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EL TORITO - LOS VEGANOS

HYDROELECTRIC COMPLEX DEVELOPMENT PROJECT

ON UPPER YUNA RIVER

VOL. V APPENDIX

I . PIEDRA GORDA DAM AND
HYDROELECTRIC PROJECT

II . PINALITO HYDROELECTRIC PROJECT

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APPENDIX I

APPENDIX - I

PIEDRA GORDA DAM AND HYDROELECTRIC PROJECT

Table of Contents

01

List of Tables

List of Figures

List of Drawings

I. INTRODUCTION

1.1 Objectives and Scope of Study

The Piedra Gorda dam is alternatively called the Alto Yuna dam. It is located at a site immediately downstream from the confluence of the Yuna river and Blanco river. Along the Yuna river upstream of the confluence, El Torito - Los Veganos hydroelectric complex has been planned and studied, while the Rio Blanco hydroelectric project is being implemented along the Blanco river. The damsite is situated 2 km upstream of the village of Los Quemados, or 9 km southwest of Bonao city. (Refer to Fig.-01)

The Piedra Gorda (Alto Yuna) dam will form one of the principal elements in the overall development of the Yuna river basin which is the second largest river basin of the Dominican Republic. Studies on the Piedra Gorda dam were made at various occasions in the past, as introduced in the subsequent Chapter 1.2, but the thorough study has not been conducted yet to define the development plan.

At the initial stage of the feasibility study on El Torito - Los Veganos hydroelectric complex, CDE requested JICA study team to review previous studies on the Piedra Gorda dam and hydroelectric project. In view of the fact that El Torito - Los Veganos complex might have effects on the Piedra Gorda project in the downstream and that the location of Los Veganos power station is affected by the high water level of the Piedra Gorda reservoir, JICA team agreed to carry out a preliminary study on the Piedra Gorda project. The preliminary study has therefore objectives to review previous studies on the basis of some investigations to be additionally executed on the Piedra Gorda project.

The scope of the preliminary study is limited to the works as enumerated hereunder.

1) To review discharges at Piedra Gorda, by referring to the results of hydrometeorological study on El Torito - Los Veganos complex,

2) To prepare topographic map of the damsite and reservoir area on the

scale of 1/5,000 by means of aerial photo mapping,

3) To review geologic conditions at the damsite, through surface geologic survey, aerial photo interpretation on the characteristics of the Bonao fault, geophysical exploration and core drilling to the minimum extent,

4) To review availability of construction materials for embankment,

5) To review technical viability to construct a large dam at Piedra Gorda, and

6) To preliminarily study on the development plan of the Piedra Gorda dam and hydroelectric project.

Among the review and studies, specific attention has been drawn to the geologic conditions at the damsite, because the Bonao fault is running along the river course near the damsite and the geologic conditions are decisive in the technical feasibility of a large dam construction plan. Attention has also been directed to define, as much as possible, the high water level of the Piedra Gorda reservoir which has effects on the selection of power station site of Los Veganos hydroelectric scheme.

1.2 Previous Studies

The construction of the Piedra Gorda (Alto Yuna) dam was studied, in 1973, by Hanson-Rodriguez in the framework of the development of the Oriental Cibao valley. The study proposed to first construct the Hatillo dam to secure water for irrigation in Cotui area (around 12,000 ha.) and to prevent seasonal floods in the lower basin. Then, water of the Yuna river can be diverted to the Rincon dam through Yuna-Cañabon canal having a conveyance capacity of 10 m^3/s. To maximize the area for irrigation in the area downstream from the Rincon dam, construction of the Piedra Gorda (Alto Yuna) dam and reservoir with a storage capacity of 100 million m^3 was proposed to regulate discharge and to generate hydropower.

One of the major constraints for the Piedra Gorda dam project was the geologic conditions, especially effect of the Bonao fault. Hanson-Rodriguez counted on the geologic investigation by an expatriate geologist. The investigations, however, were only limited to the surface geologic survey and the technical possibility to construct a large dam at Pierdra Gorda was not defined through the study.

The roll of the Piedra Gorda (Alto Yuna) dam was subsequently reviewed by CEA-ONAPLAN in 1980 through the master plan on the regional development of the Oriental Cibao valley. Water of the upper Yuna river basin is to be utilized for municipal and industrial water supply to Bonao city and Falconbridge, for irrigation water supply in the Bonao valley where the Yuna-Bejucal and Yuna-Caracol canals are presently served, and for diversion to the Jima river basin through Yuna-Cañabon canal. In case the Piedra Gorda multipurpose dam is constructed with its effective storage capacity of 60 million m^3, the stored water will be utilized for power generation and diverted to the Yuna-Cañabon canal (amplified) at the maximum discharge of 15 m^3/s, in addition to meet the water demand in the Bonao valley.

On the other hand, INDRHI team (headed by Ing. Devers) realized the study on water requirement in the irrigable area of 14,840 ha. at the maximum in the Jima-Camu downstream of the Rincon dam and 1,500 ha. in the Bonao valley. The team also studied on the operation of the Rincon reservoir to determine the capacity of transbasin from the Yuna river to the Rincon reservoir. It was concluded that diversion of 15 m^3/s through amplification of the Yuna-Cañabon canal will suffice the irrigation water requirement in the Jima-Camu area, and the diverted water can be harnessed through the existing Rincon power station. By installing an additional generating unit of 10 MW, the Rincon power station will increase its annual energy production. The study by INDRHI also demonstrated that irrigable area in Cotui downstream from the Hatillo dam (about 12,000 ha.) could be secured by water available from the remaining catchment area of other tributary basins even if 15 m^3/s water is diverted at Piedra Gorda.

In 1981, CDE-ENEL carried out pre-feasibility study on 8 hydroelectric schemes in the upper Yuna river basin, inclusive of the Piedra Gorda project. The Piedra Gorda dam and reservoir was studied on the basis of water requirement for irrigation (14,840 ha.) estimated by INDRHI and in the light of some storage schemes in the upper stream. (El Torito, Los Veganos and Pinalito). The study concluded that the effective storage of 60 million m^3 at the Piedra Gorda reservoir, with its high water level at EL 350 m, would be sufficient to guarantee all the water requirement contemplated by the project. The proposed outline of the project is summarized as follows:

Annual mean discharge	: 17.28 m^3/s
Piedra Gorda Dam	: 75 m in height
Effective storage capacity	: 60 million m^3
Headrace tunnel	: 3.8 km in length on the left bank
Power station	
Installed capacity	: 46.08 MW
Primary energy	: 86.01 GWh
Secondary energy	: 33.44 GWh
Water diversion to Rincon	: 11.0 m^3/s
Total cost of dam and power station	: $74.65 million (1981 price)
B/C ratio	: 1.47

Under the CDE Power Expansion Plan prepared by CDE-SOFRELEC in 1980-81, the Piedra Gorda (Alto Yuna) dam and power station is programmed to start its commercial operation in 1990.

II. PHYSICAL CONDITIONS

2.1 Hydrometeorology

The Piedra Gorda (Alto Yuna) damsite is located in the uppermost part of the Yuna river basin (5,498 km^2). At the damsite, the catchment area is approximately 358 km^2.

Climatologic data available in the upper Yuna river basin are limited, except for some rainfall records. Temperature, relative humidity and evaporation are only recorded at Juma Bonao gauging station located in Bonao valley at about 9 km northeast of the damsite. At Juma Bonao, the annual mean temperature is 24.1°C, and the monthly mean temperature ranges from 22.2°C in January-February to 25.5°C in July-August. The monthly mean relative humidity fluctuates in the range of 83-88%. The annual mean evaporation is around 4 mm/day. (Details are presented in Annex C.2 of the report on El Torito - Los Veganos complex.)

Rainfall gauging stations installed in the upper Yuna river basin provide a limited period of records, except for Los Quemados station located at 2 km downstream from the damsite. At Los Quemados, hourly precipitation record is available since 1967. The annual mean rainfall at this station is around 1,940 mm. The dry months are January (92 mm), June (114 mm), February (141 mm) and March (143 mm). (Refer to Table -01)

The rainfall in the catchment area of the Piedra Gorda dam shows sporadic areal distribution. In general, such tributary basins as Arroyo Colorado and Arroyo Tireo have relatively high precipitation, while rainfall decreases in the northwestern part of the area. For instance, the annual mean precipitation at Constanza located to the west of the Yuna river basin is around 1,020 mm. Comparative analysis on rainfall records available for a short period in the basin indicates a low correlation coefficient.

At Los Quemados hydrological station (catchment area of 369 km^2), daily discharge record of the Yuna river is available during the period from 1962 to 1979. The recording was discontinued thereafter because the gauging station was destroyed at the time of flood caused by the hurricane

David on August 31, 1979. The annual mean discharge recorded at Los Quemados is around 17.5 m^3/s. (Refer to Table -02)

At a site immediately upstream of Los Quemados gauging station, Yuna water has been taken for use by irrigation in the Bonao valley. Such an irrigation water intake is added to the discharge observed at Los Quemados gauging station, and the synthetic discharge at Los Quemados is calculated on a daily basis. (Refer to the hydrograph on Fig.-02) The monthly mean discharge is presented for reference on Table -03 and Table -04.

Discharge available at the Piedra Gorda damsite is calculated on the basis of discharge record at Los Quemados, in proportion to the catchment area (Piedra Gorda = 358 km^2; Los Quemados = 369 km^2). The available discharge for power generation is to be estimated by means of mass-curve method on the basis of the estimated daily discharge.

The flood discharge has been estimated through analysis on probable precipitation and probable maximum precipitation, as well as on the basis of runoff analysis by the storage function method. The probable flood discharge and probable maximum flood at the Piedra Gorda damsite is estimated as summarized on Table -05. The design flood discharge of spillway for a fill-type dam construction is estimated at 3,240 m^3/s. (Detailed procedures on analysis are explained in Annex C.5 of the report on El Torito - Los Veganos complex.)

The sediment yield in the upper Yuna river basin is substantial due mainly to the shifting cultivation and deforestation. The specific sediment yield in the area of El Torito - Los Veganos complex has been studied by means of aerial photo interpretation, land use study and by experimental formula. It is estimated that the sediment yield is around 2,000 $m^3/km^2/$year. (Refer to Annex C.6 of El Torito - Los Veganos complex study report.) Although further study is to be executed in other sub-basins of the Piedra Gorda project at the stage of feasibility study, such a specific sediment yield estimated for El Torito - Los Veganos complex is provisionally applied in this preliminary study on the Piedra Gorda dam.

2.2 Topography

The proposed damsite is located approximately 2 km upstream of the village of Los Quemados. The Yuna river, after running through the alpine relief in topography, debouches into the Bonao valley of extensive flat land at a site immediately downstream from the damsite. Toward the north of the damsite, an escarpment with a height of about 300 m is apparently traceable. This conspicuous difference in physiography is probably due to the Bonao fault activity which plays an important role in the structural history of regional geology.

The Piedra Gorda damsite shows an open V-shaped valley. The present riverbed is about 80 m in width and the riverbed elevation is approximately EL. 266 m. The right abutment dips 50°, while the left abutment dips 25°. It is inferred that such physiography has probably resulted from rock formation, i.e., schistosed green rock in the right abutment, and calcareous tuff, sandstone and limestone in the left abutment.

It appears that such a topographic condition at the damsite favours the construction of a large dam. During the course of the study, a topographic map on the scale of 1/5,000 has been prepared to cover the damsite and reservoir area, on the basis of 1/20,000 scaled aerial photographs taken in 1980-81.

2.3 Geology

2.3.1 Geologic Investigations:

During the course of this study, geologic investigations have been executed to cover the following works:

a) Surface geologic survey on the basis of 1/5,000 scaled topographic maps

b) Interpretation of 1/20,000 scaled aerial photographs

c) Petrographic study on rock samples

d) Geophysical exploration at damsite (Refer to Table -06)
(6 lines with a total length of 2,930 m)

e) Core drilling at damsite (Refer to Table -06)
(3 holes with a total depth of 162.8 m)

f) Water pressure test (17 times)

The result of investigations are reflected in studying general geology around the damsite, interpretation of fault activity and engineering geology at the proposed damsite, as described in the subsequent Sections.

2.3.2 General Geology:

The geology in the study area is divided into the Duarte Formation, the Tireo Formation, the Plutonic igneous rocks, Terrace deposit, Debris and River bed, in an ascending order. The geologic age of the Duarte Formation is uncertain, according to the previous studies, but is considered to be Pre-Middle Albian (uppermost of Lower Cretaceous) after G.O. Bowin (1966). The Tireo Formation is identified to be upper Cretaceous sediments by fossils. The Plutonic igneous rocks, which are not exposed in the study area but crop out in the immediate adjacent area, are not positioned in geologic age, but are inferred to be successive phase of the Duarte Formation or to be slightly younger. The stratigraphic sequence of the study area is shown on Table -07. The representative rock samples in the Duarte Formation and Tireo Formation have been petrographically checked by microscope, and they are demonstrated on Table -08.

In the upper Yuna river basin, the Duarte Formation is composed of three rock facies; a) gneiss, b) amphibolite, foliated diorite and peridotite and c) green schist. Among these, the last facies of green schist is solely exposed in the study area.

On the basis of detailed petrographic studies, the Duarte Formation shows a systematic pattern of metamorphism which was probably caused by the anatexis (a high temperature metamorphic process by which Plutonic rock in the deeper levels of the crust is dissolved and regenerated as a magma) in the regional metamorphism. High grade metamorphic rocks of diorite, gneiss and amphibolite occupy the eastern part of the Duarte Formation and are in intrusion contact (?) with Plutonic igneous batholith. On the other hand, low grade metamorphic rocks formed of several kinds of schists are distributed in the western part.

The Duarte Formation is in thrust fault contact with the Tireo Formation in the central part of the study area and is accompanied by a fractured zone of approximately 15 meters in thickness at maximum. To the south, however, the fractured zone gradually pinches out and eventually the Duarte Formation have upturned the Tireo Formation near the village of Los Veganos.

Green schist is distributed to the east of the study area, having a general trend of schistosity of NW to SE and dipping 30° to 50° NE. The rock is intensively schistosed and exfoliated throughout the study area. However massive facies are dominant in the adjacent area, except for some sporadic spot.

The Tireo Formation crops out in the western part of the study area. The rock is made up mostly of clastic and pyroclastic rocks such as well bedded sediments of limestone, sandstone, conglomerate and slate, associated with tuff and altered andesite. The Tireo Formation is believed to be late Cretaceous in age as a result of key foraminifera fossil found in the limestone. The Tireo Formation is inferred to be thrust over by the older Duarte Formation along the Bonao Fault, which is traceable from Piedra Gorda as far as Los Veganos, and the bedding plane shows a trend of NNW-SSE strike and dips 25° to 35° eastward. The Tireo Formation distributed near Piedra Gorda is characterized by the accumulation of limestone, conglomerate, sandstone and tuff. Specially corroded open crack is recognizable in bedded-limestone outcrop, but it shows low permeability judging from the water pressure test in drill holes of PG-B1 and PG-B2. This favours the construction of a dam at Piedra Gorda site.

Numbers of landslides are distinguishable in the vicinity of the reservoir area. It is uncertain, at this stage, if these faults and landslides will present serious problems in case of evaluating storage capacity filled with sediments and induced mass movement by impounded water.

The terrace deposit is distributed mostly along the main stream of Yuna river and is made up of uncemented loose mixture of sand, silt and gravel. Terrace deposit is divided into lower, middle and upper, but the criteria of those are ambiguous. They are classified on the basis of the gap in elevation where the terrace deposit exists. The highest terrace, which shows a biggest elevation gap above the present river level, is observable in both riversides of the Yuna river near Piedra Gorda. The elevation gap reaches 60 meters, which indicates the terrace was deposited in relatively older age than the middle and lower terraces. In case of the middle and lower terrace, the gap ranges from 5 to 30 meters in elevation above the present river level.

Debris consists of loose and unconsolidated deposit of rock and soil, which is distributed in the toes of landslide massif and in the gentle slope fan caused by flood pour. The debris with relatively great extent is mapped in the geologic map. Some of the debris, which are distributed near the damsite will be acceptable as earth materials for dam embankment.

The present river deposit forms the river course where most of the deposit underlies the water level. The deposit is made up of uncemented loose mixture of sand, silt and gravel. Consequently, the deposit can be evaluated as aggregate materials.

The geologic map in and around the proposed damsite is illustrated on Fig.-U3.

2.3.3 Fault Activity:

The geology of the study area is characterized by faults, some of which are recognizable not only by aerial photo interpretation but also by field geologic survey. Such faults will have an engineering geologic effect on the project in terms of dam construction and tunnel excavation.

The investigation to date demonstrates nothing to verify a certainty of the Bonao Fault activity in recent years, but the current geologic mapping has brought a new finding to discuss on. In the adjacent downstream from the damsite, gently undulating hills consisting of old river terrace deposit and overburden debris are sporadically observable. They show an elevation ranging from 310 m to 325 m, rising up about 50 m from the present riverbed. Besides, they are distributed on both sides of the Bonao Fault, approximately maintaining an equivalent elevation. Moreover, it is anticipated that sand and gravel of the terrace may have been deposited in the period older than 0.1 to 0.2 million years in geologic age which is assigned to the Shimosueyoshi or the Tama period (standard division in Japan) in the Quaternary age.

These facts will make it possible to interpret that the Bonao Fault has been inactive in a vertical dimension since that time. The fact that an alluvial fan deposit is undeveloped near the river mouths of small rivers which flow down carving the escarpment along the Bonao Fault, is consistent with the preceding interpretation. It has been noted at the same place that a sharp turn (echelon pattern) of river course is not observed. This will imply that the Bonao Fault is inactive even in a sense of lateral displacement.

A discussion regarding the fault activity can be deepened by a monitoring observation of micro-earthquakes along the Bonao Fault and an accurate traverse levelling across the Fault.

2.3.4 Engineering Geology:

The engineering geologic conditions around the proposed damsite have been studied, though preliminary as they are, on the basis of geophysical exploration, core drillings and water pressure tests. The interpreted geologic profile is prepared as illustrated on Fig.-04, by referring to the profile of geophysical exploration as shown on Fig.-05 to Fig.-08. Three drilling holes are logged as demonstrated on PGL.-01 to 03. Further, the result of water pressure tests in the boreholes is shown on Table -09 to Table -11, as well as on Fig.-09 to Fig.-12. The engineering geologic conditions will be discussed hereinafter from the viewpoint of constructing a large dam of some 100 m in height.

The fault which is thought to be an extension of the Bonao Fault, is inferred to pass beneath the riverbed at the damsite. Actually, the seismic explorations suggest a possible existence of the Fault, which is interpreted as a low elastic velocity zone of 2.4 to 3.0 km/sec, whereas the elastic velocity in the surrounding zone reaches 4.6 to 4.8 km/sec which is equivalent to that of hard and fresh rock in a general sense. In addition, the fault zone dips 40° to 50° toward the right downstream, approximately in parallel to the dipping of the exposed rock in both abutments. (Refer to Fig.-04.) The thickness of the fault is probably less than 15 meters.

The drill PG-B1 in the riverbed and the inclined drill PG-B2 clarify some other characters of the fault zone. The zone is composed of an extremely schistosed green rock, easy to exfoliate, broken by hand and contains flaky fragments, but not so clayey.

Although a final decision should await further detailed investigations, it is anticipated from the observations explained above that the fault shear zone in the dam axis foundation can be treated by an appreciable dental excavation and subsequent backfilling with core material or others.

The weathered zone is slightly deeper in the left abutment, if compared with the right abutment. This probably reflects the nature of the rock on both abutments. The right abutment consists of green schist and green rock belonging to the Duarte Formation. It strikes N10°W to N20°E and dips toward east or to the abutment. While, the left abutment is composed of reddish purple calcareous tuff in the upstream and greyish limestone in the downstream. Since they strike N45°W and dip northeast (to the riverside), the Duarte Formation upturns and overlies the Tireo Formation in geological sense. It is expected that the layer exceeding an elastic velocity of 2.3 to 2.5 km/sec is durable enough for fill-type dam axis foundation. Consequently, the excavation will be at maximum 20 meters from the ground surface.

Further, the core drilling proves that an alluvial river gravel reaches about 14 meters in thickness around the middle of the riverstream.

In the light of geologic conditions as explained above, the Piedra Gorda damsite seems to be appropriate for a fill-type dam construction, in order to steer clear of constraint factors that the Bonao Fault is inferred to bevel in the foundation rock and that the weathered zone is estimated to be deep in both abutments. Geohydrologically, it is anticipated that the rock in the right abutment holds a watertight feature and shows a relatively high water table, since surface water is discernible in a small valley incised in the abutment. On the contrary, in the downstream side of the left abutment where limestone is distributed, no surface water is seen in a valley. This indicates that a water table is low probably due to open crack and cave showing high permeability. However, in the upperstream where calcareous tuff is dominant, plenty of surface water is flowing. This presumably results from rock nature of possessing low permeability. Judging from these facts, the upperstream side (A and B axes of the seismic lines) appears to be more suitable for a dam axis.

The water level of the drill hole PG-B3 shows a head of confined aquifer, which is composed of conglomerate. The confined layer is probably slate, judging from the water pressure test.

2.3.5 Design Earthquake Acceleration:

The seismic data since 1911 have been reviewed, inclusive of CDE's seismograph network record in 1980-81. As explained in detail in the feasibility study report on El Torito - Los Veganos complex, Annex D.4, the peak ground acceleration has been estimated for the Piedra Gorda damsite (long. 70.48°, lat. 18.87°) in the following 4 cases:

A (Case 1) Historical earthquake data from 1946 through 1980 is used (data in 1911-45 are excluded).

B Historical earthquake data from 1911 through 1980 are all included.

B - 1 (Case 2) Epicenter of earthquate 1911 (M=7.0) is assumed to be located 70 km (Z=0) west of the proposed damsites (after Taber, 1922).

B - 2 (Case 3) Epicenter of earthquake 1911 (M=7.0) is assumed to be located 14.6 km (Z=46) west of Piedra Gorda (after Gutenberg and Richter, 1956).

B - 3 (Case 4) Epicenter of earthquake 1911 (M=7.0) is assumed to be located 50 km (Z=0) west of Piedra Gorda.

In each case the peak ground acceleration has been calculated as summarized hereunder.

(Unit: g)

		Return Period (Year)			
		(34)	(69)	(100)	(200)
A	(Case 1)	0.102	-	0.123	0.142
B - 1	(Case 2)	-	0.123	-	-
B - 2	(Case 3)	-	0.177	-	-
B - 3	(Case 4)	-	0.168	-	-

It is considered that Case 1 is relatively equal to the evaluation according to the data reliability. For the sake of the design earthquake acceleration of the proposed Piedra Gorda damsite, the value of 0.175 g is adopted, including some safe measure.

2.4 Construction Materials

2.4.1 Sources of Construction Materials:

Preliminary survey on construction materials for the Piedra Gorda dam and the appurtenant structures has been made on the basis of geologic investigation, as well as field reconnaissance in and around the proposed damsite. The available sources of construction materials, such as earth materials for impervious core, filter and concrete aggregate, inner shell materials, outer and riprap materials are proposed as described hereunder. (Refer also to Fig.-13).

(1) Earth material for impervious core is available from borrow areas which are located at the left bank side of the Rio Yuna of about 1,500 m and 3,500 m downstream from the proposed damsite.

(2) Filter and concrete aggregate are available from borrow areas which are located at the riverbed of the Rio Yuna in and around the damsite.

(3) Inner shell material such as gravel, cobble and boulder are available from same borrow areas as filter and concrete aggregate.

(4) Outer shell and riprap materials are available from a quarry site which is located at 1.3 km southeast of the damsite.

2.4.2 Property of Materials

Although no laboratory test has been executed on these materials, property of earth materials, sand and gravel, boulders and rock materials is basically similar to those identified for El Torito - Los Veganos complex, judging from the site reconnaissance. It is noted further that the sand and gravel borrow area upstream of the damsite is located close to the borrow area whose property was tested at the laboratory for the Rio Blanco project. Consequently, it is provisionally assumed that the available construction materials will have design values as summarized hereunder.

	Shear Strength		Unit Weight			Permeability
	C (t/m^2)	ϕ (°)	Dry (t/m^3)	Wet (t/m^3)	Sat. (t/m^3)	K (cm/sec)
Earth material	2	30	1.55	1.80	2.00	$1x10^{-6}$
Filter material	0	38	2.06	2.10	2.20	$1x10^{-3}$
Inner shell mate.	0	39	2.06	2.10	2.20	$1x10^{-2,-3}$
Outer shell mate.	0	41	1.93	1.95	2.10	$1x10^{0,-1}$

For further detailed study, it is suggestible to carry out the laboratory test of construction materials to confirm the property and to estimate design values.

III. PRELIMINARY PLAN

3.1 Limitations

The Piedra Gorda dam will be constructed for multiple purposes. Water stored in the Piedra Gorda reservoir is utilized for power generation, water supply to Bonao city and Falconbridge, as well as for irrigation in Bonao valley. Further, tail water will be controlled by afterbay weir, and it may be diverted to the existing Rincon reservoir for power generation and extension of irrigation area in the Jima river basin.

The study on construction of the Piedra Gorda dam should therefore be made as an integrated system. However, the irrigable areas in Bonao valley and the Jima river basin downstream from the Rincon dam have not been defined yet, and diversion water requirement for irrigation is not definable at this stage.

Under such circumstances, the study is provisionally made to utilize water stored by the Piedra Gorda dam primary for power generation. Requirement of water supply for Bonao city and Falconbridge, as well as for irrigation in Bonao valley and Jima river basin, is secured by release of water from the reservoir for such purposes, in case such a requirement exceeds over the firm discharge planned for power generation.

3.2 Firm Discharge

By constructing the Piedra Gorda dam, water to be stored in the reservoir is estimated by the storage curve as shown on Fig.-14. Discharge available for guaranteed power generation is estimated by means of mass curve method, on the basis of daily synthetic discharge calculated at Piedra Gorda. The second worst drought year in 10 years' record from 1969-78 is selected as a base year (1977). The discharge mass curve is prepared as shown on Fig.-15. On the basis of the mass curve, as well as the reservoir capacity for various draft value as shown on Fig.-16, the firm discharge available for power generation by Piedra Gorda reservoir is estimated as summarized hereunder.

	Case-1	Case-2	Case-3	Case-4
High water level (EL.m)	340	350	360	370
Effective storage (10^6m^3)	29	47	67	92
Firm discharge (m^3/s)	8.5	10.3	12.2	13.3

It is noted that the firm discharge is calculated on the assumption that the water storage scheme in the upper stream at El Torito, Los Veganos and Pinalito is not materialized. The effect of water storage at El Torito (T1-T2 combined dams) on the Piedra Gorda scheme is assessed in Chapter 3.5 below, and it is incorporated into the benefit of dam plan in evaluating it with the alternative weir plan for El Torito scheme.

Water supply to Bonao city is required at 0.3 m^3/s, and the Falconbridge mine has a water right of 0.63 m^3/s. According to the preliminary study by INDRHI, water requirement for irrigation in Bonao valley with a presumed area of 2,000 ha. is estimated to range from 0.08 m^3/s in November to 1.55 m^3/s in June. Further, water diversion for irrigation in the Jima river basin downstream from the Rincon dam is preliminary estimated to be required for the maximum of around 13.9 m^3/s for the area of 14,840 ha. identified by Hanson Rodriguez in 1973. Although the irrigable area in the Jima river basin, as well as in Bonao valley, is not definable yet, the annual mean discharge required for irrigation, municipal and industrial water supply is estimated at less than 8 m^3/s.

On such an assumption, the firm discharge available for power generation in the second worst drought year is lowered for a period of less than one month, in order to release stored water for securing irrigation requirement. In any case, the study is to be further made in future by defining irrigable area and irrigation water requirement in the Jima river basin and Bonao valley.

By referring to the study on power demand and supply made for El Torito - Los Veganos complex, the Piedra Gorda power station is planned to be operated to cover the peak load for the minimum duration of 6 hours a day. Consequently, the Piedra Gorda reservoir will be operated to have the maximum discharge for power generation, as follows:

	Case-1	Case-2	Case-3	Case-4
High water level (EL.m)	340	350	360	370
Firm discharge (m^3/s)	8.5	10.3	12.2	13.3
Maximum discharge (m^3/s)	34.0	41.2	48.8	53.2

3.3 Optimization

The optimum scale of reservoir is studied by analysing the power benefit and the cost to be incurred for construction of dam and power station. As summarized on Table-12, the reservoir with the high water level at EL. 350 m (Case-2) turns out to be most advantageous. Consequently, it is provisionally adopted that the Piedra Gorda dam will be preliminarily designed under the following conditions:

High water level (EL.m)	350.0
Low water level (EL.m)	315.0
Rated water level (EL.m)	332.5
Tail water level (EL.m)	254.0
Gross storage capacity (10^6m^3)	65.0
Dead storage capacity (10^6m^3)	18.0
Effective storage capacity ($10^6/m^3$)	47.0
Firm discharge (m^3/s)	10.3
Max. discharge (m^3/s)	41.2

3.4 Water Diversion

Tail water from the Piedra Gorda power station is planned to be once stored by the afterbay weir. The regulated water will be utilized for the municipal and industrial water supply (0.93 m^3/s) in Bonao and for irrigation in the Bonao valley. Further, water is planned to be diverted to the Rincon reservoir, by constructing an intake structures on the left abutment of the afterbay weir and by amplifying the Yuna-Cañabon canal. It is presumed that the water diversion to the Rincon reservoir is made in such a volume as remained after municipal and industrial water supply, as well as irrigation (2,000 ha.) in the Bonao valley, as shown on Table-13.

In case the Piedra Gorda tail water is diverted to the Rincon reservoir, annual energy output at the Hatillo dam and power station will be decreased. However, water required for irrigation in the area downstream from the Hatillo dam (said to be around 12,000 ha.) can be fed by the remaining catchment area (1,192 km^2 at Hatillo - 358 km^2 at Piedra Gorda). On the other hand, available head at the Rincon power station is much higher than Hatillo, and requirement for irrigation water is of greater significance in the area downstream from the Rincon dam. Consequently, the energy decrease at the Hatillo power station is calculated as a negative benefit.

3.5 Power Generation

Use of reservoir water for power generation is planned in the same manner as applied for El Torito dam plan. As a result, the power output under the Piedra Gorda plan is calculated as summarized hereunder.

	Installed Capacity (MW)	Primary Energy (GWh)	Secondary Energy (GWh)	Total Energy (GWh)
Piedra Gorda	27.0	53.7	54.2	107.9
Rincon	10.0	21.3	0.2	21.5
Hatillo	-	-	-) 8.8	-) 8.8
Total	37.0	75.0	45.6	120.6

In case that the alternative plan to construct El Torito dam plan is selected for implementation, the effect of water regulation and El Torito dam is expectable at the Piedra Gorda scheme. This effect is estimated as follows:

	Without El Torito dam	With El Torito dam	Difference
Firm discharge (m^3/S)	10.3	10.8	0.5
Installed capacity (MW)	27.0	29.0	2.0
Primary energy (GWh)	53.7	57.8	4.1
Secondary energy (GWh)	54.2	51.0	-3.2
Total energy (GWh)	107.9	108.8	0.9

The effect of water regulation at El Torito is regarded as an associated benefit of El Torito dam plan and is taken into account in comparatively evaluating the two alternative plans; Pino de Yuna weir plan or El Torito dam plan.

IV. LAYOUT OF THE PROJECT

4.1 Piedra Gorda Dam

4.1.1 Damsite

The proposed damsite is located at 2.0 km upstream of Los Quemados. The site offers a V-shaped valley, with the right abutment dipping 50° and the left abutment dipping 25°. The riverbed is about 80 m in width, and alluvial river gravel is about 14 m in thickness, at maximum. The right abutment consists of green schist and green rock of the Duarte Formation, and is covered with debris of about 5 m in thickness. The left abutment is composed of calcareous tuff in the upstream and greyish limestone in the downstream of the Tireo Formation. The Duarte Formation upturns and overlies the Tireo Formation, and an extension of the Bonao fault is inferred at their contact. The fault zone, less than 15 m in thickness, dips 40-50° toward the right-downstream. As explained in Chapter 2.3.4, it is anticipated that the fault shear zone in the dam axis foundation can be treated by a dental excavation and backfilling with a dental concrete.

In view of the geohydrological observation, the dam axis is provisionally selected at the upstream side where calcareous tuff is dominant. A general layout of the Piedra Gorda scheme is illustrated on DWG.-01.

4.1.2 Dam Type and Design Criteria

In view of the topographic and geotechnical conditions at the damsite, it appears desirable to design a fill-type dam at Piedra Gorda. Major reasons are:

a) Bonao fault is inferred to bevel in the foundation rock

b) Weathered zone is relatively deep, or 15-20 m in thickness, in both abutment

c) Earth materials for impervious core, filter and inner shell materials, and riprap materials are available near the damsite.

Although it should be further studied during the stage of feasibility study, it is preliminarily decided to adopt a fill-type dam construction at Piedra Gorda.

Major criteria applied in the layout of the Piedra Gorda dam is summarized as follows:

1) Dam Height:

The high water level is selected at EL. 350.0 m. The flood water level at the design flood discharge of 3,240 m^3/s is calculated at 4.0 m, on the basis of the spillway overflow depth and overflow length. The height of waves to be caused by wind is estimated to be less than 1.0 m. By adding 1.0 m for the case of fill-type dam, the dam crest elevation is set at EL. 356.0 m.

Dam is placed on the foundation to be excavated for 16 m in depth at maximum from the ground surface (EL. 266 m). Consequently, the height of dam from the foundation is 106 m.

2) Design Earthquake Acceleration:

As explained in Chapter 2.3.5, a value of 0.175 g is adopted for the Piedra Gorda dam.

3) Design Value of Embankment Materials:

Although laboratory tests of the construction materials have not been executed yet, it is preliminarily studied that the property of earth materials, sand and gravel, boulders and rock materials is similar to those identified by El Torito - Los Veganos complex, and that the same design values are applicable in the layout of the Piedra Gorda dam at this stage.

4) Zoning and Stability:

Dam zoning is preliminarily planned to utilize sand, gravel, cobble and boulders in the riverbed to the maximum extent. The slopes of the dam is designed at 1:3.1 in the upstream slope and 1:2.0 in the downstream slope, on the basis of the slope stability analysis by surface sliding method.

On the basis of the design criteria explained above, a layout of the Piedra Gorda dam is drawn as shown on DWG.-02.

4.1.3 Spillway and River Diversion

A spillway is preferably designed as a side channel on the left abutment of the Piedra Gorda dam, in view of the topographic conditions at the damsite. The overflow length of the spillway has also topographic limitations, and it is designed to be 170 m in length.

Cofferdams and river diversion tunnels are designed under the design flood discharge of 1,580 m^3/s, which is equivalent to the probable flood for the return period of 20 years. Two diversion tunnels are planned in the right and left abutments, each having an inside diameter of 9.2 m. The upstream cofferdam will have a height of 40 m.

4.2 Piedra Gorda Power Station

Under the previous study by ENEL, a power station was located on the left bank of the Yuna river, at about 4 km downstream from the Piedra gorda dam. The dam and headrace tunnel plan was adopted. Under such a plan, a higher head would be made available. However, this plan has disadvantages, as follows:

a) The headrace tunnel was aligned close to and in parallel with the Bonao fault.

b) The afterbay weir site was to be found downstream, and the weir crest length was much wider.

c) Gain in the head was relatively small, or around 19 m in height, if compared with the length of the headrace tunnel (about 3.8 km).

As an alternative, the Piedra Gorda power station is planned to be located on the right bank of the toe of the Piedra Gorda dam. Under this plan, a part of the diversion tunnel to be excavated in the right abutment can be utilized as a power intake tunnel to economize the construction cost. A favorable site for the afterbay weir is found near El Frio, or about 1.3 m downstream from the damsite. Although detailed study is to be made during the stage of feasibility study, it is preliminarily planned at the moment to locate the powerhouse on the right bank immediately downstream from the Piedra Gorda dam.

An open-type powerhouse to accommodate the generating equipment is planned to be 32 m in length, 22 m in width and 36 m in height. Two sets of Francis type turbine of 13.5 MW and generator of 15,000 kVA will be installed in the powerhouse. An outdoor switchyard is planned beside the powerhouse. A layout of the Piedra Gorda power station is shown on DWG-03.

4.3 El Frio Afterbay Weir

The Piedra Gorda power station is planned to cover the peak load for the minimum operation of 6 hours a day. Tail water is to be utilized for municipal and industrial water supply, as well as for irrigation in the Bonao valley. Water diversion to the Rincon dam is also planned for power generation and irrigation in the area downstream from the Rincon dam. Consequently, an afterbay weir is planned to be constructed near El Frio, about 1.3 km downstream from the Piedra Gorda power station.

At El Frio, riverbed is approximately 120 m in width. Although no drilling has been conducted yet at the weir site, it is presumed that the riverbed deposit has a depth similar to the Piedra Gorda damsite. Although the scale of weir has to be decided after the diversion for irrigation water is defined, it is provisionally planned to have a storage capacity of about 600,000 m^3 with the high water level at EL. 254.0 m. A concrete weir is designed to have an open portion of 120 m to spill out 100-year probable discharge of 2,380 m^3/s. The design flood of 3,240 m^3/s is spilled out over the weir crest.

At the right abutment of the weir, intake facilities for water supply to Bonao city and for irrigation on the right bank of the Yuna river is to be designed. Canals from the intake will be connected to the existing water supply and irrigation canals. At the left abutment, an intake for diversion to the Yuna-Cañabon canal is to be designed. A layout of El Frio afterbay weir is shown on DWG-04.

V. PRELIMINARY EVALUATION

5.1 Construction Cost

On the basis of layout presented in the foregoing Chapter IV, a preliminary estimate of the construction cost is made for the Piedra Gorda project, inclusive of the facilities as follows:

a) A 106 m high fill-type dam with spillway and intake structures

b) A power station with an installed capacity of 27 MW at the toe of the Piedra Gorda dam, inclusive of electro-mechanical works.

c) An afterbay weir at El Frio (20 m in height and 397 m in length)

d) Intake structures for municipal and irrigation water supply on both sides of the afterbay weir

e) Installation of the second unit (10 MW) of generating equipment at the Rincon power station

The financial cost of construction is preliminarily estimated at around US$89 million at 1983 prices, as shown on Table-14. It is noted that the price escalation and the cost for amplification of the Yuna-Cañabon canal, as well as cost for resettlement and other associated cost, are precluded in the preliminary estimate.

5.2 Preliminary Evaluation

For the preliminary economic evaluation, the economic cost of the project is estimated by applying a shadow exchange rate of 1:1.6 for the cost to be incurred in foreign currency and by deducting a transfer payment of 10% from the cost in local currency.

On the other hand, the capacity value and primary energy value of alternative gas-turbine power, as well as the secondary energy value of alternative coal / oil power, are estimated as follows:

	10 MW scale Alternative power	28 MW class Alternative power
Capacity value	547.38/kW	388.69/kW
Primary energy	0.1626/kWh	0.1549/kWh
Secondary energy	0.0612/kWh	0.0612/kWh

The value of alternative power is calculated for the total installed capacity and energy output estimated in Chapter 3.5.

Under such conditions, the economic internal rate of return of the Piedra Gorda dam and power project is preliminarily estimated at 13.0% (Refer to Table-15). In case that 28 MW class alternative power is adopted, the internal rate will slightly decrease to 12.0%. (Refer to Table-16)

It is noted that the preliminary evaluation has been made only for the benefit to accrue from the power generation, and the benefit obtainable from the irrigation water supply in the Bonao valley and in the irrigable area downstream from the Rincon dam is not counted at this moment. If irrigation and other benefits are taken into account, the economic feasibility of the construction of the Piedra Gorda dam is heightened and becomes more attractive.

It is suggestible that evaluation of the Piedra Gorda dam will be conducted in more detail during the stage of feasibility study, by defining the irrigable area and irrigation benefit, as well as by studying the allocation of dam and other structure cost for each purpose of the project.

VI. CONCLUSION AND RECOMMENDATION

Through the investigation and studies conducted to-date, the implementation of the Piedra Gorda project is preliminarily appraised to be technically and economically feasible. The project will greatly contribute for the power generation (37 MW in installed capacity and 120 GWh in energy output envisaged under the preliminary study), as well as for irrigation, municipal and industrial water supply. It is therefore recommended that a feasibility study be made on the Piedra Gorda project.

Under the CDE power expansion plan, the Piedra Gorda (Alto Yuna) power station is programmed to be commissioned by 1990. In view of the period required for the construction and pre-construction works, it is suggested that the feasibility study on the Piedra Gorda project will be started at the earliest possible time.

For the execution of the feasibility study, it is advisable that the investigation and studies will incorporate, inter-alia, the following aspects:

a) The property of the fractured zone by the fault remains to be clarified, though the location and extent of the fault have been investigated under this preliminary study. The laboratory tests, including uniaxial compression test and permeability test, are to be made on core samples in order to define design values.

b) The thickness of river deposit has been investigated, but its permeability, grain size and other property are remained to be clarified further by means of excavating test pits on the riverbed at the damsite.

c) In view of the geological formation in both abutment of the damsite (green schist and green rock in the right abutment and calcareous tuff and limestone in the left abutment), it is desirable that test adits are excavated for in-situ rock test in both abutments. Such adits may be utilized for grout gallery in the construction stage. Further, it is preferable to excavate a shaft from the right bank adit to reach the fractured zone for the in-situ rock test of the zone.

d) Soil-mechanic test is to be conducted at the laboratory with respect to the earth and rock materials, as well as filter and concrete aggregates.

e) To define the use of water to be stored in the Piedra Gorda reservoir, the irrigable area in the Bonao valley and in the area downstream from the Rincon dam is to be defined.

f) A preliminary design for the amplification of the Yuna-Cañabon canal is also to be prepared in the light of irrigation water requirement and regulation by the Rincon reservoir.

g) The operation of the Piedra Gorda power station, as well as the Piedra Gorda reservoir, is to be studied further in an integrated harmony with the operation of other power stations constructed and planned in the upper Yuna river basin, including El Torito - Los Veganos complex, Rio Blanco power station, Pinalito project, Rincon dam and power station and Hatillo dam and power station.

TABLES

Table-01 MONTHLY RAINFALL AT LOS QUEMADOS

unit : mm

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	MEAN
1967	49.40	0.	52.40	248.40	58.50	209.50	179.80	63.10	105.00	253.00	114.00	0.	1333.10	111.09
1968	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1969	0.	0.	0.	0.	0.	12.00	156.00	90.00	192.90	178.20	133.40	151.30	913.80	76.15
1970	63.00	128.00	63.00	102.00	423.00	207.00	241.00	317.00	197.00	195.00	173.00	173.00	2282.00	190.17
1971	114.50	488.00	88.80	160.60	277.50	19.00	158.10	192.00	223.00	219.10	163.50	137.00	2241.10	186.76
1972	68.30	64.50	242.10	127.00	191.70	189.00	286.00	256.00	157.50	298.00	49.00	268.00	2197.10	183.09
1973	51.80	84.90	34.30	160.30	188.80	92.70	100.90	153.60	150.40	172.30	243.80	136.20	1570.00	130.83
1974	190.00	189.00	185.00	249.00	133.00	65.10	116.00	155.60	88.70	227.00	101.20	19.70	1719.30	143.27
1975	67.40	39.50	87.50	78.50	296.40	44.00	47.60	257.00	103.70	223.60	89.40	308.70	1643.30	136.94
1976	27.00	210.00	192.30	265.00	74.00	74.00	122.00	130.00	228.00	284.00	103.00	99.00	1808.30	150.69
1977	36.10	38.40	22.30	357.20	328.00	50.80	187.70	248.60	156.00	139.20	458.80	211.20	2234.30	186.19
1978	134.50	50.30	207.70	312.80	170.20	117.40	86.80	257.90	255.90	194.20	119.50	101.00	2008.20	167.35
1979	25.40	0.	395.50	397.80	533.70	346.20	220.60	754.90	338.40	165.40	408.70	173.60	3760.20	313.35
1980	158.30	71.30	78.00	209.30	426.80	80.80	132.70	173.10	358.80	147.80	24.20	188.70	2049.80	170.82
1981	87.60	195.00	296.90	307.20	742.40	146.60	358.20	364.90	287.30	510.90	299.20	150.60	3746.80	312.23
1982	248.70	199.10	73.90	281.30	440.40	85.90	0.	180.40	87.00	194.90	253.60	326.30	2371.50	197.63
1983	63.10	77.20	119.70	156.90	575.10	76.70	0.	0.	0.	0.	0.	0.	1068.70	89.06
TOTAL	1385.10	1835.20	2139.40	3413.30	4859.50	1816.70	2393.40	3594.10	2929.60	3402.60	2734.30	2444.30	32947.50	2745.63
MEAN	92.34	141.17	142.63	227.55	323.97	113.54	170.96	239.61	195.31	226.84	182.29	174.59	1938.09	161.51

Table -02 MONTHLY MEAN DISCHARGE AT LOS QUEMADOS

(Unit: m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1962	-	-	-	21.50	21.70	27.29	13.50	11.60	15.79	14.39	10.99	8.79	16.17
1963	7.76	7.69	13.20	13.20	31.29	17.30	15.99	17.40	12.99	34.80	27.29	12.60	17.63
1964	9.00	5.91	4.68	17.30	8.03	9.87	12.30	14.30	11.49	12.60	11.10	18.79	11.28
1965	11.20	12.69	5.21	2.83	36.20	20.70	17.30	11.82	15.49	14.39	23.40	11.99	15.25
1966	17.10	7.55	8.77	15.60	23.10	13.30	-	-	-	-	-	-	14.24
1967	-	-	-	-	-	-	-	-	-	-	-	-	-
1968	8.40	9.78	7.44	6.64	11.20	7.01	10.30	15.20	8.90	5.23	17.60	38.30	12.17
1969	18.19	8.87	6.92	24.39	29.50	12.69	9.18	9.28	13.20	13.62	32.39	22.40	16.72
1970	8.90	10.39	9.71	5.61	34.20	27.39	15.39	20.89	23.50	22.70	40.50	56.20	22.95
1971	20.29	53.69	17.40	15.99	17.10	11.39	10.39	12.19	12.49	14.99	15.69	19.40	18.42
1972	19.39	11.39	19.59	13.59	17.09	19.20	19.69	24.70	21.39	29.49	12.09	35.00	20.22
1973	13.39	13.39	9.60	7.90	7.77	9.52	10.19	9.65	12.50	21.70	15.99	24.79	13.03
1974	27.19	22.79	27.89	18.20	13.39	9.27	6.47	25.29	30.69	33.89	13.50	14.59	20.26
1975	9.77	7.60	6.31	4.68	6.87	4.26	3.43	6.73	6.67	10.79	32.09	60.99	13.35
1976	12.87	21.20	23.39	37.59	45.29	18.20	51.49	55.69	64.30	52.89	14.69	16.69	34.52
1977	6.18	4.72	3.33	17.79	21.50	9.60	6.52	9.25	13.50	11.89	37.35	25.70	13.94
1978	18.20	8.89	7.57	22.69	17.59	10.39	8.22	14.59	10.19	7.54	8.48	9.50	11.99
1979	7.87	8.35	27.50	35.19	41.79	41.00	26.09	27.59	-	-	-	-	26.92
Average	13.48	13.43	12.41	16.51	22.57	15.79	14.78	17.89	18.21	20.06	20.88	25.05	17.59

Table -03 MONTHLY MEAN IRRIGATION WATER USE

(Unit: m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1969	-	-	-	-	-	-	-	1.03	0.96	0.90	0.50	0.51
1970	0.73	0.76	0.92	1.21	0.84	0.72	0.72	0.83	0.63	(0.90)	(0.43)	(0.49)
1971	0.36	0.52	0.46	0.65	0.71	0.63	0.56	0.54	0.68	0.87	0.70	0.81
1972	0.39	0.47	0.78	0.71	0.84	0.83	0.68	0.28	0.31	0.33	0.35	0.23
1973	0.30	0.30	(0.25)	-	-	-	0.91	-	(0.54)	0.42	0.36	(0.24)
1974	(0.34)	-	-	-	-	(0.32)	0.26	(0.28)	-	(0.17)	(0.04)	(0.11)
1975	-	(0.06)	(0.14)	0.25	0.31	0.32	0.35	0.38	0.40	0.41	0.37	(0.58)
1976	(0.45)	0.36	0.48	0.59	0.73	0.71	0.81	0.86	0.49	0.58	0.80	0.73
1977	0.83	0.93	0.87	0.97	0.89	1.09	0.95	0.86	0.97	1.00	0.85	0.81
1978	1.14	1.21	1.30	0.80	1.13	1.18	0.99	-	1.06	1.20	1.18	1.17
1979	-	-	-	-	-	-	-	-	-	-	-	-
Average	0.63	0.65	0.80	0.74	0.78	0.78	0.69	0.68	0.69	0.71	0.64	0.71

Table -04 SYNTHETIC DISCHARGE AT LOS QUEMADOS

Unit: m^3/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1969	19.41	9.52	7.71	25.12	30.30	13.49	9.86	9.87	13.88	14.44	33.02	23.15	17.51
1970	9.52	11.03	10.51	6.35	34.95	28.19	16.10	21.61	24.18	23.37	41.11	56.91	23.74
1971	20.91	54.34	18.24	16.74	17.92	12.21	11.05	12.83	13.16	15.50	16.34	20.15	18.87
1972	20.06	12.08	20.41	14.32	17.88	19.93	20.41	25.42	22.10	30.24	12.74	35.72	21.03
1973	14.04	14.00	10.38	8.68	8.56	10.42	10.94	10.13	13.17	22.39	16.64	25.04	13.71
1974	27.59	25.32	28.53	18.89	14.14	10.04	7.17	25.99	31.39	34.41	14.23	15.24	21.07
1975	10.40	8.25	7.12	5.42	7.65	5.04	4.13	7.42	7.37	11.48	32.72	61.66	14.12
1976	13.75	21.85	24.15	38.32	46.08	18.93	52.22	56.33	64.97	53.64	15.30	17.43	35.33
1977	6.79	5.38	4.14	18.53	22.25	10.38	6.95	9.92	14.16	12.37	37.28	26.44	14.56
1978	18.85	9.55	8.38	23.50	18.37	11.16	8.91	15.26	10.93	8.26	9.13	10.20	12.72
MEAN	16.13	17.13	13.96	17.59	21.81	13.98	14.77	19.48	21.53	22.61	22.85	29.19	19.25

Table -05 FLOOD DISCHARGE ESTIMATED AT PIEDRA GORDA

	Estimated Discharge (m^3/s)	Specific Discharge ($m^3/s/km^2$)
Actual rainfall	1,945	5.4
Return period: 1/20	1,572	4.4
1/50	2,039	5.7
1/100	2,377	6.6
1/200	2,692	7.5
Probable maximum flood	3,449	9.6
Design flood:		
Fill-type dam	3,240	
Coffer dam	1,580	

Reference: El Torito - Los Veganos Complex, Annex C.5

Table -06 GEOPHYSICAL AND DRILLING SURVEY AT PIEDRA GORDA DAMSITE

[GEOPHYSICAL EXPLORATION]

Line No.	Length (m)	Reference
PG-A	575	Fig.-04
PG-B	580	Fig.-05
PG-C	740	Fig.-06
PG-1	345	Fig.-07
PG-2	345	Fig.-07
PG-3	345	Fig.-07
(Total)	(2,930)	

[CORE DRILLING]

Hole No.	Location	Ground Elevation	Drilling Depth	Permeab. Test	Reference
PG-B1	Riverbed	266.80	32.8	6	PGL-01
PG-B2	Right bank	268.56	80.0 (inclined)	10	PGL-02
PG-B3	Left bank	320.03	50.0	8	PGL-03
(Total)			(162.8)		

Table -07 STRATIGRAPHIC SEQUENCE OF STUDY AREA

Geologic Age		Formation	Lithology
Cenozoic	Quaternary	Alluvial deposit	Present river deposit Debris Middle & lower terrace deposit Upper terrace deposit
		(unconformably)	
Mesozoic	Upper Cretaceous (Middle Albian)	Tireo formation	Limestone, Marl Andesite, Dacite, Tuff breccia, Limestone, Tuff, Sandstone, Slate, Chert
		(Fault)	
Age unknown	Pré-Middle Albian	Duarte formation	Amphibolite, Foliated diorite, Peridotite Green schist Gneiss
		(Intrusion) /1	
Age unknown	Pre-Middle Albian (?)	Plutonic igneous rocks	Coarse grained quartz diorite (Partly foliated)

/1 Relation is not necessarily confirmed.

Table -08 PETROGRAPHIC DESCRIPTION OF ROCK SAMPLES

Sample	Texture of Structure	Rock Name	Constituent Minerals	Original Rock
Duarte Formation				
322	Banded T.	Artinolite chlorite schist	Actinolite, chlorite, albite, epidote, quartz, calcite, iron ore	Tuffaceous shale
323	Banded T.	Epidote Actinolite schist	Epidote, chlorite, actinolite, calcite, quartz, albite, iron ore	Lithic Tuff (Basic Tuff)
72201	Porphroblastic T.	Epidote Actinolite schist	Epidote, actinolite, albite, quartz, iron ore	Basic Tuff
Tireo Formation				
72202	Green tuff or green rock		Chlorite, albite, quartz, clay-minerals, iron ore	To be welded tuff (?)
PG-B3 (47.2m)	Oil Conglomerate		Basaltic - andestic pebble matrix: calcareous marl and tuff	with organic matter
PG-B3 (38.0m)	Conglomerate		Basaltic - andestic pebble matrix: calcareous marl and tuff	with organic matter and foraminifera shell
72701	Calcareous siltstone		A little basaltic to andesific pebble in biomicrite	Foraminifera shell
7503	Altered Basalt or Altered Andesite		Plagioclase, ground mass and mafic minerals altered to calcite and Irone Ores, Cavities are fill with calcite	Amygdal basult or andesite

Table-09 WATER PRESSURE TEST (1)

Borehold Number: PG-B1

Depth (from) (m)	Depth (to) (m)	Length Tested (m)	Hole Dia. (m)	Pressure Reading (kg/cm²)	Static Head (m)	Gauge Height (m)	Friction Loss (m)	Total Head (m)	Water Injected (l/min)	Coefficient of Permeability (cm/s)	Lugeon Unit -	Step No.
5.50	10.00	4.50	5.5	0.5	1.60	1.75	5.24	3.11	69.0	6.7E-03	492.6	1
10.00	15.00	5.00	5.5	1.0	1.80	3.00	1.80	13.00	30.0	6.4E-04	46.2	1
10.00	15.00	5.00	5.5	2.0	1.80	3.00	4.80	20.00	49.0	6.8E-04	45.0	2
15.00	20.00	5.00	5.5	1.0	1.80	3.00	0.51	14.29	13.0	2.5E-04	18.2	1
15.00	20.00	5.00	5.5	3.0	1.80	3.00	1.73	33.07	24.0	2.0E-04	14.5	2
15.00	20.00	5.00	5.5	5.0	1.80	3.00	4.33	50.47	38.0	2.1E-04	15.1	3
15.00	20.00	5.00	5.5	4.0	1.80	3.00	3.67	41.13	35.0	2.3E-04	17.0	4
15.00	20.00	5.00	5.5	2.0	1.80	3.00	1.32	23.48	21.0	2.5E-04	17.9	5
20.00	25.00	5.00	5.5	1.0	1.60	3.00	0.40	14.20	10.0	1.9E-04	14.1	1
20.00	25.00	5.00	5.5	3.0	1.60	3.00	2.30	32.30	24.0	2.1E-04	14.9	2
20.00	25.00	5.00	5.5	5.0	1.60	3.00	4.36	50.24	33.0	1.8E-04	13.1	3
20.00	25.00	5.00	5.5	7.0	1.60	3.00	6.40	68.20	40.0	1.6E-04	11.7	4
20.00	25.00	5.00	5.5	10.0	1.60	3.00	8.46	96.14	46.0	1.3E-04	9.6	5
20.00	25.00	5.00	5.5	8.0	1.60	3.00	5.48	79.12	37.0	1.3E-04	9.4	6
20.00	25.00	5.00	5.5	6.0	1.60	3.00	1.76	62.84	21.0	9.2E-05	6.7	7
20.00	25.00	5.00	5.5	4.0	1.60	3.00	0.68	43.92	13.0	8.2E-05	5.9	8
20.00	25.00	5.00	5.5	2.0	1.60	3.00	0.10	24.50	5.0	5.6E-05	4.1	9
25.00	30.00	5.00	5.5	1.0	1.40	3.00	0.18	14.22	6.0	1.2E-04	8.4	1
25.00	30.00	5.00	5.5	3.0	1.40	3.00	1.62	32.78	18.0	1.5E-04	11.0	2
25.00	30.00	5.00	5.5	5.0	1.40	3.00	3.38	51.02	26.0	1.4E-04	10.2	3
25.00	30.00	5.00	5.5	7.0	1.40	3.00	4.30	69.90	30.0	1.2E-04	8.6	4
25.00	30.00	5.00	5.5	10.0	1.40	3.00	8.40	96.00	41.0	1.2E-04	8.5	5
25.00	30.00	5.00	5.5	8.0	1.40	3.00	6.85	77.56	37.0	1.3E-04	9.5	6
25.00	30.00	5.00	5.5	6.0	1.40	3.00	2.20	62.20	21.0	9.3E-05	6.8	7
25.00	30.00	5.00	5.5	4.0	1.40	3.00	0.84	43.56	13.0	8.2E-05	6.0	8
25.00	30.00	5.00	5.5	2.0	1.40	3.00	0.18	24.22	6.0	6.8E-05	5.0	9
30.00	35.00	5.00	5.5	1.0	1.40	3.00	5.05	9.35	29.0	8.6E-04	62.0	1
30.00	35.00	5.00	5.5	3.0	1.40	3.00	21.60	12.80	60.0	1.3E-03	93.7	2
30.00	35.00	5.00	5.5	2.0	1.40	3.00	9.60	14.80	40.0	7.5E-04	54.1	3
35.00	40.00	5.00	5.5	1.0	1.60	3.00	0.00	14.60	0.0	0.0E+00	0.0	1
35.00	40.00	5.00	5.5	3.0	1.60	3.00	0.03	34.57	2.0	1.6E-05	1.2	2
35.00	40.00	5.00	5.0	5.0	1.60	3.00	0.11	54.49	4.0	2.0E-05	1.5	3
35.00	40.00	5.00	5.5	7.0	1.60	3.00	0.45	73.15	8.0	3.0E-05	2.2	4
35.00	40.00	5.00	5.5	10.0	1.60	3.00	2.27	102.33	18.0	4.9E-05	3.5	5
35.00	40.00	5.00	5.5	8.0	1.60	3.00	1.18	83.42	13.0	4.3E-05	3.1	6
35.00	40.00	5.00	5.5	6.0	1.60	3.00	0.57	64.03	9.0	3.9E-05	2.8	7
35.00	40.00	5.00	5.5	4.0	1.60	3.00	0.25	44.35	6.0	3.7E-05	2.7	8
35.00	40.00	5.00	5.5	2.0	1.60	3.00	0.06	24.54	3.0	3.4E-05	2.4	9

(Continued)

Borehole Number: PG-B1

Depth (from) (m)	Depth (to) (m)	Length Tested (m)	Hole Dia. (cm)	Pressure Reading (kg/cm²)	Static Head (m)	Gauge Height (m)	Friction Loss (m)	Total Head (m)	Water Injected (1 min)	Coefficient of Permeability (cm/s)	Lugeon Unit	Step No.
24.50	29.60	5.10	5.5	1.0	0.75	2.00	0.00	12.75	0.0	0.0E+00	0.0	1
24.50	29.60	5.10	5.5	3.0	0.75	2.00	0.00	32.75	0.0	0.0E+00	0.0	2
24.50	29.60	5.10	5.5	5.0	0.75	2.00	0.00	52.75	0.0	0.0E+00	0.0	3
24.50	29.60	5.10	5.5	7.0	0.75	2.00	0.00	72.75	0.0	0.0E+00	0.0	4
24.50	29.60	5.10	5.5	10.0	0.75	2.00	0.00	102.75	0.0	0.0E+00	0.0	5
24.50	29.60	5.10	5.5	8.0	0.75	2.00	0.00	82.75	0.0	0.0E+00	0.0	6
24.50	29.60	5.10	5.5	6.0	0.75	2.00	0.00	62.75	0.0	0.0E+00	0.0	7
24.50	29.60	5.10	5.5	4.0	0.75	2.00	0.00	42.75	0.0	0.0E+00	0.0	8
24.50	29.60	5.10	5.5	2.0	0.75	2.00	0.00	22.75	0.0	0.0E+00	0.0	9
29.50	32.80	3.30	5.5	1.0	0.70	2.00	0.00	12.70	0.0	0.0E+00	0.0	1
29.50	32.80	3.30	5.5	3.0	0.70	2.00	0.00	32.70	0.0	0.0E+00	0.0	2
29.50	32.80	3.30	5.5	5.0	0.70	2.00	0.00	52.70	0.0	0.0E+00	0.0	3
29.50	32.80	3.30	5.5	7.0	0.70	2.00	0.00	72.70	0.0	0.0E+00	0.0	4
29.50	32.80	3.30	5.5	10.0	0.70	2.00	0.00	102.70	0.0	0.0E+00	0.0	5
29.50	32.80	3.30	5.5	8.0	0.70	2.00	0.00	82.70	0.0	0.0E+00	0.0	6
29.50	32.80	3.30	5.5	6.0	0.70	2.00	0.00	62.70	0.0	0.0E+00	0.0	7
29.50	32.80	3.30	5.5	4.0	0.70	2.00	0.00	42.70	0.0	0.0E+00	0.0	8
29.50	32.80	3.30	5.5	2.0	0.70	2.00	0.00	22.70	0.0	0.0E+00	0.0	9

Table-10 WATER PRESSURE TEST (2)

Borehole Number: PG-B2

Depth (from) (m)	Depth (to) (m)	Length Tested (m)	Hole Dia. (cm)	Pressure Reading (kg/cm²)	Static Head (m)	Gauge Height (m)	Friction Loss (m)	Total Head (m)	Water Injected (l min)	Coefficient of Permeability (cm/s)	Lugeon Unit -	Step No.
28.50	33.15	4.65	7.6	1.0	3.64	0.40	0.00	14.04	0.0	0.0E+00	0.0	1
28.50	33.15	4.65	7.6	4.0	3.64	0.40	0.00	44.04	0.0	0.0E+00	0.0	2
28.50	33.15	4.65	7.6	6.0	3.64	0.40	0.00	64.04	0.0	0.0E+00	0.0	3
28.50	33.15	4.65	7.6	8.0	3.64	0.40	0.00	84.04	1.2	3.9E-06	0.3	4
28.50	33.15	4.65	7.6	10.0	3.64	0.40	0.03	104.01	3.1	8.2E-06	0.6	5
28.50	33.15	4.65	7.6	9.0	3.64	0.40	0.01	94.03	2.0	5.8E-06	0.5	6
28.50	33.15	4.65	7.6	7.0	3.64	0.40	0.02	74.02	2.3	8.5E-06	0.7	7
28.50	33.15	4.65	7.6	5.0	3.64	0.40	0.01	54.03	1.8	9.1E-06	0.7	8
28.50	33.15	4.65	7.6	3.0	3.64	0.40	0.02	34.02	2.7	2.2E-05	1.7	9
28.50	33.15	4.65	7.6	1.0	3.64	0.40	0.00	14.04	0.5	9.8E-06	0.8	10
33.00	38.00	5.00	7.6	2.0	6.93	0.40	0.00	27.33	0.0	0.0E+00	0.0	1
33.00	38.00	5.00	7.6	4.0	6.93	0.40	0.02	47.31	2.2	1.2E-05	0.9	2
33.00	38.00	5.00	7.6	6.0	6.93	0.40	0.01	67.32	2.0	7.7E-06	0.6	3
33.00	38.00	5.00	7.6	8.0	6.93	0.40	0.03	87.30	3.0	8.9E-06	0.7	4
33.00	38.00	5.00	7.6	10.0	6.93	0.40	0.05	107.28	3.7	8.9E-06	0.7	5
33.00	38.00	5.00	7.6	9.0	6.93	0.40	0.05	97.28	3.7	9.8E-06	0.8	6
33.00	38.00	5.00	7.6	7.0	6.93	0.40	0.03	77.30	3.2	1.1E-05	0.8	7
33.00	38.00	5.00	7.6	5.0	6.93	0.40	0.03	57.30	2.9	1.3E-05	1.0	8
33.00	38.00	5.00	7.6	3.0	6.93	0.40	0.02	37.31	2.7	1.9E-05	1.4	9
33.00	38.00	5.00	7.6	1.0	6.93	0.40	0.00	17.33	0.7	1.0E-05	0.8	10
38.00	43.00	5.00	7.6	2.0	3.64	0.40	0.00	24.04	0.0	0.0E+00	0.0	1
38.00	43.00	5.00	7.6	4.0	3.64	0.40	0.02	44.02	2.0	1.2E-05	0.9	2
38.00	43.00	5.00	7.6	6.0	3.64	0.40	0.03	64.01	3.0	1.2E-05	0.9	3
38.00	43.00	5.00	7.6	8.0	3.64	0.40	0.06	83.98	4.0	1.2E-05	1.0	4
38.00	43.00	5.00	7.6	10.0	3.64	0.40	0.09	103.95	5.0	1.2E-05	1.0	5
38.00	43.00	5.00	7.6	9.0	3.64	0.40	0.08	93.96	4.5	1.2E-05	1.0	6
38.00	43.00	5.00	7.6	7.0	3.64	0.40	0.05	73.99	3.6	1.3E-05	1.0	7
38.00	43.00	5.00	7.6	5.0	3.64	0.40	0.01	54.03	1.7	8.1E-06	0.6	8
38.00	43.00	5.00	7.6	3.0	3.64	0.40	0.01	34.03	1.2	9.1E-06	0.7	9
38.00	43.00	5.00	7.6	1.0	3.64	0.40	0.00	14.04	0.5	9.2E-06	0.7	10
43.00	48.00	5.00	6.9	2.0	3.94	0.40	0.05	24.29	3.5	3.8E-05	2.9	1
43.00	48.00	5.00	6.9	4.0	3.94	0.40	0.07	44.27	4.0	2.4E-05	1.8	2
43.00	48.00	5.00	6.9	6.0	3.94	0.40	0.09	64.25	4.7	1.9E-05	1.5	3
43.00	48.00	5.00	6.9	8.0	3.94	0.40	0.06	84.28	3.6	1.1E-05	0.9	4
43.00	48.00	5.00	6.9	10.0	3.94	0.40	0.19	104.15	6.6	1.7E-05	1.3	5
43.00	48.00	5.00	6.9	9.0	3.94	0.40	0.15	94.19	6.0	1.7E-05	1.3	6
43.00	48.00	5.00	6.9	7.0	3.94	0.40	0.13	74.21	5.4	1.9E-05	1.5	7
43.00	48.00	5.00	6.9	5.0	3.94	0.40	0.07	54.27	4.1	2.0E-05	1.5	8
43.00	48.00	5.00	6.9	3.0	3.94	0.40	0.06	34.28	3.7	2.8E-05	2.2	9
43.00	48.00	5.00	6.9	1.0	3.94	0.40	0.03	14.31	2.5	4.6E-05	3.5	10

(Continued)

Borehole Number: PG-82

Depth (from) (m)	Depth (to) (m)	Length Tested (m)	Hole Dia. (cm)	Pressure Reading (kg/cm²)	Static Head (m)	Gauge Height (m)	Friction Loss (m)	Total Head (m)	Water Injected (l min)	Coefficient of Permeability (cm/s)	Lugeon Unit	Step No.
48.00	53.00	5.00	6.9	2.0	3.52	0.40	0.03	23.89	2.6	2.9E-05	2.2	1
48.00	53.00	5.00	6.9	4.0	3.52	0.40	0.09	43.83	4.3	2.6E-05	2.0	2
48.00	53.00	5.00	6.9	6.0	3.52	0.40	0.10	63.82	4.5	1.9E-05	1.4	3
48.00	53.00	5.00	6.9	8.0	3.52	0.40	0.18	83.74	6.2	2.0E-05	1.5	4
48.00	53.00	5.00	6.9	10.0	3.52	0.40	0.27	103.65	7.5	1.9E-05	1.4	5
48.00	53.00	5.00	6.9	9.0	3.52	0.40	0.17	93.75	6.0	1.7E-05	1.3	6
48.00	53.00	5.00	6.9	7.0	3.52	0.40	0.12	73.80	5.0	1.8E-05	1.4	7
48.00	53.00	5.00	6.9	5.0	3.52	0.40	0.04	53.88	3.0	1.5E-05	1.1	8
48.00	53.00	5.00	6.9	3.0	3.52	0.40	0.03	33.89	2.5	1.9E-05	1.5	9
48.00	53.00	5.00	6.9	1.0	3.52	0.40	0.02	13.90	2.0	3.8E-05	2.9	10
53.00	58.00	5.00	6.9	2.0	3.60	0.40	0.13	23.87	5.0	5.5E-05	4.2	1
53.00	58.00	5.00	6.9	4.0	3.60	0.40	0.18	43.82	5.8	3.5E-05	2.6	2
53.00	58.00	5.00	6.9	6.0	3.60	0.40	0.20	63.80	6.1	2.5E-05	1.9	3
53.00	58.00	5.00	6.9	8.0	3.60	0.40	0.16	83.84	5.5	1.7E-05	1.3	4
53.00	58.00	5.00	6.9	10.0	3.60	0.40	0.26	103.74	7.0	1.8E-05	1.3	5
53.00	58.00	5.00	6.9	9.0	3.60	0.40	0.16	93.84	5.5	1.5E-05	1.2	6
53.00	58.00	5.00	6.9	7.0	3.60	0.40	0.10	73.90	4.3	1.5E-05	1.2	7
53.00	58.00	5.00	6.9	5.0	3.60	0.40	0.08	53.92	4.0	2.0E-05	1.5	8
53.00	58.00	5.00	6.9	3.0	3.60	0.40	0.06	33.94	3.5	2.7E-05	2.1	9
53.00	58.00	5.00	6.9	1.0	3.60	0.40	0.03	13.97	2.2	4.2E-05	3.1	10
58.00	64.00	6.00	6.9	2.0	3.56	0.40	1.48	22.48	16.0	1.6E-04	11.9	1
58.00	64.00	6.00	6.9	4.0	3.56	0.40	3.54	40.42	24.7	1.4E-04	10.2	2
58.00	64.00	6.00	6.9	6.0	3.56	0.40	6.70	57.26	34.0	1.4E-04	9.9	3
58.00	64.00	6.00	6.9	8.0	3.56	0.40	10.72	73.24	43.0	1.3E-04	9.8	4
58.00	64.00	6.00	6.9	10.0	3.56	0.40	12.27	91.69	46.0	1.1E-04	8.4	5
58.00	64.00	6.00	6.9	9.0	3.56	0.40	7.73	86.23	36.5	9.7E-05	7.1	6
58.00	64.00	6.00	6.9	7.0	3.56	0.40	5.40	68.56	30.5	1.0E-04	7.4	7
58.00	64.00	6.00	6.9	5.0	3.56	0.40	3.34	50.62	24.0	1.1E-04	7.9	8
58.00	64.00	6.00	6.9	3.0	3.56	0.40	1.39	32.57	15.5	1.1E-04	7.9	9
58.00	64.00	6.00	6.9	1.0	3.56	0.40	0.91	13.05	12.5	2.2E-04	16.0	10
64.00	70.00	6.00	6.9	2.0	3.60	0.40	0.10	23.90	4.0	3.8E-05	2.8	1
64.00	70.00	6.00	6.9	4.0	3.60	0.40	0.41	43.59	8.0	4.2E-05	3.1	2
64.00	70.00	6.00	6.9	6.0	3.60	0.40	1.00	63.00	12.5	4.5E-05	3.3	3
64.00	70.00	6.00	6.9	8.0	3.60	0.40	1.25	82.75	14.0	3.9E-05	2.8	4
64.00	70.00	6.00	6.9	10.0	3.60	0.40	2.31	101.69	19.0	4.3E-05	3.1	5
64.00	70.00	6.00	6.9	9.0	3.60	0.40	0.92	93.08	12.0	2.9E-05	2.1	6
64.00	70.00	6.00	6.9	7.0	3.60	0.40	0.77	73.23	11.0	3.4E-05	2.5	7
64.00	70.00	6.00	6.9	5.0	3.60	0.40	0.27	53.73	6.5	2.8E-05	2.0	8
64.00	70.00	6.00	6.9	3.0	3.60	0.40	0.10	33.90	4.0	2.7E-05	2.0	9
64.00	70.00	6.00	6.9	1.0	3.60	0.40	0.03	13.97	2.0	3.3E-05	2.4	10

(Continued)

Borehole Number: PG-82

Depth (from) (m)	Depth (to) (m)	Length Tested (m)	Hole Dia. (cm)	Pressure Reading (kg/cm²)	Static Head (m)	Gauge Height (m)	Friction Loss (m)	Total Head (m)	Water Injected (l min)	Coefficient of Permeability (cm/s)	Lugeon Unit	Step No.
70.00	75.00	5.00	6.9	2.0	3.29	0.40	0.01	23.68	1.0	1.1E-05	0.8	1
70.00	75.00	5.00	6.9	4.0	3.29	0.40	0.02	43.67	1.5	9.1E-06	0.7	2
70.00	75.00	5.00	6.9	6.0	3.29	0.40	0.06	63.63	3.0	1.2E-05	0.9	3
70.00	75.00	5.00	6.9	8.0	3.29	0.40	0.30	83.39	6.5	2.1E-05	1.6	4
70.00	75.00	5.00	6.9	10.0	3.29	0.40	0.45	103.24	8.0	2.0E-05	1.5	5
70.00	75.00	5.00	6.9	9.0	3.29	0.40	0.34	93.35	7.0	2.0E-05	1.5	6
70.00	75.00	5.00	6.9	7.0	3.29	0.40	0.13	73.56	4.3	1.5E-05	1.2	7
70.00	75.00	5.00	6.9	5.0	3.29	0.40	0.11	53.58	4.0	2.0E-05	1.5	8
70.00	75.00	5.00	6.9	3.0	3.29	0.40	0.11	33.58	4.0	3.1E-05	2.4	9
70.00	75.00	5.00	6.9	1.0	3.29	0.40	0.00	13.69	0.0	0.0E+00	0.0	10
75.00	80.00	5.00	6.9	2.0	3.72	0.40	0.05	24.07	2.5	2.7E-05	2.1	1
75.00	80.00	5.00	6.9	4.0	3.72	0.40	0.09	44.03	3.5	2.1E-05	1.6	2
75.00	80.00	5.00	6.9	6.0	3.72	0.40	0.42	63.70	7.5	3.1E-05	2.4	3
75.00	80.00	5.00	6.9	8.0	3.72	0.40	0.54	83.58	8.5	2.7E-05	2.0	4
75.00	80.00	5.00	6.9	10.0	3.72	0.40	0.65	103.47	9.3	2.4E-05	1.8	5
75.00	80.00	5.00	6.9	9.0	3.72	0.40	0.62	93.50	9.1	2.6E-05	1.9	6
75.00	80.00	5.00	6.9	7.0	3.72	0.40	0.55	73.57	8.6	3.1E-05	2.3	7
75.00	80.00	5.00	6.9	5.0	3.72	0.40	0.19	53.93	5.0	2.4E-05	1.9	8
75.00	80.00	5.00	6.9	3.0	3.72	0.40	0.03	34.09	2.0	1.5E-05	1.2	9
75.00	80.00	5.00	6.9	1.0	3.72	0.40	0.02	14.10	1.5	2.8E-05	2.1	10

Table-11 WATER PRESSURE TEST (3)

Borehole Number: PG-B3

Depth (from) (m)	Depth (to) (m)	Length Tested (m)	Hole Dia. (cm)	Pressure Reading (kg/cm2)	Static Head (m)	Gauge Height (m)	Friction Loss (m)	Total Head (m)	Water Injected (l min)	Coefficient of Permeability (cm/s)	Lugeon Unit -	Step No.
20.50	25.40	4.90	5.5	1.0	22.95	3.00	21.25	14.70	72.0	1.4E-03	100.0	1
25.50	30.90	5.40	5.5	1.0	23.20	3.00	2.25	33.95	21.0	1.6E-04	11.5	1
25.50	30.90	5.40	5.5	3.0	23.20	3.00	3.45	52.75	26.0	1.3E-04	9.1	2
25.50	30.90	5.40	5.5	5.0	23.20	3.00	4.50	71.30	31.0	1.1E-04	8.1	3
25.50	30.90	5.40	5.5	7.0	23.20	3.00	5.22	90.98	32.0	9.1E-05	6.5	4
25.50	30.90	5.40	5.5	10.0	23.20	3.00	9.87	116.33	44.0	9.8E-05	7.0	5
25.50	30.90	5.40	5.5	8.0	23.20	3.00	7.36	98.84	38.0	10.0E-05	7.1	6
25.50	30.90	5.40	5.5	6.0	23.20	3.00	5.22	80.98	32.0	1.0E-04	7.3	7
25.50	30.90	5.40	5.5	4.0	23.20	3.00	3.45	62.75	26.0	1.1E-04	7.7	8
25.50	30.90	5.40	5.5	2.0	23.20	3.00	2.25	43.95	21.0	1.2E-04	8.8	9
30.50	35.10	4.60	5.5	1.0	23.30	3.00	0.00	36.30	0.0	0.0E+00	0.0	1
30.50	35.10	4.60	5.5	3.0	23.30	3.00	0.00	56.30	0.0	0.0E+00	0.0	2
30.50	35.10	4.60	5.5	5.0	23.30	3.00	0.01	76.29	1.0	3.9E-06	0.3	3
30.50	35.10	4.60	5.5	7.0	23.30	3.00	0.10	96.20	4.0	1.2E-05	0.9	4
30.50	35.10	4.60	5.5	10.0	23.30	3.00	0.49	125.81	9.0	2.1E-05	1.6	5
30.50	35.10	4.60	5.5	8.0	23.30	3.00	0.22	106.08	6.0	1.7E-05	1.2	6
30.50	35.10	4.60	5.5	6.0	23.30	3.00	0.10	86.20	4.0	1.4E-05	1.0	7
30.50	35.10	4.60	5.5	4.0	23.30	3.00	0.01	66.29	1.0	4.5E-06	0.3	8
30.50	35.10	4.60	5.5	2.0	23.30	3.00	0.00	46.30	0.0	0.0E+00	0.0	9
35.10	41.10	6.00	5.5	1.0	22.70	3.00	0.00	35.70	0.0	0.0E+00	0.0	1
35.10	41.10	6.00	5.5	3.0	22.70	3.00	0.00	55.70	0.0	0.0E+00	0.0	2
35.10	41.10	6.00	5.5	5.0	22.70	3.00	0.00	75.70	0.0	0.0E+00	0.0	3
35.10	41.10	6.00	5.5	7.0	22.70	3.00	0.00	95.70	0.0	0.0E+00	0.0	4
35.10	41.10	6.00	5.5	10.0	22.70	3.00	0.00	125.70	0.0	0.0E+00	0.0	5
35.10	41.10	6.00	5.5	8.0	22.70	3.00	0.00	105.70	0.0	0.0E+00	0.0	6
35.10	41.10	6.00	5.5	6.0	22.70	3.00	0.00	85.70	0.0	0.0E+00	0.0	7
35.10	41.10	6.00	5.5	4.0	22.70	3.00	0.00	65.70	0.0	0.0E+00	0.0	8
35.10	41.10	6.00	5.5	2.0	22.70	3.00	0.00	45.70	0.0	0.0E+00	0.0	9
41.00	45.60	4.60	5.5	1.0	22.70	3.00	0.00	35.70	0.0	0.0E+00	0.0	1
45.50	50.00	4.50	5.5	1.0	17.50	3.00	14.56	15.94	40.0	7.5E-04	55.8	1
45.50	50.00	4.50	5.5	3.0	17.50	3.00	27.50	22.97	55.0	7.2E-04	53.2	2
45.50	50.00	4.50	5.5	5.0	17.50	3.00	42.08	28.42	68.0	7.2E-04	53.2	3
45.50	50.00	4.50	5.5	4.0	17.50	3.00	33.86	26.64	61.0	6.9E-04	50.9	4
45.50	50.00	4.50	5.5	2.0	17.50	3.00	20.10	20.40	47.0	6.9E-04	51.2	5

Table - 12 ECONOMIC COMPARISON OF ALTERNATIVES IN ANNUAL COST

Description H.W.L.(EL.M)	Alternatives in Piedra Gorda Dam 340	350	360	370
1. Power Generation				
Installed Capacity (KW)	29,000	37,000	46,000	53,000
Annual Energy Output (GWh)	108.6	129.4	148.2	164.4
Primary	(57.7)	(75.0)	(93.3)	(107.2)
Secondary	(50.9)	(54.4)	(54.9)	(57.2)
2. Construction Cost (1000 US$)	78,185	88,951	109,828	127,481
3. Annual Equivalent Benefit (B) (1000 US$)				
Capacity Benefit	1,923	2,454	3,051	3,515
Energy Benefit	12,064	14,960	17,827	20,122
Primary	(8,944)	(11,625)	(14,462)	(16,616)
Secondary	(3,120)	(3,335)	(3,365)	(3,506)
Total	13,986	17,414	20,878	23,637
4. Annual Equivalent Cost (C) (1000 US$)				
Capital Recovery Cost	9,415	10,711	13,225	15,351
O & M Cost	1,936	2,202	2,718	3,155
Total	11,351	12,913	15,943	18,506
5. Annual Net Benefit (B-C) (1000 US$)	2,636	4,500	4,934	5,131
6. Benefit Cost Ratio (B/C)	1.23	1.35	1.31	1.28

Table -13 PROVISIONAL WATER DIVERSION TO RINCON RESERVOIR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Piedra Gorda firm discharge	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30
Municipal water supply, Bonao	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Falconbridge	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Irrigation in Bonao valley (2,000 ha) /1	0.15	1.23	1.26	0.94	1.12	0.23	1.55	1.47	1.32	0.95	0.08	0.10
Provisional diversion to Rincon	9.22	8.14	8.11	8.43	8.25	9.14	7.82	7.90	8.05	8.62	9.27	9.27

Note: /1 Preliminary estimate by Devers, INDRHI

Table-14 PRELIMINARY ESTIMATE OF CONSTRUCTION COST

(US$1,000)

	Work Item	Foreign Currency	Local Currency	Total
1)	Preparatory works	996	783	1,779
2)	Civil works (including afterbay weir)	33,204	26,089	59,293
3)	Metal works	1,679	790	2,469
4)	Generating equipment (incl. Rincon 2nd unit)	8,789	1,057	9,846
5)	Land acquisition	-	1,835	1,835
6)	Engineering and administration (about 7.5% of Item 1-5)	3,350	2,292	5,642
7)	Physical contingency (about 10% of Item 1-6)	4,802	3,285	8,087
	Total	52,820	36,131	88,951

Table - 15 ECONOMIC INTERNAL RATE OF RETURN (1)

Unit: RD$10³

Year	Costs				Benefit /1						Surplus Deficit
	Capacity Cost		O & M	Total	Capacity Value	Primary Energy	Secondary Energy	Fixed O & M	Variable O & M	Total	
	F.C.	L.C.									
1	1,690	650		2,340							-2,340
2	12,677	4,878		17,554							-17,555
3	19,437	7,479		26,916							-26,916
4	35,494	13,658		49,152	9,579					9,579	-39,573
5	15,212	5,854		21,066	9,579					9,579	-11,487
6 - 20			585	585		12,488	2,652	404	365	15,909	15,324
21 - 22			585	585	8,621	12,488	2,652	404	365	24,536	23,945
23 - 36			585	585		12,488	2,652	404	365	15,909	15,324
37	3,565		585	4,150		12,488	2,652	404	365	15,909	11,759
38			585	585	8,621	12,488	2,652	404	365	24,536	23,945
39	14,260	429	585	15,274	8,621	12,488	2,652	404	365	24,530	9,256
40		1,340	585	1,925		12,488	2,652	404	365	15,909	13,984
41 - 50			585	585		12,488	2,652	404	365	15,909	15,324

Economic Internal Rate of Return: 13.0%

Note: /1: Capacity value and energy value of alternative 10 MW class power

Table - 16 ECONOMIC INTERNAL RATE OF RETURN (2)

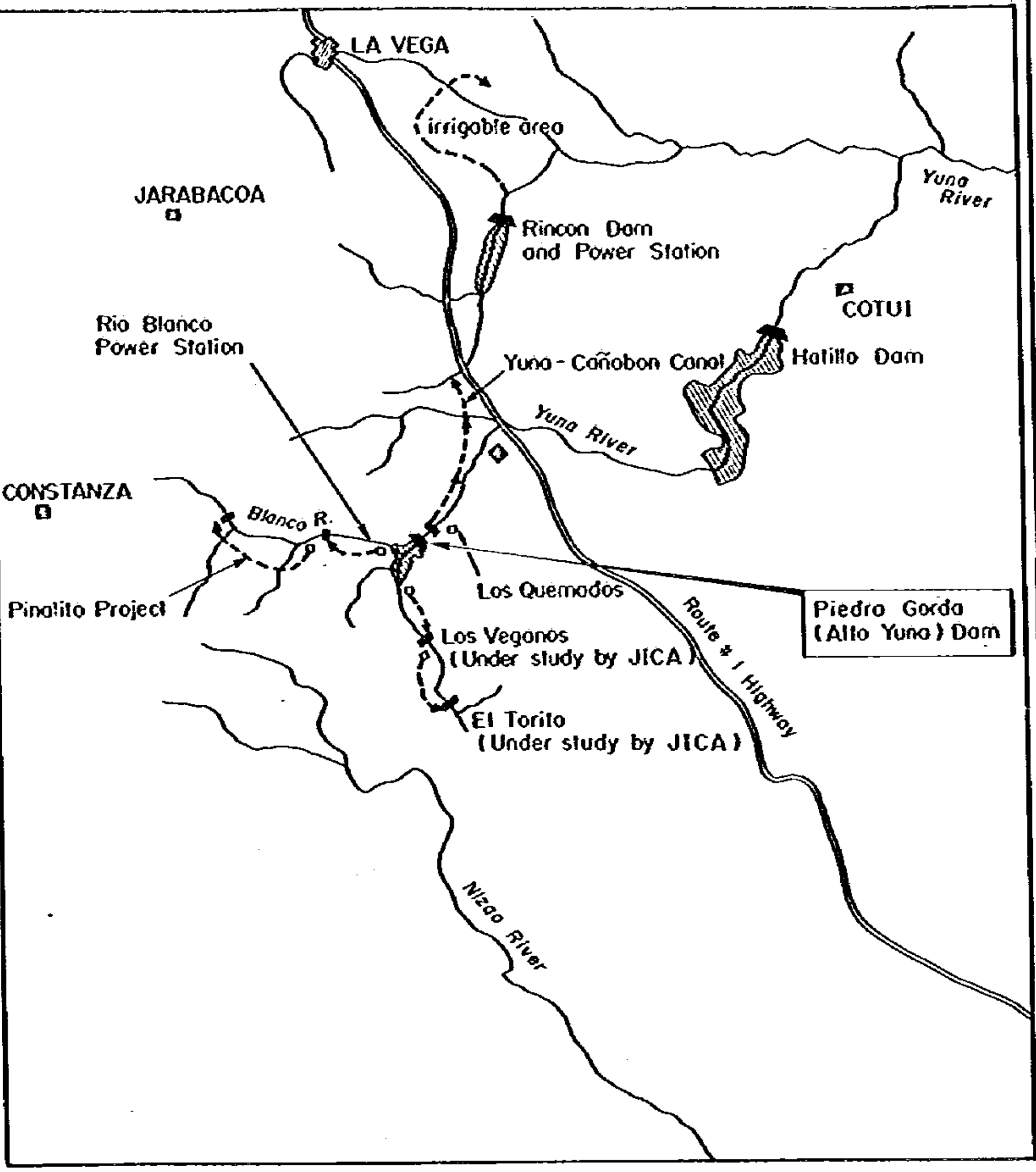
Unit: RD$10³

Year	Costs				Benefit /1						Surplus Deficit
	Capacity Cost		O & M	Total	Capacity Value	Primary Energy	Secondary Energy	Fixed O & M	Variable O & M	Total	
	F.C.	L.C.									
1	1,690	650		2,340							-2,340
2	12,677	4,878		17,555							-17,555
3	19,437	7,479		26,916							-26,916
4	35,494	13,658		49,152	6,802					6,802	-42,350
5	15,212	5,854		21,066	6,802					6,802	-14,264
6 - 20			585	585		11,896	2,652	404	365	15,317	14,732
21 - 22			585	585	6,121	11,896	2,652	404	365	21,438	20,853
23 - 36			585	585		11,896	2,652	404	365	15,317	14,732
37	3,565		585	4,150		11,896	2,652	404	365	15,317	11,167
38			585	585		11,896	2,652	404	365	21,438	20,853
39	14,260	429	585	15,274	6,121	11,896	2,652	404	365	21,438	6,164
40		1,340	585	1,925	6,121	11,896	2,652	404	365	15,317	13,392
41 - 50			585	585		11,896	2,652	404	365	15,317	14,732

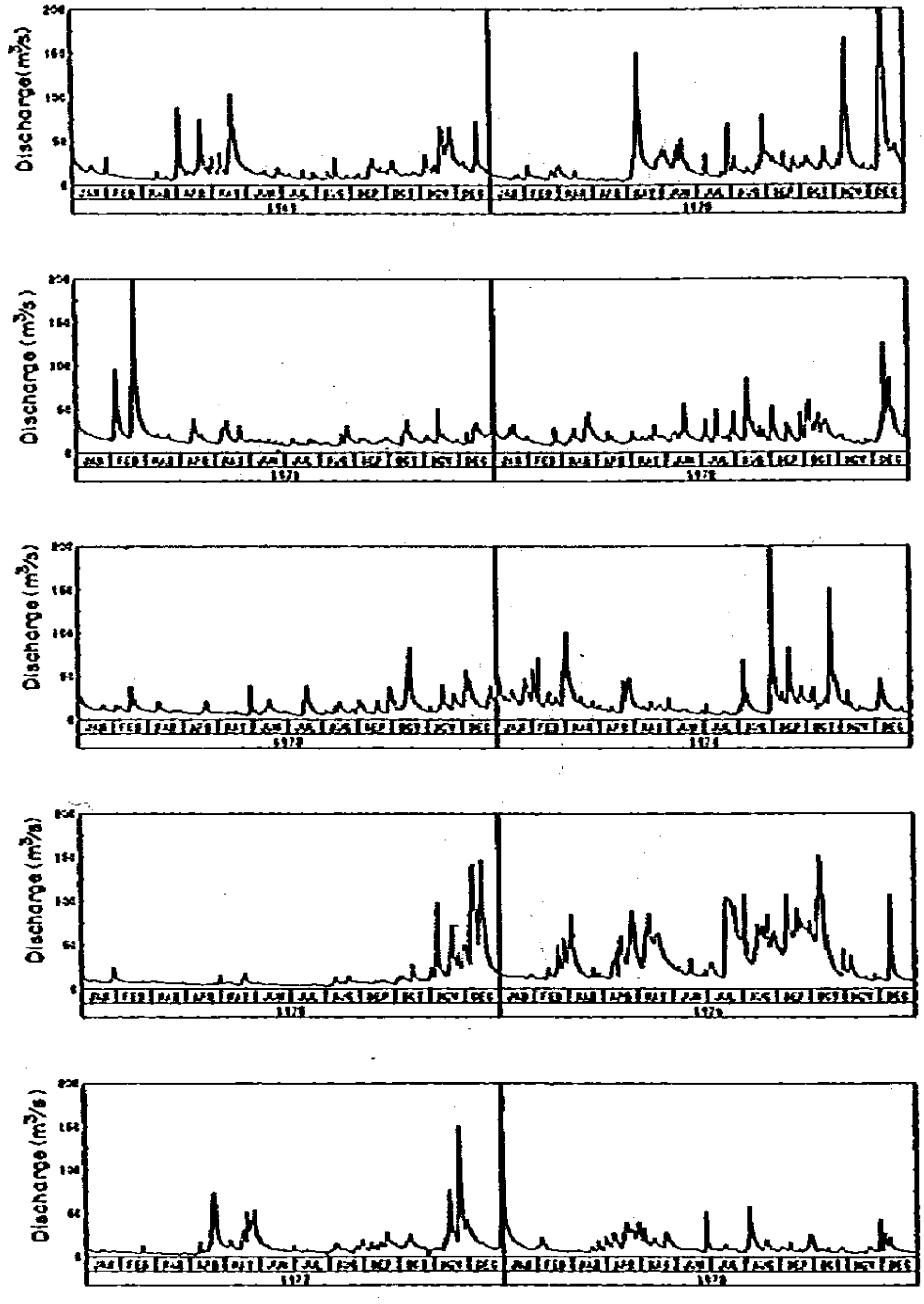
Economic Internal Rate of Return: 12.0%

Note: /1: Capacity value and energy value of alternative 28 MW class power

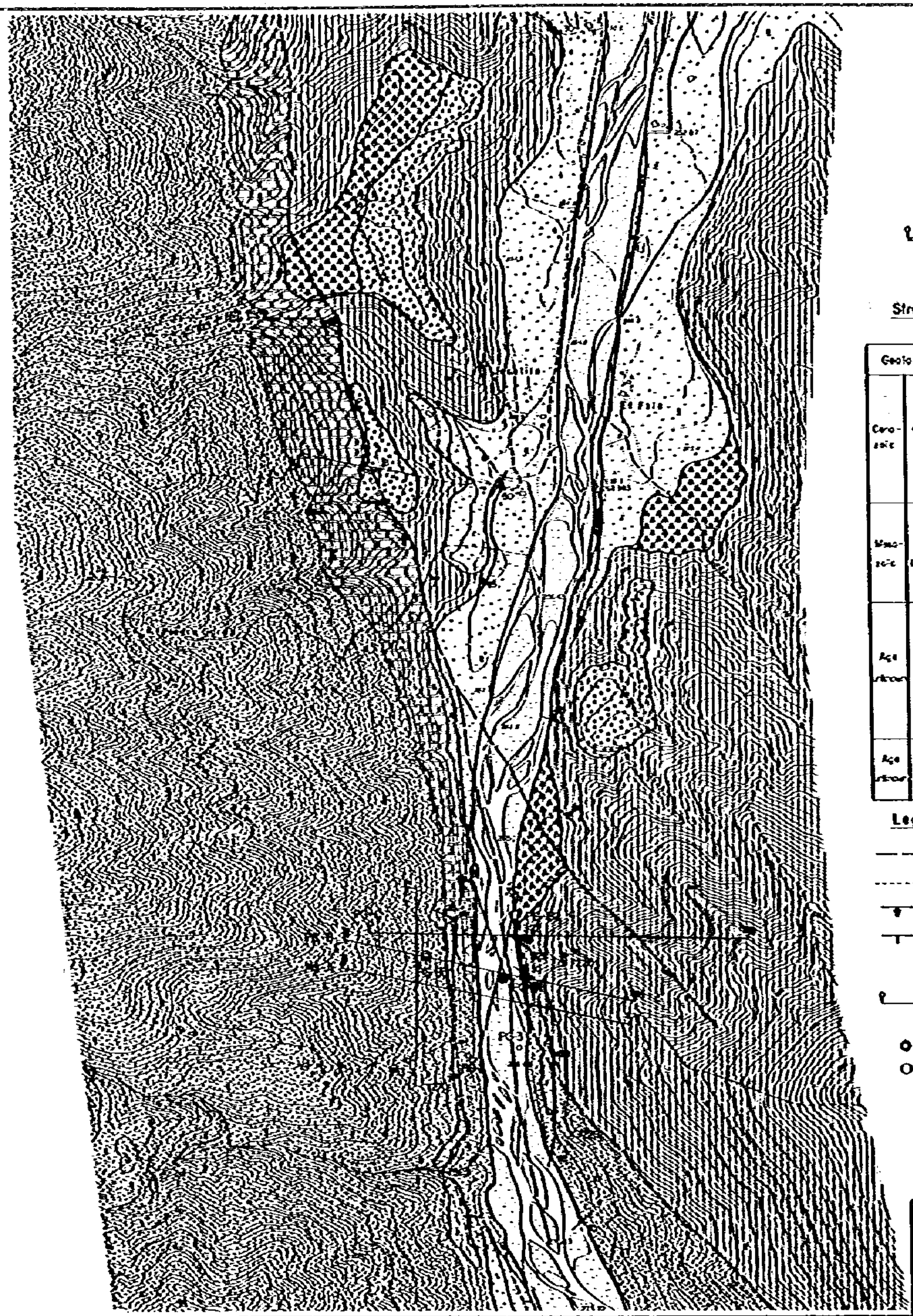
FIGURES



CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Location Map
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO LOS VEGANOS	01	
JAPAN INTERNATIONAL COOPERATION AGENCY		



CORPORACIÓN DOMINICANA DE ELECTRICIDAD	Fig.	Hydrograph at Los Quemados
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	02	
JAPAN INTERNATIONAL COOPERATION AGENCY		



Stratigraphic sequence of Upper Yuna Project Area

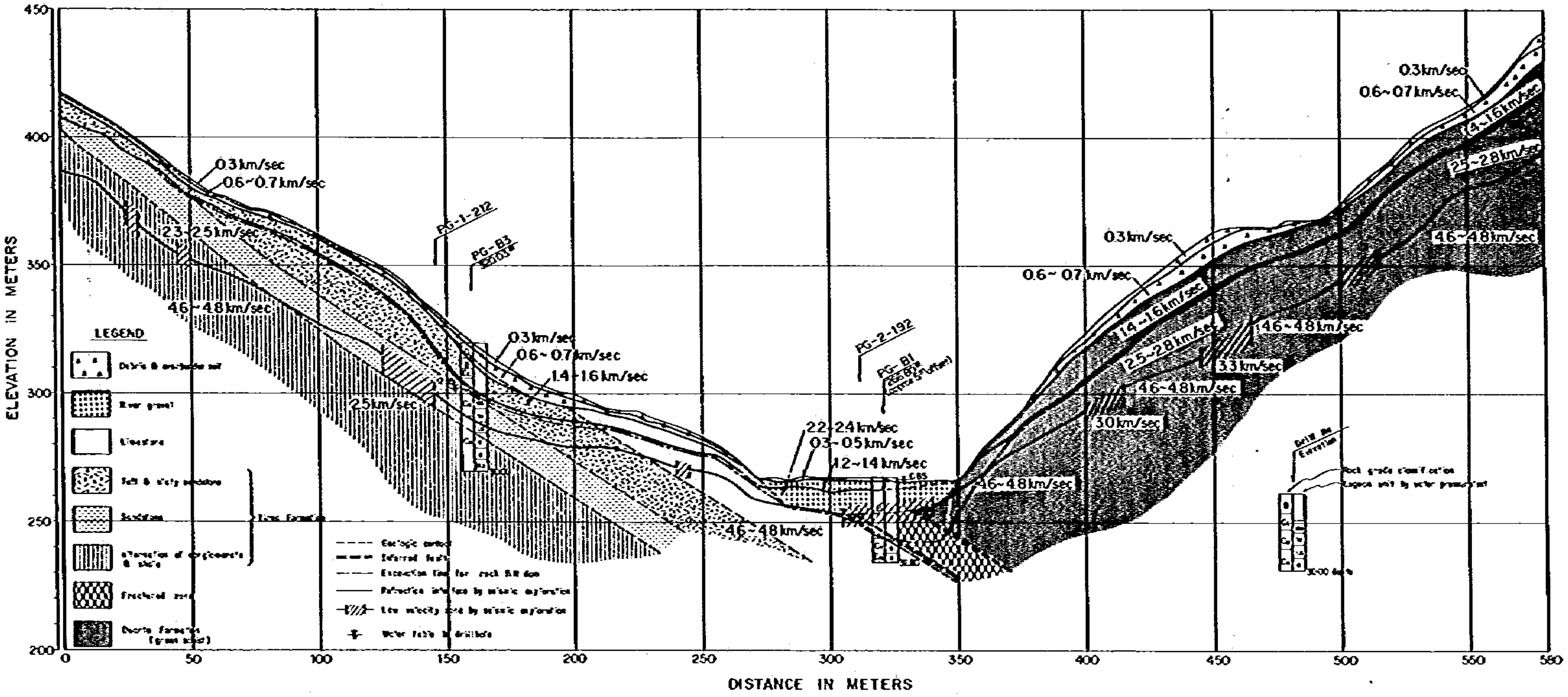
Geologic Age		Formation	Symbol	Lithology
Ceno-zoic	Quaternary	Alluvial deposit		Present river deposit
				Debris
				Middle & lower terrace deposit
				Upper terrace deposit
		(Unconformably)		
Meso-zoic	Upper Cretaceous (Middle Albian)	Tireo Formation		Limestone, Marl
				Andesite, Dacite, Tuff breccia, Limestone, Tuff, Sandstone, Slate, Chert
		(Fault)		
Age unknown	Pre-Middle Albian	Duarte Formation		Amphibolite, Foliated diorite, Peridotite (not exposed)
				Green schist
				Gneiss (not exposed)
		(Intrusion)		
Age unknown	Pre-Middle Albian (?)	Plutonic igneous rocks		Coarse grained quartz diorite (Partly foliated) (not exposed)

Legend

- Inferred fault
- geologic contact
- schistosity
- bedding
- Jointing
- Landslide
- Surface erosion
- Spring
- × Sample locality (Petrographically checked under microscope)
- 0 — 300 Geophysical exploration line (meter) (Total length 2,930m)
- Drillhole by JICA (Total depth 826m)
- Drillhole by CDE (80m, 50° from horizon)

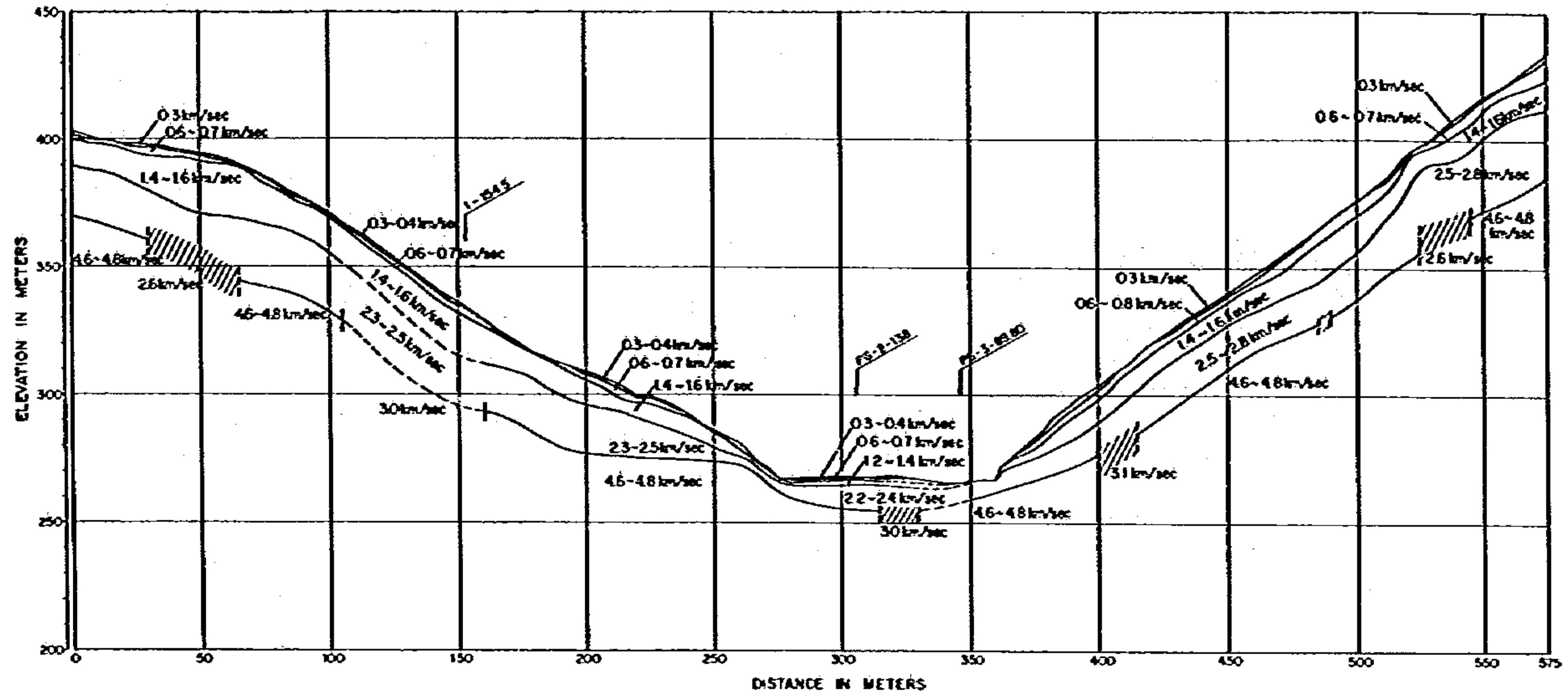
CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Geologic Map & Location Map of Piedra Gorda Scheme Area
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO LOS VEGANOS	03	
JAPAN INTERNATIONAL COOPERATION AGENCY		

Dwg No.PG4 PG-B damsite (Piedra Gorda)



CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Interpretation Profile of Geophysical Exploration
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	04	
JAPAN INTERNATIONAL COOPERATION AGENCY		

PG-A



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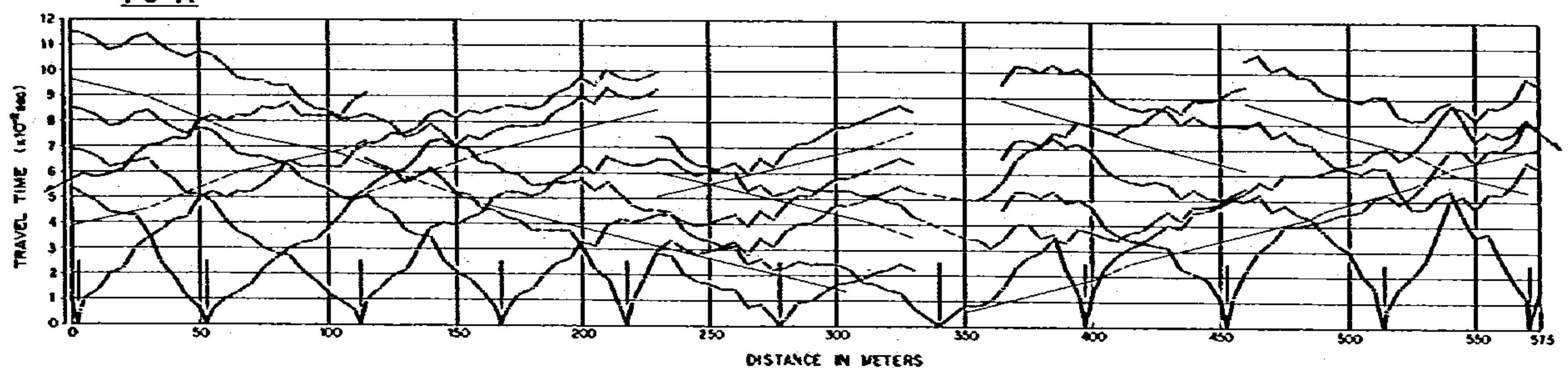
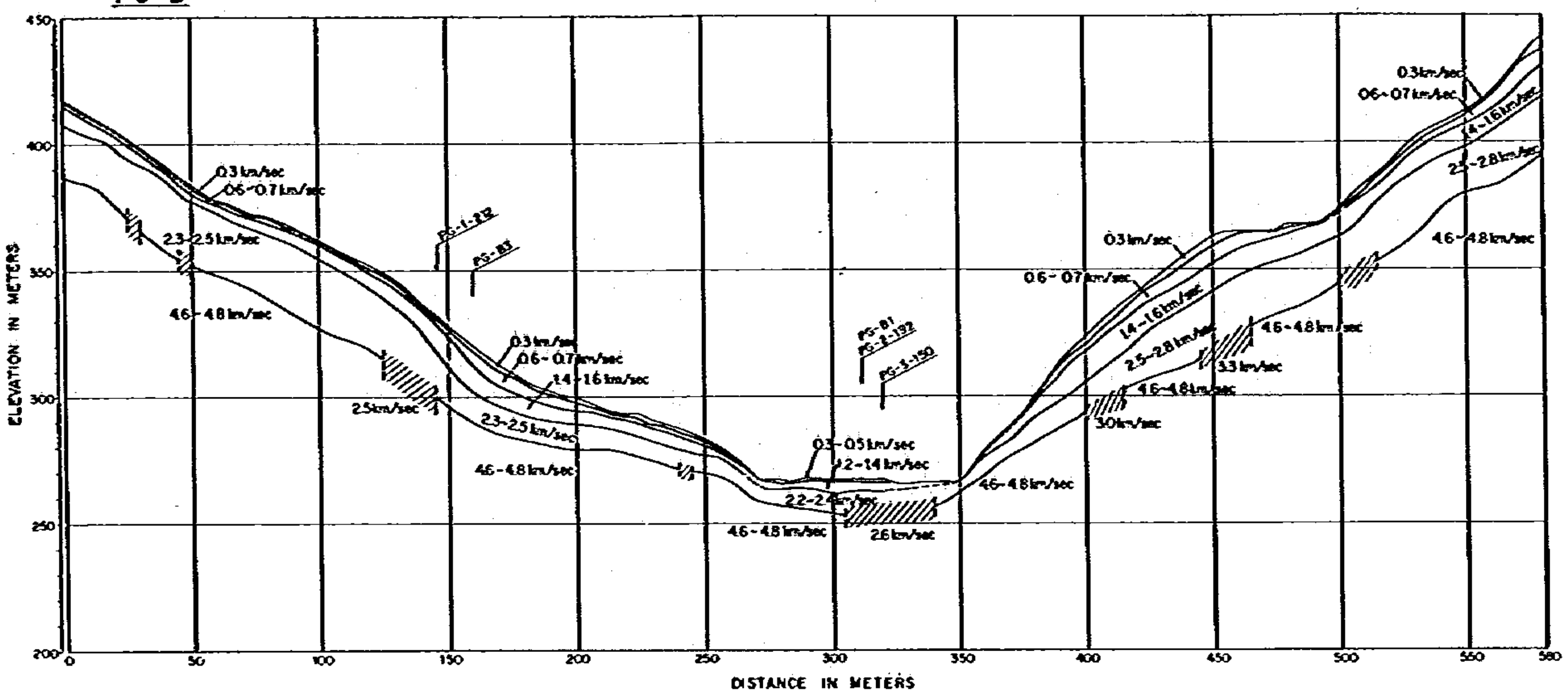
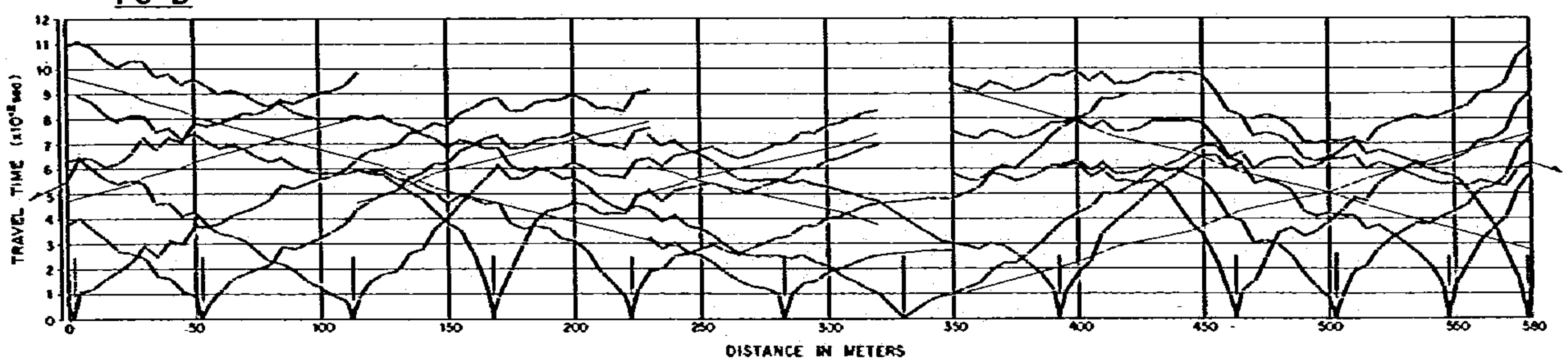


CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Interpretation Profile of Geophysical Exploration
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	05	
JAPAN INTERNATIONAL COOPERATION AGENCY		

PG-B

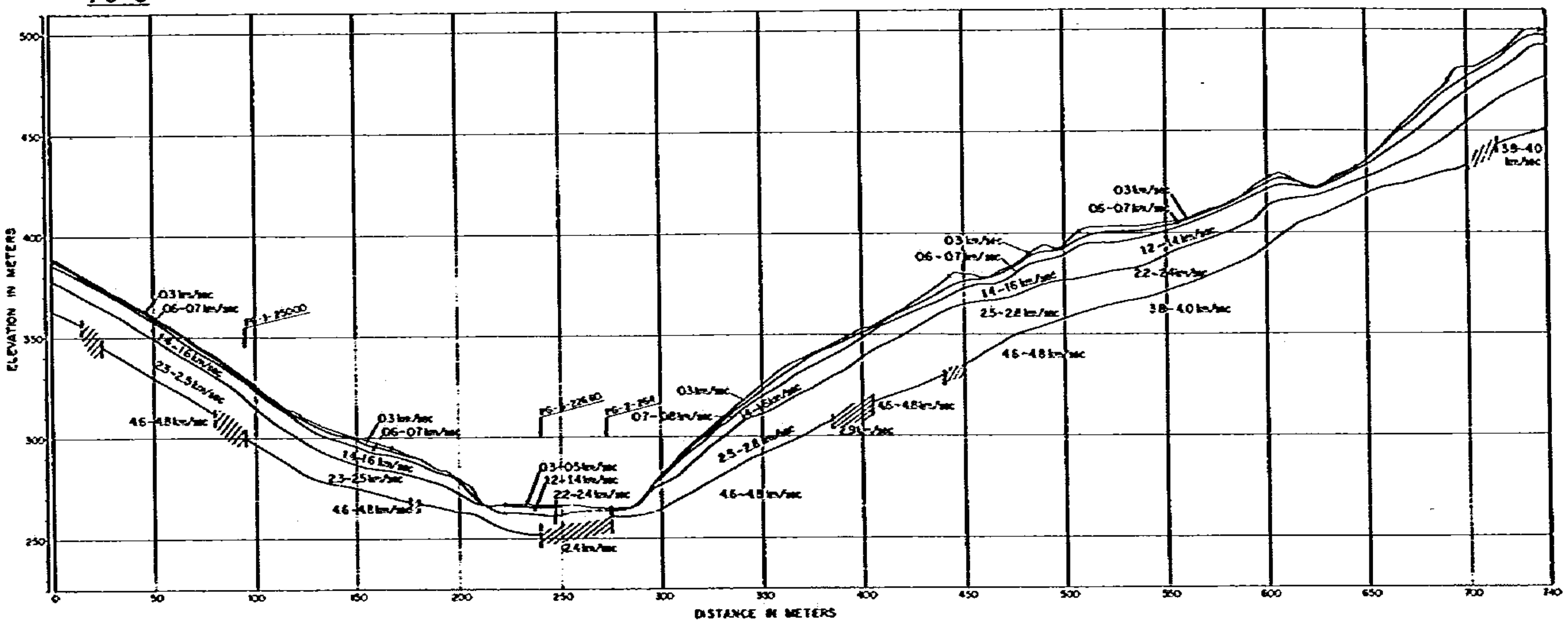


PG-B

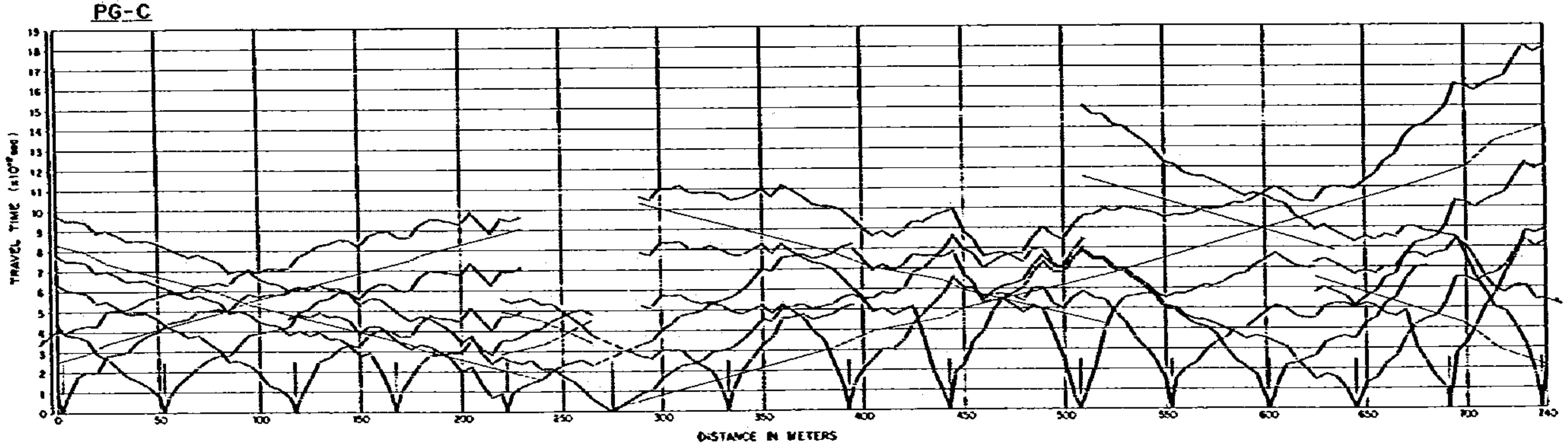


CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Interpretation Profile of Geophysical Exploration
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	06	
JAPAN INTERNATIONAL COOPERATION AGENCY		

PG-C

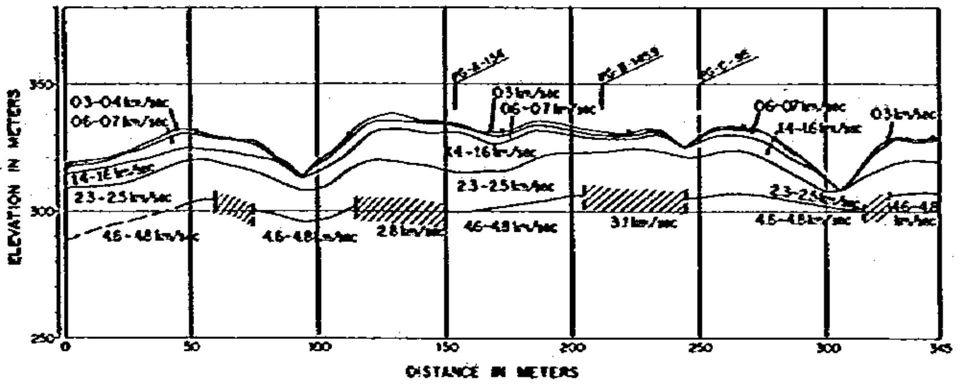


PG-C



CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Interpretation Profile of Geophysical Exploration
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO LOS VEGANOS	07	
JAPAN INTERNATIONAL COOPERATION AGENCY		

PG-1



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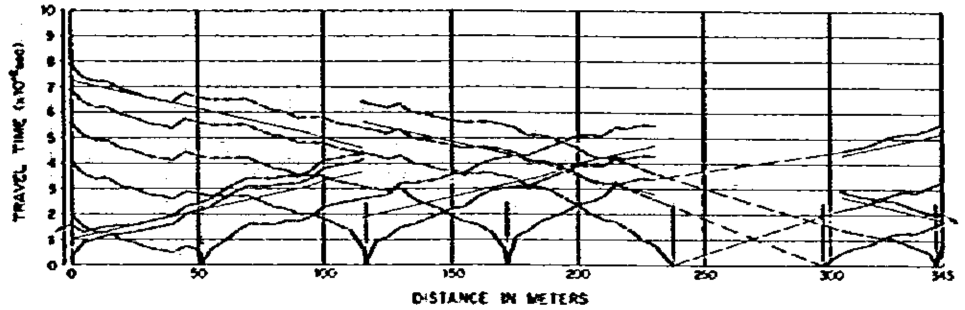
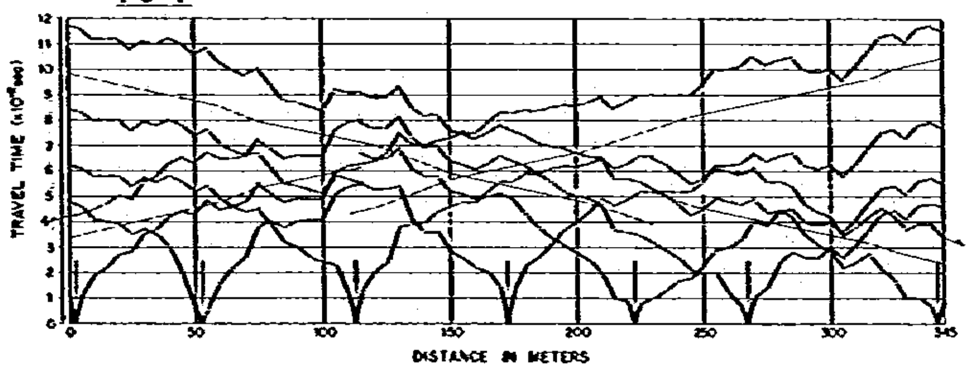


PG-1



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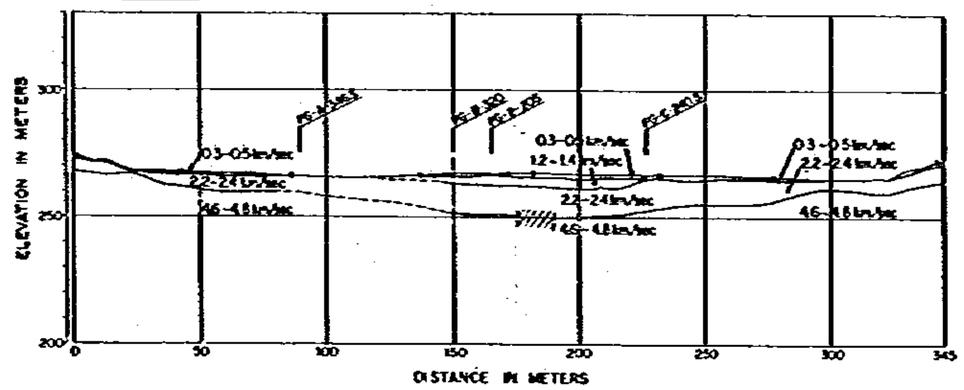
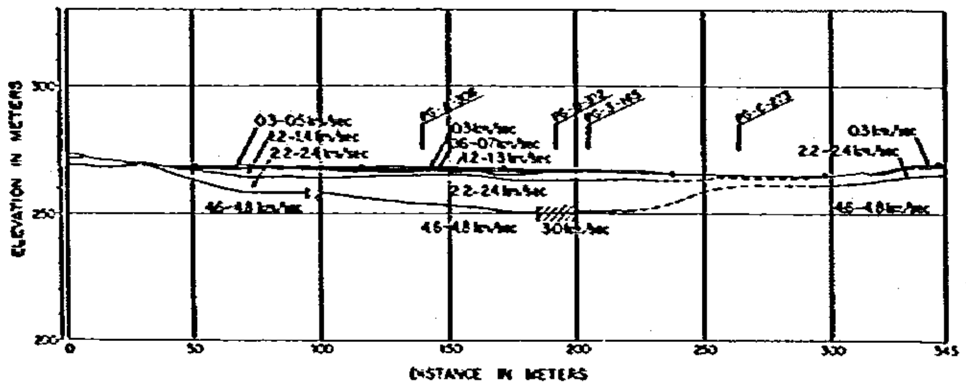
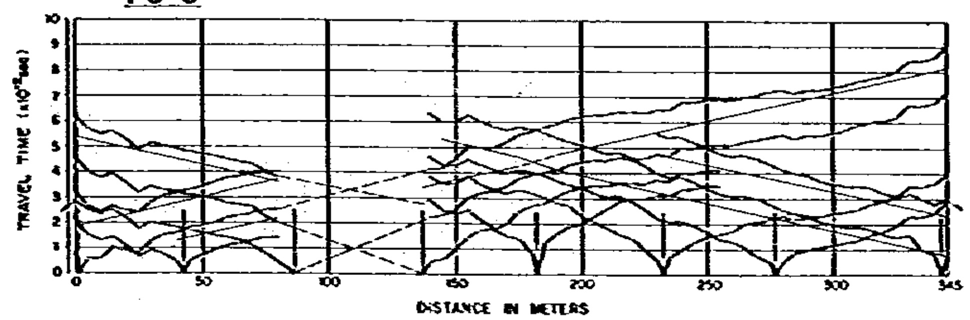


PG-2



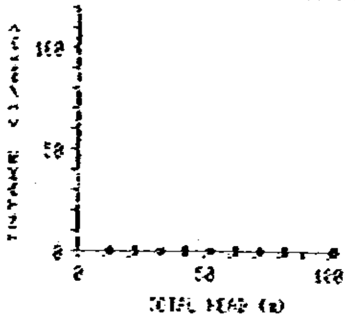
PG-3



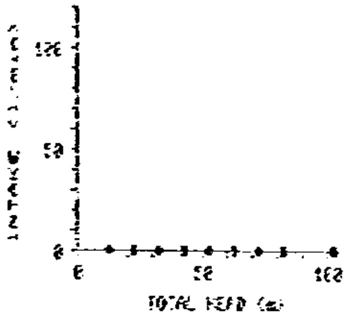
CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Interpretation Profile of Geophysical Exploration
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	08	
JAPAN INTERNATIONAL COOPERATION AGENCY		

Fig.PG.1

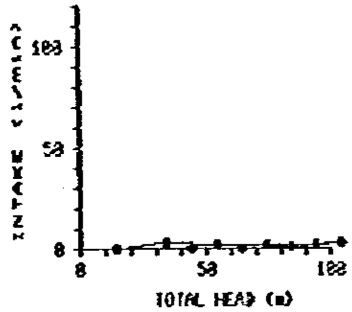
HOLE No : PG-01
DEPTH : 24.5 - 29.5 m



HOLE No : PG-01
DEPTH : 29.5 - 32.3 m

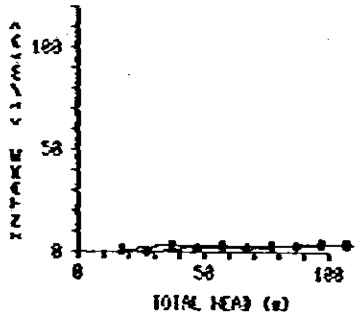


HOLE No : PG-02
DEPTH : 28.5 - 33.15 m



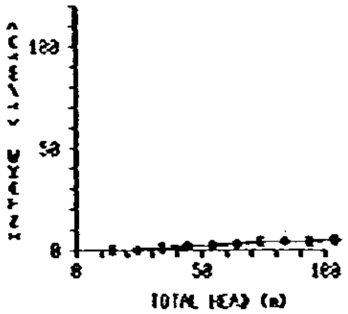
STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	14.0	0.0	0.0	0.0E+00
2	44.0	0.0	0.0	0.0E+00
3	64.0	0.0	0.0	0.0E+00
4	84.0	1.2	0.3	3.5E-06
5	104.0	3.1	0.6	8.2E-06
6	94.0	2.0	0.5	5.8E-06
7	74.0	2.3	0.7	8.5E-06
8	54.0	1.8	0.7	9.1E-06
9	34.0	2.7	1.7	2.2E-05
10	14.0	0.5	0.8	9.8E-06

HOLE No : PG-02
DEPTH : 33 - 38 m



STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	27.3	0.0	0.0	0.0E+00
2	47.3	2.2	0.9	1.2E-05
3	67.3	2.0	0.6	7.7E-06
4	87.3	3.0	0.7	8.9E-06
5	107.3	3.7	0.7	8.9E-06
6	97.3	3.7	0.8	9.5E-06
7	77.3	3.2	0.8	1.1E-05
8	57.3	2.9	1.0	1.3E-05
9	37.3	2.7	1.4	1.9E-05
10	17.3	0.7	0.8	1.0E-05

HOLE No : PG-02
DEPTH : 38 - 43 m

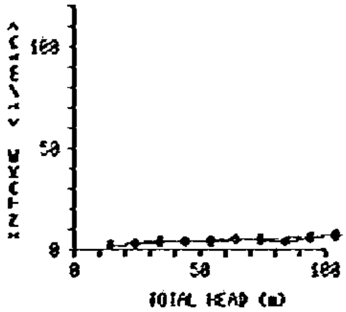


STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	24.0	0.0	0.0	0.0E+00
2	44.0	2.9	0.9	1.2E-05
3	64.0	3.0	0.9	1.2E-05
4	84.0	4.0	1.0	1.2E-05
5	103.9	5.0	1.0	1.2E-05
6	94.0	4.5	1.0	1.2E-05
7	74.0	3.6	1.0	1.3E-05
8	54.0	1.7	0.6	8.1E-06
9	34.0	1.2	0.7	9.1E-06
10	14.0	0.5	0.7	9.2E-06

CORPORACION DOMINICANA DE ELECTRICIDAD	Fig. 09	Woter Pressure Test
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO LOS VEGANOS		
JAPAN INTERNATIONAL COOPERATION AGENCY		

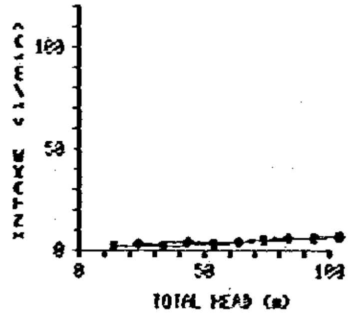
Fig.F0.2

HOLE No : PG-02
DEPTH : 43 - 48 m



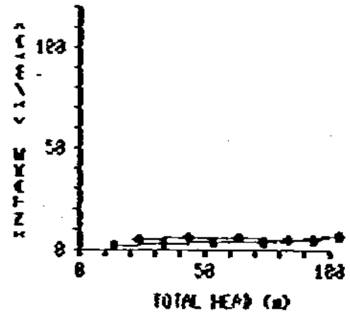
STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	24.3	3.5	2.9	3.8E-05
2	44.3	4.0	1.8	2.4E-05
3	64.2	4.7	1.5	1.9E-05
4	84.3	3.6	0.9	1.1E-05
5	104.2	6.6	1.3	1.7E-05
6	94.2	6.0	1.3	1.7E-05
7	74.2	5.4	1.5	1.9E-05
8	54.3	4.1	1.5	2.0E-05
9	34.3	3.7	2.2	2.8E-05
10	14.3	2.5	3.5	4.6E-05

HOLE No : PG-02
DEPTH : 48 - 53 m



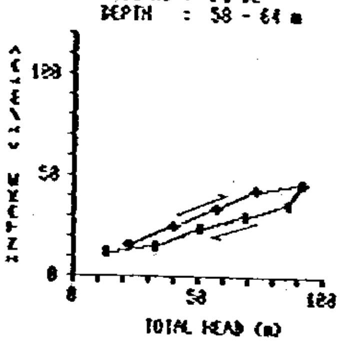
STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	23.9	2.6	2.2	2.9E-05
2	43.8	4.3	2.0	2.6E-05
3	63.8	4.5	1.4	1.9E-05
4	83.7	6.2	1.5	2.0E-05
5	103.7	7.5	1.4	1.9E-05
6	93.7	6.8	1.3	1.7E-05
7	73.8	5.0	1.4	1.8E-05
8	53.9	3.0	1.1	1.5E-05
9	33.9	2.5	1.5	1.9E-05
10	13.9	2.0	2.9	3.6E-05

HOLE No : PG-02
DEPTH : 53 - 58 m



STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	23.9	5.0	4.2	5.5E-05
2	43.8	5.8	2.6	3.5E-05
3	63.8	6.1	1.9	2.5E-05
4	83.8	5.5	1.3	1.7E-05
5	103.7	7.0	1.3	1.6E-05
6	93.8	5.5	1.2	1.5E-05
7	73.9	4.3	1.2	1.5E-05
8	53.9	4.0	1.5	2.0E-05
9	33.9	3.5	2.1	2.7E-05
10	14.0	2.2	3.1	4.2E-05

HOLE No : PG-02
DEPTH : 58 - 64 m

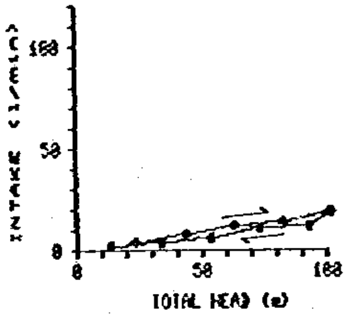


STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	22.5	16.0	11.9	1.6E-04
2	40.4	24.7	10.2	1.4E-04
3	57.3	34.0	9.9	1.4E-04
4	73.2	43.0	9.8	1.3E-04
5	91.7	45.0	8.4	1.1E-04
6	86.2	36.5	7.1	9.7E-05
7	68.5	30.5	7.4	1.0E-04
8	50.6	24.0	7.9	1.1E-04
9	32.6	15.5	7.9	1.1E-04
10	13.1	12.5	16.0	2.2E-04

CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Water Pressure Test
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO LOS VEGANOS	10	
JAPAN INTERNATIONAL COOPERATION AGENCY		

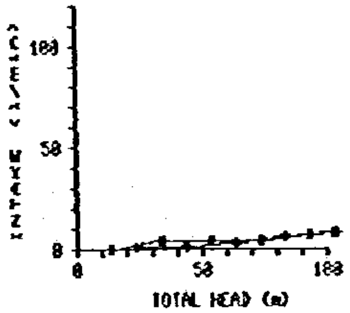
Fig.PO.3

HOLE No : PG-02
DEPTH : 64 - 70 m



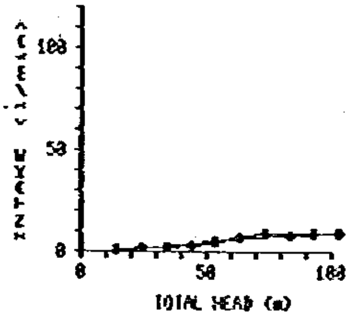
STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	23.9	4.0	2.8	3.2E-05
2	43.6	8.0	3.1	4.2E-05
3	63.0	12.5	3.3	4.5E-05
4	82.7	14.0	2.8	3.9E-05
5	101.7	19.0	3.1	4.3E-05
6	93.1	12.0	2.1	2.9E-05
7	73.2	11.0	2.5	3.4E-05
8	53.7	6.5	2.0	2.8E-05
9	33.9	4.0	2.0	2.7E-05
10	14.0	2.0	2.4	3.3E-05

HOLE No : PG-02
DEPTH : 70 - 75 m



STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	23.7	1.0	0.8	1.1E-05
2	43.7	1.5	0.7	9.1E-06
3	63.6	3.0	0.9	1.2E-05
4	83.4	6.5	1.6	2.1E-05
5	103.2	8.0	1.5	2.0E-05
6	93.3	7.0	1.5	2.0E-05
7	73.6	4.3	1.2	1.5E-05
8	53.6	4.0	1.5	2.0E-05
9	33.6	4.0	2.4	3.1E-05
10	13.7	0.0	0.0	0.0E+00

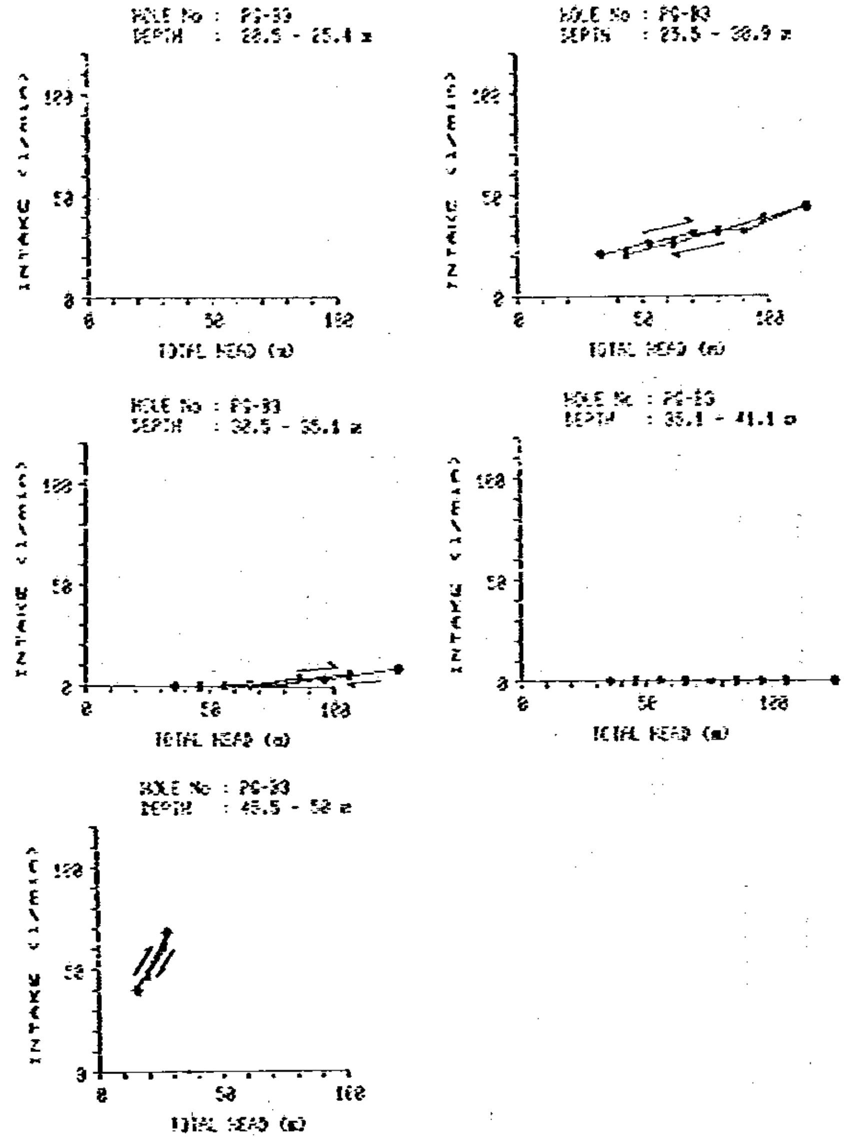
HOLE No : PG-02
DEPTH : 75 - 80 m



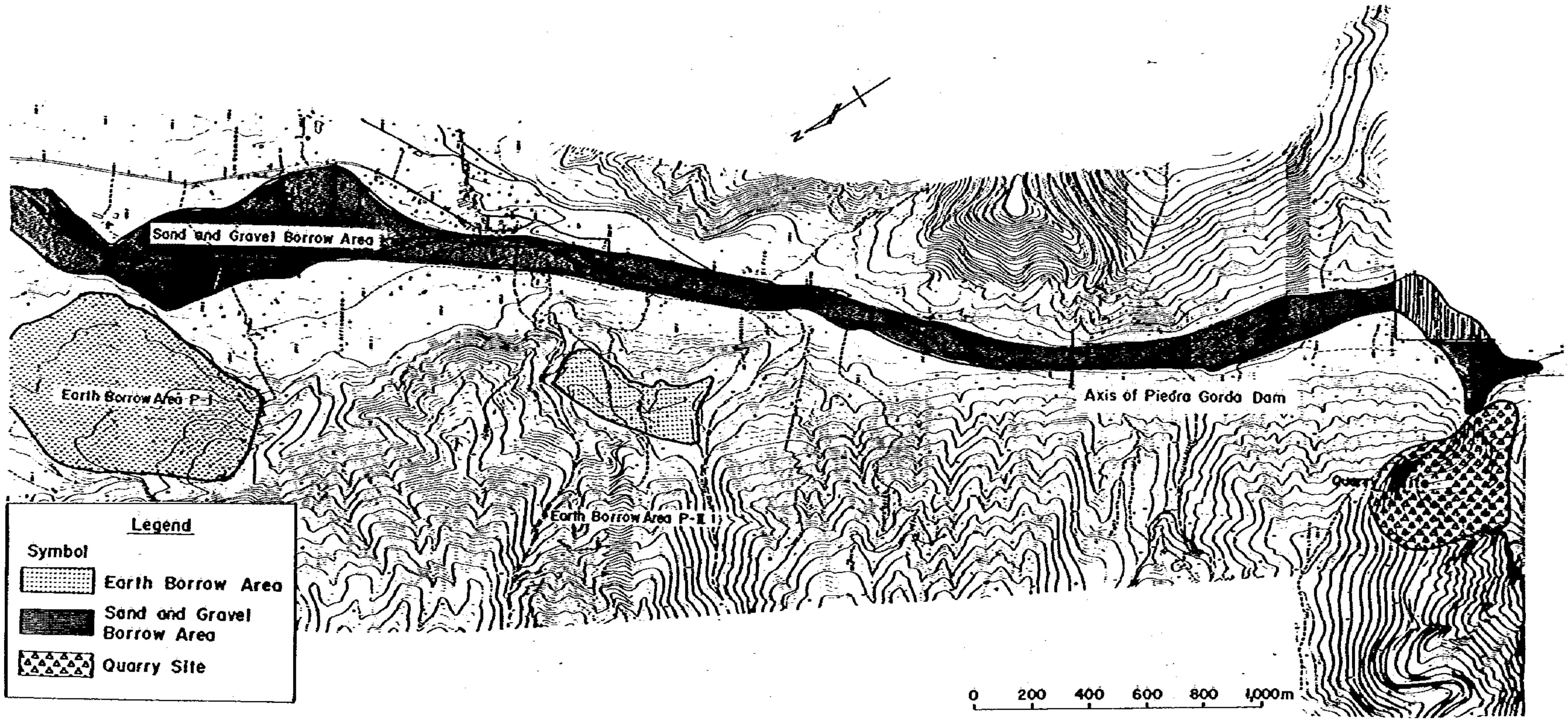
STEP	HEAD (m)	INTAKE (l/min)	Lu ( )	K (cm/sec)
1	24.1	2.5	2.1	2.7E-05
2	44.0	3.5	1.6	2.1E-05
3	63.7	7.5	2.4	3.1E-05
4	83.6	8.5	2.0	2.7E-05
5	103.5	9.3	1.8	2.4E-05
6	93.5	9.1	1.9	2.6E-05
7	73.6	8.6	2.3	3.1E-05
8	53.9	5.0	1.9	2.4E-05
9	34.1	2.0	1.2	1.5E-05
10	14.1	1.5	2.1	2.6E-05

CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Water Pressure Test
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	11	
JAPAN INTERNATIONAL COOPERATION AGENCY		

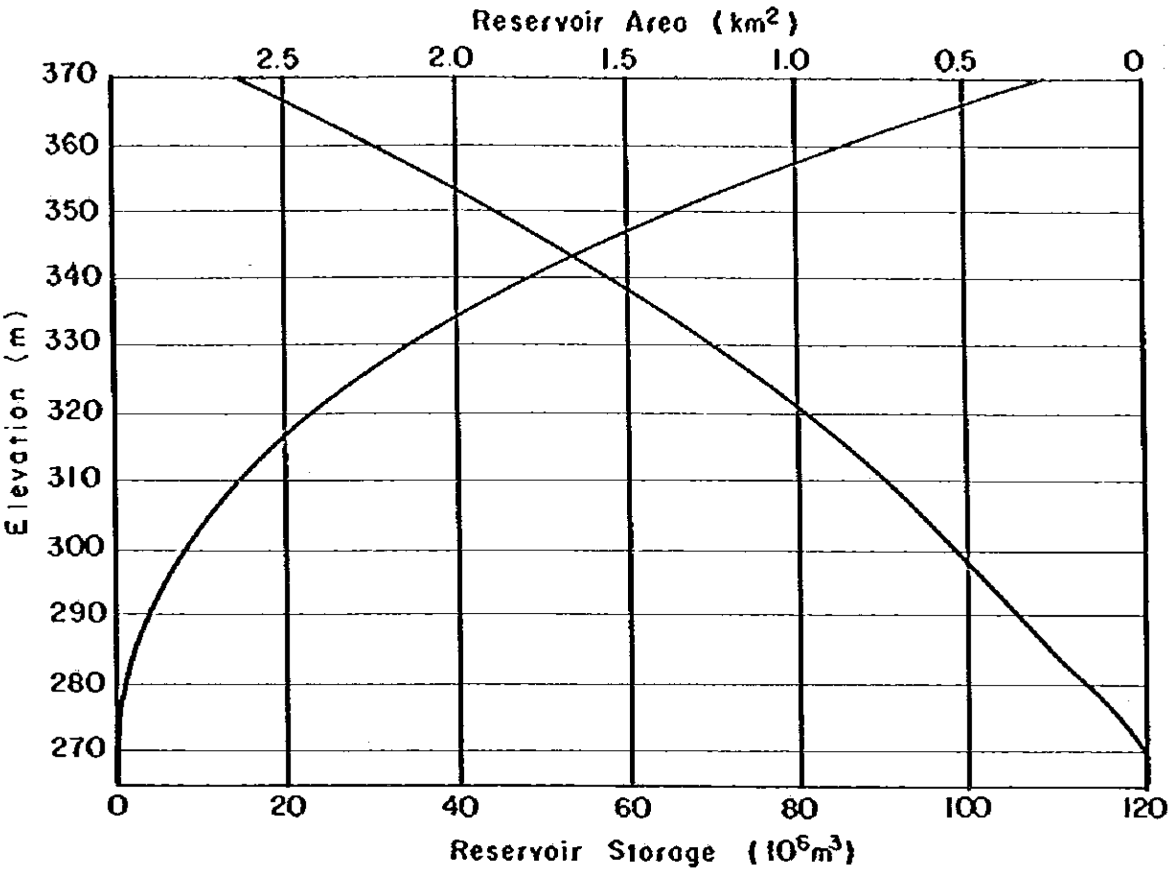
Fig.PG.4



CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Water Pressure Test
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO LOS VEGANOS	12	
JAPAN INTERNATIONAL COOPERATION AGENCY		

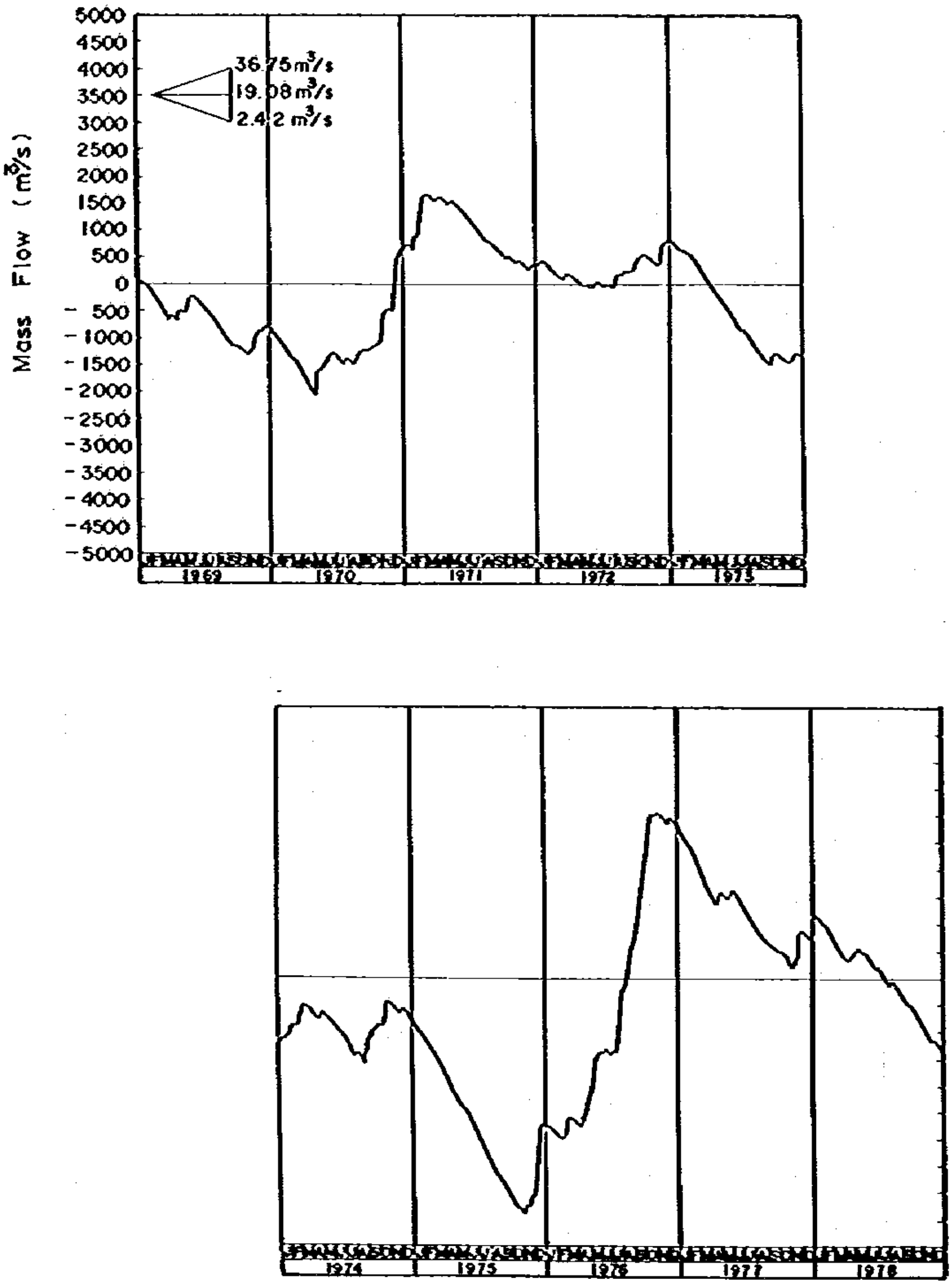


CORPORACIÓN DOMINICANA DE ELECTRICIDAD	Fig.	Location Map of Borrow Areas and Quarry Sites, Piedra Gorda Damsite
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	13	
JAPAN INTERNATIONAL COOPERATION AGENCY		

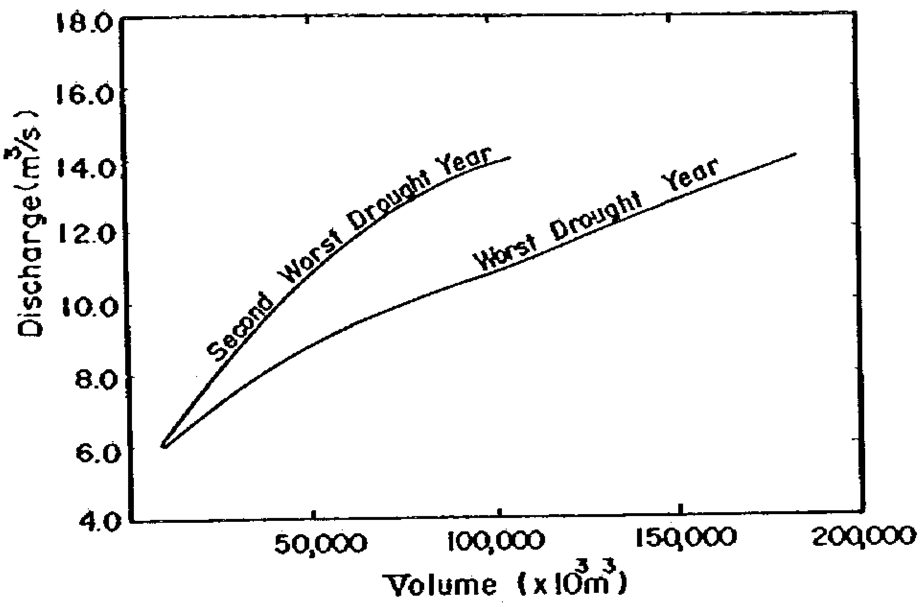


Elevation (m)	Reservoir Storage (10^6m^3)	Reservoir Area (km^2)	Elevation (m)	Reservoir Storage (10^6m^3)	Reservoir Area (km^2)
270	0	0	315	18.1	0.84
275	0.2	0.07	320	22.6	0.97
280	0.7	0.13	325	27.8	1.09
285	1.7	0.26	330	33.6	1.23
290	3.3	0.36	335	40.1	1.38
295	5.3	0.45	340	47.4	1.54
300	7.8	0.56	350	64.7	1.90
305	10.8	0.63	360	85.4	2.24
310	14.2	0.73	370	109.8	2.64

CORPORACIÓN DOMINICANA DE ELECTRICIDAD	Fig. 14	Storage Volume of Piedra Gorda dam
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS		
JAPAN INTERNATIONAL COOPERATION AGENCY		



CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Discharge Mass Curve at Piedra Gorda
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	15	
JAPAN INTERNATIONAL COOPERATION AGENCY		



Discharge Q (m^3/s)	For the Worst Drought Year			For the Second Worst Drought Year		
	$V'max_1$ (m^3/s)	$Vmax_1$ ($=V'max_1 \times 86,400$) ($\times 10^3 m^3$)	Date	$V'max_2$ (m^3/s)	$Vmax_2$ ($=V'max_2 \times 86,400$) ($\times 10^3 m^3$)	Date
6.0	112.97	9,760.0	'75 AUG. 8	104.69	9,050.0	'77 APR 9
8.0	405.95	35,940.0	〃 OCT. 2	282.58	24,400.0	〃 〃 〃
10.0	904.28	78,130.0	〃 〃 〃	501.69	43,350.0	〃 〃 17
12.0	1,500.01	129,600.0	〃 〃 15	738.87	63,840.0	〃 〃 〃
14.0	2,144.15	185,250.0	〃 〃 31	1,232.28	106,470.0	〃 MAR. 15

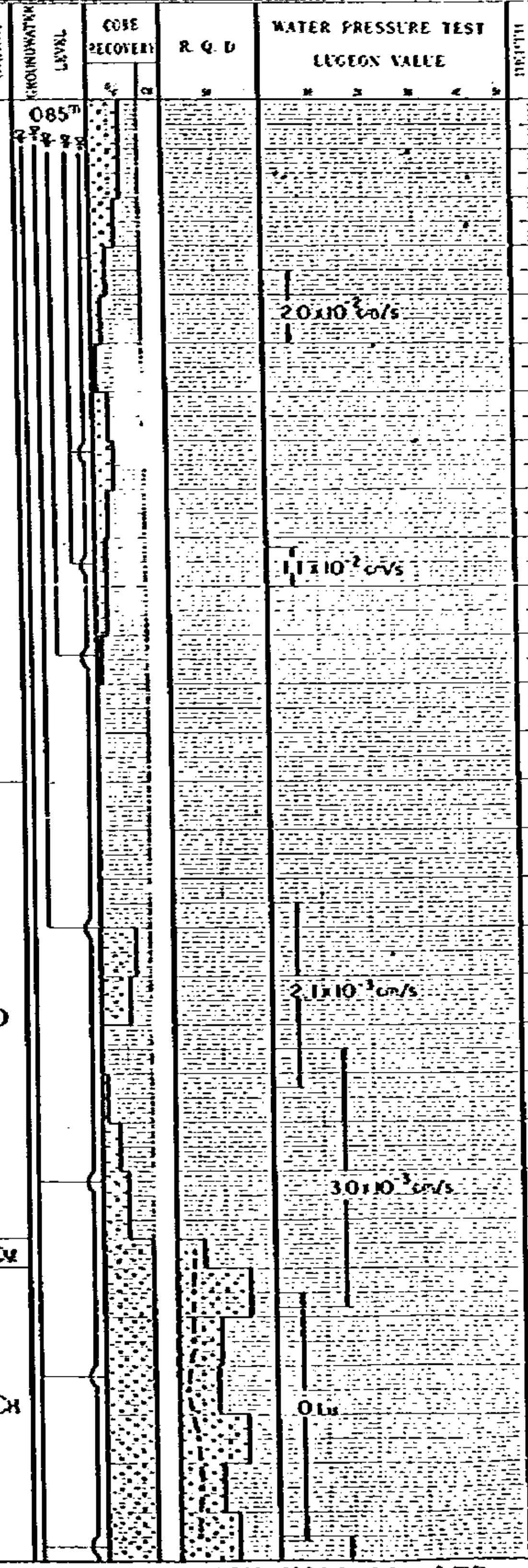
CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Reservoir Capacity for Various Draft Values at Piedra Gorda
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	16	
JAPAN INTERNATIONAL COOPERATION AGENCY		

PGL-01 (1) **Log Sheet**

HOLE NO. PG-B1 SHEET NO. 1 OF 2

PROJECT	El Torito-Los Veganos Hydroelectric Development Project			DEPTH	32.8 m	ELEVATION	266.80 m
SITE	Piedra Gorda Damsite(river)	COORDINATE	: :	INCLINATION	Vertical	DRILL RIG	TDC-1G
AVERAGE CORE RECOVERY	47.4%	DATE	FROM 7/18 TO 7/27 '83	DRILLED	OCHIAI, T.	LOGGED	TSUJI, K.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	DESCRIPTION	ROCK GRADE
7/18 – 7/20	9.70	257.10	Present river gravel (grey to purple grey)	Loose, unconsolidated Poor core recovery 5.0-6.3m: cuttings only sampled 8.5-9.7m: cuttings only sampled	
	9.90	256.90		Silt with granule gravel	
7/21	14.00	252.80	Present river gravel (grey)	Loose, unconsolidated (sub-angular) Granule gravel to coarse sand 11.4-12.9m: cuttings only sampled 12.9-14.0m:	
7/22	17.00	249.80	Fractured schist (dark reddish purple)	Epidote actinolite schist Fractured and very schistosed 14.0-17.0m: cuttings only sampled	
	18.80	248.00	Moderately fractured schist (dark reddish purple)	Weakly cemented schist Short cylindric core, easily broken by hand, weakly fractured	D
	21.80	245.00	Fractured schist (dark reddish purple)	Fault clay associated with angular fragment (cemented fractured schist) 19.8-20.0m: cuttings only sampled 20.1-21.0m: cuttings only sampled 20.0-20.1m: no water drill sample	
7/23	22.20	244.60	Fractured amph.	Fragment core	
	23.40	243.40	Amphibolite (dark green)	Schistosed amphibolite 23.3-23.4m: green schist	
				Slightly weathered limestone	CM
7/24 – 7/27			Limestone (grey-greenish grey)	Fresh & hard rock with thin calcite network vein Crack is tight 23.6-24.4m: weakly foliated structure dipping 50° Below 24.4m: massive rock with small black silty lens 26.5m: weakly foliated dipping 55° 26.0-29.0m: crack dips 30°-50° & 90° 27.0-29.0m: long cylindric core	CH



* R.Q.D is Rock Quality Designation. R.Q.D = Total length of cylindrical cores longer than 10 cm / Total core length × 100%
* LUGEON VALUE is l/m/min under injection water pressure of 10 kg/cm²
* DEPTH and ELEVATION are in meter

NIPPON KOEI CO., LTD.
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LOG FORM-II

HOLE NO.

PGL-01 (2) **Log Sheet** HOLE NO. PG-81 SHEET NO. 2 OF 2

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION	ROCK GRADE	GROUNDWATER LEVEL	CORE RECOVERY	R.Q.D	WATER PRESSURE TEST LUGEON VALUE	DEPTH
	31		Limestone (greenish grey - dark grey)		Fresh and hard, long cylindric core Crack is tight and dips 9?° and 30°±	CH				0 Lu	
	32										
7/26	33 32.80	234.00									

HOLE NO.

LOG FORM C

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CONSULTING ENGINEERS. TOKYO.

PGL-02 (1) **Log Sheet** HOLE NO. PG-B2 SHEET NO. 1 OF 3

PROJECT	El Torito-Los Vegaros Hydroelectric Development Project			DEPTH	80.0 m	ELEVATION	268.56 m
SITE	Piedra Gorda Damsite	COORDINATE	: :	INCLINATION	50° from horizon	DRILL RIG	Longyear 34
AVERAGE CORE RECOVERY	67.00%	DATE	FROM 9/22 TO 10/14, '83	DRILLED	Geo Civil	LOGGED	NISHIOKA, S.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	DESCRIPTION	ROCK GRADE	GROUNDWATER LEVEL
		268.56				
	1.00	267.79	Top soil & loose deposit	Brown - grey. Including gravels		
9/22	11.00	260.33	Decomposed schist	Purple, soft. Clayey, purple to grey. Soft. 5.50-6.00m: hard schistose sandstone. 9.00-11.00 Quartzite fragments and dissected purple schist		Oct.3, 6 4.75m; 5.15m Oct.7
9/23, 9/26	15.00	257.07	Intensively weathered schist	Soft to moderately hard flaky or fragmental core samples are recovered. Fractured	D	
9/27, 9/28, 9/29	26.75	243.07	Fractured schist	Clayey decomposed schist is recovered in 15.0-15.15m. Other than the above, only drill slime is taken up to 25.0m. Bluish grey. Fractured schist is sampled in 25.0-25.5 m.		
9/30			Weathered schist	Bluish grey schist, moderately hard. 27.05-27.75 m no core. 29.50-30.00 m purple, soft. Clayey.	CL, CM	

Core recovery (%): 30, 20, 60, 15, 25, 80, 40, 35, 40, 45, 20, 40, 40, 90, 90, 10, 0, 0, 0, 0, 0, 0, 0, 0, 0, 50, 25, 35, 100, 65

Water pressure test, Lugeon value: 0.6 (8.2×10^{-5} cm/s)

*RQD = Rock Quality Designation. RQD = Total length of cylindric cores longer than 10 cm / Total core length × 100%
*LUGEON VALUE is [illegible] water injection under pressure of 10kg/cm²
*DEPTH and ELEVATION are in meter

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LOG FORM-B

HOLE NO.

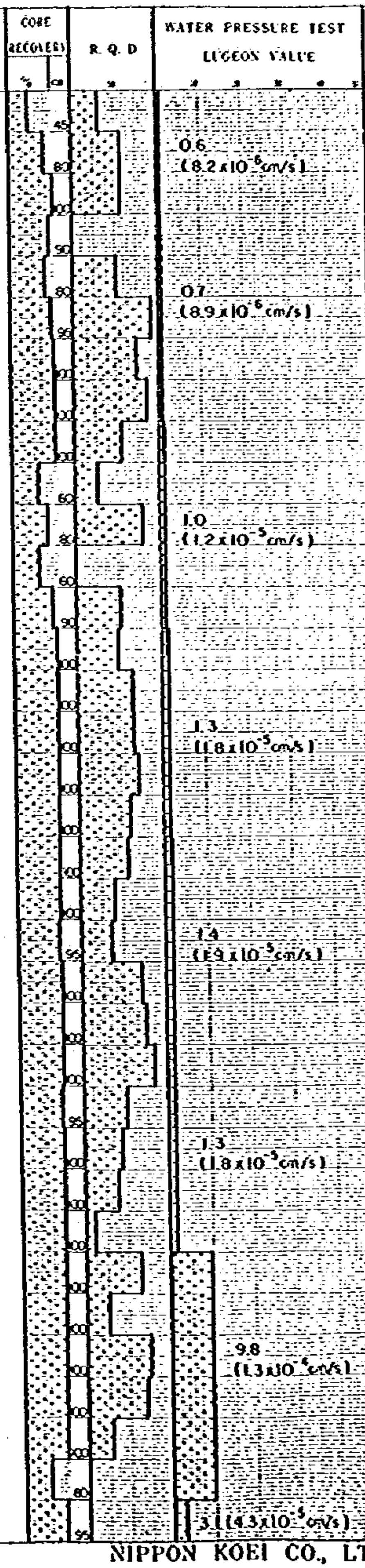
17

PGL-02 (2)

Log Sheet

HOLE NO. PG-82 SHEET NO. 2 OF 3

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION	ROCK GRADE	GROUNDWATER LEVEL
			Weathered schist				
10/1	31.00	244.81	Schist		Dark grey, distorted but moderately hard. Almost fresh, with tight cracks at more than 50 cm interval.	CM	
10/4	34.25	242.32	Schist		Purple, moderately hard. Appears to have once been intensively distorted and fractured but cured and re-solidified afterwards. Fresh. Interval of cracks is more than 50 cm in general. 41.0–41.9: somewhat fractured.	CH / CM	
	41.90	236.46	Muddy shale		Dark grey, compact.		
10/5, 10/6, 10/7, 10/10, 10/11	42.23	236.21	Limestone		Dark grey, fresh hard, with tight cracks at 15 to 30 cm interval. 54.40–54.60: Vertical crack. Cracky at 62.5 and in 63–64. 63.6–64.0 no core.	B / CM / B / CL	
	64.41	219.23	Slaty sandstone		Dark grey, hard.		



HOLE NO.

LOG FORM-C

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

Log Sheet

HOLE NO. PG-B2 SHEET NO. 3 OF 3

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	COLUMN SECTION	DESCRIPTION	ROCK GRADE	GROUNDWATER LEVEL	CORE RECOVERY (%)	R.Q.D (%)	WATER PRESSURE TEST LUGEON VALUE
	66				Dark grey, hard. Part cracky. Interval of cracks is 5 to 15 cm. Cracks are tightly closed.			95		
	67							75		3.1 (4.3 x 10^{-5} cm/s)
	68							95		
10/12	69							60		
	70							80		
	71		Slaty sandstone		70-75m Altered and fractured. Greenish dark grey, with warped slickensides. 70-72m cracks with clay at 5 cm interval, and 72-75m tight cracks at 5 to 15 cm interval.	CM		30		
	72							30		1.5 (2.0 x 10^{-5} cm/s)
	73							55		
	74							100		
10/13	75							60		
	76							100		
	77							100		1.8 (2.4 x 10^{-5} cm/s)
	78				Below 76m, solid with some tight cracks.			100		
	79							100		
10/14	80 (80.00)	158.56						100		

LOG FORM C

HOLE NO.

PGL-03 (1) **Log Sheet**

HOLE NO. PG-B3 SHEET NO. 1 OF 2

PROJECT	El Torito-Los Veganos Hydroelectric Developrent Project			DEPTH	50.0 m	ELEVATION	320.03 m
SITE	Piedra Gorda Damsite (left abut.)	COORDINATE	: :	DIRECTION	Vertical	DRILL RIG	TDC-1G
AVERAGE CORE RECOVERY	79.9%	DATE	FROM 8/1 TO 8/8 '83	DRILLED	OCHIAI, T.	LOGGED	TSUJI, K.

DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	DESCRIPTION	ROCK GRADE	GROUNDWATER LEVEL	WATER PRESSURE TEST LUGEON VALUE
	1.50	318.53	Top soil (dark brown)	Loose, soft soil			
8/1	5.80	314.23	Debris (dull yell. brown to reddish brown)	Loose, unconsolidated angular rock fragment associated with clay. Clay dominant. No water drill			3.2 x 10^{-3} cm/s
	10.00	310.03	Completely weathered tuff (dull yell. brown)	Completely weathered rock 6.0-6.7^m: small fragment core 6.7-7.6^m: cuttings only sampled	D		1.1 x 10^{-3} cm/s
8/2	19.50	300.53	Weathered tuff (greenish grey - pale brown)	Weathered tuff with thin calcite vein. 10.0-13.0^m: short cylindric core 13.0-15.0^m: small fragment core 15.0-15.5^m: porphyritic tuff 15.0-16.0^m: fresh green tuff 16.0-16.5^m: tuff including white crystal & lapillus 17.0-19.5^m: small fragment core Dark green tuff with calcite thin net work vein Excavation depth for fill dam.	CL D	Confined ground water 17.50^m	
8/3	25.20	294.83	Fine sandstone (greenish grey)	Fresh and hard rock Bedding plane dips 35° to 45° Crack mostly open 20.0^m: partly coarse sandstone 22.0-24.0^m: cracky. Crack stained in brown 23.0^m: partly calcareous sandstone 24.0-25.0^m: colored in greenish black Long cylindric core	CM		100 (1.4 x 10^{-3} cm/s)
	26.00	294.03	Very coarse sandstone (greenish grey)	Granule bearing (max.ø 2 - 3 mm)			
8/4			Fine sandstone (greenish grey)	Fresh and hard rock 26.5-28.7^m: cracky, crack stained in brown Bedding plane dips 45° Long cylindric core	CH		7.0 (9.8 x 10^{-5} cm/s)

* R.Q.D is Rock Quality Designation. R.Q.D = (Total length of cylindric cores longer than 10 cm / Total core length) x 100%
* LUGEON VALUE is 1 l/m in order injection water pressure of 10kg/cm^2
* DEPTH and ELEVATION are in meter

NIPPON KOEI CO., LTD.
CONSULTING ENGINEERS, TOKYO.

LOG FORM B

HOLE NO.

PGL-03 (2) **Log Sheet**

HOLE NO. PG-B3 SHEET NO. 2 OF 2

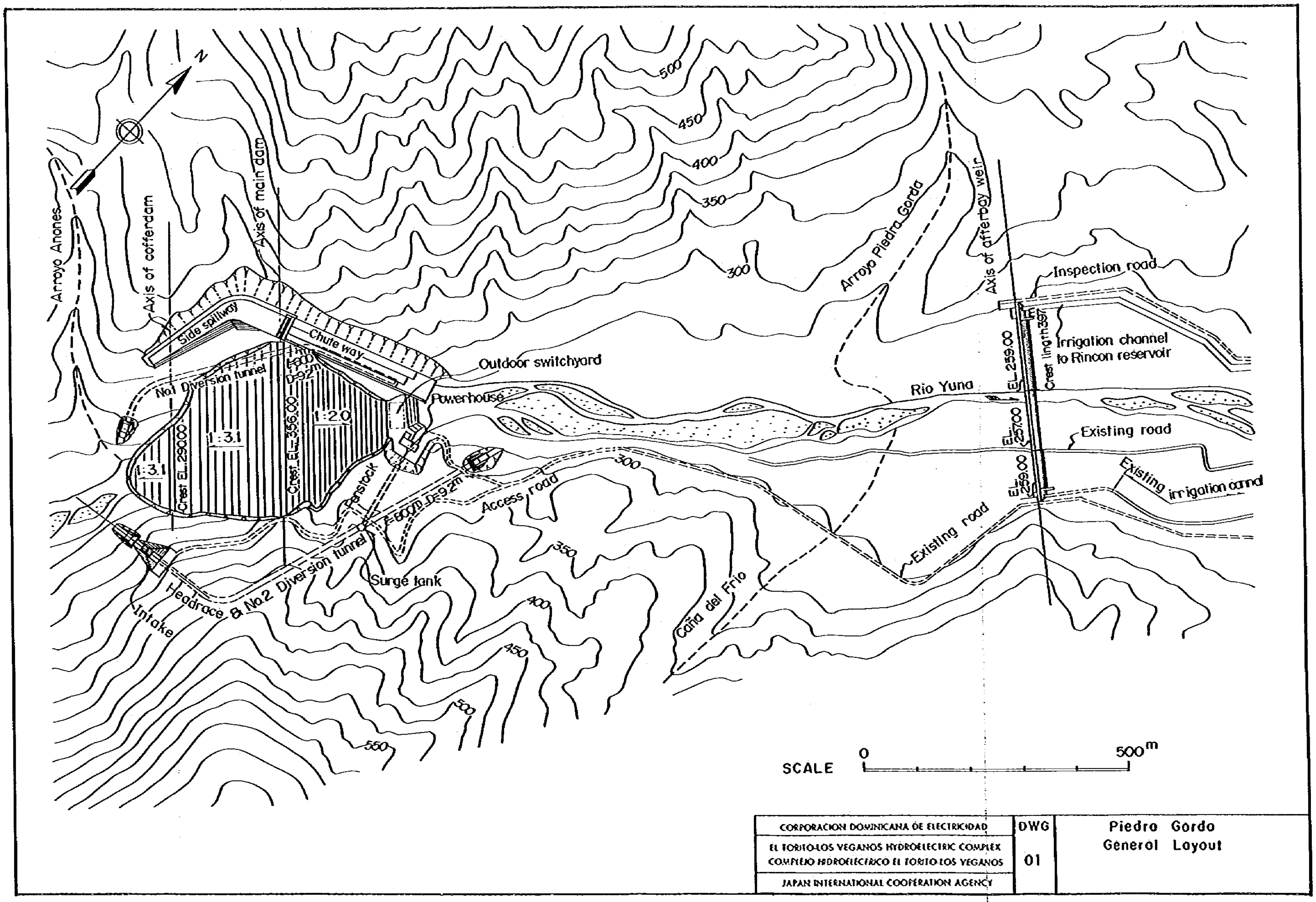
DATE	DEPTH	ELEVATION	ROCK TYPE OR FORMATION	DESCRIPTION	ROCK GRADE	GROUNDWATER LEVEL	WATER PRESSURE TEST LUGEON VALUE
8/5	34.50	285.53	Fine sandstone (greenish grey)	Fresh and hard rock long cylindric core showing stripe pattern of black and white (thickness 1-5 cm) Bedding plane dips 40° Crack stained in brown down to 34.0m Including pebble from 33.5m		water leak	7.0 (9.8×10^{-3} cm/s) 1.6 (2.1×10^{-5} cm/s)
	35.30	284.73	Coarse sandstone (dark green)	Including pebble (max. ø2.5 cm) Sub-angular			
8/6	42.50	277.53	Granule conglomerate (grey-greenish grey)	Fresh and hard rock Sub-angular pebble (max. 3 cm) Organic material (tar) included 38.1-38.5m: cracky calcite Vein dominant Bedding plane dips 40° Sample at 38.0m was petrographically checked	CH		0
	43.00	277.03	Shale (black)	Tar-bearing calcareous			
	44.00	276.03	Conglomerate (greenish grey)	Pebble-sized, tar bearing			0
	44.60	275.43	Shale (black)	Tar bearing, calcareous			
	45.80	274.23	Calcareous shale (dark reddish purple)	Very hard			
	46.85	273.18	Conglomerate (greenish grey)	Pebble-sized (ø 1-2 cm dominant) Tar bearing			
	47.10	272.93	Shale (black)	Tar bearing			
	48.00	272.03	Conglomerate (greenish grey)	Pebble-sized, tar bearing Sample at 47.2m checked by microscope			53.2 (7.2×10^{-4} cm/s)
8/7	50.00	270.03	Calcareous shale (grey)	Fresh and hard rock with calcite vein, including chalcopyrite Tar bearing			

HOLE NO.

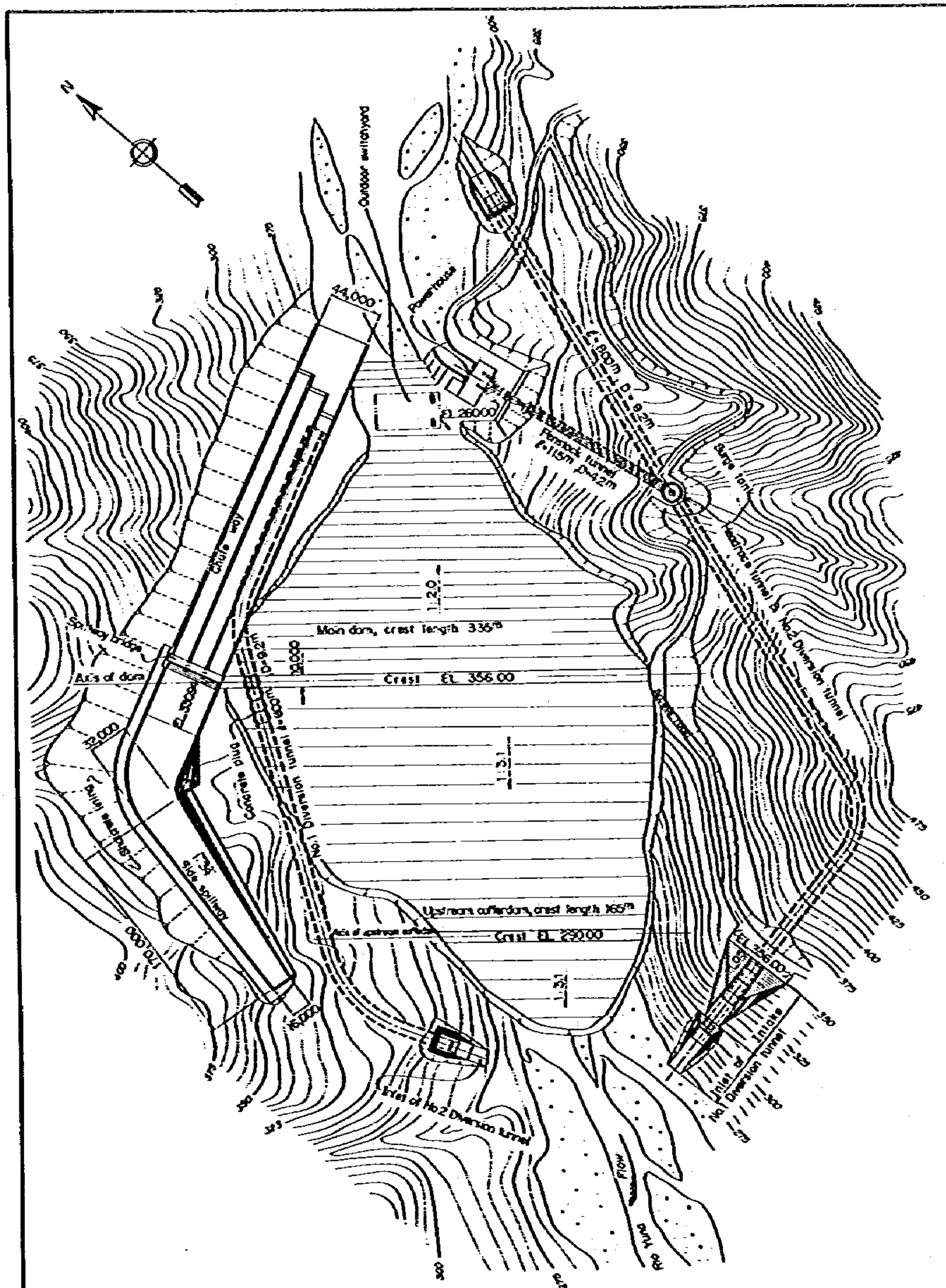
LOG FORM C

23

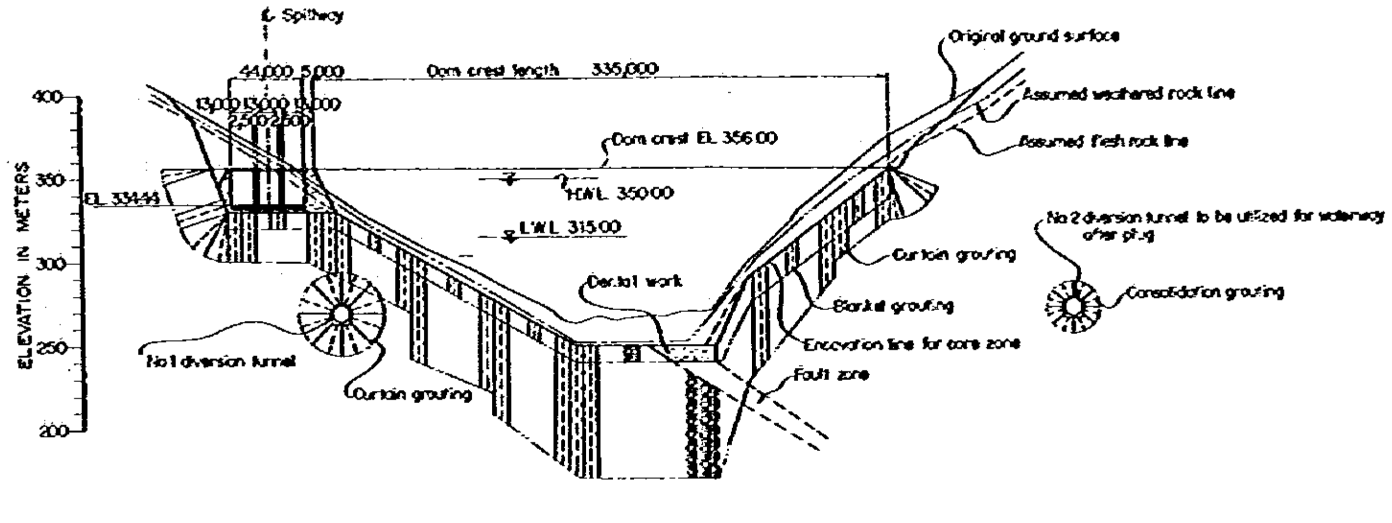
DRAWINGS



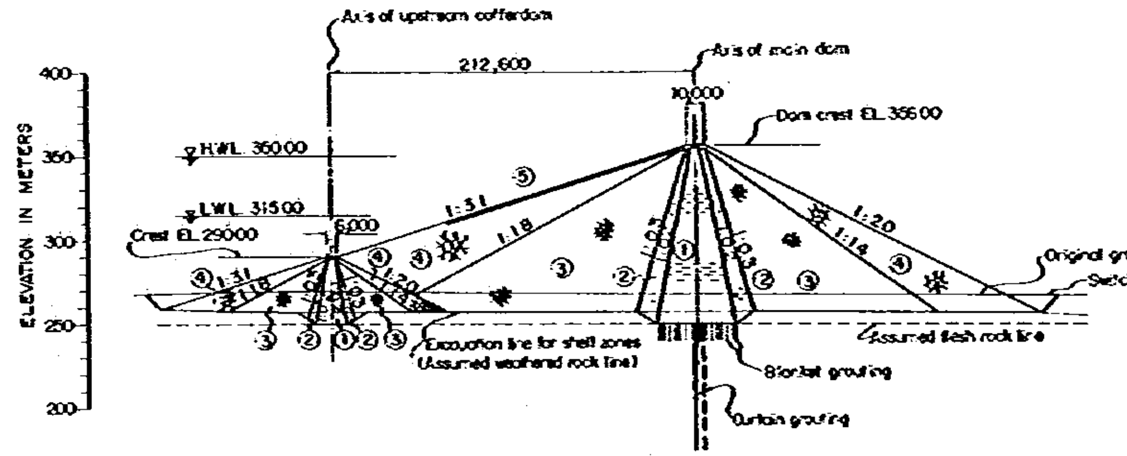
N
Arroyo Anones
Axis of cofferdam
Axis of main dam
500
450
400
350
300
Arroyo Piedra Gorda
Axis of afterbay weir
Inspection road
Irrigation channel to Rincon reservoir
Side spillway
Chute way
Outdoor switchyard
No.1 Diversion tunnel
Powerhouse
Rio Yuna
1:3.1
1:2.0
Crest EL.290.00
Crest EL.356.00
EL.259.00
EL.257.00
Existing road
Existing irrigation canal
Penstock
Access road
Surge tank
Headrace & No.2 Diversion tunnel
Intake
Existing road
Caña del Frio
550
SCALE
0
500m
CORPORACION DOMINICANA DE ELECTRICIDAD
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX
COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS
JAPAN INTERNATIONAL COOPERATION AGENCY
DWG
01
Piedra Gorda
General Layout



PLAN



UPSTREAM ELEVATION

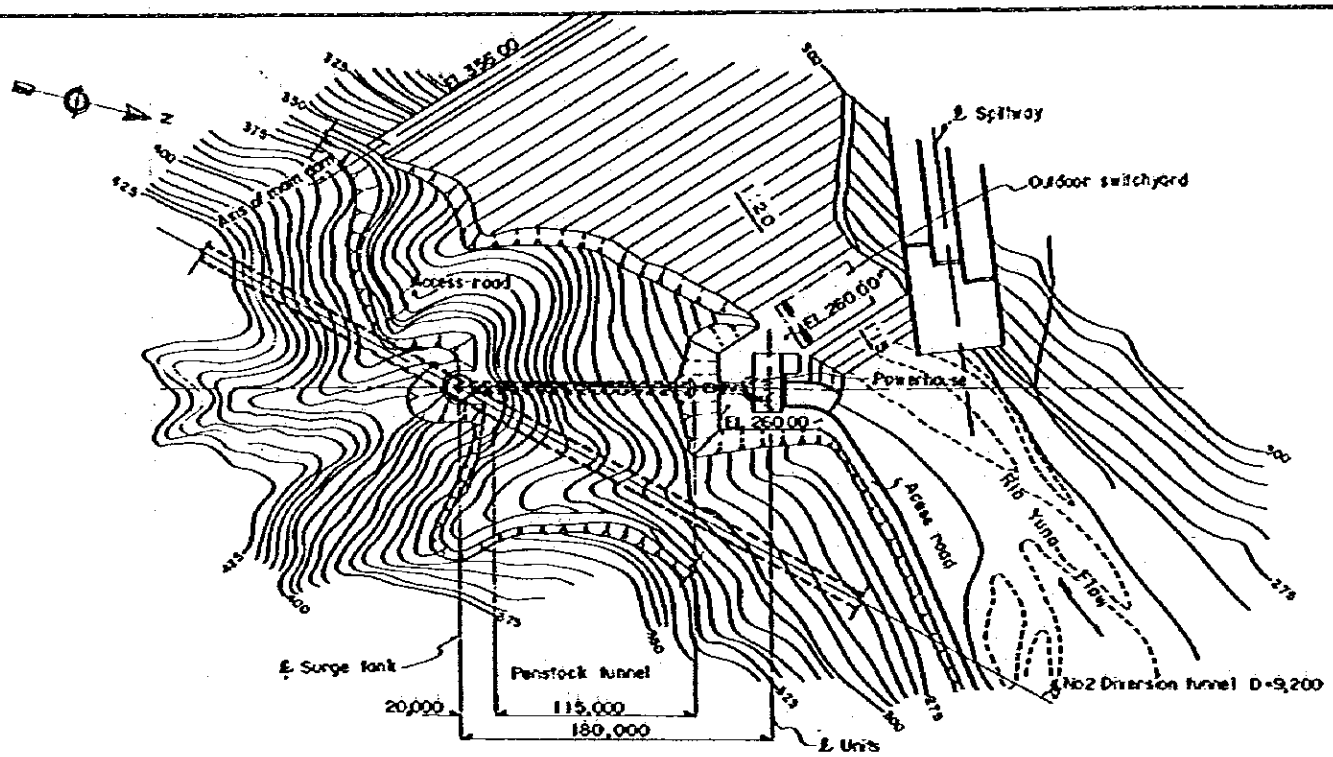


TYPICAL CROSS SECTION

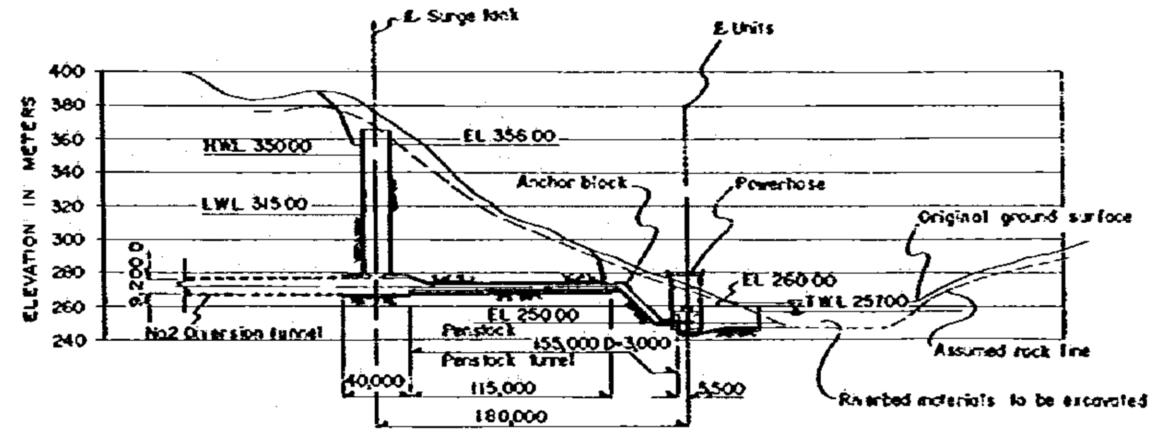
ZONE	MATERIAL
①	Impervious core
②	Filter
③	Random material
④	Rock
⑤	Rock riprap

SCALE 0 — 200m

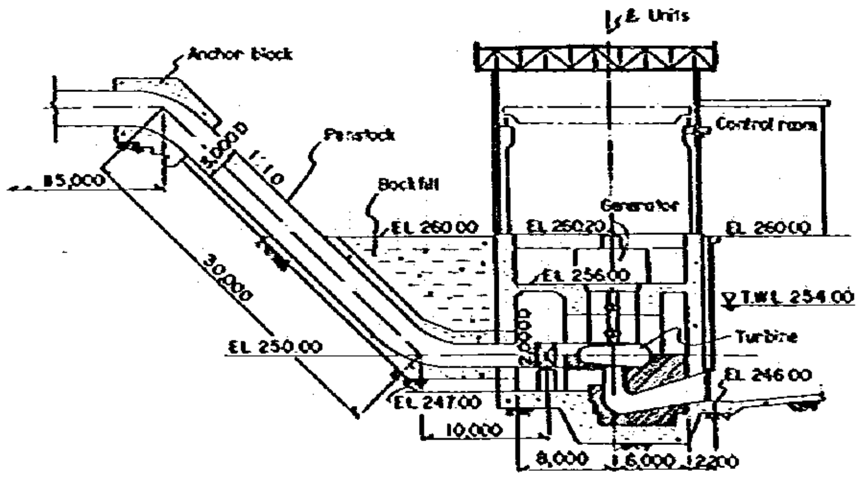
CORPORACION DOMINICANA DE ELECTRICIDAD	DWG	Piedra Gorda Dam
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX / COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	02	
JAPAN INTERNATIONAL COOPERATION AGENCY		



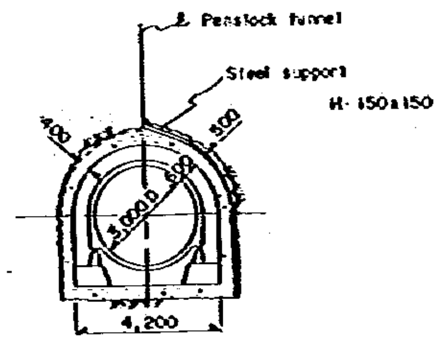
PLAN SCALE A



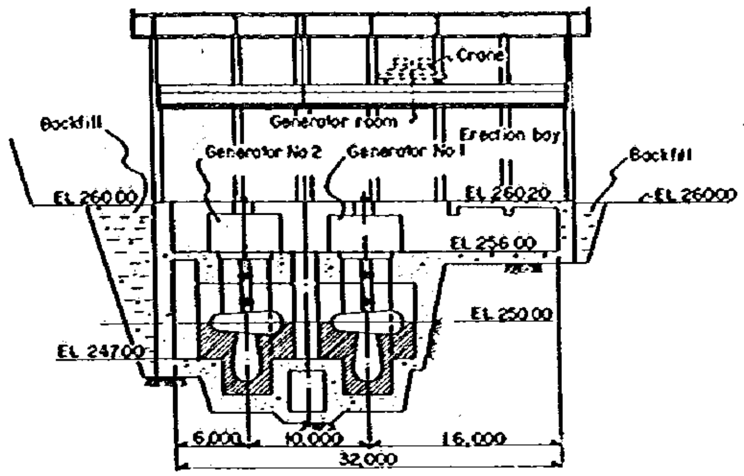
PROFILE SCALE A



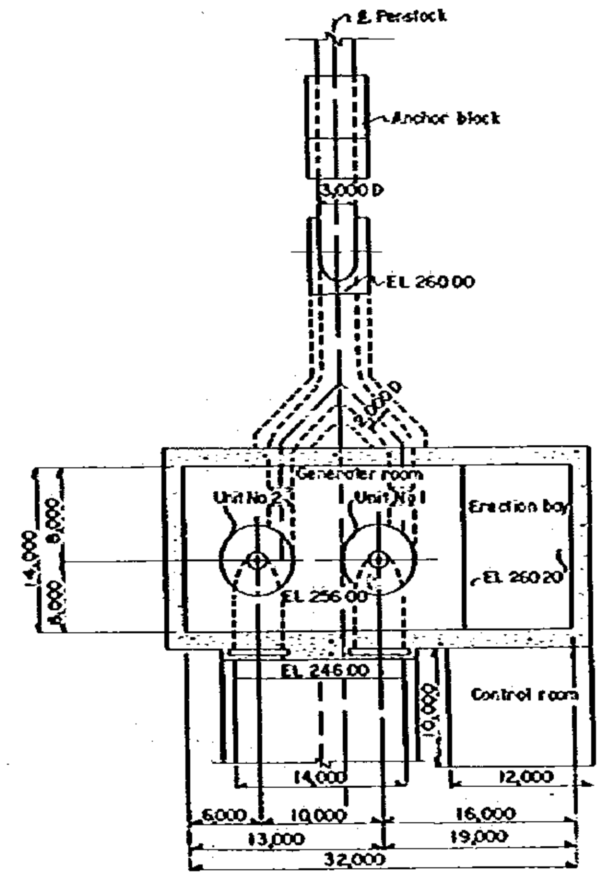
STANDARD SECTION SCALE B



TYPICAL SECTION OF PENSTOCK TUNNEL SCALE C



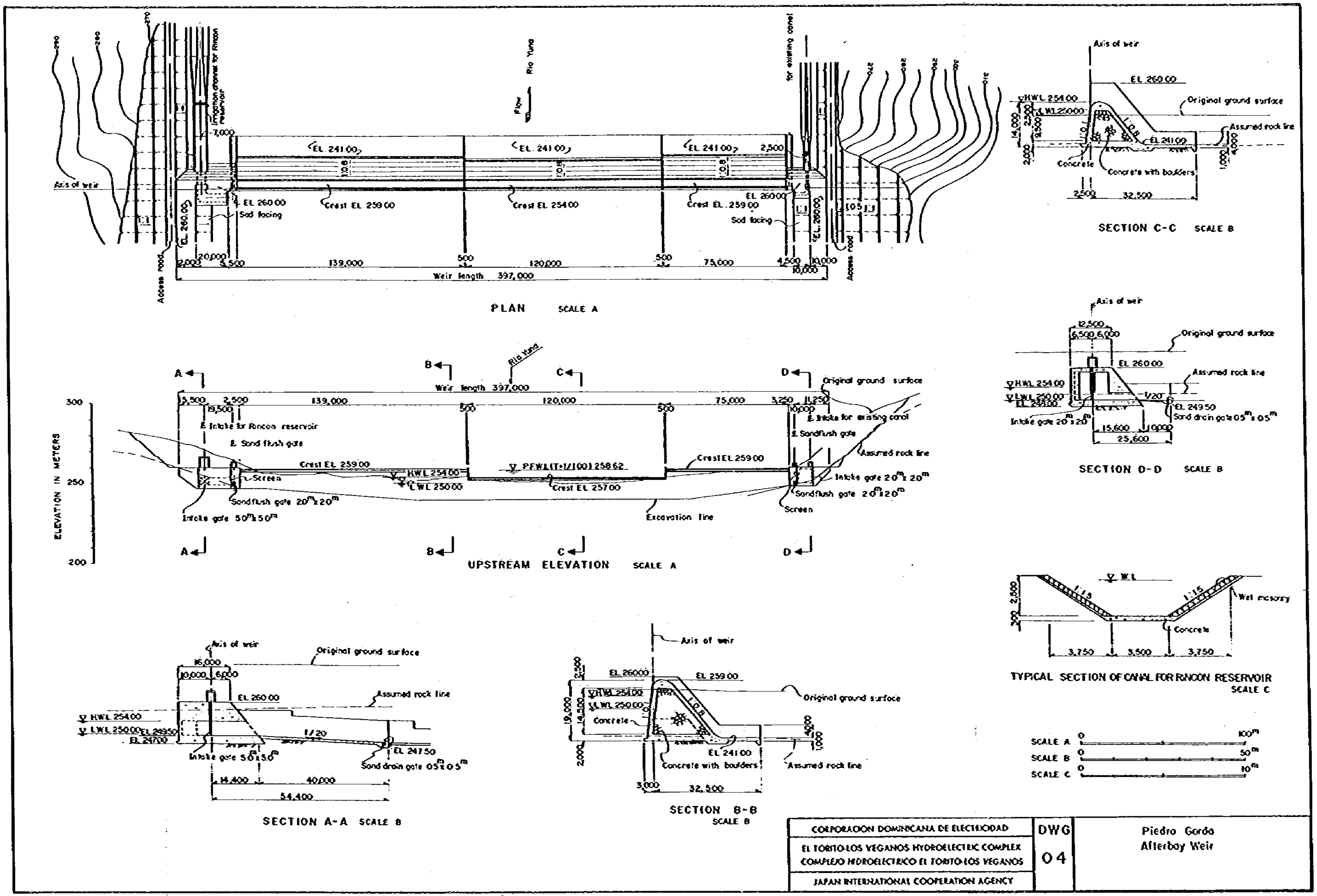
LONGITUDINAL SECTION SCALE B



PLAN (EL. 256.00) SCALE B

SCALE A 0 200m
SCALE B 0 30m
SCALE C 0 10m

CORPORACION DOMINICANA DE ELECTRICIDAD	DWG	Piedro Gordo Powerstation
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	03	
JAPAN INTERNATIONAL COOPERATION AGENCY		


PLAN SCALE A
Rio Yuna
Flow
Irrigation channel for Rincon reservoir
for existing canal
Axis of weir
EL 241.00
EL 260.00
Crest EL 259.00
Crest EL 254.00
Sod facing
Access road
Weir length 397,000
139,000
120,000
75,000
UPSTREAM ELEVATION SCALE A
ELEVATION IN METERS
Original ground surface
℄ Intake for Rincon reservoir
℄ Sand flush gate
℄ Intake for existing canal
℄ Sandflush gate
Assumed rock line
PFWL(T=1/100) 258.62
Crest EL 257.00
HWL 254.00
LWL 250.00
Screen
Sandflush gate 2.0m x 2.0m
Intake gate 5.0m x 5.0m
Intake gate 2.0m x 2.0m
Excavation line
SECTION C-C SCALE B
Concrete
Concrete with boulders
SECTION D-D SCALE B
Sand drain gate 0.5m x 0.5m
SECTION A-A SCALE B
SECTION B-B SCALE B
TYPICAL SECTION OF CANAL FOR RINCON RESERVOIR SCALE C
Wet masonry
SCALE A 0 100m
SCALE B 0 50m
SCALE C 0 10m
CORPORACION DOMINICANA DE ELECTRICIDAD
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX
COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS
JAPAN INTERNATIONAL COOPERATION AGENCY
DWG 04
Piedra Gorda Afterbay Weir

APPENDIX II

APPENDIX - II

PINALITO HYDROELECTRIC PROJECT

Table of Contents

List of Tables

List of Figures

List of Drawings

I. INTRODUCTION

1.1 Objectives and Scope of Study

The Pinalito hydroelectric project is located in the upper stream of the Tireo river, which is called the Blanco river in the lower reach and forms a major tributary of the Yuna river. Along the Blanco river, the Rio Blanco hydroelectric project is being implemented, and the Pinalito scheme is planned to utilize water available in the Tireo river basin upstream of the intake site for the Rio Blanco project. The Pinalito project forms a part of hydroelectric development projects in the upper Yuna river basin.

At the initial stage of the feasibility study on El Torito - Los Veganos hydroelectric complex, which is located on the Yuna mainstream, CDE requested JICA study team to preliminarily review on the Pinalito hydroelectric scheme on the basis of the exising data. JICA team agreed to carry out a preliminary study to review a previous study, without executing additional surveys particularly for the Pinalito scheme.

The scope of this study, therefore, is limited to the works as enumerated hereunder.

1) To make a reconnaissance at the site proposed previously for construction of the Pinalito dam.

2) To review a plan previously proposed and to preliminarily study on alternatives for further study to be executed in the subsequent stage.

The data available for the Pinalito project is substantially limited, and the review is obliged to be very preliminary in nature.

1.2 Previous Study

The Pinalito project was formulated through a master planning of hydroelectric development in the upper Yuna river basin conducted by CDE-ENEL in 1981. On the basis of reconnaissance survey and 1/50,000 topographic map, as well as preliminary study on available discharge, a development plan has been proposed to construct a dam and reservoir at Pinalito on the Tireo river, and to collect water of such tributaries as Arroyo Madre Vieja, Arroyo Sonàdor and Cañada Arroyón to be led to the headrace tunnel from the Pinalito intake to the power station to be located at a site just upstream of the intake weir for the Río Blanco hydroelectric project. The proposed outline of the Pinalito project is summarized as follows:

Catchment area:	Pinalito damsite	59.0 km^2
	Weir on A. Madre Vieja	7.8
	Weir on A. Soñador	33.1
	Weir on C. Arroyón	21.0
	Small tributaries	2.1
	Total:	123.0 km^2
Pinalito dam:	High water level	EL. 1,197 m
	Storage capacity	$8.62 \times 10^6 m^3$
	Dam height	47.0 m
Headrace tunnel		10.5 km
Power station:	Head	563.0 m
	Installed capacity	35.7 MW
	Annual energy output	107.6 GWh

Construction of a concrete dam has been proposed at Pinalito. According to CDE-ENEL study, the Pinalito project is preliminarily evaluated to be economically feasible.

II. PHYSICAL CONDITIONS

2.1 Location and Topography

The Tireo river originates in the southern slope of the Alto de la Randera, and runs through the high plateau developed around Tireo Arriba, with elevation ranging from 1,200-1,300 m above mean sea level. A damsite is found on the Tireo river at the eastern corner of the plateau. The damsite, called Pinalito site, is located at about 13 km to the east of Tireo Arriba, or approximately 24 km to the east of Constanza. The riverbed elevation is around 1,145 m above mean sea level. (Refer to Fig.-01)

The river flows down rapidly on the eastern slope of the plateau. It joins with Arroyo Madre Vieja at a site about 1.3 km downstream from the Pinalito damsite. At a site further downstream, Arroyo Soñador also joins the Tireo river. Near the confluence with Arroyo Blanco, a diversion weir for the Rio Blanco hydroelectric project is designed to be constructed, with a high water level at 624 m above mean sea level. Consequently, a gross head of nearly 520 m is available in the river course of 12.0 km between the Pinalito damsite and the Rio Blanco diversion weir site.

The Tireo river is called the Blanco river in the lower reach downstream from the confluence with Arroyo Blanco. The Blanco river finally joins with the Yuna mainstream at a site about 3.7 km upstream of Los Quemados.

In the plateau around Tireo Arriba, the land is rather extensively utilized for cultivation of such crops as cabbage, carrot, garlic, onion, potato, etc. and irrigation by pumping up Tireo water is practised extensively. In the sub-basins of other tributaries, land is not used for crop cultivation, except for shifting cultivation.

2.2 Hydrometeorology

Rainfall in the plateau of the upper Tireo river is relatively small. The rainfall recorded at Constanza (EL. 1,215 m) since 1931 averaged at around 1,020 mm. Likewise, the rainfall record at El Rio in the Jimenoa river basin, located at about 7 km to the north of the Pinalito damsite, also demonstrates that the annual mean rainfall is around 1,270 mm. At Cruz de Cuaba gauging station (EL. 1,540 m) in the upper Tireo, rainfall records is only available for some months in 1981. On the other hand, in the lower Tireo river basin, rainfall at Los Botados averaged at 1,950 mm in 1980-82.

The isohyet map on Fig.-02 demonstrates a pattern of rainfall distribution in the Tireo river and Blanco river basin. In general, rainfall increases in the lower part of the basin. On the basin of this isohyet map, the basin rainfall of tributary is estimated at around 1,270 mm in the Tireo mainstream (Pinalito sub-basin), 1,410 mm in Arroyo Madre Vieja sub-basin and 1,590 mm in Arroyo Sonador sub-basin.

Although a hydrological gauging station was established in 1981 at Pinalito, the record is substantially short in period and it is affected by use of water for irrigation in and around Tireo Arriba. Under such a circumstance, run-off at each intake site of the tributaries is preliminarily estimated in accordance with the following formula:

$$Qs = Q_L \cdot CF$$

$$CF = \frac{CAs}{CAL} \cdot \frac{BRs}{BR_L}$$

where: Qs = Discharge at sub-basin intake site
Q_L = Discharge at Los Quemados
CF = Conversion factor to Los Quemados
CAs = Catchment area at sub-basin intake site
CAL = Catchment area at Los Quemados (369 km^2)
BRs = Sub-basin rainfall
BR_L = Basin rainfall at Los Quemados (2,360 mm)

The conversion factor (CF) is estimated as shown on Table-01. It is presumed that 0.205 of discharge record at Los Quemados is available from the sub-basin with a total catchment area of 119.5 km^2.

The flood discharge at the Pinalito damsite is preliminarily estimated in the same manner as applied for El Torito - Los Veganos complex. It is estimated that the probable flood for the return period of 200 years will be around 590 m^3/s, as shown on Table-02.

2.3 Geology

The geologic reconnaissance has been made only at the proposed Pinalito damsite. General engineering geologic conditions at the damsite are briefly described hereunder.

The Pinalito damsite is occupied by green lapilli tuff and purple tuff which belong to the Cretaceous Tireo Formation (ENEL's classification into "DICCHI BASALTICI" is misinterpreted.). They strike N30°E to N50°E and dip 30° to 50° southeast near the damsite, or 30° northwest in the upperstream. In particular, jointings are developed near the damsite. Strike and dip of jointings are: N15°E-50°E with 30 cm wide interval, N40°W-40°W with 30 cm wide interval, N70°E-65°S with 5 cm to 20 cm wide interval and N40°E-70°W with 40 cm wide interval. Since the jointings are open in the outcrops, the superficial zone of the damsite probably shows high permeability with the implication that it requires waterstop treatment by grouting. Further, a remarkable tortuous river course near the site appears to be subject to such developing joint system.

The right abutment is deeply weathered compared to the left abutment, where a blocky exposure of lapilli tuff is sporadically observed. In the riverside, a fresh and hard rock crops out, continuing toward the downstream. The old river terrace deposit of less than 1 m in thickness is distributed at places.

The site appears to be suitable for a concrete gravity dam or a rockfill dam, assuming that the proposed dam would rise about 60 to 70 meters above the present streambed. This probably depends on an availability of materials in the surrounding area.

2.4 Construction Materials

Reconnaissance has also been carried out in and around the Pinalito damsite.

Earth and rock materials for dam embankment are obtainable in sufficient quantity in the vicinity of the proposed damsite at Pinalito. However, filter materials for fill-type dam or concrete aggregates for construction of a gravity type dam are unavailable near the damsite.

Determination of dam type, from technical and economic point of view, is concequently dependent on availability of sand and gravel in the area downstream from the damsite, in case a dam of 60-70 m in height is planned to be constructed. If the dam height is lower, say 40 m or less, it is conceivable to design an earth-fill type dam at Pinalito. In any case, further investigation should be carried out, with particular attention to the availability of sand and gravel materials in the vicinity of the proposed damsite.

III. PRELIMINARY PLAN

3.1 Alternative Plan

The development of hydroelectric power in the Tireo river basin upstream of the intake site for the Rio Blanco project is basically planned to utilize the relatively high head available inbetween the highland and the Rio Blanco intake site. On the other hand, the available run-off is relatively limited, and water is to be collected as much as possible from the tributary sub-basins.

Under such basin concepts, two alternative plans are preliminarily studied. The first alternative contemplates construction of a dam at the Pinalito damsite and water diversion from Arroyo Madre Vieja, Arroyo Soñador, and small tributaries of Arroyo Blanco. This alternative plan, called the Pinalito dam plan, is originally proposed by CDE-ENEL study in 1981. The second alternative, called the Pinalito weir plan, is to construct an intake weir at the proposed Pinalito damsite, and to divert water from sub-basins as contemplated under the Pinalito dam plan. These alternative plans are comparatively studied herein.

3.2 Available Discharge

On the basis of conversion factor estimated in Chapter 2.2, water available at each intake site is calculated preliminarily. For the Pinalito dam plan, the firm discharge for power generation is calculated by means of mass curve method. Through the discharge mass curve as shown on Fig.-03 and the reservoir capacity for various draft values as shown on Fig.-04 and Fig.-05, the firm discharge is estimated as summarized hereunder.

	Case-1	Case-2	Case-3	Case-4
High water level (EL.m)	1,190	1,195	1,200	1,205
Effective storage ($10^6 m^3$)	2.6	6.0	11.1	17.0
Firm discharge (m^3/s)	1.70	2.00	2.20	2.30

Through the economic comparative study among alternative scales of reservoir, as shown on Table-03 and Fig.-06, it appears that the Case-3 to have the high water level at EL. 1,200 m with the firm discharge of 2.2 m^3/s will be more advantageous.

As in the case of El Torito - Los Veganos complex, power station is planned to be operated to cover the peak load for 6 hours. The maximum discharge for power generation is therefore 8.8 m^3/s. The operation for 6 hours at Pinalito will be coordinated with 6-hour peak operation at the Rio Blanco power station, as well as future implementation of the Piedra Gorda power station in the downstream reach.

On the other hand, 90% dependable discharge at each intake site is estimated by applying conversion factors explained in Chapter 2.2 to the discharge recorded at Los Quemados, as summarized hereunder. (Refer to Fig.-07)

	Q_{90}
Pinalito	0.67
Madre Vieja	0.11
Soñador	0.43
Arroyón	0.14
C. de Blanco	0.13
A. Blanco	0.12
Total	1.60

In case of the Pinalito weir plan, the firm discharge for power generation is assumed at 1.60 m^3/s. The maximum discharge for 6-hour peak load operation is 6.40 m^3/s.

It is noted that water is utilized for irrigation in the Cerro Tireo valley upstream of the Pinalito dam/weir site. In the subsequent stage of the study on the Pinalito project, such a water use is to be estimated and the water available for power generation should be assessed in more detail.

3.3 Pinalito Dam Plan

A preliminary plan is formulated on the basis of 1/50,000 scaled topographic map. In view of the fact that sand and gravel for concrete aggregates are unavailable in sufficient quantity near the damsite, as noted in Chapter 2.4, the Pinalito dam is provisionally planned as a fill-type dam.

Dam crest elevation is set at EL. 1,204.5 m, on 4.5 m higher than the high water level. Since the dam foundation is planned to be excavated down to EL. 1,147.0 m, the height of the Piedra Gorda dam is 57.5 m. The dam crest length is 210 m, and the embankment volume is estimated at 1,060 x 10^3 m^3. A diversion tunnel is planned to be excavated in the left abutment, and the intake structure will be installed in the right abutment. (Refer to DWG-01 and DWG-02)

For intake of water from the tributaries, 5 intake weirs are planned to be constructed, as follows:

a) A. Madre Vieja weir, located at about 1.0 km upstream of its confluence with Rio Tireo

b) A. Soñador weir, located at about 4.0 km upstream of its confluence with Rio Tireo

c) C. Arroyón weir, located at about 3.0 km upstream of its confluence with Rio Blanco

d) C. Blanco weir, located at about 0.8 km upstream of the confluence with A. Blanco

e) A. Blanco weir, located at about 0.8 km upstream of the confluence with C. Blanco

These weirs will be of overflow type, with screen on the crest. (Refer to DWG-03)

A headrace tunnel from the Pinalito dam to the surge tank will be approximately 11.0 km in length. A diversion tunnel from C. Arroyón weir, C. Blanco weir and A. Blanco weir will be 3.9 km in length.

The Pinalito power station will be located close to the intake storage of the Rio Blanco project, to obtain the maximum head. (Under ENEL plan, power station was located at about 500 m upstream of the site proposed herein). The tail water of the power station is set at the level equal to the high water level of the Rio Blanco intake storage (EL. 624.0 m). An effective head of 529.9 m is made available under the Pinalito dam plan.

An installed capacity is planned to be 39 MW. The annual primary energy is estimated at 84.4 GWh and the secondary energy at 51.8 GWh.

3.4 Pinalito Weir Plan

The Pinalito intake weir is provisionally planned to locate at the same site as the dam plan. The intake weir is planned for the high water level at EL. 1,163.5 m, with a storage capacity of 138,000 m^3 for daily regulation for 6-hour peak operation. The crest elevation is set at EL. 1,168.0 m, and the weir crest has a length of 100.0 m. The height of weir is 21 m from the foundation excavation line. The weir is preliminarily designed to have two roller gates of 10 m x 9 m, and to have ogee portion of 20 m in length. (Refer to DWG-04)

In case of the Pinalito weir plan, the intake sites for water diversion from tributaries will be shifted to the downstream. (Refer to DWG-01) The length of the headrace tunnel from the Pinalito weir to the surge tank will be reduced to 10.3 km. The diversion tunnel from C. Arroyon weir, C. Blanco weir and A. Blanco weir will be 4.1 km in length.

At the powerhouse to be located on the right bank of the Tireo river, about 100 m upstream of its confluence with Arroyo Blanco. (Refer to DWG-05) An effective head is 519.5 m. The installed capacity is estimated at 28 MW. Two sets of Pelton type turbine and 15.6 MVA generators will be installed. The annual primary energy output is estimated at 59.3 GWh, and the secondary energy output is 66.6 GWh. Power will be transmitted for about 8 km to the substation located at the Rio Blanco power station.

IV. EVALUATION AND RECOMMENDATION

4.1 Preliminary Evaluation

The construction cost of the Pinalito dam plan and weir plan is preliminarily estimated as shown on Table-04 and Table-05. On the other hand, the benefit is estimated on the basis of the alternative power by gas turbine for the primary energy and by coal-fired plant for the secondary energy.

The study resulted in that both of the Pinalito dam plan and the Pinalito weir plan will turn out to be economically feasible, as shown on Table-03 and Table-06. It is preliminarily appraised that the Pinalito weir plan will be more attractive than the Pinalito dam plan.

4.2 Recommendation

As preliminarily evaluated above, the Pinalito dam plan and weir plan appear to be economically feasible, and it is recommended to carry out further study, at pre-feasibility level, on the Pinalito project.

In the pre-feasibility study, attention will be paid, among others, to the following points:

a) Hydrological analysis is to be made to estimate the dependable discharge as accurately as possible. Hydrological study should include estimate of water utilized for irrigation in the Cerro Tireo valley.

b) As an alternative to the weir construction at the Pinalito dam/weir site, it is conceived to locate the intake weir at a site immediately downstream from the confluence with Arroyo Madre Vieja, thus enabling construction of one weir instead of two weirs on the tributaries. It is recommended to study on this alternative plan in the subsequent stage of the study.

c) An integrated and systematic operation of the Pinalito power station with other power stations in the upper Yuna river basin (Río Blanco, El Torito, Los Veganos and Piedra Gorda) is recommended to be studied further.

TABLES

Table -01 DISCHARGE CONVERSION FACTOR

Sub-Basin (Intake)	Catchment Area (km^2)	Basic Rain-fall (mm)	Conversion Factor
Pinalito	59.0	1,270	0.086
A. Madre Vieja	8.4	1,410	0.014
A. Sonador	30.0	1,590	0.055
C. Arroyon	8.2	1,920	0.018
C. de Blanco	7.5	2,000	0.017
A. Blanco	6.4	2,100	0.015
Total	119.5		0.205
Los Quemados	369.0	2,360	1.000

Table -02 FLOOD DISCHARGE ESTIMATED AT PINALITO

	Estimated Discharge (m^3/s)	Specific Discharge ($m^3/s/km^2$)
Actual rainfall	357	6.1
Return period: 1/20	265	4.5
1/50	383	6.5
1/100	485	8.2
1/200	584	9.9
Probable maximum flood	819	13.9
Design Flood:		
Weir	490	
Concrete dam	590	
Fill-type dam	700	
Coffer dam	270	

Reference: El Torito - Los Veganos Complex, Annex C.5

Table-03 ECONOMIC COMPARISON OF ALTERNATIVES FOR PINALITO DAM SCHEME

Description H.W.L. (EL.m)	Alternatives in Pinalito Dam 1,190	1,195	1,200	1,205
1. Power Generation				
Installed Capacity (kW)	31,000	36,000	39,000	41,000
Annual Energy Output (GWh)	130.0	133.8	136.2	138.5
Primary	(67.0)	(77.9)	(84.4)	(89.6)
Secondary	(63.0)	(55.9)	(51.8)	(48.9)
2. Construction Cost (1000 RD$)	91,105	97,932	100,783	107,723
3. Annual Equivalent Benefit (B) (1000 RD$)				
Capacity Benefit	2,056	2,388	2,586	2,719
Energy Benefit	14,247	15,501	16,257	16,886
Primary	(10,385)	(12,075)	(13,082)	(13,888)
Secondary	(3,862)	(3,426)	(3,175)	(2,998)
Total	16,303	17,889	18,844	19,605
4. Annual Equivalent Cost (C) (1000 RD$)				
Capital Recovery Cost	10,971	11,793	12,136	12,972
O & M Cost	2,255	2,424	2,495	2,666
Total	13,226	14,217	14,630	15,638
5. Annual Net Benefit (B - C) (1000 RD$)	3,077	3,672	4,213	3,967
6. Benefit Cost Ratio (B/C)	1.23	1.26	1.29	1.25

Table-04 CONSTRUCTION COST OF PINALITO DAM

Work Items	Cost (10^3 RD$)		
	F.C.	L.C.	Total
1. Preparatory Works	1,258	770	2,028
2. Civil Works	39,693	29,227	68,920
3. Metal Works	2,355	908	3,263
4. Generating Equipment	8,290	649	8,939
5. Land Acquisition		2,078	2,078
6. Engineering Service & Government Administration	3,870	2,522	6,392
7. Physical Contingency	5,547	3,615	9,162
Total	61,013	39,770	100,783

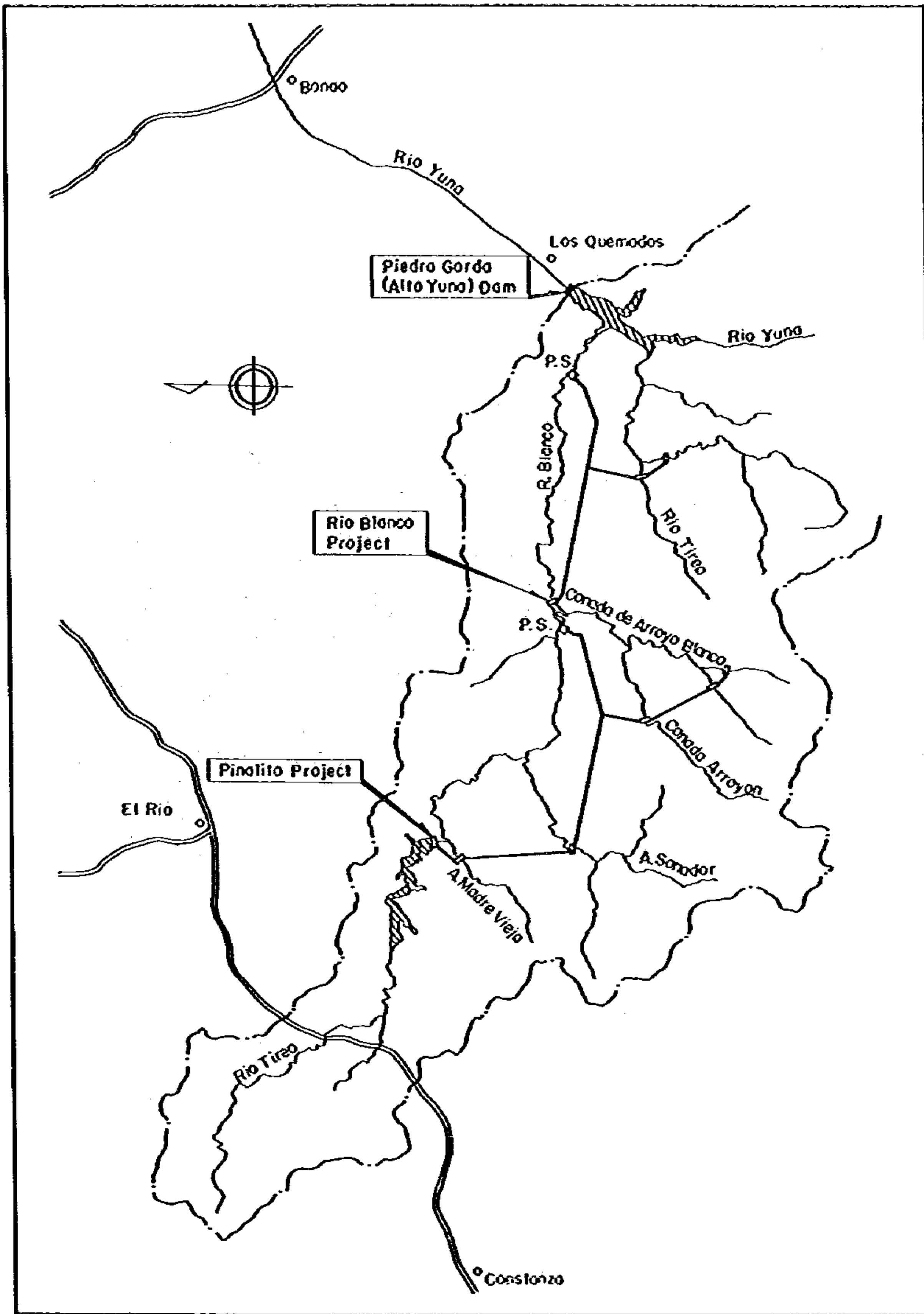
Table-05 CONSTRUCTION COST OF PINALITO WEIR

Work Items	Cost (10^3 RD$)		
	F.C.	L.C.	Total
1. Preparatory Works	850	474	1,324
2. Civil Works	23,309	17,165	40,474
3. Metal Works	3,082	1,188	4,270
4. Generating Equipment	7,608	596	8,204
5. Land Acquisition		704	868
6. Engineering Service & Government Administration	2,614	1,522	4,136
7. Physical Contingency	3,746	2,182	5,928
Total	41,209	23,994	65,203

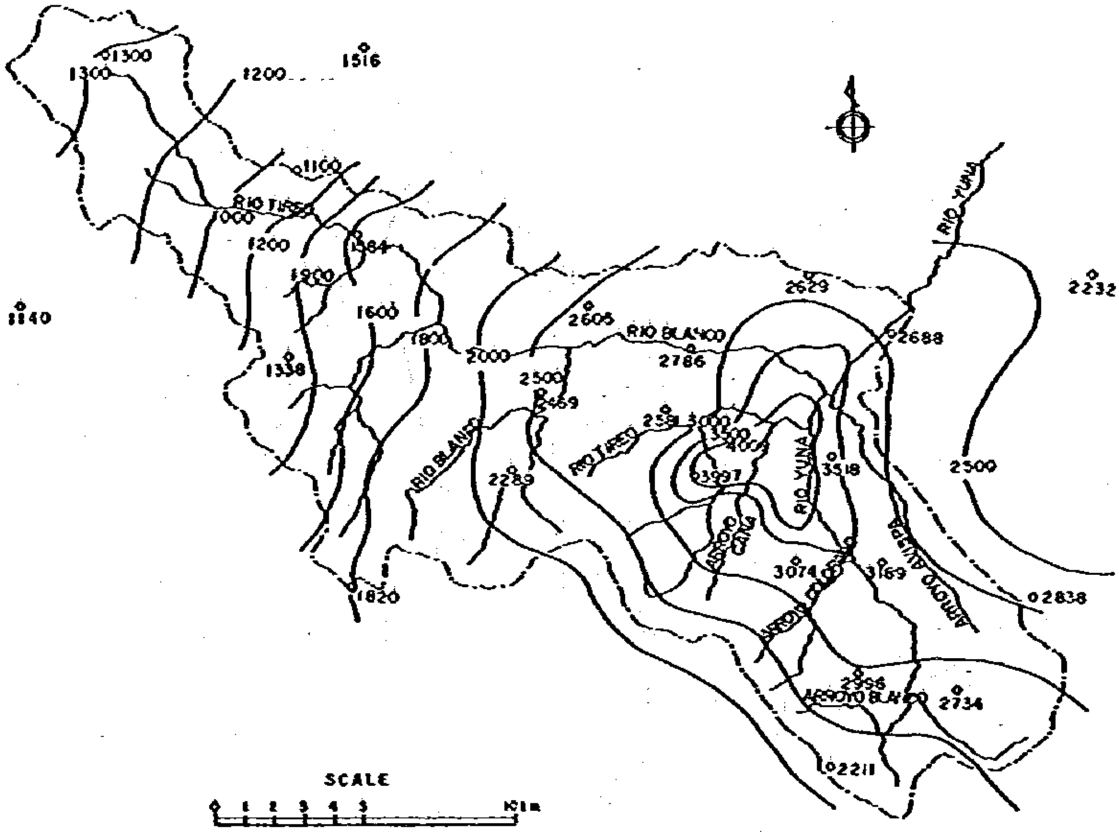
Table-06 ECONOMIC VIABILITY OF PINALITO WEIR SCHEME

Description	Pinalito Weir (138,000 m^3)
1. Power Generation	
Installed Capacity (kW)	28,000
Annual Energy Output (GWh)	125.9
Primary	(59.3)
Secondary	(66.6)
2. Construction Cost (1000 RD$)	65,203
3. Annual Equivalent Benefit (B) (1000 RD$)	
Capacity Benefit	1,857
Energy Benefit	13,274
Primary	(9,192)
Secondary	(4,083)
Total	15,131
4. Annual Equivalent Cost (C) (1000 RD$)	
Capital Recovery Cost	7,852
O & M Cost	1,628
Total	9,480
5. Annual Net Benefit (B - C) (1000 RD$)	5,651
6. Benefit Cost Ratio (B/C)	1.60

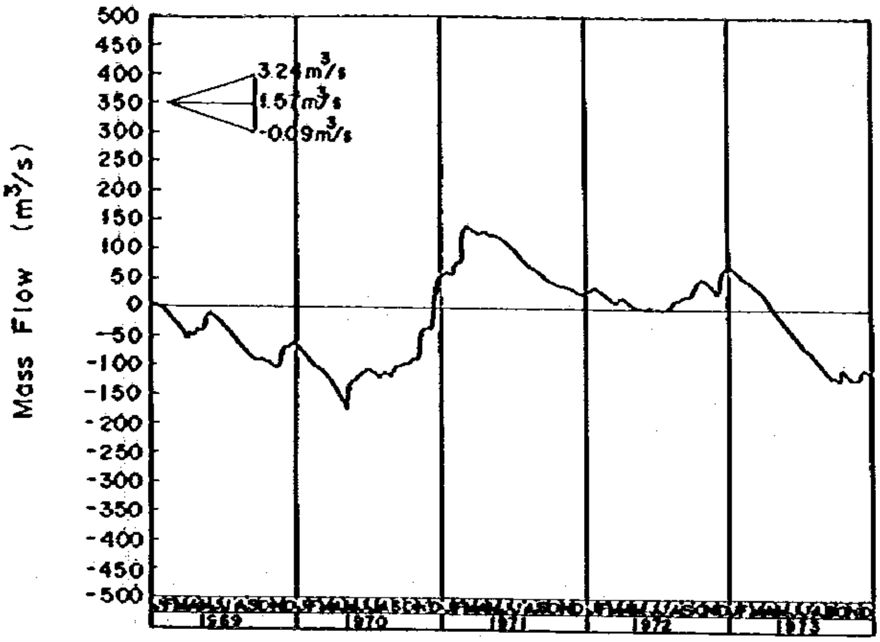
FIGURES

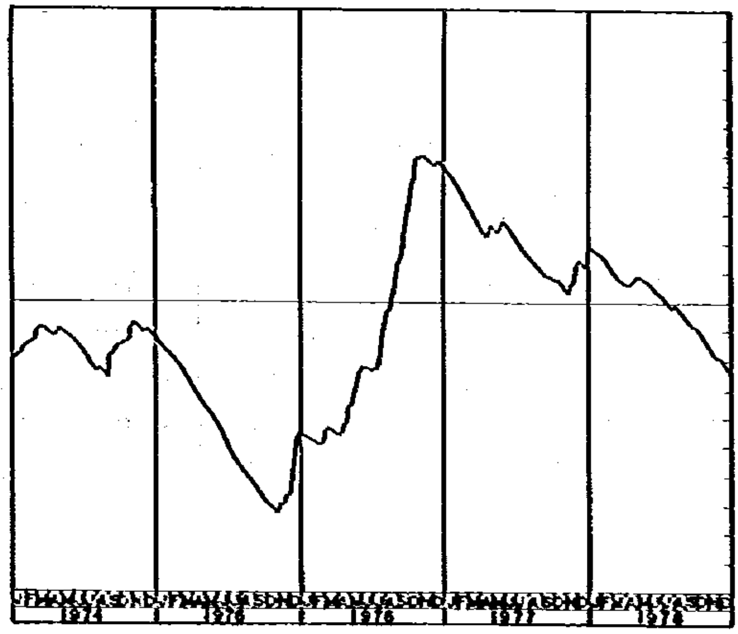


CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Location Map
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO LOS VEGANOS	01	
JAPAN INTERNATIONAL COOPERATION AGENCY		

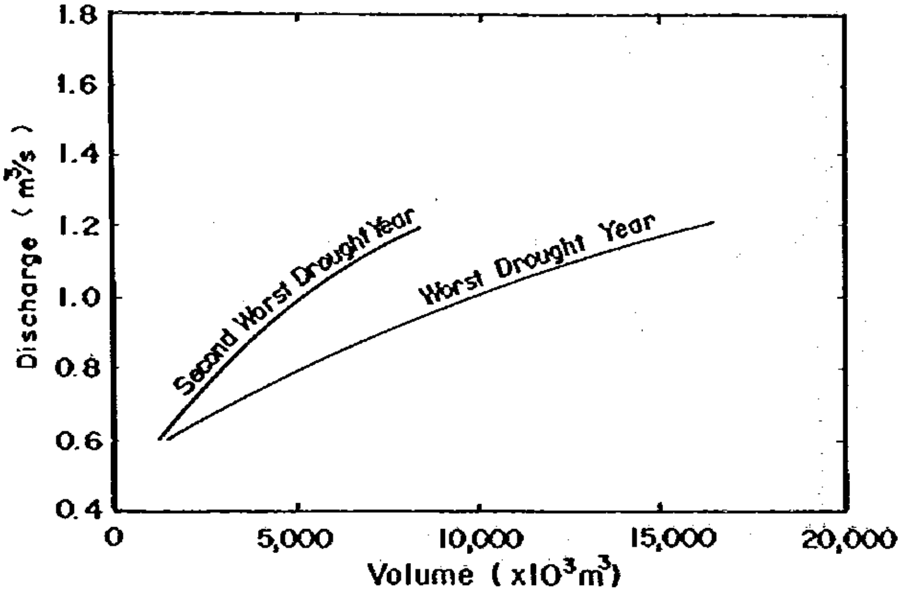


CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Isohyetal Map
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	02	
JAPAN INTERNATIONAL COOPERATION AGENCY		





CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Discharge Mass Curve at Pinalito
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	03	
JAPAN INTERNATIONAL COOPERATION AGENCY		



Discharge Q (m^3/s)	For the Worst Drought Year $V'max_1$ (m^3/s)	$Vmax_1$ (=$V'max_1$x86,400) ($x10^3m^3$)	Date	For the Second Worst Drought Year $V'max_2$ (m^3/s)	$Vmax_2$ (=$V'max_2$x86,400) ($x10^3m^3$)	Date
0.6	17.34	1,500.0	'75 AUG. 8	14.53	1,260.0	'77 APR. 9
0.8	58.45	5,050.0	〃 OCT. 2	34.56	2,790.0	〃 〃 17
1.0	113.50	9,810.0	〃 〃 25	57.82	5,000.0	〃 〃 〃
1.2	176.76	15,270.0	〃 〃 31	97.26	8,400.0	'79 MAR.15

CORPORACION DOMINICANA DE ELECTRICIDAD

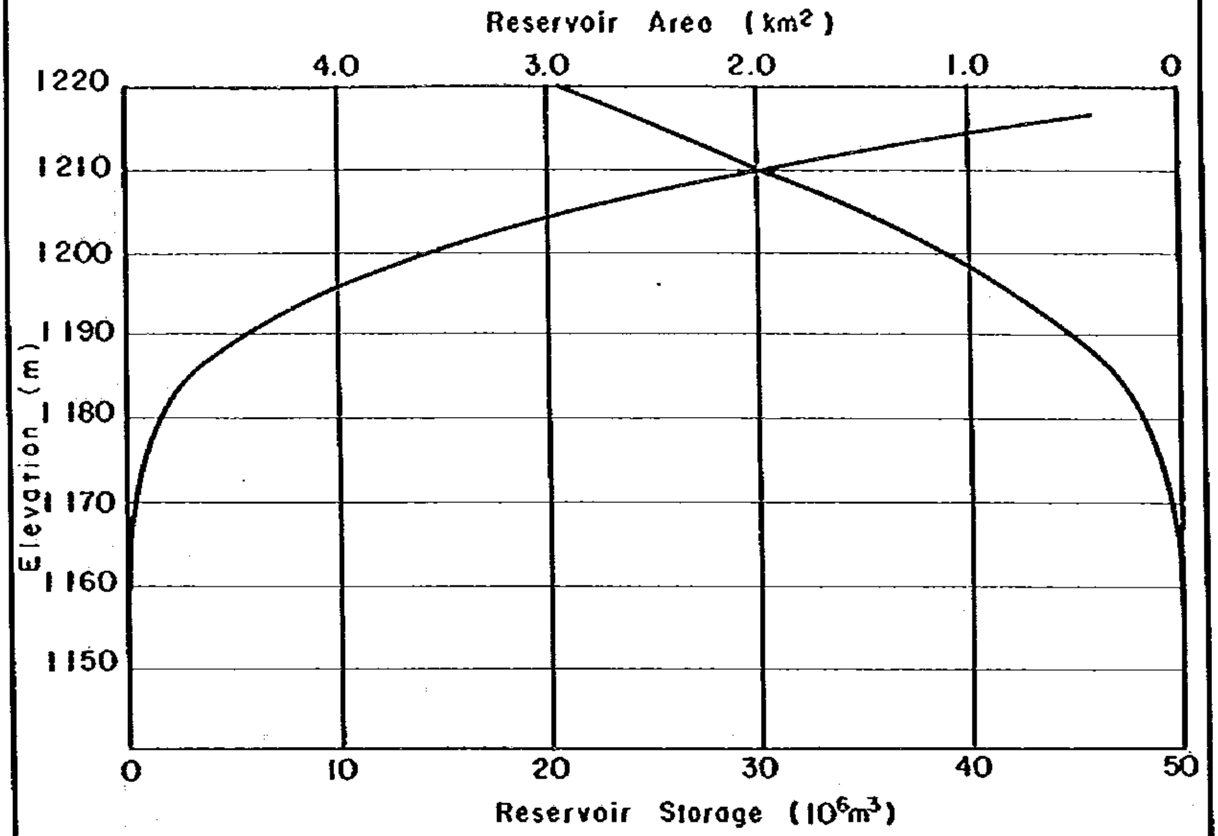
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX

COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS

JAPAN INTERNATIONAL COOPERATION AGENCY

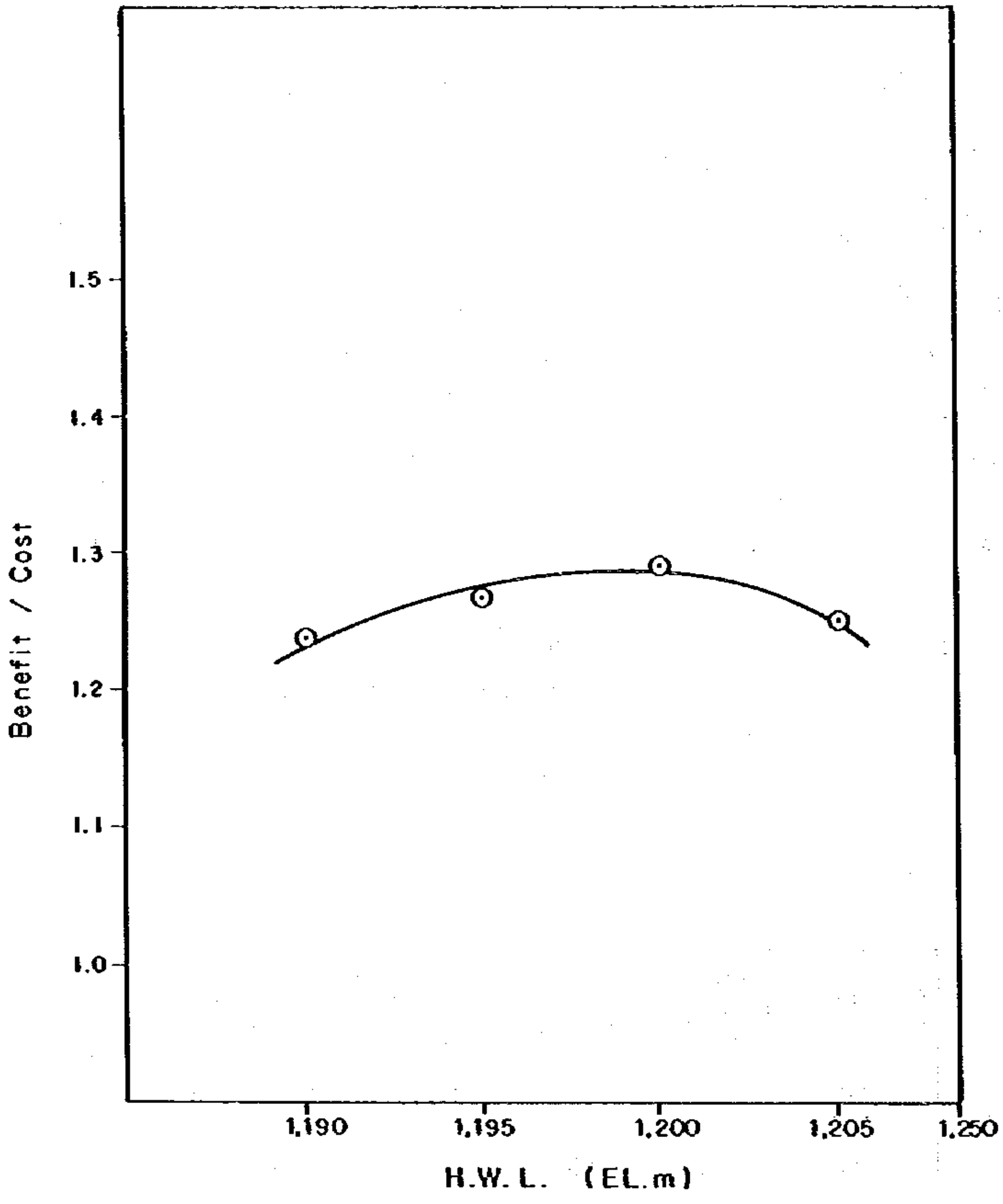
Fig. 04

Reservoir Capacity for Various Draft Values at Pinalato

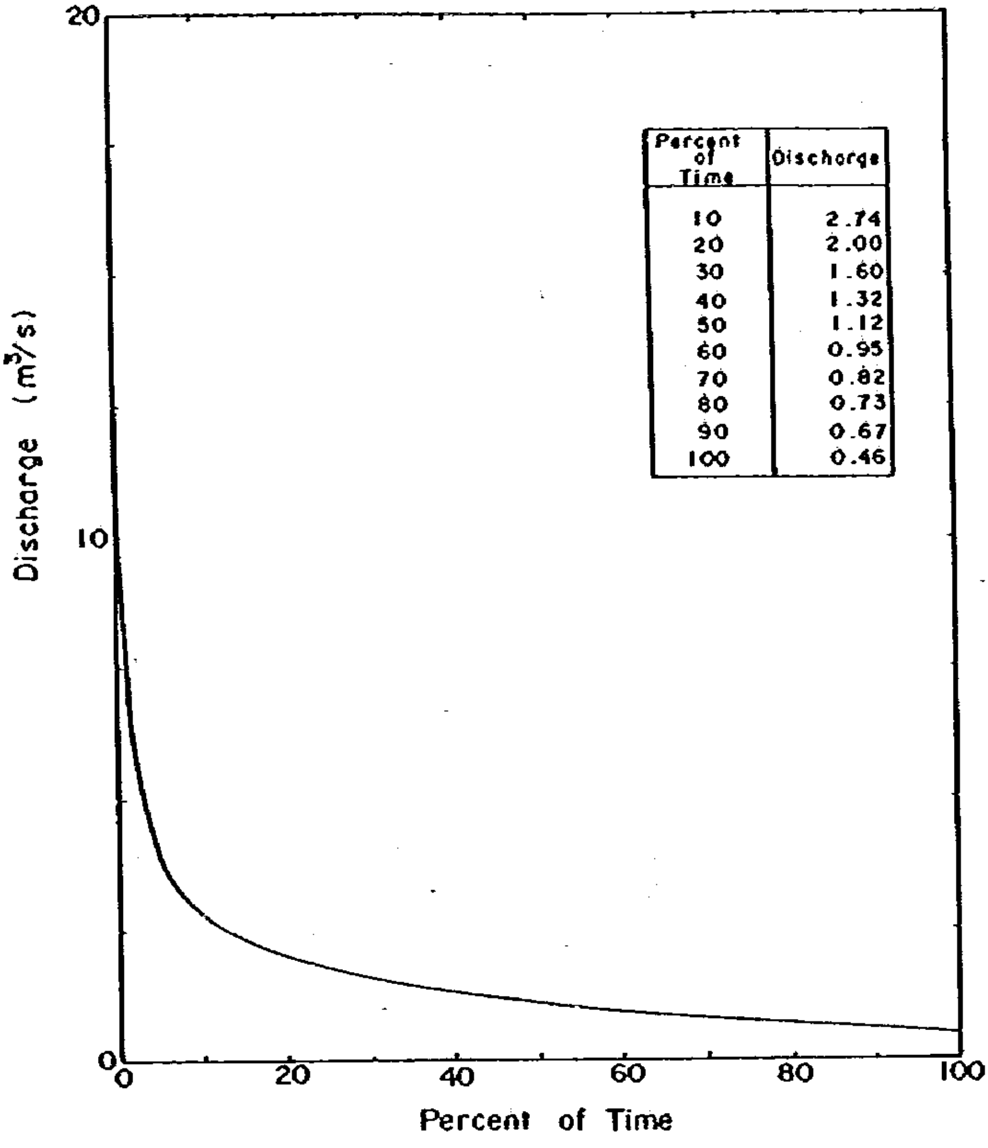


Elevation (m)	Reservoir Storage (10^6m^3)	Reservoir Area (km^2)	Elevation (m)	Reservoir Storage (10^6m^3)	Reservoir Area (km^2)
1150	0	0	1200	14.1	1.10
1160	0.035	0.007	1220	54.6	2.95
1180	1.61	0.15			

CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Storage Volume of Pinolito dam
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	05	
JAPAN INTERNATIONAL COOPERATION AGENCY		



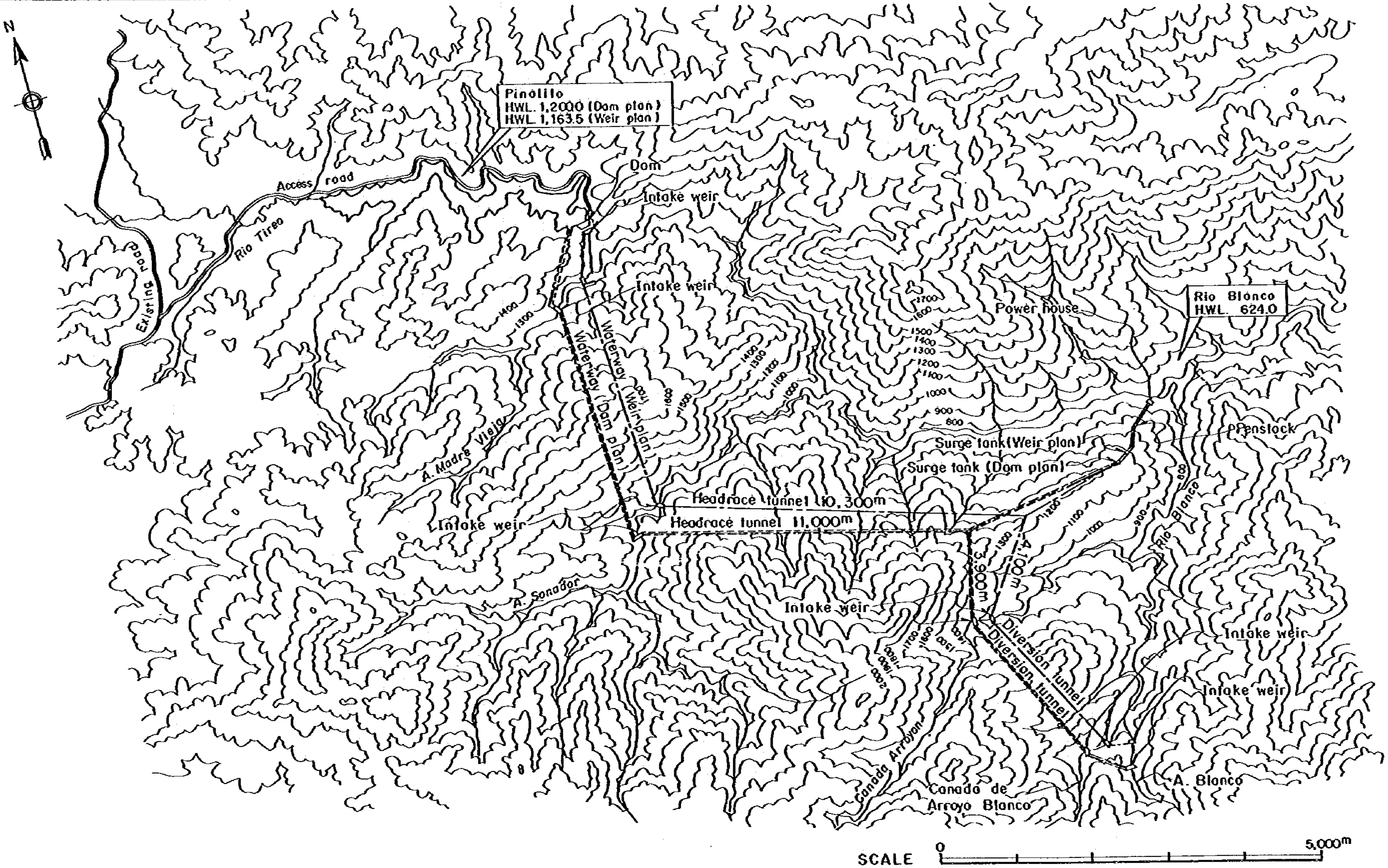
CORPORACIÓN DOMINICANA DE ELECTRICIDAD	Fig.	Economic Comparison of Alternatives for Pinalito Dam Scheme
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	06	
JAPAN INTERNATIONAL COOPERATION AGENCY		



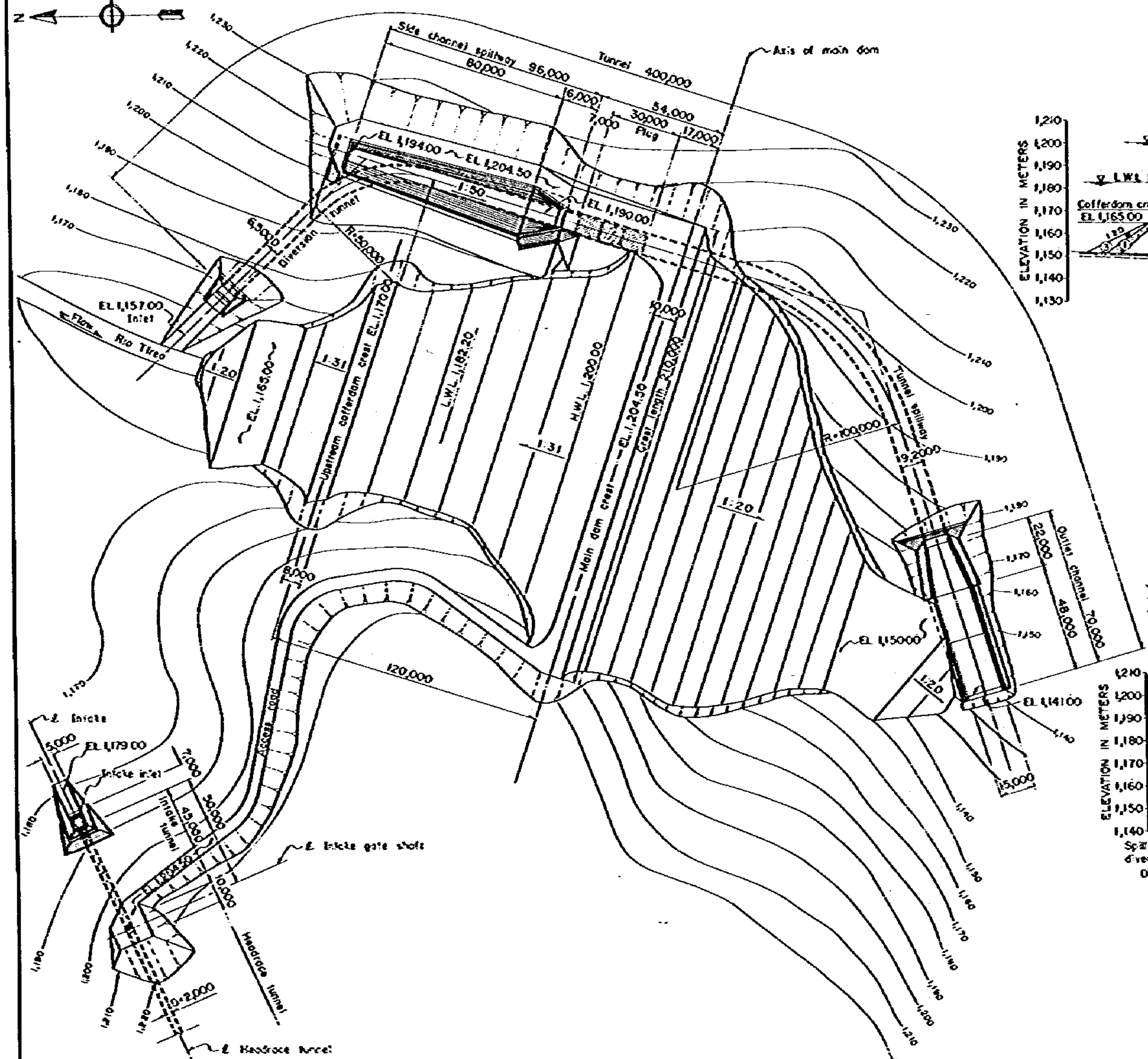
Percent of Time	Discharge
10	2.74
20	2.00
30	1.60
40	1.32
50	1.12
60	0.95
70	0.82
80	0.73
90	0.67
100	0.46

CORPORACION DOMINICANA DE ELECTRICIDAD	Fig.	Discharge Duration Curve at Pinalito
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	07	
JAPAN INTERNATIONAL COOPERATION AGENCY		

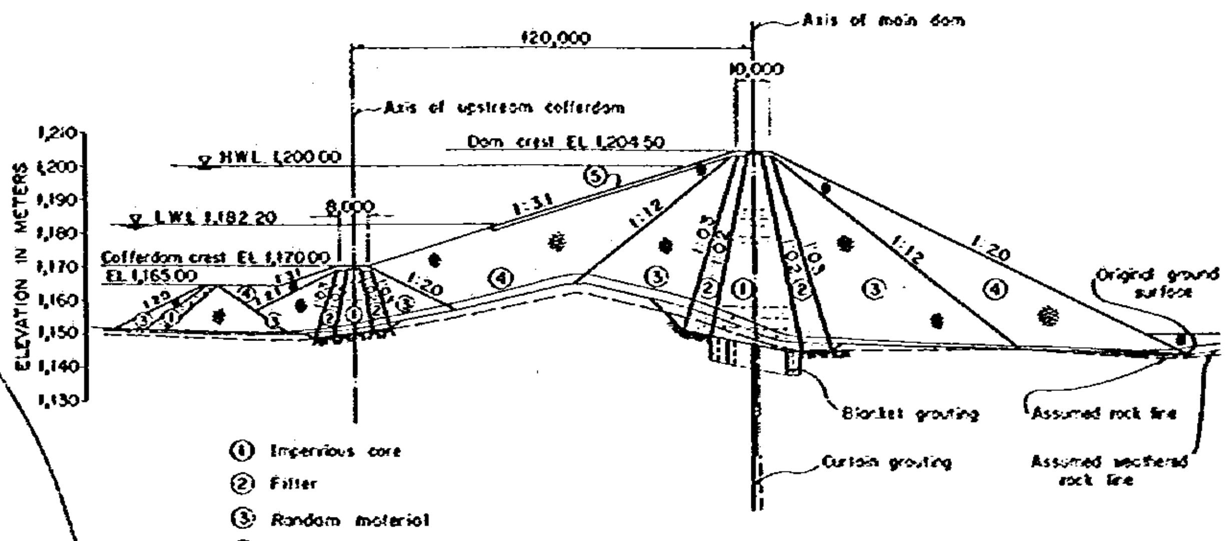
DRAWINGS



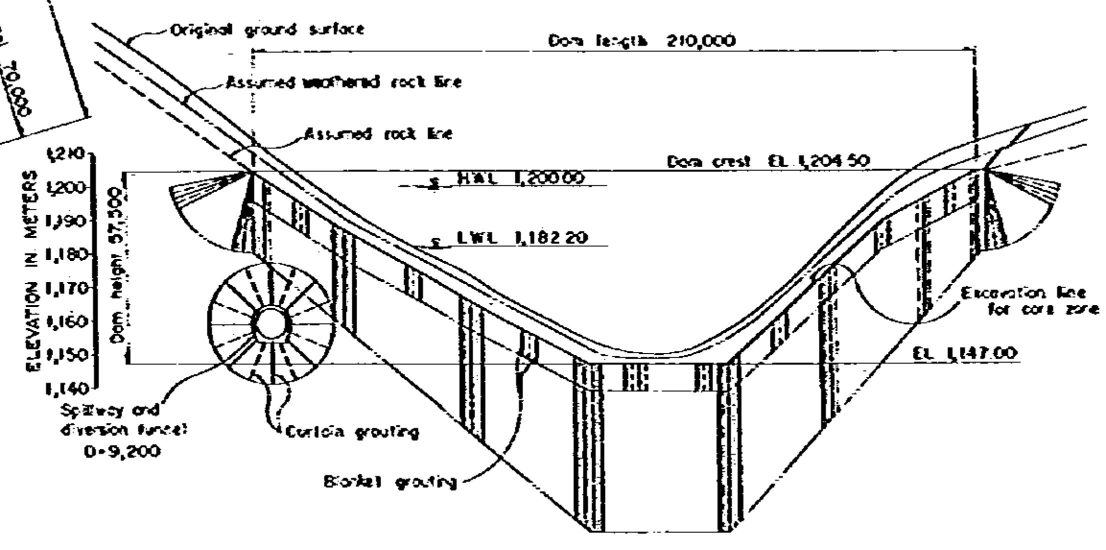
CORPORACION DOMINICANA DE ELECTRICIDAD	DWG	Pinalito General Layout
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	01	
JAPAN INTERNATIONAL COOPERATION AGENCY		



PLAN



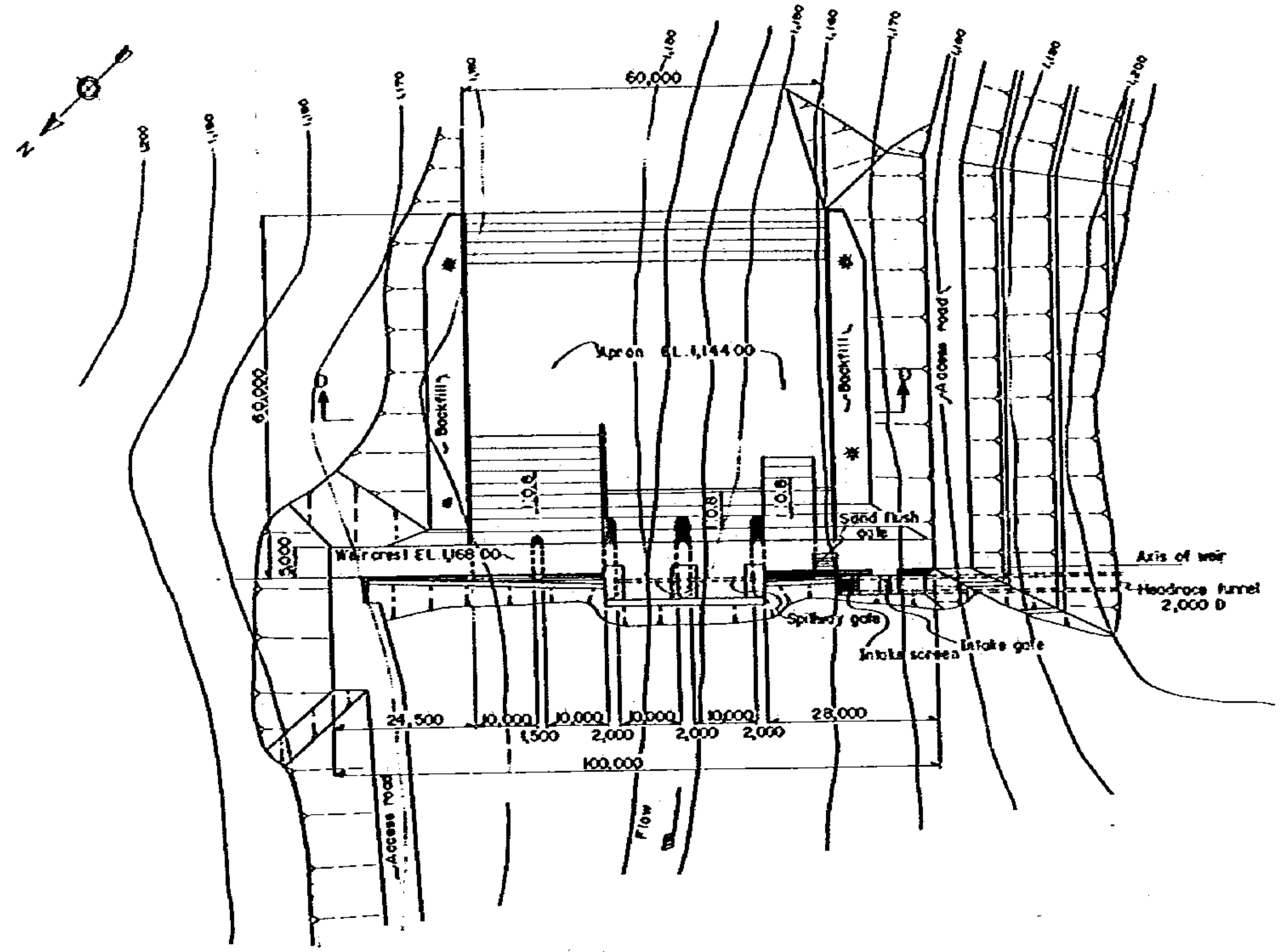
TYPICAL SECTION



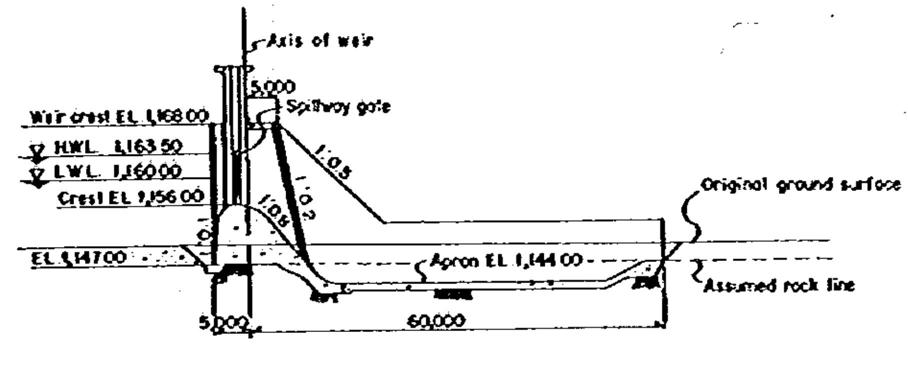
PROFILE

SCALE 0 100m

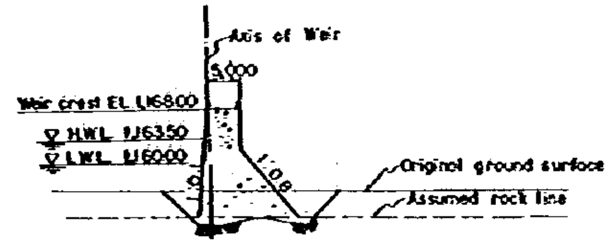
CORPORACION DOMINICANA DE ELECTRICIDAD	DWG	Pinalito Dam Scheme
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	0 2	
JAPAN INTERNATIONAL COOPERATION AGENCY		



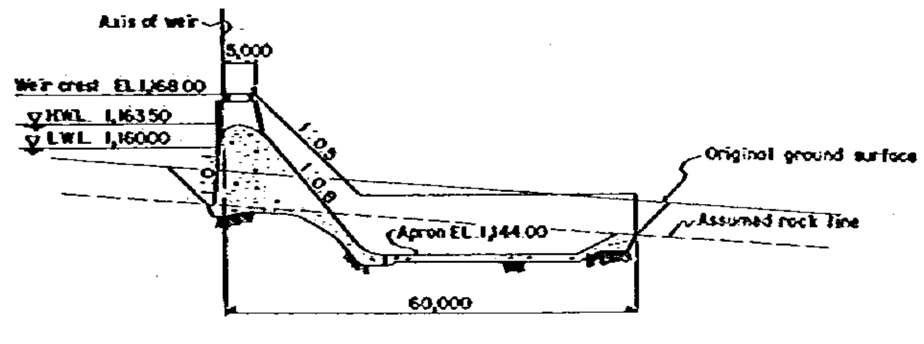
PLAN



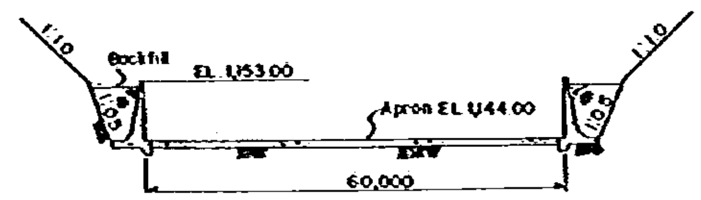
SECTION A-A



SECTION B-B



SECTION C-C



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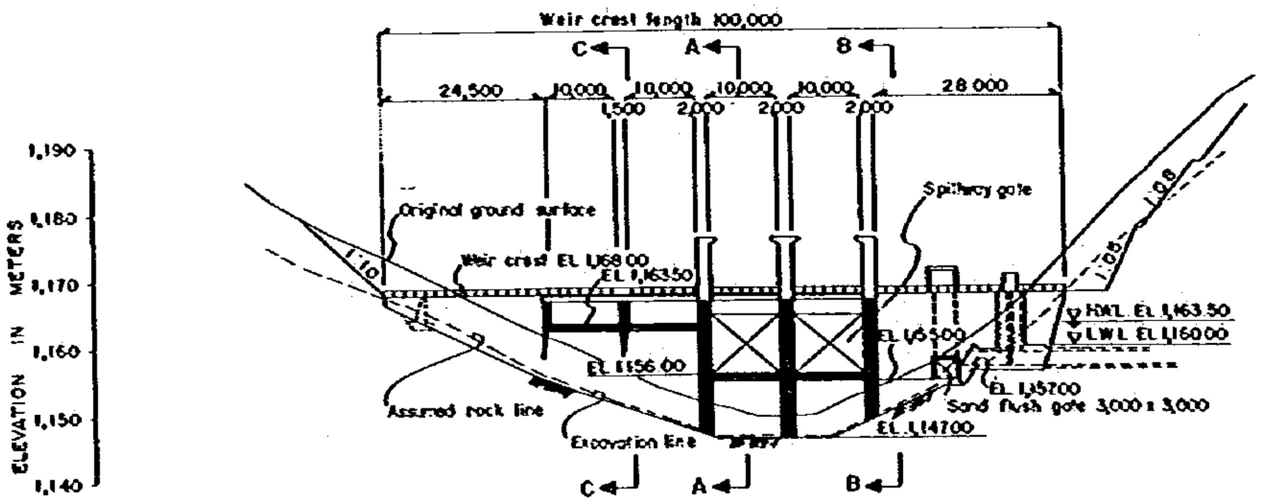
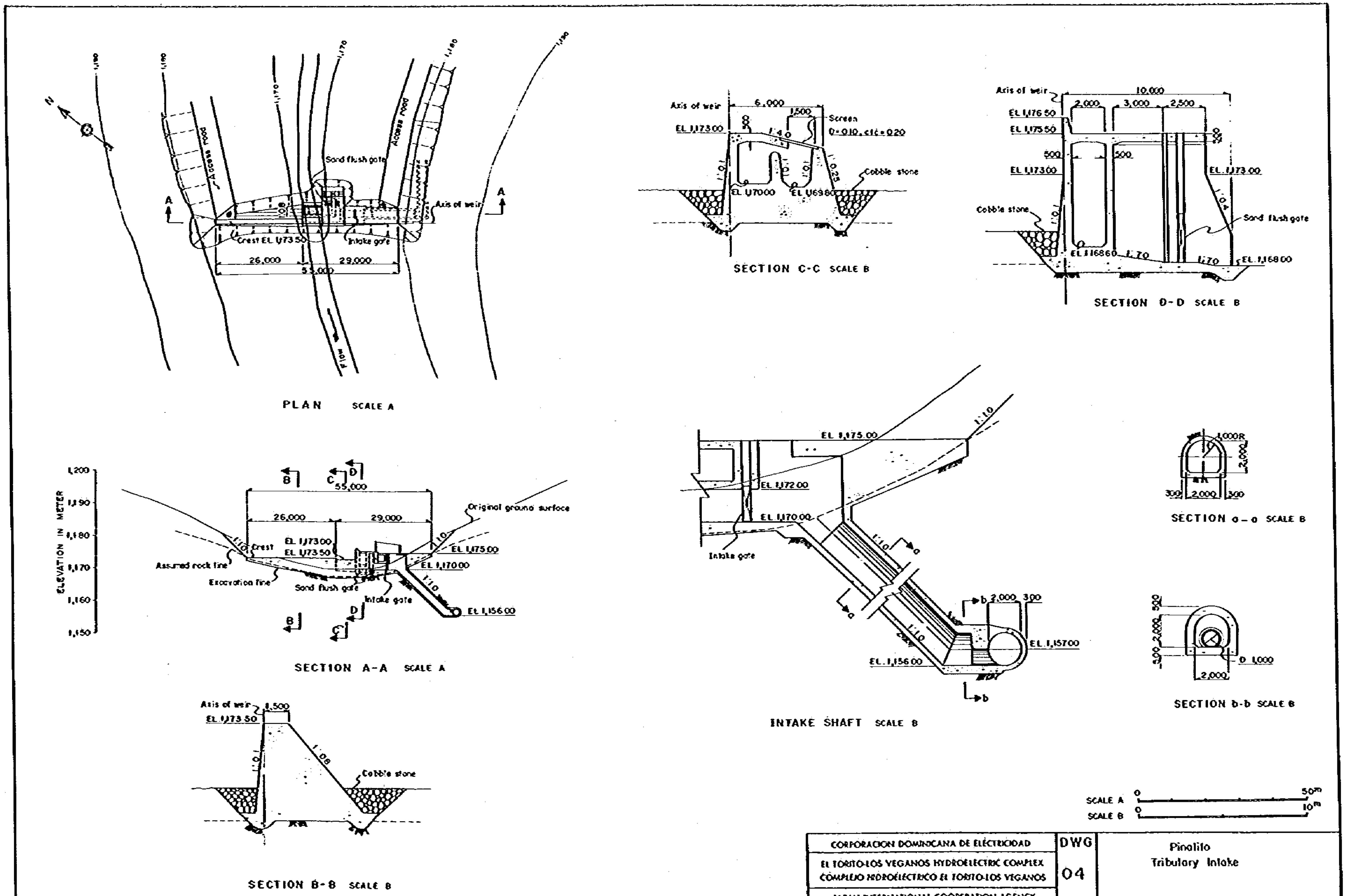


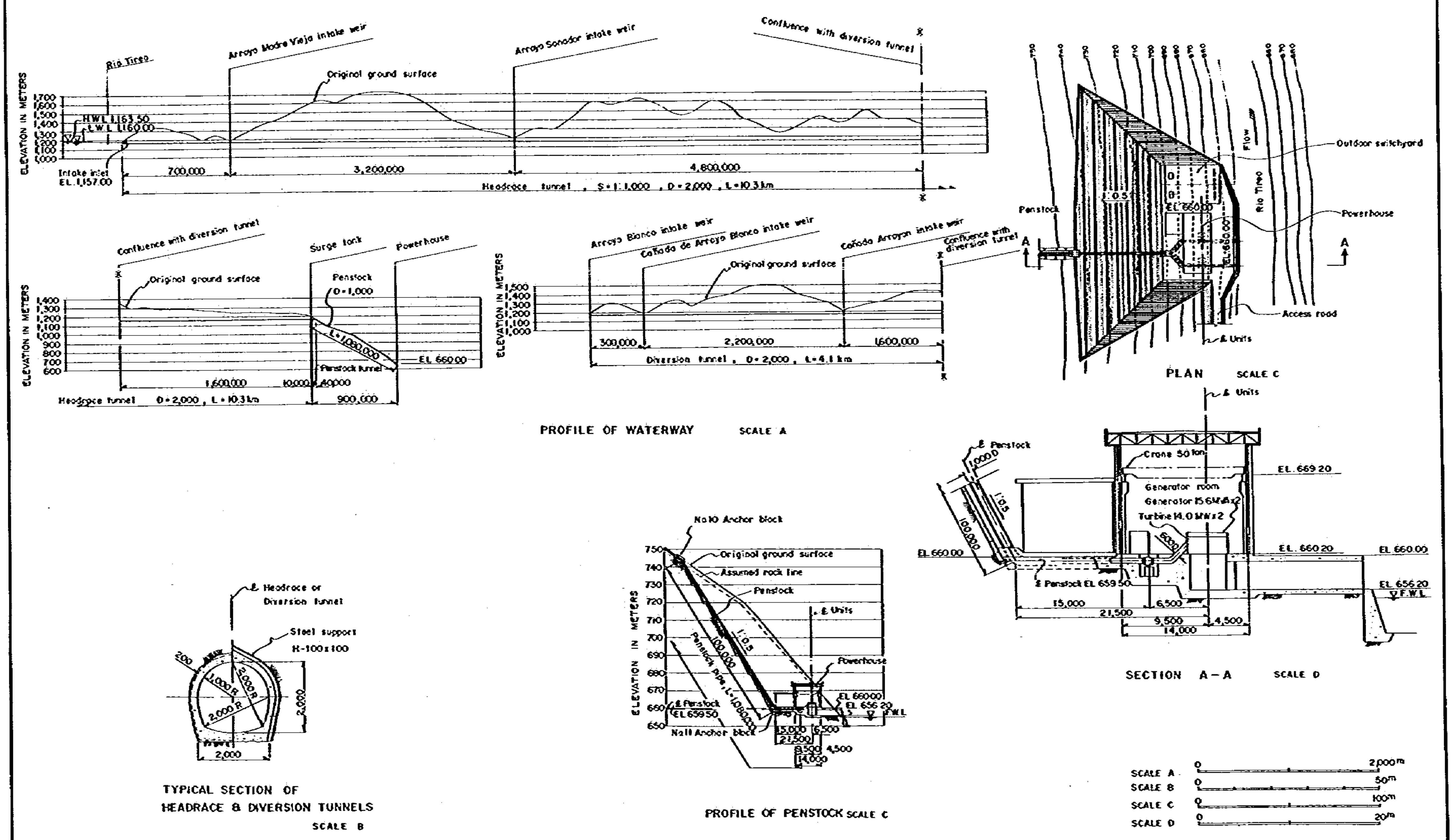
UPSTREAM ELEVATION

SCALE 0 — 50m

CORPORACION DOMINICANA DE ELECTRICIDAD	DWG	Pinalito Weir Scheme
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	03	
JAPAN INTERNATIONAL COOPERATION AGENCY		



CORPORACION DOMINICANA DE ELECTRICIDAD	DWG	Pinalito Tributary Intake
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO-LOS VEGANOS	04	
JAPAN INTERNATIONAL COOPERATION AGENCY		



CORPORACIÓN DOMINICANA DE ELECTRICIDAD	DWG	Pinalito Powerstation
EL TORITO-LOS VEGANOS HYDROELECTRIC COMPLEX COMPLEJO HIDROELECTRICO EL TORITO LOS VEGANOS	05	
JAPAN INTERNATIONAL COOPERATION AGENCY		