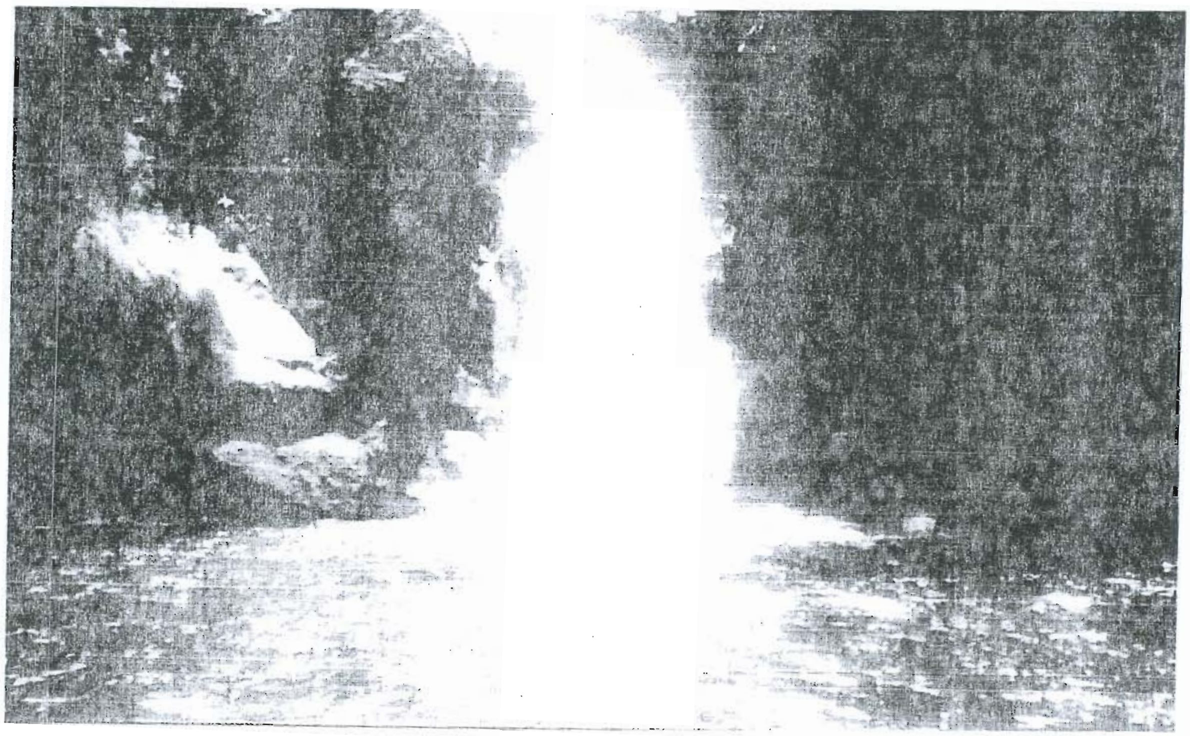
MUNICIPALITY OF MERCEDES

COLASI RIVER MINI-HYDRO PLANT

COMPREHENSIVE FEASIBILITY STUDY



THROUGH THE INITIATIVE OF MAYOR PEPITO PAJARILLO LO
AND THE SANGGUNIANG BAYAN OF MERCEDES

NOVEMBER 2003

ADELCON INCORPORATED

The site was initially visited on 26 September 2003 and then several reconnaissance trips and detailed surveys were undertaken lasting up to 15 November 2003.

1.4 PROJECT LOCATION AND RELATIVE DISTANCES

1.4.1 General

The Colasi river, where a proposed mini-hydro power system will be situated, is located about forty (40) kilometers southeast (SE) of Daet, the capitol town of the Province of Camarines Norte. Figure 1-1 shows the location map.

1.4.2 Specific Location of Primary Scheme

The proposed project site is located within the political boundary of Mercedes Municipality. The proposed diversion dam is situated at 13° 55' 12' latitude and 123° 03' 04' longitude. Similarly, the power plant site is located at 13° 03' 37' latitude and 123° 50' 49' longitude.

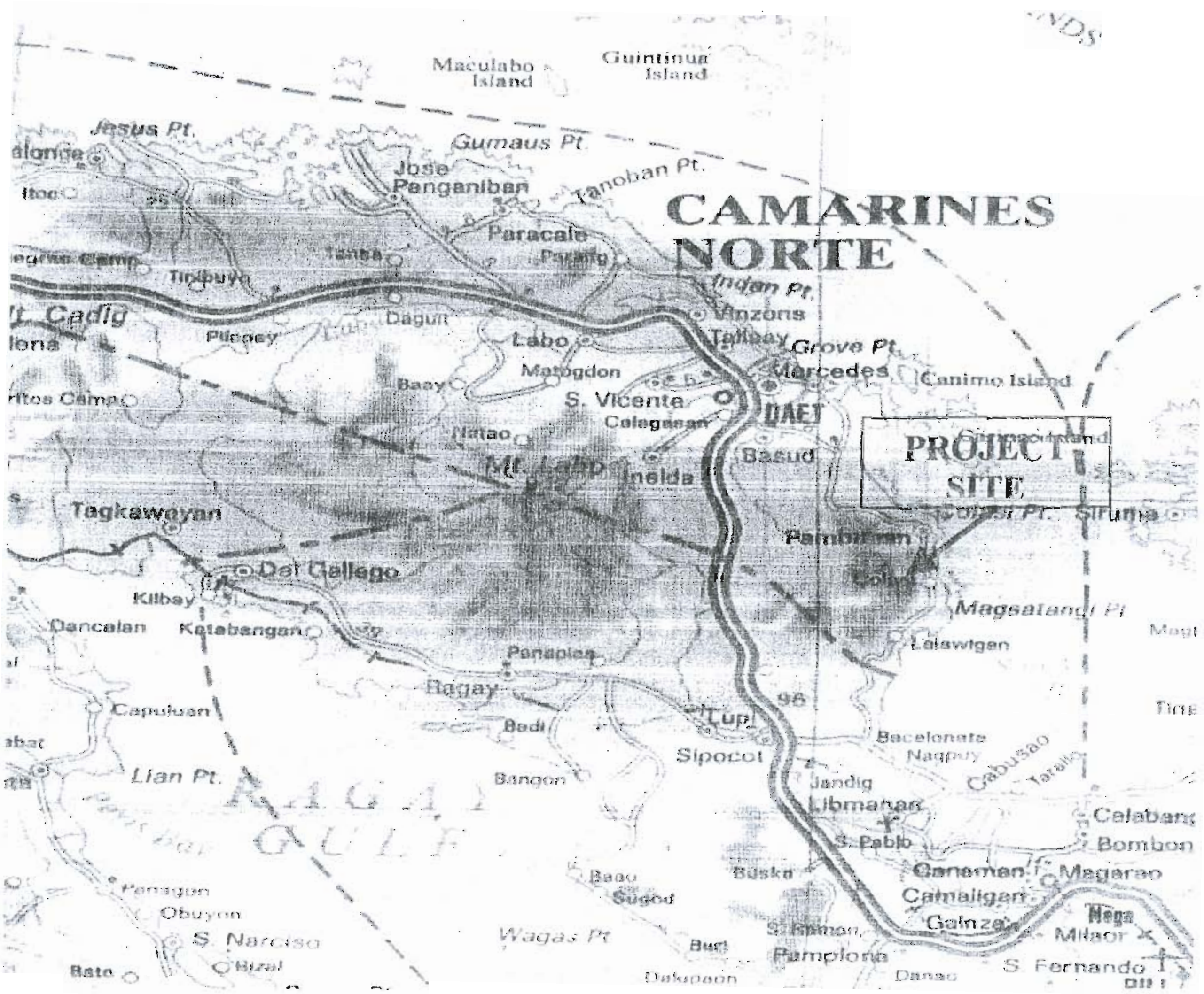


FIGURE 1-1
PROJECT LOCATION MAP

CHAPTER 4.0: WATER RESOURCES

4.1 WATER SOURCE DESCRIPTION

The mini-hydro site is located at the upper reaches of the Colasi river draining the west-east slope of Colasi mountains.

The mini-hydro site is situated on a mountainous area. The watershed cover consisting of relatively thick second growth forest trees and undergrowths is classified as generally in good hydrologic condition. Small expanses of relatively flat grounds are planted to upland rice, corn and vegetables. The river and tributary system is classified under youthful development stage. The channels are characterized with the presence of deep v-shaped valleys, steep slopes, rapids and waterfalls.

The delineation of the watershed area is shown figure 4-1 based on a best weir location of Elev. 280 meters (m) above mean sea level. On the basis of this level, the calculated drainage area is:

WATERSHED AREA = 9.3 Km^2

4.2 HYDROMETEOROLOGICAL CHARACTERISTICS

The area falls under type II climate. This climate type is characterized by no district seasons with very pronounced maximum rainfall from October to January and no dry season. Normally under this type, rainfall is fairly well distributed throughout the year.

The following is a summary of climactic conditions at the project site:

- Area Climate Classification ………….. Type II
- Normal Dry Periods…………………… No pronounced dry season
- Normal Rainfall Period……………… Fairly distributed yearly with pronounced maximum rainfall from October to Jan.
- Mean Maximum Rainfall (Dec.)……… 598.8 mm.
- Mean Minimum Rainfall (March)……. 147 mm.
- Mean Annual Rainfall ……………….. 3311 mm.
- Mean Annual Temperature…………… 27.10 °C
- Reference Data Records……………… PAGASA Weather Bureau

The figures shown in subsequent pages further illustrate the hydrometeorological characteristics of the project area. These are:

- Figure 4-2 : Typical graph of type II climate for the entire Philippines
- Figure 4-3 : Mean Monthly and Annual Rainfall Depth
- Figure 4-4 : Rainfall-Intensity-Frequency Duration Data (RIDF)

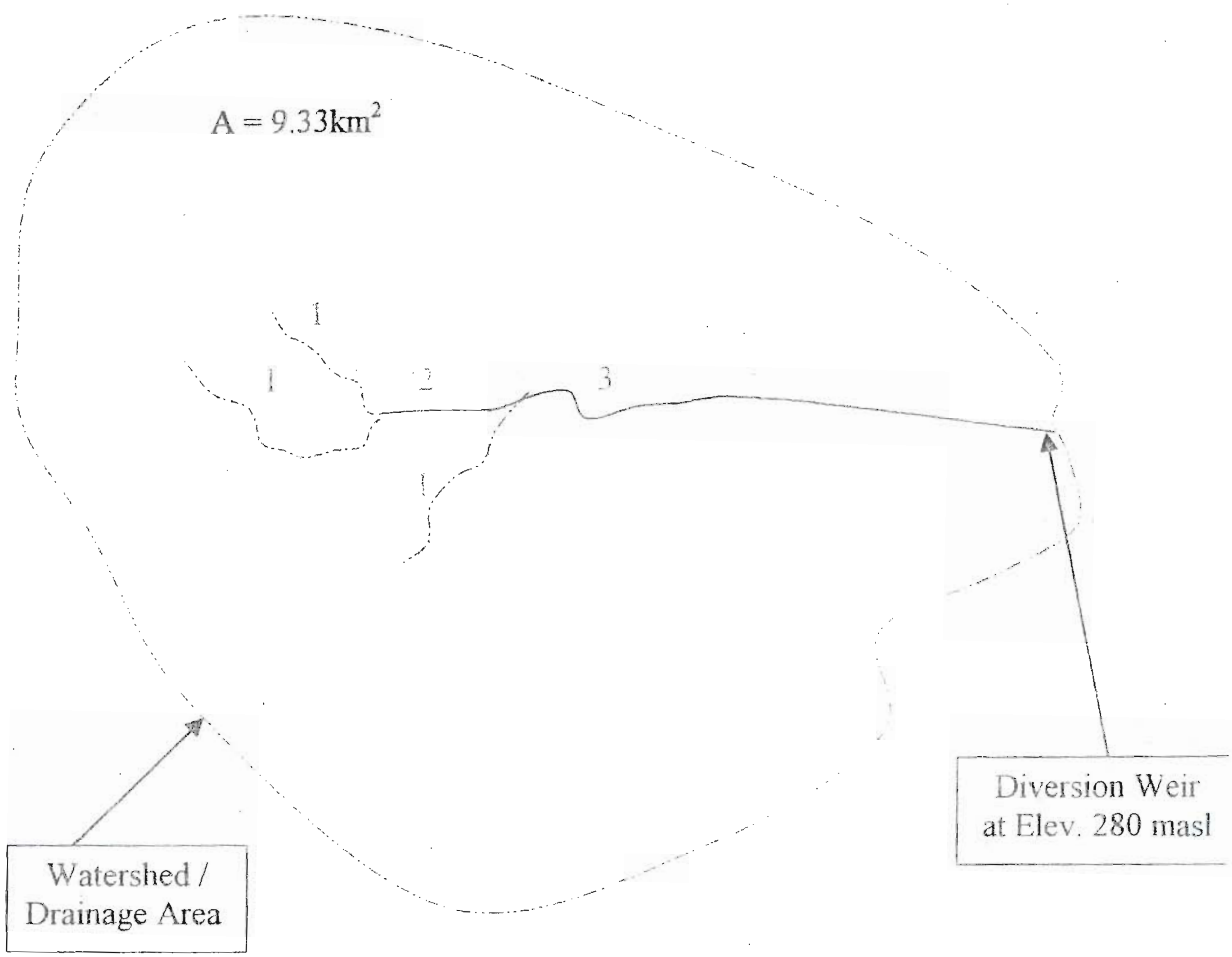


FIGURE 4-1
WATERSHED AREA

CHAPTER 05: PLAN OF DEVELOPMENT

5.1 CIVIL WORKS SCHEMATIC

5.1.1 General Plan of Development

Civil works consist of the construction of the intake weir, headrace canal, surge tank, penstock, powerhouse, and auxiliary support structures. The general plan of development is shown in Figures 5-1a to 5-1c. Based on the geological and water resource considerations as explained in the foregoing chapters, the proposed weir site is located at El. 280.80 meters (m). The proposed headrace route will be at the left bank of the river (looking upstream). The tailrace level at the proposed power plant site was set at El. 125.00 based on the tailwater rating curve. Additional details of the various scheme of the plant installation are presented in the outline drawings of Figures 5-2 through 5-8.

5.1.2 Weir Structure

The type of weir will be an ogee crest concrete overflow run-off-the-river type structure, boulder core with concrete binder and wearing surface, complete with sluiceway, headrace, intake, hydraulic gates, and other appurtenant structures as shown in Figures 5-3a and 5-3b.

For preliminary design due to seismic load, an acceleration of 0.15 is assumed.

The weir salient features are as follows:

Height	1.80 m.
Crest Length	17 m.
Dam Base Width	6.0 m.
Crest Elevation	El. 280.80 m.
Type	Overflow Type
Location	Colasi River

5.1.3 Headrace

The headrace will be a fiberglass reinforced pipe (FRP) running from the weir's intake through hillside cuts in a fairly uniform gradient parallel to the river up to the location of the surge tank and the penstock. It is designed based on a uniform flow of 0.58 cu.m./sec (cms) and is shown on Figures 5-1a to 5-1c.

The main features of the headrace canal are as follows:

Type	Conduit with removable cover
Length	1,980 meters
Dimensions	0.70 m. I.D.
Slope	0.0055

Along the headrace alignment where gullies or depression are encountered, provision of supplementary water crossing structures will be considered.

5.1.4 Surge Tank

A surge tank will be located at a comparatively flat area in the rugged terrain. The surge tank will provide: (1) a way where pressure will be released during excessive pressure build-up and; (2) An immediate storage facility of water going to the penstock.

The main feature of the surge tank are as follows:

Type	Johnson's type with outer tank and inner riser
Dimension	3 m. outer diameter by 5 m. depth with riser pipe 0.70 m. diameter

Reference is made to Figure 5-4 for the details of surge tank.

5.1.5 Penstock

The penstock, taking off from the surge tank is a high pressure pipeline of FRP material designed to resist the maximum bursting pressure of 156 m. It will be anchored at every major bends where the thrust due to hydrodynamic pressure is of maximum value and will be supported at intermediate locations by concrete saddle for support.

There are two section of the penstock, namely:

Main Penstock

a. Material.................................... FRP material
   Length..................................... 284 m.
   Internal Diameter........................ 0.50 m.

b. Branch Penstock

Number of Branches 2

Material .... FRP material

Length per branch .... 10 m.

Diameter per branch .... 0.30 m

5.1.6 Powerhouse

Referring to Figure 5-6 shows the outline design of the powerhouse. Gross floor dimension of powerhouse is 16.5 by 10.5 meters for a floor area of 168 square meters (sq.m.).

5.1.7 Service Road

An access road will be build from the existing barangay main road to the plant site with distance of about 3 kilometers (km) include a 4.50-meter travel way.

5.2 ELECTRO-MECHANICAL EQUIPMENT AND RELATED WORKS

5.2.1 General

The electro-mechanical equipment and related works mainly covers the generating equipment of the plant including appurtenant works and distribution lines.

5.2.2 Hydraulic Turbines

The proposed maximum turbine discharge of 0.29 cms. with a net head of 140 m. will yield a maximum turbine output of 330 KW. The Pelton type of turbines are chosen for the given head/discharge relation. To prevent damages to runner and distributors, these turbines will normally not be allowed to run below 40 percent of maximum discharge.

An optimization of power production and total costs has resulted in the chosen installation of two (2) turbines with identical output of 330-KW each. For the two units, the turbine capacity sums to 640 KW. A summary on the data for the turbines are:

- Type - Pelton
- Turbine Output - 320 KW
- Number of Units - 2
- Gross Head - 155 m.
- Net design head - 140 m.
- Speed of Rotation – 1200 rpm
- Run-away speed – 2011 rpm
- Discharge, Maximum for 2 units – 0.58 cms
- Discharge, per unit – 0.20 / unit
- Shaft Orientation – Horizontal

Each turbines consists of the following main parts:

- The turbine itself consists of the rotating parts the flume part, the guiding components, discharge components, the bearing and the governing mechanism;

- The rotating part consist of the runner, the main shaft, the flywheel and the coupling;
- The main shaft is of horizontal arrangement and runner of stainless steel buckets;
- The flume part consists of the expansion joint, the inlet elbow pipe and the spiral case;
- The discharge components consist of the tail elbow tube and the straight conical tube;
- The main bearing is of the enclosed type and lubricated with dilute oil. The lubricating oil is # 32 turbine oil. Cooling water may be drawn from the special casing.

5.2.3 Hydraulic Governor

To control the opening of the guide apparatus and to ensure that the unit will run steadily at fixed speed under a given load, governor of the single neglecting flow-through-type are proposed. The operating voltage is 220 Volts; 60 Hz; 3 Phase.

5.2.4 Valve

A 0.30-m butterfly valve will be installed at the inlet to each turbine. The mode of operation is electrical or manual. The type of connection is of the flange type. The control voltage is 220 Volts; 60 Hz.

5.2.5 Generator

The generating units will consist of two (2) horizontal shaft type generators with the following data:

Total Plant Output	-	600 KW for 2 units
Generator Output / Unit	-	300 KW
Power Factor	-	0.8 lag
Voltage	-	480 VAC
Frequency		60 Hz
Speed	-	1200 rpm
Connection	-	Wye

All the two (2) generators will be of the three-phase synchronous type directly coupled to the turbines through a shaft.

The excitation system will be a double winding shunt reactor with SCR Regulator.

5.2.6 Step-up Tranformer

A three-phase power transformer of 750 KVA rated capacity will step-up the generator voltage to the line voltage of 13.2 KV. The transformer will be of the outdoor type with oil immersed self cooling and will be supplied with off-load tap charger (12.58%) on the 13.2 KV line side. It will be mounted on a concrete foundation outside the powerhouse.

5.2.7 Low Voltage Switchgear

The low voltage switchgear will be of the indoor metal clad closed cubicle with draw type circuit breakers. It will be further equipped with air breaking medium, protective relays, instruments meter and synchroscope.

5.2.8 Auxiliary Service Supply

For auxiliary service supply, 3 units of 10 KVA single phase transformer will be supplied for lowering the system voltage from 7620 to 240 VAC. For DC supply, a 48 volts for control, protection, emergency & electronic equipment will be supplied. The batteries will be equipped with charger.

5.2.9 Switch and Take-Off

The 13.2 KV take-off will be annexed to the power station. The step-up transformer and take-off structures will be located adjacent to the powerhouse. The major configurations are, listed, to wit: Air break switch (ABS), Lighting Arrester, Circuit Breakers, Poles, Cross-arms, Insulator, Bolts and Nuts, Grounding rod and couplings.

5.2.10 Control and Protection Panel

The power station will be operated from the control and relay room from where starting, stopping and load and voltage control take place. As a protective scheme, the turbine and the voltage regulating system will be designed for automatic operation. All protection relays and devices will be located within the building.

Reference is made to figures 5-5 and 5-8 for the electro-mechanical works schematic diagrams.

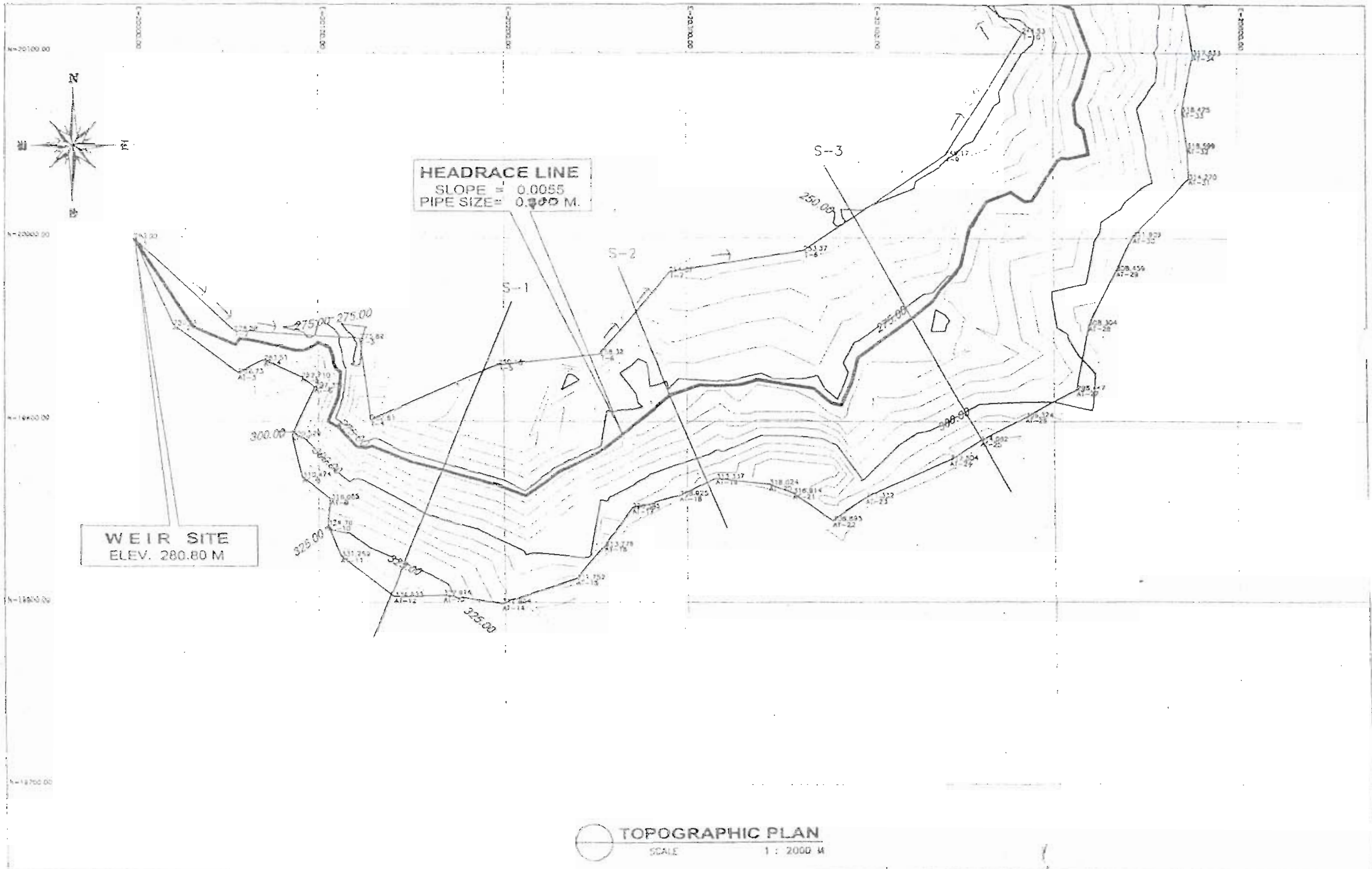


FIGURE 5-1a: PLAN OF DEVELOPMENT (Sheet 1 of 3)

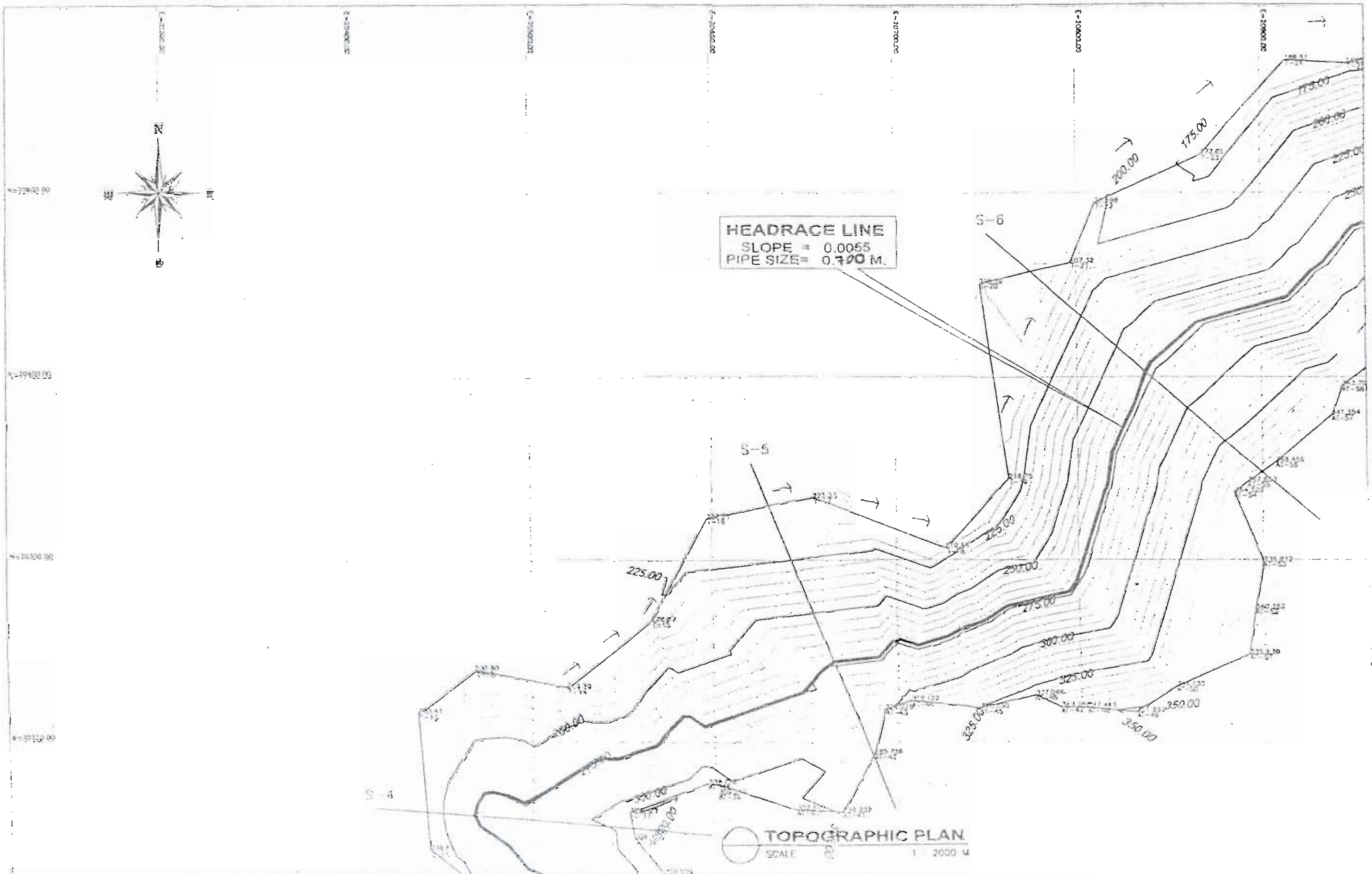


FIGURE 5-1b: PLAN OF DEVELOPMENT (Sheet 2 of 3)

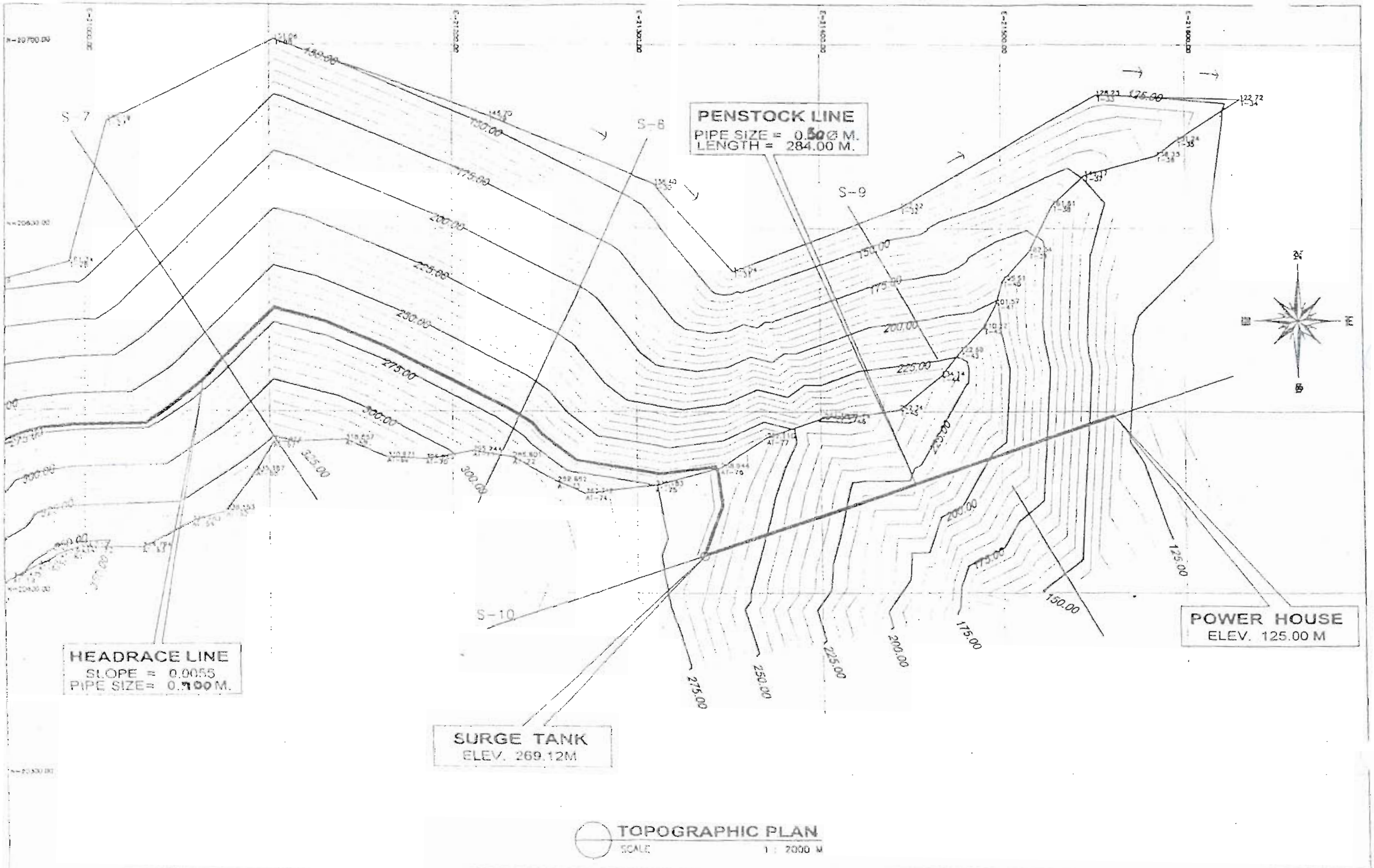
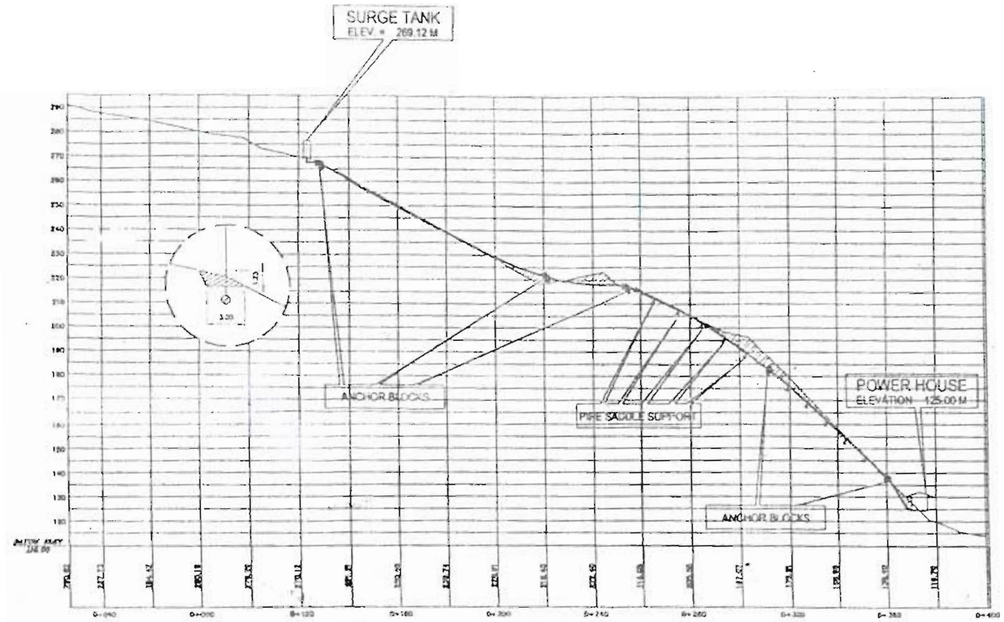
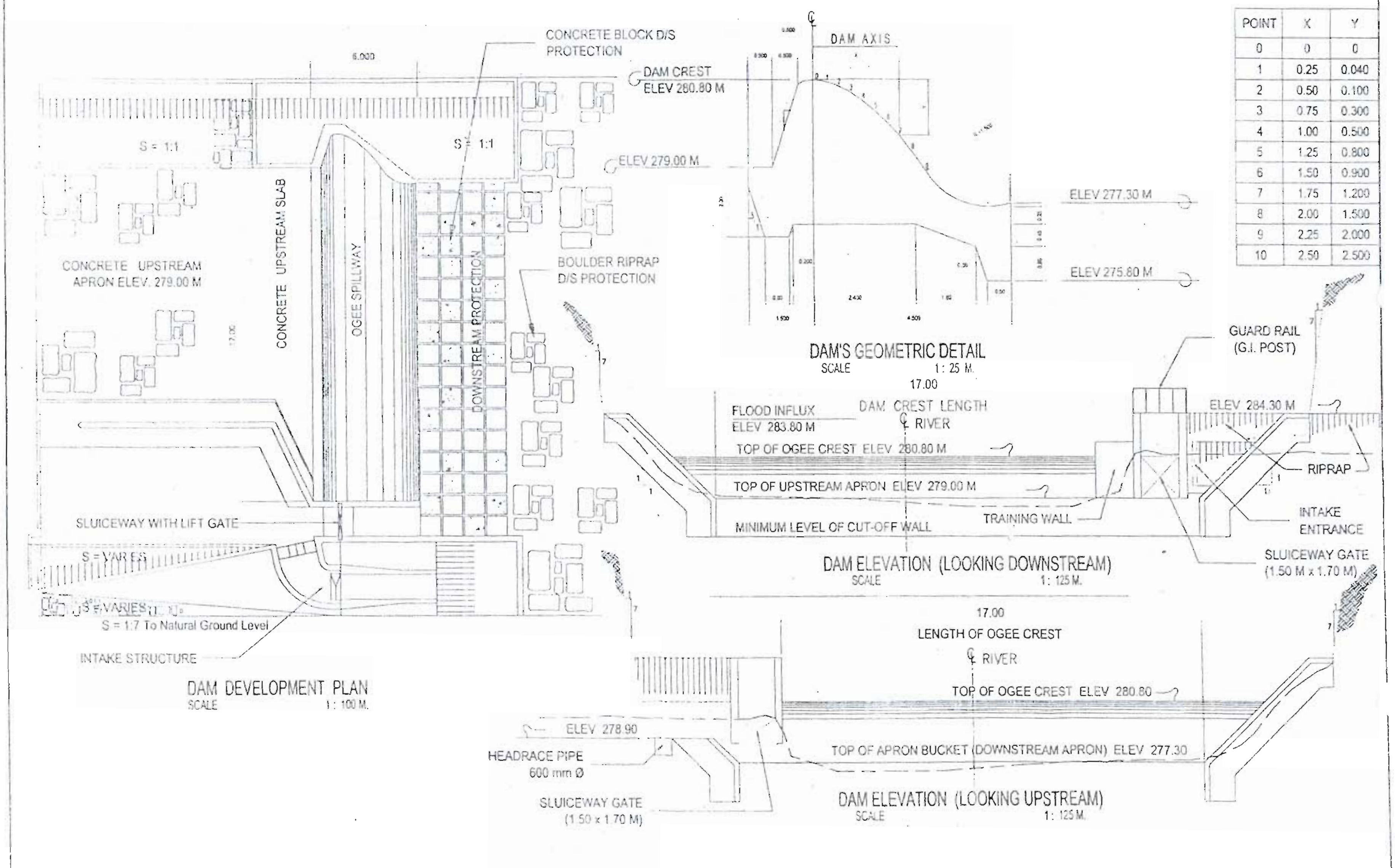


FIGURE 5-1c: PLAN OF DEVELOPMENT (Sheet 3 of 3)



SECTION - 10

FIGURE 5-2: PENSTOCK PROFILE



POINT	X	Y
0	0	0
1	0.25	0.040
2	0.50	0.100
3	0.75	0.300
4	1.00	0.500
5	1.25	0.800
6	1.50	0.900
7	1.75	1.200
8	2.00	1.500
9	2.25	2.000
10	2.50	2.500

FIGURE 5-3a: WEIR SCHEMATIC DETAILS (Sheet 1 of 2)

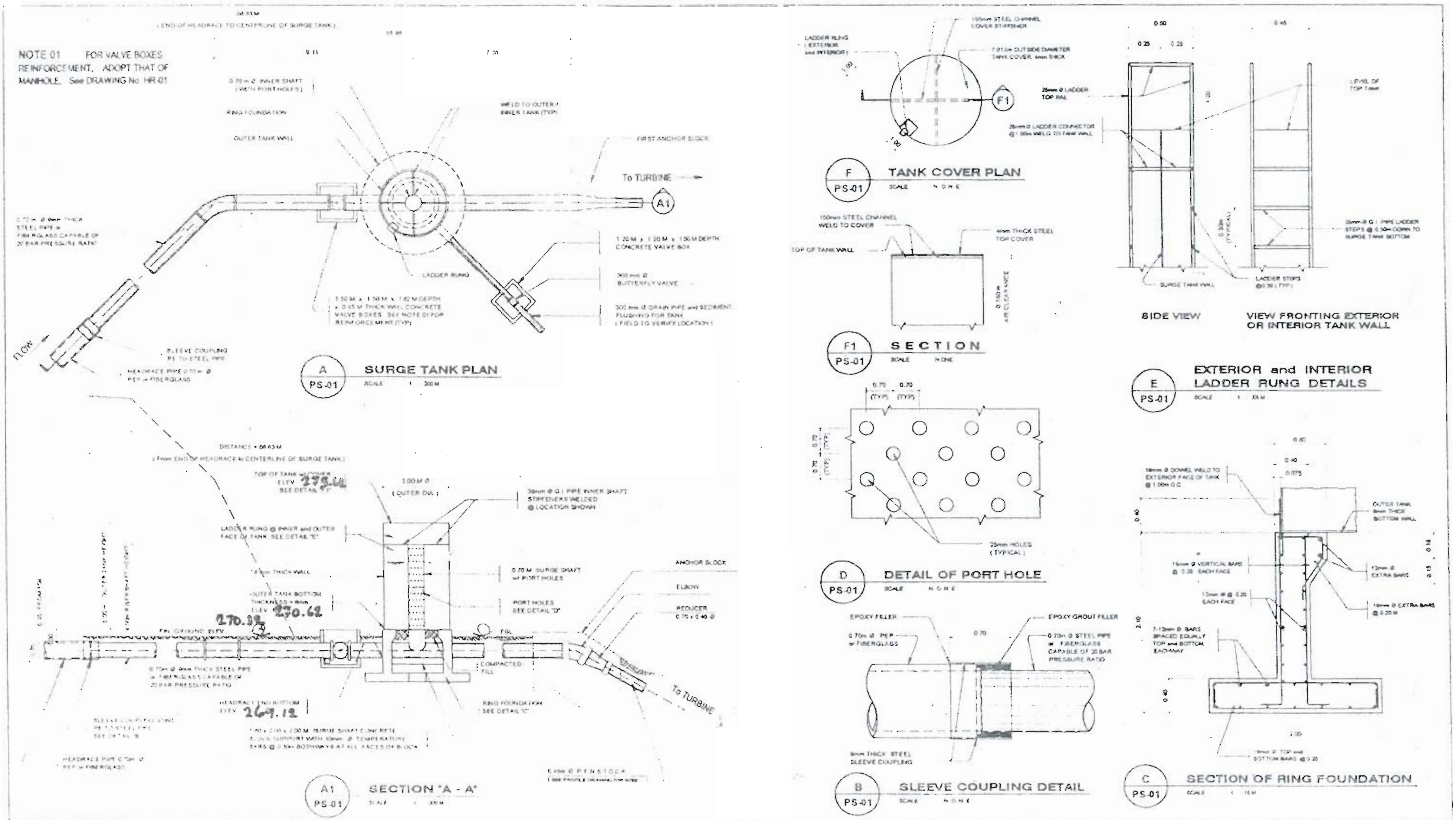


FIGURE 5-4: SURGE TANK DETAILS

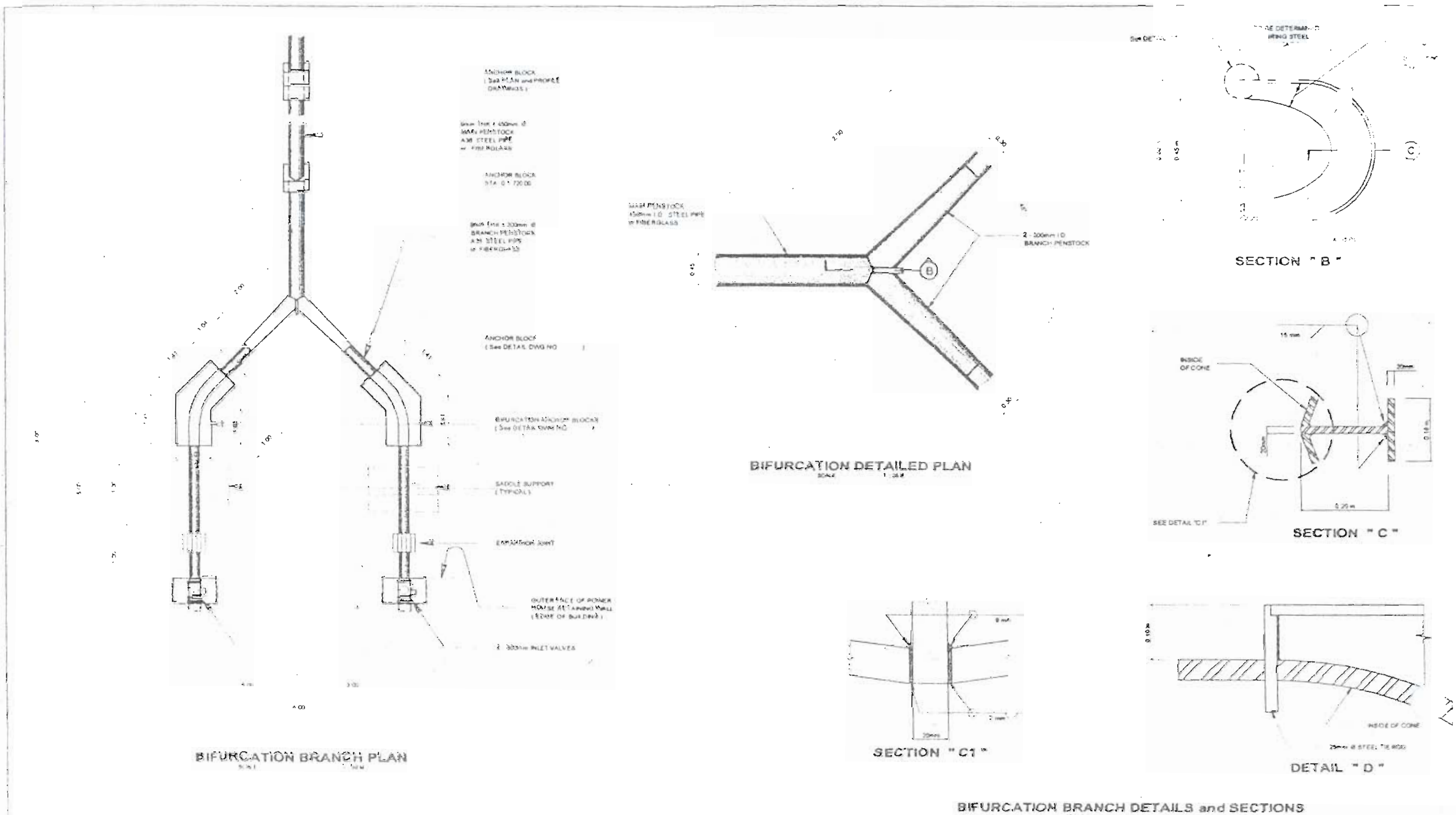


FIGURE 5-5: PENSTOCK BIFURCATION DETAILS

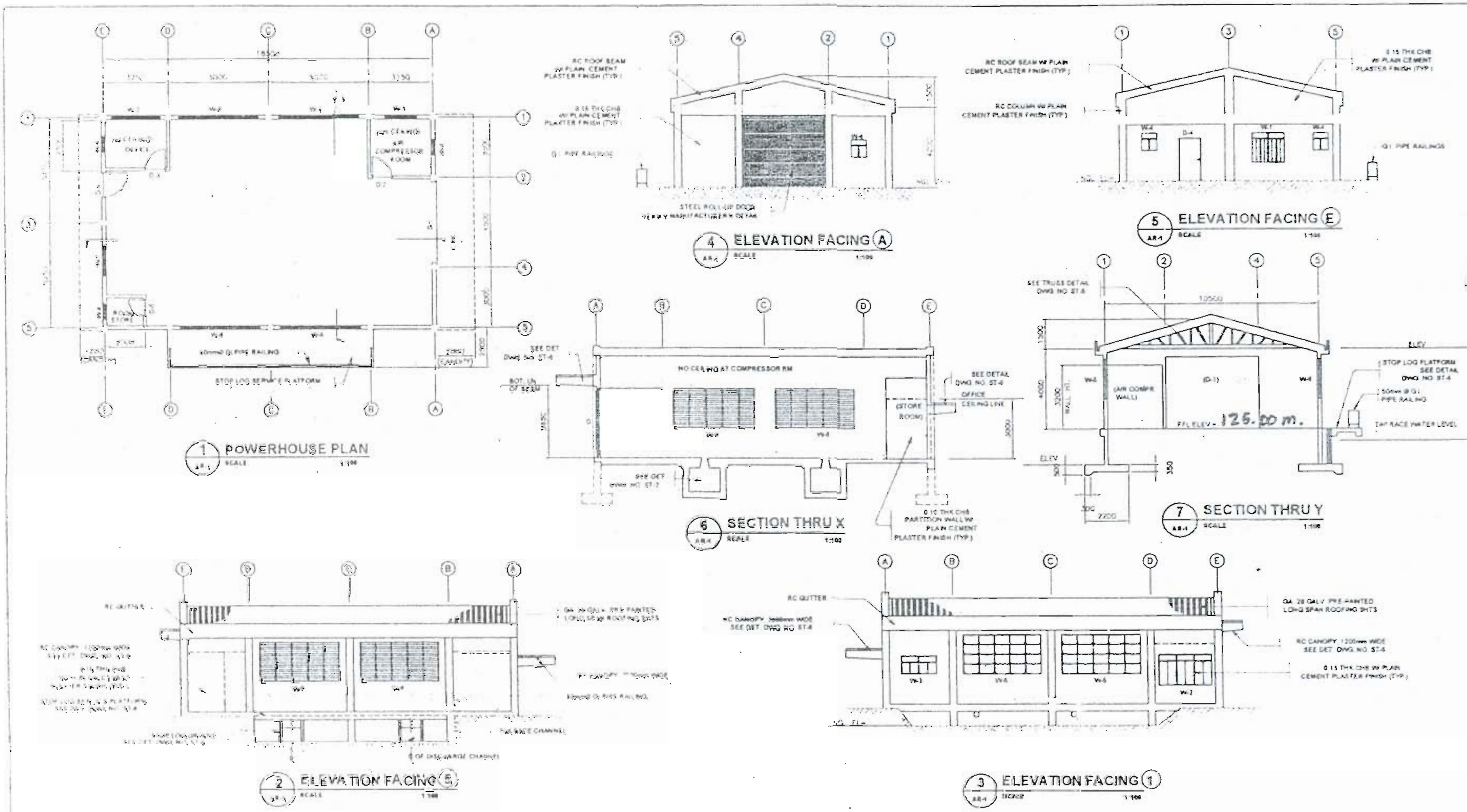
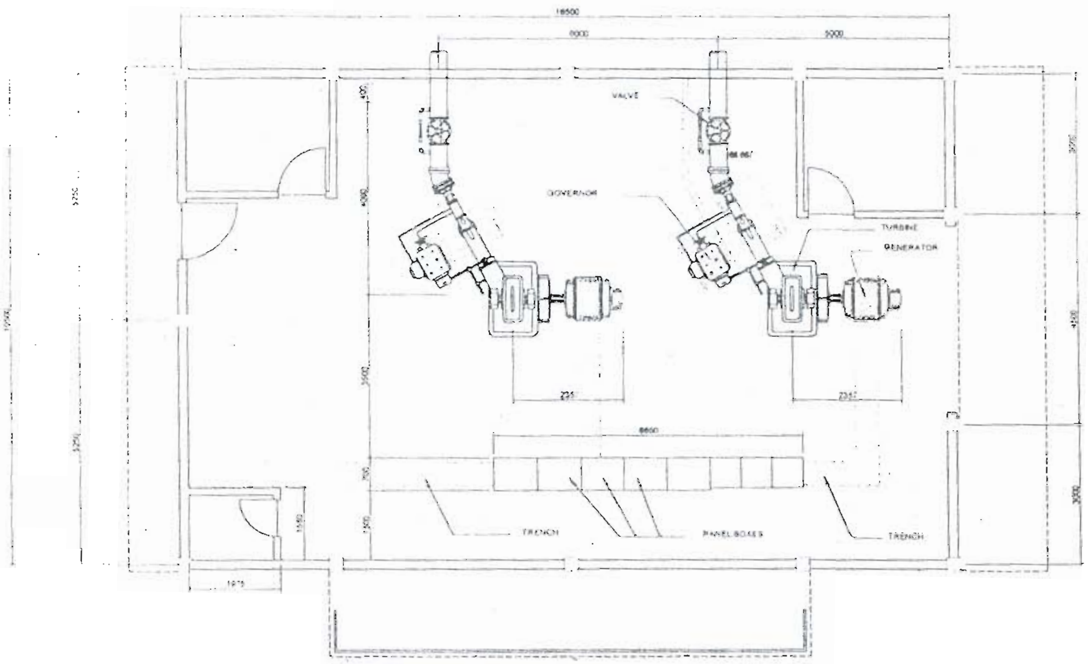
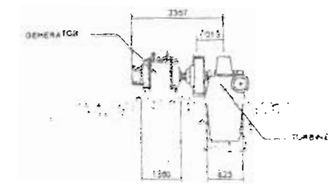


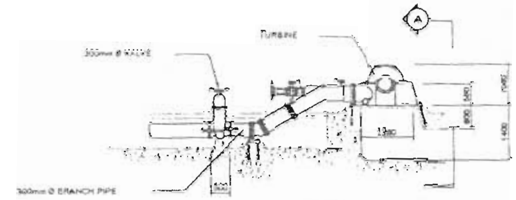
FIGURE 5-6: POWERHOUSE SCHEMATIC DETAILS



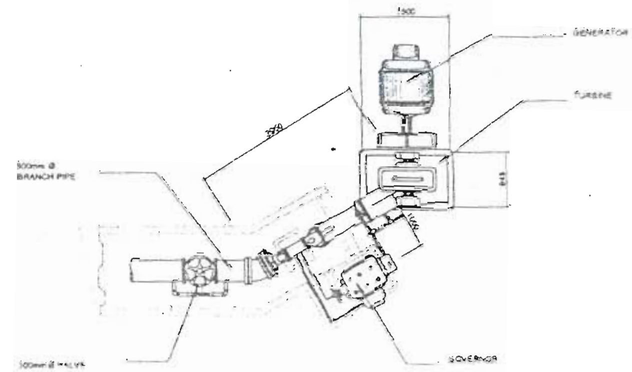
EQUIPMENT LAYOUT PLAN



SECTION THRU 'A - A'



ELEVATION



INDIVIDUAL PLAN

EQUIPMENT SPECIFICATION

- 2 × 320 KW TURBO IMPULSE TURBINE, 140M NET HEAD, 0.29 CMS/UNIT
- 2 × 300 KW SYNCHRONOUS GENERATOR, 1200 RPM RATED SPEED
- EFFICIENCY OF TURBINE AT DESIGNED POINT 84.2%
- RATED EFFICIENCY OF GENERATOR 91.0%
- GENERATOR VOLTAGE 480V, 60 Hz
- STAINLESS RUNNER OF TURBINE
- SOURCE PEOPLE'S REPUBLIC OF CHINA

FIGURE 5-7: ELECTRO-MECHANICAL DETAILS (Equipment Layout)

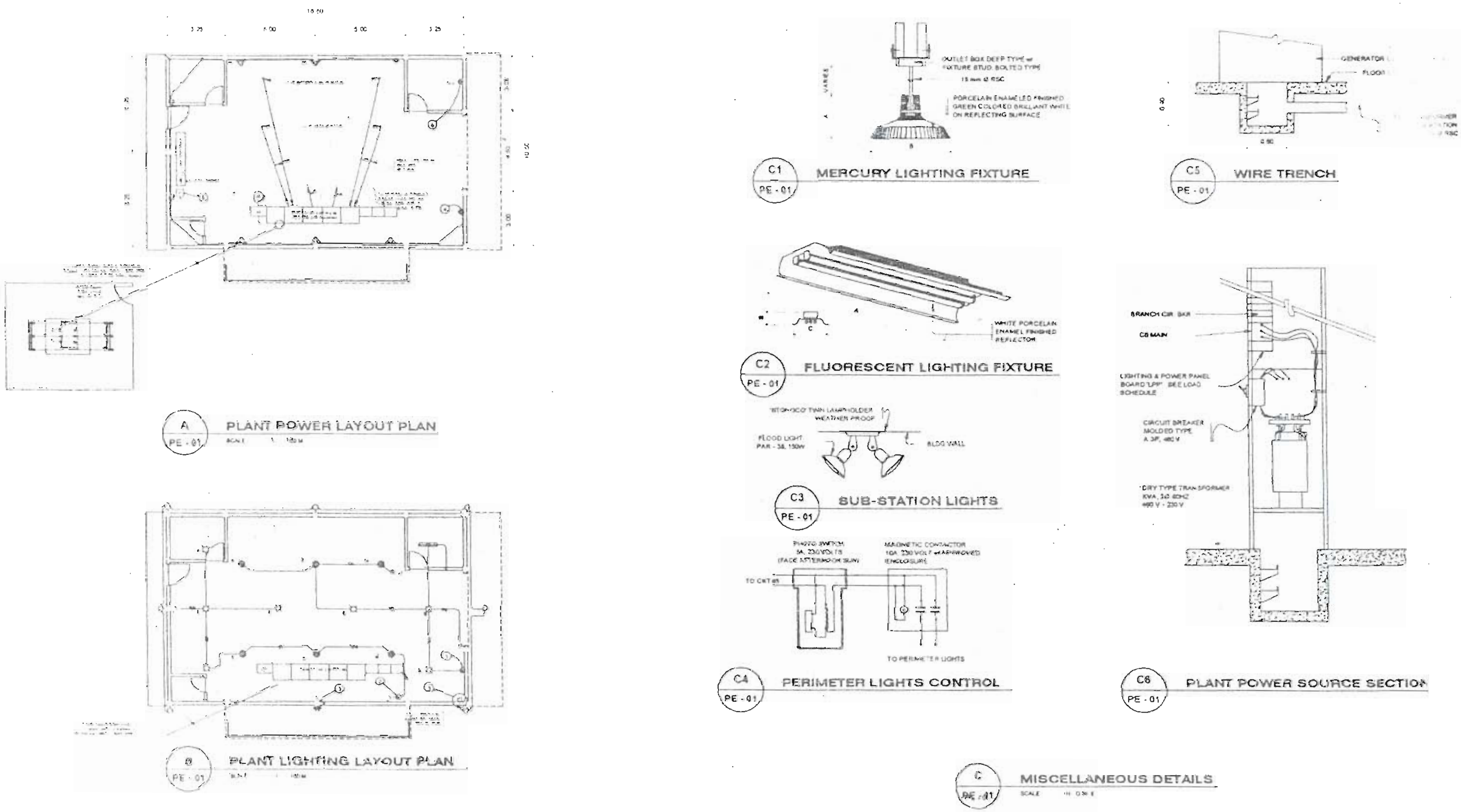


FIGURE 5-8a: ELECTRICAL DETAILS (Powerhouse)

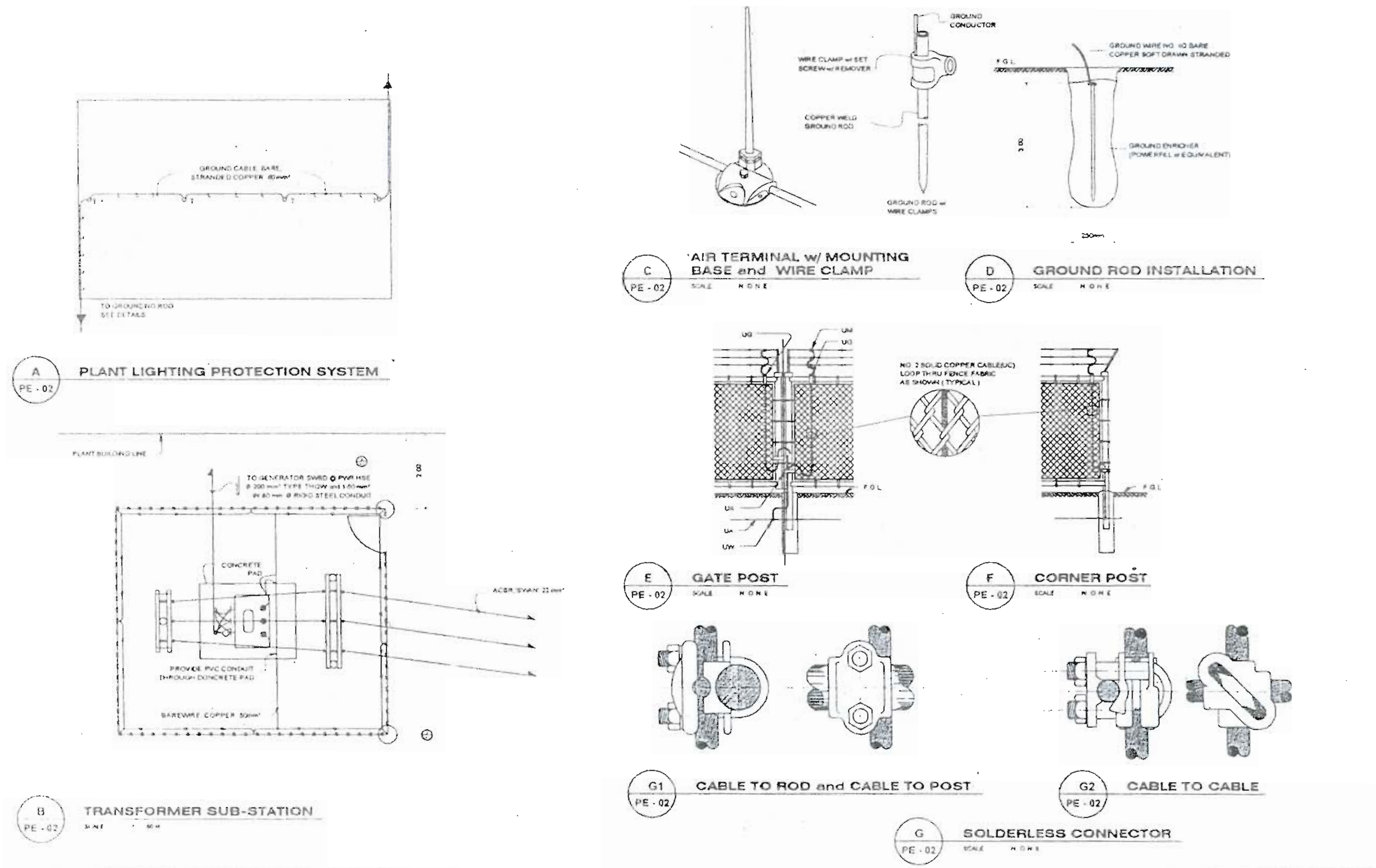


FIGURE 5-8b: ELECTRICAL DETAILS (Sub-Station)

LOAD SCHEDULE

LIGHTING & POWER PANELBOARD "LPP" 3 Ø 230V 60Hz (See DETAIL DWG No. CMPE-01)

CKT NO.	DESCRIPTION	LOAD VA/CKT	AMP LOAD PER PHASE A	AMP LOAD PER PHASE B	AMP LOAD PER PHASE C	CB RATING AF	CB RATING AT	POLE	BR. CKT. WIRE SIZE
1	[illegible]	534	2.30			50	15	2	[illegible]
2	[illegible]	552		2.40		50	15	2	[illegible]
3	[illegible]	161			0.70	50	15	2	[illegible]
4	[illegible]	1620	7.04			50	15	2	[illegible]
5	[illegible]	1840		8.00		50	20	2	[illegible]
6	[illegible]	2000			8.70	50	20	2	[illegible]
7	[illegible]	2000	8.70			50	20	2	
8	[illegible]	2000		8.70		50	20	2	
9	[illegible]	1600			7.00	50	15	2	
10	[illegible]	1600	7.00			50	15	2	
TOTALS		13907	25.04	18.70	16.40				

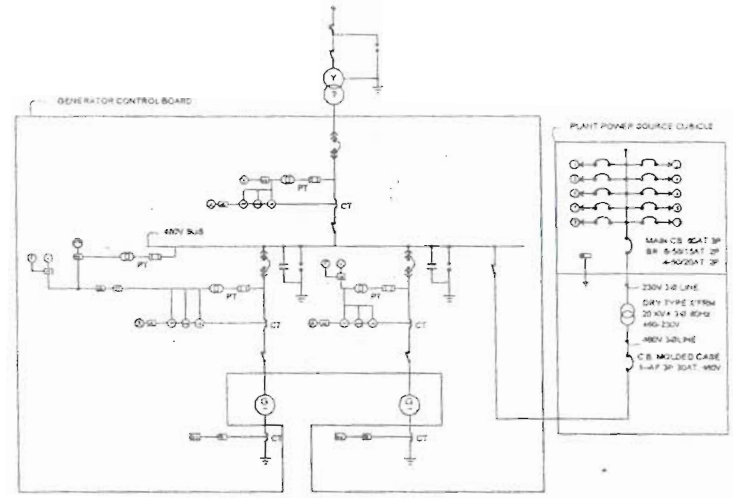
MAIN CIRCUIT BREAKER: 25.04+2.5(8.00) = 45.04 AMP USE 100AF 3P 60AT, 250V

FEEDER CONDUCTOR: 25.04+0.25(8.00) = 29.54 SAY 30A USE 14mm² TYPE THW

*ESL 23W: ENERGY SAVING LAMP 23W, 230V, "OSRAM DULUX EL LONGLIFE" OR EQUAL
BL-125W: BALLASTLESS MERCURY LAMP, 125W, 230V
FL-1-40W: FLUORESCENT LAMP, SINGLE 40W w/ HPF BALLAST

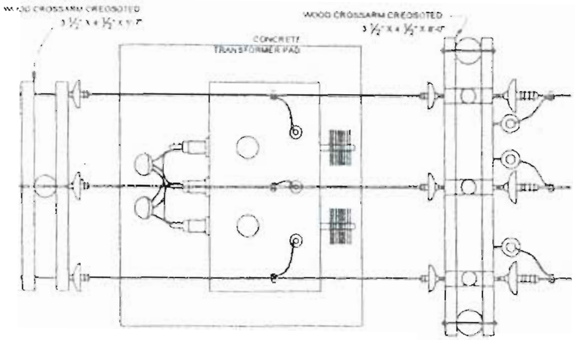
LEGEND

- FLUORESCENT LIGHTING FIXTURE, CEILING MOUNTED, 1-40W w/ HPF BALLAST
- MERCURY LAMP, 125 WATT, BALLASTLESS, w/ SHALLOW REFLECTOR, PENDANT MTD
- LIGHTING OUTLET, 23WATT, ESL 23 w/ SHALLOW REFLECTOR, PENDANT MTD
- PERIMETER LIGHT, 23 WATT, ESL 23 w/ SHALLOW REFLECTOR, PENDNT MTD
- SUB STATION LIGHTS, 2-150W PAR 38, FLOODLIGHTS
- DUPLEX CONVENIENCE OUTLET, FLUSH MOUNTED, GROUNDING TYPE
- WP SINGLE CONVENIENCE OUTLET, FLUSH MOUNTED, GROUNDING TYPE, WEATHER PROOF
- ACU SINGLE CONVENIENCE OUTLET, FLUSH MOUNTED, GROUNDING TYPE FOR ACU
- THUMBLER SWITCH, FLUSH MOUNTED. NUMERAL DENOTES NUMBER OF GANG
- MAGNETIC CONTACTOR, INDIVIDUALLY ENCLOSED, CONTROLLED BY PHOTO SW
- PHOTO SWITCH, TO CONTROL, HOLDING COIL OF ABOVE CONTACTOR
- PANEL BOARD CIRCUIT BREAKER TYPE, FOR PLANT LIGHTING & POWER CIRCUITS SEE DETAILS and ONE LINE DIAGRAM
- WIRING in EXPOSED CONDUIT RUNS. HASH MARKS DENOTES NUMBER OF CONDUCTORS WITHOUT HASH MARKS DENOTES TWO CONDUCTORS
- WIRING in UNDER FLOOR CONDUIT RUNS.(SAME NOTES ON NUMBER OF CONDUCTORS)
- GROUND CONDUCTOR, SIZE OF CONDUCTOR AS INDICATED
- LIGHTING CABLE, SIZE OF CABLE AS INDICATED
- BRANCH CIRCUIT HOMERUN. NUMERAL INDICATES CIRCUIT NO.
- BATTERY CHARGER, SIZE & RATING AS PER SPECIFICATION
- SAFETY SWITCH, 30A 3PST, 250V, FUSIBLE TYPE
- POWER TRANSFORMER, 500KVA, 13.2KV 0.48KV, 1 Ø 60Hz, OIL IMMERSED
- AIR CIRCUIT BREAKER (SEE SPECIFICATION)
- PRIMARY DISCONNECT, POLE MTD. 15KV
- LIGHTING ARRESTER, 15KV
- POTENTIAL (INSTRUMENT) TRANSFORMER, 480V 120V, 1 Ø 60Hz
- CURRENT TRANSFORMER, RATING AS INDICATED
- SWITCHBOARD MTD INSTRUMENT. V-VOLTMETER, A-AMMETER, F-FREQUENCY METER, PF-POWER FACTOR METER, KW-KILOWATT METER; KWH-KILOWATT HOUR METER
- INSTRUMENT SWITCH. AS-AMMETER SW, VS-VOLTMETER SW; SS-SYNCHRONIZING SW
- PROTECTIVE RELAY. 59-OVERVOLTAGE RELAY, 27-UNDERVOLTAGE RELAY, 49-OVERLOAD RELAY, 12-OVERSPEED DEVICE, 51-TIME OVERCURRENT RELAY, 50-INSTANTANEOUS OVERCURRENT RELAY, 87-DIFFERENTIAL CURRENT RELAY



A / PE-03 SCHEMATIC ONE-LINE DIAGRAM

FIGURE 5-8c: ELECTRICAL DETAILS (One-Line Diagram)



A
PE - 04
PLAN VIEW OF TRANSFORMER SUB-STATION w/o THE FENCE
SCALE NONE

NOTES:

1 ALL WORKS COVERED BY THESE PLANS & SPECIFICATION SHALL COMPLY WITH THE APPLICABLE REQUIREMENTS OF THE LATEST EDITION OF THE PHILIPPINE ELECTRICAL CODE, THE EXISTING ORDINANCES OF THE MUNICIPALITY AND THE RULES AND REGULATIONS OF THE LOCALITY.

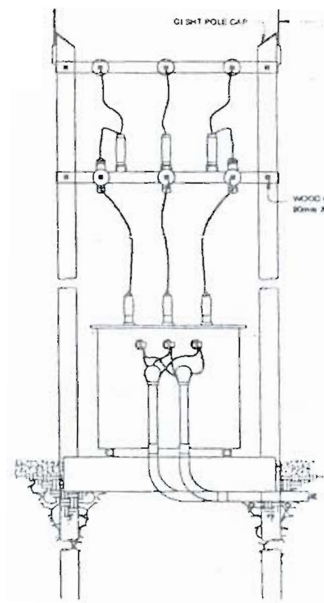
2 ACTUAL AND RELATIVE POSITIONS OF MANUFACTURER SUPPLIED DEVICES AND EQUIPMENT ARE TENTATIVE AND SHOULD BE VERIFIED IN THE FIELD.

3 THE PREPARATIONS OF THESE PLANS AND SPECIFICATIONS WERE DONE WITH DILIGENT CARE, BUT SHOULD THERE BE CONFLICT BETWEEN THESE DOCUMENTS, THE SPECIFICATIONS WILL PREVAIL.

4 THE MAIN GROUNDING CONDUCTOR SHALL BE 50mm², BARE SOFT DRAWN COPPER, STRANDED UNLESS OTHERWISE INDICATED.

5 GROUNDING CONDUCTORS AND BONDING JUMPERS SHALL BE CONNECTED BY EXOTHERMIC WELDING, OR PRESSURE CONNECTORS OR CLAMPS APPROVED FOR THE PURPOSE. CONNECTION DEVICES OR FITTINGS THAT DEPEND SOLELY ON SOLDER SHALL NOT BE USED.

6 WOODEN POLES AND CROSSARMS SHALL BE CREOSOTED AS PER TREATMENT AA OR BETTER. POLES SHALL BE SET ON THE GROUND APPROXIMATELY ONE SIX OF ITS LENGTH OR IN ACCORDANCE WITH GOOD ENGINEERING PRACTICE. REINFORCED CONCRETE POLES MAY BE USED PROPER SETTING SHOULD BE ADJUSTED.



B
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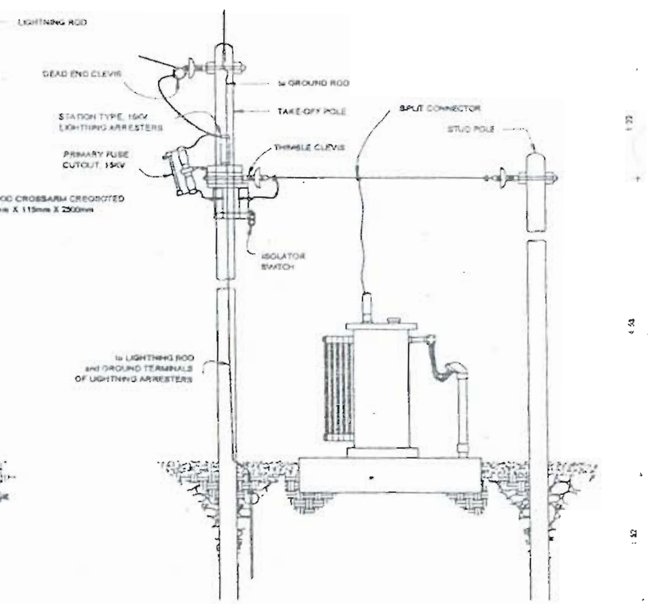
SUB-STATION TAKE-OFF POLE
SCALE NONE



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SUB-STATION ELEVATION w/o THE FENCE
SCALE NONE

FIGURE 5-8d: ELECTRICAL DETAILS (Take-Off)

CHAPTER 6.0: STABILITY OF GROUND SLOPES

6.1 INTRODUCTION

The stability of ground slopes relies on the geological and geotechnical conditions of the project area based mainly from surface geologic mapping and from available geological literatures.

Sub-surface investigation such as test pitting and sampling, auger boring and core drilling, as necessary, will be undertaken during the detailed engineering phase of the study. Such undertaking will define the rock foundation characteristics at the proposed structures like weir, powerhouse, headrace and penstock routes.

6.2 REGIONAL GEOLOGY

6.2.1 Physiography

Camarines Norte is clustered under the Bicol sub-province of the Eastern Physiographic Province, which constitute one of the four-(4) physiographic provinces that comprise the Philippine Archipelago. The classification and division of a physiographic province is based on the island and submarine morphology.

The Bicol sub-province extends from Southern Sierra Madre to the southern tip of Bicol Peninsula and includes the islands of Polilio and Catanduanes. The Bicol Peninsula forms the southern part of Luzon. Mt. Labo (942 m.) in the northern part of Camarines Norte is one of the dormant volcanoes along the eastern part. The eastern coast is characterized by very irregular, deep and extensive coastal embayments. The coastal feature of Barangay Colasi, Mercedes, Camarines Norte reflects this general characteristic having a deep coastal embayment with depth of about 80 meters.

6.2.2 Lithology

Pre-cretaceous schist's and quartzite's are the basement rocks in the region. This rock suite is uncomfortably overlained by cretaceous to quaternary volcanics and sedimentary rocks which are separated by either faults or uncomformities.

The oldest tertiary sedimentary rocks resting on the metamorphic and volcanic rocks is the Universal Formation (Meek, etal 1941). This formation is intruded by diorite and related rocks. The Universal Formation is composed of conglomerate, arkose, carbonaceous and argillaceous shale and limestone. Later intrusion of Larap Volcanics buried the Universal Formation. Subsequent deposition of the Lower Miocene Bosigon Formation overlain the Larap Volcanics with an angular unconformity.

The lower member of the Bosigon Formation consists of conglomerate, sandstone, calcareous shale and limestone. The upper member is a thick intercalation of basaltic flows, volcanic wackes, tuff breccias, cherts and limestone. Overlying the extensive Bosigon Formation in Camarines Norte distirict is the Sta. Elena Formation of Late Miocene age. This sedimentary unit is a thick interbedded sequence of conglomerate, sandstone, siltstone, shale and limestone. The project area is believed to be located on the sedimentary units of Sta. Elena Formation and Bosigon Formation.

The alluvial deposits consisting of unsorted to poorly sorted and unconsolidated soil, silt, sand and gravel along flood plains and large river valleys cover the northeastern and eastern parts of the province. The alluvial layer includes volcanic debris.

6.2.3 Structures

From Fig. 6-1 (Fold Pattern) Camarines Norte belongs to the NW-SE system of major folds based on the axial trends. The NW-SE set exhibit axial traces ranging between N45W to N10W.

The most significant normal or gravity fault in the Bicol region is the NW trending fault in the central part of Camarines Sur that crosses Ragay gulf. Thrust faults on the other hand are located in the northeastern parts of Camarines Norte, Camarines Sur and Catanduanes Island (Miranda and Vargas, 1967), as shown in Fig.6-2-Crustal Fractures Map of the Philippines, as modified, in the MGB publication of 1982.

6.3 LOCAL GEOLOGY

The project area is on the southeastern coast of Camarines Norte bounded by San Miguel Bay. Going inland, the topography is characterized by rolling hills to folded steep valleys or gorges. Low lying rounded peaks have top elevation ranging from 245 meters to 400 meters, while the highest peak stands at 957 meters wherein the watershed limit is delineated.

Local thrust faulting and folding have developed the steep riverbanks that rises from 100 meters to 400 meters elevation. The Colasi River, which is the hydro resource, flows through one of the river systems whose gorges could be exploited for a medium length headrace distance and a gross head of about 160 meters.

The river flows through three (3) waterfall/drops, all downstream of the weir site. The water falls range in height from 20 m to 40 m. Outcrops of sedimentary rocks consisting of sand stone, conglomerate and few limestone lined the river bed and river banks. The riverbed is littered with boulders of sandstone and conglomerate and some volcanics. Flat areas observed at the weir site are covered with sandy soil mixed with cobbles and boulders. Along the existing trail at right bank facing upstream, the soil cover is thin and composed of sandy clay with loose weathered rock fragments.

6.4 ENGINEERING GEOLOGY

Geological Investigation was limited to surface geologic mapping at the proposed weir site, headrace route and powerhouse site. Sub-surface investigation to determine the foundation characteristics and slope stability as well as the suitability of construction materials will be carried out at the detailed engineering level of study wherein the location of the weir, headrace route and powerhouse have already been determined. Rock exposures, however, indicate a stable ground slope condition.

Surface geologic mapping was conducted along river channel from elevation 280 meters, which is the weir site to the powerhouse site at about elevation 120 meters.

6.4.1 Weir /Intake

The proposed run-of river diversion weir will be founded on the massive sedimentary rocks. The conglomerate and sandstone exhibit irregular interbedding with traces of limestone layer on top. The width section is about 20 meters. Riverbed deposits of mostly boulders are scattered along a 100-meter stretch downstream to the first waterfall. The width of the river channel narrows downstream as the left and right banks turn steep.

6.4.2 Penstock / Headrace route

The penstock/headrace route is being considered along the left bank (facing upstream) of Colasi River because it has a shorter length than locating it at the opposite bank. Both riverbanks have relatively steep slopes. However, the right bank (facing upstream) has a slightly lesser steep slope but would require much longer headrace route and would necessitate at least four (4) major waterway crossing structures. At elevation 125 meters, where the powerhouse site is proposed, the left bank rises at an angle of 75 to 80 degrees to a height of about 50 meters. From thereon, however, the slopes of the left bank becomes gentler, hence, much more convenient than the rightbank for the laying of penstock line. Further, the LGU plan to build an access road at least up to the powerhouse area, on the left bank

The rock foundation along the route is solid mass of sandstone and conglomerate. Foundation of the penstock apparently will be on sound rock. Where the ground is very steep, rock bolting may be required.

The slope surface are moderately to densely forest with second growth trees that protects the slope from potential landslides. With an underlying mass of rock with relatively thin cover of about a meter, the slopes appear stable. The rock surface does not show any significant discontinuities of fracturing due to forest cover.

6.4.3 Powerhouse Site

The proposed powerhouse station is located approximately 1,980 meters downstream of weir site running at mild slope downstream running along contour elevation 280 (-) meters. The difference in elevation from the weir (elevation 280.80 m.) to the powerhouse (elevation 125 m.) is 155.80 meters. The ground surface is made up of conglomerate and sandstone cobbles and boulders with thin veneer of clayey soil of not more than a meter in thickness. The vicinity is fairly covered with trees and bushes and heavy vegetation is noted above 20 meters from the river level.

At detailed engineering phase, test pitting or auger borings are recommended to probe into the depth and thickness of the overburden composed of soil and cobbles/boulders but based on the outcrops, they appear to be thin. High-angled joints are sparingly seen and spaced at 1.0 to 1.5 meters. Some of the joints are open.

6.5 SEISMICITY

Seismicity of the region can be assessed from studies conducted jointly by the Philippine Institute of Volcanology (PHIVOLCS) and the United States Geological Society (USGS) in 1994 and published with the title "Estimates of the Regional Ground Motion Hazard in the Philippines."

The study produced probabilistic ground motion hazard contour maps to estimate peak ground acceleration that have 10 % probability of being exceeded in 50 years for rock, medium soil and soft soil site conditions. The estimates were calculated based on data from 21 seismic zones that describe the geographic content and frequency of earthquake occurrence for the major tectonic elements of the Philippine region.

The authors adopted the ground motion attenuation equation developed by Fukushima and Tanaka in 1990 who assumed that regional attenuation characteristics between the Western Pacific Island arc settings are similar. The attenuation equation is:

$$LOG_{10} A = 0.41M - LOG_{10} (R = 0.032 \times 10^{0.41M}) - 0.0034 R + 1.30$$

Where A = mean peak acceleration, *cm/sec²*

R = shortest distance between site and fault rupture, *km*

M = surface wave magnitude

In reference to the ground motion hazard maps, the project area belongs to seismic source zone 7.0 (Figure 6-3) having a peak ground acceleration estimated value of 0.23g (Figure 6-4) with a corresponding return period of 50 years for the sedimentary rocks. For medium soil, the estimated value is 0.35 g (Figure 6-5) while peak acceleration for soft soil is almost doubled at 0.65 g (Fig. 6-7).

6.6 PHOTOGRAPHS

The subsequent pages show the surface geologic characteristics in photographs.

Photo 1 – Downstream view from the weir site showing a narrowing river channel and river bed deposits of boulders and cobbles. Note the vegetation on both riverbanks.

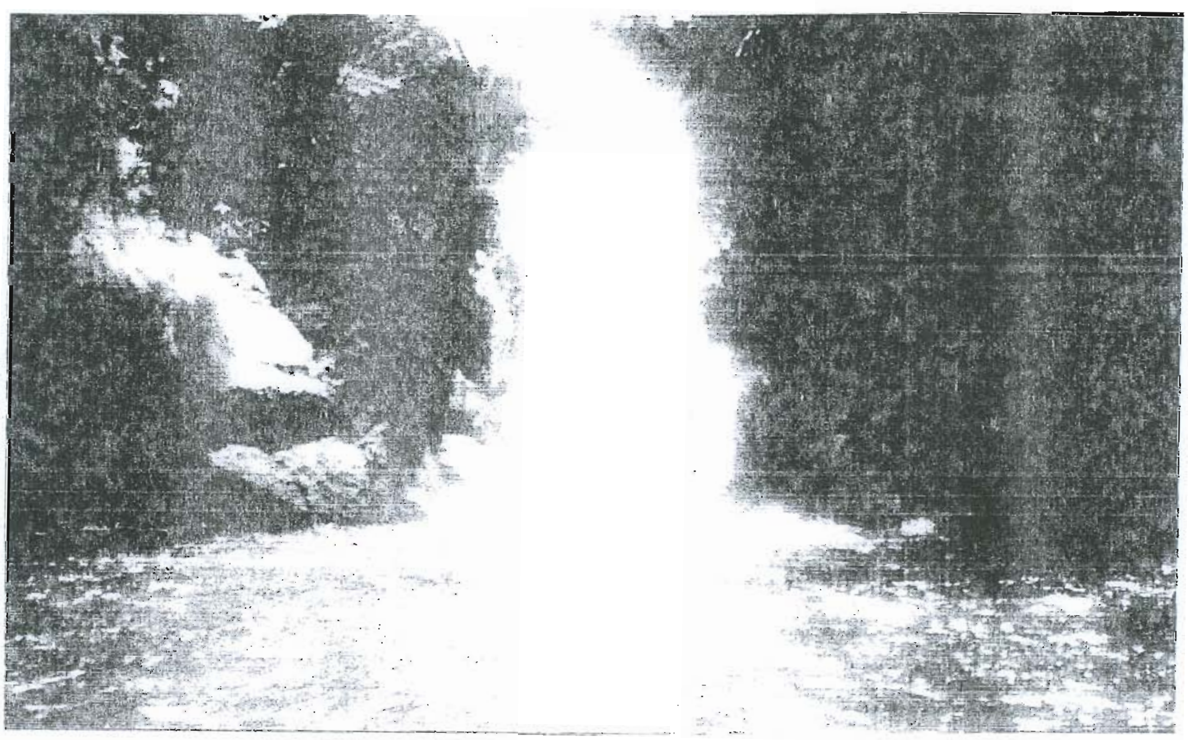

Photo 2 – View of the 1st waterfall at El. 168 m. Massive bed rock of conglomerate/ sandstone lining the riverbanks

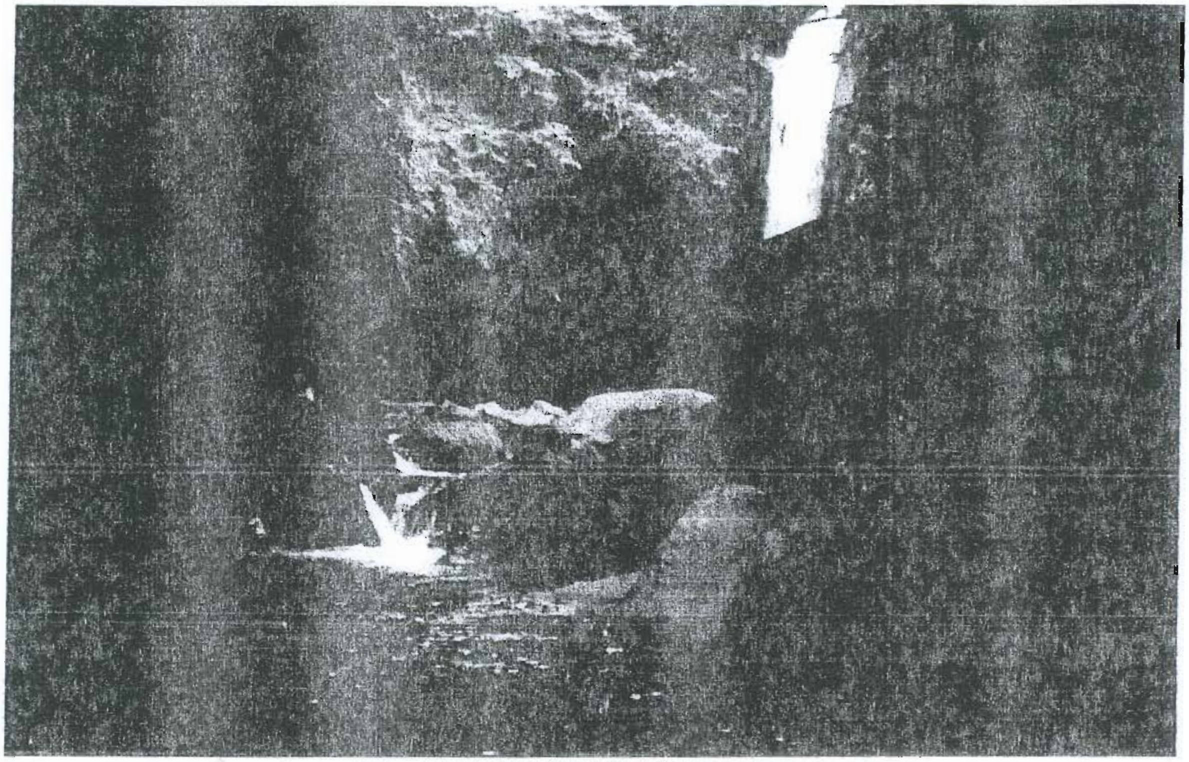

Photo 3 - Another view of the Colasi river with the third falls at El. 203 meters, also showing nature of river bed and watercourse

Photo 4 - Another view of the proposed headrace route uphill of the exposed rock surface

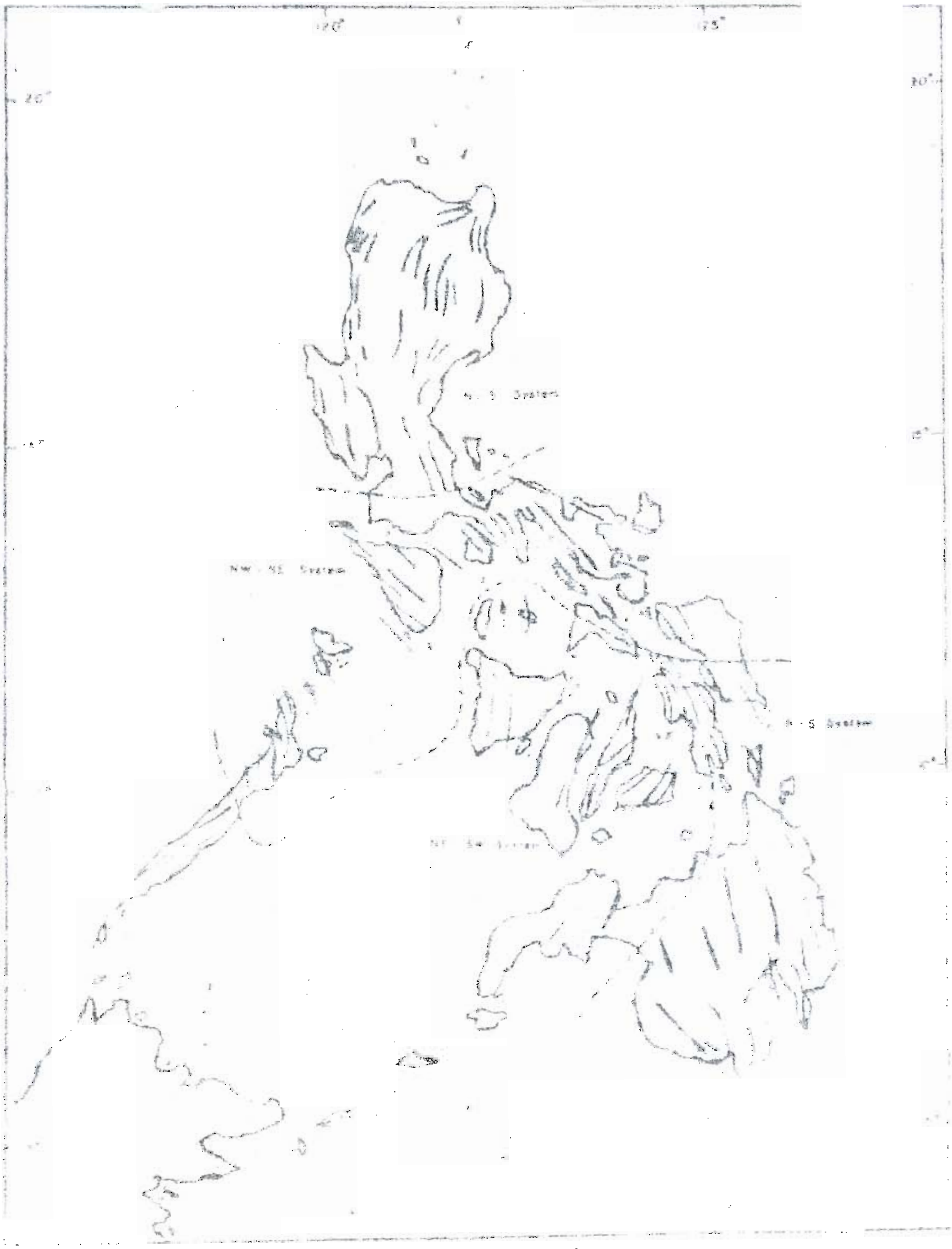

FIGURE 6-1
Fold Patterns

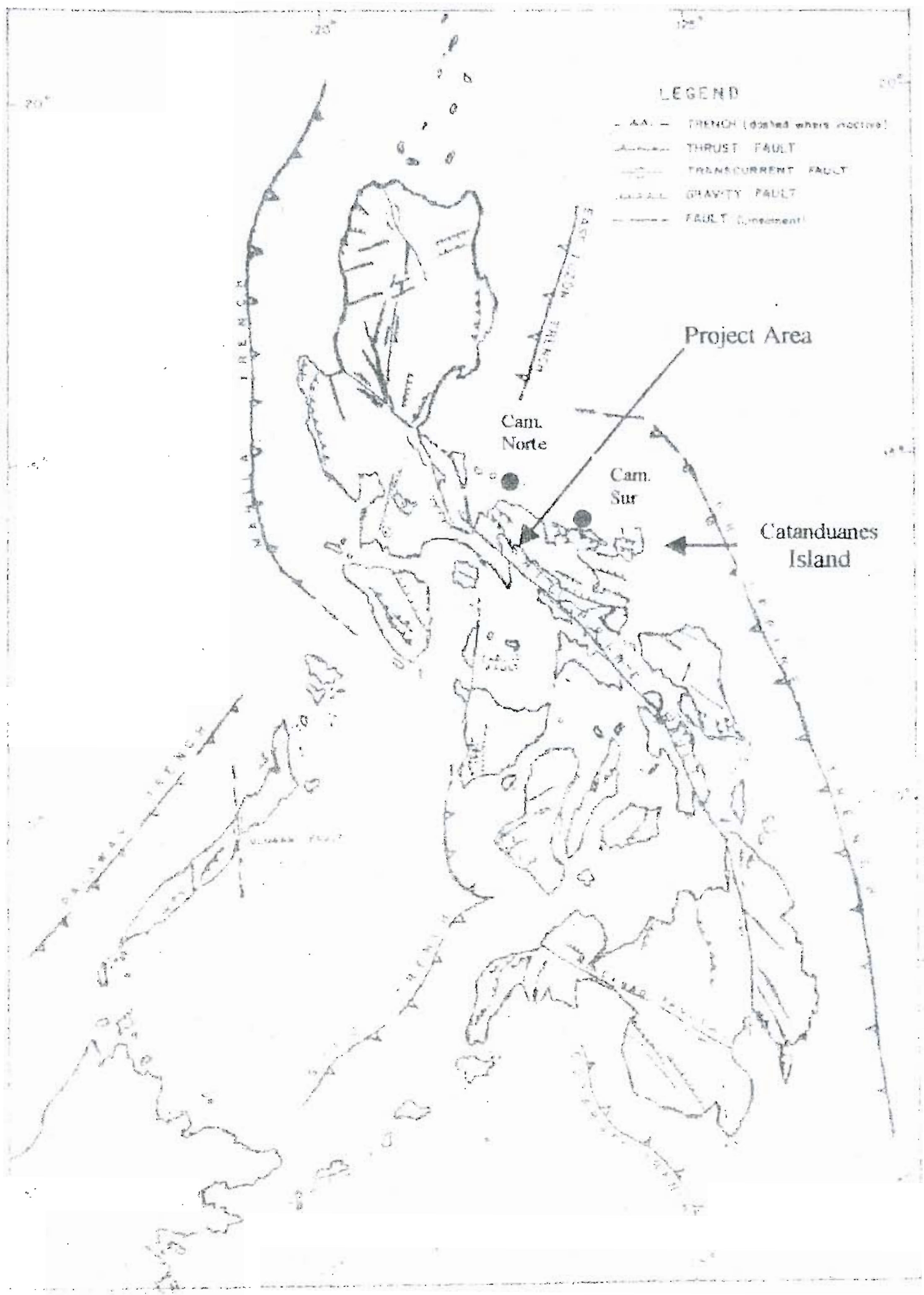

FIGURE 6-2
Crustal Fractures

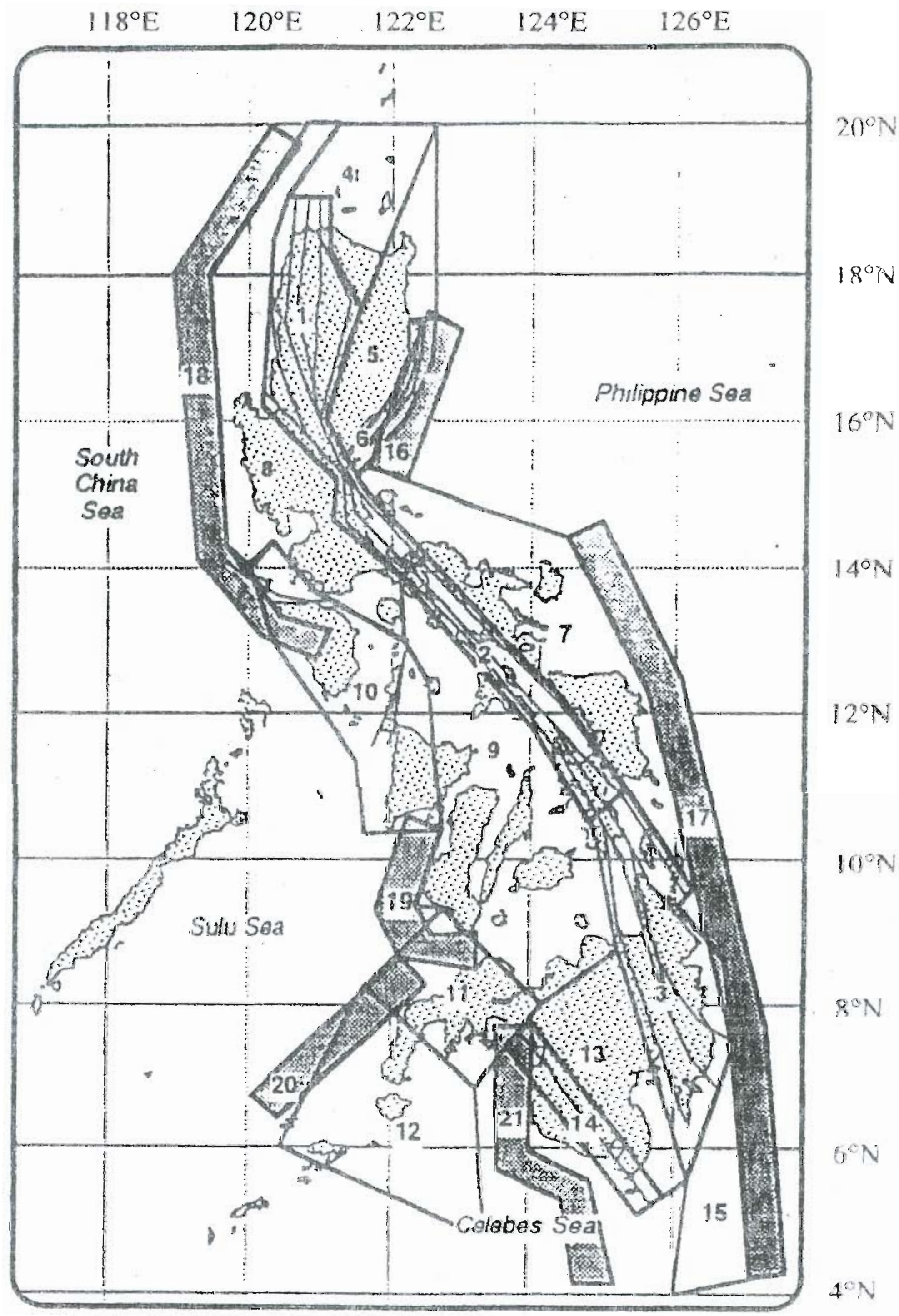

FIGURE 6-3

Seismic source zones and modeled faults seismic source zones are labeled 1 through 21 for reference in the text and in Table 1. Dark shading indicated dipping-plane seismic sources that are used to model the shallow plate interfaces of subduction.

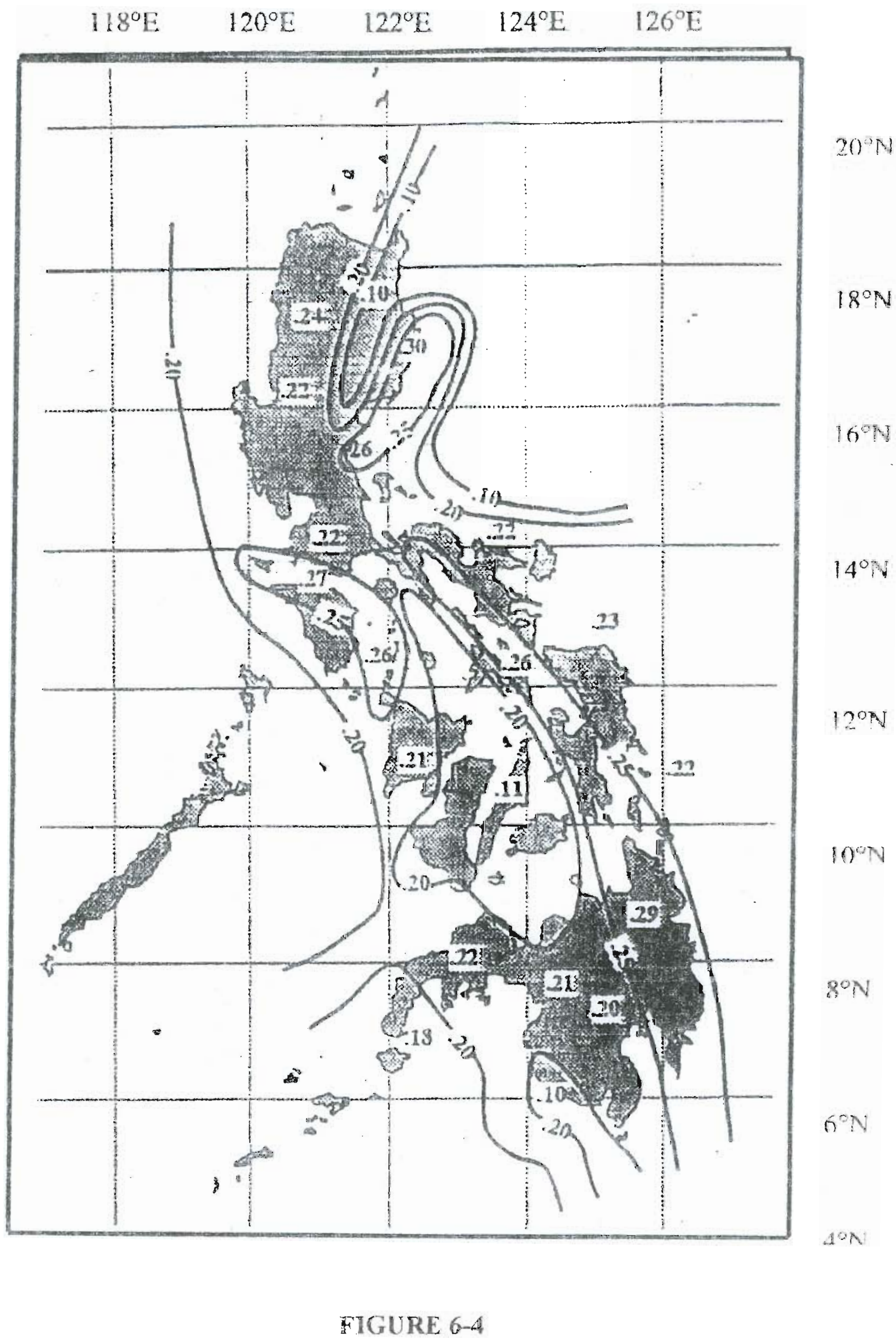

FIGURE 6-4

Map showing peak horizontal acceleration amplitudes in rock for the Philippine region. Acceleration values have a 10 percent probability of exceedance in 50 years. Contours are in terms of

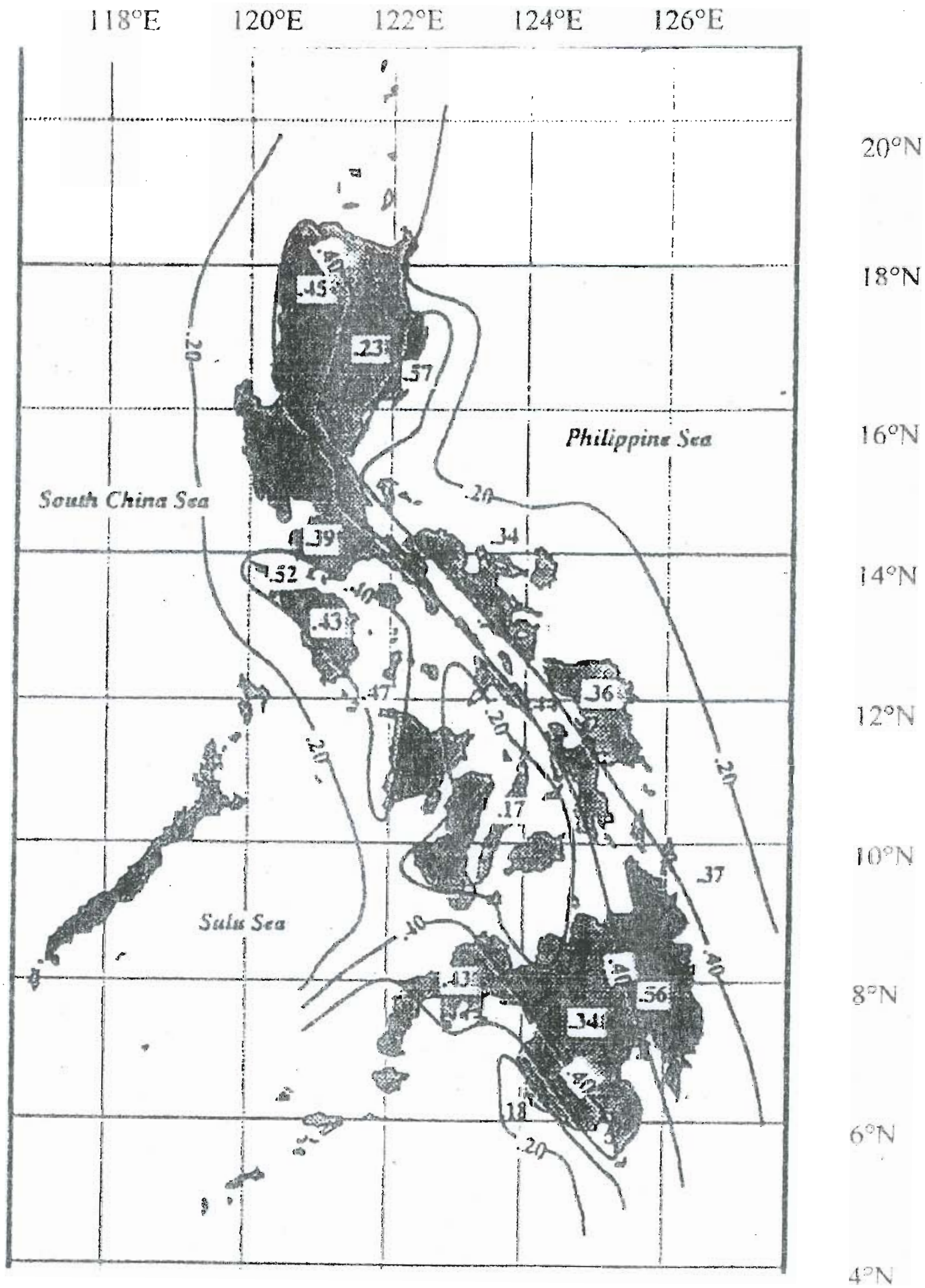

FIGURE 6-5

Map showing peak horizontal acceleration amplitudes in medium soil for the Philippine region. Acceleration values have a 10 percent Probability of exceedance in 50 years. Contours are in terms of the acceleration of gravity (G).

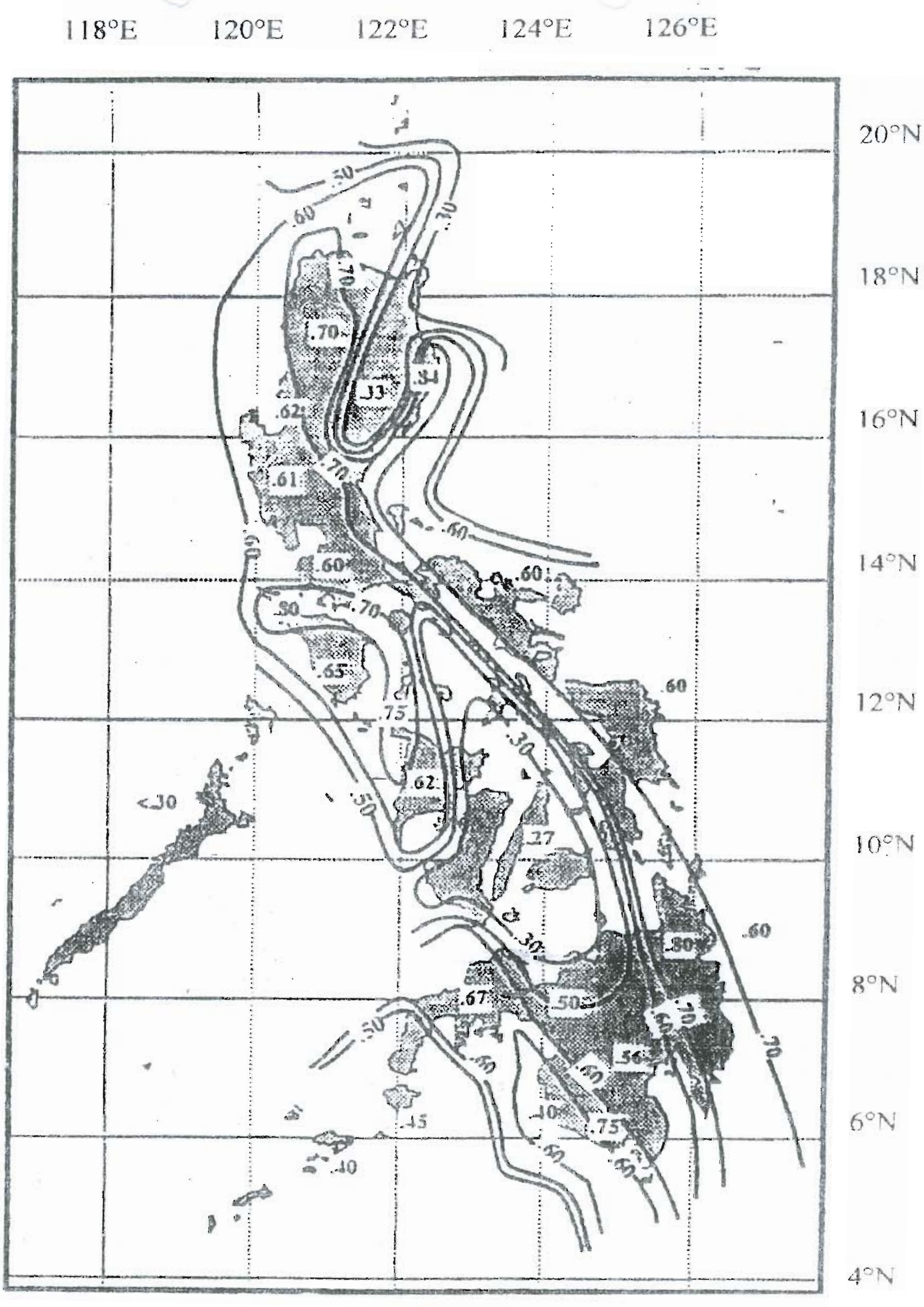

FIGURE 6-6

Map showing peak horizontal acceleration amplitudes in <u>soft soil</u> for the Philippine region. Acceleration values have a 10 percent probability of exceedance in 50 years. Contours are in terms of the acceleration of gravity (G).