CHAPTER 5 GEOLOGY AND MATERIALS

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5.1 Introduction

This is the geological study for the feasibility of the Chespi hydroelectric power development project mentioned in Chapter 1 and was carried out from 1985 to 1986.

The preliminary geological study such as the photogeological interpretations and surface geological reconnaissances have been made by INECEL in 1984 concerning this Project, and the results have been complied as "Informe Geologico del Hidroelectrico Chespi".

In this Feasibility Study, photogeological interpretations, surface geological reconnaissances, seismic prospecting, and exploratory drilling were newly performed from the regulating pond area to the powerhouse site with the JICA Survey Team and INECEL cooperating in the work. The geological study in this Report is based on the results of these investigations.

5.2 Geological Investigation Works

The geological investigations carried out in this project area mainly consisted of photogeological interpretations, surface geological survey, seismic prospecting, and exploratory drilling.

Seismic prospecting was done with cooperation between the JICA Survey Team and INECEL, while with regard to exploratory drilling, a contract was directly signed between the Survey Team and a local drilling contractor, with the work done under the supervision of Survey Team and INECEL engineers.

Mapa Geologico del Ecuador, Escala 1:100,000, "Otavalo," "Pacto," and Escala 1:50,000, "El Quinche," (by *Direccion General de Geologia* y Minas, 1980) were referred to for the geology of the whole catchment area.

The investigation methods and quantities in the Study were the following:

o Photogeological interpretation

Interpreted area: Regulating pond, headrace route, dam site,
powerhouse site, approximately 30 km^2

Scale of photograph; 1:22,000

o Surface geological survey

Surveyed area: Regulating pond, headrace route, dam, powerhouse
site surroundings

Scale of topographical map: 1:5,000 (aerial survey map: regulating
pond, headrace route)
1:1,000 (aerial survey map: dam, regulating pond
downstream area, surge tank, penstock, powerhouse)

o Seismic prospecting

Prospected area and quantity: Regulating pond downstream area
5 prospecting lines, 975 m
Surge tank, penstock, powerhouse site, -----
5 prospecting lines, 1,435 m

o Drilling (including permeability test)

Investigated area and Quantity: Dam site, ---- 2 drillholes, 175 m
Surge tank, penstock, powerhouse site, ---- 3 drillholes, 195 m

5.3 Regional Geology

5.3.1 General Geology of Ecuador

Ecuador may be divided topographically and geologically into the three zones described below. These are a western coastal zone (La Costa) which has few mountains and is flat, a mountainous zone (La Sierra) where the elevation averages 4,000 m on top of which there are active and inactive volcanoes distributed, and an eastern zone (El Oriente) which is connected with the great Amazon Plain.

Of these, La Sierra has two parallel Andes Mountain chains which extend north-south to north-northeast - south-southwest and the other the Eastern Mountain Range (Cordillera Oriental) and an inter-Andean plain (Altiplano) of width from 30 to 40 km between these two parallel mountain chains.

Of these two parallel mountain chains, one is called the Western Mountain Range (Cordillera Occidental) and the other the Eastern Mountain Range (Cordillera Oriental).

The Cordillera Occidental has distributions of Jurassic to Cretaceous systems consisting of volcanic rocks presenting a green color on having been subjected to a slight degree of alteration, pyroclastic materials, and sedimentary rocks, while the Cordillera Oriental has distributions mainly of metamorphic rocks consisting of crystalline schists and gneisses. As for the Altiplano, most of it is made up of Quaternary systems related to volcanic activity.

The site of this Project is located in the Cordillera Occidental.

5.3.2 Topography and Geology of Project Area

a) Topography

The Guayllabamba river springs from the vicinity of Mt. Illiniza (EL. 5,263 m) in the Cordillera Occidental approximately 60 km south of Quito and flows north through the Altiplano. The river changes its course to west-northwest from the vicinity of the project site located approximately 30 km north of Quito, merges with the Blanco river flowing north through the La Costa approximately 100 km downstream from the project site to become the Esmeraldas river. The Esmeraldas river flows north further for approximately 70 km from the confluence to discharge into the Pacific Ocean.

The project area is situated on the midstream to upstream part of the Guayllabamba river (river-bed elevation 1,100 - 1,400 m), and the topographical features of the area differ greatly between the western (downstream) side and the eastern (upstream) side from the vicinity of the regulating pond. That is, the western side of the regulating pond presents a rugged, mature topography of elevation 2,000 to 3,000 m formed by erosion of Mesozoic basement rocks (volcanic rock and sedimentary rock). On the other hand, at the eastern side of the regulating pond, there is a wide distribution of Quaternary volcanic products which are eroded to form repetitions of vertical cliffs and flat areas, the topography as a whole being of slightly gentle relief.

b) Geology

The surroundings of the project area, as shown in Dwg. 5-1, consist mainly of Mesozoic Cretaceous system and Quaternary volcanic products. The Cretaceous systems consist of volcanic rocks, pyroclastic rocks, and sedimentary rocks, and are distributed to the west of the regulating pond area. They trend north-south to north-northeast-south-southwest.

The volcanic products of the Quaternary Period are mainly ejecta from the Mojanda and Pululahua volcanoes and are widely distributed to the east of the regulating pond area. The project area from the regulating pond to the powerhouse site where civil structures are to be located, is composed of the Mesozoic Cretaceous Macuchi Formation, Perlabi Formation, Silante Formation, and Yunguilla Formation, and Quaternary Lahar deposit, pyroclastic material, and talus deposit which overlie Cretaceous rocks.

The stratigraphy in this project area is shown in Table 5-3.

i) Distribution and rock type of each formation

- Macuchi formation (K_M)

The Macuchi Formation is distributed from approximately 500 m upstream of the dam site to approximately 2 km downstream, and includes the dam site along the Guayllabamba river. Other than the dam site, a part of the headrace tunnel will be located in this formation. This formation is composed mainly of andesite, tuff, agglomerate, shale, and calcareous sandstone. Generally it strikes N5° - 30°E and dips 60° - 90°W.

- Perlabi formation (K_P)

The Perlabi Formation is handled as a part of the Macuchi Formation according to the officially published geological map, "Mapa Geologico del Ecuador, Escala 1:100,000, 'Otavalo,'" but it will be handled as a separate formation in this Report.

This formation is distributed widely at the eastern (upstream) side of the Macuchi Formation distribution area. The greater part of the regulating pond will be located in this Perlabi Formation.

This formation mainly consists of phyllite, tuff and shale, the strikes and dips of which are N5° - 30°E, 62°W - 80°E, roughly the same as the Macuchi Formation.

- Silante formation (K_S)

The Silante Formation is distributed at the Western side of a point approximately 1 km east of the powerhouse site. The surge tank, penstock, and powerhouse sites will be located in the Silante Formation.

This formation consists of tuffaceous conglomerate, coarse-grained tuff, sandy tuff, and tuffaceous mudstone. It strikes N10° - 25°E and dips 65° - 80°E.

. Yunguilla formation (K_Y)

The Yunguilla Formation is distributed from the vicinity of the Jondanga river to approximately 1 km east of the projected powerhouse site. The greater part of the headrace tunnel will pass through this formation.

This formation consists of sandstone (partially calcareous), shale, and chert. It strikes N15° - 30°E and dips 40° - 90°E.

. Lahar deposit (Lh)

The Lahar deposit is a volcanic mudflow along the Guayllabamba river. It is distributed at the slopes on both banks of the river below El. 1,500 to 1,600 m, and much of it comprises vertical cliffs made by the erosion action of the Guayllabamba river.

This deposit, as is clear from the fact that its origin was a volcanic mudflow, is governed with respect to its layer thickness and distribution form by the original topography of the basement rocks (Macuchi Formation, Perlabi Formation, Yunguilla Formation), and there is much variation. As a general trend, however, the quantity distributed is large at the upstream part of the Guayllabamba river and small at the downstream part. This deposit is distributed in comparatively large quantity in the vicinity of the regulating pond area of the Project, while there is none at the powerhouse site.

. Pyroclastic material (Py)

Pyroclastic material consists mainly of pumice and volcanic ash, is distributed on slopes along the Guayllabamba river at El. 1,500 to 1,600 m and higher, and often forms flat plane.

This deposit is found frequently in the project area and shows a trend of being thickly deposited in the Vicinity of the regulating pond area and thinly along slopes at the powerhouse site.

ii) Geological structure

The Perlabi, Macuchi, Silante, and Yunguilla formations distributed in the project area all show strikes of north-northeast-south-southwest, and although there is some minor folding locally, as a whole the Silante and Yunguilla formations dip steeply to the east, and the Perlabi and Macuchi formations to the west.

The Macuchi and Perlabi formations and the Yunguilla and Silante formations are respectively distributed in conformity, whereas the Yunguilla and Macuchi formations contact each other by a fault in the north-south direction estimated along the Jondanga river.

Faults and folding observed in and around the project area, and lineaments interpreted from aerial photographs are predominant in the north-south direction parallel to the strikes of the basement rock formations.

5.4 Geology at Various Structures Sites

5.4.1 Regulating Pond

a) Topography

The regulating pond will have a slender shape extending in the east-west direction.

The length will be 2,500 m, the valley width at high water level (El. 1,448 m) will be 30 to 150 m (mostly less than 100 m), and the total storage capacity will be 3,367 x 10^3 m^3.

The downstream part of the regulating pond comprises a steep V-shaped valley. On the other hand, the midstream and upstream parts of the regulating pond presents a topography where vertical cliffs and flat planes of Lahar deposit and pyroclastic material formed by erosion of Guayllabamba river exist in the form of numerous steps, which as a whole make up a somewhat gently sloped valley.

b) Geology

i) Geology

The Mesozoic Cretaceous Macuchi and Perlabi formations and overlying Quaternary Lahar deposit, pyroclastic material, and talus deposit are distributed at the regulating pond and surroundings.

The Macuchi Formation distributed at this site is made up of more or less fresh andesite, tuff, and shale. This formation is distributed at the downstream part of the regulating pond from the dam axis to approximately 600 m upstream.

The Perlabi Formation consists of more or less fresh phyllite, tuff, and shale, and is widely distributed at the midstream and upstream parts of the regulating pond.

The two formations mentioned above strike N5° - N10°E and dip 78°E - 82°W, roughly perpendicular to the Guayllabamba river and steeply dipping to the downstream or upstream side.

Lahar deposit is widely distributed at both banks of the upstream part of the regulating pond and the left-bank side of the midstream and downstream parts, while at the right-bank side of the midstream and downstream parts, it is generally distributed thinly along the slopes. These distribution patterns, as stated in 5.3.2), are governed by the original topography of the basement rock of the Macuchi and Perlabi formations, so that there is much variation.

The Lahar deposit is generally composed of a silty matrix and subangular to subrounded cobbles to boulders. The quantities of gravels average 40 to 50 percent. The greater part of the deposit is unstratified, but there are cases when the matrix is sandy and the material is well-stratified. This deposit is not very well-compacted where the matrix is sandy, but parts with silty matrix are firm.

The pyroclastic material overlies the Lahar deposit and is widely distributed at both banks of the upstream part of the regulating pond and the left-bank side of the midstream to downstream part. This deposit consists of pumice and volcanic ash, is grayish-white to light red in color, and is not compacted very well.

There are very small distributions of terrace deposit at the right bank of the upstream part of the regulating pond slightly above the planned high water level.

Talus deposit is scattered at midheights of slopes, and most are distributed at considerably higher than the planned high water level.

Prominent landslides and slope collapses are not seen in the surroundings of the regulating pond area.

ii) Results of seismic prospecting

In order to investigate the distribution form of Lahar deposit below high water level of the regulating pond, seismic prospectings (refraction method) were carried out on five prospecting lines, total length 975 m at the left bank 300 to 600 m upstream from the dam site and at the right bank 400 to 700 m upstream from the dam site.

The P-wave velocities obtained as a result of these seismic prospectings, as shown in Table 5-4, were 0.3 to 0.5 km/sec for overburden and talus deposit, 0.7 to 1.0 km/sec for Lahar deposit, 2.1 to 2.6 km/sec for weathered basement rock, and 3.6 to 4.4 km/sec for basement rock.

The thickness of Lahar deposit along these prospecting lines is about 15 m maximum at the left-bank side and about 20 m maximum at the right-bank side.

c) Geological engineering assessment

Judging by the geological condition of the ground surface and results of seismic prospectings, the following geological engineering assessments can be regarding this regulating pond.

i) Watertightness of regulating pond

Judging by the lithological characters of the Macuchi and Perlabi formations composing the basement of the regulating pond and the surrounding topography, it is considered that the watertightness of the regulating pond is amply guaranteed.

ii) Collapses inside regulating pond

It is considered that a possibility exists of a part of the Lahar deposit distributed in the regulating pond area collapsing after impoundment of water. However, it is judged that collapses will not affect the dam and regulating pond greatly for the reasons given below.

1 The places where the possibility exists of collapses of cliffs occuring when Lahar deposit becomes wet upon impoundment of water are the three listed below, where the Lahar deposit is distributed below the planned high water level.

- Upstream part of regulating pond in the vicinity of the Guayllabamba river and Perlabi river confluence

- Left bank 300 to 600 m upstream of dam site

- Right bank 400 to 700 m upstream of dam site

2 Of the three places above, at the one in the vicinity of the confluence of the Guayllabamba river and the Perlabi river at the upstream part of the regulating pond, the planned high water level will be approximately 3 m higher than the present river bed. This means that only the bottom part of the Lahar deposit cliff will be submerged slightly. The Lahar deposit is well-compacted as a whole, and it is thought there is little possibility of the cliff at this site collapsing.

3 On the other hand, at the left bank 300 to 600 m upstream from the dam axis and the right bank 400 to 700 m upstream, the cliffs of Lahar deposit approximately 40 m in height formed along the Guayllabamba river will be located completely under the planned high water level. When a Lahar deposit cliff is in a wet condition to its top, unlike the previously-mentioned upstream part of the regulating pond, it is thought there will be a possibility of collapse of the cliff occurring.

However, judging by the condition of the Lahar deposit eroded in stepped form that is seen at present, even if a collapse should occur, that collapse would be limited to the vicinity of where the planned high water level plane crosses with the Macuchi Formation comprising the basement rock, and it is estimated that parts higher up will form roughly vertical cliffs similarly to the present and become stable. Further, all of the collapse will not occur at the same time, but progress gradually from the bottom of the slope. This manner of collapsing and the final stabilized form of collapse described previously need to be studied further before final design carrying out investigative drilling and physical property tests to clarify the nature and physical characteristics of the Lahar deposits.

4 Regarding increase in sedimentation in the regulating pond due to collapsed debris from the Lahar deposit, it is thought this can be amply dealt with by providing a flushing capabililty at the dam itself.

5.4.2 Dam

a) Topography

The dam site is located in a steep V-shaped valley of river-bed width 13 m, and valley width at high water level elevation (El. 1,448 m) of 100 m.

The left bank of the dam is sloped approximately 55 deg from the river bed to about 10 m below the high water level elevation, and a slope of approximately 40 deg above. On the other hand, the right bank is sloped approximately 60 deg to the vicinity of the high water level and approximately 50 deg above.

Both banks at the dam site are slopes of relatively monotonous reliefs, but at the left-bank slopes upstream and downstream of the dam site there are flat planes here and there at elevations of 1,400 to 1,500 m.

Regarding gullies discharging into the Guayllabamba river in the vicinity of the dam site, there is only the Quebrada Nariguera Grande approximately 150 m downstream of the dam site running in from the rightbank side in a roughly north-south direction.

Prominent landslides and collapse topography are not seen in the surroundings of the dam site.

b) Geology

i) Basement rock

The dam foundation rock consists of andesite belonging to the Macuchi Formation. This andesite presents a gray to greenish-gray color, is more or less massive and hard, and is distributed from approximately 200 m downstream of the planned dam axis to approximately 300 m upstream. This andesite has been subjected to alteration such as chloritization, saussuritization, and zeolitization, but reduction in physical strength due to these alteration are not recognizable.

Rock is exposed continuously from the river bed to the vicinity of the high water level, and comparatively fresh bedrock is exposed at around the river bed due to the strong erosive action of the Guayllabamba river.

However, as can be seen from the results of exploratory drillholes D-1 and D-2, the basement rock is weathered along cracks to depth of 30 to 35 m at the middles of the slopes covered thinly by talus deposit.

Joints in the andesite are seen to have strikes and dips of N-S, 90°, N10° - 20°W 40° - 60°E, N60° - 70°E 60° - 90°N. Of these, the joints having strike and dip of N-S, 90°, N10° - 20°W 40° - 60°E roughly perpendicular to the dam axis are predominant, and at the left-bank slope at around El. 1,500 to 1,600 m, there are small cliffs in the directions of these joint planes. The intervals of the joint planes vary from several centimeters to about 2 m. There are no intercalated materials at these joint planes and the joints are more or less tight.

According to surface reconnaissances made so far, there is one fault at the place 30 to 40 m right of the right abutment of the dam with strike and dip of N14°W, 78°W parallel to the Guayllabamba river having a sheared zone 70 to 80 cm in width, but otherwise, it is thought prominent faults do not exist in the vicinity of the dam except that it is necessary to confirm by exploratory drilling whether faults exist along the river channel.

ii) Surface deposits at slopes

Lahar deposit and talus deposit which are unconsolidated but well-compacted are distributed as surface deposits. Talus deposit is thinly distributed at midheights of the slopes at both banks. The thickness is estimated to be 2 to 3 m.

iii) River deposits

The dam site is located in a steep V-shaped valley, with both banks of the flow channel directly comprising rock walls, and river deposits cannot be seen. The river deposits seen along the Guayllabamba river upstream and downstream of the dam site are distributed only in small areas at deep pools in the river, and it is estimated that the thickness of river deposits is fairly small at damsite where the river-bed width is narrow and the channel is straight.

However, further investigations will be needed to confirm the thickness of the river deposits before final design.

c) Geological engineering assessment

A gravity-type dam has been selected for this site mainly due to conditions of topography and design.

Judging by the geological condition of the ground surface and the results of exploratory drillings including permeability tests, the following geological engineering assessments may be made concerning this site considering a gravity dam.

1 It is judged that the andesite distributed at this site possesses enough load-bearing capacity as the foundation for

the concrete gravity dam of 60 m class height presently planned.

2 According to the results from the exploratory drillhole D-1, it is thought that the bedrock which can serve as a dam foundation can be obtained at the left-bank slope near high water level by excavation of approximately 5 m of the ground surface.

According to the results from the exploratory drillhole D-2, the foundation rock at midheight of the right abutment is cracky to a depth of about 20 m. However, since the intake structures will be located at the right-bank side, this cracky portion will be completely removed through excavation, and there will be little problem concerning load-bearing capacity of the right abutment of the dam.

3 According to the results of permeability tests performed at this site, the Lugeon values at both abutments of the dam are low, being Lu = 0.6 - 23.5 from the ground surface to a depth of 35 - 45 m, and Lu = 0 - 0.8 at deeper than 35 - 45 m. It is judged based on this that the required imperviousness can be amply obtained for the foundation rock through ordinary treatment by grouting.

However, as stated in b), "Geology," there is development of joints crossing perpendicularly with the dam axis and having vertical dips at this site, and a possibility exists that there are high permeable portions along these joints. Therefore, it will be necessary to perform inclined drilling to grasp the permeability properties of the foundation rock in detail.

4 Groundwater at the dam site is found at a depth of 34.0 m at Drillhole D-1 provided at the left bank and 31.95 m at Drillhole D-2 at the right bank, and it is estimated that the groundwater table rises at the right and left banks more or less in accordance with the topography.

5 In the vicinity of the right abutment, there will be a cut slope of a height of approximately 80 m during construction,

and according to the results of the exploratory drillhole D-2 in the vicinity, the bedrock at the right-bank slope has a large number of cracks close to the ground surface. Therefore, it will be necessary for thorough care to be exercised for stabilization of cut slopes during excavation.

5.4.3 Headrace

a) Topography

The route of the headrace tunnel comprises rugged mountain terrain as a whole. The first half of the headrace tunnel cuts more or less perpendicularly across three ridges extending north-south with their ridgelines at elevations of 2,000 to 2,500 m and gullies extending roughly in straight lines in between.

On the other hand, the latter half of the headrace tunnel will pass roughly parallel under a ridge of elevation from 1,800 to 2,400 m extending in the east-west direction.

The earth cover of the tunnel will be more than 400 m over at least 70 percent of the entire tunnel length and 1,050 m at maximum. The sections with cover of 100 m or less will be a total of about 300 m (4 percent of tunnel length) at the two ends of the tunnel. The cover from the intake to Quebrada Fucal de San Joaquin is slightly thin at 200 to 300 m.

b) Geology

The Macuchi Formation, Yunguilla Formation, and Silante Formation are distributed along the headrace tunnel in the order of mention.

The Macuchi Formation consists of andesite, tuff, and agglomerate, and is distributed from the vicinity of the intake to the vicinity of the Jondanga river.

The andesite and the agglomerate are more or less massive and hard. The tuff contains intercalated siliceous shale, and the thickness of individual beds are mostly 5 to 10 cm. Although this formation generally strikes N5° - 30°E, and dips 60° - 90°W, it strikes N10° - 30°E and dips 50° - 60°E around the Jondanga river. Therefore a synclinal structure having its axis in the north-south direction is estimated to exist.

The Yunguilla Formation consists of sandstone (partly calcareous sandstone), shale, and chert, and is distributed from the vicinity of the Jondanga river to approximately 1 km east of the powerhouse. The sandstone is more or less fresh and hard. Although calcareous sandstone exists in part, solution phenomena cannot be seen. The shale is gray to dark gray in color and has been subjected to shearing in a direction parallel to bedding planes near the boundaries with the Macuchi and Silante formations. The chert is bedded chert of thickness of individual beds 3 to 10 cm, and is estimated to be distributed in a thickness of approximately 500 m at roughly the middle of the tunnel route, but the detail distribution is unknown at present.

These rocks generally strike N15° - 30°E and dip 40° - 90°E.

The Silante Formation consists of tuffaceous conglomerate, coarse-grained tuff, sandy tuff, and tuffaceous mudstone, and is distributed in the vicinity of the end of the headrace tunnel. These rocks, with the exception of the tuffaceous mudstone, are generally hard although slightly cracky. This formation strikes N10° - 25°E and dips 65° - 84°E.

The only prominent fault confirmed along the headrace tunnel route is the one seen at Quebrada Guayllabamba. This fault has a strike and dip of N20°E, 72°W, and a cemented sheared zone of width 50 cm or more.

However, according to photogeological interpretations, the route of the headrace tunnel has five distinct lineaments in the north-south direction. Of these five, the lineament observed along the Jondanga river is thought to be a fault comprising the boundary between the Macuchi and Yunguilla formation judging by the geological structure of the surroundings.

The gullies allong the headrace tunnel route are seen to have abundant running water throughout the year in spite of their catchment areas being comparatively small.

c) Geological engineering assessment

Judging by the geological condition at the ground surface and the results of photogeological interpretations, the following geological engineering assessments can be made regarding the headrace tunnel route:

1 The Macuchi, Yunguilla, and Silante formations are distributed along the headrace tunnel route in order from the intake side and the proportions of the tunnel length made up by the respective formations are approximately 30, 55, and 15 percent.

2 Rocks thought to make tunnel excavation exceedingly difficult over long sections are not distributed at the headrace tunnel route. The greater part of tunnel excavation will be done roughly perpendicular to the bedding plane of the individual formations.

3 Faults with large-scale sheared zones have not been observed so far along the headrace tunnel route.

However, the fault estimated to exist along the Jondanga river comprises the boundary between the Macuchi and Yunguilla formations, it is expected there will be a cracky part accompanying the synclinal structure to the east of the fault, so that it will be necessary to carry out thorough investigations for the final design through geological reconnaissance, seismic prospecting and drilling.

4 The gullies along the tunnel route all have abundant running water up to parts of high elevation throughout the year and it is imagined that there is much groundwater in the entire mountain body. It will be necessary to carry out studies hereafter to obtain a grasp in somewhat more detail in connection with the tunnel regarding faults that can be paths for groundwater and to what degree loosening of rock exists.

In the event bedded chert is crushed inside a mountain body having a large quantity of groundwater as in this case, there is likelihood of collapsing of tunnels and outflow of crushed rock fragments occuring. Therefore, it is necessary for more detailed surface geological survey to be made hereafter to accurately grasp the distribution of bedded chert and the distribution and properties of faults in the surrounding area.

5.4.4 Surge Tank, Penstock, Powerhouse

a) Topography

This site is located at a slip-off slope spread out at the right-bank side of the bending Guayllabamba river and a ridge continuing from the slope.

The ridge at which the surge tank and penstock are to be located has a slope of approximately 40 deg and extends roughly in an east-west direction. A small gully running in an east-west direction is seen approximately 150 m to the downstream side of the ridgelinme, but gullies cannot be seen on the upstream side and there is a continuation of slope with little relief.

The powerhouse is to be located on a terrace spread out to a width of 40 to 50 m at the end of the abovementioned ridge. The relative height from the present river bed to the terrace surface is approximately 50 m, and presents a steep cliff.

b) Geology

i) Geology

Tuffs of the Silante Formation and overlying pyroclastic material, terrace deposit, and talus deposit are distributed at this area.

The tuffs of the Silante Formation consist mainly of coarse-grained tuff and sandy tuff which are mutually transitional, and have intercalations of tuffaceous conglomerate and tuffaceious mudstone beds several centimeters to several meters in width.

Coarse-grained tuff and sandy tuff are bluish-gray to greenish-gray in color, and are unbedded. These rocks are massive and hard where fresh, but cracks are slightly developed.

The tuffaceous conglomerate is pale bluish-gray in color and contains subangular to subrounded gravels 2 to 10 cm in diameter in the taffaceous matrix. The varieties of these gravels are chert, black shale, and volcanic rocks. This rock is generally unbedded and is hard where fresh, but weathered portions are fairly brittle.

The tuffaceous mudstone is reddish-brown in color, is brittle as a whole, and cracks are developed at very close spacings of 0.5 to 2 cm.

These tuffs of the Silante Formation strike N10° - 25°E and dip 65° - 80°E, perpendicular to the direction of the penstock and inclined steeply toward the mountain. The rocks are outcropped continuously at the slope approximately 100 m south of the penstock site, but at the ridge of the penstock route, they are covered by surface deposits of pyroclastic material and talus deposit.

Prominent joints in the Silante Formation strike N70° - 80°W and dip 80° - 90°S, crossing perpendicularly with the strike of the formation.

Pyroclastic material is distributed widely over the middle part of the slope at elevations of 1,200 to 1,400 m, and the thickness is more than 10 m at about 200 m to the north of the penstock route, and 3 to 4 m at the penstock route. This deposit is grayish-white to pale rose in color, consists of small gravels of pumice and volcanic ash, is unconsolidated and not very much compacted

Terrace deposit is distributed in a thickness of approximately 6 m in the vicinity of the powerhouse site. This deposit consists mainly of gravel and sand, and contains a slight amount of silt.

Talus deposit is distributed at the upper and lower parts of the penstock route slope. This deposit consists of the gravels several centimeters to several tens of centimeters in diameter, is unconsolidated and of low degree of compaction, and the thickness is from 2 to 4 m at the penstock route.

Prominent faults and landslides are not observable in this area.

ii) Seismic prospecting results

Seismic prospectings were performed in this area by the refraction method on five prospecting lines totalling 1,435 m in length to investigate the thickness of surface deposits and approximate nature of the basement rock.

The P-wave velocities obtained by this seismic prospectings, as shown in Table 5-4, are 0.3 to 0.45 km/sec for talus deposit and pyroclastic material, 0.6 to 1.1 km/sec for terrace deposit and strongly weathered basement rock, 1.4 to 2.4 km/sec for weathered basement rock, and 2.2 to 3.3 km/sec for basement rock.

According to these seismic prospecting results, the properties of the basement rock (Silante Formation) at the profile of the penstock can be summarized as follows:

- Strongly weathered basement rock is distributed above El. 1,250 m, and the thickness increases with increased height on the slope, being about 10 m in the vicinity of the surge tank site.

- Weathered basement rock is distributed from the bottom part to the top part of the slope, the thickness being greatest at the middle of the slope (vicinity of El. 1,300 m) and is approximately 23 m.

- The elastic wave velocity of the basement rock deeper inside than the weathered portion is from 3.0 to 3.1

km/sec from the lower to the middle part of the slope, but is slightly lower at 2.2 to 2.7 km/sec at the upper part of the slope.

c) Geological engineering assessment

Judging by the geological conditions at the ground surface and results of seismic prospecting and exploratory drilling, the following geological engineering assessments can be made regarding the surge tank, penstock, and powerhouse sites.

1 The greater part of the surge tank will be located in the basement rock consisting of tuffs having an elastic wave velocity of Vp = 2.7 km/sec, but according to the results from Drillhole S-1, the condition of this bedrock is cracky to the bottom of the drillhole. Therefore, in excavation for the surge tank, the stability of the shaft wall may be a problem.

   As for the cut slope of height about 50 m that will be produced behind the surge tank, it will be necessary for thorough attention to be paid to securing stability of the cut slope.

2 The foundations of penstock anchor blocks, will be located on tuffs of weathered basement rock of elastic wave velocities Vp = 1.6 to 1.8 km/sec, and overlying strongly weathered basement rock and pyroclastic material will be excavated and removed. The weathered basement rock, according to the results of the exploratory drillholes S-1 and P-1, is thought to have adequate bearing capacity as the foundation rock for anchor blocks of the penstock, but it will be necessary to grasp the properties of weathered bedrock in more detail.

   Further, judging from the directionalities of the bedding and joint planes of the basement rock, it is thought there is little possibility of sliding or collapsing of the basement rock occurring along the penstock route.

3 The vertical shaft portion of the penstock, judging by the results from the exploratory drillhole P-1, consists of basement rock of tuffs which are generally fresh and hard, and have few cracks and is thought not to pose any special problem.

4 The powerhouse will be constructed excavating the terrace plane of relative height approximately 50 m from the river bed of the Guayllabamba river down to the neighborhood of the river bed.

The basement rock of tuffs to be the foundation of the powerhouse, although slightly cracky, is thought to possess adequate bearing capacity as a foundation for the planned powerhouse.

The cut slope of height approximately 40 m to be produced behind the powerhouse will consist of slightly cracky basement rock, and it will be necessary to exercise care concerning stability of the slope.

5.4.5 Additional Geological Investigation Works for Detailed Design

It is thought necessary for the additional geological investigation works indicated in Table 5-2, Dwg. 5-4, and Dwg. 5-8 to be carried out on the main structure sites of this Project for the purpose of detailed design.

The quantities of additional geological investigation works as follows:

Dam Site

Drilling	4 drillholes	215 m
Adit	2 adits	70 m

Regulating Pond

Drilling	4 drillholes	135 m
Pit	2 pits	11 m

Penstock, Powerhouse Sites

Drilling	3 drillholes	115 m

5.5 Construction Materials

The construction materials required for this Project are mainly concrete aggregates needed for the dam, tunnel, and powerhouse.

There are no distributions of river deposits and terrace sand-gravel in the project area sufficient in quantity to supply the necessary aggregates, while most of the rocks from tunnel excavation will be shale and chert belonging to the Yunguilla Formation with highly developed bedding and it is thought they are not suitable as concrete aggregates. Accordingly, crushed stone obtained from quarries will be used as concrete aggregates.

As prospective sites for quarries, when transport roads are considered, there are the vicinity of a point at the right bank approximately 1.5 km downstream from the dam site where more or less massive and hard andesite is distributed, and the vicinity of a point approximately 600 m north of the powerhouse site where more or less massive and hard tuff is distributed.

However, andesites and tuffs may cause alkali-aggregate reaction depending on the type, and it will be necessary for alkali-aggregate reaction tests to be carried out. In case there is no fear of such reaction, it will then be necessary for tests to be carried out for the examination of the chemical and physical properties of these rocks.

Table 5-1 Completed Geological Investigation Works

Completed Drill Hole

Site	Hole No.	Coordinate		EL. (m)	Direction	Length (m)
Dam	D – 1	$15215.^{979}$N	$781819.^{674}$E	$1444.^{85}$	90°	85
	D – 2	$15231.^{654}$N	$781930.^{706}$E	$1450.^{18}$	90°	90
Surge tank	S – 1	$16314.^{125}$N	$774815.^{966}$E	$1471.^{27}$	90°	70
Penstock	P – 1	$16340.^{551}$N	$774466.^{949}$E	$1208.^{74}$	90°	65
Powerhouse	Ph–1	$16347.^{230}$N	$774373.^{498}$E	1189.11	90°	60
Total	5 Holes					370

Completed Seismic Prospecting

Site	No. of Line	No. of Spreads	No. of Receiving points	Length (m)
Regulating Pondage Area	A	3	70	345
	B	1	23	110
	C	1	22	105
	D	3	61	300
	E	1	23	115
Sub-Total	5 Lines			975
Powerhouse Area	A	6	121	600
	B	1	24	115
	C	3	61	300
	D	3	62	305
	E	1	24	115
Sub-Total	5 Lines			1435
Total	10 Lines			2410

Table 5–2 Additional Geological Investigation Works (proposed)

Site	Kind of work	No. of work	Coordinate		Direction	EL. (m)	Length (m)	Remarks
Dam	Drill Hole	D – 3	781852E	15204N	N60 E70°	1417	80	o Permeability Tests
		D – 4	781897E	15230N	S60W65°	1407	65	
		D – 5	781852E	15204N	S60W65°	1417	35	
		D – 6	781897E	15230N	N60 E65°	1407	35	
	Adit	T – 1	781841E	15198N		1436	30	o Plate bearing Tests
		T – 2	781897E	15230N		1407	40	
Regulating pondage	Drill Hole	RL – 1	782159E	14973N	90°	1458	30	o Standard Penetration Tests
		RL – 2	782215E	14985N	90°	1448	30	
		RR – 1	782401E	15042N	90°	1461	40	
		RR – 2	782343E	15062N	90°	1464	35	
	Pit	PT – 1	782171E	14994N		1448	5	o Sampling for slaking tests and triaxial compression tests
		PT – 2	782394E	15104N		1482	6	
Powerhouse and Penstock	Drill Hole	P – 2	774734E	16314N	90°	1398	30	
		P – 3	774583E	16329N	90°	1290	30	
		Ph – 2	774402E	16347N	90°	1189	55	
Total	Drill Hole	11 Holes					465	
	Adit	2 Adits					70	
	Pit	2 Pits					11	

Table 5–3 General Geologic Sequence of Chespi Project Area

Era	Period	Stratigraphic Unit	Lithology	Main distribution relating to the civil structures
Cenozoic	Quaternary	Talus depotit	Breccia, Silt	
		Terrace deposit	Gravel, Sand, Silt	Powerhouse, a part of regulating pondage
		Pyroclastics	Pebble of pumice and volcanic ash	Penstock
		Lahar deposit	Cobble to Boulder with Silty matrix	Regulating Pondage
Mesozoic	Cretaceous	Yunguilla formation	Sandstone, Calcareous sandstone, Shale, Chert	Great part of waterway
		Silante formation	Coarse tuff, Sandy tuff, Tuffaceous mudstone, Tuffaceous conglomerate	Surge tank, Penstock, Powerhouse and a part of waterway
		Macuchi formation	Andesite, Agglomerate, Tuff, Shale, Calcareous sandstone	Damsite and a part of waterway
		Perlabi formation	Phyllite, Tuff, Shale	Regulating pondage area

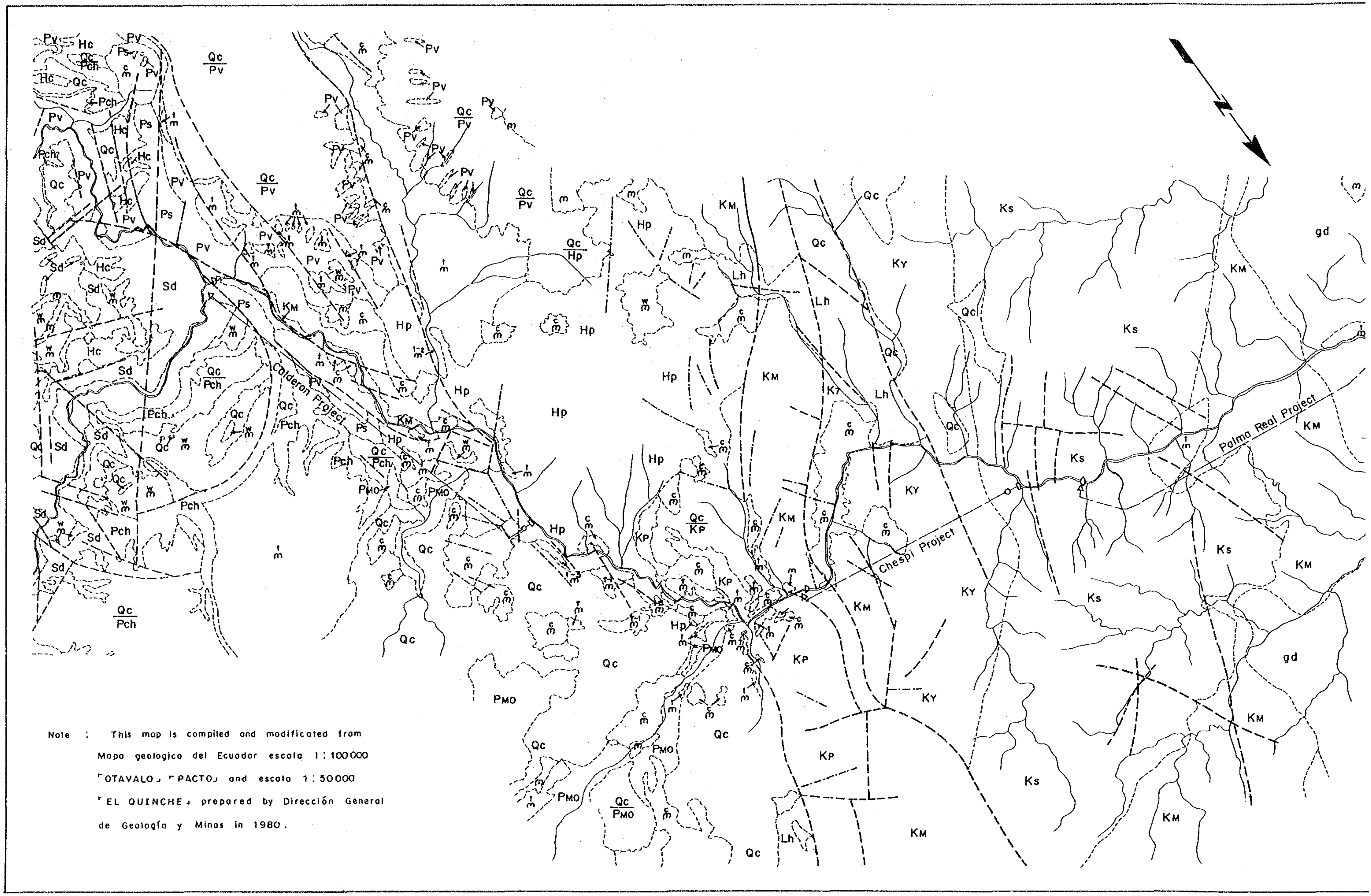
Table 5–4 P-Wave Velocity (in km/sec) of Each Prospecting Line

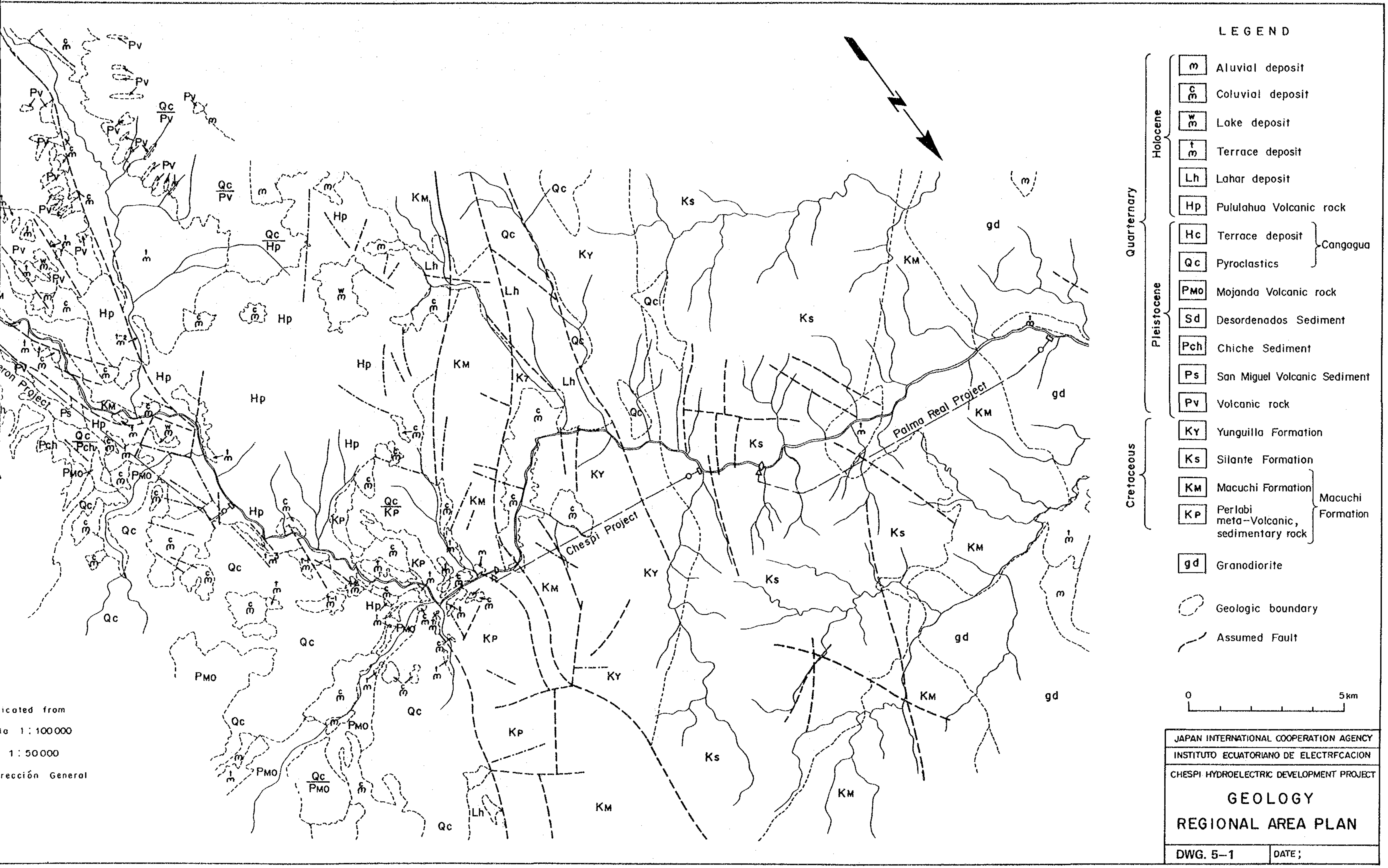
[Regulating Pondage Area]

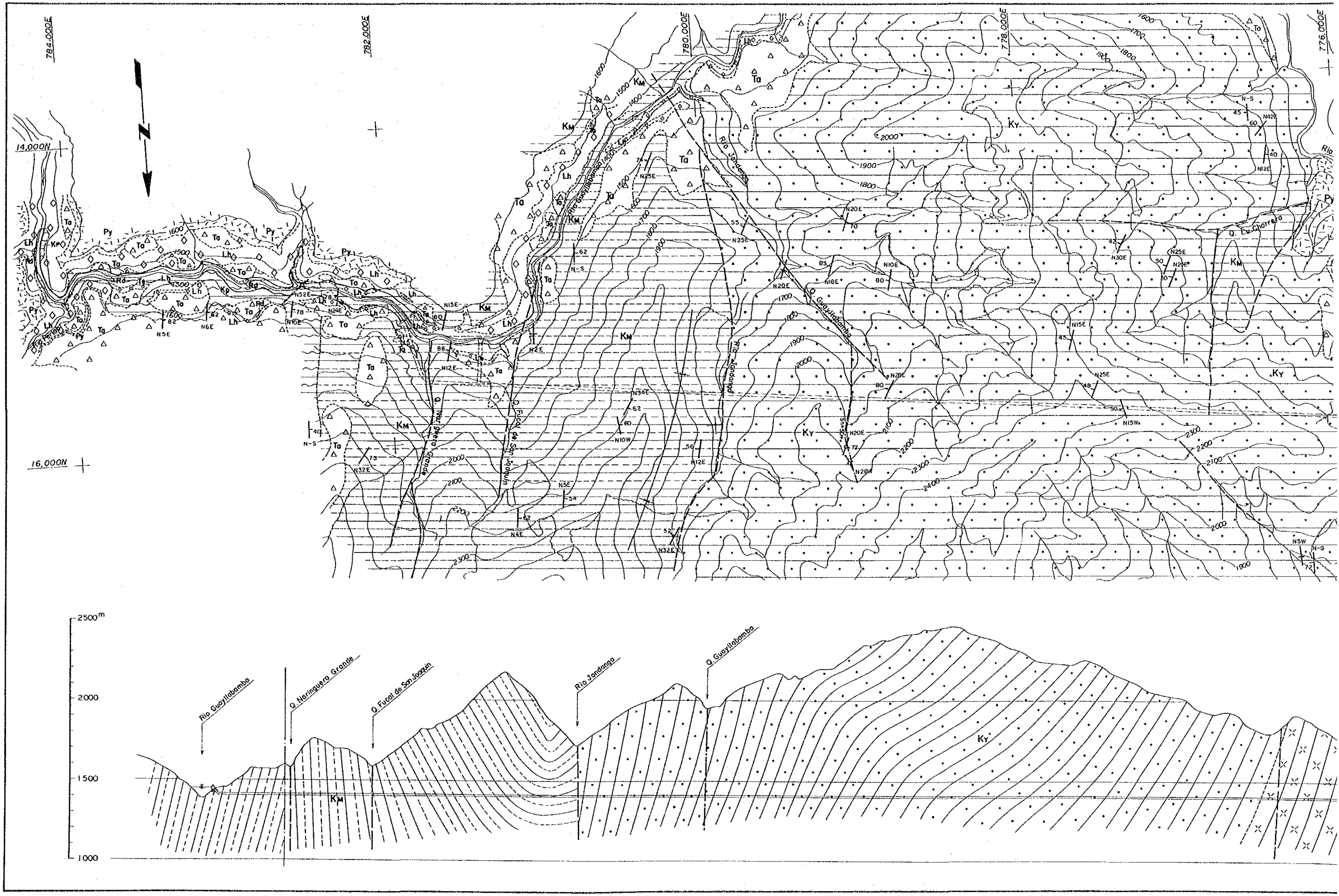
Layer \ Line	A	B	C	D	E	Geological Correspondence (assumed)
1st Layer	0.3 – 0.35	0.3 – 0.4	0.3 – 0.4	0.3 – 0.5	0.4 – 0.5	Topsoil and Talus deposit
2nd Layer	0.85 – 1.0	0.9 – 1.0	0.85	0.7 – 0.9	0.7 – 0.8	Lahar deposit
3rd Layer	2.5	2.5	2.5	2.1 – 2.6	2.3	Weathered bedrock
4th Layer	4.4	4.4	4.4	3.6 – 4.4	3.6	Bedrock

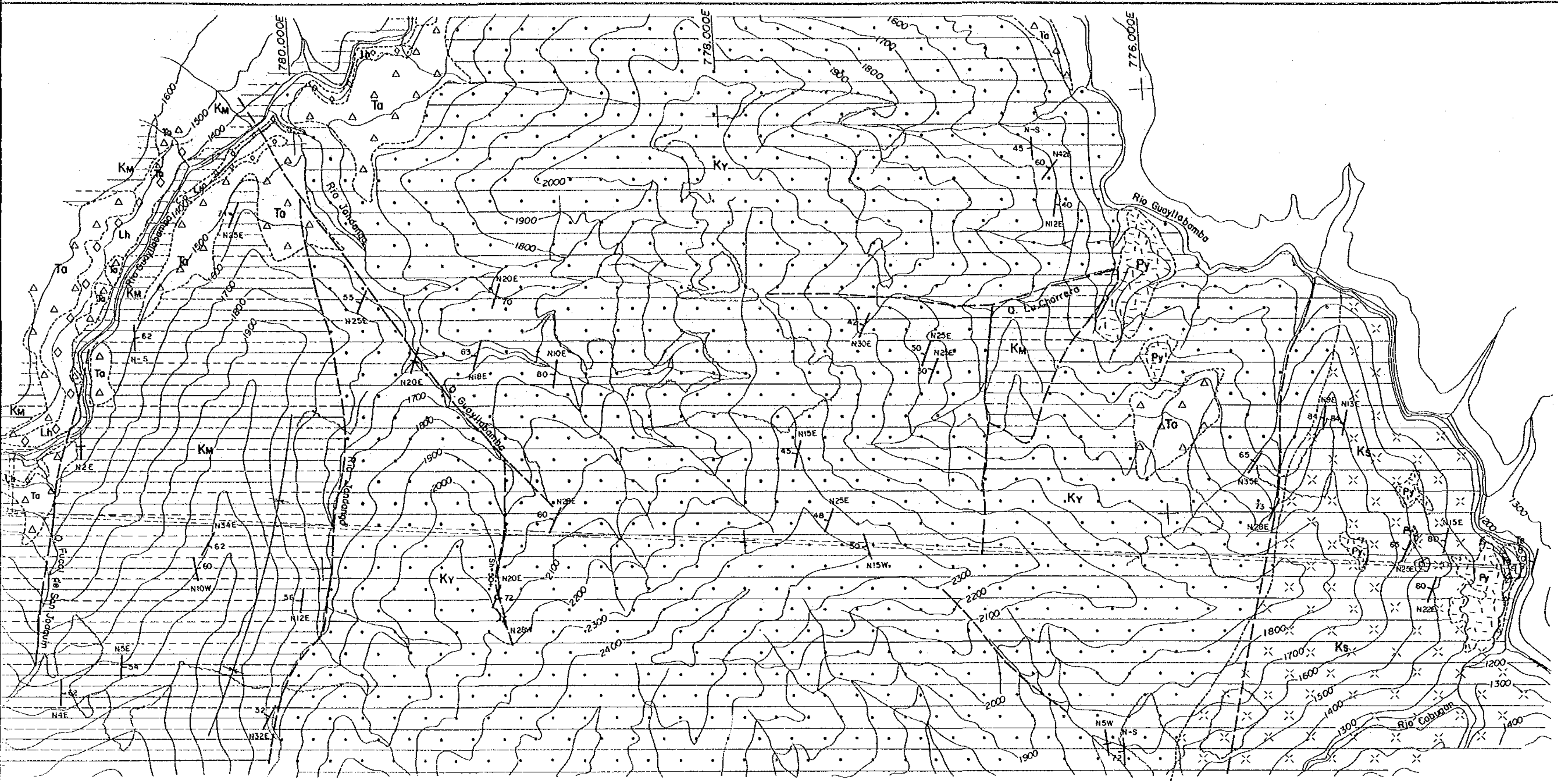
[Powerhouse Area]

Layer \ Line	A	B	C	D	E	Geological Correspondence (assumed)
1st Layer	0.3 – 0.45	0.4 – 0.45	0.3 – 0.35	0.3 – 0.35	0.3	Talus deposit and Pyroclastics
2nd Layer	0.8 – 1.1	0.9 – 1.0	0.6 – 0.8	1.0 – 1.2	0.85 – 1.1	Highly weathered bedrock and Terrace deposit
3rd Layer	1.6 – 1.8	1.6	1.4 – 1.6	1.6 – 2.4	—	Weathered bedrock
4th Layer	2.2 – 3.1	2.7	2.9 – 3.0	3.1 – 3.3	3.0	Bedrock


Calderon Project
Chespi Project
Palma Real Project
Note : This map is compiled and modificated from Mapa geologico del Ecuador escala 1 : 100000 「OTAVALO」「PACTO」 and escala 1 : 50000 「EL QUINCHE」 prepared by Dirección General de Geología y Minas in 1980.


LEGEND
Holocene
Quarternary
Pleistocene
Cretaceous
m Aluvial deposit
Coluvial deposit
Lake deposit
Terrace deposit
Lh Lahar deposit
Hp Pululahua Volcanic rock
Hc Terrace deposit
Qc Pyroclastics
Cangagua
PMO Mojanda Volcanic rock
Sd Desordenados Sediment
Pch Chiche Sediment
Ps San Miguel Volcanic Sediment
Pv Volcanic rock
KY Yunguilla Formation
Ks Silante Formation
KM Macuchi Formation
KP Perlabi meta-Volcanic, sedimentary rock
Macuchi Formation
gd Granodiorite
Geologic boundary
Assumed Fault
0
5km
Chespi Project
Palma Real Project
icated from
a 1 : 100000
1 : 50000
rección General
JAPAN INTERNATIONAL COOPERATION AGENCY
INSTITUTO ECUATORIANO DE ELECTRFCACION
CHESPI HYDROELECTRIC DEVELOPMENT PROJECT
GEOLOGY
REGIONAL AREA PLAN
DWG. 5-1
DATE ;


784,000E
782,000E
780,000E
778,000E
776,000E
14,000N
16,000N
N
Rio Guayllabamba
Rio Jondonga
Q. Guayllabamba
Q. Naringuero Grande
Q. Fucal de San Joaquin
Q. La Chorrera
Km
Ky
Ta
Py
Lh
Rd
Kp
2500m
2000
1500
1000



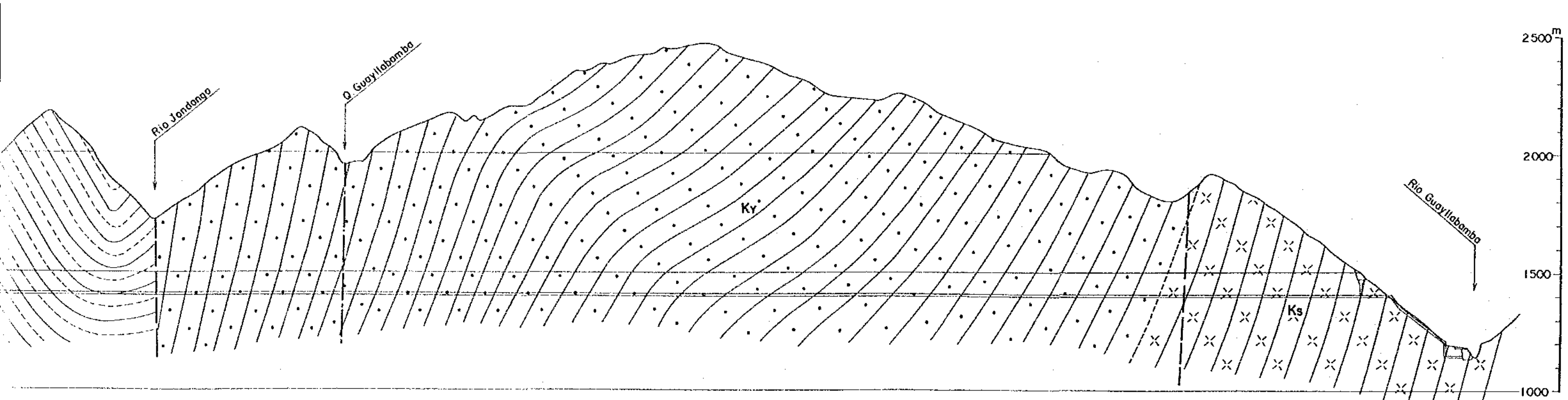
LEGEND

Quaternary
- Ta — Talus deposit
- Rd — Recent river deposit
- Te — Terrace deposit
- Py — Pyroclastics
- Lh — Lahar deposit

Cretaceous
- Ky — Yunguilla formation; sandstone, calcareous sandstone, shale, chert
- Ks — Silante formation; coarse tuff, sandy tuff, tuffaceous mudstone, tuffaceous conglomerate
- Km — Macuchi formation; andesite, agglomerate, tuff shale, calcareous sandstone
- Kp — Perlabi formation; phyllite, tuff, shale.

- Strike and dip of strata
- Strike and dip of fault (Sh; width of shear zone)
- Assumed fault and aerophoto lineament
- Axis of syncline
- Geologic boundary

0 — 1000m



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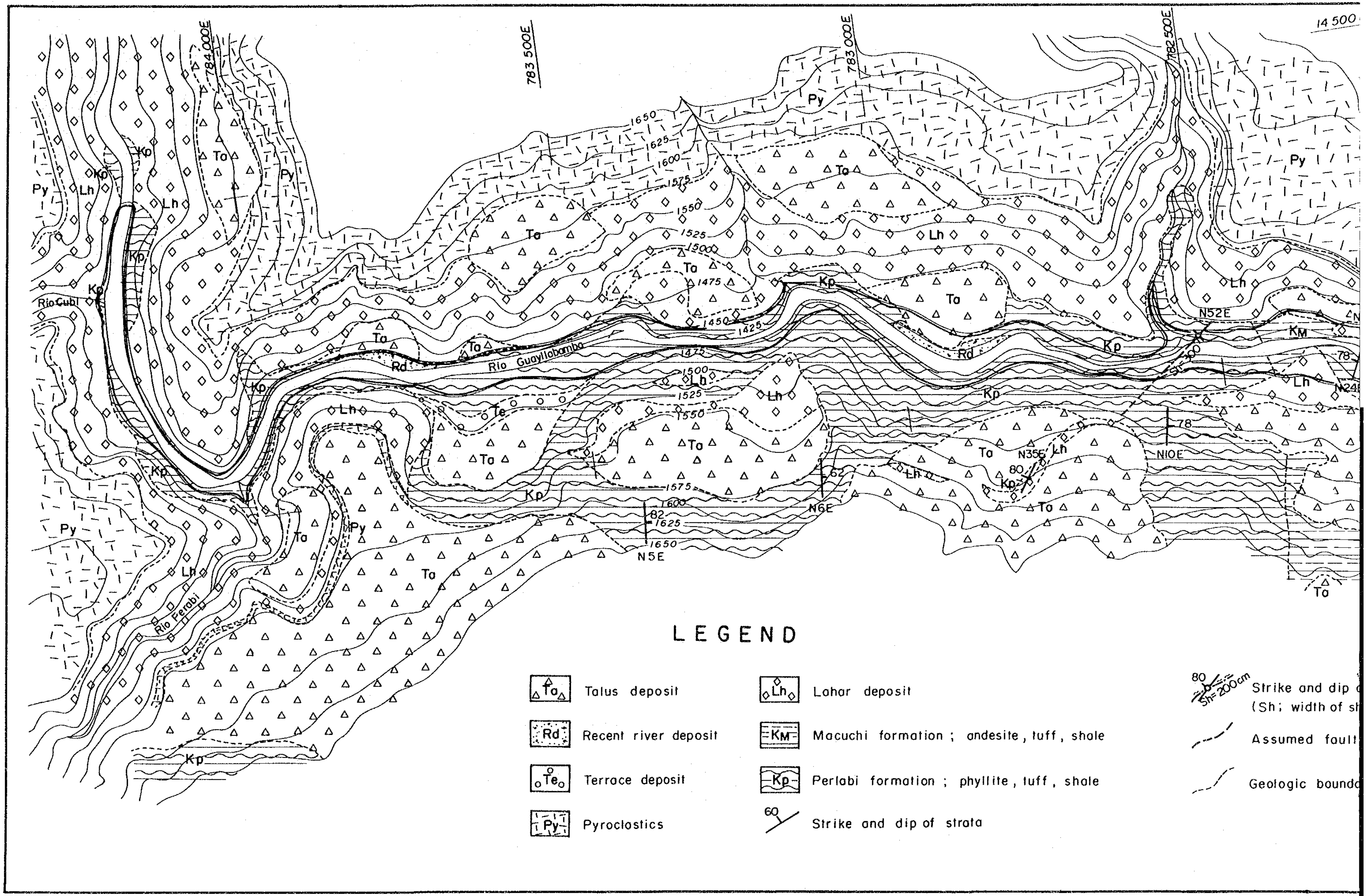
INSTITUTO ECUATORIANO DE ELECTRFICACION

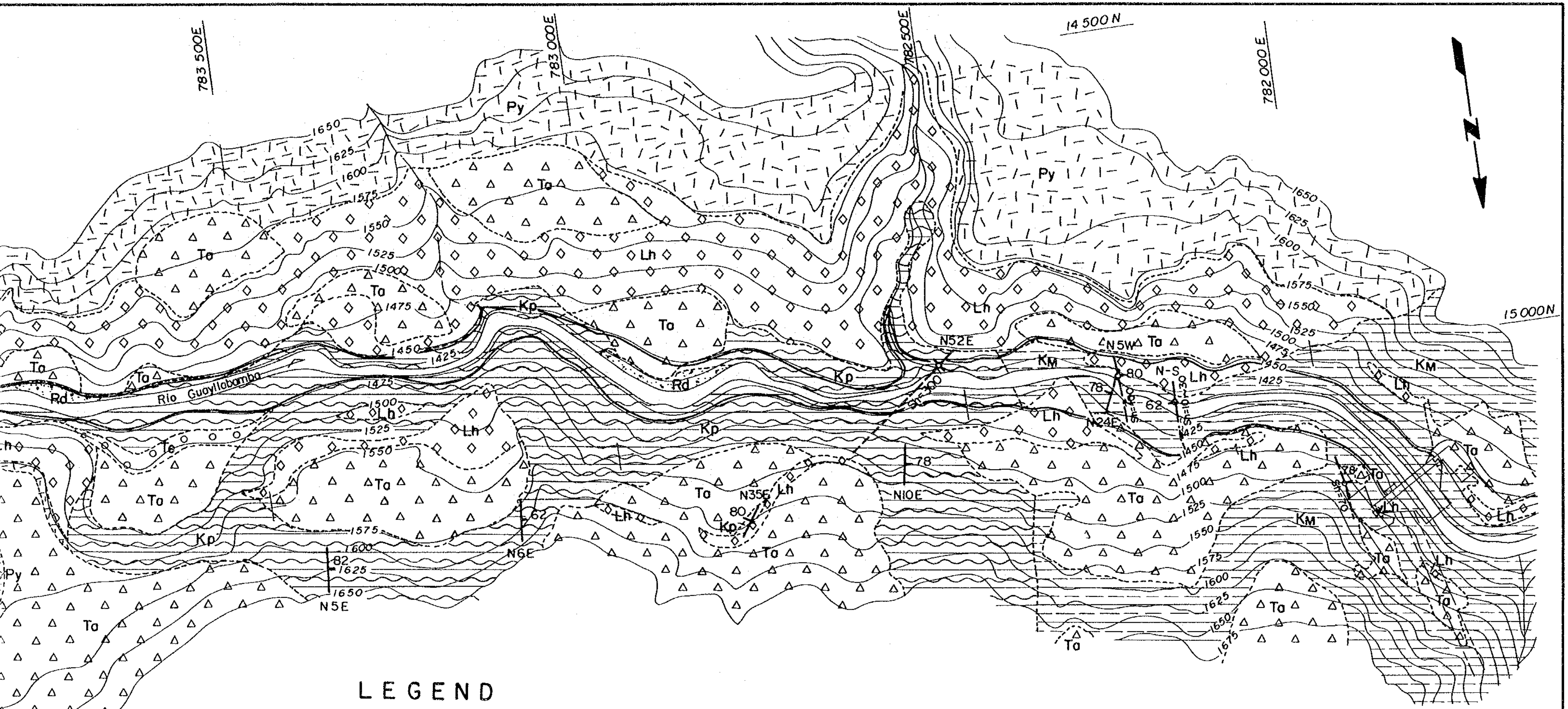
CHESPI HYDROELECTRIC DEVELOPMENT PROJECT

GEOLOGY

GENERAL PROJECT AREA PLAN AND WATERWAY PROFILE

DWG. 5-2 | DATE ;


784 000E
783 500E
783 000E
782 500E
14 500
Rio Cubi
Rio Guayllabamba
Rio Perabi
N5E
N6E
N10E
N35E
N52E
LEGEND
Talus deposit
Recent river deposit
Terrace deposit
Pyroclastics
Lahar deposit
Macuchi formation ; andesite, tuff, shale
Perlabi formation ; phyllite, tuff, shale
Strike and dip of strata
Assumed fault
Geologic bounda



LEGEND

Ta — Talus deposit	Lh — Lahar deposit
Rd — Recent river deposit	KM — Macuchi formation ; andesite, tuff, shale
Te — Terrace deposit	Kp — Perlabi formation ; phyllite, tuff, shale
Py — Pyroclastics	60 — Strike and dip of strata

80 Sh=200cm — Strike and dip of fault (Sh ; width of shear zone)

Assumed fault

Geologic boundary

0 — 300 m

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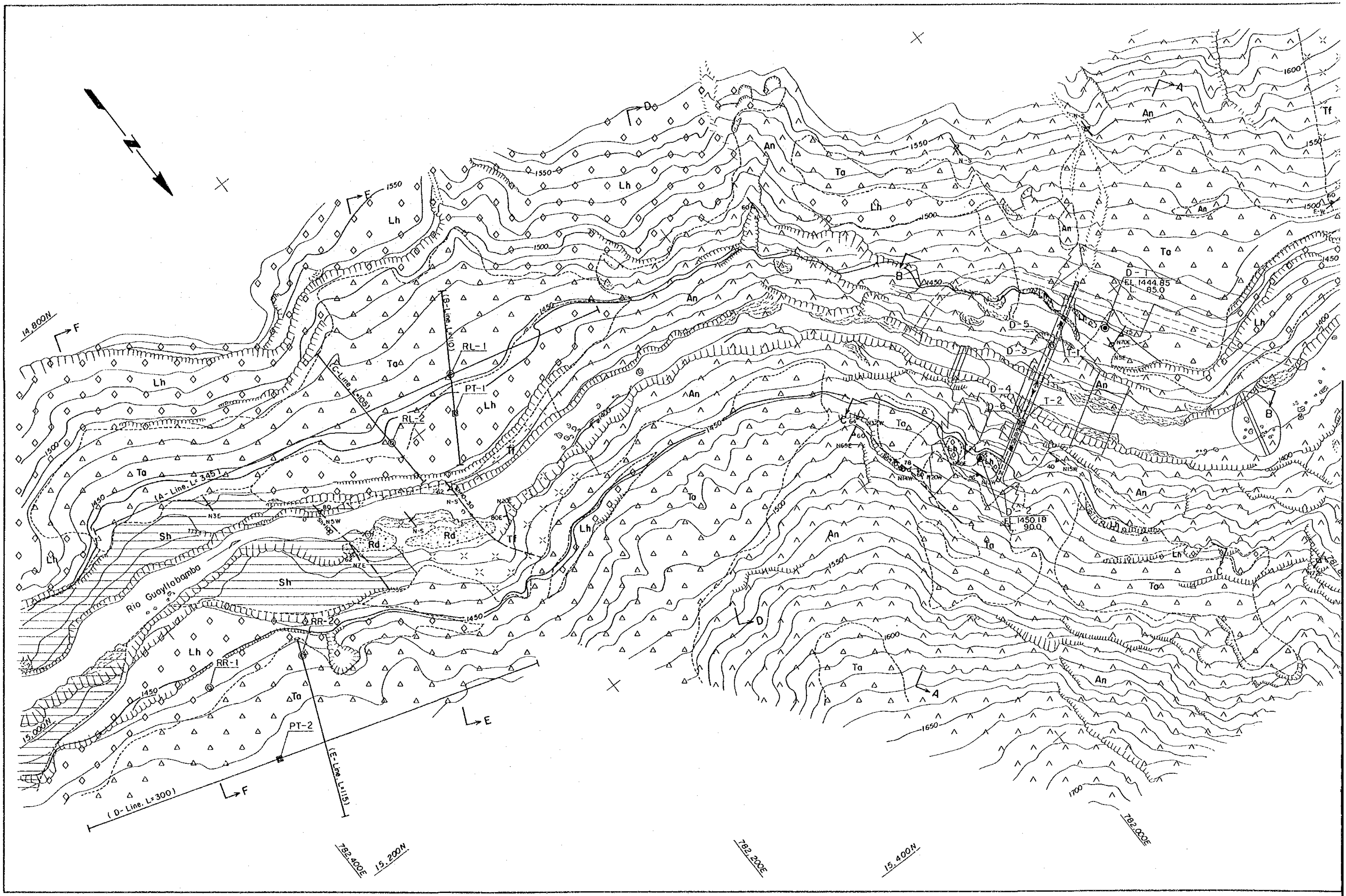
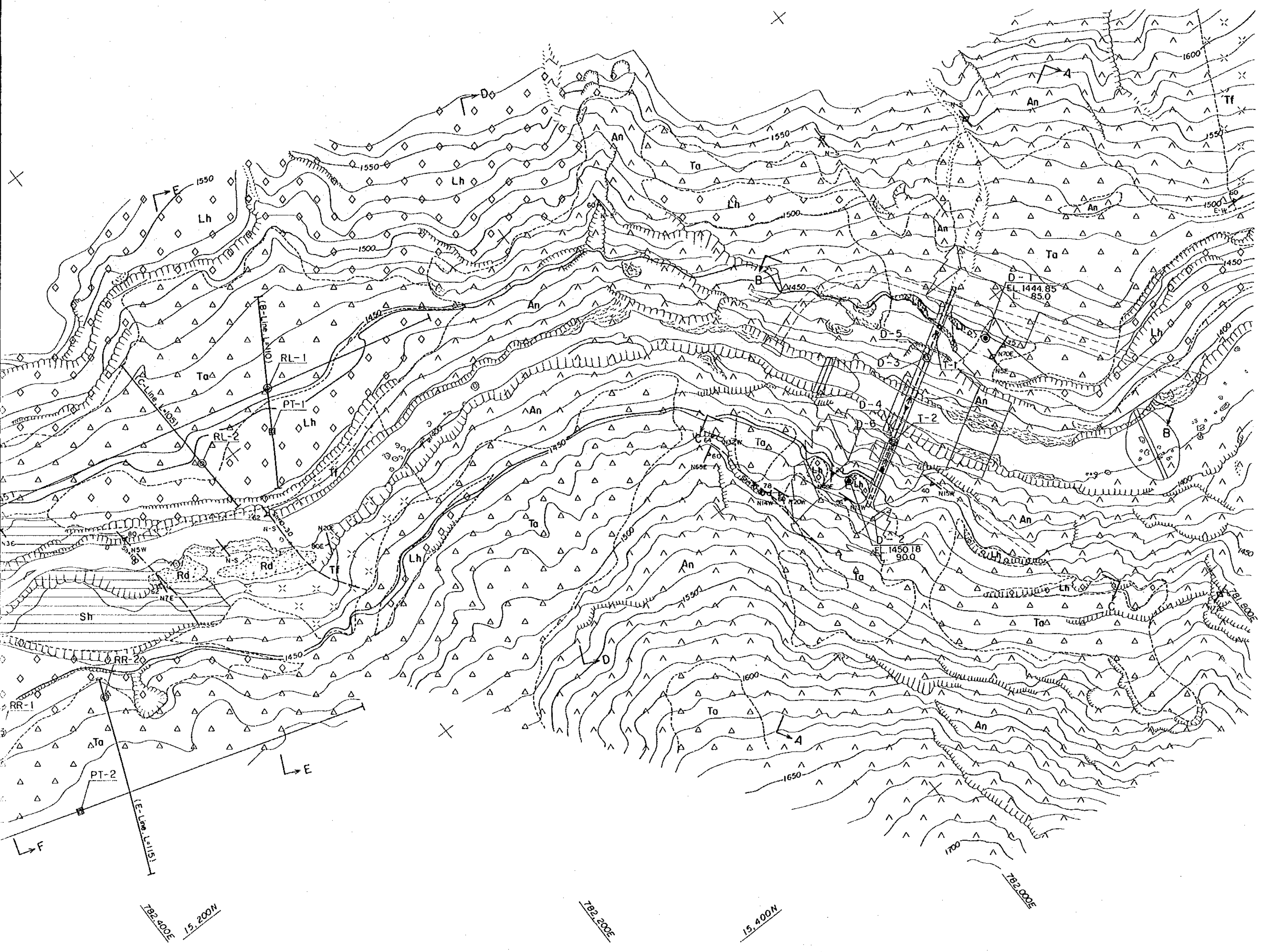
INSTITUTO ECUATORIANO DE ELECTRFICACION

CHESPI HYDROELECTRIC DEVELOPMENT PROJECT

GEOLOGY
REGULATING PONDAGE
AREA PLAN

DWG. 5–3 | DATE ;


N
Rio Guayllabamba
Lh
Ta
An
Sh
Rd
Tf
(A-Line, L=345)
(B-Line, L=110)
(C-Line, L=105)
(D-Line, L=300)
(E-Line, L=115)
RL-1
RL-2
PT-1
PT-2
RR-1
RR-2
D-1
EL.1444.85
L. 85.0
D-2
EL.1450.18
90.0
D-3
D-4
D-5
D-6
T-1
T-2
14,800N
15,000N
15,200N
15,400N
782,400E
782,200E
782,000E
1450
1500
1550
1600
1650
1700



LEGEND

- Ta — Talus deposit
- Rd — Recent river deposit
- Lh — Lahar deposit
- An — Andesite } Macuchi formation
- Tf — Tuff } Macuchi formation
- Sh — Shale } Macuchi formation
- 70 — Strike and dip of strata
- 80 — Strike and dip of joint
- 80, Sh=100cm — Strike and dip of fault (Sh : width of shear zone)
- Assumed fault
- Geologic boundary
- P- EL. L. — Drill hole (EL. ; elevation, L. ; length in m.)
- P- — Additional drill hole for definite study (proposed)
- A (L=) — Seismic prospecting line (Length in m.)
- T-1 — Planned adit for definite study (proposed)
- PT-1 — Planned pit for definite study (proposed)

0 — 100m

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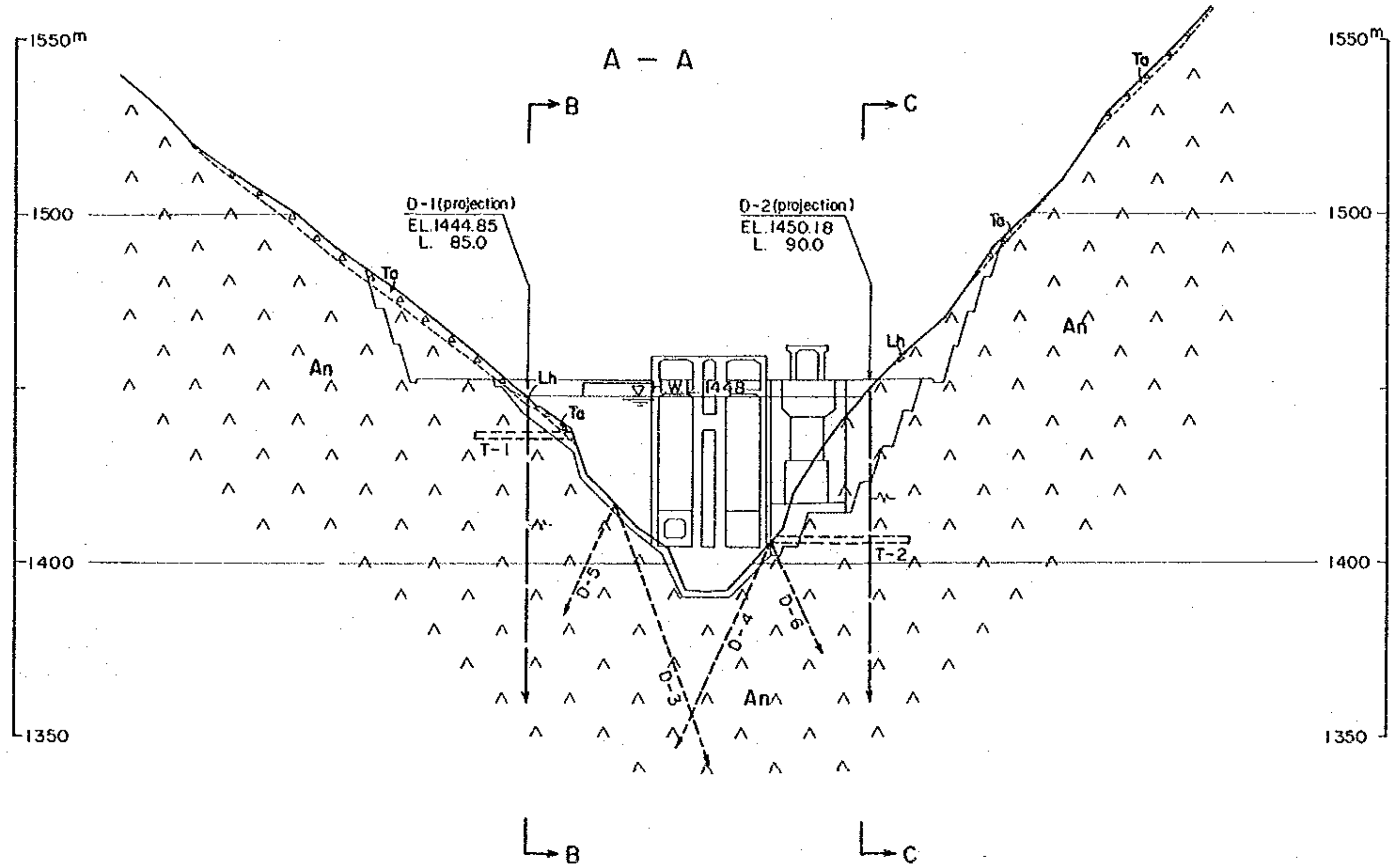
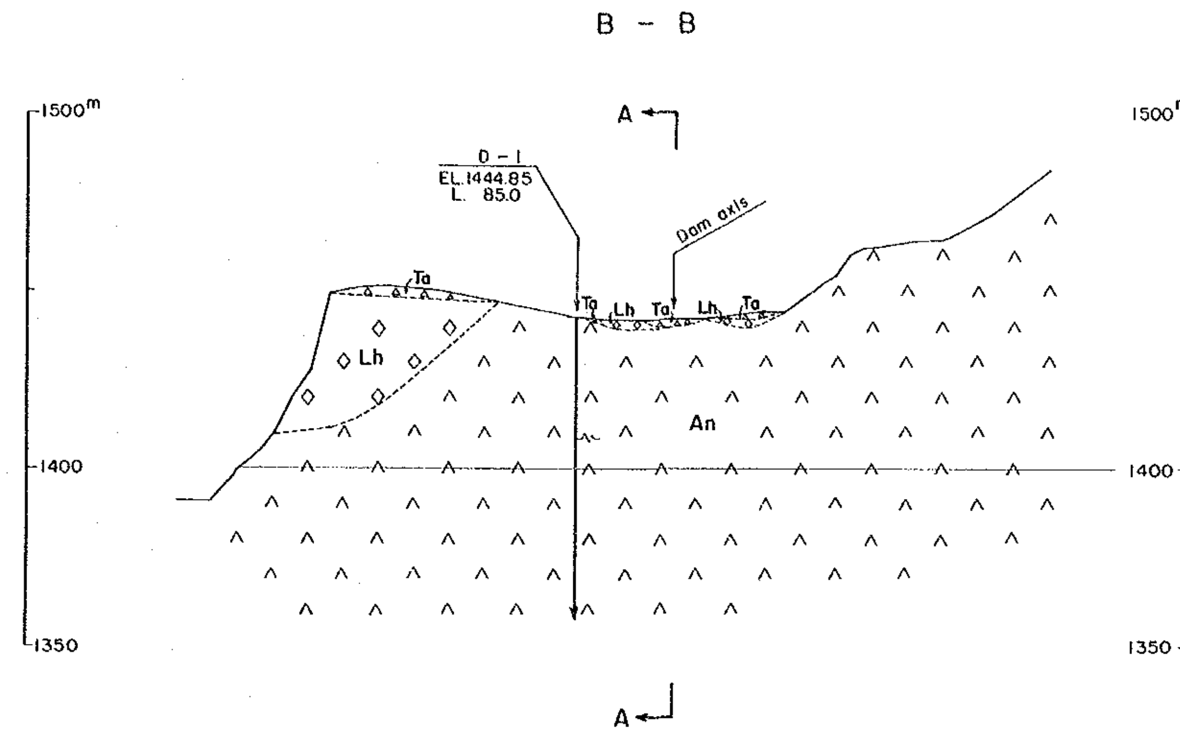
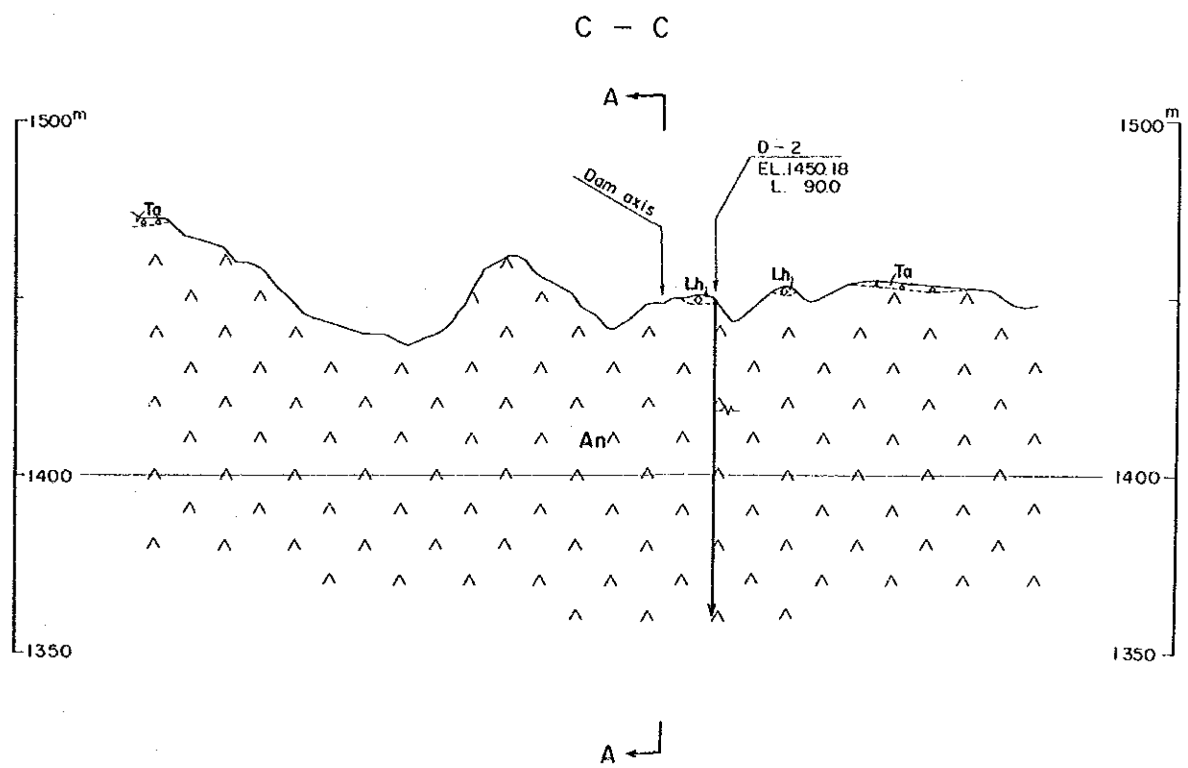
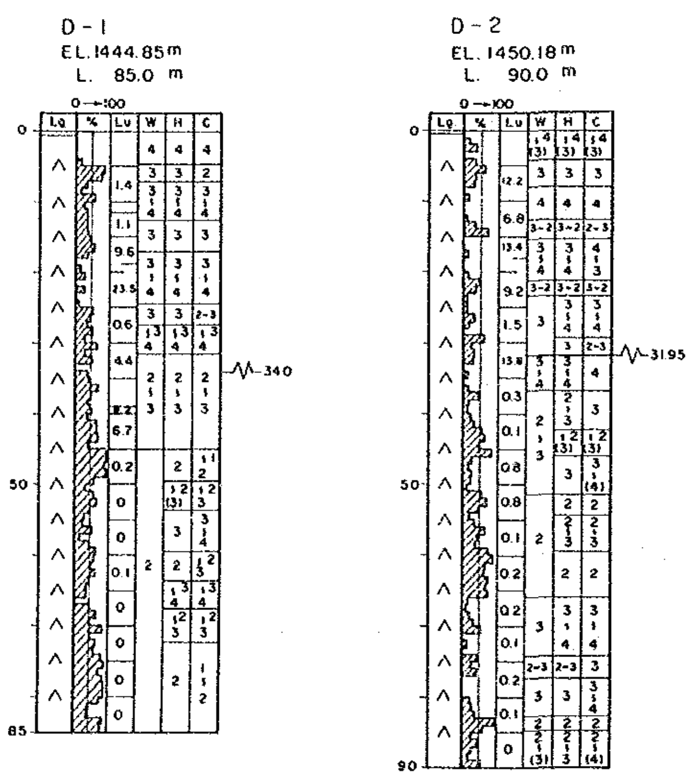
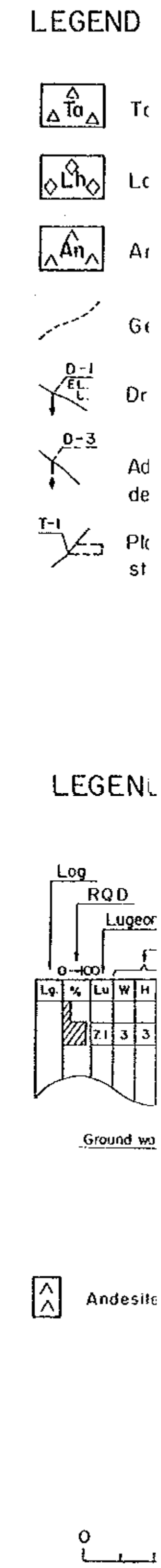
INSTITUTO ECUATORIANO DE ELECTRFICACION
CHESPI HYDROELECTRIC DEVELOPMENT PROJECT
GEOLOGY DAMSITE AND ITS VICINITY PLAN
DWG. 5-4 — DATE ;











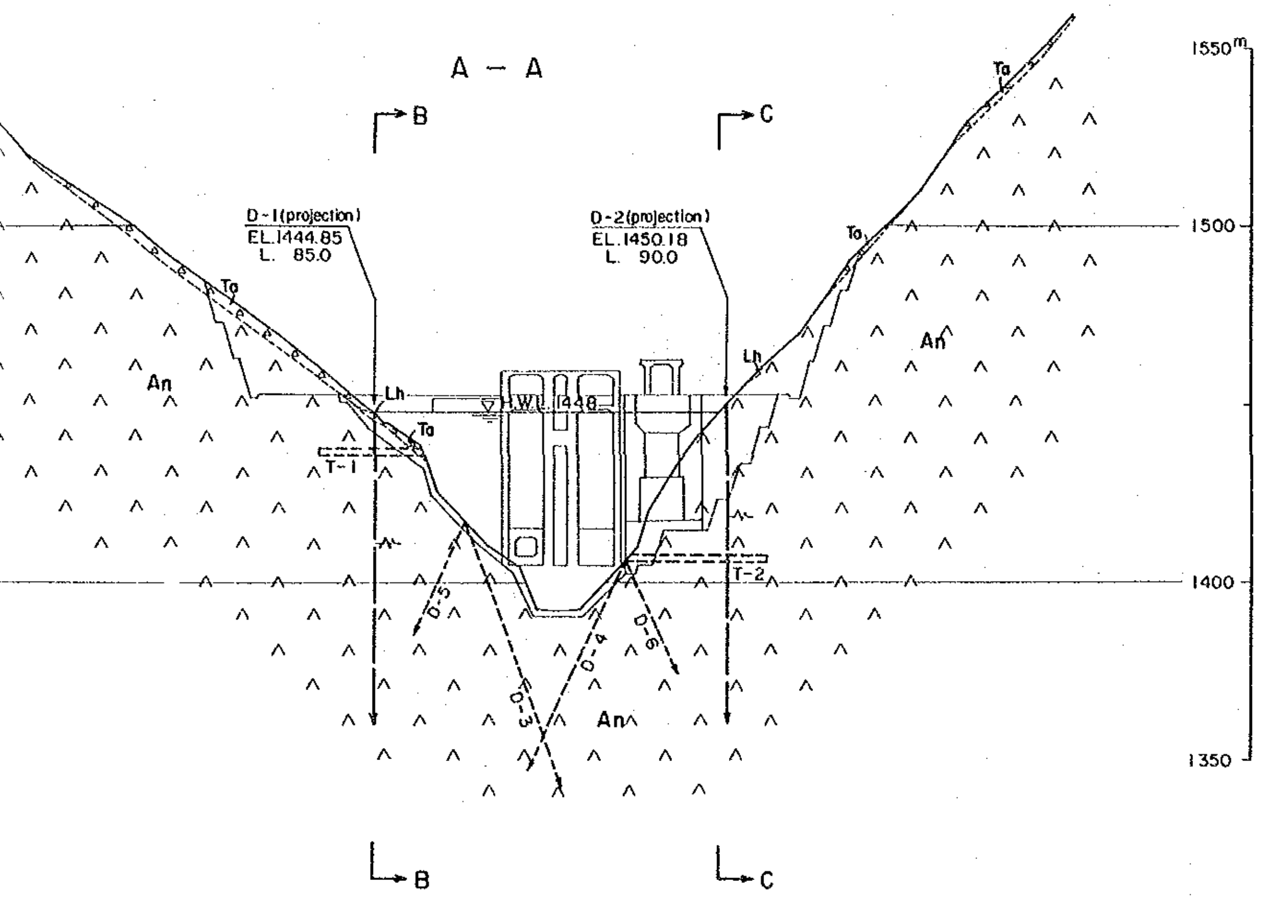
JAPAN INTE

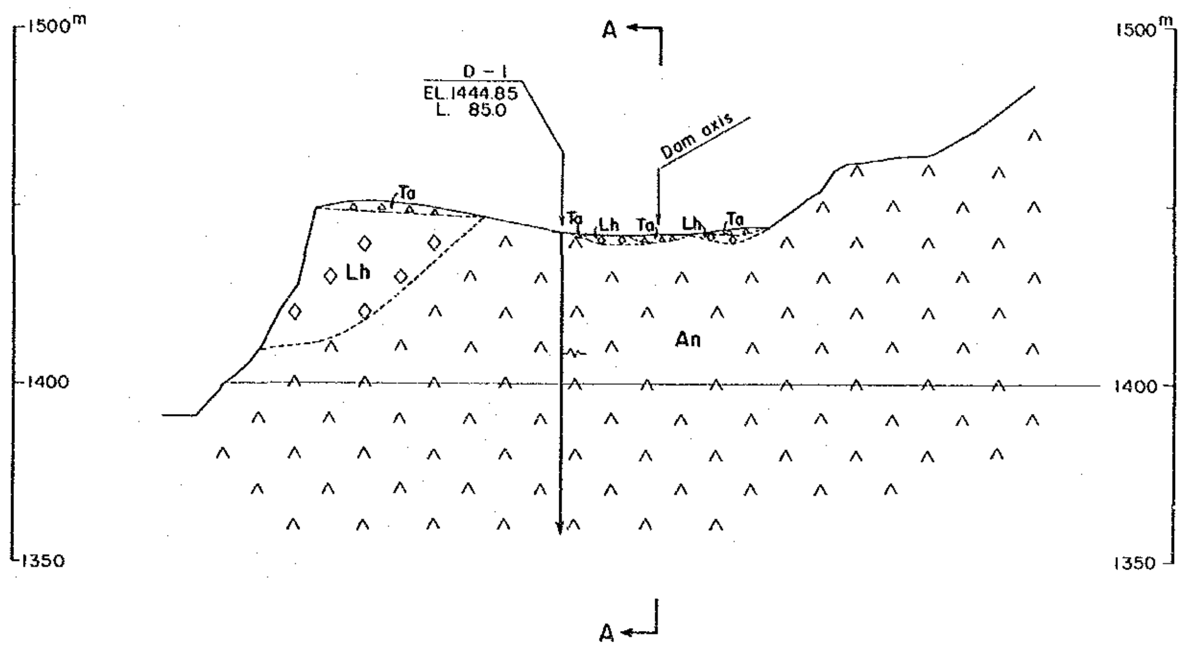
INSTITUTO

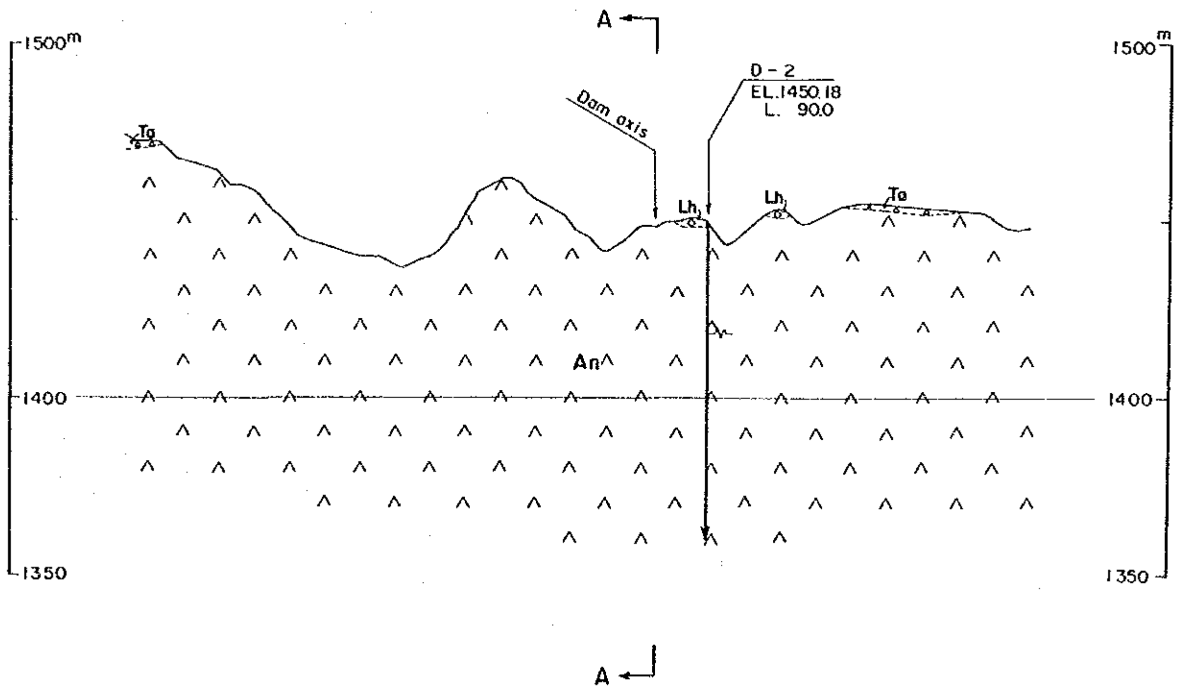
CHESPI HYDR

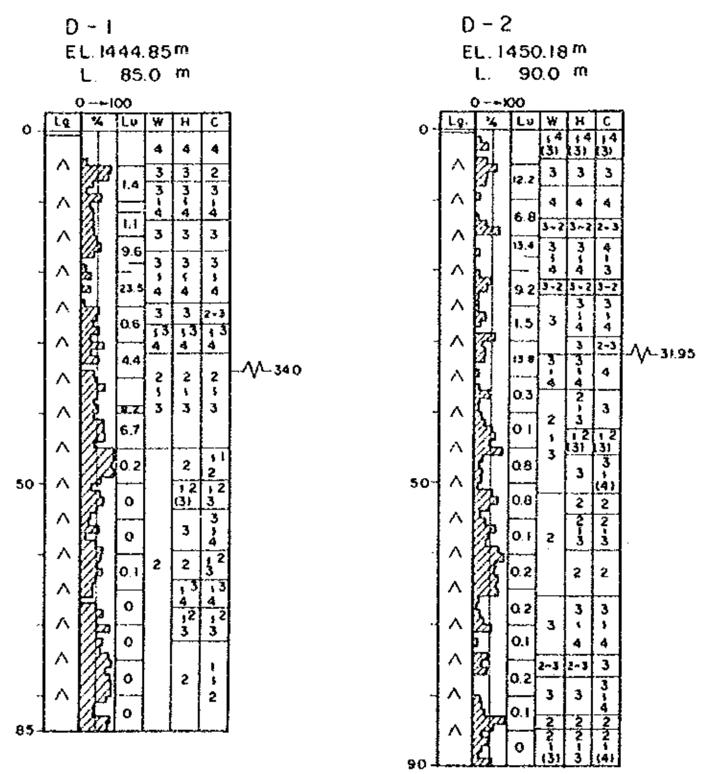
PROFIL
LOG

DWG. 5–

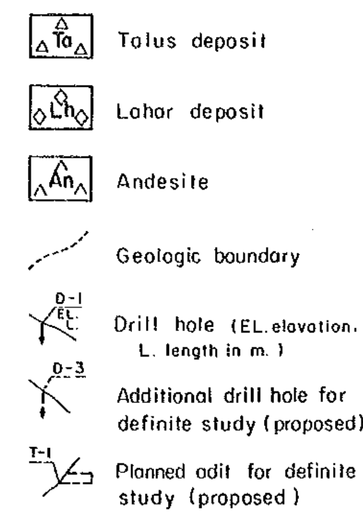




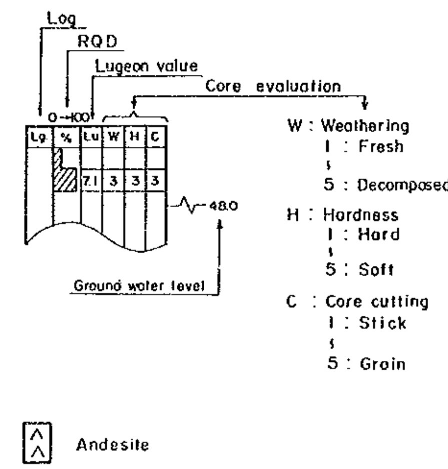


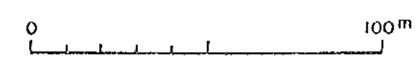


LEGEND (1) (For profile)



LEGEND (2) (For core log.)





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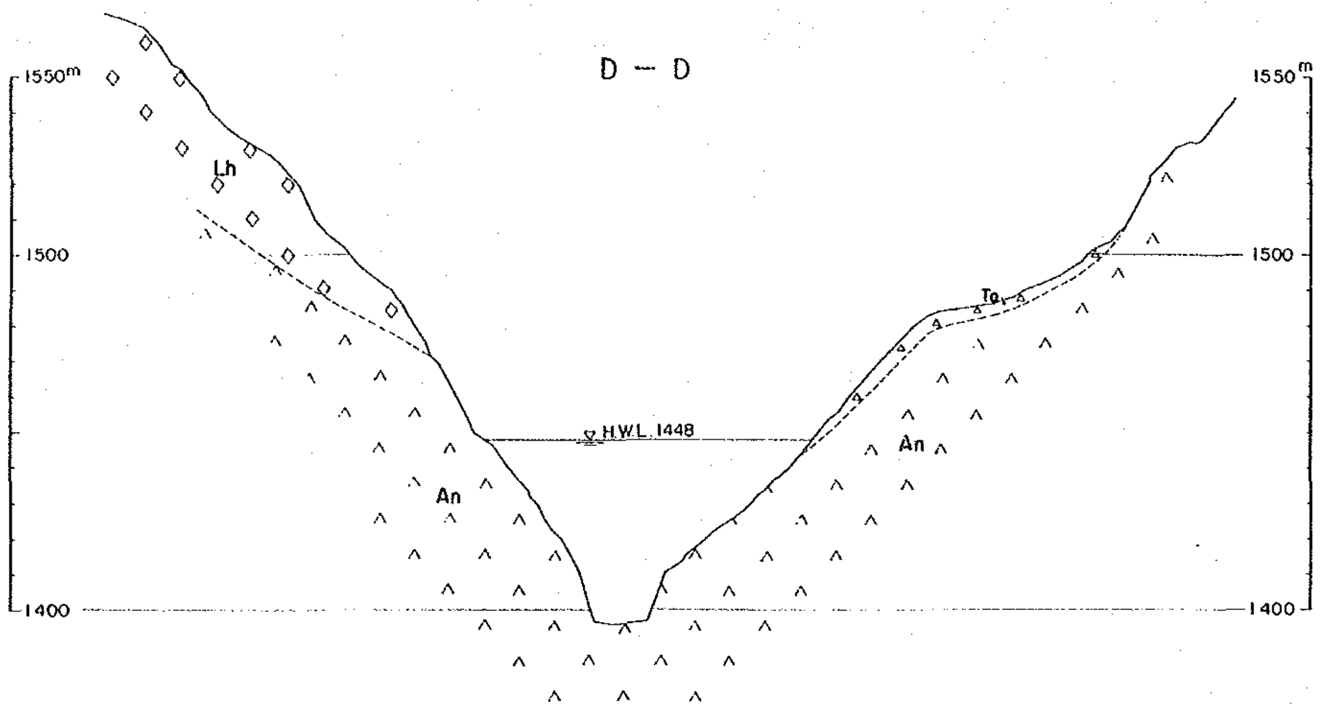
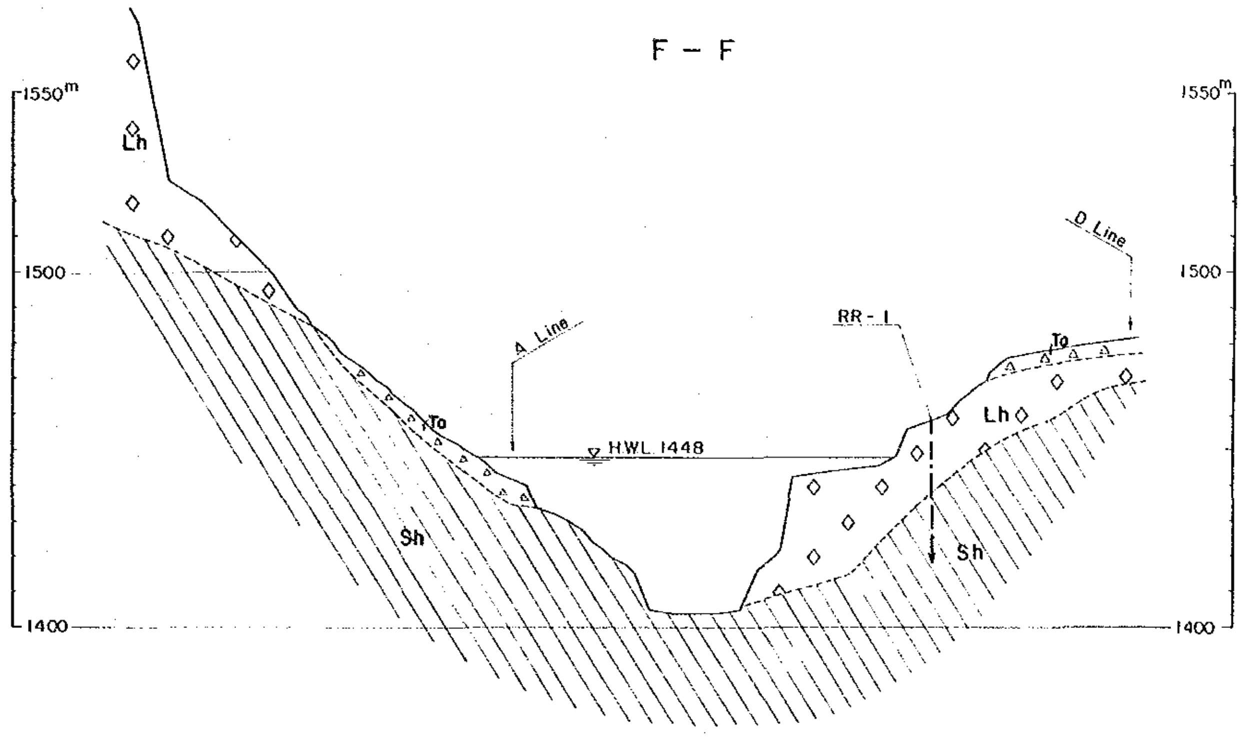
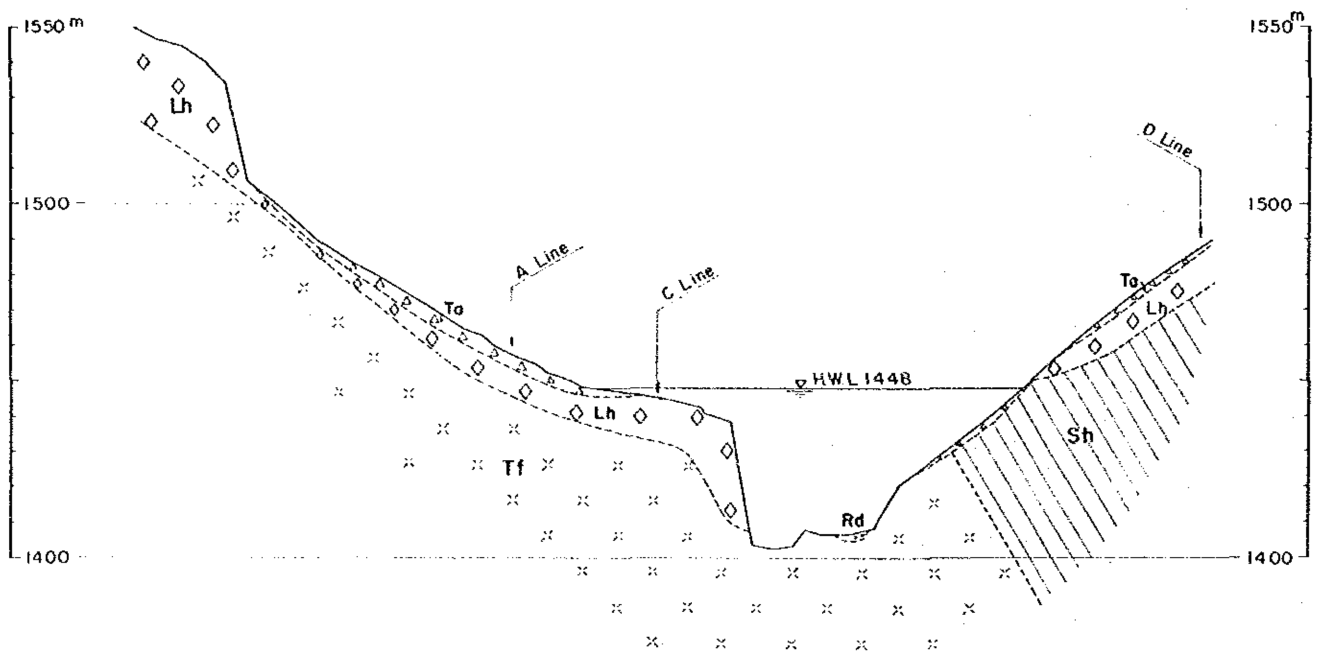
CHESPI HYDROELECTRIC DEVELOPMENT PROJECT

GEOLOGY
DAMSITE
PROFILE A-A, B-B, C-C AND
LOG OF DRILL HOLE

DWG. 5-5	DATE ;







LEGEND

- Ta — Talus deposit
- Rd — Recent river deposit
- Lh — Lahar deposit
- An — Andesite (Macuchi formation)
- Tf — Tuff (Macuchi formation)
- Sh — Shale (Macuchi formation)
- Geologic boundary
- A Line — Seismic prospecting line
- RR-1 — Additional drill hole for definite sdudy (proposed)

0 — 100m

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INSTITUTO ECUATORIANO DE ELECTRFICACION

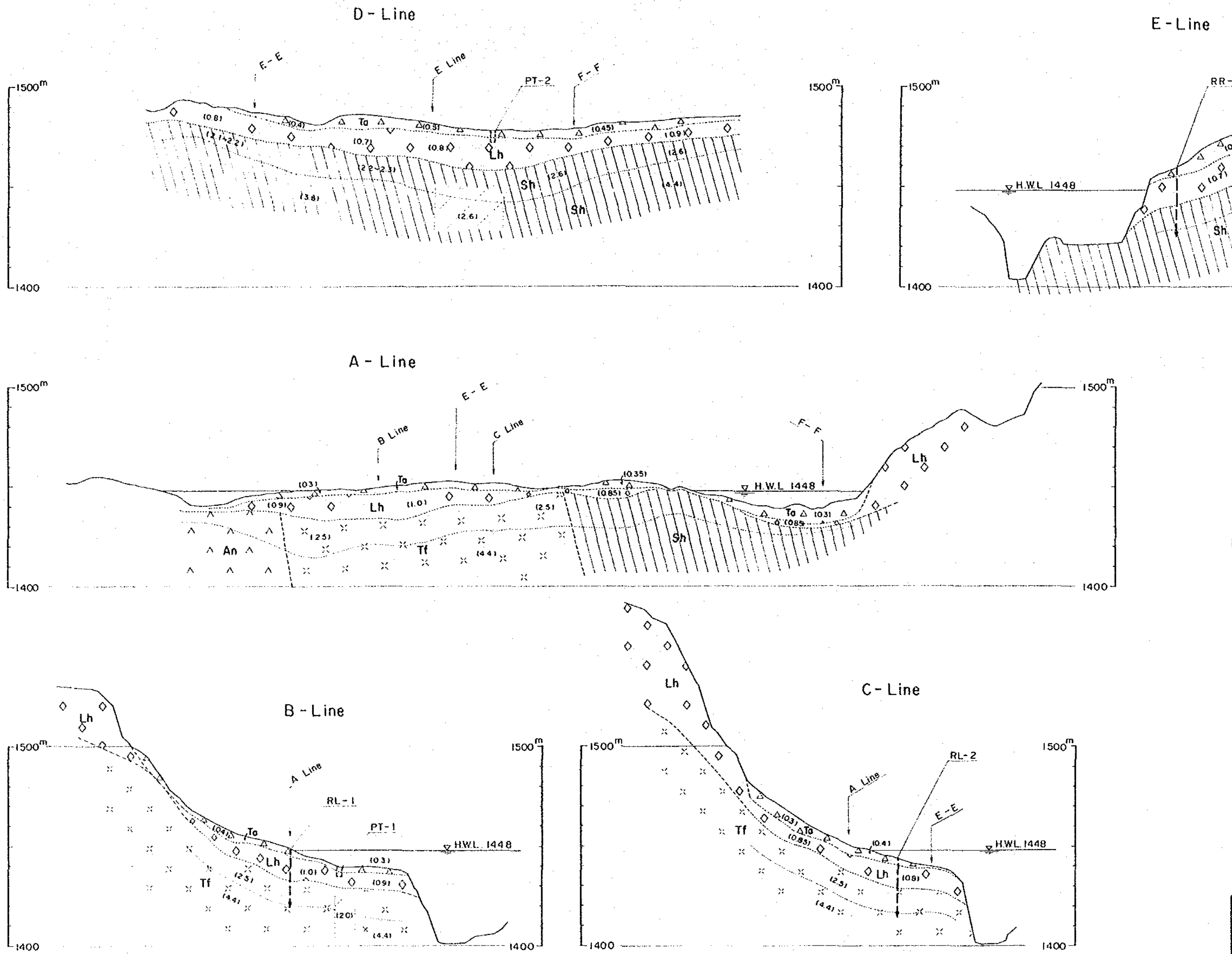
CHESPI HYDROELECTRIC DEVELOPMENT PROJECT

GEOLOGY

REGULATING PONDAGE AREA

PROFILE D-D, E-E AND F-F

DWG. 5-6	DATE ;



LEGEND

Ta	Talus deposit	
Lh	Lahar deposit	
An	Andesite	Macuchi formation
Tf	Tuff	Macuchi formation
Sh	Shale	Macuchi formation
	Geologic boundary	
(1.0) (2.5)	Seismic primary wave velocity (in km/sec) and its boundary	
A Line	Seismic prospecting line	
(2.0)	Relatively low velocity zone (in km/sec)	
RL-1	Additional drill hole for definite study (proposed)	
PT-1	Planned pit for definite study (proposed)	

0 100m

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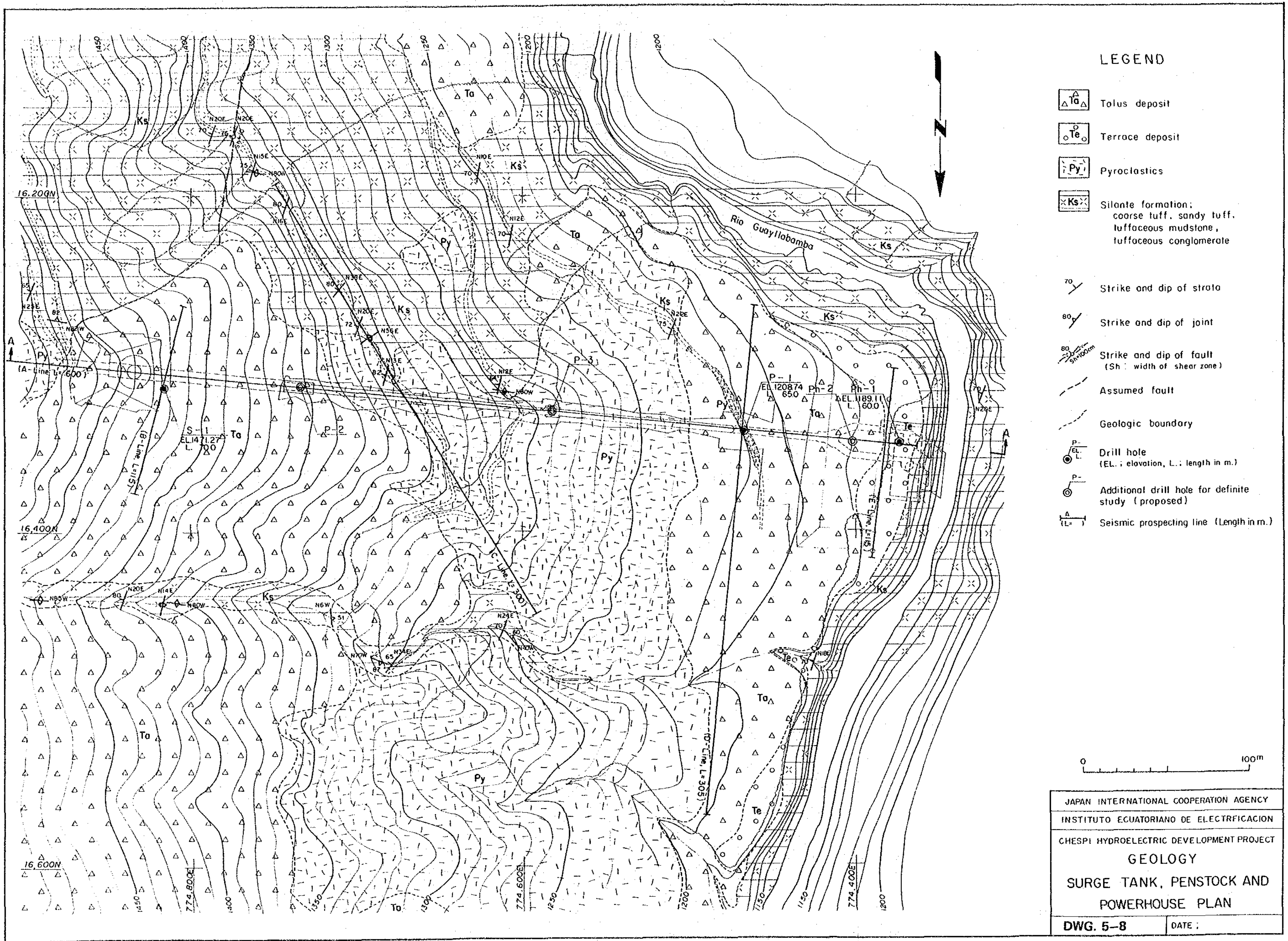
INSTITUTO ECUATORIANO DE ELECTRFICACION

CHESPI HYDROELECTRIC DEVELOPMENT PROJECT

GEOLOGY
REGULATING PONDAGE AREA
PROFILE A-Line, B-Line, C-Line, D-Line AND E - Line

DWG. 5–7 | DATE ;



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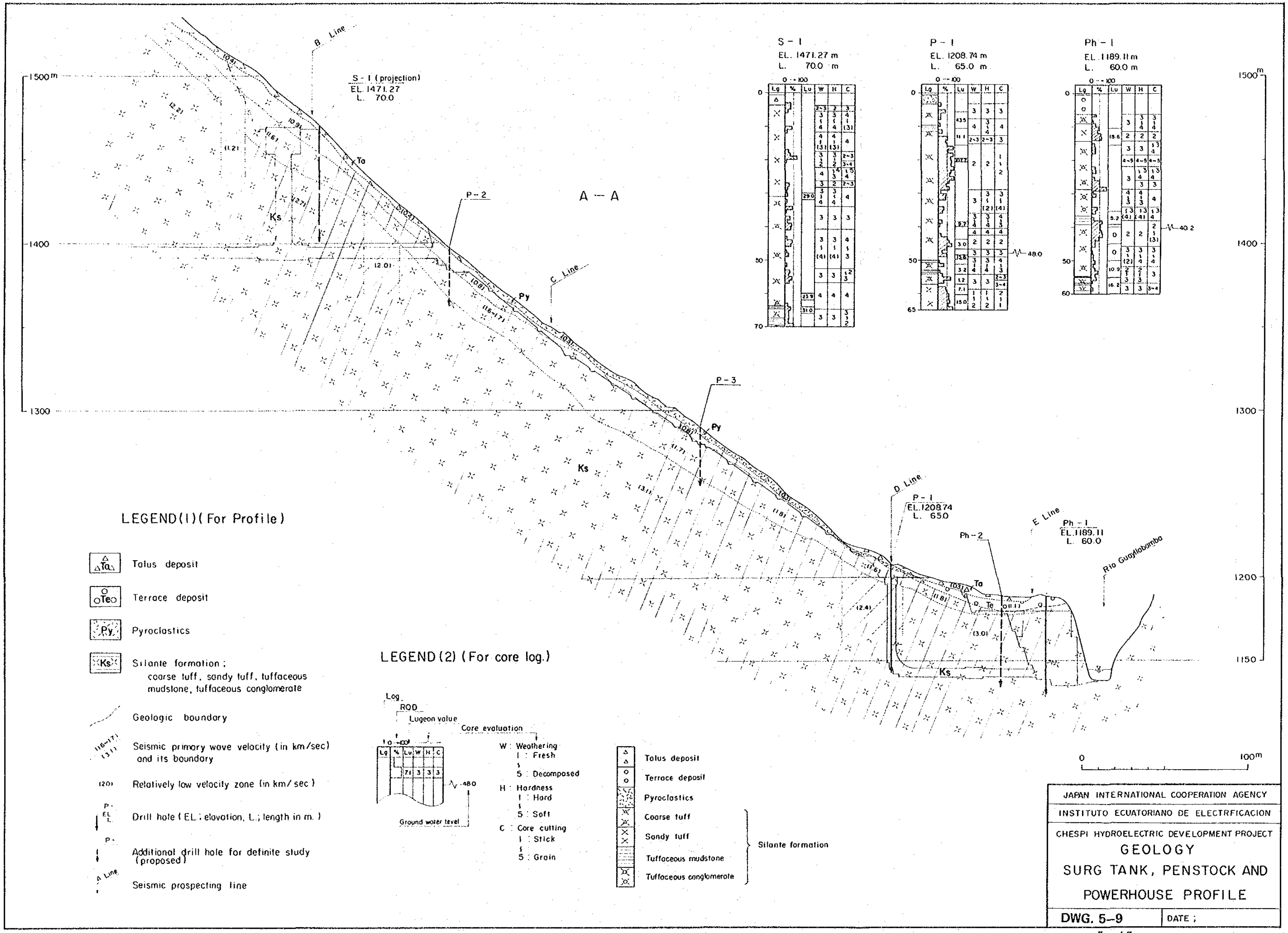
INSTITUTO ECUATORIANO DE ELECTRFICACION

CHESPI HYDROELECTRIC DEVELOPMENT PROJECT

GEOLOGY

SURGE TANK, PENSTOCK AND POWERHOUSE PLAN

DWG. 5-8 | DATE :


A — A
B Line
C Line
D Line
E Line
S - I (projection)
EL. 1471.27
L. 70.0
P - 2
P - 3
P - I
EL. 1208.74
L. 65.0
Ph - I
EL. 1189.11
L. 60.0
Ph - 2
Rio Guayllabamba
Ta
Py
Ks
Te
1500m
1400
1300
1200
1150
S - I
EL. 1471.27 m
L. 70.0 m
P - I
EL. 1208.74 m
L. 65.0 m
Ph - I
EL. 1189.11 m
L. 60.0 m
Lg
%
Lu
W
H
C
LEGEND (1) (For Profile)
Talus deposit
Terrace deposit
Pyroclastics
Silante formation ;
coarse tuff, sandy tuff, tuffaceous mudstone, tuffaceous conglomerate
Geologic boundary
Seismic primary wave velocity (in km/sec) and its boundary
Relatively low velocity zone (in km/sec)
Drill hole (EL.; elevation, L.; length in m.)
Additional drill hole for definite study (proposed)
Seismic prospecting line
LEGEND (2) (For core log.)
Log
RQD
Lugeon value
Core evaluation
Ground water level
W : Weathering
1 : Fresh
5 : Decomposed
H : Hordness
1 : Hard
5 : Soft
C : Core cutting
1 : Stick
5 : Grain
Talus deposit
Terrace deposit
Pyroclastics
Coarse tuff
Sandy tuff
Tuffaceous mudstone
Tuffaceous conglomerate
Silante formation
0
100m
JAPAN INTERNATIONAL COOPERATION AGENCY
INSTITUTO ECUATORIANO DE ELECTRFICACION
CHESPI HYDROELECTRIC DEVELOPMENT PROJECT
GEOLOGY
SURG TANK, PENSTOCK AND
POWERHOUSE PROFILE
DWG. 5-9
DATE ;

CHAPTER 6 DEVELOPMENT SCHEME

CHAPTER 6 DEVELOPMENT SCHEME

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CHAPTER 6 DEVELOPMENT SCHEME

6.1 Outline of Development Scheme

6.1.1 Outline of Project Site

This Project is located on the midstream stretch of the Rio Guayllabamba. The Rio Guayllabamba is a major river in the Republic of Ecuador which rises from the Andes Mountains, flows west gathering water from numerous tributaries, and upon merging with the major tributary Rio Quininde, changes its name to the Rio Esmeraldas and discharges into the Pacific Ocean at the city of Esmeraldas.

The project site is located approximately 30 km north of Quito. The surroundings of the project area comprise steep mountains of elevation 2,500 to 3,000 m, but at around elevations of 1,500 to 1,700 m along the Rio Guayllabamba and its tributaries, flat planes made by deposition of volcanic products can be seen in the form of a number of steps. In general, both banks of the Rio Guayllabamba comprise vertical cliffs of several tens of meters.

Upstream of the dam site there are continuations of gentle slopes that are close to being bare ground. Past the dam site, there is a gradual increase in vegetation, and at the powerhouse site there are heavy growths of plants such as banana in keeping with the subtropical climate.

The Mesozoic Cretaceous Macuchi, Perlabi, Silante, and Yunguilla formations are distributed in the project area and overlying these are Quaternary Lahar and colluvium deposits.

The Macuchi Formation is distributed from approximately 500 m upstream of the dam axis to approximately 2 km downstream, and the Perlabi Formation is distributed from approximately 2 km downstream of the dam axis to approximately 1 km east of the powerhouse site. The Simante Formation is distributed to the west from approximately 1 km east of the powerhouse site.

The Lahar and colluvium are distributed at parts of low elevation along the Rio Guayllabamba, and vertical cliffs are formed due to eroding action of the river.

6.1.2 Power Generation Scheme

The Chespi project had been considered as a site of favorable economics as shown on the Master Plan review. The basic layout is limited by topographical and geological factors. Taking the projected dam site as the boundary, at the upstream side the river bends substantially to the left and it will not be possible to shorten the waterway length. On the other hand, since the stream and the waterway parallel each other at the upstream side, the ratio of waterway head to length is abruptly lowered and hydro efficiency of the river is poor. Further, the high water level is limited by distribution of Lahar and there is a limit to securing storage capacity.

Consequently, for the power generating system, it is judged that a daily regulating pond type will be optimum. With this point as the basis, the dam site was selected considering the volume required for regulation and sedimentation, and the layout of principal structures, and then geological investigations were carried out. Judging by the topographical and geological conditions of the powerhouse site, it is condidered that the location described in this Report has been optimized.

The Chespi Hydroelectric Power Development Project is for obtaining a maximum output of 167 MW with maximum available discharge of 70 m^3/s utilizing a head of 278 m obtained shortcutting a meandering portion of the Rio Guayllabamba with a headrace tunnel of approximately 7,500 m. The available energy production of this power station is estimated to be 940 x 10^6 kWh, and this electric energy will be used mainly to meet the demands of Quito and the Northern Region.

An outline of the power generation scheme is given below.

a) Dam

The dam site was selected considering topographical conditions, geological conditions, and power generation type. it was judged that there would be no problem in particular from a geological standpoint as a result of geological investigations including field investigation works.

The daily regulating pont capacity required is 1,512,000 m^3 for regulating time of 12 hours, with dam height at 60 m.

Sedimentation within the regulating pond is to be flushed out by providing two scour gates. The function of the regulating pond can be secured by flushing out sediment about twice in an ordinary discharge year. The regulating pond is to fulfill the role of a settling basin and surface intake facilities allowing intake from only the surface portion of the regulating pond are to be provided.

Handling of floods is to be done by discharge from a free overflow section provided at the top of the dam in case of normal floods, while in case of design flood discharge the scour getes will also have to be used.

b) Waterway

In view of economy and construction facilities the headrace tunnel with an inside diameter of 5.2 m is planned to connect in a straight line to the surge tank.

The surge tank is to be of a structure having an orifice type with upper water chamber in consideration of topographical and geological conditions.

The penstock route is decided including considerations of the powerhouse location. Hence, technical and economic comparison studies were made of the penstock route and powerhouse location, and a layout for the upper part to be surface type and the lower part a vertical shaft and tunnel was selected.

c) Powerhouse

Regarding the powerhouse, a semi-underground type was found to be the most economical as a result of comparison studies including the penstock route. Francis and Pelton types are suitable for the turbines, and it was decided to provide two Francis turbines as a result of economic comparison studies.

6.1.3 Power Transmission Line and Transformers Scheme

A step-up substation is to be provided utilizing the rooftop of the powerhouse. Since there will be a distance of 50 m from the generator hall to the ground surface, 13.8-kV XLPE cables are to be used between the generators and the main transformers. The substation is to be of ordinary type.

A 138-kV transmission line is to be constructed from the step-up substation at Chespi Power Station to San Antonio Substation for interconnection with the power system. The length of this transmission line will be approximately 22 km.

The voltage of the dam distribution line is to be 13.8 kV with the length about 10 km.

6.1.4 Timing of Development

The final decision on the timing of development for the Chespi Project and other hydroelectric development sites under planning by INECEL should be made by INECEL upon carrying out overall comparisons of technical, economic, and financial factors.

If this Project is to be carried out aiming for start of operation in the mid-1990s, around the year 1995 is considered to be appropriate. Furthermore, since hydroelectric power stations of the National Interconnected System are located mainly in the Amazon River Basin, the electric energy of the rainy season at Chespi site will be almost all effective, and the variations in monthly energy production of other hydroelectric power stations will be smoothed out. As for the demands of the capital city area and the Northern

Region, they are presently depending on supply by capacities in the Southern region, but through commissioning of this Project, the dependence on supply from the above region will be eased.

6.1.5 Approximate Construction Cost

The construction cost of the Chespi Project is estimated applying the preliminary design, construction methods, and construction matereials based on the engineering level that can be relied on at the present time, and taking into consideration the topographical and geological conditions of the project site, regional conditions, project scale, etc. The time of estimation was taken to be December 1985, and the construction cost will be US$299 x 10^6 as described in Chapter 9.

As for the construction schedule, a period of 5 years is estimated taking into consideration the abovementioned conditions.

6.1.6 Economic Nature

The economic nature of the Project calculated by the internal rate of return method is 6.19 percent in terms of financial IRR and 13.50 percent in terms of economic IRR. Meanwhile, according to the comparisons with the alternative thermal facilities based on economic costs, the benefit minus cost will be 182 x 10^6 US$ at discount rate of 12 percent. The internal rate of return, when compared with the social discount rate in Ecuador, cannot be said to be of a high level at all, but it is condsidered that economical development of the Project will be feasible.

6.1.7 Development Scheme

The optimum development scheme will be described under 6.3, while an outline of the optimum development scheme is given in Table 6-1.

Table 6–1 Development Scale at Chespi Project

Development System	Unit	Daily Regulation Type			
Case (Qmax)	m³/s	50	60	70	80
Catchment Area	km²	4,606	4,606	4,606	4,606
Average Annual Runoff	m³/s	60.1	60.1	60.1	60.1
Available Discharge	〃	42.4	46.7	49.9	52.3
Reservoir (Pondage)					
High Water Level	m	1,446.0	1,447.0	1,448.0	1 449.0
Low Water Level	m	1,436.0	1,436.0	1,436.0	1,436.0
Available Drawdown	m	10.0	11.0	12.0	13.0
Total Storage Capacity	10^3 m³	2,881	3,124	3,367	3,528
Effective Storage Capacity	10^3 m³	1,080	1,296	1,512	1,728
Dam					
Type		C.G	C.G	C.G	C.G
H × L	m × m	57.0×115.0	58.5×118.0	60.0×120.0	61.0×127.0
Volume	m³	105,000	110,000	116,000	120,000
Tunnel					
D × L × n	m × m × n	4.4×7,360×1	4.8×7,360×1	5.2×7,360×1	5.6×7,360×1
Power Generating					
Intake Water Level	m	1,441.0	1,441.5	1,442.0	1,442.5
Tailracewater Level	m	1,147.0	1,147.5	1,148.0	1,148.5
Effective Head	m	278.5	278.5	278.5	278.5
Maximum Discharge	m³/s	50	60	70	80
Installed Capacity	MW	119	143	167	190
Annual Energy Production	10^6kWh	833.0	917.3	979.0	1,019.2
Construction Cost	10^3 US$	260,000	278,900	299,130	340,460
Net Present Value (B-C)	10^3 US$	126,800	160,234	182,585	181,641
Benefit-Cost Ratio (B/C)	———	1.488	1.575	1.610	1.534

6.2 Electric Energy Calculations

6.2.1 General

In carrying out studies of the development scale, and financial and economic analyses, the calculation of electric energy is an important factor along with computation of construction cost. When only the electric energy of Chespi Hydroelectric Power Station is considered in calculation of electric energy, the trend of effectivization in the entire National Interconnected System (SNI) of the energy produced is not discernable. Consequently, when the Chespi Project has gone into operation, it will be necessary to pursue the relation of the energy produced at the power station with the demand and supply of electric power.

For this reason, it is to be attempted to clarify the position of Chespi Hydroelectric Power Station in the SNI by examining the relationship of the energy produced in the balance of demand and supply in the SNI.

Various factors must be taken into consideration in attempting to clarify the relationship of power demand and supply with the SNI as the object, and in the study here the fundamental matters necessary for calculation of electric energy were as follows:

6.2.2 Conditions of Energy Calculations

a) Power Stations to be Included in Electric Energy Calculations

The amount at the primary substation of each power station is adopted for calculating effective energy in the SNI. The relationship of demand and supply of electric power is investigated using these effective energy amounts.

The actual electric energy amounts of 1984 are used for the effective electric energy of the existing hydroelectric power station group. However, the effective electric energy of Paute-A, B Power Station is to be calculated separately.

The power station names and the calculation symbols used in the calculation of power demand and supply balance in the SNI are as follows:

EX : existing hydroelectric power station group
EPZ: Paute Power Station
EAG: Agoyan Power Station
EDP: Daule Peripa Power Station
ECH: Chespi Power Station
EPM: Paute Mazar Power Station
ESP: San Francisco Power Station

b) Period of Electric Energy Calculation and Year of Commissioning

Calculations of effective electric energy amounts at all power stations in the SNI are to be made up to the year 2000 taking into consideration the development program of INECEL.

The years of commissioning of the various power stations included in the abovementioned development are assumed as follows:

Agoyan Power Station	1988
Paute-C Power Station	1992
Paute Mazar Power Station	1996
San Francisco Power Station	1997

From the standpoint of the present Feasibility Study of Chespi Hydroelectric Power Station, it was considered the year of commissioning as being in the period from 1994 to 1997, and the year of commissioning was estimated after carrying out a study of the electric power demand and supply balance. Nevertheless INECEL is finally to decide the actual year of commissioning after comparison with other alternative projects.

c) Interval of Electric Energy Calculation

The objective of the electric energy calculation is to seasonally grasp the trend of effectivization of electric energy (salable electric energy) of Chespi Hydroelectric Power Station as seen from the demand and supply balance of electric power, and to reflect this in the benefit calculations of this power station. Consequently, it is thought the details of the electric power demand and supply balance cannot be clearly distinguished unless calculations are made in units of months.

d) Electric Energy of Thermal Power Stations

The total power demand in the SNI is to be supplied on a priority basis with the effective electric energy of hydroelectric power stations at that time. Demand that cannot be supplied with the effective electric energy of hydroelectric power stations is to be supplied with the effective electric energy of thermal powre stations. However, in the event that the power demand of that month which must be supplied by thermal power stations does not exceed the power supply capacity of thermal power stations, the net power demand is all to be supplied by the thermal power stations. Conversely, when the demand exceeds the capacity, the power supply capability is to be calculated by the equation below.

$$ETLi = PIi \times (1 - f_t) \times f_p \times H$$

where,

- ETLi: effective electric energy of thermal power stations in the month of calculation (MWh)
- PIi : total power generating capacity of thermal power stations (MW)
- f_t : loss factor (5%)
- f_p : monthly equipment utility factor (95%)
- H : number of hours of power generation in that month (hr)

Generally speaking, the annual equipment utility factor of a thermal power station may be considered to be approximately 80 percent, but in the study here, a monthly equipment utility factor of 95 percent was adopted since it can be considered that the periods of operation of thermal power stations will be in units of several months. The reason for this is that it can be considered overhauling of thermal power stations will not be done when net power demand is high. Consequently, it will be necessary for a reexamination to be made in case equipment utility factor exceeds 80 percent at all times as a result of balancing power demand and supply.

6.2.3 Period of Hydrological Data

It is necessary to examine how the electric energy of this Project will be effectivized in the system as a whole. For this purpose, it is necessary for the electric energy amounts of this Project interconnected with the entire system and the group of other power stations to be computed as a whole system. By applying all of the energy supply capability of the entire power stations including this Project to the energy demand, the trend of effectivization of the electric energy of this Project will be made clear.

It is necessary for the hydrological periods of the various power stations to be made identical in order to carry out the abovementioned study. For this purpose, hydrological power spectral analysis were performed on the rainfall records of Quito Meteorological Gauging Station for the 91-year period from 1891 to 1982. As a result, it was learned that strong correlations existed in the order of 18 years, 9 years, and 5 years as hydrological periods. (See 4.4, Chapter 4, Meteorology and Hydrology.)

Taking into account the results of the abovementioned study, the 20-year period of January 1965 to December 1984 was adopted as the identical hydrological period for this Project and other power stations.

6.2.4 Energy Calculations

The specifications of the various power stations used for calculating the electric energy supply capabilities of the power stations included in the National Interconnected System are as given in Table 6-2. The electric energy amounts of the two power stations of Doule Peripa and Paute Mazar were calculated on reservoir operation by mass curve using the data given.

Fig. 6–1 Calculation Procedure of Energy Balance in the SNI

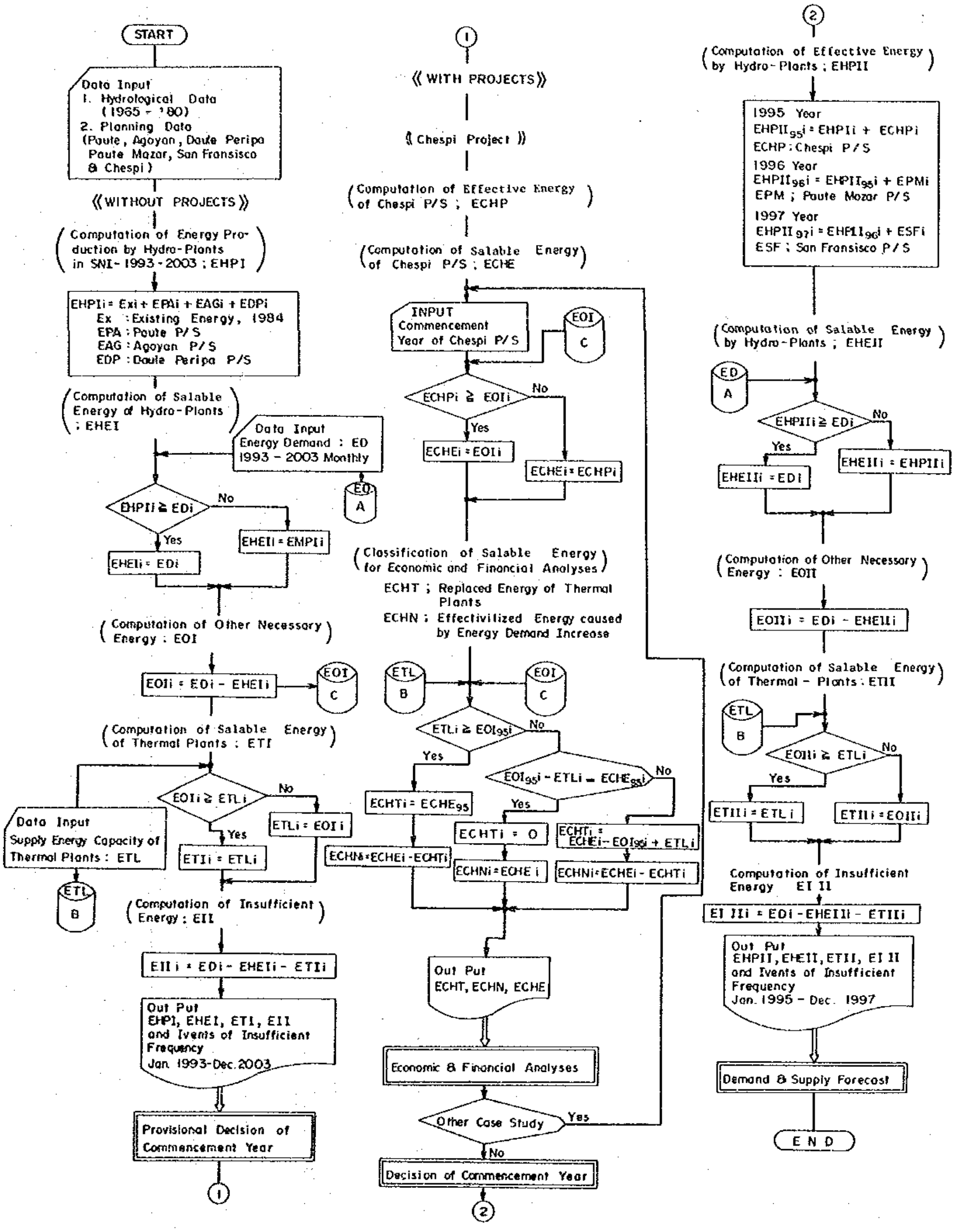

Table 6–2 Particulars of Power Plants

Item	Unit	Paute A, B	Paute C	Agoyan	Daule Peripa	Chespi	Paute Mazar	San Francisco
Commencement year	Year	1983	1992	1988	1991	* 1995	1996	1997
Installed Capacity	MW	500	500	156	130	167	180	210
Maximum Discharge	m^3/S	100	100	120	238	70	144	136.4
Effective Head (For calculating Energy)	m	604	604	156	58.2	278	137	200.7
Combined Efficiency (For calculating Energy)	$9.8\Sigma\eta$	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Loss (Station Service, Failure, Repair and others)	%	3.5	3.5	3.5	3.5	4.0	3.5	3.5

Table 6–3 Effective Energy of the Existing Hydro-Plants (1984): EX-1

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1966	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1967	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1968	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1969	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1970	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1971	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1972	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1973	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1974	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1975	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1976	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1977	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1978	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1979	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1980	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1981	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1982	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1983	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
1984	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
Average	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
Max.	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6
Min.	37.0	41.5	47.7	47.5	46.3	42.5	33.4	27.0	26.5	36.5	33.7	39.0	458.6

Table 6–4 Effective Energy of the Existing Hydro-Plants (1984): EX-2

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1966	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1967	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1968	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1969	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1970	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1971	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1972	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1973	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1974	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1975	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1976	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1977	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1978	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1979	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1980	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1981	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1982	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1983	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
1984	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
Average	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
Max.	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9
Min.	20.2	24.6	26.3	25.3	26.5	27.5	25.7	25.3	23.4	25.9	21.1	23.1	294.9

Table 6–5 Effective Energy of the Paute A, B P/S: (EPA–1)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	170.5	147.3	214.9	343.9	355.4	343.9	355.4	355.4	343.9	355.4	343.9	220.1	3,550.0
1966	355.4	267.5	355.4	343.9	292.7	318.6	355.4	355.4	306.7	291.6	152.6	163.8	3,559.0
1967	315.4	232.2	218.0	315.0	355.4	343.9	355.4	355.4	343.9	355.4	225.1	195.7	3,610.8
1968	284.6	101.8	338.6	343.9	219.0	343.9	355.4	355.4	343.9	355.4	191.7	91.5	3,325.1
1969	131.1	235.1	237.0	343.9	355.4	343.9	355.4	355.4	343.9	233.1	304.8	355.4	3,594.4
1970	355.4	321.0	355.4	343.9	355.4	343.9	355.4	355.4	343.9	355.3	343.8	355.3	4,184.1
1971	300.2	321.0	355.4	343.9	355.4	343.9	355.4	355.4	343.9	355.4	230.1	209.8	3,869.8
1972	355.4	317.5	355.4	343.9	355.4	343.9	355.4	355.4	343.9	333.2	343.8	310.7	4,113.9
1973	350.3	321.0	349.7	343.9	355.4	343.9	355.4	355.4	343.9	256.8	256.1	167.1	3,798.9
1974	176.9	320.9	320.4	241.5	355.4	343.9	355.4	355.4	343.9	355.4	343.8	355.3	3,868.2
1975	355.4	296.7	355.4	343.9	355.4	343.9	355.4	355.4	343.9	355.4	343.8	191.3	3,995.9
1976	262.9	205.6	258.9	343.9	355.4	343.9	355.4	355.4	343.9	209.5	268.0	215.4	3,518.2
1977	182.0	321.0	355.4	343.9	355.4	343.9	355.4	355.4	343.9	355.3	159.8	217.3	3,688.7
1978	174.5	228.6	355.4	343.9	355.4	343.9	355.4	355.4	343.9	355.3	176.4	150.7	3,538.8
1979	120.0	84.3	283.1	343.9	355.4	343.9	355.4	355.4	221.0	191.0	123.8	200.6	2,977.8
1980	160.0	206.6	281.3	343.9	355.4	343.9	355.4	355.4	343.9	355.4	343.8	265.5	3,710.5
1981	114.9	160.6	355.4	343.8	249.7	343.8	355.4	205.4	229.4	136.6	90.0	153.6	2,738.6
1982	146.8	109.8	129.0	343.8	355.4	279.0	355.4	355.4	277.7	355.2	299.2	355.4	3,362.1
1983	332.3	304.2	355.4	343.8	355.4	259.9	274.2	294.3	315.9	355.4	170.3	293.5	3,654.6
1984	131.0	332.3	355.4	343.8	304.2	343.8	355.4	355.4	302.4	355.4	188.6	262.3	3,630.0
Average	238.7	241.7	309.2	337.3	337.6	335.2	351.3	344.8	323.4	313.6	245.0	236.5	3,614.3
Max.	355.4	321.0	355.4	343.9	355.4	343.9	355.4	355.4	343.9	355.4	343.9	355.4	4,184.1
Min.	120.0	84.3	129.0	241.5	219.0	259.9	274.2	294.3	221.0	136.6	90.0	91.5	2,977.8

Table 6–6 Effective Energy of the Paute C, P/S: (EPA–2)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	0	0	0	9.1	277.3	343.9	305.5	95.0	121.9	2.9	143.5	0	1,299.1
1966	68.6	0	34.7	25.8	0	0	84.3	100.9	0	0	0	0	314.5
1967	0	0	0	0	259.5	258.1	355.4	355.4	10.4	51.5	0	0	1,290.3
1968	0	0	0	0.9	0	3.8	355.4	355.4	23.0	71.4	0	0	809.9
1969	0	0	0	315.1	13.5	146.2	174.4	216.3	79.4	0	0	54.8	999.7
1970	31.7	300.6	168.4	228.6	264.1	343.9	226.9	355.4	219.6	27.9	10.6	13.1	2,190.8
1971	0	8.3	303.7	165.7	2.3	224.7	355.4	269.3	243.4	91.2	0	0	1,664.0
1972	64.5	0	21.9	123.7	180.7	278.0	355.4	61.3	197.4	0	17.2	0	1,300.1
1973	0	101.7	0	160.9	149.3	131.0	274.6	288.6	161.7	0	0	0	1,267.8
1974	0	93.8	0	0	300.5	80.6	355.4	137.4	303.9	289.6	38.3	15.2	1,614.7
1975	18.9	0	242.1	73.5	275.2	343.9	355.4	355.4	86.9	128.9	49.5	0	1,929.7
1976	0	0	0	343.9	355.4	343.9	355.4	355.4	68.0	0	0	0	1,822.0
1977	0	17.2	19.4	343.9	32.3	343.9	280.0	108.1	158.9	40.3	0	0	1,344.0
1978	0	0	139.1	343.9	355.4	343.9	355.4	353.6	142.6	300.5	0	0	2,334.4
1979	0	0	0	179.1	132.9	137.2	112.7	23.4	0	0	0	0	585.3
1980	0	0	0	173.6	66.9	297.5	334.8	68.0	35.0	173.3	3.2	0	1,152.3
1981	0	0	36.0	41.9	0	40.7	104.0	0	0	0	0	0	222.6
1982	0	0	0	29.0	57.6	0	106.7	132.5	0	0	0	130.6	456.4
1983	0	0	2.9	181.8	131.7	0	0	0	0	12.5	0	0	328.9
1984	0	88.4	22.5	343.9	0	91.7	217.4	57.6	0	85.2	0	0	906.7
Average	9.2	30.5	49.6	154.2	142.7	187.7	253.2	184.5	92.6	63.8	13.1	10.7	1,191.8
Max.	68.6	300.6	303.7	343.9	355.4	343.9	355.4	355.4	303.9	300.5	143.5	130.6	2,334.4
Min.	0	0	0	0	0	0	0	0	0	0	0	0	222.6

Table 6–7 Effective Energy of the Agoyan P/S: (EAG)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	52.8	47.3	63.0	87.6	99.0	95.8	99.0	99.0	95.8	89.5	95.8	74.9	999.5
1966	99.0	87.3	99.0	95.8	89.2	82.5	99.0	99.0	91.7	74.3	47.7	73.7	1,038.2
1967	99.0	70.8	70.6	58.8	69.8	95.8	99.0	99.0	88.8	99.0	75.0	54.0	979.6
1968	91.8	56.1	92.4	79.1	52.2	93.5	99.0	99.0	83.2	99.0	55.8	32.9	934.0
1969	40.1	49.0	67.2	95.8	92.4	95.8	99.0	99.0	95.8	72.4	87.7	99.0	993.2
1970	99.0	89.4	99.0	95.8	99.0	95.8	99.0	99.0	95.8	79.3	94.9	78.8	1,124.8
1971	67.2	60.4	99.0	95.8	92.6	95.8	99.0	99.0	95.8	99.0	78.6	69.3	1,051.5
1972	99.0	92.1	80.6	95.8	99.0	95.8	99.0	99.0	95.8	78.4	88.6	89.1	1,112.2
1973	99.0	89.4	99.0	95.8	99.0	95.8	99.0	99.0	95.8	89.3	58.2	41.7	1,061.0
1974	47.0	80.8	91.4	70.9	99.0	95.8	99.0	99.0	95.8	99.0	95.8	99.0	1,072.5
1975	99.0	89.4	99.0	95.8	99.0	95.8	99.0	99.0	95.8	99.0	95.8	70.4	1,137.0
1976	99.0	67.3	61.3	95.8	99.0	95.8	99.0	99.0	87.4	52.4	73.6	73.6	1,003.2
1977	50.3	89.4	99.0	95.8	91.4	95.8	99.0	99.0	95.8	94.9	53.9	62.2	1,026.5
1978	59.6	83.4	99.0	95.8	99.0	95.8	99.0	99.0	95.8	99.0	49.5	51.5	1,026.4
1979	41.9	31.5	63.5	81.3	95.8	95.8	85.7	89.4	70.4	61.9	44.9	57.1	819.2
1980	52.8	54.9	93.9	95.8	99.0	95.8	99.0	92.8	91.2	99.0	70.7	55.6	1,000.5
1981	39.6	55.8	80.2	76.0	67.7	78.3	99.0	60.7	66.4	51.7	51.8	55.9	783.1
1982	52.8	41.4	49.2	83.0	98.4	81.6	99.0	99.0	79.3	80.4	85.2	89.2	938.5
1983	73.2	89.4	99.0	95.8	99.0	75.1	44.4	84.8	91.9	97.3	46.5	53.0	949.4
1984	77.8	75.8	95.7	95.8	99.0	95.8	99.0	85.3	95.8	78.3	55.0	61.8	1,015.1
Average	72.0	70.1	85.0	89.1	91.9	92.4	95.6	94.9	90.2	84.7	70.2	67.2	1,003.3
Max.	99.0	92.1	99.0	95.8	99.0	95.8	99.0	99.0	95.8	99.0	95.8	99.0	1,137.0
Min.	39.6	31.5	61.3	58.8	52.2	75.1	44.4	60.7	66.4	51.7	44.9	32.9	819.2

Table 6–8 Effective Energy of the Daule Peripa P/S: (EDP)

Unit : GWH

Year / Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	38.8	71.4	79.0	76.5	79.0	72.7	61.8	61.8	59.8	61.8	59.8	61.8	784.2
1966	61.8	55.8	61.8	59.8	52.8	43.4	44.8	44.8	43.4	44.8	43.4	44.8	601.4
1967	44.8	40.5	44.8	35.9	37.2	35.9	37.1	37.1	35.9	37.2	35.9	37.1	459.4
1968	37.1	34.7	37.1	35.9	37.2	35.9	37.1	37.1	35.9	37.2	35.9	37.1	438.2
1969	37.1	33.5	51.5	49.9	51.5	49.8	51.5	51.5	49.9	51.5	49.9	51.5	579.1
1970	51.5	46.5	51.5	49.9	51.5	49.8	51.5	51.5	49.9	51.5	49.9	51.5	606.5
1971	51.5	46.5	51.5	49.9	51.5	49.8	51.5	51.5	49.9	51.5	49.9	51.5	606.5
1972	51.5	70.8	75.7	73.2	75.7	73.2	75.7	75.7	73.2	75.7	73.3	75.7	869.4
1973	80.3	72.5	80.3	77.7	80.3	46.3	47.9	47.9	46.4	47.9	46.3	47.9	721.7
1974	47.9	43.3	47.9	46.3	47.9	46.3	47.9	47.9	46.4	47.9	46.4	47.9	564.0
1975	69.7	63.0	69.7	67.4	69.7	67.4	69.7	69.7	67.4	69.7	67.4	69.7	820.5
1976	80.3	75.1	80.3	77.7	80.2	47.0	48.6	48.6	47.0	48.6	47.0	48.6	729.0
1977	48.6	43.9	48.6	47.0	51.3	49.6	51.3	51.3	49.7	51.3	49.7	51.3	593.6
1978	51.3	46.4	51.3	49.7	51.3	37.6	38.8	38.9	37.6	38.9	37.6	38.9	518.3
1979	38.8	35.1	38.9	37.6	38.8	37.6	38.8	38.9	37.6	38.8	37.6	38.9	457.4
1980	38.8	36.3	38.9	37.6	38.8	37.6	38.8	38.9	37.6	38.9	37.6	38.9	458.7
1981	38.6	34.9	38.6	37.4	38.6	37.4	38.6	38.6	37.4	38.6	37.4	38.6	454.7
1982	38.6	34.9	38.6	37.4	38.6	37.4	38.6	38.6	37.4	38.6	77.7	80.3	536.7
1983	80.3	72.5	80.3	77.7	80.3	77.7	77.0	63.4	61.3	63.4	61.3	63.4	858.7
1984	63.4	59.3	63.4	61.3	63.4	69.5	71.8	71.8	69.5	71.8	69.5	71.8	806.5
Average	52.5	50.8	56.5	54.3	55.8	50.1	50.9	50.3	48.7	50.3	50.7	49.8	623.2
Max.	80.3	75.1	80.3	77.7	80.3	77.7	77.0	69.7	73.2	75.7	73.3	80.3	869.4
Min.	37.1	33.5	37.1	35.9	37.2	35.9	37.1	37.1	35.9	37.2	35.9	37.1	438.2

Table 6–9 Effective Energy of the Chespi P/S: (ECHP) ($Q=70m^3/s$)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	66.1	103.7	111.6	84.4	68.8	57.6	50.0	71.3	102.8	96.8	920.8
1966	78.5	61.0	90.3	84.0	79.5	54.8	65.4	42.1	53.3	67.3	72.8	98.3	847.5
1967	83.0	93.4	103.2	76.6	65.5	85.1	83.2	68.1	39.6	64.5	59.0	40.6	861.9
1968	55.1	71.6	103.7	94.7	51.8	60.5	78.4	44.0	50.8	97.1	84.4	59.2	851.3
1969	60.9	69.6	72.1	108.0	94.2	81.0	66.2	65.9	58.0	90.4	105.0	112.2	983.6
1970	110.1	102.4	114.0	108.1	113.6	99.5	58.2	69.1	63.5	55.2	102.5	79.9	1,076.4
1971	95.5	98.5	112.3	106.5	99.8	80.6	62.6	38.6	51.2	93.6	100.1	89.1	1,031.4
1972	90.2	98.5	103.7	106.4	110.2	91.6	89.1	48.1	38.4	41.4	91.1	95.8	1,003.9
1973	73.3	72.5	82.5	106.5	82.9	68.1	63.2	63.0	36.4	43.0	105.5	109.9	906.6
1974	55.5	93.2	97.6	68.5	108.3	97.6	92.3	69.2	58.6	102.3	104.8	97.3	1,045.2
1975	108.8	101.0	113.5	109.8	113.7	93.0	114.0	112.2	75.9	85.8	108.4	93.4	1,229.5
1976	96.3	99.6	100.6	103.7	109.4	107.9	99.3	74.0	43.1	49.3	76.3	82.3	1,041.7
1977	68.4	74.3	84.5	100.8	85.0	83.6	78.5	63.7	60.6	66.9	56.0	50.8	873.1
1978	45.1	32.0	76.4	101.9	86.5	76.3	64.2	52.0	48.2	47.6	40.1	57.5	727.7
1979	44.5	30.6	85.2	86.7	100.7	87.5	55.3	50.6	63.9	53.8	42.9	42.4	744.1
1980	53.6	89.7	98.0	101.9	90.9	79.2	53.1	45.8	40.3	68.4	69.7	67.2	858.5
1981	58.8	66.1	102.1	106.1	90.7	52.9	75.9	42.9	43.2	41.6	61.3	54.0	795.6
1982	94.6	77.1	92.0	97.5	102.1	66.2	55.9	55.8	46.6	75.5	95.7	108.4	967.4
1983	107.5	95.3	111.0	110.3	113.8	84.1	62.4	51.0	48.5	60.2	60.5	89.2	993.8
1984	91.5	101.3	108.3	104.8	108.3	97.6	73.1	47.0	74.4	87.1	77.6	70.6	1,041.6
Average	76.5	78.8	95.9	99.3	95.9	80.5	73.0	57.5	50.7	68.1	80.8	79.7	939.8
Max.	110.1	102.4	114.0	110.3	113.8	107.9	114.0	112.2	75.9	102.3	108.4	112.2	1,229.5
Min.	44.5	30.6	66.1	68.5	51.8	52.9	53.1	38.6	36.4	41.4	40.1	40.6	727.7

Table 6–10 Effective Energy of the Paute Mazar P/S: (EPM)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	51.2	46.2	51.2	49.6	80.3	77.7	80.3	70.1	67.9	62.8	60.8	54.0	752.1
1966	54.0	48.7	54.0	52.2	53.9	52.2	54.0	53.9	48.5	50.1	48.5	50.1	620.1
1967	50.1	45.3	50.1	48.5	86.8	84.0	86.8	86.8	58.9	60.8	50.3	51.9	760.3
1968	51.9	48.6	51.9	50.3	51.9	50.3	61.8	61.8	59.8	61.8	44.8	46.3	641.2
1969	46.3	41.8	46.2	68.7	71.0	68.7	71.0	71.0	68.6	71.0	68.6	71.0	763.9
1970	71.0	82.1	90.8	87.9	90.8	87.9	90.8	90.9	82.7	72.5	70.2	72.5	990.1
1971	72.5	65.5	72.5	70.2	72.5	70.2	72.5	72.5	70.2	65.7	63.5	65.7	833.5
1972	65.7	61.5	65.7	63.6	70.6	68.3	70.6	70.6	68.3	70.6	68.3	70.6	814.4
1973	70.6	63.8	70.6	68.3	70.6	68.3	70.6	70.6	68.4	52.5	50.8	52.5	777.6
1974	52.5	47.4	52.5	50.8	82.1	79.4	82.1	82.1	79.4	82.1	79.4	82.0	851.8
1975	82.1	74.1	100.6	97.4	100.6	97.4	100.6	100.6	71.2	73.6	59.5	61.5	1019.2
1976	61.5	57.5	61.5	110.7	114.3	110.7	114.3	114.3	60.9	55.0	53.3	55.0	969.1
1977	55.0	49.7	64.6	62.5	64.6	62.5	64.6	64.6	62.5	56.1	48.9	50.5	706.1
1978	50.6	45.7	91.5	88.6	91.5	88.6	91.5	91.5	85.6	88.4	44.2	45.7	903.4
1979	45.7	41.3	45.7	49.2	50.8	49.2	50.8	50.8	40.8	42.1	40.8	42.1	549.3
1980	42.1	39.4	42.1	65.1	67.2	65.1	67.2	67.2	65.1	67.2	49.5	51.2	688.4
1981	57.4	51.9	57.4	55.6	57.4	55.6	57.4	41.2	39.9	41.2	39.9	41.2	596.1
1982	41.2	37.2	41.2	59.6	61.7	59.7	63.1	63.1	61.1	63.1	61.1	63.1	675.3
1983	63.1	57.0	63.1	61.1	63.1	56.6	58.5	58.5	56.6	58.5	56.6	58.5	711.2
1984	58.5	73.8	78.8	84.8	87.7	84.8	74.4	74.4	57.6	59.5	51.3	53.0	838.6
Average	57.2	53.9	62.6	67.2	74.5	71.9	74.2	72.8	63.7	62.7	55.5	56.9	773.1
Max.	82.1	82.1	100.6	110.7	114.3	110.7	114.3	114.3	85.6	88.4	79.4	82.0	·······
Min.	41.2	37.2	41.2	48.5	50.8	49.2	50.8	41.2	39.9	41.2	39.9	41.2	·······

Table 6–11 Effective Energy of the San Francisco P/S: (ESF)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	80.9	71.9	97.6	130.0	153.1	148.1	153.1	153.1	148.1	135.9	148.1	115.5	1,535.4
1966	153.1	130.7	153.1	148.1	142.2	133.9	153.1	153.1	148.1	118.3	78.0	114.2	1,625.9
1967	153.1	107.4	108.2	98.9	117.3	148.1	153.1	153.1	148.1	153.1	116.6	86.2	1,543.2
1968	144.7	83.5	136.3	121.2	87.8	148.1	153.1	153.1	139.3	153.1	94.5	53.3	1,468.0
1969	79.8	76.7	104.5	148.1	145.2	148.1	153.1	153.1	148.1	112.3	135.5	153.1	1,557.6
1970	153.1	138.3	153.1	148.1	153.1	148.1	153.1	153.1	148.1	124.3	138.2	117.9	1,728.5
1971	101.3	90.7	153.1	148.1	146.9	148.1	153.1	153.1	148.1	153.1	114.1	101.7	1,611.4
1972	153.1	131.1	125.4	148.1	153.1	148.1	153.1	153.1	148.1	119.1	129.5	132.5	1,694.3
1973	153.1	138.3	146.8	148.1	153.1	148.1	153.1	153.1	148.1	128.3	86.9	61.8	1,618.8
1974	69.2	114.9	129.8	109.9	153.1	148.1	153.1	153.1	148.1	153.1	148.1	153.1	1,633.6
1975	153.1	138.3	153.1	148.1	153.1	148.1	153.1	153.1	148.1	153.1	148.1	106.3	1,755.5
1976	153.1	101.4	96.5	148.1	153.1	148.1	153.1	153.1	145.3	83.0	121.5	115.4	1,571.7
1977	81.7	138.3	153.1	148.1	153.1	148.1	153.1	153.1	148.1	153.1	89.1	110.2	1,629.1
1978	91.2	132.3	153.1	148.1	153.1	148.1	153.1	153.1	148.1	153.1	77.1	79.0	1,589.4
1979	62.3	45.8	97.5	128.6	151.3	148.1	145.8	144.2	110.3	94.9	67.3	87.0	1,283.1
1980	80.0	83.9	152.7	148.1	153.1	148.1	153.1	153.1	148.1	153.1	112.7	87.1	1,573.1
1981	64.5	87.3	125.7	128.8	110.1	139.1	153.1	93.0	102.5	93.3	80.2	99.8	1,277.4
1982	105.9	71.1	95.5	148.1	153.1	148.1	153.1	153.1	148.1	140.8	140.8	151.6	1,609.3
1983	142.6	138.3	97.4	148.1	153.1	138.8	106.9	153.1	148.1	153.1	86.8	95.8	1,562.1
1984	124.2	135.0	153.1	148.1	153.1	148.1	153.1	153.1	148.1	139.8	96.9	113.4	1,666.0
Average	115.0	107.7	129.3	139.5	144.5	146.5	150.4	149.6	143.3	133.4	110.5	106.7	1,576.5
Max.	153.1	138.3	153.1	148.1	153.1	148.1	153.1	153.1	148.1	153.1	148.1	153.1	1,755.6
Min.	62.3	45.8	95.5	98.9	87.8	133.9	106.9	93.0	102.5	83.0	67.3	53.3	1,277.4

On calculation of the electric energy of each month from January 1965 to December 1984, the results will be as shown in Table 6-3 ~ 6-11. Along with examination of the effectivization trend of the electric energy and year of development of the Chespi Project, the effectivized electric energy of each year after start of operation, that is, the salable electric energy, is used for calculation of the benefit which is the basic data for study of the development scale and financial and economic analyses.

6.2.5 Salable Energy of Chespi Project

The salable energy of Chespi Power Station is calculated considering the National Interconnected System.

The conditions for calcudlations are as follows:

a) The supply capabilities of hydroelectric power stations developed before start of operation of the Chespi Project are to be applied to demand on a priority basis.

b) The effective electric energy of Chespi Project is applied to the remaining demand after deducting the effective electric energy of other hydroelectric power stations from the total demand to obtain the salable energy.

Considering that the majority of hydro power stations are located mainly in the sourthern part, the electric power of this project site, which is located in the northern part to the pacific side and is close to the major load center of Quito, is expected to become effectivilized at a speed greater than that calculated here. Therefore, it may be said that a result superior to the economic nature obtained in this Report is hidden within.

In the economic analysis the salable energy is divided into the two kinds below.

a) Capacity corresponding to the reduction in fuel combustion at existing thermal power stations

b) Capacity corresponding to new electric power demand increase

Here, the electric energy corresponding to the savings in fuel at the thermal power stations is defined as the alternative electric energy of the thermal power stations. This alternative electric energy of thermal power stations is the alternative electric energy at the time of start of operation which continues in the subsequent years. However, the alternative electric energy of thermal power stations will be decreased as the scrapping program for thermal power stations progresses.

Meanwhile, the salable electric energy corresponding to the power demand increase increases with growth in energy demand and continues until all of the electric energy of this Project has become effective.

The flow chart and the salable energy on the above calculations is shown in Fig. 6-1 and Table 6-13 - 6-19.

The salable energy in each year until all of the energy has become effective in case of commissioning of this Project in 1995 is shown in Table 6-12.

Table 6-12 Salable Energy of the Chespi P/S

Year	Replaced Energy	Effectivilized Energy	Total
1995	537.2	18.3	555.5
1996	536.7	118.7	655.4
1997	467.6	240.8	708.4
1998	427.7	327.6	755.3
1999	386.0	456.1	842.1
2000	381.5	538.9	920.4
2001	386.2	553.6	939.8

Table 6–13 Salable Energy of the Chespi P/S: (ECHE) (1995)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	66.1	97.5	0	0	0	25.6	0	71.3	0	96.8	465.0
1966	56.3	61.0	76.8	84.0	79.5	54.8	34.1	36.7	53.3	67.3	72.8	98.3	774.9
1967	83.0	93.4	103.2	76.6	0	0	0	0	39.6	64.5	59.0	40.6	559.9
1968	55.1	71.6	103.7	94.7	51.8	60.5	0	0	50.8	79.6	84.4	59.2	711.4
1969	60.9	69.6	72.1	0	94.2	0	0	0	47.9	90.4	105.0	98.7	638.8
1970	103.5	0	0	0	0	0	0	0	0	55.2	102.5	79.9	341.1
1971	95.5	98.5	0	0	99.8	0	0	0	0	45.4	100.1	89.1	528.4
1972	70.7	98.1	94.1	0	0	0	0	45.4	0	41.4	91.1	95.8	536.6
1973	73.3	16.8	82.5	0	0	0	0	0	0	43.0	105.5	109.9	431.0
1974	55.5	62.6	97.6	68.5	0	40.8	0	0	0	0	104.8	97.3	527.1
1975	98.1	101.0	0	34.0	0	0	0	0	22.8	0	80.2	93.4	429.5
1976	96.3	99.6	100.6	0	0	0	0	0	43.1	49.3	76.3	82.3	547.5
1977	68.4	74.3	84.5	0	85.0	0	0	23.0	0	66.9	56.0	50.8	508.9
1978	45.1	32.0	0	0	0	0	0	0	0	0	40.1	57.5	174.7
1979	44.5	30.6	85.2	0	14.1	0	24.9	50.6	63.9	53.8	42.9	42.4	452.9
1980	53.6	89.7	98.0	0	76.9	0	0	45.8	40.3	0	69.7	67.2	541.2
1981	58.8	66.1	102.1	106.1	90.7	52.9	20.6	42.9	43.2	41.6	61.3	54.0	740.3
1982	94.6	77.1	92.0	97.5	87.1	66.2	17.9	11.3	46.6	75.5	95.7	3.9	765.4
1983	107.5	95.3	90.1	0	0	84.1	62.4	51.0	48.5	60.2	60.5	89.2	748.8
1984	91.5	45.6	90.7	0	108.3	6.7	0	66.7	74.4	51.8	77.6	70.6	683.9
Average	73.6	66.6	72.0	32.9	39.4	18.3	8.8	20.0	28.7	47.9	74.3	73.8	555.5
Max.	107.5	101.0	103.7	106.1	108.3	84.1	62.4	66.7	74.4	90.4	105.5	109.9	765.4
Min.	44.5	0	0	0	0	0	0	0	0	0	0	3.9	174.7

Table 6—14 Salable Energy of the Chespi P/S: (ECHE) (1996)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	66.1	103.7	0	0	0	57.6	50.0	71.3	65.1	96.8	618.3
1966	78.5	61.0	90.3	84.0	79.5	54.8	65.4	42.1	53.3	67.3	72.8	98.3	847.5
1967	83.0	93.4	103.2	76.6	0	0	0	0	39.6	64.5	59.0	40.6	559.9
1968	55.1	71.6	103.7	94.7	51.8	60.5	0	0	50.8	97.1	84.4	59.2	728.9
1969	60.9	69.6	72.1	0	94.2	41.7	7.1	0	58.0	90.4	105.0	112.2	711.2
1970	110.1	0	25.7	0	0	0	0	0	0	55.2	102.5	79.9	373.4
1971	95.5	98.5	0	0	99.8	0	0	0	0	93.6	100.1	89.1	576.6
1972	90.2	98.5	103.7	48.9	0	0	0	48.1	0	41.4	91.1	95.8	617.7
1973	73.3	72.5	82.5	7.2	26.2	60.3	0	0	36.4	43.0	105.5	109.9	616.8
1974	55.5	93.2	97.6	68.5	0	97.6	0	68.2	0	0	104.8	97.3	682.7
1975	108.8	101.0	0	104.9	0	0	0	0	75.9	62.2	108.4	93.4	654.6
1976	96.3	99.6	100.6	0	0	0	0	0	43.1	49.3	76.3	82.3	547.5
1977	68.4	74.3	84.5	0	85.0	0	0	63.7	37.2	66.9	56.0	50.8	586.8
1978	45.1	32.0	55.2	0	0	0	0	0	48.2	0	40.1	57.5	278.1
1979	44.5	30.6	85.2	43.6	87.2	62.9	55.3	50.6	63.9	53.8	42.9	42.4	662.9
1980	53.6	89.7	98.0	34.6	90.9	0	0	45.8	40.3	48.6	69.7	67.2	638.4
1981	58.8	66.1	102.1	106.1	90.7	52.9	75.9	42.9	43.2	41.6	61.3	54.0	795.6
1982	94.6	77.1	92.0	97.5	102.1	66.2	55.9	55.8	46.6	75.5	95.7	78.3	937.3
1983	107.5	95.3	110.0	0	43.8	84.1	62.4	51.0	48.5	60.2	60.5	89.2	812.5
1984	91.5	101.3	108.3	0	108.3	97.6	0	47.0	74.4	87.1	77.6	70.6	863.7
Average	76.5	73.7	79.0	43.5	48.0	33.9	16.1	28.6	40.5	58.5	78.9	78.2	655.4
Max.	110.1	101.3	108.3	106.1	108.3	97.6	75.9	63.7	74.4	97.1	108.4	112.2	937.3
Min.	44.5	0	0	0	0	0	0	0	0	0	40.1	40.6	278.1

Table 6—15 Salable Energy of the Chespi P/S: (ECHE) (1997)

Unit : GWH

Year \ Month	Jan.	Peb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	66.1	103.7	0	0	0	57.6	50.0	71.3	102.8	96.8	920.8
1966	78.5	61.0	90.3	84.0	79.5	54.8	65.4	42.1	53.3	67.3	72.8	98.3	847.5
1967	83.0	93.4	103.2	76.6	46.0	0	0	0	39.6	64.5	59.0	40.6	605.9
1968	55.1	71.6	103.7	94.7	51.8	60.5	0	0	50.8	97.1	84.4	59.2	728.9
1969	60.9	69.6	72.1	0	94.2	81.0	61.9	41.5	58.0	90.4	105.5	112.2	847.3
1970	110.1	0	82.6	23.1	0	0	9.4	0	30.4	55.2	102.5	79.9	493.2
1971	95.5	98.5	0	86.0	99.8	18.1	0	0	6.6	93.6	100.1	89.1	687.3
1972	90.2	98.5	103.7	104.6	57.0	0	0	48.1	29.2	41.4	91.1	95.8	759.6
1973	73.3	72.5	82.5	62.9	82.9	68.2	0	0	36.4	43.0	105.5	109.9	737.1
1974	55.5	93.2	97.6	68.5	0	97.6	0	69.2	0	0	104.8	97.3	683.7
1975	108.8	101.0	0	109.8	0	0	0	0	75.9	85.8	108.4	93.4	683.1
1976	96.3	99.6	100.6	0	0	0	0	0	43.1	49.3	76.3	82.3	547.5
1977	68.4	74.3	84.5	0	85.0	0	0	63.7	60.6	66.9	56.0	50.8	610.2
1978	45.1	32.0	76.4	0	0	0	0	0	48.2	0	40.1	57.5	299.3
1979	44.5	30.6	85.2	86.7	100.7	87.5	55.3	50.6	63.9	53.8	42.9	42.4	744.1
1980	53.6	89.7	98.0	90.3	90.9	0	0	45.8	40.3	68.4	69.7	67.2	713.9
1981	58.8	66.1	102.1	106.1	90.7	52.9	75.9	42.9	43.2	41.6	61.3	54.0	795.6
1982	94.6	77.1	92.0	97.5	102.1	66.2	55.9	55.8	46.6	75.5	95.7	108.4	967.4
1983	107.5	95.3	111.0	42.1	101.4	84.1	62.4	51.0	48.5	60.2	60.5	89.2	913.2
1984	91.5	101.3	108.3	0	108.3	97.6	0	47.0	74.4	87.1	77.6	70.6	863.7
Average	76.5	73.7	83.0	61.0	59.5	38.4	19.3	30.8	45.0	60.6	80.9	79.7	708.4
Max.	110.1	101.3	111.0	106.1	108.3	97.6	75.9	63.7	74.4	97.1	108.4	112.2	1,116.0
Min.	44.5	0	0	0	0	0	0	0	39.6	0	40.1	40.6	164.8

Table 6–16 Salable Energy of the Chespi P/S: (ECHE) (1998)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	66.1	103.7	9.7	0	0	57.6	50.0	71.3	102.8	96.8	665.7
1966	78.5	61.0	90.3	84.0	79.5	54.8	65.4	42.1	53.3	67.3	72.8	98.3	847.5
1967	83.0	93.4	103.2	76.6	65.5	49.5	0	0	39.6	64.5	59.0	40.6	674.9
1968	55.1	71.6	103.7	94.7	51.8	60.5	0	0	50.8	97.1	84.4	59.2	728.9
1969	60.9	69.6	72.1	0	94.2	81.0	66.2	65.9	58.0	90.4	105.0	112.2	875.5
1970	110.1	16.3	114.0	74.1	50.4	0	58.2	0	63.5	55.2	102.5	79.9	724.2
1971	95.5	98.5	0	106.5	99.8	68.3	0	38.6	54.1	93.6	100.1	89.1	844.1
1972	90.2	98.5	103.7	105.9	109.6	0	0	48.1	38.4	41.4	91.1	95.8	822.7
1973	73.3	72.5	82.5	106.2	82.9	68.2	15.5	23.9	36.4	43.0	105.5	109.9	819.8
1974	55.5	93.2	97.6	68.5	17.6	97.6	0	69.2	0	32.8	104.8	97.3	734.1
1975	108.8	101.0	42.7	109.8	21.1	0	0	0	75.9	85.8	108.4	93.4	746.9
1976	96.3	99.6	100.6	0	0	0	0	0	43.1	49.3	76.3	82.3	547.5
1977	68.4	74.3	84.5	0	85.0	0	6.7	63.7	60.6	66.9	56.0	50.8	616.9
1978	45.1	32.0	76.4	0	0	0	0	0	48.2	30.8	40.1	57.5	330.1
1979	44.5	30.6	85.2	86.7	100.7	87.5	55.3	50.6	63.9	53.8	42.9	42.4	744.1
1980	53.6	89.7	98.0	102.5	90.9	7.7	0	45.8	40.3	68.4	69.7	67.2	733.8
1981	58.8	66.1	102.1	106.1	90.7	52.9	75.9	42.9	43.2	41.6	61.3	54.0	795.6
1982	94.6	77.1	92.0	97.5	102.1	66.2	55.9	55.8	46.6	75.5	95.7	108.4	967.4
1983	107.5	95.3	111.0	93.1	113.8	84.1	62.4	51.0	48.5	60.2	60.5	89.2	976.6
1984	91.5	101.3	108.3	0	108.3	97.6	48.8	47.0	74.4	87.1	77.6	70.6	912.5
Average	76.5	74.5	86.7	70.8	68.7	43.8	25.5	35.1	49.4	63.8	80.8	79.7	755.3
Max.	110.1	101.3	114.0	109.8	113.8	97.6	75.9	65.9	74.4	97.1	108.4	112.2	1.145.7
Min.	44.5	0	0	0	0	0	0	0	36.4	30.8	40.1	40.6	192.4

Table 6–17 Salable Energy of the Chespi P/S: (ECHE) (1999)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	66.1	103.7	84.5	0	41.9	57.6	50.0	71.3	102.8	96.8	782.4
1966	78.5	61.0	90.3	84.0	79.5	54.8	65.4	42.1	53.3	67.3	72.8	98.3	847.5
1967	83.0	93.4	103.2	76.6	65.5	85.1	16.7	40.5	39.6	64.5	59.0	40.6	861.9
1968	55.1	71.6	103.7	94.7	51.8	60.5	16.7	40.5	50.8	97.1	84.4	59.2	786.1
1969	60.9	69.6	72.1	59.9	94.2	81.0	66.2	65.9	58.0	90.4	105.0	112.2	935.4
1970	110.1	86.6	114.0	108.4	113.6	20.5	58.2	26.1	63.5	55.2	102.5	79.9	888.4
1971	95.5	98.5	73.2	106.5	99.8	80.6	62.6	38.6	54.1	93.6	100.1	89.1	992.2
1972	90.2	98.5	103.7	105.9	110.2	63.0	0	48.1	38.4	41.4	91.1	95.8	886.3
1973	73.3	72.5	82.5	106.2	82.9	68.2	63.2	63.0	36.4	43.0	105.5	109.9	906.6
1974	55.5	93.2	97.6	68.5	92.4	97.6	5.9	69.2	58.6	102.3	104.8	97.3	942.9
1975	108.8	101.0	113.5	109.8	95.9	2.9	0	7.9	75.9	85.8	108.4	93.4	903.3
1976	96.3	99.6	100.6	3.2	5.1	23.3	5.2	29.0	43.1	49.3	76.3	82.3	613.3
1977	68.4	74.3	84.5	33.9	85.0	20.6	77.9	63.7	60.6	66.9	56.0	50.8	742.6
1978	45.1	32.0	76.4	31.2	34.1	32.7	14.9	40.5	48.2	47.6	40.1	57.5	500.3
1979	44.5	30.6	85.2	86.7	100.7	87.5	55.3	50.6	63.9	53.8	42.9	42.4	714.1
1980	53.6	89.7	98.0	102.5	90.9	79.1	35.5	45.8	40.3	68.4	69.7	67.2	840.7
1981	58.8	66.1	102.1	106.1	90.7	52.9	75.9	42.9	43.2	41.6	61.3	54.0	795.6
1982	94.6	77.1	92.0	97.5	102.1	66.2	55.9	55.8	46.6	75.5	95.7	108.4	967.4
1983	107.5	95.3	111.0	110.3	113.8	84.1	62.4	51.0	48.5	60.2	60.5	89.2	993.8
1984	91.5	101.3	108.3	19.7	108.3	97.6	73.1	47.0	74.4	87.1	77.6	70.6	956.5
Average	76.5	78.0	93.9	80.8	85.1	57.9	42.6	46.3	52.4	68.1	80.8	79.7	842.1
Max.	110.1	101.3	114.0	110.3	113.8	97.6	77.9	63.0	74.4	97.1	108.4	112.2	1.158.5
Min.	44.5	0	66.1	3.2	5.1	0	0	0	36.4	41.4	40.1	40.6	277.4

Table 6—18 Salable Energy of the Chespi P/S: (ECHE) (2000)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	66.1	103.7	111.6	78.2	68.8	57.6	50.0	71.3	102.8	96.8	914.6
1966	78.5	61.0	90.3	84.0	79.5	54.8	65.4	42.1	53.3	67.3	72.8	98.3	847.5
1967	83.0	93.4	103.2	76.6	65.5	85.1	83.2	68.1	39.6	64.5	59.0	40.5	861.9
1968	55.1	71.6	103.7	94.7	51.8	60.5	78.4	44.0	50.8	97.1	84.4	59.2	851.3
1969	60.9	69.6	72.1	108.1	94.2	81.0	66.2	65.9	58.0	90.4	105.0	112.2	983.6
1970	110.1	102.4	114.0	108.4	113.6	89.1	58.2	69.1	63.5	55.2	102.5	79.9	1,066.0
1971	95.5	98.5	112.3	106.5	99.8	80.6	62.6	38.6	54.1	93.6	100.1	89.1	1,031.4
1972	90.2	98.5	103.7	105.9	110.2	91.6	58.7	48.1	38.4	41.4	91.1	95.8	973.6
1973	73.3	72.5	82.5	106.2	82.9	63.2	63.2	63.0	36.4	43.0	105.5	109.9	906.6
1974	55.5	93.2	97.6	68.5	108.3	97.6	86.5	69.2	58.6	102.3	104.8	97.3	1,039.4
1975	108.8	101.0	113.5	109.8	113.7	57.6	64.7	89.9	75.9	85.8	108.4	93.4	1,122.5
1976	96.3	99.6	100.6	85.1	89.6	103.9	85.8	74.2	43.1	49.3	76.3	82.3	986.1
1977	63.4	74.3	84.5	100.8	85.0	83.6	78.5	63.7	60.6	66.9	56.0	50.8	873.1
1978	45.1	32.0	76.4	101.9	86.5	76.3	64.2	52.0	48.2	47.6	40.1	57.5	727.7
1979	44.5	30.6	85.2	86.7	100.7	87.5	55.3	50.6	63.9	53.8	42.9	42.4	744.1
1980	53.6	89.7	98.0	102.5	90.9	79.2	53.1	45.8	40.3	68.4	69.7	67.2	858.5
1981	58.8	66.1	102.1	106.1	90.7	52.9	75.9	42.9	43.2	41.6	61.3	54.0	795.6
1982	94.6	77.1	92.0	97.5	102.1	66.2	55.9	55.8	46.6	75.5	95.7	108.4	967.4
1983	107.5	95.3	111.0	110.3	113.8	84.1	62.4	51.0	48.5	60.2	60.5	89.2	993.8
1984	91.5	101.3	108.3	101.6	108.3	97.6	73.1	47.0	74.4	87.1	77.6	70.6	1,038.4
Average	76.5	78.8	95.9	98.2	914.9	78.8	59.4	56.9	52.4	68.1	80.8	79.7	920.4
Max.	110.1	101.3	114.0	110.5	113.8	103.9	85.8	89.9	74.4	97.1	108.4	112.2	1,206.5
Min.	44.5	0	66.1	68.5	51.8	54.8	53.1	38.6	36.4	41.4	40.1	40.6	535.8

Table 6–19 Salable Energy of the Chespi P/S: (ECHE) (2001)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	66.1	103.7	111.6	84.4	68.8	57.6	50.0	71.3	102.8	96.8	920.8
1966	78.5	61.0	90.3	84.0	79.5	54.8	65.4	42.1	53.3	67.3	72.8	98.3	847.5
1967	83.0	93.4	103.2	76.6	65.5	85.1	83.2	68.2	39.6	64.5	59.0	40.6	861.9
1968	55.1	71.6	103.7	94.7	51.8	60.5	78.4	44.0	50.8	97.1	84.4	59.2	851.3
1969	60.9	69.6	72.1	108.1	94.2	81.0	66.2	65.9	58.0	90.4	105.0	112.2	983.6
1970	110.1	102.4	114.0	108.4	113.6	99.5	58.2	69.1	63.5	55.2	102.5	79.9	1,066.0
1971	95.5	98.5	112.3	106.5	99.8	80.6	62.6	38.6	54.1	93.6	100.1	89.1	1,031.4
1972	90.2	98.5	103.7	105.9	110.2	91.6	89.1	48.1	38.4	41.4	91.1	95.8	1,003.9
1973	73.3	72.5	82.5	106.2	82.9	68.2	63.2	63.0	36.4	43.0	105.5	109.9	906.6
1974	55.5	93.2	97.6	68.5	108.3	97.6	92.3	69.2	58.6	102.3	104.8	97.3	1,045.2
1975	108.8	101.0	113.5	109.8	113.7	93.0	114.0	112.2	75.9	85.8	108.4	93.4	1,229.5
1976	96.3	99.6	100.6	103.7	109.4	107.9	99.3	74.2	43.1	49.3	76.3	82.3	1,042.0
1977	68.4	74.3	84.5	100.8	85.0	83.6	78.5	63.7	60.6	66.9	56.0	50.8	873.1
1978	45.1	32.0	76.4	101.9	86.5	76.3	64.2	52.0	48.2	47.6	40.1	57.5	727.7
1979	44.5	30.6	85.2	86.7	100.7	87.5	55.3	50.6	63.9	53.8	42.9	42.4	744.1
1980	53.6	89.7	98.0	102.5	90.9	79.2	53.1	45.8	40.3	68.4	69.7	67.2	858.5
1981	58.8	66.1	102.1	106.1	90.7	52.9	75.9	42.9	43.2	41.6	61.3	54.0	795.6
1982	94.6	77.1	92.0	97.5	102.1	66.2	55.9	55.8	46.6	75.5	95.7	108.4	967.4
1983	107.5	65.3	111.0	110.3	113.8	84.1	62.4	51.0	48.5	60.2	60.5	89.2	993.8
1984	91.5	101.3	108.3	104.8	108.3	97.6	73.1	47.0	74.4	87.1	77.6	70.6	1,041.6
Average	76.5	78.8	95.9	99.3	95.9	81.4	73.0	58.1	52.4	68.1	80.8	79.7	939.9
Max.	110.1	101.3	114.0	110.3	113.8	107.9	114.0	112.2	74.4	97.1	108.4	112.2	1,262.9
Min.	44.5	0	66.1	68.5	51.8	54.8	53.1	38.6	36.4	41.4	40.1	40.6	535.9

6.3 Examination of Development Scheme

6.3.1 General

It is the general practice to use an alternative thermal for aming comparison studies of the development scale. Therefore, the study will be made in this Report assuming an alternative thermal plant.

In effect, the development scale is to be decided comparing the costs required during the 50-year service life of this Project and the costs of a thermal power station which is equivalent to this Project.

The costs required during the service life of this Project are construction cost, operation and maintenance cost, and equipment renewal cost. These costs are developed according to individual year and a cash flow is prepared. Meanwhile, an alternative thermal power station which is equivalent to this Project is assumed and the construction cost, operation and maintenance cost, and equipment renewal cost of this thermal power station are assumed. Further, the fuel cost corresponding to the electric energy produced by the Project is developed according to individual year and a cash flow is prepared. The abovementioned various costs of the alternative thermal power station are taken to amount to the benefit of this Project.

The various costs (construction cost, operation and maintenance cost, and equipment renewal cost) are estimated based on the contions below.

a) Interest during construction and import duty are excluded.

b) A shadow exchange rate is considered for the local currency requirements in the various costs.

The present cost (C) and benefit (B) are obtained from the previously-mentioned cash flow of cost and benefit. The difference between these values (B - C) is to be the net benefit, and the development scale at which net benefit is maximum is taken to be the optimum development scale.

The specifications of the alternative thermal power station are assumed as follows;

i) Installed Capacity

$$PT = fx \times PH$$

where,

PT: installed capacity of alternative thermal power station (kW)

PH: installed capacity of Chespi Hydroelectric Power Station (kW)

$$fx: = \frac{(1-0.002) \times (1-0.005) \times (1-0.02) \times (1-0.03) \times (1-0.02)}{(1-0.06) \times (1-0.05) \times (1-0.12) \times (1-0.03)}$$

$$= 1.21$$

	Chespi Hydro P.S.	Alternative Thermal P.S.
Station service ratio	0.2%	6.0%
Failure ratio	0.5%	5.0%
Repair ratio	2.0%	12.0%
Transmission loss ratio	3.0%	3.0%
Flushing loss ratio	2.0%*	-

* (3 day/each time, 1.5 times in ordinary year)

ii) Construction Cost

The construction cost of the alternative thermal power station is to be calculated based on international prices, and interest during construction is not included in the construction cost

Construction cost	:	US$800/kW	
Breakdown	:	Foreign currency portion	75%
		local currency portion	25%

iii) Fuel Cost

Fuel cost is to be calculated based on international prices and is to be computed by the equation below.

$$Cp = f_f \times C_f$$
$$= US\$0.0348/kWh$$

where,

Fuel consumption rate ff = 0.2937 ℓ/kWh

Fuel price Cf = US$118.4/kℓ

iv) Operation and Maintenance Cost

As operation and maintenance cost, 1.5 to 3.0 percent of construction cost of US$800/kW (not including interest curing cosntruction) is calculated as the performeance in INECEL facilities, and the 2.6 percent recorded at Gonzalo Zevallos Thermal Power Station is adopted here.

v) Construction Period and Cost Flow by year

The construction period is taken to be 4 years and the cash flow by year is assumed to consist of 10 percent in the first year, 20 percent in the second year, 40 percent in the third year, and 30 percent in the fourth year.

vi) Service Period

The nominal service period is 30 years and this is to be adopted.

6.3.2 Selection of Development Scheme

In view of the topography and the geology, the basic layout of this power station will remain unchanged even if the development scale were to be changed. Consequently, the factors for determining the development scale of the power station are effective head and maximum available discharge.

In the case of this power station, the effective head will be determined by the intake water level at the daily regulating pond, the head loss of the waterway, and the outlet water level, and the effective head will not be greatly altered even though the development scale were to be changed. Basically, therefore, the matter would be a comparison study of the case of the maximum available discharge being varied.

The maximum available discharges for examining the development scale are to be the four levels of 50 m^3/s, 60 m^3/s, 70 m^3/s, and 80 m^3/s.

The specifications for the individual development scales are as given in Table 6-1.

6.3.3 Cash Flow of Cost and Benefit

Cash flows of construction costs, operation and maintenance costs, and equipment renewal costs of this Project and the alternative thermal power station, and of the fuel cost corresponding to electric energy equivalent of that of this Project calculated according to development scale are given in Tables 6-20, 6-21, 6-22, and 6-23. Calculation of Energy production as shown Tables 6-24, 6-25 and 6-26.

6.3.4 Examination Results of Development Scheme

The present cost (C) and benefit (B) of each case are determined in accordance with the assumption listed in 6.3.2, and the results of economic comparisons are given in Tables 6-20, 6-21, 6-22, and 6-23, and in Fig. 6-2.

In selection of the optimum development scale, the scheme with the greatest investment effect (B - C) is generally adopted. This Project also is fundamentally according to this concept, and as shown in Fig. 6-2, the plan for maximum available discharge of 70 m^3/s (P = 167 MW) where (B - C) is maximum and it was adopted as the optimum development scale for the Project.

Table 6–20 Comparison of Total Cost and Benefit (Case.50.T)

Discounted Cash Flow Method

Discount rate = 12.0000 (%) 12 B2= 2448
B=386780.28 B/C =1.487728615 N1= 0
C= 259980.4 B-C =126799.8808 M1= 34.8

Year	Serial Number	Cost Flow	Discounted Cost Flow	Benefit Flow	Discounted Benefit Flow
1990	-5	23193	40873.99	0	0.00
1991	-4	31931	50244.05	10036	15791.84
1992	-3	46975	65996.49	20072	28199.71
1993	-2	50671	63561.70	40144	50356.63
1994	-1	28225	31612.00	30108	33720.96
1995	0	708	708.00	19848	19848.00
1996	1	708	632.14	22562.4	20145.00
1997	2	708	564.41	24041.4	19165.66
1998	3	708	503.94	25628.28	18241.70
1999	4	708	449.95	27845.04	17696.03
2000	5	708	401.74	30221.88	17148.71
2001	6	708	358.69	30277.56	15339.55
2002	7	708	320.26	30277.56	13696.03
2003	8	708	285.95	30277.56	12228.60
2004	9	708	255.31	30277.56	10918.39
2005	10	708	227.96	30277.56	9748.56
2006	11	708	203.53	30277.56	8704.07
2007	12	708	181.73	30277.56	7771.50
2008	13	708	162.26	30277.56	6938.84
2009	14	708	144.87	30277.56	6195.39
2010	15	708	129.35	30277.56	5531.60
2011	16	708	115.49	30277.56	4938.93
2012	17	708	103.12	30277.56	4409.76
2013	18	708	92.07	30277.56	3937.28
2014	19	708	82.20	30277.56	3515.43
2015	20	708	73.40	30277.56	3138.78
2016	21	708	65.53	30277.56	2802.48
2017	22	708	58.51	30277.56	2502.21
2018	23	708	52.24	30277.56	2234.12
2019	24	708	46.64	30277.56	1994.75
2020	25	708	41.65	30277.56	1781.03
2021	26	708	37.18	40313.56	2117.30
2022	27	708	33.20	50349.56	2361.07
2023	28	708	29.64	70421.56	2948.50
2024	29	708	26.47	60385.56	2257.41
2025	30	708	23.63	30277.56	1010.60
2026	31	708	21.10	30277.56	902.32
2027	32	7859	209.12	30277.56	805.65
2028	33	24634	585.25	30277.56	719.33
2029	34	17129	363.35	30277.56	642.26
2030	35	708	13.41	30277.56	573.44
2031	36	708	11.97	30277.56	512.00
2032	37	708	10.69	30277.56	457.15
2033	38	708	9.54	30277.56	408.17
2034	39	708	8.52	30277.56	364.43
2035	40	708	7.61	30277.56	325.39
2036	41	708	6.79	30277.56	290.52
2037	42	708	6.07	30277.56	259.40
2038	43	708	5.42	30277.56	231.60
2039	44	708	4.84	30277.56	206.79
2040	45	708	4.32	30277.56	184.63
2041	46	708	3.85	30277.56	164.85
2042	47	708	3.44	30277.56	147.19
2043	48	708	3.07	30277.56	131.42
2044	49	708	2.74	30277.56	117.34
2045	50		0.00	0	0.00
2046	51		0.00		0.00
	Total	263893	259980.40	1683079.64	386780.28

Note: B-Benefit C-Cost B2-O&M Cost M-Fuel Cost

Table 6–21 Comparison of Total Cost and Benefit (Case.60.T)

Discounted Cash Flow Method

Discount rate = 12.0000 (%) 12 B2= 2941
B=439075.99 B/C =1.574645729 M1= 0
C=278841.13 B-C =160234.8638 M1= 34.8

Year	Serial Number	Cost Flow	Discounted Cost Flow	Benefit Flow	Discounted Benefit Flow
1990	-5	24161	42579.94	0	0.00
1991	-4	34321	54004.76	11907	18735.90
1992	-3	50786	71350.67	23815	33458.36
1993	-2	54783	68719.80	47629	59745.82
1994	-1	30317	33955.04	35722	40008.64
1995	0	756	756.00	21607.72	21607.72
1996	1	756	675.00	25870.72	23098.86
1997	2	756	602.68	26921.68	21461.80
1998	3	756	538.11	28143.16	20031.75
1999	4	756	480.45	30659.2	19484.48
2000	5	756	428.97	32855.08	18642.85
2001	6	756	383.01	33585.88	17015.65
2002	7	756	341.98	33585.88	15192.55
2003	8	756	305.34	33585.88	13564.77
2004	9	756	272.62	33585.88	12111.41
2005	10	756	243.41	33585.88	10813.75
2006	11	756	217.33	33585.88	9655.14
2007	12	756	194.05	33585.88	8620.66
2008	13	756	173.26	33585.88	7697.02
2009	14	756	154.69	33585.88	6872.34
2010	15	756	138.12	33585.88	6136.01
2011	16	756	123.32	33585.88	5478.58
2012	17	756	110.11	33585.88	4891.59
2013	18	756	98.31	33585.88	4367.49
2014	19	756	87.78	33585.88	3899.55
2015	20	756	78.37	33585.88	3481.74
2016	21	756	69.98	33585.88	3108.70
2017	22	756	62.48	33585.88	2775.62
2018	23	756	55.78	33585.88	2478.23
2019	24	756	49.81	33585.88	2212.71
2020	25	756	44.47	33585.88	1975.63
2021	26	756	39.71	45492.88	2389.32
2022	27	756	35.45	57400.88	2691.73
2023	28	756	31.65	81214.88	3400.41
2024	29	756	28.26	69307.88	2590.96
2025	30	756	25.23	33585.88	1121.03
2026	31	756	22.53	33585.88	1000.92
2027	32	8741	232.59	33585.88	893.68
2028	33	26477	629.03	33585.88	797.92
2029	34	18472	391.83	33585.88	712.43
2030	35	756	14.32	33585.88	636.10
2031	36	756	12.78	33585.88	567.95
2032	37	756	11.41	33585.88	507.10
2033	38	756	10.19	33585.88	452.76
2034	39	756	9.10	33585.88	404.25
2035	40	756	8.12	33585.88	360.94
2036	41	756	7.25	33585.88	322.27
2037	42	756	6.48	33585.88	287.74
2038	43	756	5.78	33585.88	256.91
2039	44	756	5.16	33585.88	229.38
2040	45	756	4.61	33585.88	204.81
2041	46	756	4.12	33585.88	182.86
2042	47	756	3.68	33585.88	163.27
2043	48	756	3.28	33585.88	145.78
2044	49	756	2.93	33585.88	130.16
2045	50		0.00	0	0.00
2046	51		0.00		0.00
	Total	283590	278841.13	1881982.28	439075.99

Note: B-Benefit C-Cost B2-O&M Cost M-Fuel Cost

Table 6—22 Comparison of Total Cost and Benefit (Case.70.T)

Discounted Cash Flow Method

12
Discount rate = 12.0000 (%) B2= 3434
B=481632.88 B/C =1.610558178 N1= 0
C=299047.18 B-C =182585.7024 M1= 34.8

Year	Serial Number	Cost Flow	Discounted Cost Flow	Benefit Flow	Discounted Benefit Flow
1990	-5	25196	44403.96	0	0.00
1991	-4	36879	58029.82	13744	21626.45
1992	-3	54885	77109.47	27489	38620.07
1993	-2	59201	74261.73	54978	68964.40
1994	-1	32558	36464.96	41233	46180.96
1995	0	804	804.00	22765.4	22765.40
1996	1	804	717.86	26241.92	23430.29
1997	2	804	640.94	28086.32	22390.24
1998	3	804	572.27	29718.44	21153.00
1999	4	804	510.96	32739.08	20806.28
2000	5	804	456.21	35463.92	20123.18
2001	6	804	407.33	36139.04	18309.16
2002	7	804	363.69	36139.04	16347.47
2003	8	804	324.72	36139.04	14595.95
2004	9	804	289.93	36139.04	13032.10
2005	10	804	258.87	36139.04	11635.80
2006	11	804	231.13	36139.04	10389.11
2007	12	804	206.37	36139.04	9275.99
2008	13	804	184.26	36139.04	8282.14
2009	14	804	164.51	36139.04	7394.76
2010	15	804	146.89	36139.04	6602.47
2011	16	804	131.15	36139.04	5895.06
2012	17	804	117.10	36139.04	5263.45
2013	18	804	104.55	36139.04	4699.51
2014	19	804	93.35	36139.04	4195.99
2015	20	804	83.35	36139.04	3746.42
2016	21	804	74.42	36139.04	3345.02
2017	22	804	66.44	36139.04	2986.62
2018	23	804	59.33	36139.04	2666.63
2019	24	804	52.97	36139.04	2380.92
2020	25	804	47.29	36139.04	2125.82
2021	26	804	42.23	49883.04	2619.90
2022	27	804	37.70	63628.04	2983.75
2023	28	804	33.66	91117.04	3815.00
2024	29	804	30.06	77372.04	2892.42
2025	30	804	26.84	36139.04	1206.25
2026	31	804	23.96	36139.04	1077.01
2027	32	9700	258.10	36139.04	961.61
2028	33	28465	676.26	36139.04	858.58
2029	34	19912	422.38	36139.04	766.59
2030	35	804	15.23	36139.04	684.46
2031	36	804	13.60	36139.04	611.12
2032	37	804	12.14	36139.04	545.64
2033	38	804	10.84	36139.04	487.18
2034	39	804	9.68	36139.04	434.98
2035	40	804	8.64	36139.04	388.38
2036	41	804	7.71	36139.04	346.77
2037	42	804	6.89	36139.04	309.61
2038	43	804	6.15	36139.04	276.44
2039	44	804	5.49	36139.04	246.82
2040	45	804	4.90	36139.04	220.38
2041	46	804	4.38	36139.04	196.76
2042	47	804	3.91	36139.04	175.68
2043	48	804	3.49	36139.04	156.86
2044	49	804	3.12	36139.04	140.05
2045	50		0.00	0	0.00
2046	51		0.00	0	0.00
	Total	304584	299047.18	2040020.84	481632.88

Note: B-Benefit C-Cost B2-O&M Cost M-Fuel Cost

Table 6–23 Comparison of Total Cost and Benefit (Case.80.T)

Discounted Cash Flow Method

Discount rate = 12.0000 (%) B2= 3927
B=521841.89 B/C =1.533923804 M1= 0
C=340200.66 B-C =181641.2307 M1= 34.8

Year	Serial Number	Cost Flow	Discounted Cost Flow	Benefit Flow	Discounted Benefit Flow
1990	-5	27751	48906.74	0	0.00
1991	-4	43213	67996.49	15522	24424.17
1992	-3	63555	89290.20	31044	43614.58
1993	-2	67244	84350.87	62088	77883.19
1994	-1	36078	40407.36	46566	52153.92
1995	0	844	844.00	24097.08	24097.08
1996	1	844	753.57	28109.52	25097.79
1997	2	844	672.83	30148.8	24034.44
1998	3	844	600.74	31676.52	22546.72
1999	4	844	536.38	34269.12	21778.65
2000	5	844	478.91	37463.76	21257.94
2001	6	844	427.60	37975.32	19239.48
2002	7	844	381.78	37975.32	17178.11
2003	8	844	340.88	37975.32	15337.59
2004	9	844	304.35	37975.32	13694.28
2005	10	844	271.75	37975.32	12227.04
2006	11	844	242.63	37975.32	10917.00
2007	12	844	216.63	37975.32	9747.32
2008	13	844	193.42	37975.32	8702.96
2009	14	844	172.70	37975.32	7770.50
2010	15	844	154.20	37975.32	6937.95
2011	16	844	137.67	37975.32	6194.60
2012	17	844	122.92	37975.32	5530.89
2013	18	844	109.75	37975.32	4938.30
2014	19	844	97.99	37975.32	4409.19
2015	20	844	87.49	37975.32	3936.78
2016	21	844	78.12	37975.32	3514.98
2017	22	844	69.75	37975.32	3138.38
2018	23	844	62.28	37975.32	2802.12
2019	24	844	55.60	37975.32	2501.89
2020	25	844	49.65	37975.32	2233.83
2021	26	844	44.33	53497.32	2809.72
2022	27	844	39.58	69019.32	3236.56
2023	28	844	35.34	100063.32	4189.58
2024	29	844	31.55	84541.32	3160.43
2025	30	844	28.17	37975.32	1267.54
2026	31	844	25.15	37975.32	1131.73
2027	32	10627	282.77	37975.32	1010.47
2028	33	30449	723.40	37975.32	902.21
2029	34	21363	453.16	37975.32	805.54
2030	35	844	15.98	37975.32	719.23
2031	36	844	14.27	37975.32	642.17
2032	37	844	12.74	37975.32	573.37
2033	38	844	11.38	37975.32	511.94
2034	39	844	10.16	37975.32	457.09
2035	40	844	9.07	37975.32	408.11
2036	41	844	8.10	37975.32	364.39
2037	42	844	7.23	37975.32	325.35
2038	43	844	6.46	37975.32	290.49
2039	44	844	5.76	37975.32	259.36
2040	45	844	5.15	37975.32	231.57
2041	46	844	4.60	37975.32	206.76
2042	47	844	4.10	37975.32	184.61
2043	48	844	3.66	37975.32	164.83
2044	49	844	3.27	37975.32	147.17
2045	50		0.00		0.00
2046	51		0.00		0.00
	Total	339949	340200.66	2167118.88	521841.89

Note: B-Benefit C-Cost B2-O&M Cost M-Fuel Cost

Table 6–24 Effective Energy of the Chespi P/S: (ECHP) ($Q=50 m^3/s$)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.6	62.1	78.8	81.4	74.7	64.3	55.7	49.9	65.0	73.1	80.4	797.9
1966	73.6	58.0	77.6	74.6	73.3	54.1	59.4	42.1	51.0	64.7	66.0	80.4	774.8
1967	74.7	73.3	80.4	71.1	65.3	73.3	71.2	62.8	39.6	60.0	56.0	40.6	768.1
1968	53.1	62.7	80.8	76.7	51.8	57.5	67.7	43.1	50.2	78.1	73.8	59.0	754.5
1969	60.1	62.6	66.6	78.8	77.8	71.0	62.4	61.0	55.1	77.0	78.8	81.4	832.5
1970	81.4	73.5	81.4	78.8	81.4	77.6	57.9	62.2	61.5	54.5	78.5	71.5	860.2
1971	76.4	72.4	81.4	78.8	81.1	73.9	55.4	38.6	51.5	77.7	77.3	75.1	839.6
1972	76.2	74.4	81.1	78.6	81.4	76.0	77.9	48.1	37.6	41.4	73.2	78.3	823.9
1973	71.0	66.2	68.9	78.6	73.6	64.6	56.6	62.2	36.2	41.4	78.7	81.4	779.3
1974	54.9	72.8	79.1	66.2	81.4	78.8	81.4	72.9	61.6	81.4	78.8	76.6	885.9
1975	81.4	73.5	81.4	78.8	81.4	78.8	81.4	81.4	78.8	75.5	78.8	77.2	948.4
1976	79.3	76.1	79.0	78.3	81.4	78.8	79.3	72.5	43.1	49.3	71.4	74.3	862.8
1977	68.0	67.4	73.8	78.3	79.3	74.3	70.5	62.7	55.8	70.4	59.0	53.5	818.2
1978	42.0	32.0	69.4	78.4	73.2	66.5	61.7	50.9	48.2	46.8	40.1	55.5	664.6
1979	44.5	30.6	74.4	76.1	80.6	74.4	55.0	50.3	63.7	53.8	42.9	42.4	688.7
1980	52.3	72.2	81.1	78.8	79.3	70.0	52.7	45.6	40.3	62.9	66.2	64.8	766.3
1981	57.2	61.7	79.6	78.8	77.8	52.9	66.7	42.9	43.2	41.6	59.5	53.3	715.2
1982	79.5	70.9	80.3	78.5	81.4	63.1	53.4	55.3	46.6	59.0	77.7	52.7	808.4
1983	81.4	73.5	81.4	78.8	81.4	74.9	57.8	51.0	48.5	57.3	59.5	52.5	798.0
1984	81.4	76.2	81.4	78.8	81.4	78.8	76.9	49.5	78.4	81.4	78.8	74.4	917.4
Average	67.4	64.9	77.1	77.2	77.3	70.7	65.5	55.5	52.0	62.5	68.7	66.3	805.1
Max.	81.4	76.2	81.4	78.8	81.4	78.8	81.4	81.4	78.4	81.4	78.8	81.4	948.4
Min.	42.0	30.6	62.1	66.2	51.8	52.9	53.4	38.6	36.2	41.4	40.1	40.6	664.6

Table 6–25 Effective Energy of the Chespi P/S: (ECHP) ($Q=60m^3/s$)

Unit：GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	64.3	93.2	97.7	81.4	66.9	57.0	50.0	68.5	91.7	91.0	869.4
1966	76.8	59.9	85.5	80.8	77.2	54.8	63.2	42.1	52.2	66.5	70.4	91.0	820.5
1967	80.1	85.0	93.0	75.0	65.5	80.6	78.4	66.1	39.6	62.4	58.0	40.6	824.3
1968	54.8	68.0	93.8	87.8	51.8	59.7	73.9	44.0	50.8	39.2	80.0	59.2	813.0
1969	60.9	67.3	69.9	94.4	87.2	76.6	65.1	64.9	56.9	84.4	93.7	97.3	918.6
1970	96.9	88.2	97.7	94.5	97.7	90.2	58.2	66.2	63.1	55.2	91.6	77.4	977.0
1971	86.7	85.9	97.1	93.7	92.8	78.6	59.7	38.6	53.0	87.5	90.1	83.0	946.7
1972	83.9	87.0	94.1	93.4	97.2	85.2	85.2	48.1	38.1	41.4	82.7	88.2	924.6
1973	73.2	70.0	75.8	93.1	79.7	68.1	60.8	63.0	36.4	42.5	93.2	97.0	852.8
1974	55.5	84.7	90.2	67.8	97.7	94.5	97.1	72.9	61.6	97.7	94.5	87.5	1.001.7
1975	96.6	87.5	97.7	94.5	97.7	94.5	97.7	97.7	79.9	81.6	94.0	87.2	1.106.6
1976	90.1	90.0	90.9	91.8	96.7	94.5	90.3	73.8	43.1	49.3	75.4	80.1	966.1
1977	68.4	71.9	80.1	91.0	83.9	80.5	75.8	63.4	58.4	70.4	59.0	53.5	830.6
1978	43.7	32.0	73.7	92.7	80.8	72.6	63.6	51.9	48.2	47.6	40.1	57.0	703.8
1979	44.5	30.6	81.3	83.3	92.6	82.5	55.3	50.6	63.9	53.8	42.9	42.4	723.6
1980	53.0	82.5	91.8	93.3	87.1	76.3	53.1	45.8	40.3	66.3	68.8	66.9	825.3
1981	58.3	65.1	96.9	90.7	86.8	52.9	75.1	41.8	43.2	41.6	61.3	54.0	767.7
1982	81.6	75.2	89.2	90.7	93.9	65.4	55.0	55.8	46.6	72.7	88.4	92.2	906.7
1983	96.1	86.9	97.6	94.5	97.7	81.4	59.4	51.0	48.5	52.5	60.1	88.1	913.8
1984	96.4	91.4	97.7	94.5	97.7	94.5	76.9	49.5	78.4	91.7	81.7	73.4	1.023.8
Average	72.8	72.9	87.9	89.5	88.1	78.2	70.5	57.2	52.6	66.1	75.9	75.4	885.8
Max.	96.9	91.4	97.7	94.5	97.7	94.5	97.7	97.7	79.9	97.7	94.5	97.3	1.106.6
Min.	43.7	30.6	64.3	67.8	51.8	52.9	38.6	38.6	36.4	41.4	40.1	40.6	703.8

Table 6–26 Effective Energy of the Chespi P/S: (ECHP) ($Q=80m^3/s$)

Unit : GWH

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1965	58.9	48.8	67.1	110.8	121.0	86.4	70.4	58.1	50.0	72.0	112.6	98.6	954.7
1966	78.9	61.5	93.3	86.3	81.0	54.8	66.4	42.1	54.3	67.8	73.9	103.2	863.7
1967	85.4	98.9	111.3	77.0	65.5	87.8	86.9	69.7	39.6	66.2	60.1	40.6	888.8
1968	55.1	74.5	111.4	99.8	51.8	60.7	80.5	44.0	50.8	101.4	87.1	59.2	875.9
1969	60.9	71.3	73.0	121.2	99.8	84.5	66.2	65.9	58.1	94.6	112.6	123.7	1,031.8
1970	121.0	116.4	128.9	116.7	126.4	106.9	58.2	70.5	63.5	55.2	110.1	80.9	1,154.8
1971	101.1	109.3	127.3	116.7	103.2	81.6	65.2	38.6	54.7	96.3	107.4	93.8	1,094.8
1972	96.2	106.9	110.6	117.7	121.9	94.6	90.0	48.1	38.4	41.4	96.8	100.5	1,063.0
1973	73.3	74.1	87.8	117.7	85.1	68.2	65.1	63.0	36.4	43.4	115.2	117.7	947.1
1974	55.5	98.0	101.5	68.5	129.6	102.7	97.1	72.9	61.6	107.9	118.6	104.6	1,118.5
1975	117.7	111.1	127.3	122.5	128.4	125.4	129.9	122.3	79.9	89.7	119.7	98.0	1,371.9
1976	99.3	106.5	106.5	113.3	119.7	118.7	105.8	74.0	43.1	49.3	76.3	83.3	1,095.8
1977	68.4	75.3	87.3	106.1	85.5	85.6	79.9	63.7	61.0	70.4	59.0	53.5	895.7
1978	45.9	32.0	77.4	109.2	91.3	78.4	64.2	52.0	48.2	47.6	40.1	57.5	743.8
1979	44.5	30.6	86.4	88.8	105.3	90.7	55.3	50.6	63.9	53.8	42.9	42.4	755.2
1980	53.6	94.0	100.5	108.7	92.0	80.7	53.1	45.8	40.3	69.1	69.8	67.2	875.0
1981	58.8	66.1	109.1	116.2	92.3	52.9	79.2	42.9	43.2	41.6	61.3	54.0	817.6
1982	96.2	79.1	92.0	102.3	107.8	66.2	56.5	55.8	46.6	76.0	99.5	119.3	997.3
1983	115.9	98.6	125.0	125.2	128.3	84.1	62.4	51.0	48.5	60.2	60.5	89.2	1,048.9
1984	96.4	121.8	97.7	126.0	130.2	94.5	76.9	49.5	78.4	91.7	81.7	73.4	1,118.2
Average	79.2	83.7	101.1	107.5	103.3	85.3	75.5	59.0	53.0	70.0	85.3	83.0	985.6
Max.	121.0	121.8	128.9	126.0	130.2	125.4	129.9	122.3	79.9	107.9	119.7	123.7	1,371.9
Min.	44.5	30.6	67.1	68.5	51.8	52.9	53.1	38.6	36.4	41.4	40.1	40.6	743.8

Fig. 6-2 Optimum Development Scale