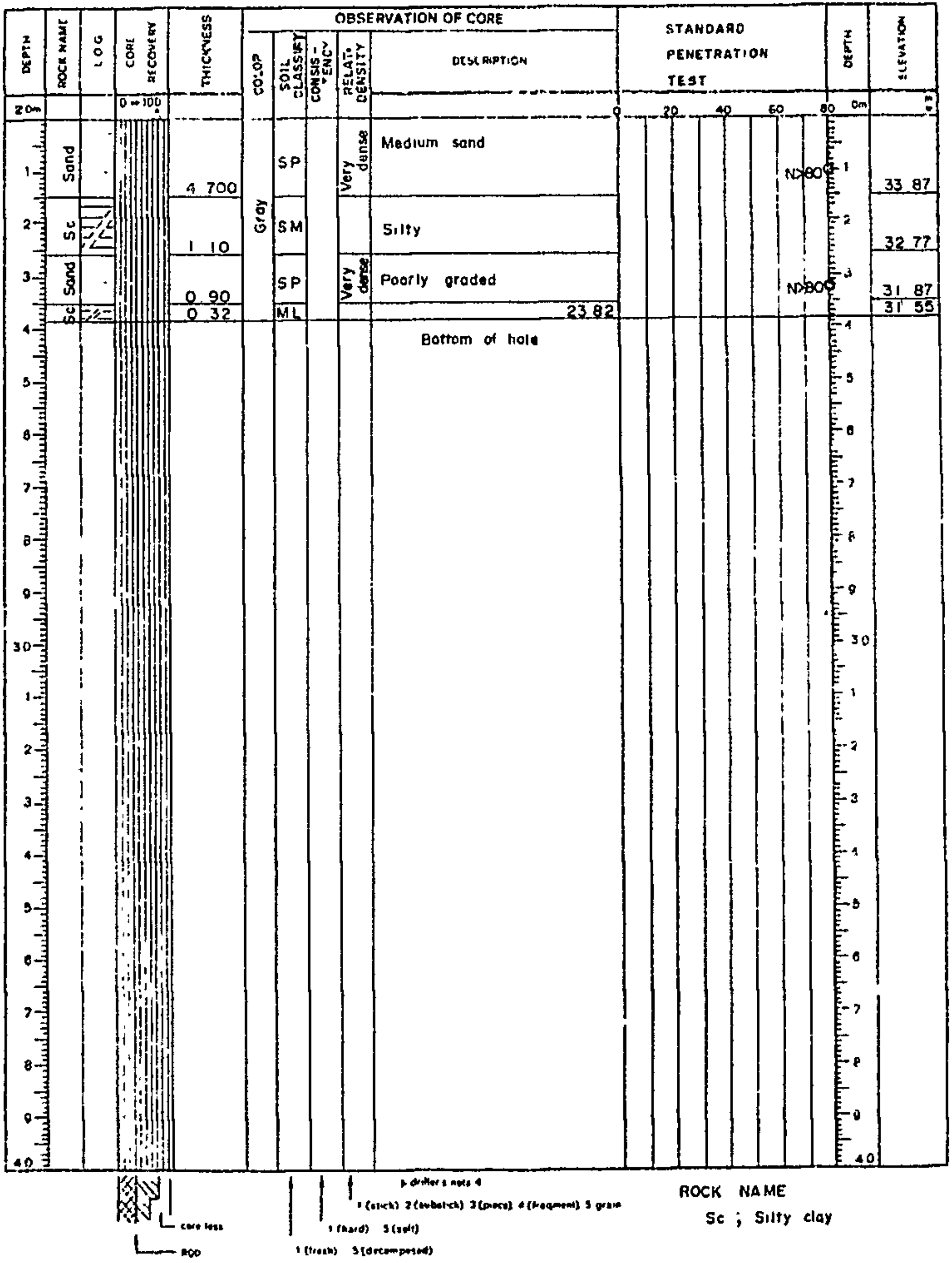
Fig.-17 GEOLOGIC LOG OF DRILL HOLE (8-8)

CURUMUY PROJECT HOLE No B - 4 (SHEET 2 OF 2)

LOCATION Penstock
ELEVATION 55 37 m
COORDINATE
ANGLE FROM HOLIZONTAL 90 °
BEARING OF ANGLE HOLE

DEPTH OF HOLE 23 82 m
DEPTH OF OVERBURDEN m
LENGTH OF ROCK DRILLING m
TOTAL LENGTH OF CORE 23 82 m
CORE RECOVERY 100 %

COMMENCED 17 -Mar - '79
COMPLETED 21 -Mar - '79
DRILLED BY
LOGGED BY K ASANO



DEPTH	ROCK NAME	THICKNESS	COLOR	SOIL CLASSIFY	CONSISTENCY	RELAT. DENSITY	DESCRIPTION	STANDARD PENETRATION TEST	ELEVATION
20m									
	Sand	4 700	Gray	SP		Very dense	Medium sand	N>80	33 87
	Sc	1 10		SM			Silty		32 77
	Sand	0 90		SP		Very dense	Poorly graded	N>80	31 87
	Sc	0 32		ML			23 82		31 55
							Bottom of hole		

ROCK NAME
Sc ; Silty clay

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CHAPTER 5 POWER GENERATION SCHEME

5.1 BASIC CONSIDERATIONS

The Poechos and Curumuy Hydroelectric Power Projects aim to supply electricity to the Piura area, utilizing the various facilities of the existing Chira-Piura Irrigation Project, effectively using the water discharged based on irrigation plans and the head produced during water diversion for the power generation.

Prior to going into the details of the Projects, the following items were given to give basic considerations upon which the power generation scheme was decided.

(1) Power generating system

(2) Layout of civil structures

(3) Utilization of bottom outlet of Poechos Dam

(4) Development scale

(5) Capacity of Curumuy Power Station regulating pondage.

5.1.1 Power Generating System

The entire electric power service area of the Poechos and Curumuy Hydroelectric Power Projects is being supplied by deisel generators. According to past performance records, about 30% of the facilities is constantly shut down for maintenance and repair, and the reliability of supply is poor.

Poechos and Curumuy Power Stations are hydro, and the reliability will be high compared with diesel generators.

However, in the case of Poechos Power Station, the irrigation discharge varies between 28.0 m^3/sec and 8.0 m^3/sec depending on demand, while the head will vary from 44 m to 19 m according to water level fluctuations of Poechos Reservoir. If power generation had to be done in step with the irrigation demand, the output would at certain periods become less than 30% of the installed capacity and the supply area would require thermal power plants to supplement the difference.

Consequently a turbine type, with which peaking operation of the power station can be done producing a constant output even if the irrigation demand is a minimum and with the reservoir water level at a minimum, shall be adopted, and the water discharged at that time is to be equalized to water demand for Sullana Intake Dam presently being planned by DEPECHP of the Ministry of Agriculture so that it can be used as irrigation water, and this scheme is to be facilitated.

As for Curumuy Power Station, it will not be affected by water level variation of the Poechos Reservoir, and the seasonal variation of the water discharged based of Irrigation Plan for Curumuy Power Station will be greater than that for Poechos Station. Moreover, since the diversion canal from the Poechos Reservoir has a length of 54 km, it will not be possible to regulate volume of water to be turbined in accordance with fluctuation in corresponding power load.

Therefore, consideration was given to providing adjacent to the head tank a regulating pondage capable of hourly regulation at Curumuy Power Station, thereby making it possible for peaking operation when the irrigation water demand is small. The water after power generation, similarly to Poechos, is to be equalized to water demand for Catacaos Intake Dam being planned on the Piura River.

As described above, both Poechos and Curumuy Power Stations are planned to be utilized for base operation with full output when discharge for irrigation is large, and for peaking operation when the discharge is small.

5.1.2 Layout of Civil Structures

(i) Poechos Power Station Site

Poechos Power Station is to be operated for base load during the irrigation season and for peak load at other periods conforming to the operation schedule of Poechos Reservoir, the purpose of which is irrigation in the first place.

Accordingly, a re-regulating pondage has been planned in consideration of the influence to be made on irrigation water intake of the Chira River downstream area during peak load operation. The site planned for the re-regulating pondage is located at the right-bank side downstream of the stilling basin of Poechos Dam, and since there is no other place where an alternative can be provided, the Study was carried out with the powerhouse location considered at the right-bank side of the energy stilling basin. Subsequently, however, DEPECHP set up a plan to construct an irrigation intake dam at the Sullana site, which is decided to be completed in 1982. If this irrigation intake dam is constructed, it will become possible to regulate the peaking power generation discharge of Poechos Power Station, and it will no longer be necessary to provide a re-regulating pondage immediately downstream of Poechos Power Station.

Consequently, where as the powerhouse location was planned up to this time limited to the right-bank side by reason of the projected site of the re-regulating pondage it became necessary to examine left-bank alternative.

Therefore, out of the right-bank and left-bank alternatives, the two most economical as indicated in Fig.-18 were selected, and these were subjected to a comparison study. As a result of the study, it was decided to adopt the left-bank proposal for the reasons given below.

(1) There are no existing diversion canal on the left-bank side so that there will be no interruption of irrigation supply due to relocation work and there

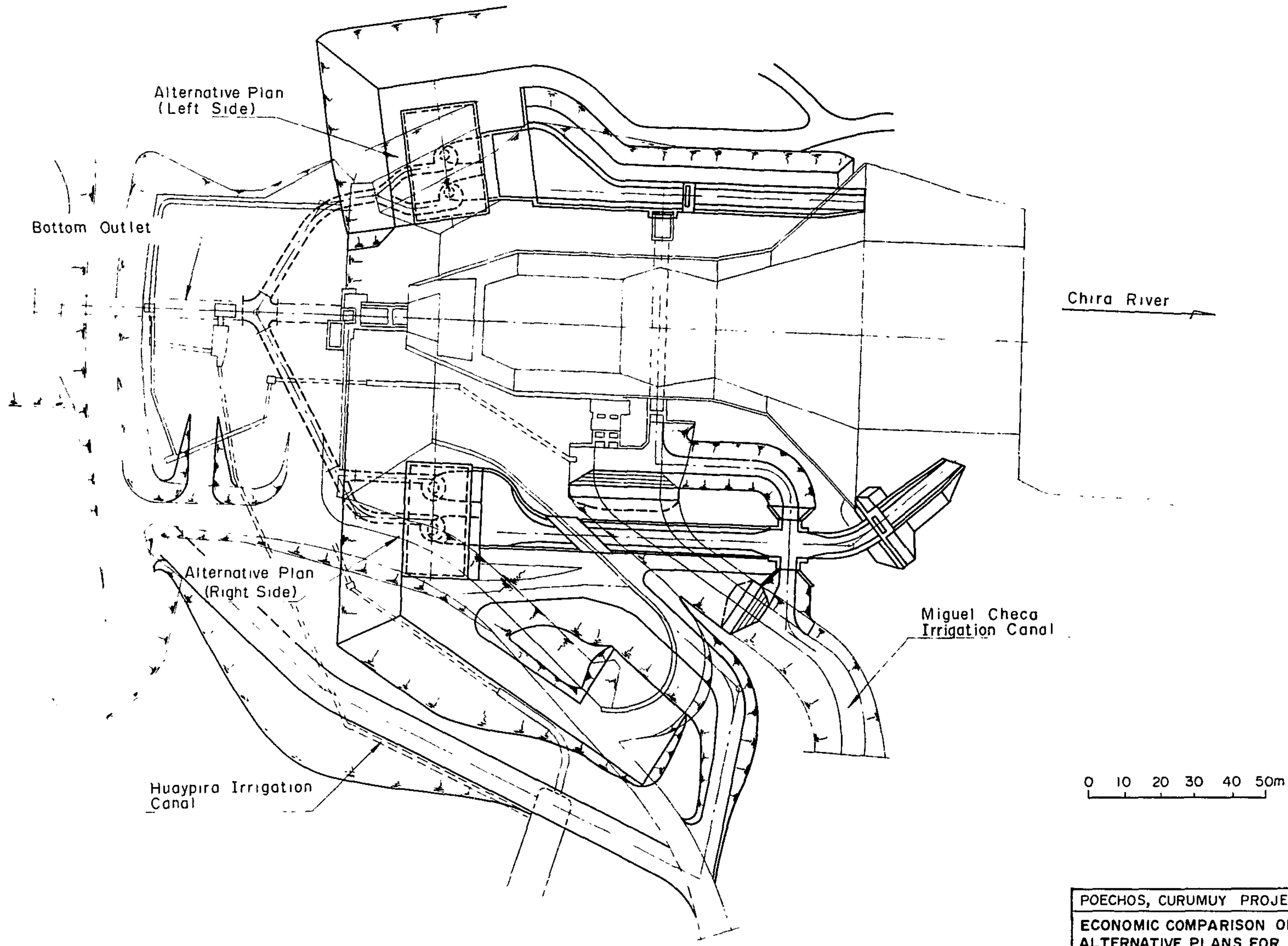
will be no adverse effects on the downstream area.

(2) Road relocation will be required in case of the right-bank proposal.

(3) Seen from a topographical standpoint, the left-bank side has an open space suitable for installing temporary facilities, and approach to the work area will be easy.

(4) As the result of a rough comparison of construction costs the left-bank side will be cheaper.

(5) With the right-bank proposal, the tailrace would be affected by high water levels during floods of the Chira River making power generation impossible.



POECHOS, CURUMUY PROJECT

ECONOMIC COMPARISON OF ALTERNATIVE PLANS FOR POECHOS POWER STATION

Fig NO 18 | AUGUST 1979

(ii) Curumuy Power Station Site

The locations of the headrace and the powerhouse were selected at the right side of Chira-Piura Diversion Canal in view of the present to topographical condition of the canal. Further, the flow in the canal will be small during the non-irrigation period, and it will be impossible for power generation to be done so that a regulating pondage will be necessary. The capacity was determined based on duration of the peaking power generation time. The point of intake from the diversion canal was made at the rectangular cross section part of the canal to make construction of intake facilities easy, and was determined considerating the spillway facilities of the regulating pondage and the head tank.

The regulation of the power generation discharge was initially planned to be done by providing a regulating pondage at the left-bank side of the present canal to regulate flow for discharge, but there is now a plan being contemplated by the Ministry of Agriculture to construct a dam on the Piura River (a site near by Catacaos City) in order to secure water resources for irrigation of the Bajo Piura area. Therefore, it was judged that an re-regulating pondage would be unnecessary for Curumuy Power Station, and it was eliminated from the present design.

5.1.3 Development Scale

(i) Basic Conception

The heads available for Poechos and Curumuy Power Stations are limited since both will utilize the structures of the existing Chira-Piura Irrigation Project.

The available discharge is determined by what degree of discharge based on the irrigation schedule planned by month is utilized for power generation. Therefore, 6 comparison proposals were made up varying the available discharges of the Poechos and Curumuy Power Stations, and the scales were determined calculating the respective energy productions, construction costs, annual costs (C) and annual benefits (B), and judgments were made from both the aspects of B/C and B-C.

(ii) Development Scale of Poechos Power Station

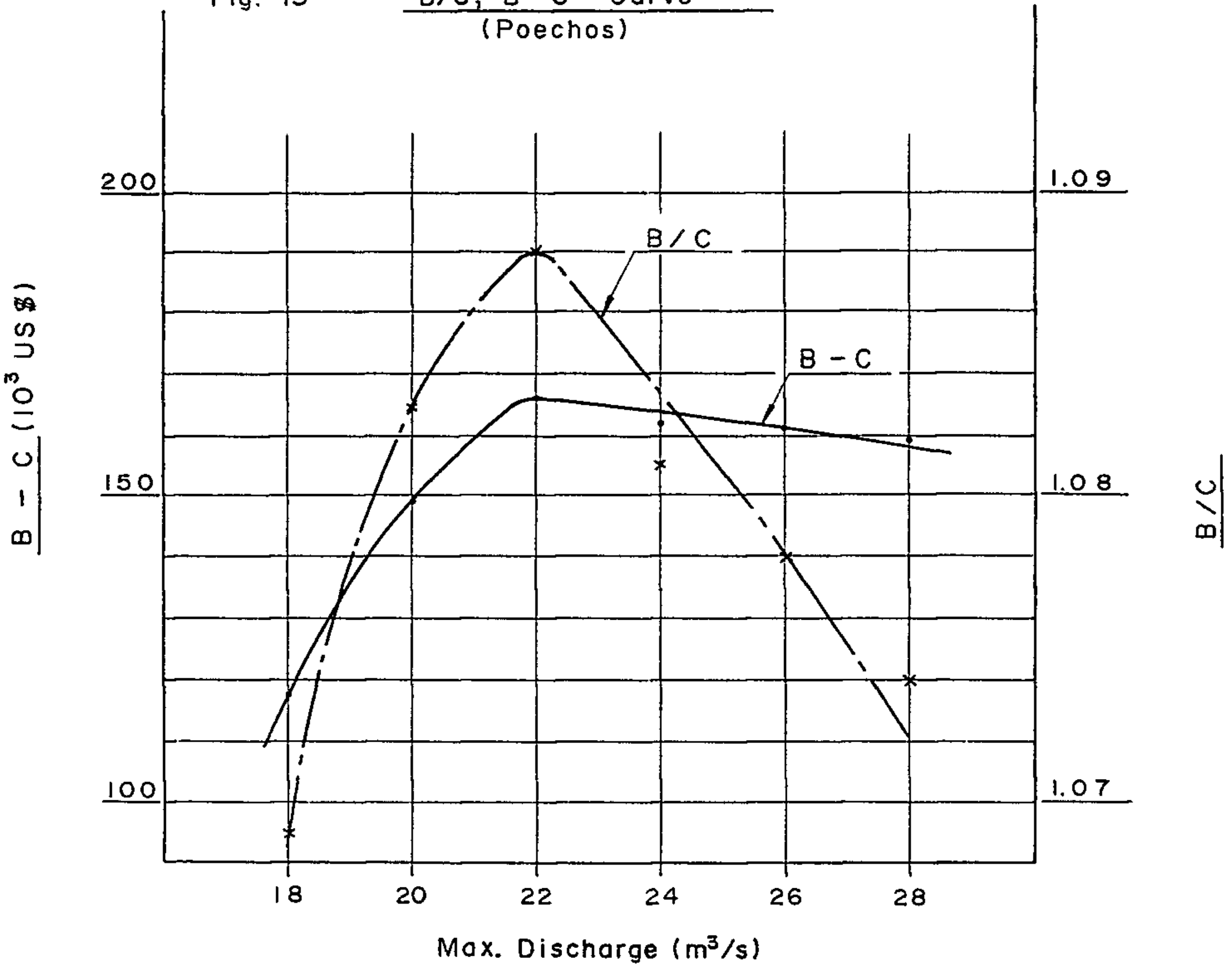
For the various alternatives for available discharge at reservoir high water surface level (W.L. 103 m) of 18 m^3/sec, 20 m^3/sec, 22 m^3/sec, 24 m^3/sec, 26 m^3/sec and 28 m^3/sec, B/C and B-C were obtained on calculating energy productions and construction costs. As a result, the conclusion was drawn that the vicinity of 22.0 m^3/sec (approximately 3,750 kW x 2 = 7,500 kW) at which B/C would be highest and B-C the reflection point would be the most advantageous (see Table II-5-1 and Fig.- 19), and as a result of study, it was decided that the installed capacity should be 3,800 kW x 2 = 7,600 kW and the available discharge 22.3 m^3/sec. Further, the turbine type was selected so that at W.L. 84.0 m roughly double the water at W.L. 103.0 m could be used in order that full output could be obtained at low water level (W.L. 84.0 m) of the reservoir.

Accordingly, calculations of energy production were made considering reservoir water level fluctuations for a period of 17 years, the efficiencies of turbines and generators according to fluctuations of available discharge, and head losses.

Table II-5-1 Economic Comparisons for the Scale of Poechos Power Station

	Q m^3/s	28	26	24	22	20	18
1	Installed Capacity (kW)	9,670	8,980	8,990	7,600	6,910	6,220
2	Available Power 0.942 (kW)	9,110	8,460	7,810	7,160	6,510	5,860
3	Energy Production (GWh)	52.80	52.77	52.27	51.14	49.58	47.42
4	Available Energy Production 0.942 (GWh)	49.74	49.71	49.24	48.17	46.70	44.67
5	2 x 109 (10^3 U.S.$)	993	922	851	780	710	639
6	4 x 0.0264 (10^6 U.S.$)	1.313	1.312	1.300	1.272	1.233	1.179
7	5 + 6 (10^6 U.S.$)	2.306	2.234	2.151	2.052	1.943	1.818
8	Construction Cost (10^6 U.S.$)	17.448	16.845	16.161	15.326	14.580	13.818
9	8 x 0.12306 (10^6 U.S.$)	2.147	2.073	1.989	1.886	1.794	1.700
10	B/C 7 / 9	1.074	1.078	1.081	1.088	1.083	1.069
11	B - C 7 - 9 (10^3 U.S.$)	159	161	162	166	149	118

Fig.-19 B/C, B-C Curve
(Poechos)



(iii) Development Scale of Curumuy Power Station

Since there would not be large variations in head as at Poechos Power Station, it was considered that total head would be constant. The energy production was calculated on considering the efficiencies of turbines and generators according to fluctuations of available discharge, and annual costs (C) and annual benefits (B) were computed on setting up the alternatives of 20 m^3/sec, 25 m^3/sec, 27.5 m^3/sec, 30 m^3/sec, 35 m^3/sec and 45 m^3/sec.

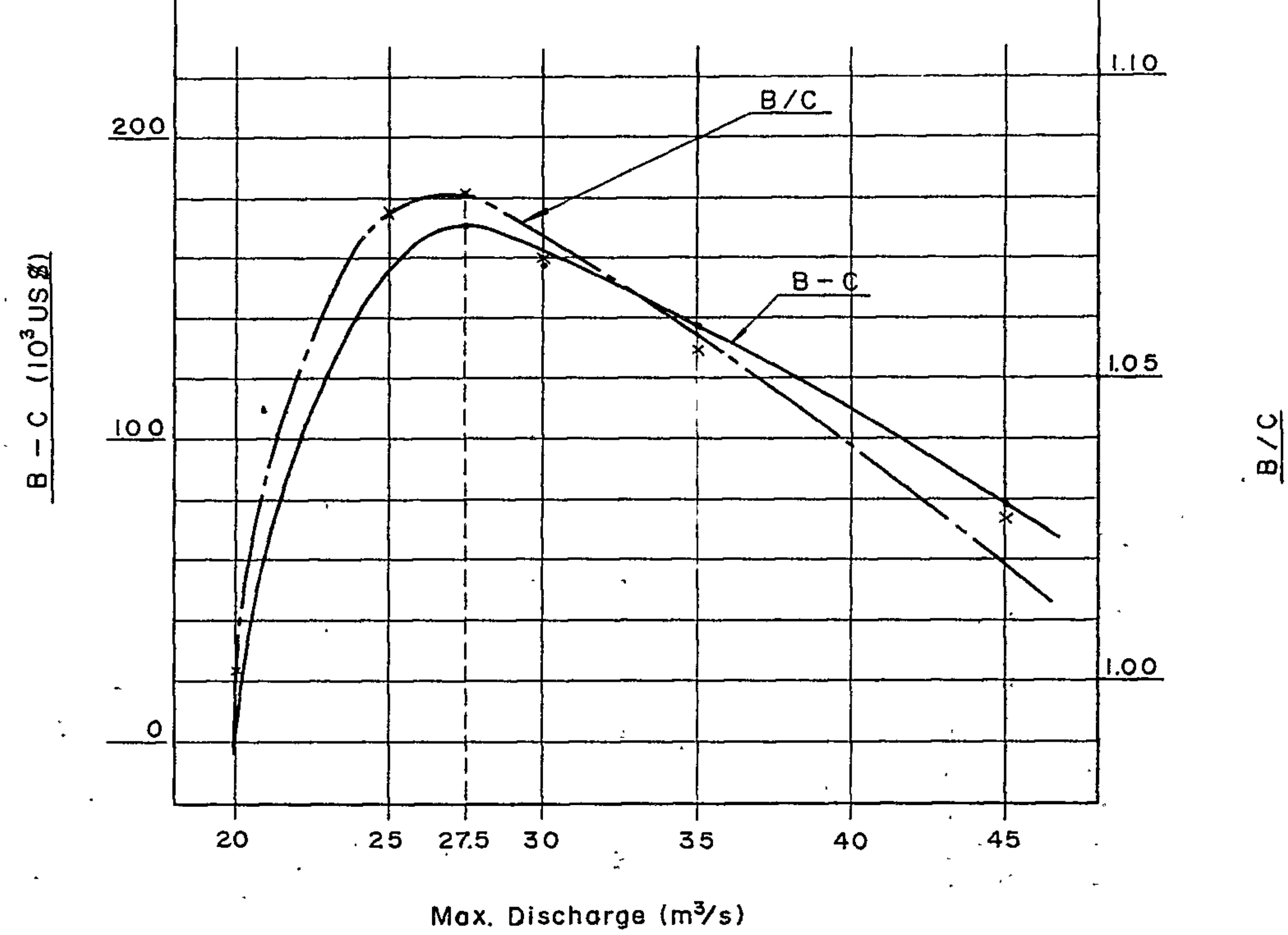
The result, as shown in Table II-5-2 and Fig.-20, was that both B/C and B-C would be the most advantageous with 27.5 m^3/sec, and it was decided to adopt 27.5 m^3/sec (4,500 kW x 2 = 9,000 kW).

Table II-5-2 Economic Comparisons for the Scale of Curumuy Power Station

	Q m^3/s	45	35	30	27.5	25	20
1	Installed Capacity (kW)	14,730	11,450	9,820	9,000	8,180	6,550
2	Available Power 0.942 (kW)	13,880	10,790	9,250	8,480	7,710	6,170
3	Energy Production (GWh)	59.54	57.77	56.15	54.83	52.99	47.50
4	Available Energy Production 0.942 (GWh)	56.09	54.42	52.89	51.65	49.92	44.75
5	2 x 109 (10^6 U.S.$)	1.513	1.176	1.008	0.924	0.840	0.673
6	4 x 0.0264 (10^6 U.S.$)	1.481	1,437	1.396	1.364	1.318	1.181
7	5 + 6 (10^6 U.S.$)	2.994	2.613	2.404	2.288	2.158	1.854
8	Construction Cost (10^6 U.S.$)	23.833	20.238	18.362	17.306	16.355	15.124
9	8 x 0.12233 (10^6 U.S.$)	2.915	2.476	2.246	2.117	2.001	1.850
10	B/C 7 / 9	1.027	1.055	1.070	1.081	1.078	1.002
11	B - C 7 - 9 (10^3 U.S.$)	79	137	158	171	157	4

Fig.-20 B/C, B-C Curve

(Curumuy)



5.1.4 Curumuy Power Station Regulating Pondage Capacity

The available discharge of the Curumuy Hydroelectric Power Project is governed by the amount of water discharged to the Piura Valley by the Chira-Piura Diversion Canal. The 95% dependable discharges at the Curumuy Power Station site according to the Chira-Piura Irrigation Project are a maximum monthly average of 45.56 m^3/sec and a minimum monthly average of 10 m^3/sec. The maximum available discharge at Curumuy Power Station, as indicated in 5.1.3, "Development Scale," is 27.5 m^3/sec in terms of monthly average.

Since water is conducted from Poechos Reservoir to the Curumuy site by an open canal of 54 km, it will be impossible to control water flow according to fluctuations in electric power load. Therefore, without a regulating pondage, the output would vary widely in accordance with fluctuations in the irrigation water discharge greatly reducing the value of the power station, so that provision of a regulating pondage would be indispensable.

The capacity of the regulating pondage for this Project was made 102,000 m^3 as a result of studies of the items below.

(i) Regulating Capacity Seen from Representative Daily Load Curve of Power Demand

Assuming that Curumuy Power Station during the low-water season would handle the top of the peak in the daily load curve, the following regulating capacities would be necessary to be adopted at 95% dependable discharge (10 m^3/sec). (See Fig.-21.)

1982	133,000 m^3; (28.5 - 10) m^3/sec x 2 hr x 3,600 sec
1986	70,000 m^3; (28.5 - 10) m^3/sec x 1.05 hr x 3,600 sec
1992	50,000 m^3; (28.5 - 10) m^3/sec x 0.75 hr x 3,600 sec

However, these are for cases of representative daily loads assumed, and it is thought there will be a fair amount of variations according to the day. In case of this power station, since the extreme tip of the peak is taken, a capacity of about 2.4-hr peaking (10% peak) will be necessary.

Accordingly, the regulating capacity necessary for 2.4-hour peaking will be (28.5 - 10) m^3/sec x 2.4 hr x 3,600 sec = 159,800 m^3.

(ii) Supplementary Water to Curumuy Power Station for Power Generation

Irrigation water to the Piura Valley is supplied by the Chira-Piura Diversion Canal when the flow of the Piura River is insufficient to meet demand. And there is no need for supplementation because the Piura River has sufficient flow during the rainy season. However, supplementation will be necessary for power

power generation. The minimum amount of water required in case of 2.4-hour peaking similarly to (i) above will be 28.5 m^3/sec x 2.4 hr x 3,600 sec = 246,000 m^3, which will be a daily average 2.85 m^3/sec.

(iii) Regulating Capacity of Chira-Piura Diversion Canal Itself

Chira-Piura Diversion Canal has a canal gradient of 0.00025, bottom width of 5 m, top width of 16 m and maximum depth of 3.63 m, and when full, a maximum capacity of 70 m^3/sec. Based on these particulars, the depth will be only 1.33 m at 95% dependable discharge (10 m^3/sec), and the canal itself can be utilized as a regulating pondage when flow is small.

Consequently, in case of flow of 10 m^3/sec, it will be possible for the canal to secure this flow and possess a regulating capacity of 59,400 m^3 as well. (In case of water storage of depth of 3.0 m in consideration of safety of the canal.)

If water is not discharged and all of the above volume were to be used as regulating pond, the regulating capacity would be 144,000 m^3 (see Fig.-22).

Based on the above, if the diversion canal were to be utilized as a regulating pond, the regulating capacity required by Curumuy Regulating Pondage would be the following:

At 10 m^3/sec discharge ... 100,400 m^3; (159,800 - 59,400)

Rainy season ... 102,000 m^3; (246,000 - 144,000)

Therefore, the capacity of Curumuy Regulating Pondage is to be 102,000 m^3 (see Fig.-23).

Fig.-21 Typical Load Curve
Interconnected Piura System

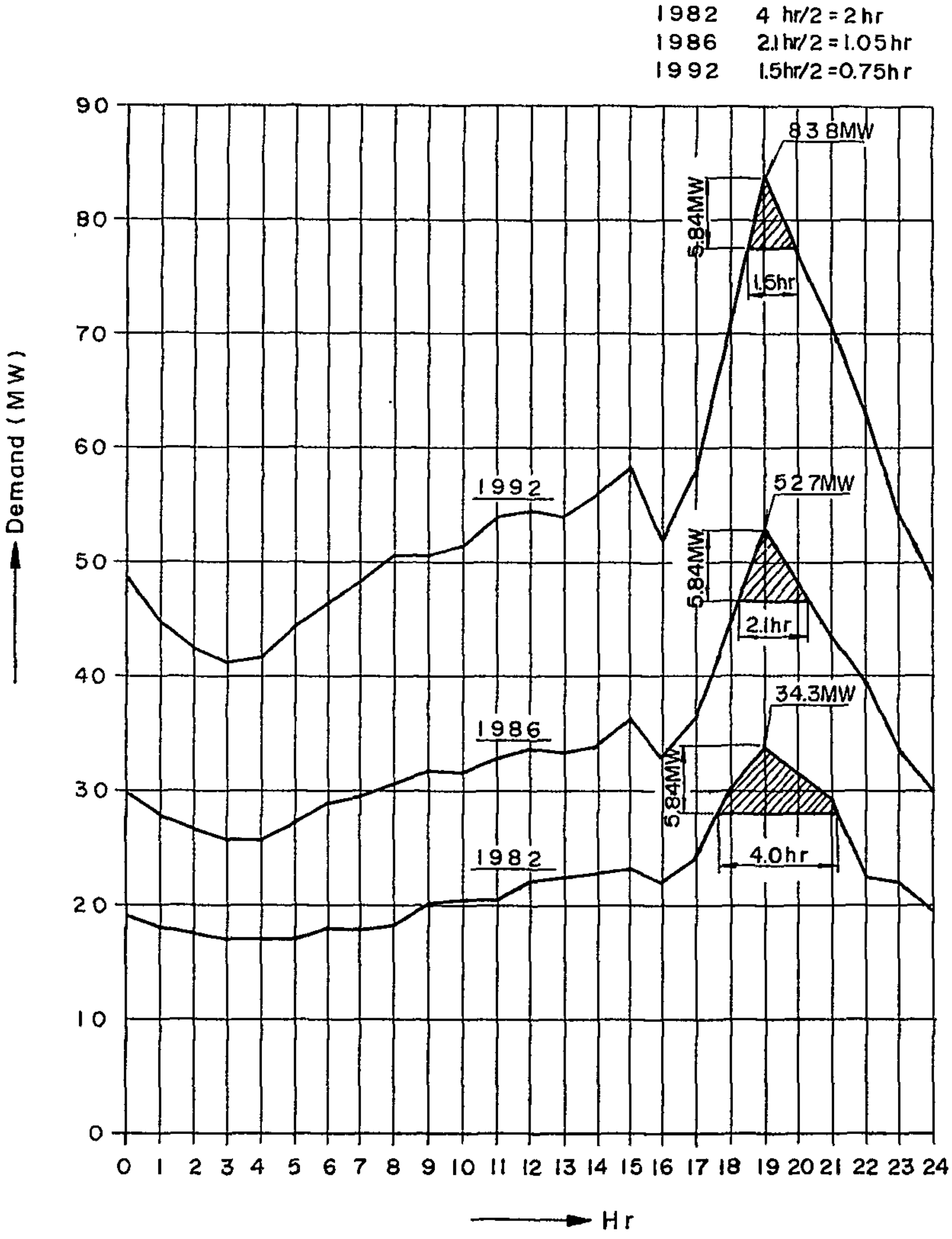


Fig - 22 Regulating Capability of Chira - Piura Canal

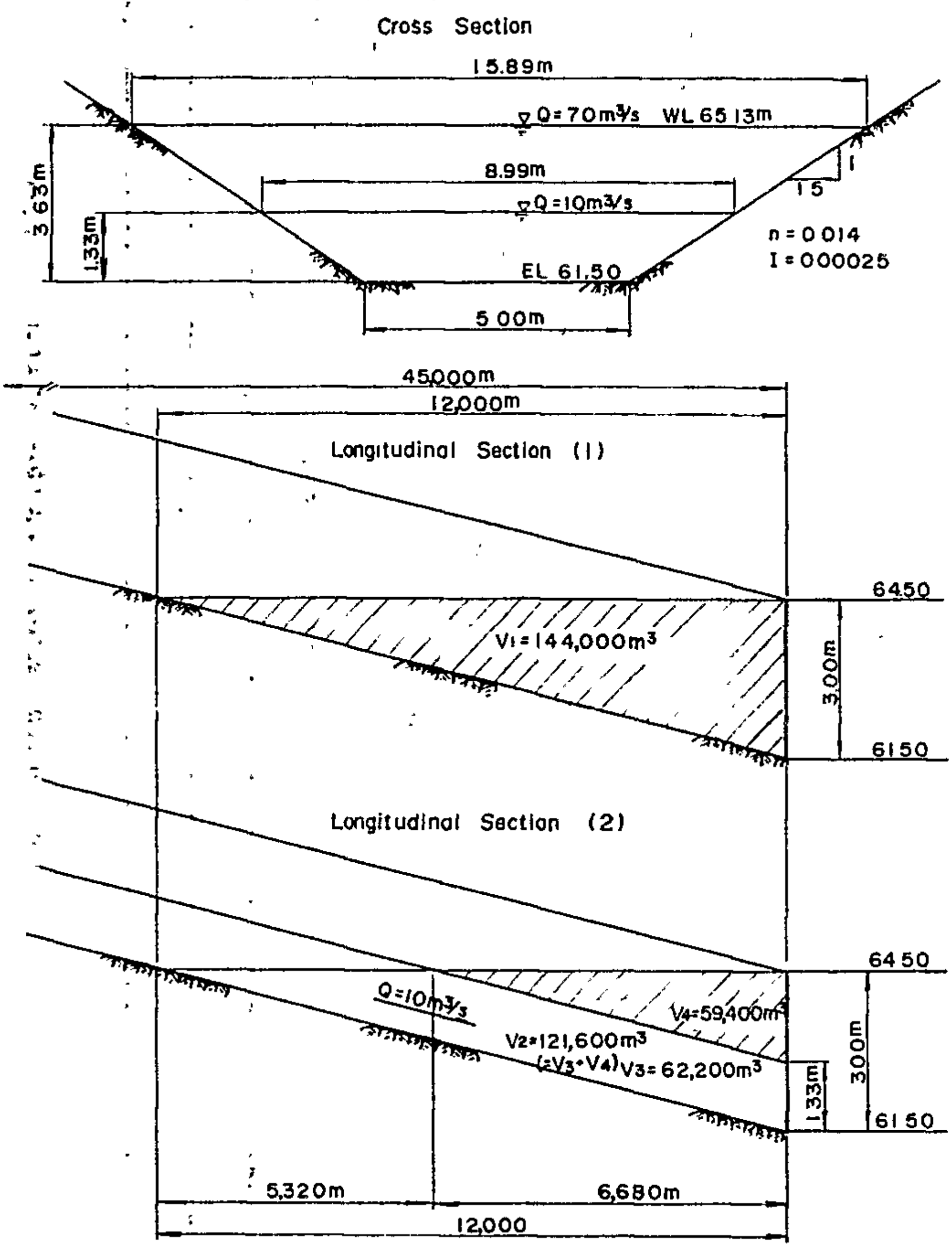
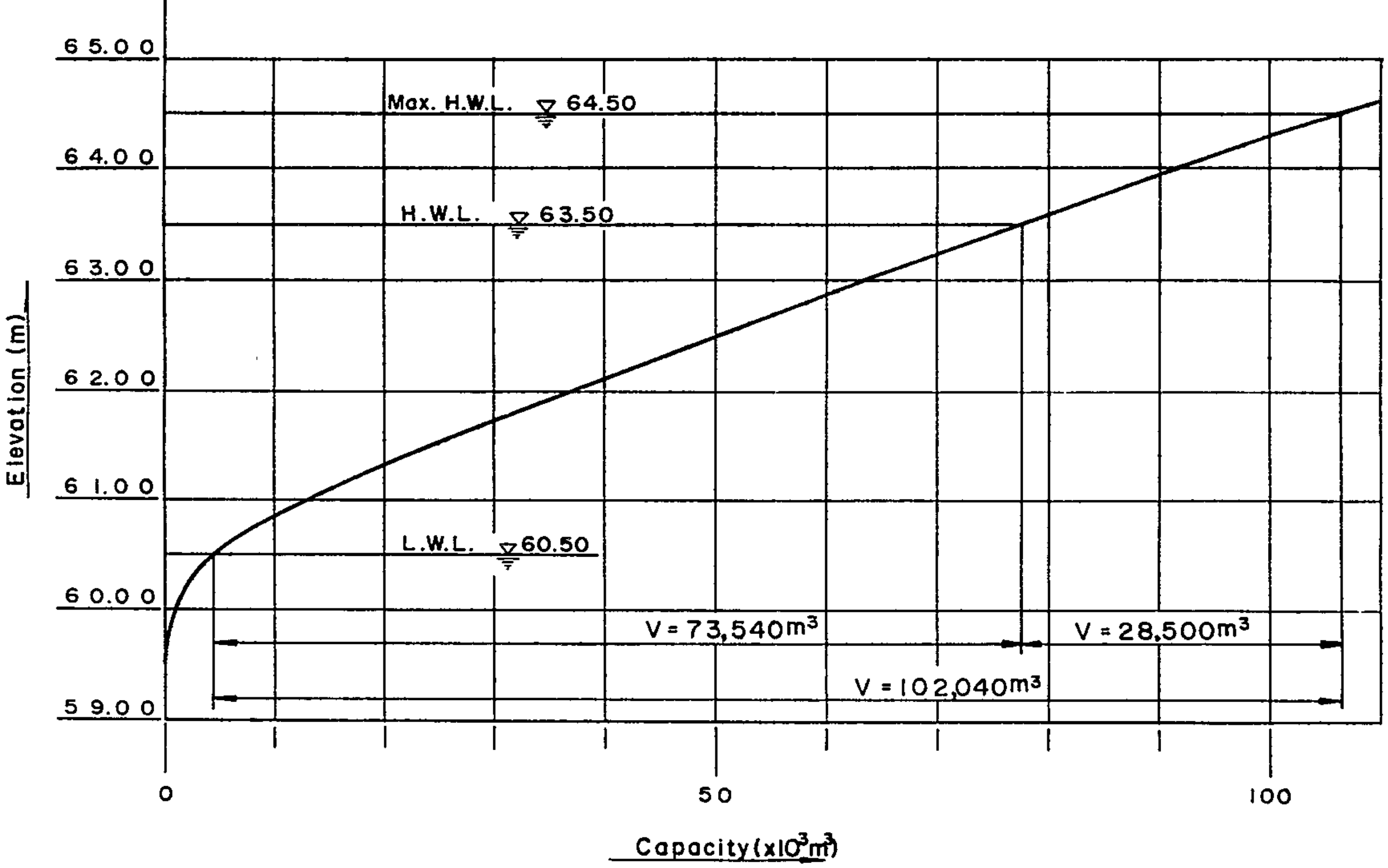


Fig.-23 Curumuy Regulating Pondage Capacity Curve



5.1.5 Utilization of Poechos Dam Bottom Outlet

The bottom outlet which is to serve as the main headrace for Poechos Power Station is located at the right-bank side of the dam. During construction of Poechos Dam it was used as a temporary diversion tunnel, and now, after completion of the dam, it has been converted into a facility for discharge of irrigation water to the downstream area of the Chira River. The particulars of this facility are as follows:

Structure: A concrete culvert of inside diameter of 8 m and a steel pipeline of inside diameter of 4.5 m protected by reinforced concrete of 30 cm thickness.

Length: Total length 415 m
- Concrete culvert section 160 m
- Steel pipe-lined section 255 m

Gates: One slide gate at connection to concrete culvert from intake orifice, 1 valve gate at end of steel pipeline, 1 radial gate also at end of steel pipeline, total 3 gates. Normal discharge controlled by radial gate.

Discharge: A maximum of 300 m3/sec supply to Chira River possible. Normally, 12.0 - 28.0 m^3/sec. Other than this, 14.0 m^3/sec supplied to Miguel Checa Canal.

Case of Use in Common of bottom outlet as Headrace of Poechos Power Station.

The bottom outlet will be subjected to influences related to the operation of the power station. In particular, water hammer pressure occurring when turbines and generators are stopped is liable to apply high internal pressure to the bottom outlet. Water hummer pressure occurring when turbines and generators are stopped is liable to apply high internal pressure to the bottom outlet. Water hammer pressure calculations were performed, and studies considering water hammer pressure were made based on drawings and calculation papers obtained from DEPECHP.

In calculations of water hammer pressure, the respective flows and necessary conditions were given for the cases of high water surface level, 95% water level and flooding, while closing times of guide vanes were varied between 5 sec and 20 sec. An electronic computer was used for calculations.

Stress analyses of the bottom outlet were made assuming the most hazardous condition of stresses due to earthquake, load rejection and temperature change acting simultaneously. As a result of calculations, all stresses produced in the bottom outlet cross sections will be within the allowable stress intensity, and consequently, there will be no problem structurally regarding use of the bottom outlet in common for the power station.

Details of the study are as shown in Appendix-3.

5.2 AVAILABLE DISCHARGE

5.2.1 Firm Available Discharge

In these Projects, the 95% dependable flows were taken to be the firm available discharge, and the 95% firm available discharges calculated based on the irrigation schedule will be the following:

Poechos Project	12 m^3/sec
Curumuy Project	10 m^3/sec

5.2.2 Maximum Available Discharge and Annual Average Available Discharge

As stated in 5.1.3 on selection of the development scale, the maximum available discharges of the Projects are as follows:

Poechos Project	At reservoir high water level	22.3 m^3/sec
	At reservoir standard water level	25.5 m^3/sec
	At reservoir minimum water level	44.2 m^3/sec
Curumuy Project	At high water level	27.6 m^3/sec
	At standard water level	28.3 m^3/sec
	At minimum water level	31.5 m^3/sec

The annual average available discharges of the Projects calculated based on the above maximum available discharges are the following:

Poechos Project	20.1 m^3/sec
Curumuy Project	21.4 m^3/sec

5.3 OUTPUT AND ENERGY PRODUCTION

5.3.1 Installed Capacity

The installed capacity of Poechos Power Station is to be 7,600 kW.

The available discharges and effective heads are shown in Table II-5-3.

Table II-5-3 Available Discharges and Effective Heads of Poechos Power Station

	Reservoir Water Level (m)	Tailrace Water Level (m)	Effective Head (m)	Available Discharge (m^3/sec)	Output (kW)
Max. Water Level	103	61.10	41.30	22.30	7,600
Standard W.L.	98	61.10	36.10	25.50	7,600
Min. W.L. (95%)	86.3	61.10	22.80	44.20	7,600
Min. W.L. (100%)	84	61.10	20.90	40.00	6,200

The installed capacity of Curumuy Power Station is to be 9,000 kW for standard effective head of 38.7 m and available discharge of 28.3 m^3/sec.

The head tank water level and the tailrace water level are to be 63.5 m and 24.0 m, respectively.

5.3.2 Dependable Peak Output and Dependable Output

The dependable peak outputs of Poechos and Curumuy Power Stations are their installed capacities, and 7,600 kW and 9,000 kW, respectively. The 95% dependable outputs throughout a year are 2,100 kW at Poechos and 3,200 kW at Curumuy.

5.3.3 Available Energy Production

The available energy production of Poechos and Curumuy, upon considering the available discharges from 1958 to 1970 and the effective heads of the respective months, and as a result of calculating in terms of monthly average, are 51.31 GWh and 55.20 GWh, respectively.

5.4 NUMBER OF UNITS AND TURBINE TYPE

From the results of study up to the present, the optimum installed capacities of the Poechos and Curumuy Projects are 7,600 kW and 9,000 kW, respectively. The reasonable number of unit is 1 unit, or 2 units.

Making the number of units small is advantageous from the economical standpoint. However, in case of 1 unit, the unit capacity would be 7,600 kW - 9,000 kW which would mean an output larger than 10% of maximum power demand of 50 - 60 MW estimated for around 1986, and may be said to be excessive since insufficient supply capability will result during faulting of the unit. Consequently, stressing supply reliability, a 2-unit proposal will be adopted, in effect, a unit capacity of 3,800 kW for Poechos, and a unit capacity of 4,500 kW for Curumuy.

Regarding the turbine type, since the head at Poechos Power Station will vary from 44 m to 19 m and the available discharge from 44 m^3/sec to 22 m^3/sec, or become approximately 50%, a Francis type will not be able to cope with these variations in load and head. Therefore, a Kaplan type is to be adopted.

As for Curumuy Power Station, the variation in head is a maximum of about 20%, and a Francis type could cope with this, but since the available discharge will be set in accordance with the demand for irrigation water, there will be many occasions when the turbines will be operated at low load (load factor 60% and under), a Francis type is to be avoided in consideration of impairment of efficiency and a Kaplan type adopted.