7.2 建設材料

7.2.1 概 要

本計画では、堤高約60mのコンクリート重力式ダムが予定されている。本章では、そのコンクリートダムの建設に必要な骨材の供給候補地について、これまでに実施された調査・試験の総括と今後の提言を述べる。

7.2.2 既往調査

骨材の供給候補地選定のために、ＩＣＥにより既に何等かの調査ないしは試験が実施された地点は河床砂礫対象３地点、原石山３地点がある。

そのうち、骨材の供給候補地選定のための現地調査工事が実施されたのは、Quebrada Azul地点のみであり、その調査内容を Table 7-26及び7-27 に示す。その概要は以下のとおりである。

コアボーリング：９孔、　合計　85.2m

弾 性 波 探 査：６測線　合計 794　m（ただし、ＪＩＣＡチームがデータを入手したのは２測線、合計 341m）

室内試験は計６地点すべてにおいて実施されており、その結果を Table 7-26 に示す。室内試験としてはSoundness及びAbrasionの測定が実施されている。これらの試験はASTM C-131, C-33及びC-88に準拠して実施されている。Soundness及びAbrasionの測定が実施されている試料数はそれぞれの地点において以下のとおりである。

Rio Paquita　地点：３試料
Rio Naranjo　地点：７試料
Rio Canas　　地点：１試料
Quebrada Azul 地点：２試料
Los Alacranes 地点：１試料

7.2.3 調査地点

(1) 河床砂礫対象地点

(a) 位 置

河床砂礫対象地点として：ＩＣＥによりPaquita川、Naranjo川及びCanas川の３地点で調査が実施されている。

Paquita川地点は本計画における発電所予定地点の下流約1.7kmの標高約40m

付近に位置している。ダムサイトからの直線距離は約８kmである。

Naranjo川地点は本計画におけるダムサイトのはるか下流、標高約70m付近のNaranjo川がほぼ完全に海岸沿いの低地に出た付近に位置している。ダムサイトからの直線距離は約12kmに達する。Canas川はPaquita川に河口の手前約３km、標高約10kmの地点で右岸側より合流する河川である。Canas川地点はそのCanas川がほぼ完全に海岸沿いの低地に出た付近の標高約50m付近に位置している。ダムサイトからはそのほぼ西方、直線距離にして約15kmに達する位置にある。

(b) 現地調査工事

河床砂礫を対象とした３地点においては記述したようにＩＣＥにより既に試料が採取され、室内試験が実施されているが、いずれの地点においてもコンクリート骨材の候補対象としての河床砂礫の賦存量を把握するための調査工事は実施されていない。

(c) 室内試験

Riverbed Deposits Siteとしては、ＩＣＥにより既に試料が採取され、室内試験として Soundness 及び Abrasion の測定が実施されており、その結果を Table 7-29 に示すが、その概要は以下のとおりである。

SoundnessはRio Paquita川地点において、32～53%、Rio Naranjo川地点において５～28%、Canas川地点において、22%となっている。

AbrasionはPaquita川地点において、22～30%、Naranjo川地点において９～21%、Canas川地点において、21%となっている。

(d) 評　価

SoundnessはNaranjo川地点において18%以下の試料が多く、ほぼ良好と言うことができるが、他の２地点においては高い値を示し、良好とは言いがたい。

Abrasionに関してはいずれの地点においても50%以下の値を示し、特に問題はないものと考えられる。

このように、河床砂礫を対象とした３地点においては室内試験が実施され、質的には問題がないと思われる地点もあるが、いずれの地点においてもコンクリー

ト骨材の候補対象としての河床砂礫の賦存量を把握するための調査工事は実施されていない。さらに、これら３地点はいずれもダム地点から遠距離にあり、コンクリート骨材の供給候補地としては当面調査対象からはずすべきと考えられる。

(2) 原石山

(a) 位　置

原石山として、ＩＣＥによりダム地点 Adit No.1, Quebrada Azul地点及びLos Alacranes地点の３地点で調査が実施されている。

ダム地点 Adit No.1は既述したように下流ダム地点の右岸に掘削された地質調査用の横坑である。

Quebrada Azul地点はNaranjo川の上流、標高約580m付近に位置する。ダム地点からの直線距離は約３kmである。

Los AlacranesはNaranjo川に標高290m付近で右岸側から合流する支流(Quebrada Lagartija) の源流域標高約520m付近に位置する。ダムサイトからの直線距離は約３kmである。

(b) 調査工事

既述したように原石山３地点のうち、採石のための調査工事がＩＣＥにより既に実施された地点はQuebrada Azul地点のみである。調査内容を Table 7-26及び7-27 に示す。

ボーリング孔及び弾性波探査の結果によると本地点では、最大厚さ約10m程度の表層体積物及び数mの風化層の深部には新鮮な砂岩が一部に礫岩を伴ってほぼ一様に分布している。小規模な断層は存在するが、それに伴う破砕帯は小さい。

(c) 室内試験

原石山地点のSoundness及びAbrasionの測定結果を Table 7-29 に示すが、その概要は以下のとおりである。

Soundnessはダム地点 Adit No.1において23%、Quebrada Azul地点において７～８%、Los Alacranes地点において57%となっている。

Abrasionはダム地点 Adit No.1において40%、Quebrada Azul地点において25

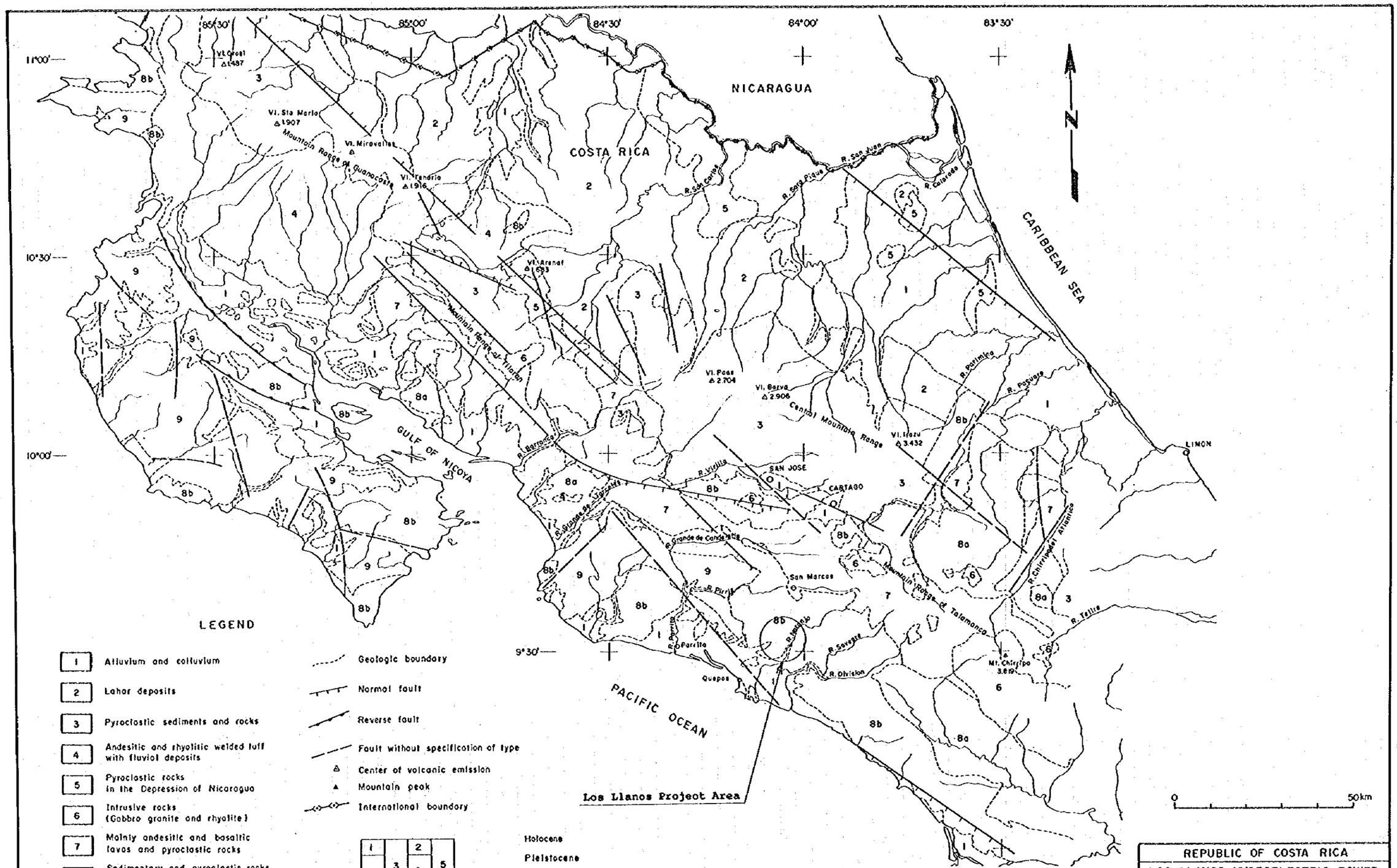
～26%、Los Alacranes地点において、32%となっている。

(d) 評　価

SoundnessはQuebrada Azul地点のみが18%以下の値を示し、良好と言うことができるが、他の2地点においては高い値を示し、良好とは言いがたい。

Abrasionはいずれの地点においても50%以下の値を示し、特に問題はないものと考えられる。

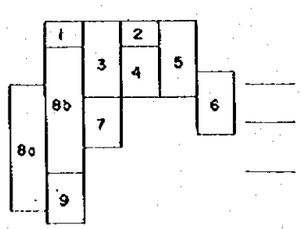
このように原石山3地点において室内試験が実施され、試験試料数が少なく即断はできないが、Quebrada Azul地点のみが品質的には問題がないと思われる数値が出ている。また、この地点における調査工事の結果から地質状況、風化状況を考えると原石山としての骨材候補岩石賦存量（本地点の場合新鮮な砂岩）も本計画におけるダムのためには充分存在すると考えられる。しかし、本地点はダムサイトからの距離がNaranjo川の流路沿いには約6㎞に達し、やや遠距離であることから、もっとダムサイトに近い場所に原石山地点を求めることが望ましい。



LEGEND

1	Alluvium and colluvium
2	Lahar deposits
3	Pyroclastic sediments and rocks
4	Andesitic and rhyolitic welded tuff with fluvial deposits
5	Pyroclastic rocks in the Depression of Nicaragua
6	Intrusive rocks (Gabbro granite and rhyolite)
7	Mainly andesitic and basaltic lavas and pyroclastic rocks
8a	Sedimentary and pyroclastic rocks with limestone
8b	Sedimentary rocks (Limestone sandstone and claystone)
9	Peridotite and tholeiitic basalt intercalated with pelagic sedimentary rocks

- Geologic boundary
- Normal fault
- Reverse fault
- Fault without specification of type
- △ Center of volcanic emission
- ▲ Mountain peak
- International boundary



Column of stratigrafic correlation

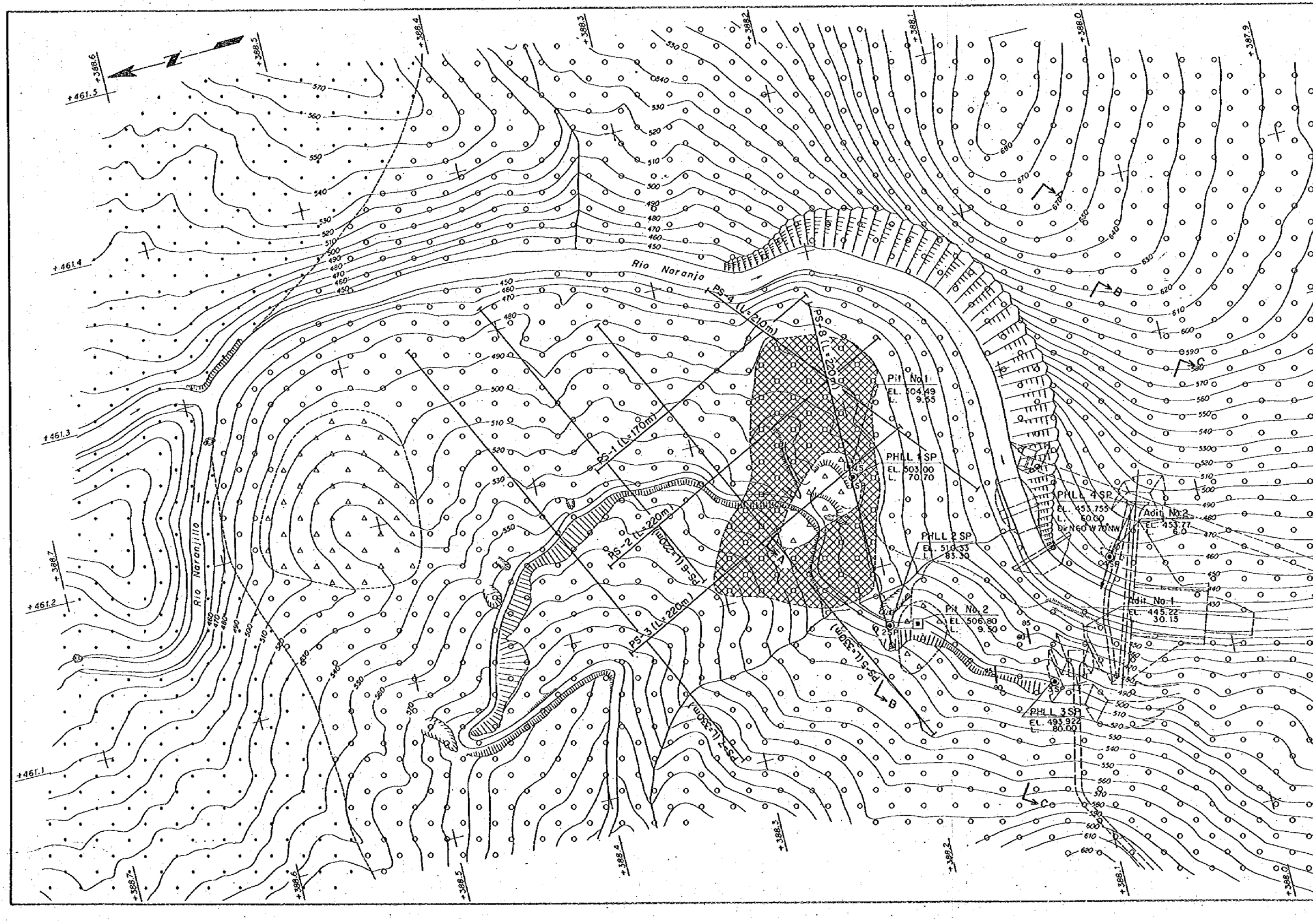
Note: This map is quoted from "INFORME FINAL MAPA GEOLOGICO DE COSTA RICA" by ICE in 1988.

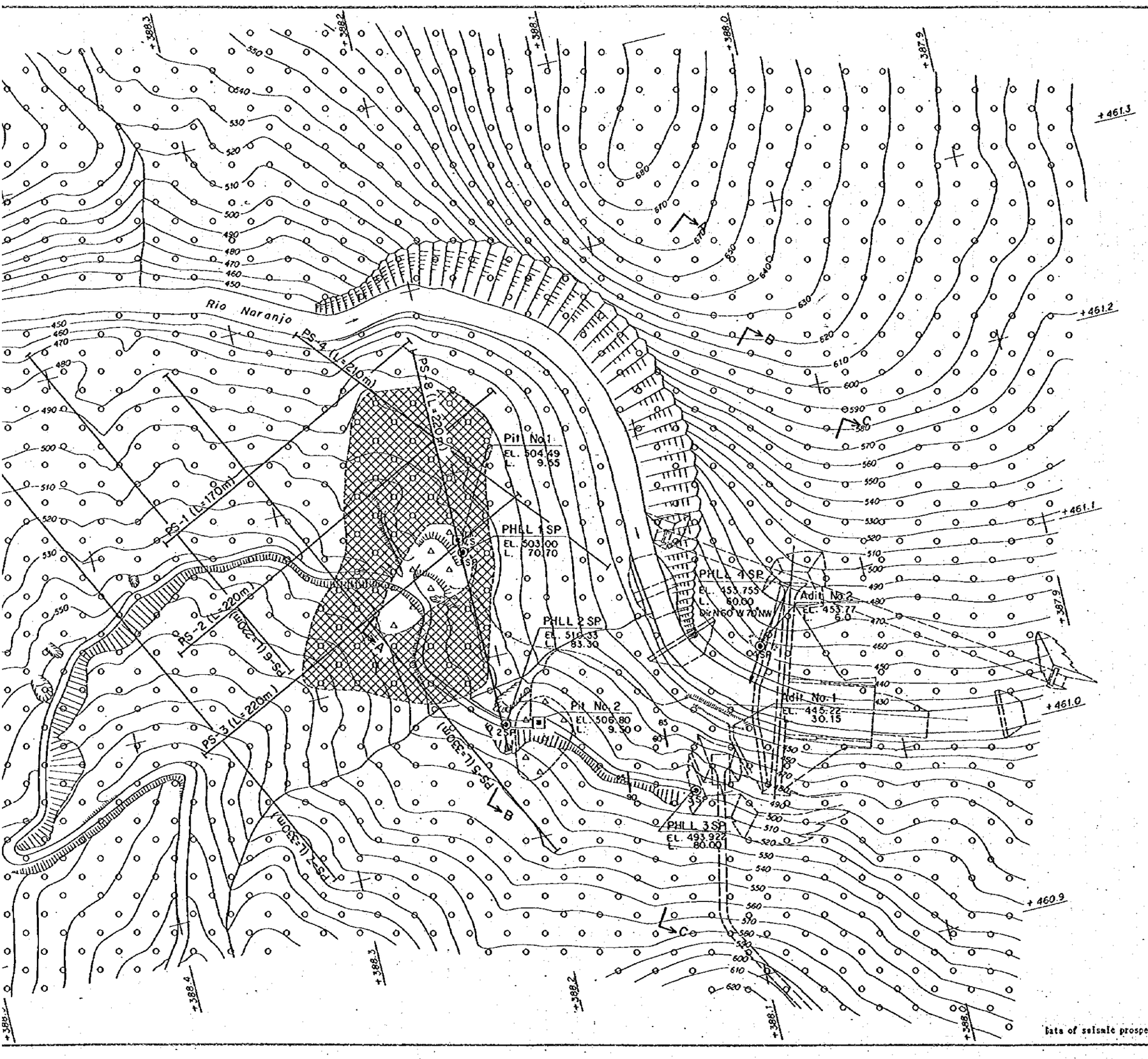
REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC MAP OF COSTA RICA

Fig. 7-1


N
Rio Naranjo
Rio Naranjillo
PS-4 (L=210m)
PS-8 (L=220m)
PS-1 (L=170m)
PS-2 (L=220m)
PS-6 (L=220m)
PS-3 (L=220m)
PS-5 (L=330m)
PS-7 (L=330m)
Pit No.1
EL. 504.49
L. 9.55
PHILL 1 SP
EL. 503.00
L. 70.70
PHILL 4 SP
EL. 453.755
L. 50.00
Dir N60°W 70°NW
Adit No.2
EL. 453.77
L. 6.0
PHILL 2 SP
EL. 519.33
L. 85.30
Pit No.2
EL. 506.80
L. 9.50
Adit No.1
EL. 445.22
30.15
PHILL 3 SP
EL. 493.922
L. 80.001
A
B
C
+388.7
+388.6
+388.5
+388.4
+388.3
+388.2
+388.1
+388.0
+387.9
+461.5
+461.4
+461.3
+461.2
+461.1



LEGEND

- Talus Deposits
- Conglomerate (Strongly Weathered)
- Conglomerate
- Sandstone
- Geologic Boundary
- Strike and dip of Bedding
- Adit
- Test Pit
- Drillhole
- Seismic Prospecting Traverse
- Geologic Section

0 — 100m

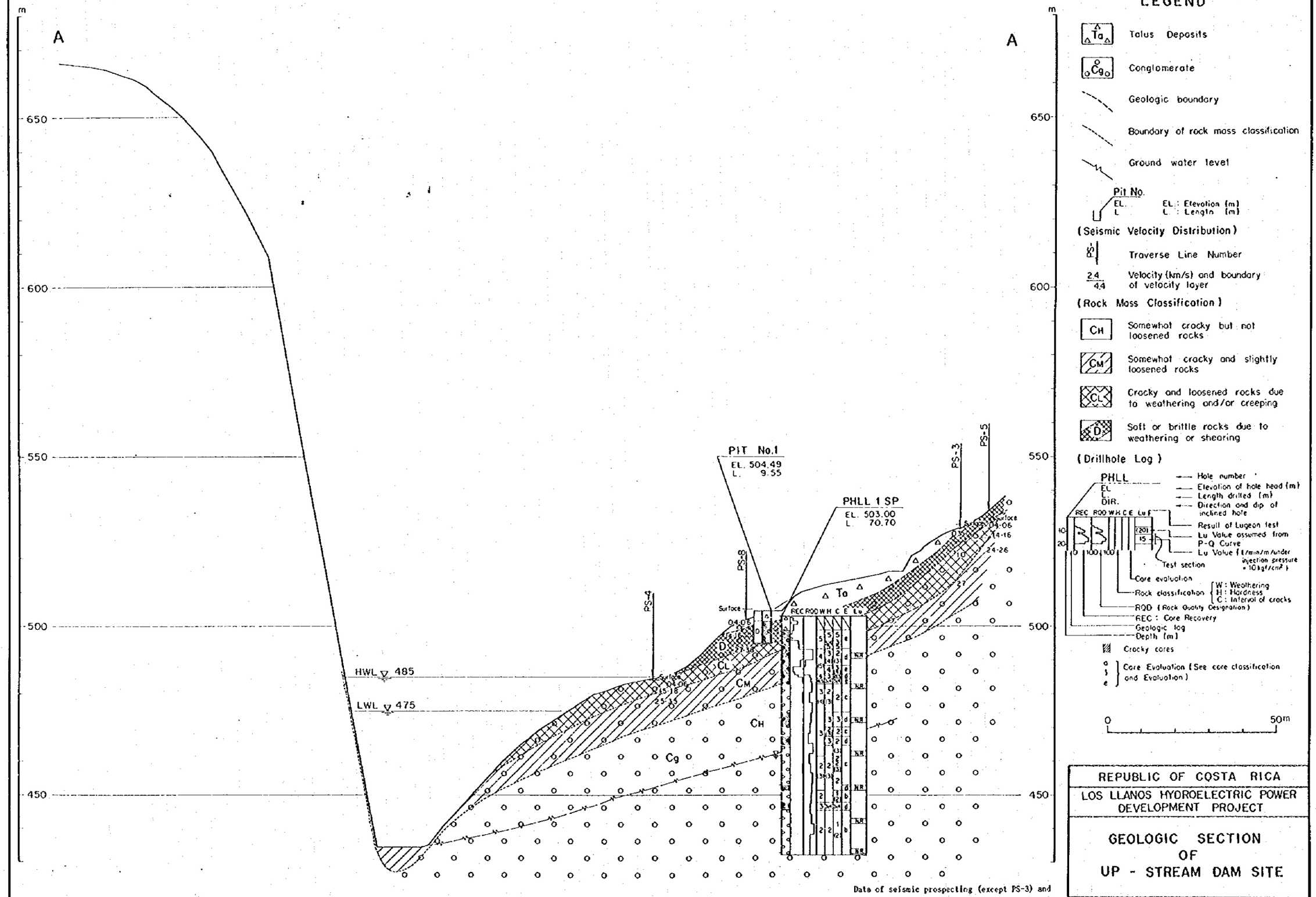
Data of seismic prospecting were offered by ICE.

REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC PLAN OF DAMSITE

Fig. 7-2 | Date :



LEGEND

- Talus Deposits (Ta)
- Conglomerate (Cg)
- Geologic boundary
- Boundary of rock mass classification
- Ground water level
- Pit No. / EL. / L — EL.: Elevation (m), L.: Length (m)

(Seismic Velocity Distribution)

- Traverse Line Number
- 2.4 / 4.4 — Velocity (km/s) and boundary of velocity layer

(Rock Mass Classification)

- CH — Somewhat cracky but not loosened rocks
- CM — Somewhat cracky and slightly loosened rocks
- CL — Cracky and loosened rocks due to weathering and/or creeping
- D — Soft or brittle rocks due to weathering or shearing

(Drillhole Log)

PHLL
EL
L
DIR.
REC RQD W H C E Lu F

- Hole number
- Elevation of hole head (m)
- Length drilled (m)
- Direction and dip of inclined hole
- Result of Lugeon test
- Lu Value assumed from P-Q Curve
- Lu Value (l/min/m/under injection pressure = 10 kgf/cm²)
- Test section
- Core evaluation
- Rock classification (W: Weathering, H: Hardness, C: Interval of cracks)
- RQD (Rock Quality Designation)
- REC: Core Recovery
- Geologic log
- Depth (m)
- Cracky cores
- a, b, c, d, e — Core Evaluation (See core classification and Evaluation)

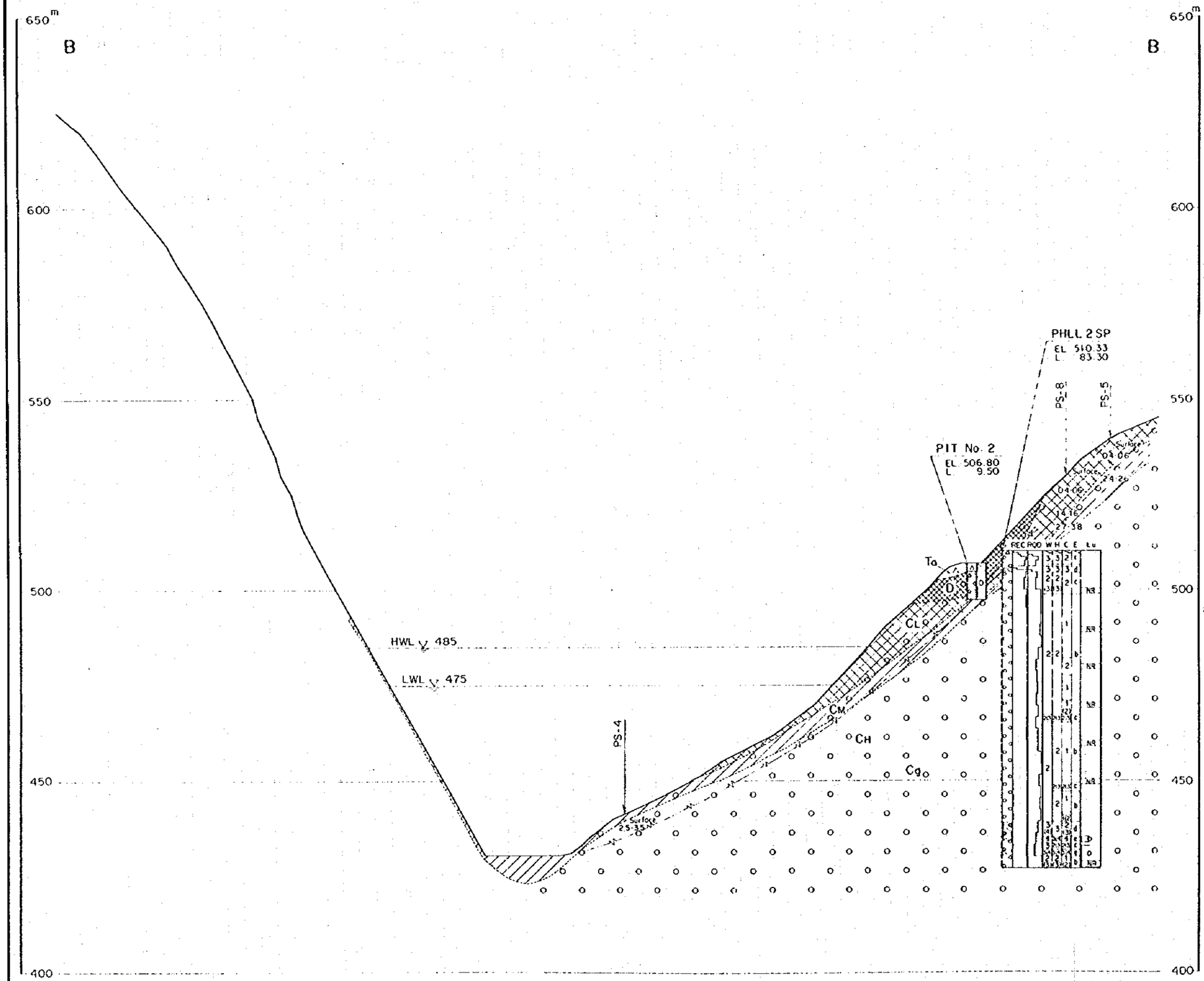
0 — 50m

REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC SECTION OF UP - STREAM DAM SITE

Fig. 7-3 | Date :



LEGEND

- Ta — Talus Deposits
- Cg — Conglomerate
- Geologic boundary
- Boundary of rock mass classification
- Ground water level
- Pit No. / EL. / L. — EL. : Elevation (m); L. : Length (m)

(Seismic Velocity Distribution)

- 8 — Traverse Line Number
- 2.4 / 4.4 — Velocity (km/s) and boundary of velocity layer

(Rock Mass Classification)

- CH — Somewhat cracky but not loosened rocks
- CM — Somewhat cracky and slightly loosened rocks
- CL — Cracky and loosened rocks due to weathering and/or creeping
- D — Soft or brittle rocks due to weathering or shearing

(Drillhole Log)

- PHLL — Hole number
- EL — Elevation of hole head (m)
- L — Length drilled (m)
- DIR. — Direction and dip of inclined hole
- REC ROD W H C E Lu — Result of Lugeon test
- Lu Value assumed from P-Q Curve
- Lu Value (l/min/m/under injection pressure ×10kg/cm²)
- Test section
- Core evaluation
- Rock classification — W : Weathering; H : Hardness; C : Interval of cracks
- ROD (Rock Quality Designation)
- REC : Core Recovery
- Geologic log
- Depth (m)
- Cracky cores
- o, j, e — Core Evaluation (See core classification and Evaluation)

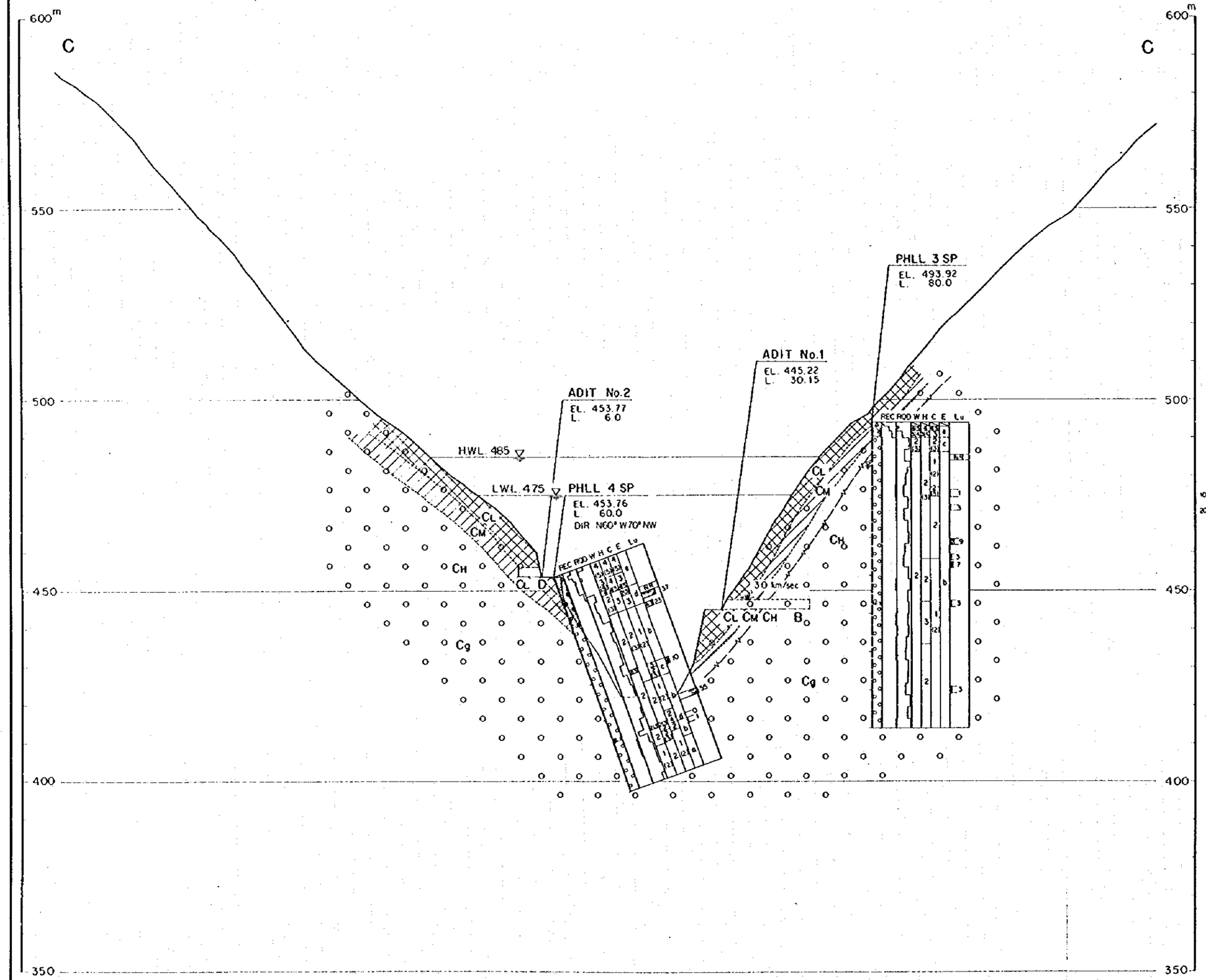
0 — 50m

REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC SECTION OF MID - STREAM DAM SITE

Fig. 7 - 4 | Date :



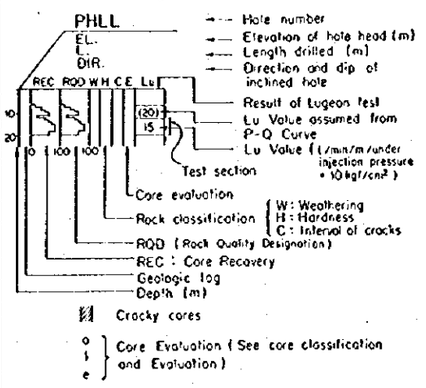
LEGEND

- Conglomerate
- Geologic boundary
- Boundary of rock mass classification
- Ground water level
- Adit No. / EL. / L. — EL. : Elevation (m), L. : Length (m)

(Rock Mass Classification)

- CH — Somewhat cracky but not loosened rocks
- CM — Somewhat cracky and slighty loosened rocks
- CL — Cracky and loosened rocks due to weathering and/or creeping
- D — Soft or brittle rocks due to weathering or shearing

(Drillhole Log)



0 — 50m

Data of drillhole (REC and ROD) were offered by ICE.

REPUBLIC OF COSTA RICA

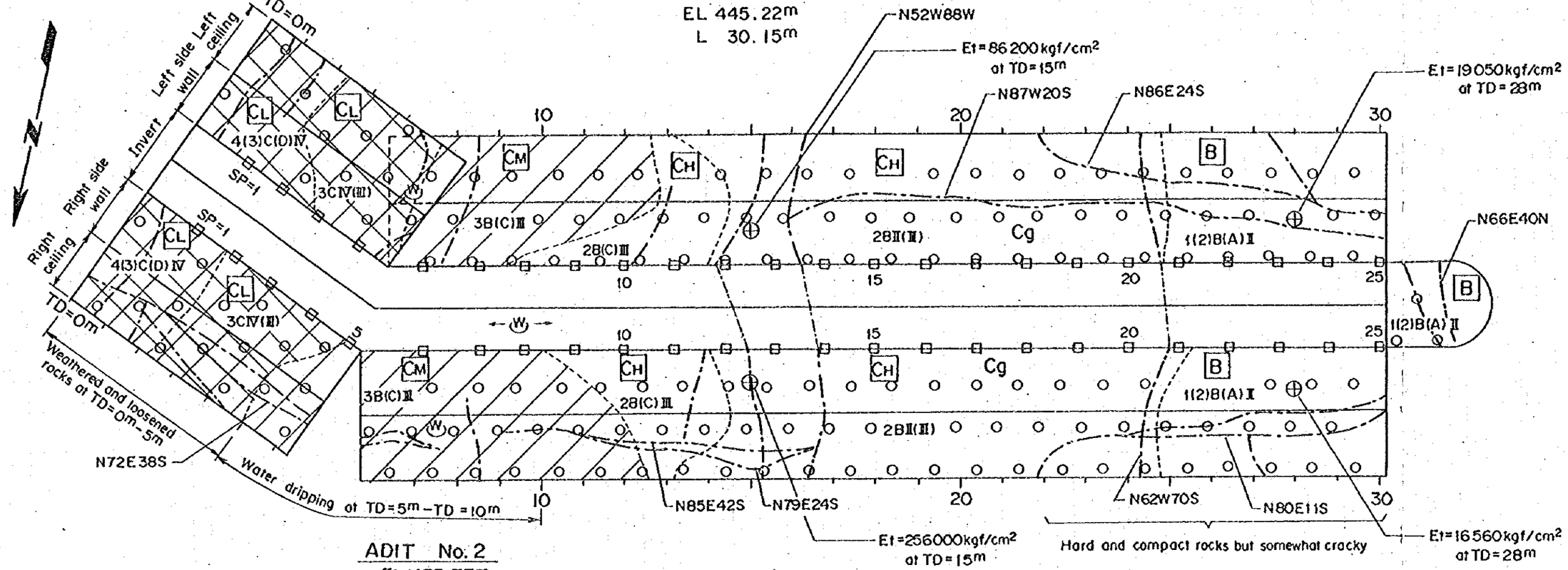
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC SECTION OF DOWN-STREAM DAM SITE

Fig. 7-5 | Date :

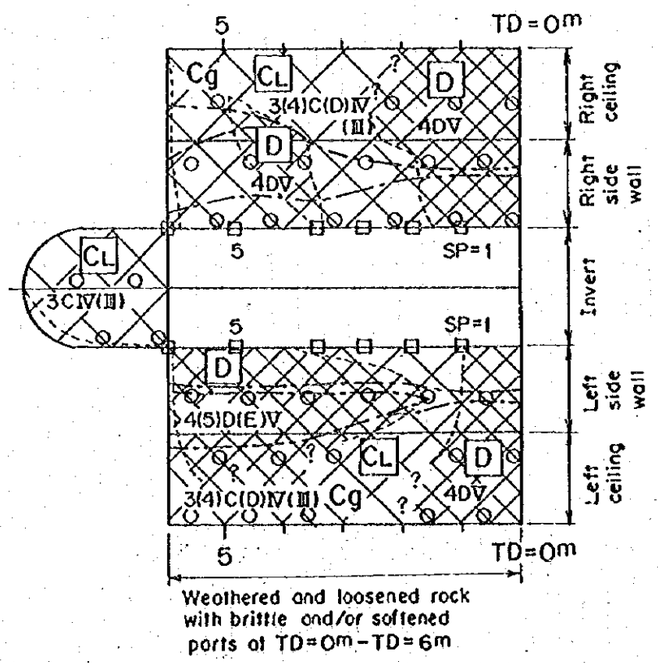
ADIT No. 1

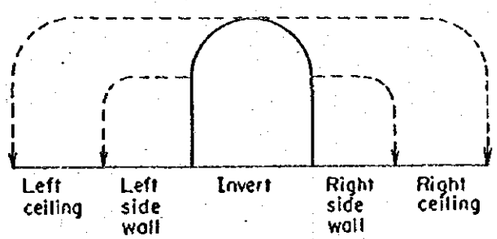
EL 445.22m
L 30.15m



ADIT No. 2

EL 453.77m
L 6.0 m



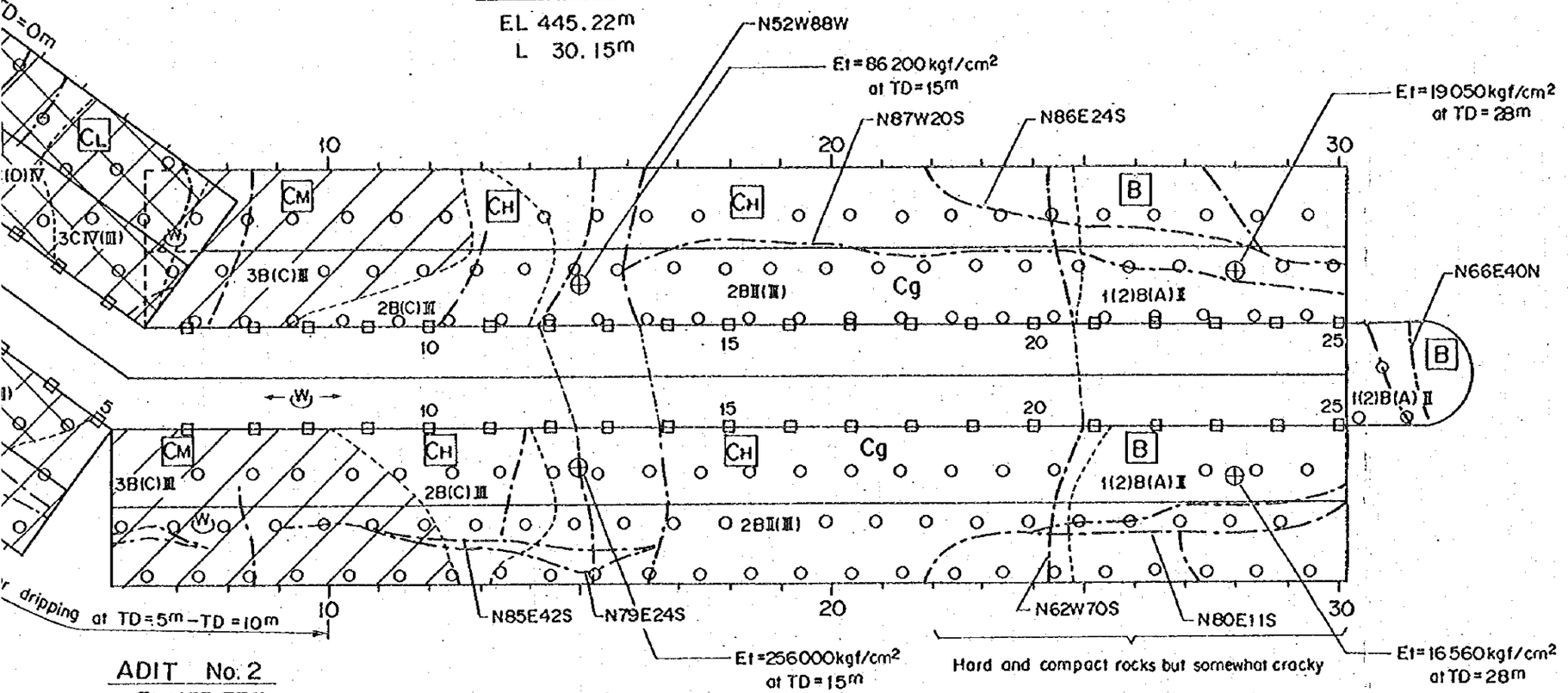


0 5m

Data of direction of adit and plate bearing test were o
by ICE.

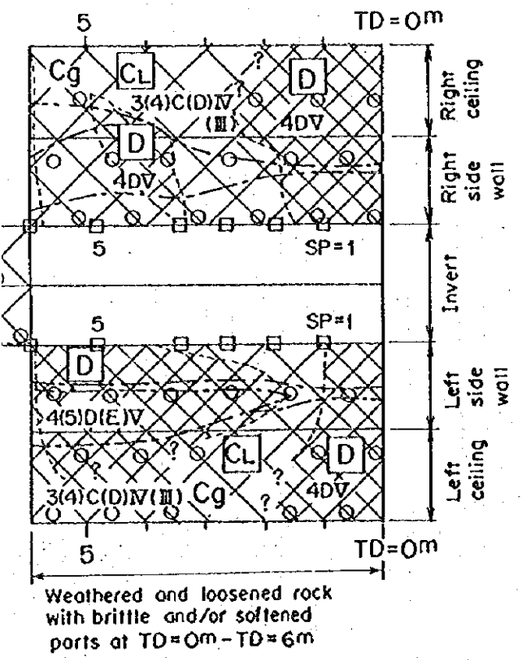
ADIT No. 1

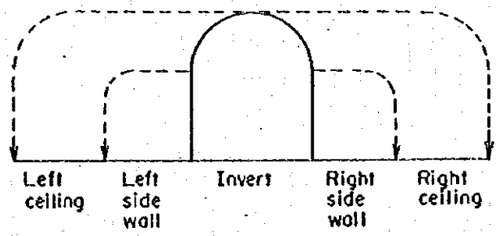
EL 445.22m
L 30.15m



ADIT No. 2

EL 453.77m
L 6.0 m





LEGEND

- Cg — Conglomerate
- Crack and/or joint
- (W) — Dripping water
- 3BII / 3CIV — Rock classification and its boundary
- TD — Adit distance (m) from its portal
- SP= — Supporting of adit and its number

(Rock Mass Classification)

- B — Generally fresh and solid but a little weathered rocks
- CH — Somewhat cracky but not loosened rocks
- CM — Somewhat cracky and slightly loosened rocks
- CL — Cracky and loosened rocks due to weathering and/or creeping
- D — Soft or brittle rocks due to weathering or shearing
- Et= — Location of plate jack test and its result (Et: Tangential elastic modulus)

Standard of Rock Classification for Adits

W	Weathering	H	Hardness	C	Interval of Cracks
1	Very fresh. No weathering of mineral coeponent.	A	Very hard. Broken into knifeedged pieces by strong hammer blow.	I	Over 100cm
2	Fresh. Some minerals are weathered slightly. Usually no broen crack.	B	Hard. Broken into pieces by strong hammer blow.	II	40-100cm
3	Fairly fresh. Some minerals are weathered. Cracks are stained and with weathered materials.	C	Somewhat brittle. Broken into pieces by medium hammer blow.	III	20-40cm
4	Weathered. Fresh portions still remain partially.	D	Very brittle. Easily broken into pieces by medium hammer blow.	IV	5-20cm
5	Strongly weathered. Most minerals are weathered and altered to second minerals.	E	Soft. Able to dig with hammer.	V	Under 5cm

0 — 5m

Data of direction of adit and plate bearing test were offered by ICE.

REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

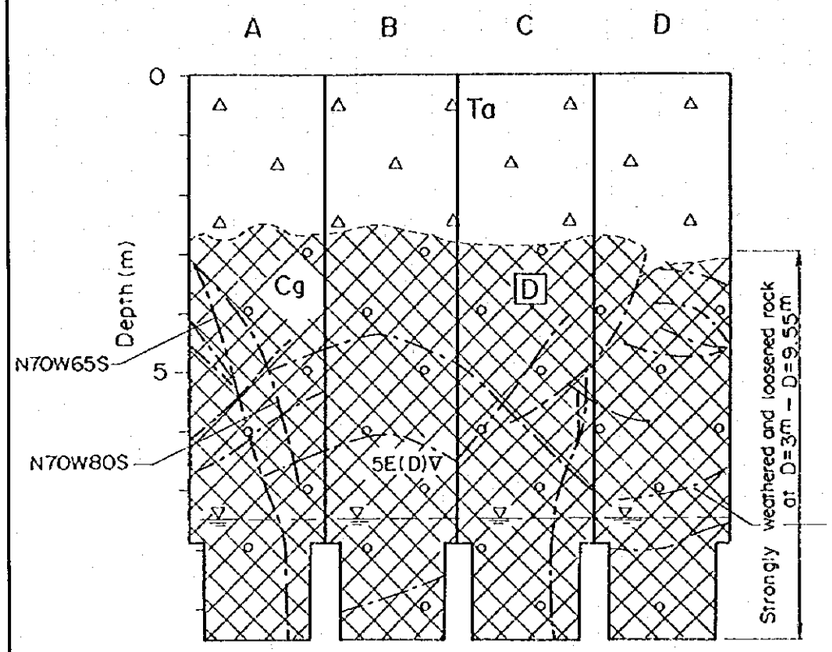
GEOLOGIC LOG OF ADIT

(ADITS No.1 and No.2)

Fig. 7-6 | Date:

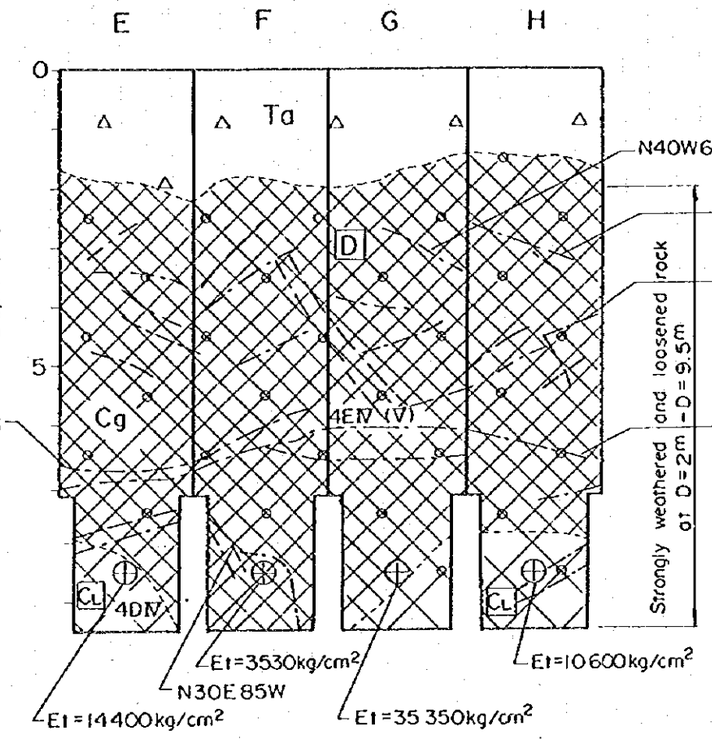
PIT No.1

EL 504.49m
L 9.55m



PIT No.2

EL 506.80m
L 9.5 m



LEGEND

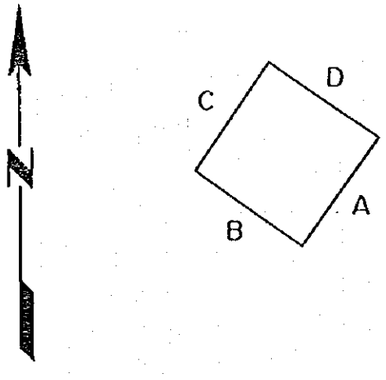
- Talus deposits
- Conglomerate
- Crack and/or joint
- 3BIII / 3CIV — Rock classification and its boundary

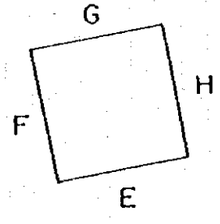
(Rock Mass Classification)

- CL — Cracky and loosened rocks due to weathering and/or creeping
- D — Soft or brittle rocks due to weathering or shearing
- E1 — Location of plate jack test and its result (E1: Tangential elastic modulus)

Standard of Rock Classification for Pits

W	Weathering	H	Hardness	C	Interval of Cracks
1	Very fresh. No weathering of mineral component.	A	Very hard. Broken into knifeedged pieces by strong hammer blow.	I	Over 100cm
2	Fresh. Some minerals are weathered slightly. Usually no brown crack.	B	Hard. Broken into pieces by strong hammer blow.	II	40-100cm
3	Fairly fresh. Some minerals are wethered. Cracks are stained and with weathered materials.	C	Somewhat brittle. Broken into pieces by medium hammer blow.	III	20-40cm
4	Weathered. Fresh portions still remain partially.	D	Very brittle. Easily broken into pieces by medium hammer blow.	IV	5-20cm
5	Strongly weathered. Most minerals are weathered and altered to second minerals.	E	Soft. Able to dig with hammer.	V	Under 5cm





0 5m

Data of geology, crack/joint and plate bearing test were offered by ICE.

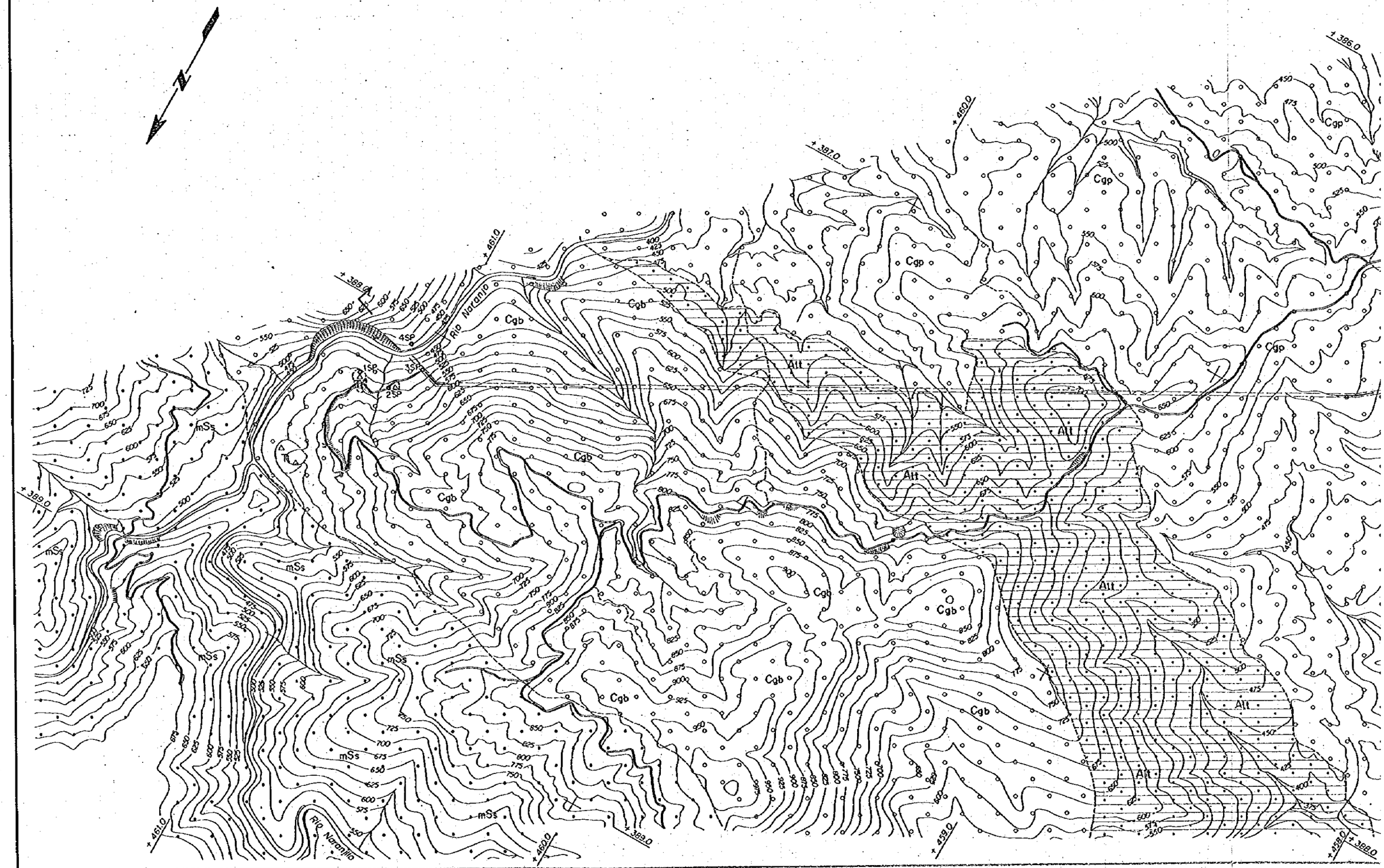
REPUBLIC OF COSTA RICA

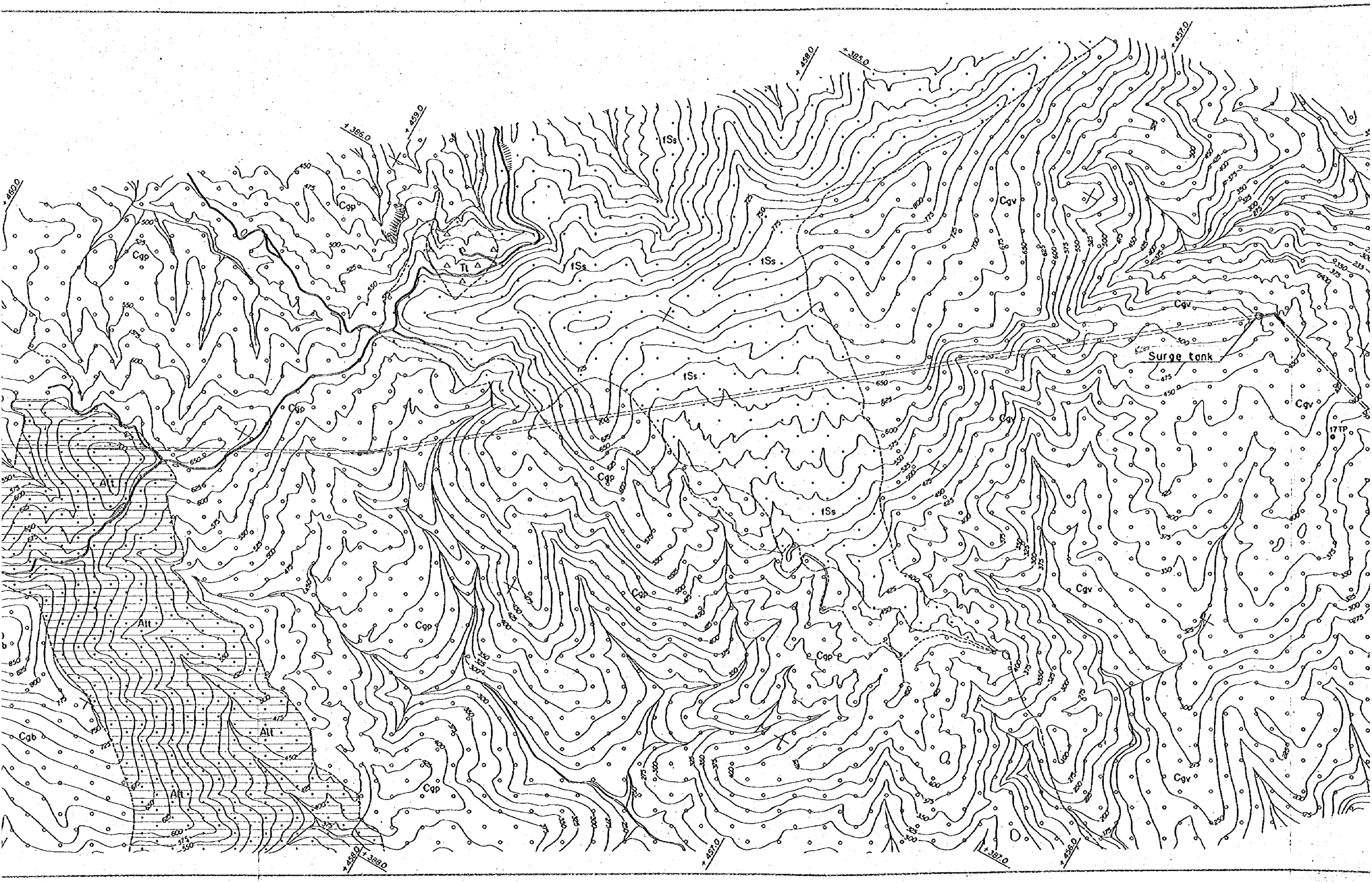
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC LOG OF PIT

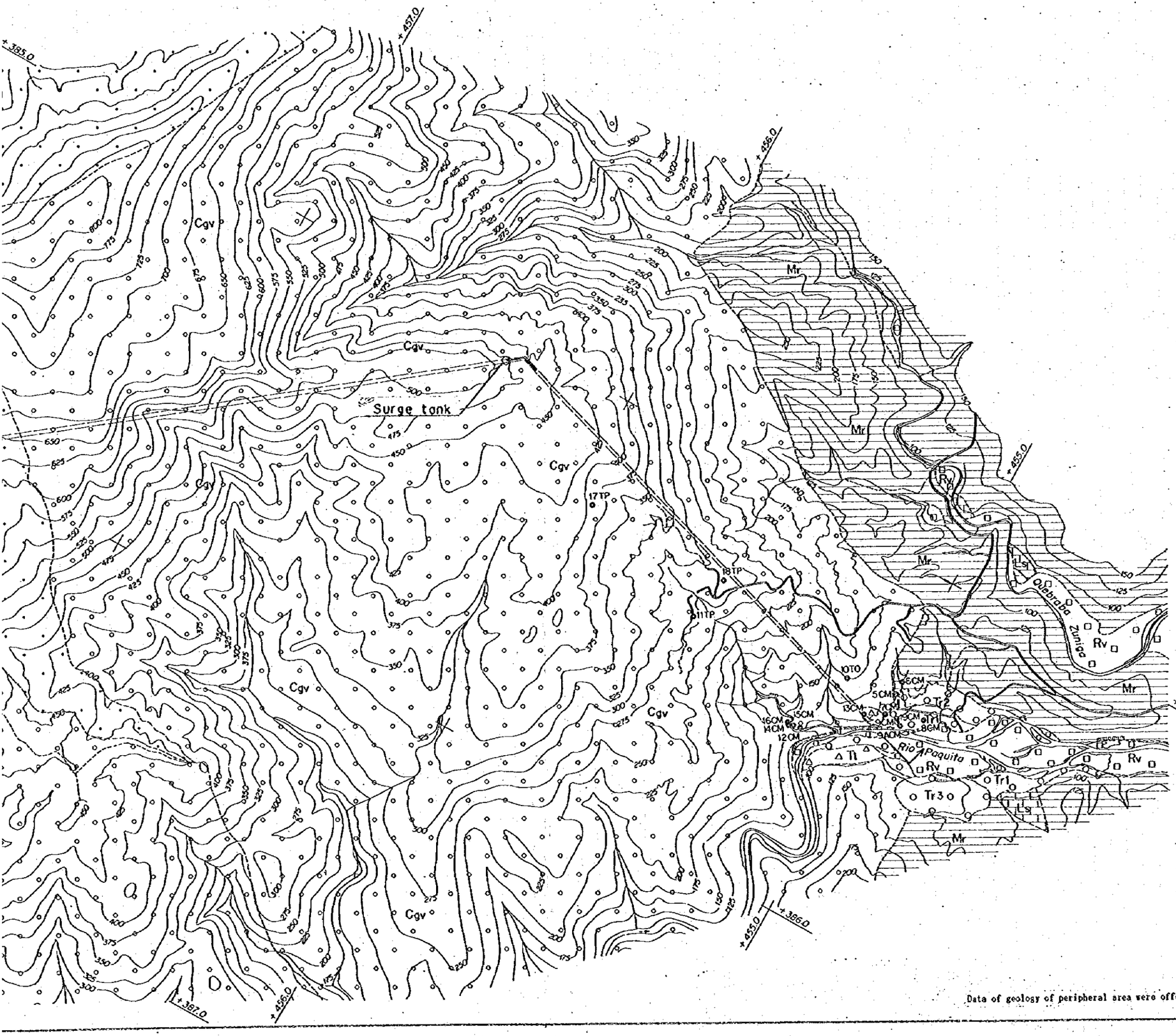
(PITS No.1 and No.2)

Fig. 7-7 | Date :


Río Naranjo
Río Naranjillo
Cgb
Cgp
Alt
mSs
+ 386.0
+ 387.0
+ 388.0
+ 389.0
+ 450.0
+ 451.0
+ 459.0



Surge tank
17TP
Cgp
Cgv
fSs
Alt
Tl
Cgb
+ 460.0
+ 386.0
+ 459.0
+ 458.0
+ 385.0
+ 457.0
+ 458.0
+ 388.0
+ 457.0
+ 387.0
+ 456.0



LEGEND

- Rv — Riverbed Deposits
- Tl — Talus Deposits
- Tr1 — Terrace Deposits (Lower)
- Tr2 — Terrace Deposits (Middle)
- Tr3 — Terrace Deposits (Upper)
- mSs — Sandstone (Medium)
- Cgb — Conglomerate (Boulder)
- Alt — Alternation of Sandstone and Siltstone
- Cgp — Conglomerate (Pebble)
- fSs — Sandstone (Fine)
- Cgv — Conglomerate (Volconic)
- Mr — Mudstone (Marl)
- Ls — Limestone
- Geologic boundary
- Fault
- Geologic Section

0 — 500m

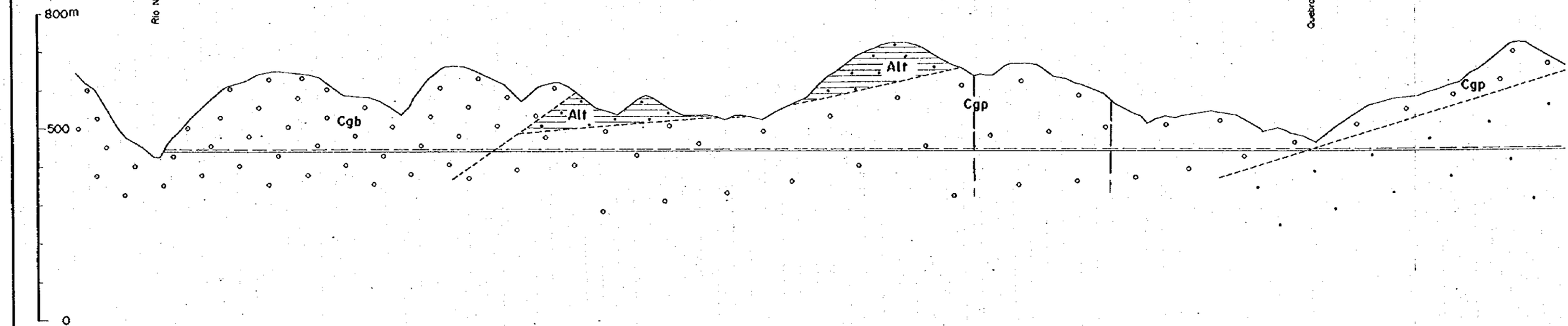
Data of geology of peripheral area were offered by ICE.

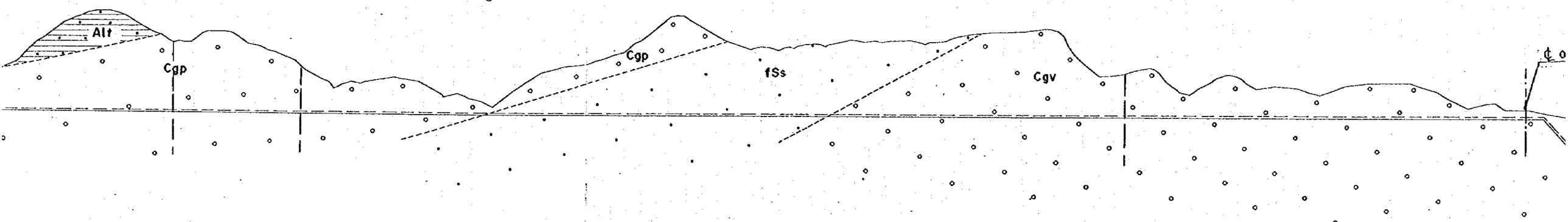
REPUBLIC OF COSTA RICA

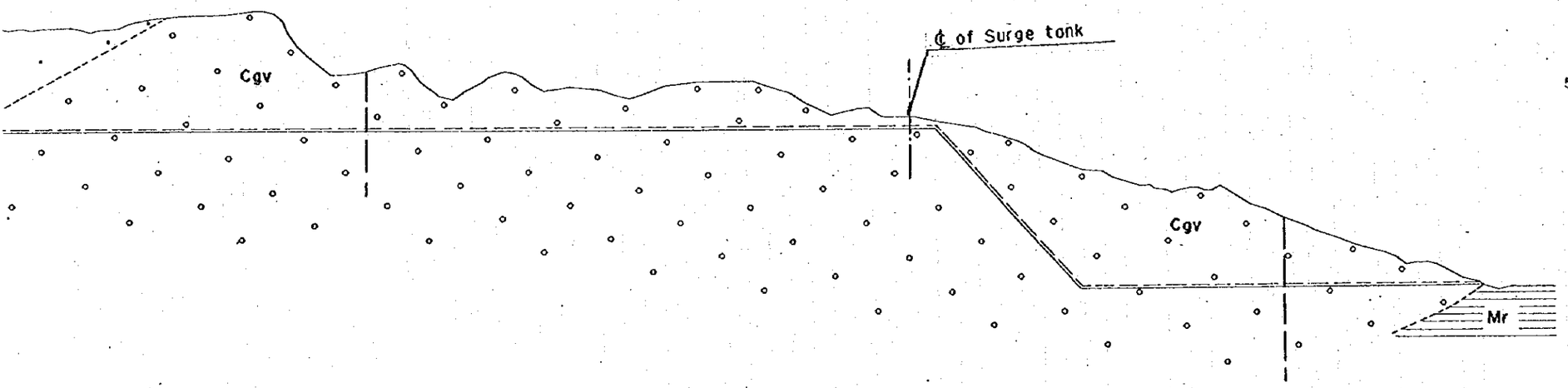
LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

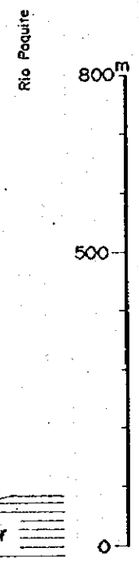
GEOLOGIC PLAN OF WATERWAY ALIGNMENT ROUTE

Fig. 7-8 | Date :


800m
500
0
Río Naranjo
Cgb
Alt
Alt
Cgp
Quebrada Jilguero
Cgp


Quebrada Jilguero
Alf
Cgp
Cgp
fSs
Cgv





LEGEND

- Rv — Riverbed Deposits
- Ti — Talus Deposits
- Tr I — Terrace Deposits (Lower)
- Cgb — Conglomerate (Boulder)
- Alt — Alternation of Sandstone and Siltstone
- Cgp — Conglomerate (Pebble)
- fSs — Sandstone (Fine)
- Cgv — Conglomerate (Volcanic)
- Mr — Mudstone (Marl)
- Geologic boundary
- Lineament by aero-photo interpretation

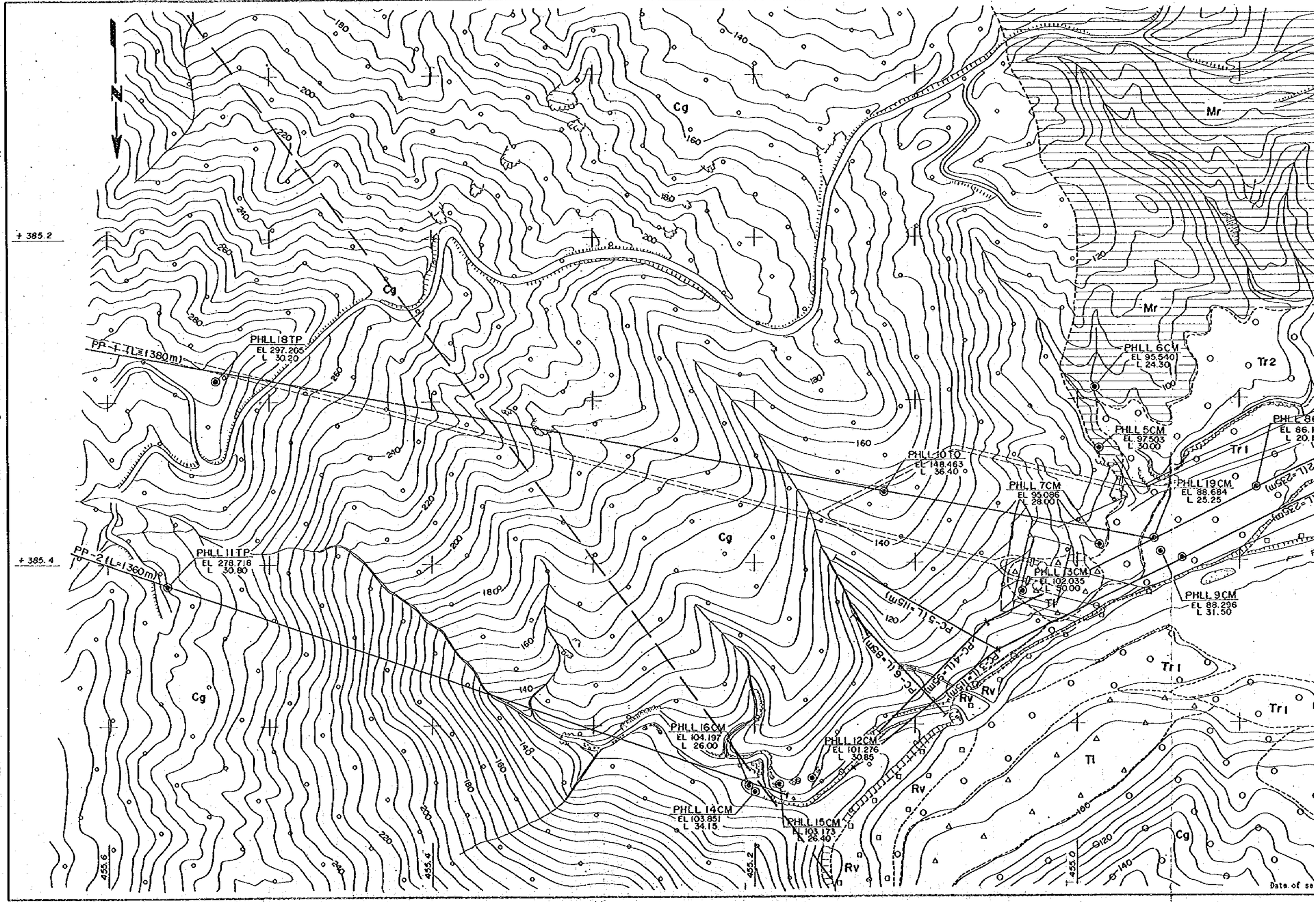
0 500m

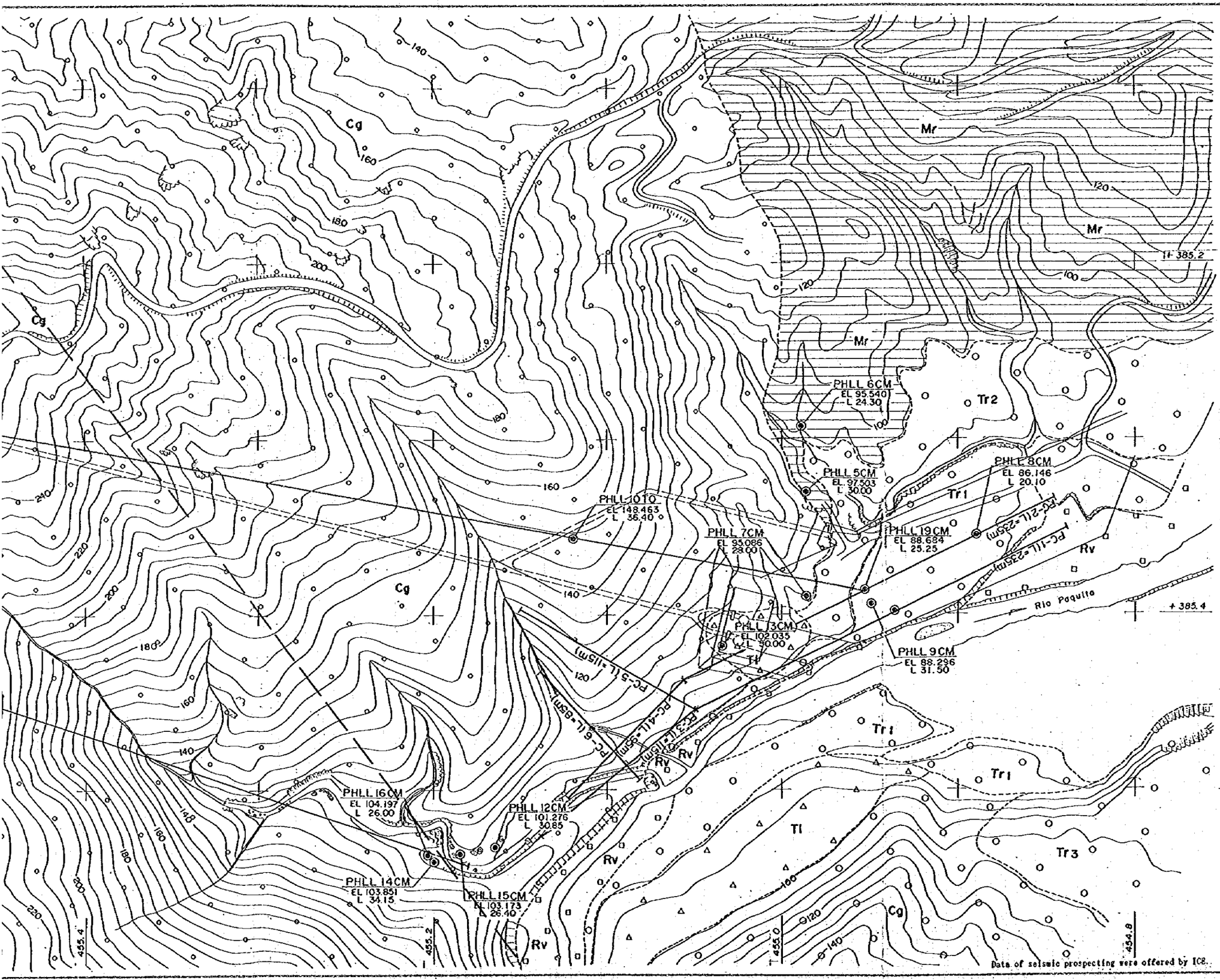
REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC SECTION
ALONG
HEADRACE TUNNEL ROUTE

Fig. 7-9 | Date :


N
+ 385.2
+ 385.4
PP-1 (L=1380m)
PP-2 (L=1360m)
PHLL 18TP
EL 297.205
L 30.20
PHLL 11TP
EL 278.718
L 30.80
PHLL 10TO
EL 148.463
L 36.40
PHLL 7CM
EL 95.086
L 28.00
PHLL 6CM
EL 95.540
L 24.30
PHLL 5CM
EL 97.503
L 30.00
PHLL 19CM
EL 88.684
L 25.25
PHLL 13CM
EL 102.035
L 30.00
PHLL 9CM
EL 88.236
L 31.50
PHLL 16CM
EL 104.197
L 26.00
PHLL 12CM
EL 101.276
L 30.85
PHLL 14CM
EL 103.851
L 34.15
PHLL 15CM
EL 103.173
L 26.40
PC-5 (L=115m)
PC-6 (L=85m)
PC-4 (L=95m)
PC-3 (L=115m)
Cg
Mr
Tr1
Tr2
Tl
Rv
455.6
455.4
455.2
455.0
Date of se



LEGEND

- Rv — Riverbed Deposits
- Tl — Talus Deposits
- Tr1 — Terrace Deposits (Lower)
- Tr2 — Terrace Deposits (Middle)
- Tr3 — Terrace Deposits (Upper)
- Cg — Conglomerate
- Mr — Mudstone (Marl)
- Geologic boundary
- Lineament by aero-photo interpretation
- Drillhole
- Seismic Prospecting Traverse
- Geologic Section

Data of seismic prospecting were offered by ICE.

REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC PLAN OF PENSTOCK ROUTE AND POWER STATION SITE

Fig. 7-10 | Date:

A

A

PHLL 18 TP
EL. 297.205
L. 30.20

RECROWH C E

300 m

200

100

0

1.0 km/s
1.8 km/s
2.1 km/s
0.9 km/s
3.6 km/s
Cg-a
1.8 km/s
0.3 km/s
0.9 km/s
1.6 km/s
2.7 km/s
2.3 km/s
1.0 km/s
Cg-d
0.8 km/s
1.6 km/s
4.0 km/s
Cg-c
3.0 km/s
1.0 km/s
1.7 km/s
2.1 km/s
4.0 km/s
Cg-b
2.8 km/s
4.5 km/s

PHLL 10 TO
EL. 148.463
L. 36.40

REC ROD W H C E

0.9 km/s
0.3 km/s
0.7 km/s
1.6 km/s

PHLL 7 CM
EL. 95.086
L. 28.0

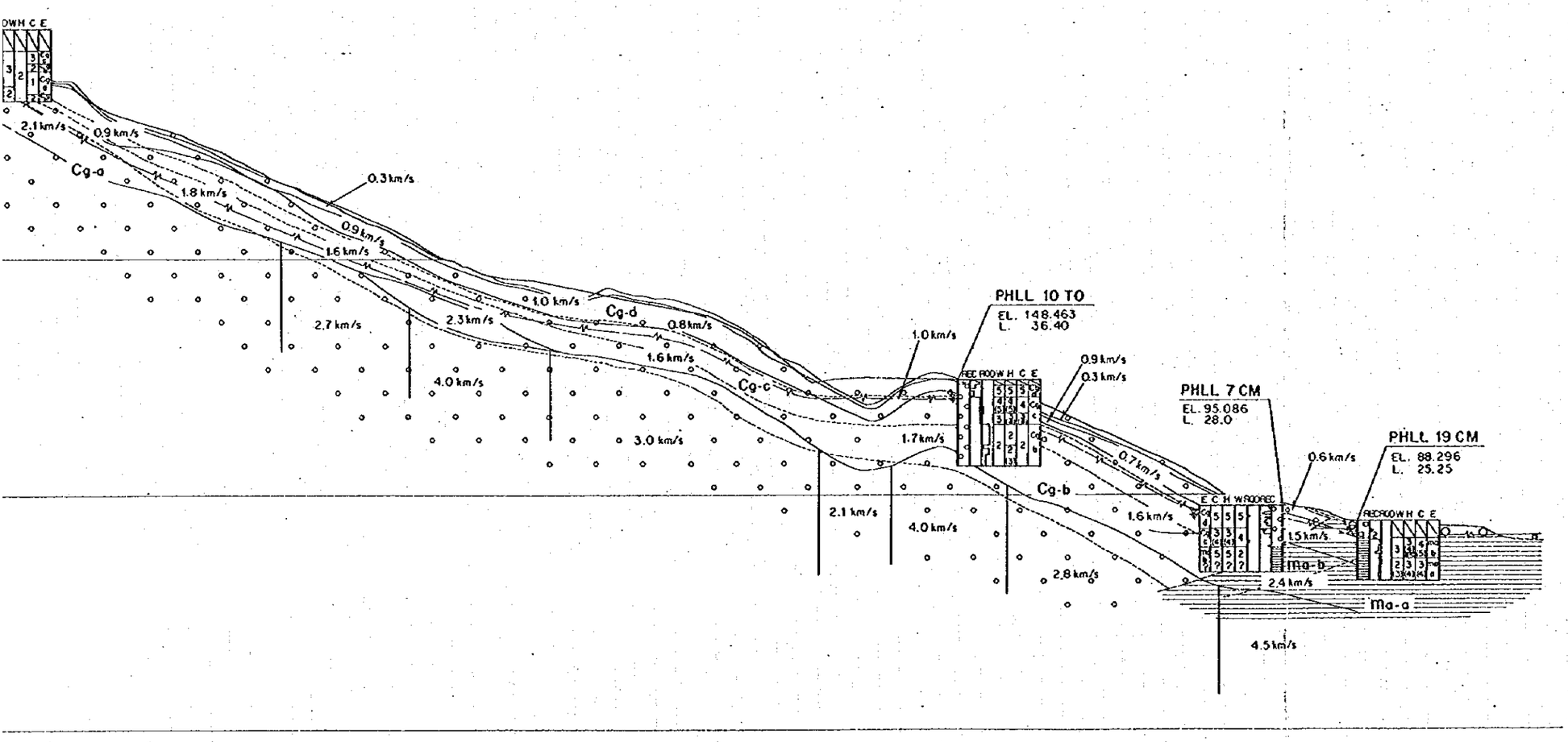
E C H WRZOREC

PHLL 19 CM
EL. 88.296
L. 25.25

0.6 km/s
1.5 km/s
Ma-b
2.4 km/s
Ma-a

REC ROD W H C E

Data of drillhole(REC and RQD) were offered by



LEGEND

- Riverbed Deposits
- Terrace Deposits (Lower)
- Terrace Deposits (Middle)
- Conglomerate
- Mudstone (Marl)
- Geologic boundary
- Boundary of rock mass classification
- Ground water level

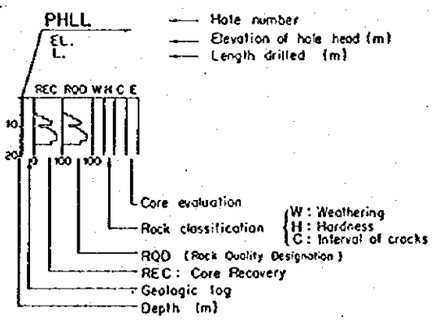
(Seismic Velocity Distribution)

- 2.4 / 4.4 — Velocity (km/s) and boundary of velocity layer

(Rock Mass Classification)

- Ma-a — See text

(Drillhole Log)



0 — 100 m

Data of drillhole(REC and RQD) were offered by ICE.

REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC SECTION OF PENSTOCK ROUTE (SECTION A - A)

Fig. 7-11 | Date :

B

B

PHLL 18 TP
EL. 297.205
L. 30.20

REC RQD W H C E

300 m

200

100

0

Cg-a

Cg-b

Cg-c

Cg-d

PHLL 13 CM
EL. 102.035
L. 50.00

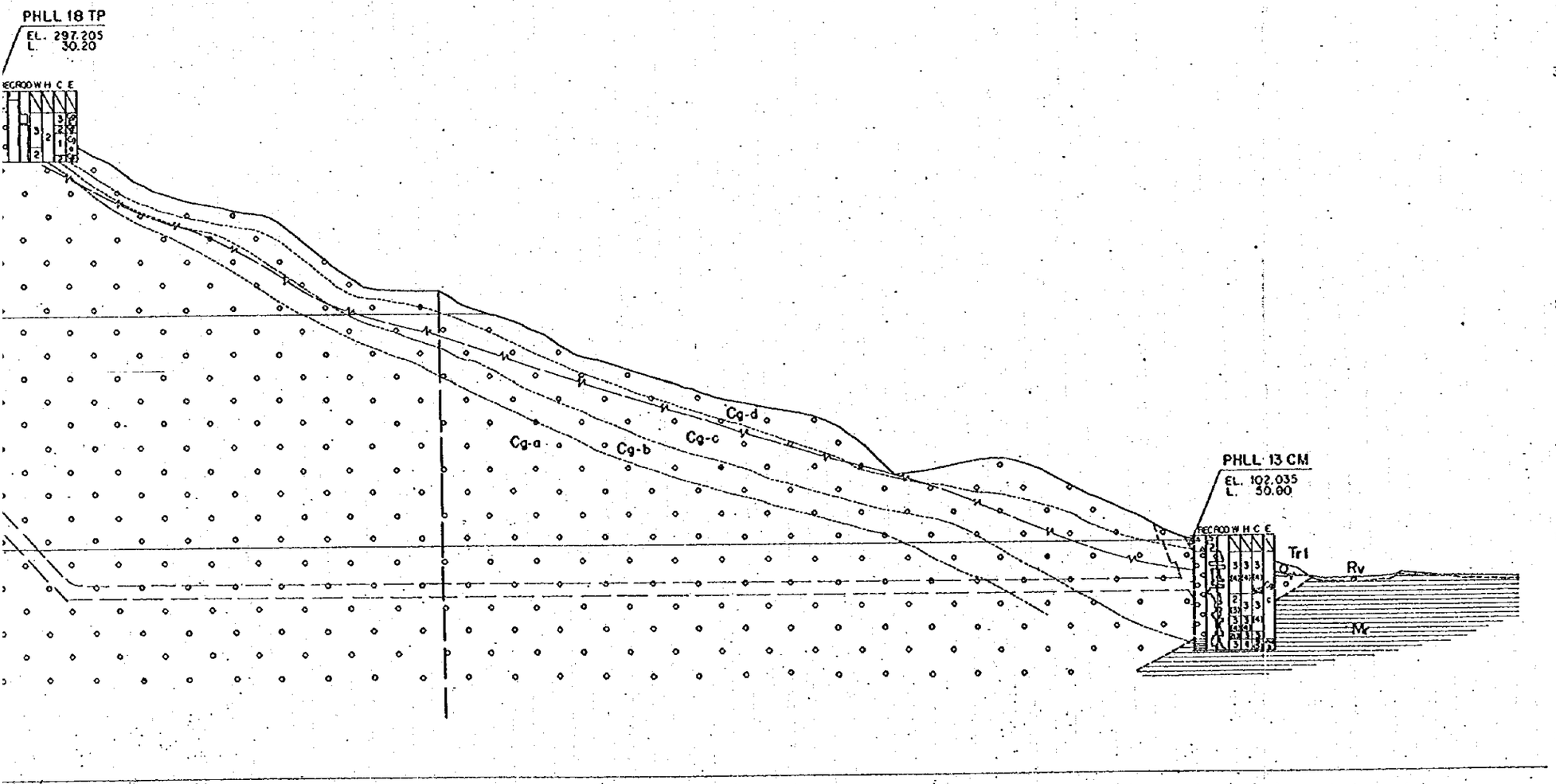
REC RQD W H C E

Tr1

Rv

Mr

: Data of drillhole(REC and RQD) were offered by ICE.



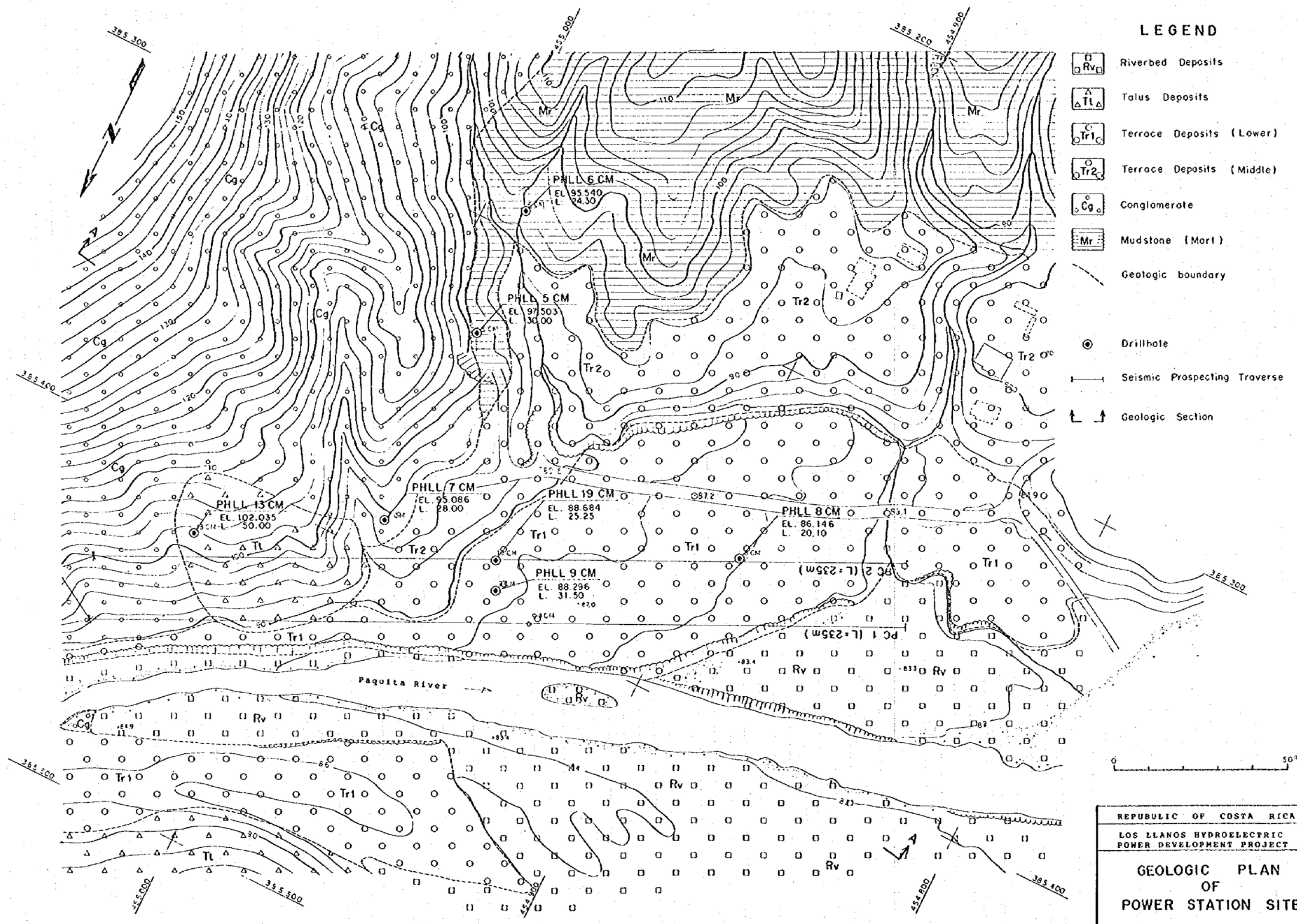
: Data of drillhole(REC and RQD) were offered by ICE.

REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC SECTION OF PENSTOCK ROUTE (SECTION B-B)

Fig. 7-12 | Date :



Data of seismic prospecting were offered by ICE.

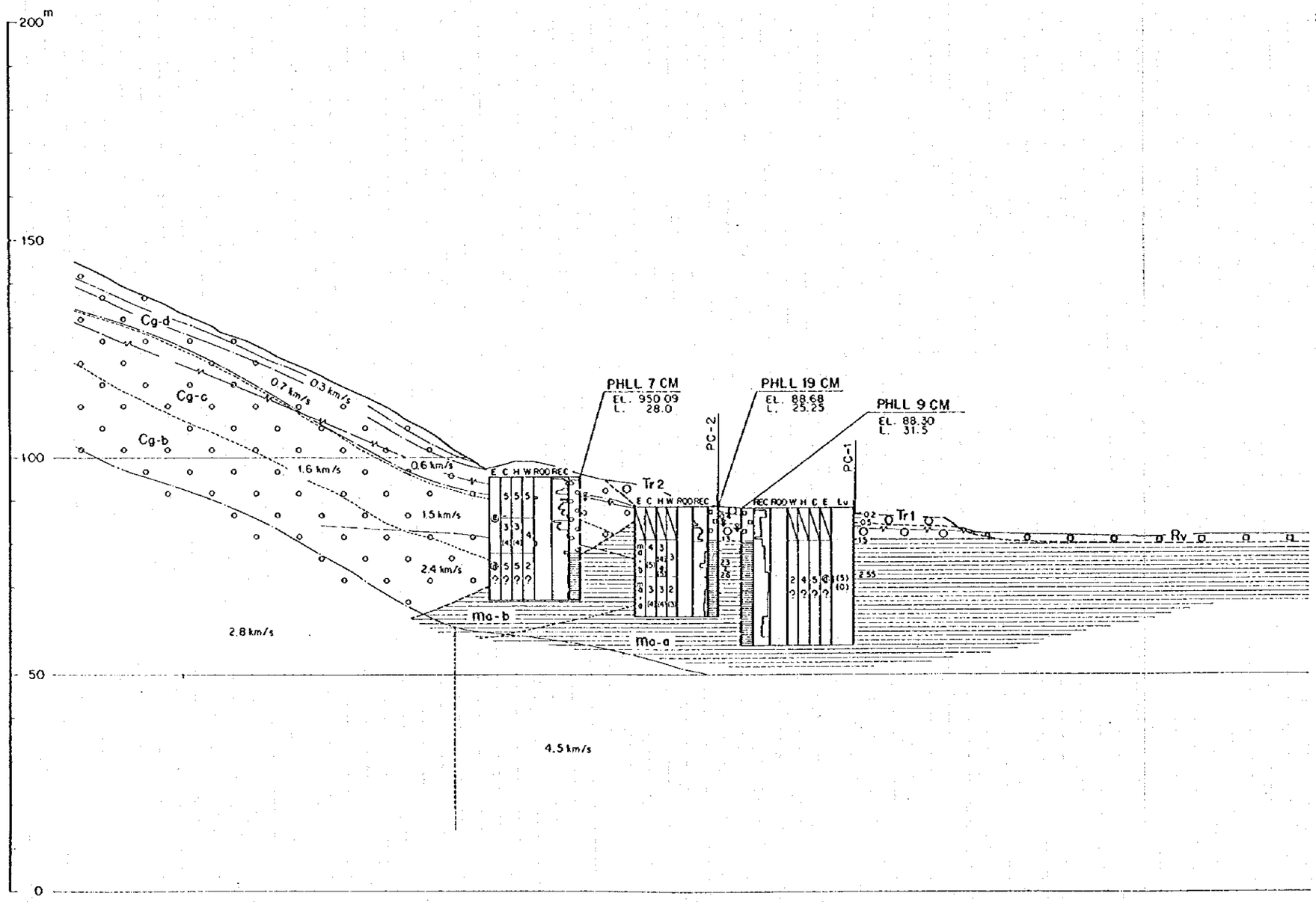
REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC PLAN OF POWER STATION SITE

Fig. 7-13

Los Llanos Power Plant Site



Data of drillhole(REC and RQD) were offered by ICE.

LEGEND

- Riverbed Deposits (Rv)
- Terrace Deposits (Lower) (Tr1)
- Terrace Deposits (Middle) (Tr2)
- Conglomerate (Cg)
- Mudstone (Marl) (Mr)
- Geologic boundary
- Boundary of rock mass classification
- Ground water level

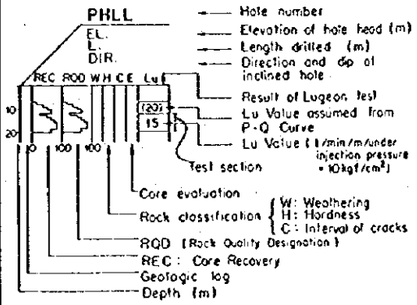
(Seismic Velocity Distribution)

- 2.4 / 4.4 Velocity (km/s) and boundary of velocity layer

(Rock Mass Classification)

- Ma-a See text

(Drillhole Log)



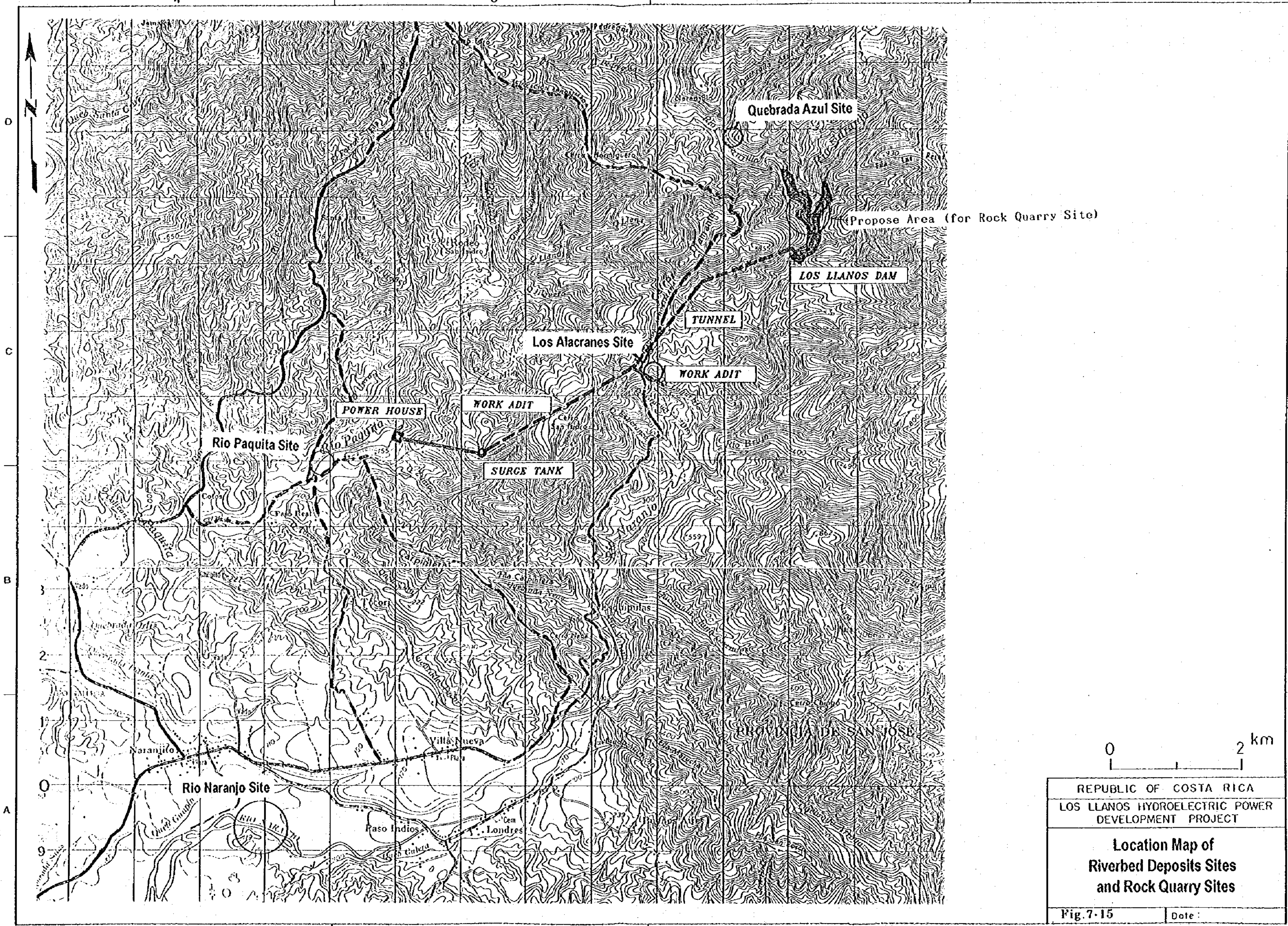
0 — 50m

REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGIC SECTION OF POWER STATION SITE (section A-A)

Fig. 7-14 | Date :



REPUBLIC OF COSTA RICA

LOS LLANOS HYDROELECTRIC POWER DEVELOPMENT PROJECT

Location Map of Riverbed Deposits Sites and Rock Quarry Sites

Fig.7-15 | Date :

Table 7-1 Core-drillholes in the Project Area

Drillhole No.	Location	Elevation m	Length m	Dir deg	Water Level Measurement	Remarks
PHLL1SP	Up Stream Damsite Right Bank	503.001	70.70	Ver.	done	Lugeon tests; 7 sections
PHLL2SP	Mid Stream Damsite Right Bank	510.332	83.30	Ver.	done	Lugeon tests; 9 sections Deformation Tests 5 sections
PHLL3SP	Down Stream Damsite Right Bank	493.922	80.00	Ver.	done	Lugeon tests; 8 sections Deformation Tests 6 sections
PHLL4SP	Down Stream Damsite Left Bank	453.755	60.00	70 300	none	Lugeon tests; 7 sections Deformation Tests 7 sections
	subtotal		294.00			
PHLL5CM	Power Station No.1 site	97.503	30.00	Ver.	done	
PHLL6CM	Power Station No.1 site	95.54	24.30	Ver.	done	
PHLL7CM	Power Station No.1 site	95.086	28.00	Ver.	done	
PHLL8CM	Power Station No.1 site	86.146	20.10	Ver.	done	
PHLL9CM	Power Station No.1 site	88.296	31.50	Ver.	done	Lugeon tests; 2 sections
PHLL10TO	Penstock Route No.1 route	148.463	36.40	Ver.	done	
PHLL11TP	Penstock Route No.2 route	278.718	30.80	Ver.	none	
PHLL12CM	Power Station No.2 site	101.276	30.85	Ver.	done	
PHLL13CM	Power Station No.1 site	102.035	50.00	Ver.	none	
PHLL14CM	Power Station No.2 site	103.851	34.15	Ver.	none	Lugeon tests; 2 sections
PHLL15CM	Power Station No.2 site	103.173	26.40	Ver.	done	
PHLL16CM	Power Station No.2 site	104.197	26.00	Ver.	none	Vp/Vs measurement (22m in length)
PHLL17TP	Penstock Route No.2 route	391.319	21.60	Ver.	none	
PHLL18TP	Penstock Route No.1 route	297.205	30.20	Ver.	none	Deformation Tests 8 sections
PHLL19CM	Power Station No.1 site	88.684	25.25	Ver.	none	Deformation Tests 6 sections
	subtotal		445.55			
	Total ; 19 drillholes		739.55			

Table 7-2 Exploratory Adits at Damsites

Adit No.	Location	Elevation m	Length m	Remarks
Adit No.1	Down Stream Damsite Right Bank	445.219	30.15	Plate Jack Tests at TD;15.0m and 28.0m Vp/Vs Measurement
Adit No.2	Down Stream Damsite Left Bank	453.766	6.00	Open Cut 5.5m in front of entrance

(Total: 2 adits, 36.15 m)

Note:Data of Length were offered by ICE

Table 7-3 Test Pits at Damsites

Pit No.	Location	Elevation m	Depth m	Remarks
Pit No.1	Up Stream Damsite Right Bank	504.492	9.55	
Pit No.2	Mid Stream Damsite Right Bank	506.798	9.50	Plate Jack Tests at ;8.5m depth

(Total: 2 pits, 19.05 m)

Note:Data of Depth were offered by ICE

Table 7-4 Seismic Prospecting Traverse in the Project Area

Traverse No	Location	Length(m)	Remarks
PS-1	Up Stream Damsite Right Bank	170	Crossing with PS-4,5,6
PS-2	Up Stream Damsite Right Bank	220	Crossing with PS-4,5,6,8
PS-3	Up-Mid Stream Damsite Right Bank	220	Crossing with PS-4,5,7,8
PS-4	Up Stream Damsite Right Bank	210	Crossing with PS-1,2,3,8
PS-5	Up Stream Damsite Right Bank	330	Crossing with PS-1,2,3
PS-6	Up Stream Damsite Right Bank	220	Crossing with PS-1,2
PS-7	Up Stream Damsite Right Bank	330	Crossing with PS-3
PS-8	Up-Mid Stream Damsite Right Bank	220	Crossing with PS-2,3,4
	sub total ; 8 lines	1,920	
PL-1	Headrace Tunnel Route	940	Middle part
PL-2	Headrace Tunnel Route	390	Lower part
	sub total ; 2 lines	1,330	
PP-1	Penstock Route No.1	1,380	Connecting with PC-2
PP-2	Penstock Route No.2	1,360	
	sub total ; 2 lines	2,740	
PC-1	Power Station No.1	235	Connecting with PC-3,5
PC-2	Power Station No.1	235	Connecting with PC-4
PC-3	Between Power Station No.1 and 2	115	Connecting with PC-1,5 Crossing with PC-6
PC-4	Between Power Station No.1 and 2	95	Connecting with PC-2 Crossing with PC-5,6
PC-5	Between Power Station No.1 and 2	115	Connecting with PC-1,3 Crossing with PC-4
PC-6	Between Power Station No.1 and 2	85	Crossing with PC-3,4
	sub total ; 6 lines	880	
	Total ;18 lines	6,870	

Table 7-5 Resistivity Survey in the Project Area

Traverse No.	Location	Length(m)	Remarks
RL-1	Headrace Tunnel Route	800	Middle part same as PL-1
RL-2	Headrace Tunnel Route	229	Lower part same as PL-2
	sub total ; 2 lines	1,029	
RP-1	Penstock Route No.1	1,330	same as PP-1
RP-2	Penstock Route No.2	1,110	same as PP-2
	sub total ; 2 lines	2,440	
RC-1	Power Station No.1	230	same as PC-1
	sub total ; 1 line	230	
	Total ;5 lines	3,699	

Correlation of Velocity and Resistivity at Power Station Site

Layer	Velocity km/sec	Resistivity ohm-m	Lithology
1	0.4-0.5	15-20 40-80	Aluvial deposits
2	2.3-2.5	15-40 10-15	Conglomerate Marlstone
3	2.8	5-10	Conglomerate Marlstone
4	3.1-4.7	-10	Conglomerate Marlstone

Note)Data were offered by ICE

Table 7-6 In-adit Vp/Vs Measurement at Damsite

Adit No.	Location	Length (m)	Remarks
Adit No.1	Down Stream Damsite Right Bank	22	

(Total: 1 adit 22 m)

Table 7- 7 Vp/Vs Logging at Power Station Site

Drillhole No.	Location	Length m	Remarks
PHLL16CM	Power Station No.2	22.00	
	Total ; 1 drillhole	22.00	

Table 7-8 Results of Plate Jack Test in Adits and Test Pits

Adit No.1

T.D. (m)	Rock Species	W	H	C	Eval	D (kg/cm2)	Et (kg/cm2)	Es (kg/cm2)	E (kg/cm2)	E/D	Cp	Def. Max.	Def. Fin.	Fin./ Max.	
15	conglomerate	2	B	II(III)	C H	60,500	256,000	144,700	317,000	5.23	0.48	24	20	83	H.R.
15	conglomerate	2	B	II(III)	C H	75,100	86,200	97,000	139,250	1.85	0.68	34	24	70	H.L.
28	conglomerate	1(2)	B	II	B	16,560	25,150	23,240	48,200	2.90	0.96	85	48	56	H.R.
28	conglomerate	1(2)	B	II	B	12,800	19,050	18,100	42,000	3.28	1.16	110	58	53	H.L.

Test Pit No.2

Depth (m)	Rock Species	W	H	C	Eval	D (kg/cm2)	Et (kg/cm2)	Es (kg/cm2)	E (kg/cm2)	E/D	Cp	Def. Max.	Def. Fin.	Fin./ Max.	
8.5	conglomerate	4	D	IV	C L	6,100	10,600	9,200	15,900	2.61	5.00	250	155	62	Par.H.R.
8.5	conglomerate	4	E	IV(V)	D	1,570	3,530	2,900	6,200	3.92	19.50	975	750	77	Par.H.L.
8.5	conglomerate	4	D	IV	C L	6,300	14,400	12,500	13,600	2.16	3.00	295	185	62	Per.H.R.
8.5	conglomerate	4	E	IV(V)	D	18,650	35,350	31,100	29,900	1.60	0.75	100	45	45	Per.H.L.

D:Modulus of deformation
Et:Tangential modulus of elasticity
Es:Secont modulus of elasticity
E:Modulus elasticity
Cp:Coefficient of deformation performance
Def.Max:Maximum deformation
Def.Fin:Final deformation

H:Horizontal
R:Right
L:Left
Par.:Pararel
Per.:Perpendicular

Note:Test Results are offered by ICE

Table 7-9 Geological Sequence and Lithological Characters in the Los Llanos Project Area and the Vicinity

Geologic Age				Symbol Mark DW1	Symbol Mark DW2	Symbol Mark DW3	Kind of Uncosolidated Deposits and/or Rocks	Remarks
Cenozoic Era	Quaternary Period	Holocene		1			Alluvium and colluvium	
					Gl	Gl	Riverbed deposits	
					Co		Colluvial deposits (Includes residual soil)	
						Ta	Talus deposits	
					Te	Te	Terrace deposits	
		Oligocene - Pleistocene		6			Intrusive rocks (Gabbro, granite, rhyolite)	
					Ir		Intrusive rocks (Monzodiorites, monzonites)	
	Tertiary Period		Oligocene - Pleistocene	8b			Sedimentary rocks (Limestone, sandstone, claystone)	
					T_I		Siltstone, claystone	
					T_{II}		Sandstone with shale and conglomerate	So-called "Terraba Formation", according to Reference No (2).
						S_i	Siltstone (Siliceous)	
						S_s	Sandstone with siltstone and shale	
					T_{III}		Sandstone, volcanic sandstone, tuff	
Mesozoic Era		Jurassic - Eocene		9			Peridotite, tholeiite basalt with pelagic sedimentary rocks	So-called "Nicoya Complex", according to Reference No. (4).
					O_o/B_a	$O_o \sim B_a$	Oolerite - basalt	

Notes: 1. "Symbol mark" in the above table refers to geological abbreviations in figures attached to this report.

2. "DW1", "DW2", and "DW3" correspond to "Fig. 7-1", "Fig. 7-2 and Fig. 7-9", and "Fig. 7-3 and Fig. 7-5", respectively.

Table 7-10 Distribution of Seismic Velocity Layers at the Damsite

Layer No.	PS-1-PS-8 *1)			PS-3 2)		
	Seismic Velocity (km/sec)	Depth(*) to Layer's Lower Boundary (m)	Remarks	Seismic Velocity (km/sec)	Depth(*) to Layer's Lower Boundary (m)	Remarks
1	0.4-0.6	0-10	Rather shallow on the foot of bank or thinned out	0.35-0.7	2-5	Rather shallow on the foot of the bank
2	1.4-1.8	5-14	Rather shallow on the the foot of the bank	0.9-1.1	10-21	Rather shallow on the foot of the bank
3	2.0-3.5	8-21	Rather shallow on the foot of the bank	2.7-3.1		
4	3.5-4.0		Rather shallow on the foot of the bank			

Note:*"Depth" is counted from the ground surface.
1) Based on interpreted profiles offered from ICE
2) Based on interpreted profile of re-analysis by JICA Study Team

Table 7-11 Distribution of Seismic Velocity Layers along Headrace Tunnel Route

Layer No.	PL-1 (Middle part)			PL-2 (Lower part)		
	Seismic Velocity (km/sec)	Depth(*) to Layer's Lower Boundary (m)	Remarks	Seismic Velocity (km/sec)	Depth(*) to Layer's Lower Boundary (m)	Remarks
1	0.3-0.4	0-2	On top of ridge only	0.3	0-6	On top of ridge only
2	0.5-0.8	0-9	On top of ridge only	0.6-0.7	6-19	On top of ridge only
3	1.0	0-12	On top of ridge only	1.0-1.1	11-31	Thinned out in part
4	1.4-1.5	0-18	Not continuous	1.4-1.7	19-37	Thinned out in part
5	1.7-2.5	5-36	Not continuous	2.0-2.2	34-66	Not continuous
6	4.5-5.0			3.4-4.6		

Note:*"Depth" is counted from the ground surface.
Based on interpreted profiles of re-analysis by JICA Study Team

Table 7-12 Distribution of Seismic Velocity Layers along Penstock Routes

Layer No.	PP-1			PP-2		
	Seismic Velocity (km/sec)	Depth(*) to Layer's Lower Boundary (m)	Remarks	Seismic Velocity (km/sec)	Depth(*) to Layer's Lower Boundary (m)	Remarks
1	0.3	0-7	Thin and partially missing	0.3	0-5	Thin and partially missing
2	0.6-1.0	0-15	Partially missing	0.6-1.0	0-15	Thin and in part only
3	1.2-1.5	0-14	High elev. part only	1.0	0-12	Thin and in part only
4	1.5-2.6	15-38		1.4-1.6	0-32	Prtially missing
5	2.3-2.4	24-40	Low elev. part only	2.5-2.9	0-96	Thick at high elev. part Thinned out at the foot of slope
6	3.6-4.5			4.3		

Note:*"Depth" is counted from the ground surface.
Based on interpreted profiles of re-analysis by JICA Study Team

Table 7-13 Distribution of Seismic Velocity Layers at the Power Station Site

Layer No.	Seismic Velocity (km/sec)	Depth(*) to Layer's Lower Boundary (m)	Remarks
1	0.2-0.3	0-4	Partially missing
2	0.5-0.6	0-7	Thin and missing at the lower part
3	1.3-1.7	3-14	Rather thin at the lower part
4	2.3-3.4		

Note:*"Depth" is counted from the ground surface.
Based on interpreted profiles of re-analysis by JICA Study Team

Table 7-14 Correlation between Seismic Velocity Layers and Geologic Conditions at the Damsite

Geologic Conditions / Layers	Topsoil	Residual Soil	Talus	Rocks			
				Strongly Weathered	Moderately Weathered	Slightly Weathered	Fresh, Sound
Layer No. 1	—	—	—	—			
Layer No. 2				—	—		
Layer No. 3					—	—	—

Table 7-15 Correlation between Seismic Velocity Layers and Geologic Conditions at Penstock Route and Power Station Site

Geologic Conditions / Layers	Topsoil	Residual Soil	Talus	Rocks			
				Strongly Weathered	Moderately Weathered	Slightly Weathered	Fresh, Sound
Layer No. 1	—	—	—				
Layer No. 2				—			
Layer No. 3				—	—		
Layer No. 4					—	—	—
Layer No. 5						—	
Layer No. 6						—	—

Table 7-16 Standard of Rock Classification for Drilling Core

W	Weathering	H	Hardness	C	Interval of Cracks
1	Very fresh. No weathering of mineral component.	1	Very hard. Broken into knifeedged pieces by strong hammer blow.	1	Over 50cm
2	Fresh. Some minerals are weathered slightly. Usually no brown crack.	2	Hard. Broken into pieces by strong hammer blow.	2	20-50cm
3	Fairly fresh. Some minerals are wethered. Cracks are stained and with weathered materials.	3	Somewhat brittle. Broken into pieces by medium hammer blow.	3	5-20cm
4	Weathered. Fresh portions still remain partially.	4	Very brittle. Easilly broken into pieces by medium hammer blow.	4	1-5cm
5	Strongly weathered. Most minerals are weathered and altered to second minerals.	5	Soft. Able to dig with hammer.	5	Under 1cm

Table 7-17 Grouping of Rock Classification for Drilling Core

Symbol Mark of Grouping	Rock Calssification for Drilling Core	Remarks
a	W=1>2 H=1>2 C=1>2	W:Weathering degree H:Hardness C:Interval of cracks
b	W=1<2 H=2>3 C=1<2	
c	W=2<3>4 H=2<3 C=2>3	
d	W=3>4>5 H=3>4 C=2<3>4	
e	W=3<4<5 H=3<4<5 C=3<4<5	

Table 7-18 Standard of Rock Mass Classification for Adits

W	Weathering	H	Hardness	C	Interval of Cracks
1	Very fresh. No weathering of mineral component.	A	Very hard. Broken into knifeedged pieces by strong hammer blow.	I	Over 100cm
2	Fresh. Some minerals are weathered slightly. Usually no brown crack.	B	Hard. Broken into pieces by strong hammer blow.	II	40-100cm
3	Fairly fresh. Some minerals are wethered. Cracks are stained and with weathered materials.	C	Somewhat brittle. Broken into pieces by medium hammer blow.	III	20-40cm
4	Weathered. Fresh portions still remain partially.	D	Very brittle. Easilly broken into pieces by medium hammer blow.	IV	5-20cm
5	Strongly weathered. Most minerals are weathered and altered to second minerals.	E	Soft. Able to dig with hammer.	V	Under 5cm

Table 7-19 Grouping of Rock Mass Classification for Adits

Symbol Mark of Grouping	Rock Calssification for Drilling Core	Remarks
A	W=1>2 H=A>B C=I>II	W:Weathering degree H:Hardness C:Interval of cracks
B	W=1>2>3 H=A>B>C C=I>II>III	
C_H	W=1<2>3 H=A<B>C C=I<II>III	
C_M	W=2>3>4 H=B>C>D C=II>III>IV	
C_L	W=2<3-4>5 H=B<C-D>E C=II<III-IV>V	
D	W=4<5 H=D<E C=IV<V	

Table 7-20 General Figures of the Headrace Tunnel Cover in its Up-stream Half and Down-stream Half Sections

Tunnnel Section	Tunnel Cover (m)	Approximate Tunnel Length (m)	Remarks
Up-stream half section	Less than 100	495	The thinnest cover is around the intake site.
	100 to 200	1,370	
	200 to 280*1	905	*1:The thickest cover in the up-stream half section.
Down-stream half section	Less than 100	945	The thinnest cover is around Quebrada Jilquero.
	100 to 200	840	
	200 to 280*2	1,050	*2:The thickest cover in the up-stream half section.

Table 7-21 Location with Thin Cover in the Headrace Tunnel

Location	Distance(TD) from Intake Site (m)	Approximate Tunnel Cover (m)	Remarks
Quebrada (A)*	630	100	
Quebrada (B)*	1,570	80	
Quebrada Jilquero	3,010	20	
Quebrada La Mina	5,320	70	

Note : *(A) and (B) are named temporarily in the report.

Table 7-22 Results of Deformation Test in Drillholes at Damsite

PHLL2SP

DEPTH(m)	ROCK	EVAL	W	H	C	Db(kgf/cm2)	Eb(kgf/cm2)
8.7	conglomerate	c	3(2)	3(2)	2	27,200	46,500
15.0	conglomerate	b	2	2	1	152,300	224,400
15.5	conglomerate	b	2	2	1	128,450	120,200
25.0	conglomerate	b	2	2	1	61,550	100,300
25.4	conglomerate	b	2	2	1	92,700	95,000
		b	AVERAGE			109,000	135,000
			S.D.			39,900	60,600
		c	AVERAGE			27,200	46,500
			S.D.			----	----

PHLL3SP

DEPTH(m)	ROCK	EVAL	W	H	C	Db(kgf/cm2)	Eb(kgf/cm2)
7.0	conglomerate	c	3(2)	3(2)	3(2)	80,000	99,500
8.0	conglomerate	b	2	2(3)	2(1)	132,336	172,050
24.5	conglomerate	b	2	2(3)	2	212,000	115,350
25.0	conglomerate	b	2	2(3)	2	129,450	158,000
39.3	conglomerate	b	2	2	1(2)	210,350	256,300
39.8	conglomerate	b	2	2	1(2)	128,150	125,700
		b	AVERAGE			162,000	165,000
			S.D.			44,500	55,800
		c	AVERAGE			80,000	99,500
			S.D.			----	----

PHLL4SP

DEPTH(m)	ROCK	EVAL	W	H	C	Db(kgf/cm2)	Eb(kgf/cm2)
20.1	conglomerate	b	2	2(3)	1(2)	34,100	77,000
29.7	conglomerate	b	2	2(3)	1(2)	48,500	77,300
30.7	conglomerate	c	2(3)	3(2)	3	47,600	60,850
40.0	conglomerate	b	2	2	1(2)	75,325	104,300
40.3	conglomerate	b	2	2	1(2)	98,525	184,438
49.8	conglomerate	b	2	2(3)	2(1)	158,850	250,665
50.3	conglomerate	b	2	2(3)	2(1)	100,160	111,300
		b	AVERAGE			86,000	134,000
			S.D.			44,400	69,300
		c	AVERAGE			47,600	60,850
			S.D.			----	----

All data

b	AVERAGE	123,000	139,000
	S.D.	51,200	55,500
c	AVERAGE	51,000	72,000
	S.D.	26,600	27,400

Note:Test Result are offered by ICE

Table 7-23 Results of Deformation Test in Drillholes at Penstock Route and Power Sation Site

PHLL18TP

DEPTH(m)	ROCK	EVAL	W	H	C	DIA(mm)	POISSON R	Db(kgf/cm2)	Eb(kgf/cm2)
10.3	conglomerate	cg-c	3	2	3	76.2	0.25	37,000	33,000
10.5	conglomerate	cg-c	3	2	3	76.2	0.25	26,000	59,000
16.1	conglomerate	cg-b	3	2	2	76.2	0.25	98,000	79,000
16.5	conglomerate	cg-b	3	2	2	76.2	0.25	108,000	72,000
22.3	conglomerate	cg-a	3	2	1	76.2	0.25	126,000	100,000
22.5	conglomerate	cg-a	3	2	1	76.2	0.25	101,000	91,000
29.3	conglomerate	cg-b	2	2	2	76.2	0.25	91,000	78,000
29.5	conglomerate	cg-b	2	2	2	76.2	0.25	54,000	65,000
		cg-a	AVERAGE					114,000	96,000
			S.D.					17,700	6,400
		cg-b	AVERAGE					88,000	74,000
			S.D.					23,600	6,500
		cg-c	AVERAGE					32,000	46,000
			S.D.					7,800	18,400

PHLL19CM

DEPTH(m)	ROCK	EVAL	W	H	C	DIA(mm)	POISSON R	Db(kgf/cm2)	Eb(kgf/cm2)
4.9	terrace dep					76.66	0.25	3,000	10,000
9.1	mudstone(marl)	ma-b	3	3(4)	4(5)	76.49	0.25	6,000	13,000
12.2	mudstone(marl)	ma-b	3	3(4)	4(5)	76.32	0.25	2,000	7,000
17.5	mudstone(marl)	ma-a	3(2)	3(4)	4(3)	75.95	0.25	9,000	19,000
22.0	mudstone(marl)	ma-a	3(2)	3(4)	4(3)	77.49	0.25	9,000	24,000
24.5	mudstone(marl)	ma-a	3(2)	3(4)	4(3)	76.79	0.25	4,000	16,000
		ma-a	AVERAGE					7,000	20,000
			S.D.					2,900	4,000
		ma-b	AVERAGE					4,000	10,000
			S.D.					2,800	4,200

Note:Result of PHLL18TP and Test Data of PHLL19CM are offered by ICE

Table 7-24 Results of Laboratory Test of Drillcore at Damsite (1/3)

PHLL1SP

DEPTH (m)	ROCK	EVAL	W	H	C	Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
9.75	conglomerate	d	4(5)	3(4)	2(3)	0.82	2.75	493
20.50	conglomerate	c	3(4)	3(2)	2	1.30	2.77	483
32.60	conglomerate	d	3	3	3	1.36	2.66	251
49.45	conglomerate	c	2(3)	2(3)	2	0.68	2.73	560
51.50	conglomerate	d	3(2)	2(3)	2	1.10	2.70	222
58.00	conglomerate	b	2	2	2(1)	0.25	2.75	964
64.75	conglomerate	b	2	2	2(1)	0.55	2.75	236
		b	AVERAGE			0.40	2.75	600
			S.D.			0.21	0.00	515
		c	AVERAGE			0.99	2.75	521
			S.D.			0.44	0.03	55
		d	AVERAGE			1.09	2.70	322
			S.D.			0.27	0.05	149

PHLL2SP

DEPTH (m)	ROCK	EVAL	W	H	C	Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
2.50	conglomerate	c	3	3	2	2.20	2.69	678
11.10	conglomerate	c	3(2)	3(2)	2	1.69	2.68	1,129
14.70	conglomerate	b	2	2	1	1.75	2.67	1,017
19.60	conglomerate	b	2	2	1	1.48	2.68	623
24.40	conglomerate	b	2	2	1	1.71	2.70	847
30.70	conglomerate	b	2	2	2	1.81	2.69	679
		b	AVERAGE			1.69	2.69	791
			S.D.			0.14	0.01	178
		c	AVERAGE			1.95	2.69	904
			S.D.			0.36	0.01	319

Table 7-24 Results of Laboratory Test of Drillcore at Dam Site (2/3)

PHLL3SP

DEPTH (m)	ROCK	EVAL	W	H	C	Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
4.70	conglomerate	c	3(2)	3(2)	3(2)	1.09	2.76	451
7.00	conglomerate	c	3(2)	3(2)	3(2)	2.00	2.68	422
10.80	conglomerate	b	2	2(3)	2(1)	0.69	2.77	1,154
14.34	conglomerate	b	2	2(3)	2(1)	0.73	2.82	635
20.30	conglomerate	b	2	2(3)	2	1.76	2.67	621
24.50	conglomerate	b	2	2(3)	2	2.07	2.81	285
30.15	conglomerate	b	2	2(3)	2	0.82	2.88	851
36.75	conglomerate	b	2	2	1(2)	1.32	2.76	567
40.00	conglomerate	b	2	2	1(2)	0.71	2.75	959
45.80	conglomerate	e	3	4	5	1.09	2.78	1,185
51.25	conglomerate	b	2	3	2(1)	1.19	2.76	850
53.60	conglomerate	b	2	3	2(1)	1.04	2.78	1,132
61.90	conglomerate	b	2	2	1(2)	1.27	2.84	340
65.55	conglomerate	b	2	2	1(2)	1.37	2.76	902
68.80	conglomerate	b	2	2	1(2)	0.68	2.79	796
74.50	conglomerate	b	2	2	1(2)	1.17	2.78	732
80.00	conglomerate	b	2	2	1(2)	0.78	2.79	847
		b	AVERAGE			1.11	2.78	762
			S.D.			0.43	0.05	256
		c	AVERAGE			1.55	2.72	436
			S.D.			0.64	0.06	20
		e	AVERAGE			1.09	2.78	1,185
			S.D.			---	---	---

PHLL4SP

DEPTH (m)	ROCK	EVAL	W	H	C	Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
12.75	conglomerate	d	3(2)	3	3	1.17	2.72	670
20.80	conglomerate	b	2	2(3)	1(2)	1.53	2.75	223
26.00	conglomerate	b	2	2(3)	1(2)	1.16	2.71	488
29.00	conglomerate	b	2	2(3)	1(2)	1.85	2.73	153
36.00	conglomerate	b	2	2	1(2)	3.11	2.77	1,207
40.00	conglomerate	b	2	2	1(2)	0.70	2.79	581
49.70	conglomerate	b	2	2(3)	2(1)	1.06	2.72	699
53.80	conglomerate	a	2(1)	2	1(2)	0.96	2.70	565
59.50	conglomerate	a	2(1)	2	1(2)	1.09	2.71	819
		a	AVERAGE			1.03	2.71	692
			S.D.			0.09	0.01	179
		b	AVERAGE			1.57	2.75	558
			S.D.			0.85	0.03	380
		d	AVERAGE			1.17	2.72	670.48
			S.D.			---	---	---

Table 7-24 Results of Laboratory Test of Drillcore at Dam Site (3/3)

Total

		Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
a	AVERAGE	1.03	2.71	692
2 samples	S.D.	0.09	0.01	179
b	AVERAGE	1.25	2.76	707
26 samples	S.D.	0.61	0.05	294
c	AVERAGE	1.49	2.72	620
6 samples	S.D.	0.58	0.04	266
d	AVERAGE	1.11	2.71	409
4 samples	S.D.	0.22	0.04	212
e	AVERAGE	1.09	2.78	1,185
1 sample	S.D.	---	---	---
all sample	AVERAGE	1.26	2.74	675
39 samples	S.D.	0.55	0.05	293

Note:Test Result are offered by ICE

Table 7-25 Results of Laboratory Test of Drillcore at Power Station Site and Penstock Route

(1/3)

PHLL10TO

DEPTH (m)	ROCK	EVAL	W	H	C	Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
11.88	conglomerate	e	5(4)	4(5)	4	15.20	2.21	----
16.35	conglomerate	d	3	4(3)	3(4)	6.43	2.54	134
17.10	conglomerate	d	3	4(3)	3(4)	7.40	2.54	211
20.25	conglomerate	b	2	2	2	4.77	2.44	396
26.75	conglomerate	b	2	2	2	8.20	2.47	96
30.25	conglomerate	b	2	2(3)	2	4.55	2.50	306
33.50	conglomerate	b	2	2(3)	2	8.16	2.45	50
		b	AVERAGE			6.42	2.47	212
			S.D.			2.03	0.03	166
		d	AVERAGE			6.92	2.54	173
			S.D.			0.69	0.00	54
		e	AVERAGE			15.20	2.21	----
			S.D.			----	----	----

PHLL11TP

DEPTH (m)	ROCK	EVAL	W	H	C	Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
9.52	conglomerate	b	2(3)	3	2(3)	7.83	2.47	45
13.42	conglomerate	b	2(3)	3	2(3)	5.64	2.59	186
16.00	conglomerate	b	2(3)	3	2(3)	6.23	2.58	130
17.10	conglomerate	b	2(3)	3	2(3)	5.07	2.54	211
21.40	conglomerate	b	2(3)	3	2(3)	7.53	2.51	33
26.25	conglomerate	b	2	2(3)	2	5.45	2.61	176
		b	AVERAGE			6.29	2.55	130
			S.D.			1.14	0.05	75

PHLL12CM

DEPTH (m)	ROCK	EVAL	W	H	C	Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
6.40	conglomerate	c	2(3)	3(4)	2(3)	6.90	2.48	----
12.20	conglomerate	c	3	4(3)	3	9.20	2.46	----
19.28	conglomerate	c	3	3	3	6.84	2.52	134
24.87	conglomerate	c	3	3	3(2)	11.10	2.42	----
		c	AVERAGE			8.51	2.47	134
			S.D.			2.05	0.04	----

Table 7-25 Results of Laboratory Test of Drillcore at Power Station Site and Penstock Route (2/3)

PHLL13CM

DEPTH (m)	ROCK	EVAL	W	H	C	Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
9.25	conglomerate	c	4(3)	4(3)	3(4)	4.90	2.58	----
12.95	conglomerate	c	4(3)	4(3)	3(4)	3.70	2.64	----
17.41	conglomerate	c	4(3)	4(3)	3(4)	4.30	2.62	----
22.35	conglomerate	c	4(3)	4(3)	3(4)	2.80	2.67	----
33.75	conglomerate	c	3(2)	3	3(4)	7.90	2.35	----
37.10	conglomerate	c	4(3)	3(4)	3(4)	5.40	2.54	----
40.66	conglomerate	c	4(3)	3(4)	3(4)	3.30	2.57	172
		c	AVERAGE			4.61	2.57	172
			S.D.			1.71	0.11	----

PHLL14CM

DEPTH (m)	ROCK	EVAL	W	H	C	Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
1.20	conglomerate	e	3	3(4)	4	3.39	2.51	195
5.15	conglomerate	b	2	3(2)	2(1)	2.22	2.49	332
8.80	conglomerate	b	2	3(2)	2(1)	3.37	2.44	335
9.40	conglomerate	b	2	3(2)	2(1)	3.10	2.53	320
18.63	conglomerate	d	2	3	4	4.32	2.66	----
23.57	conglomerate	c	2	3(2)	3	2.20	2.58	311
24.28	conglomerate	c	2	3(2)	3	2.73	2.52	294
27.87	conglomerate	c	2(3)	3(2)	3	3.67	2.43	362
28.60	conglomerate	c	2(3)	3(2)	3	3.37	2.47	369
		b	AVERAGE			2.90	2.49	329
			S.D.			0.60	0.05	7.94
		c	AVERAGE			2.99	2.50	334
			S.D.			0.66	0.06	37
		d	AVERAGE			4.32	2.66	----
			S.D.			----	----	----
		e	AVERAGE			3.39	2.51	195
			S.D.			----	----	----

Table 7-25 Results of Laboratory Test of Drillcore at Power Station Site and Penstock Route (3/3)

Total

		Absorption (%)	Specific Gravity	Unconfined Compression Strength (kgf/cm2)
b	AVERAGE	5.55	2.51	201
13samples	S.D.	1.98	0.06	126
c	AVERAGE	5.22	2.52	274
15samples	S.D.	2.63	0.09	99
d	AVERAGE	6.05	2.58	173
3samples	S.D.	1.57	0.07	54
e	AVERAGE	9.30	2.36	195
2samples	S.D.	8.35	0.21	----
all data	AVERAGE	5.67	2.51	218
33samples	S.D.	2.79	0.09	113

Note:Test data are offered by ICE.

Table 7-26 Drillholes at Quebrada Azul

Number	Depth (m)	Elev. (m)	Dir.	Location	Remarks
QA-1	11.60	581.92	V	Up-stream, Middle part of slope	
QA-2	12.45	586.73	V	Mid-stream, Middle part of slope	
QA-3	11.60	588.73	V	Down-stream, Middle part of slope	
QA-4	15.60	602.89	V	Mid-stream, Top part of slope	
QA-5	17.00	613.94	V	Mid-stream, Top part of slope	
QA-6-1	1.80	565.95	V	Mid-stream, Foot of slope	Blasting
QA-6-2	1.80	565.94	V	Mid-stream, Foot of slope	Blasting
QA-6-3	1.80	565.94	V	Mid-stream, Foot of slope	Blasting
QA-7	11.55	601.01	V	Down-stream Middle part of slope	
Total	85.20 (m)			9 holes	

Note:Data are offered by ICE

Table 7-27 Seismic Prospecting Traverses at Quebrada Azul

Name	Length (m)	Location	Remarks
PQA1	235	Foot of slope, pararell to slope	1)
PQA2	115	Top of slope, pararell to slope	2)
PQA3	107	Down-stream, perpendicular to slope	2)
PQA4	106	Mid-stream, perpendicular to slope	1)
PQA5	116	Up-stream, oblique to slope	2)
PQA6	115	Top of slope, pararell to slope	2)
Total	794	6 lines	

1) Data were offered by ICE.
2) Data have not been offered yet.

Table 7-28 Results of Laboratory Test for Concrete Aggregate

	Soundness		Abrasion
	Fine Aggregate	Coarse Aggregate	
Rock Quarry			
Dam Site Adit No.1	-	23.45 %	40 %
Quebrada Azul			
Outcrop	-	7.00 %	25 %
QA-6	-	8.15 %	26 %
Los Alacranes	-	56.50 %	32 %
Alluvial Sediments			
Rio Paquita			
Trench No.2	34.00 %	32.00 %	25 %
Trench No.7	39.80 %	50.30 %	22 %
Trench No.12	32.90 %	53.00 %	26 %
Trench No.13	-	-	30 %
Rio Naranjo			
Trench No.6	-	14.59 %	15 %
Trench No.7	-	-	-
Trench No.8	21.00 %	11.67 %	21 %
Trench No.11	-	-	-
Trench No.14	16.25 %	5.12 %	16 %
Trench No.15	-	-	17 %
Trench No.17	-	-	-
Trench No.18	-	-	-
Trench No.33	16.36 %	11.41 %	18 %
Trench No.43	-	-	-
Trench No.54	28.34 %	28.13 %	-
Trench No.61	10.91 %	15.19 %	9 %
Trench No.65	-	12.50 %	18 %
Rio Canas			
Trench No.4	24.21 %	22.30 %	21 %

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8.1　Costa Rica国の地震概説

8.1.1　概　要

環太平洋地震帯の中に位置するCosta Rica国では、これまでに幾度となく地震災害が発生している。最近の代表的な地震被害例は Table 8-1 に示すとおりである。

このように、Costa Rica国は地震活動性の高い自然環境下にあるため、電力設備の設計においては、地震に対して十分な評価検討を行い、適切な配慮を計ることが肝要である。

ここでは、水力発電施設の耐震設計を実施する際の必須の基本条件である、地震荷重を評価するための基本検討として、確率論的手法に基づく地震危険度解析を行い、ダム地点における最大加速度値の推定および設計震度の評価を実施した。

8.1.2　Costa Rica国周辺域の地震活動性

(1)　サイズモ・テクトニクス（地震地帯構造）

MexicoからColombia、Ecuador、Peruにかけての中南米地域は、Fig.8-1 に示すように、北米プレート、太平洋プレート、Cocosプレート、Caribbeanプレート、Nazcaプレート、南米プレートが複雑にぶつかりあう変動帯となっている。Costa Rica国の太平洋側地域は、CocosプレートがCaribbeanプレートの下に沈み込むプレート境界となっており、このプレート境界では、過去に数多くの地震が発生している。ちなみに、CocosプレートとCaribbeanプレートとの相対速度は、年間約9cmと推定されている。

(2)　歴史地震

1900年から1992年の期間に、Los Llanos計画地点から半径1,000km以内で発生した地震の震央を Fig.8-2 に示す。同図より明らかなように、Costa Rica国の近傍では、プレート境界域である太平洋沿岸域で地震が多発している。