1510-13166

PN-AAL-145

BICOL RIVER BASIN DEVELOPMENT PROGRAM

RINCONADA INTEGRATED AREA DEVELOPMENT

FEASIBILITY STUDIES

LAKE BATO REGULATION & DIVERSION PHASE - I

INTERIM REPORT

31 JANUARY 1978

TIPPETTS-ABBETT-McCARTHY-STRATTON
NEW YORK

TRANS-ASIA ENGINEERING ASSOCIATES, INC.
HAWAII

A Joint Venture

TIPPETTS-ABBETT-MCCARTHY-STRATTON TRANS-ASIA ENGINEERING ASSOCIATES, INC.
A JOINT VENTURE
RINCONADA INTEGRATED AREA DEVELOPMENT PROJECT

Emerald Shopping Arcade
Iriga City

14 February 1978

Atty. Salvador P. Pejo
Acting Program Director
Bicol River Basin Development
Program
Baras, Canaman
Camarines Sur

Thru : Engr. Carmelo R. Villacorta
Project Manager (GOP)
Rinconada IAD Project

Subject : Submittal of the Interim Report on
Lake Bato Regulation and Diversion

Dear Sir:

In accordance with the terms of the contract, we herewith submit fifty (50) copies of the above report. This report summarizes the results of the Phase I Study to determine (1) if the Diversion is necessary for proper functioning of the Lake Bato Regulation, and (2) if the Diversion is technically feasible.

The Diversion Channel is not a pre-requisite for the Lake Bato Regulation. The regulation would control the lake only at lower levels, and can function independently of the Diversion.

Technically, the Diversion is a viable project and it is the only feasible means of reducing the extensive flooding in the Rinconada Area. The alternative is to accept the existing flood conditions and to discourage further development in the flood-prone areas.

Economically, the Diversion is a doubtful project. The estimated cost is ₱200 million and there would not be a sufficient increase in the agricultural production and in the reduction in flood damages to justify this expenditure. However, this Phase I Study did not include an economic or social analysis, and there could be benefits from health and welfare, future development, and improved land use which could be significant.

This Interim Report has been reviewed with the Rinconada Area Steering Committee on 3 February 1978. There was expressed concern about the social problems associated with the existing flood conditions, and the need for the social benefits to be included in the study. The Steering Committee recommended that this be further reviewed by the Bicol River Basin Coordinating Committee. The Coordinating Committee reviewed the report on 10 February 1978 and recommended that an economic and social analyses of the Diversion Channel should be completed during the next phase of the study.

The economic and social analyses of the Lake Bato Diversion Channel is now in progress, and a supplement on these studies will be subsequently submitted to complete this Report.

Very truly yours,

TIPPETTS-ABBETT-MCCARTHY-STRATTON,
TRANS-ASIA ENGINEERING ASSOCIATES, INC.
A JOINT VENTURE

RICHARD R. VETTER
Resident Project Manager

/emy

LAKE BATO REGULATION AND DIVERSION

PHASE I

INTERIM REPORT

C O N T E N T S

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I. INTRODUCTION

The Comprehensive Water Resources Study (CWRS) of the Bicol River Basin identified several sub-projects within the Rinconada IAD that could be major components in the water resources development of the area. Two of these sub-projects, the Lake Bato Regulation and the Lake Bato-Pantao Bay Diversion, are inter-related and are the subject of this Interim Report on the Phase I Study. A third sub-project, the Lake Baao Regulation, is hydraulically linked to the diversion and has also been considered. This study was a preliminary appraisal to determine if (1) the diversion is technically feasible, and (2) if the diversion is necessary for proper functioning of the Lake Bato Regulation.

The scope of work for the next, Phase II, portion of this study will be defined after this Interim Report has been reviewed by interested agencies.

Technically, the Diversion is a viable project. There are approximately 11,000 hectares in the Lake Bato and Lake Baao area which are annually flooded. This area includes the urban development of Bula, Baao, Nabua and Bato with a population of approximately 100,000. The diversion would be very effective in lowering the flood levels, and it is the only apparent means of effecting any flood relief in the area.

The diversion would have little effect on the maximum flood levels along the Lower Bicol River. These maximum levels are caused primarily by tidal surges from the Estuary. There would be a reduction in the duration of flooding which would improve the interior drainage conditions along the Lower Bicol.

The diversion could be constructed with no unusual difficulties. The open channel alternative was considered the least costly and most favorable type of diversion. It could be excavated by conventional methods, and the large quantity of excavated material could be placed in the undeveloped areas adjacent to the cut and terraced and levelled for productive use.

The tunnel alternative is less favorable. The soil conditions along the alignment are considered to be moderate to poorly suited for tunneling. Heavy structural supports would be required in some reaches and reinforced concrete lining would be required throughout. These are inordinately costly and the overall cost for the tunnel alternate is considerably greater than for the open cut.

Lake Bato would be regulated, for dry season storage, at levels considerably below flood levels and this regulation could be achieved without the diversion. During flood times, the control works would be fully open and it would not restrict nor alter the existing flood pattern. However, the diversion would allow greater flexibility in the regulation of the lake for a more optimum use of this land and water resource.

Sedimentation of the lake is progressing at a minimal rate and there is no significant accretion of the shoreline. The sedimentation is caused primarily by fine silts in suspension, and the regulation would have no impact on the existing pattern.

The regulation of Lake Baao, however, could not be fully effective without the Bato Diversion. The regulation of Lake Baao would tend to restrict the flood storage in the area and cause an increase in flood levels along the Bicol River unless there were an alternate outlet for the flood waters.

II. DESCRIPTION OF LAKE BATO ENVIRONS

A. LOCATION

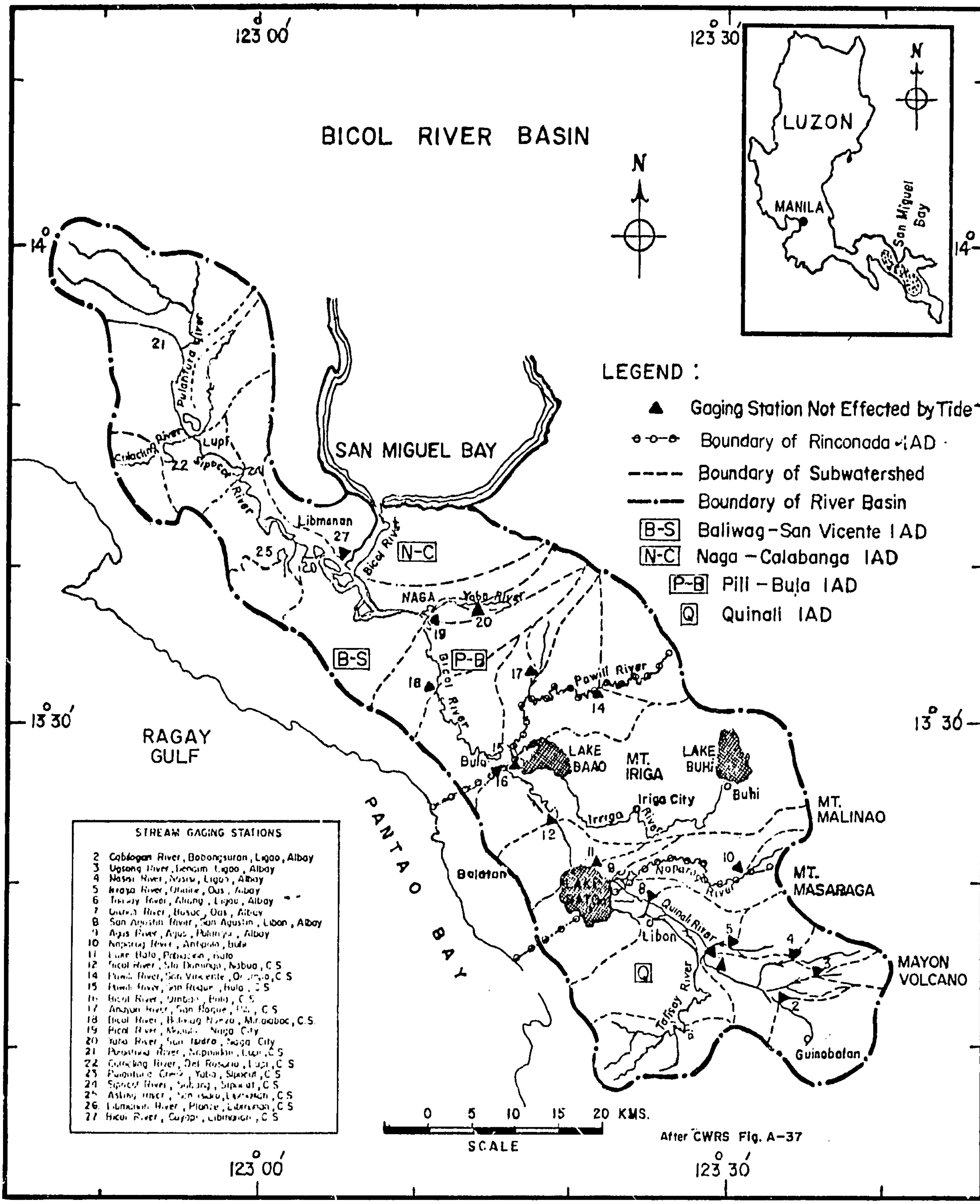
Lake Bato is located in the southern portion of the Bicol River Basin approximately 500 kilometers southeast of Manila on the Island of Luzon (Fig. 1). The Lake Bato Regulation and Diversion is a sub-project of the Rinconada Integrated Area Development Project and includes consideration of the upstream watershed in the Quinali IAD. Lake Bato has a drainage area of 874 $km.^2$ which includes the Ragay Hills and the drainage area of the Talisay River to the southwest; the slopes of Mt. Masaraga, of Mt. Mayon, and the drainage area of the Quinali River to the southeast; and the slopes of Mt. Malinao and the drainage area of the Naporong River to the east.

The project influence area includes the Bicol River downstream to Ombao with a total drainage area of 1,630 $km.^2$. In addition to Lake Bato, this total drainage area includes the foothills of Mt. Isarog and the drainage area of the Pawili River to the north, the slopes of Mt. Iriga and the drainage area of the Barit (Iriga) and the Waras Rivers to the northeast, and the Ragay Hills to the southwest.

B. TOPOGRAPHY AND SECTIONS

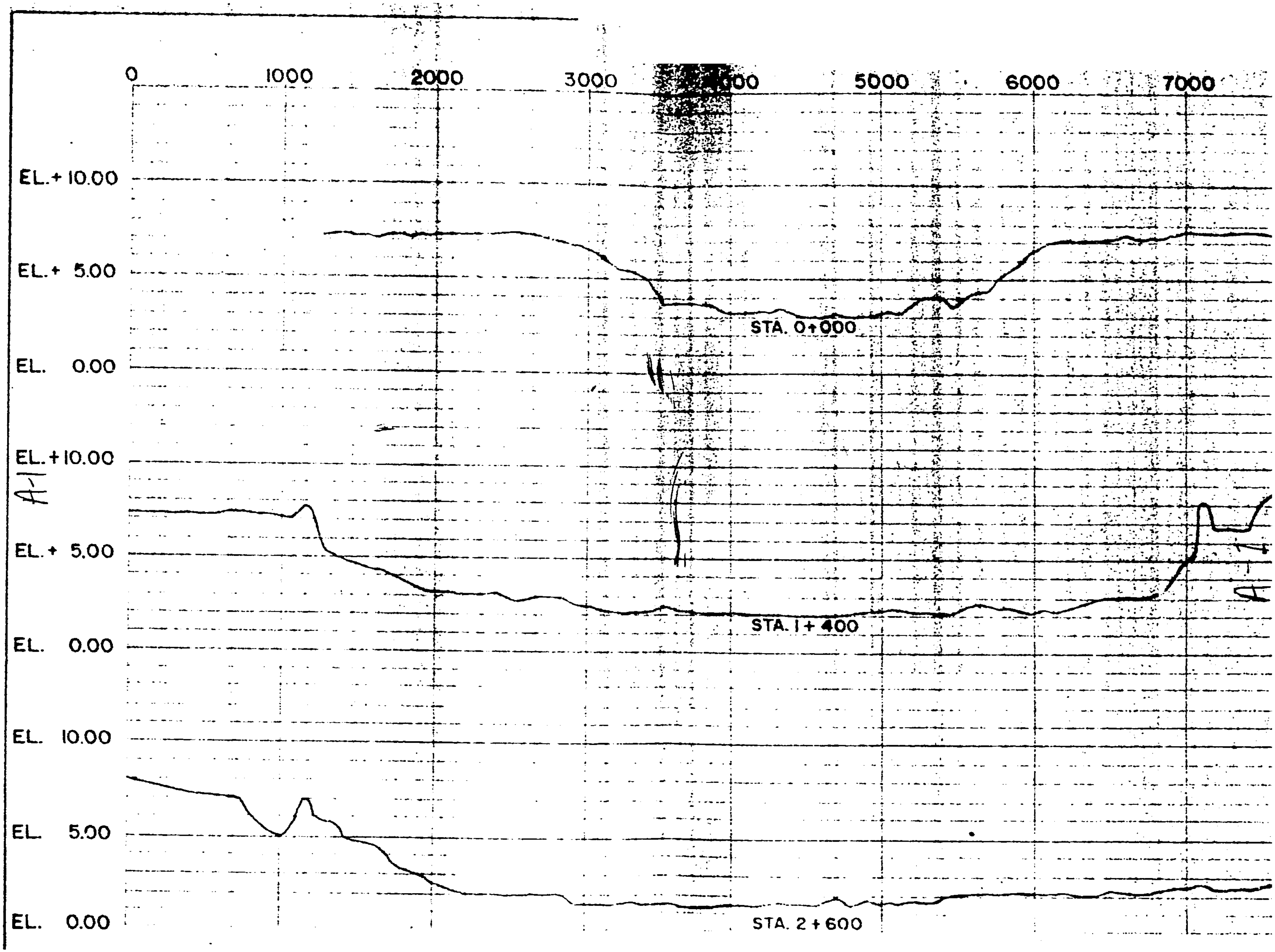
The area around Lake Bato, Lake Baao and the municipalities of Nabua and Baao are low-lying and depressed with inadequate drainage and subject to frequent flooding.

Lake Bato is a shallow, saucer-shaped lake with a bottom elevation at 1.5 meters above MSL. The surface area is approximately 25 $km.^2$ at a water elevation of 5 meters above MSL and enlarges to an area of 60 $km.^2$ at a water elevation 10.5 meters above MSL. The cross-sections of this lake are shown on Figs. 3a, b, c.



Division of Subwatersheds for Bicol River Basin and Locations of Stream Gaging Stations

Fig. II-1



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EL.+ 5.00
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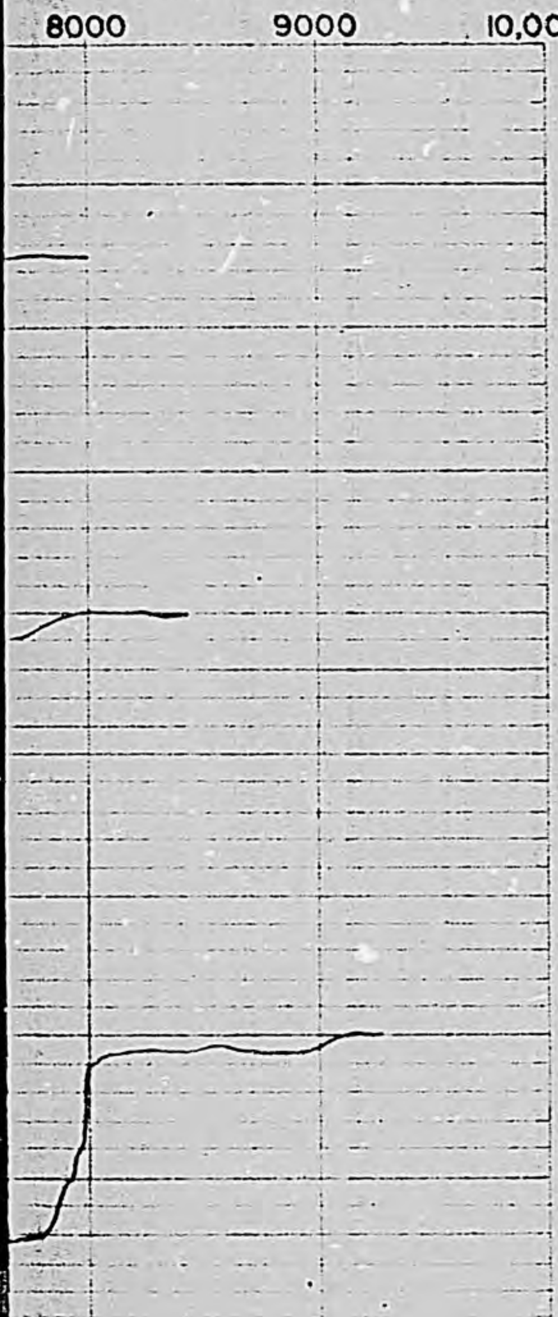
EL. 0.00
STA. 1+400
EL. 10.00
EL. 5.00
EL. 0.00
STA. 2+600
A-1



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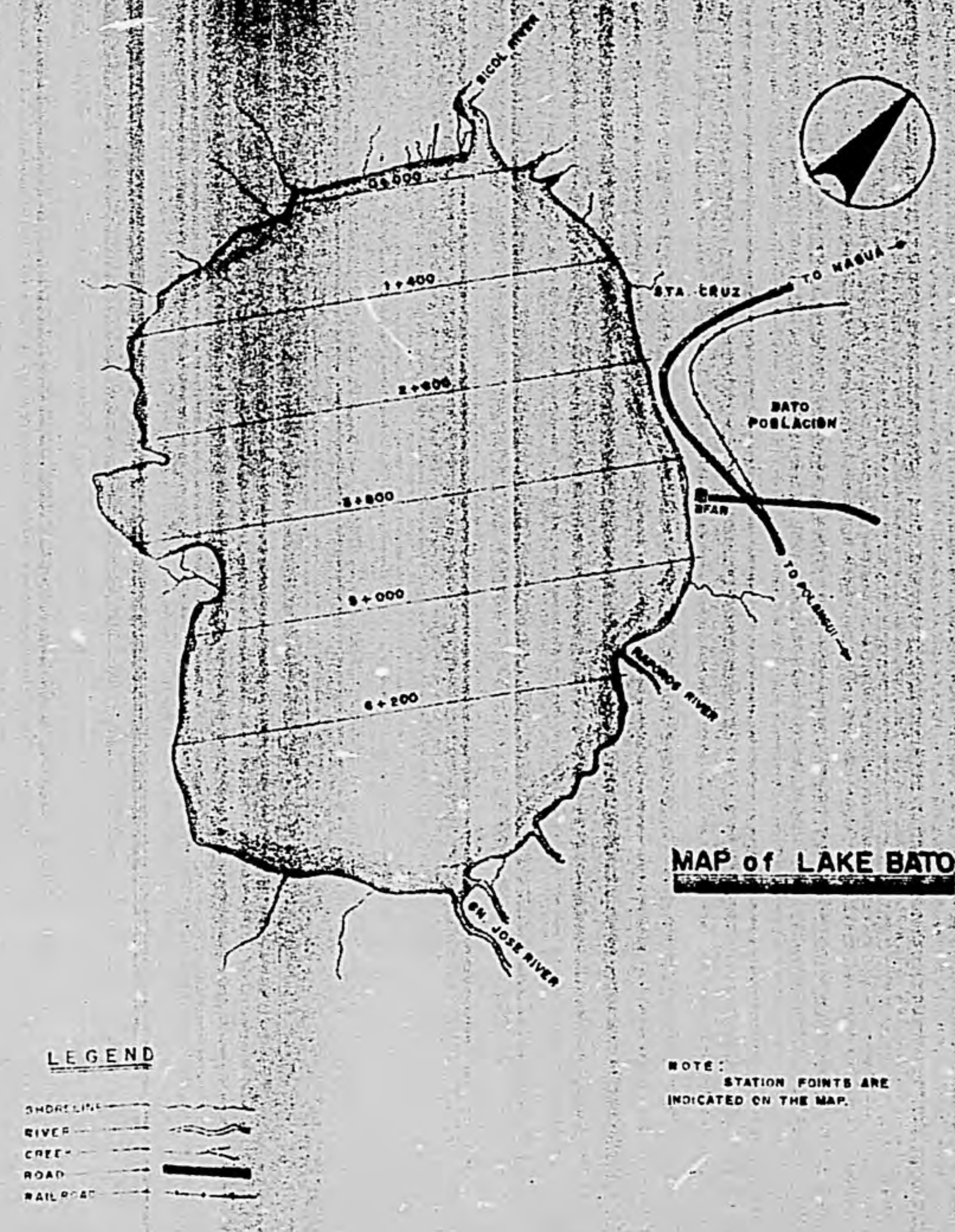
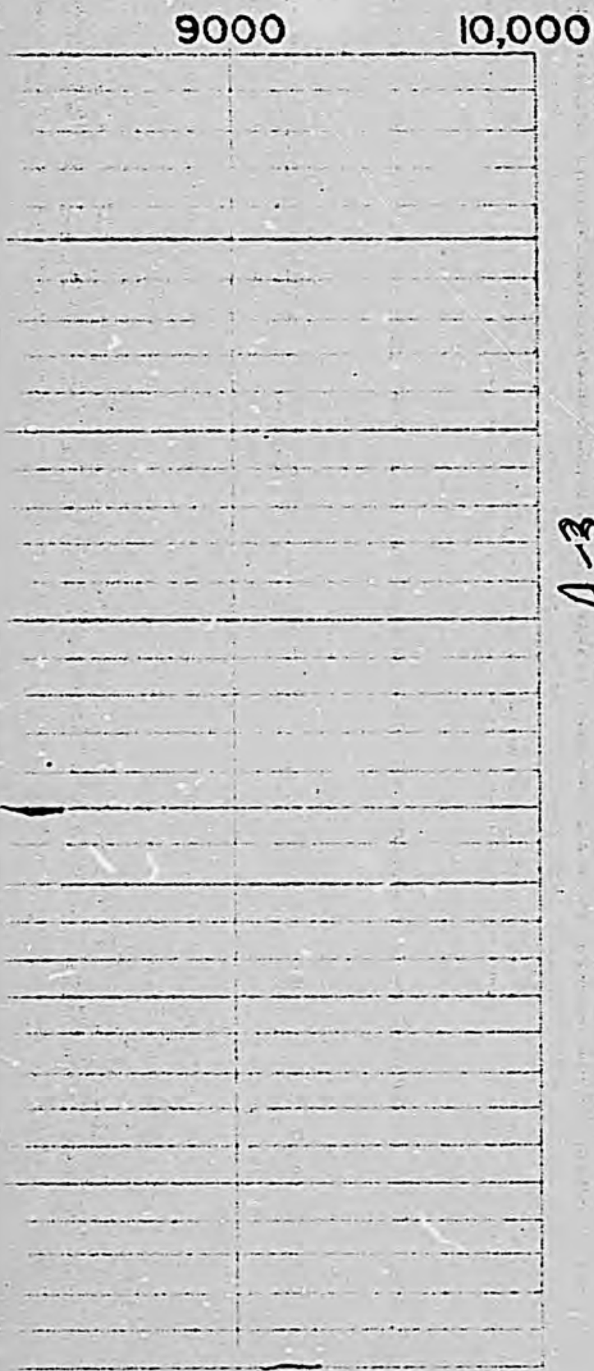
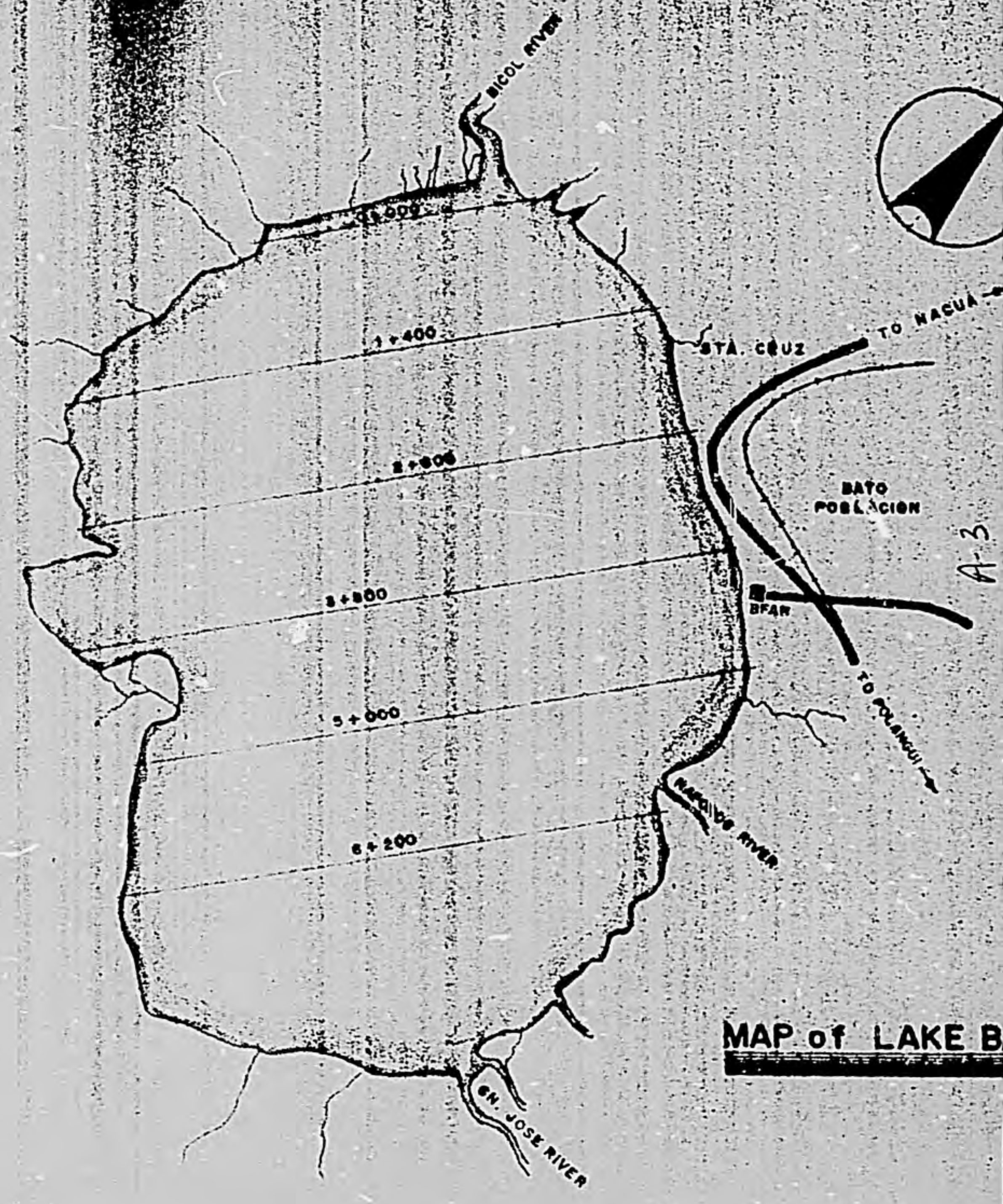


BICOL RIVER
1+400
2+600
3+800
5+000
6+200
STA. CRUZ
TO NABUA
BATO
POBLACION
BFAR
TO POLANGUI
RAPONOS RIVER
SN. JOSE RIVER
MAP of LAKE BATO
LEGEND
SHORELINE
RIVER
CREEK
ROAD
RAILROAD
NOTE:
STATION POINTS ARE
INDICATED ON THE MAP.

A-2



9000
10,000
A-3



BICOL RIVER
1+400
2+600
3+800
5+000
6+200
STA. CRUZ
TO NAGUA
BATO
POBLACION
BFAR
TO POLANGUI
RIVER
SN. JOSE RIVER
A-3

MAP of LAKE B

SCALES

(MAP)

(CROSS-SECTIONS)

VERTICAL SCALE

5 4 3 2 1 0 5 10

SCALE 1:200

HORIZONTAL SCALE

100 0 100 200 300 400 500 1000

SCALE 1:25,000

BICOL RIVER BASIN DEVELOPMENT PROGRAM

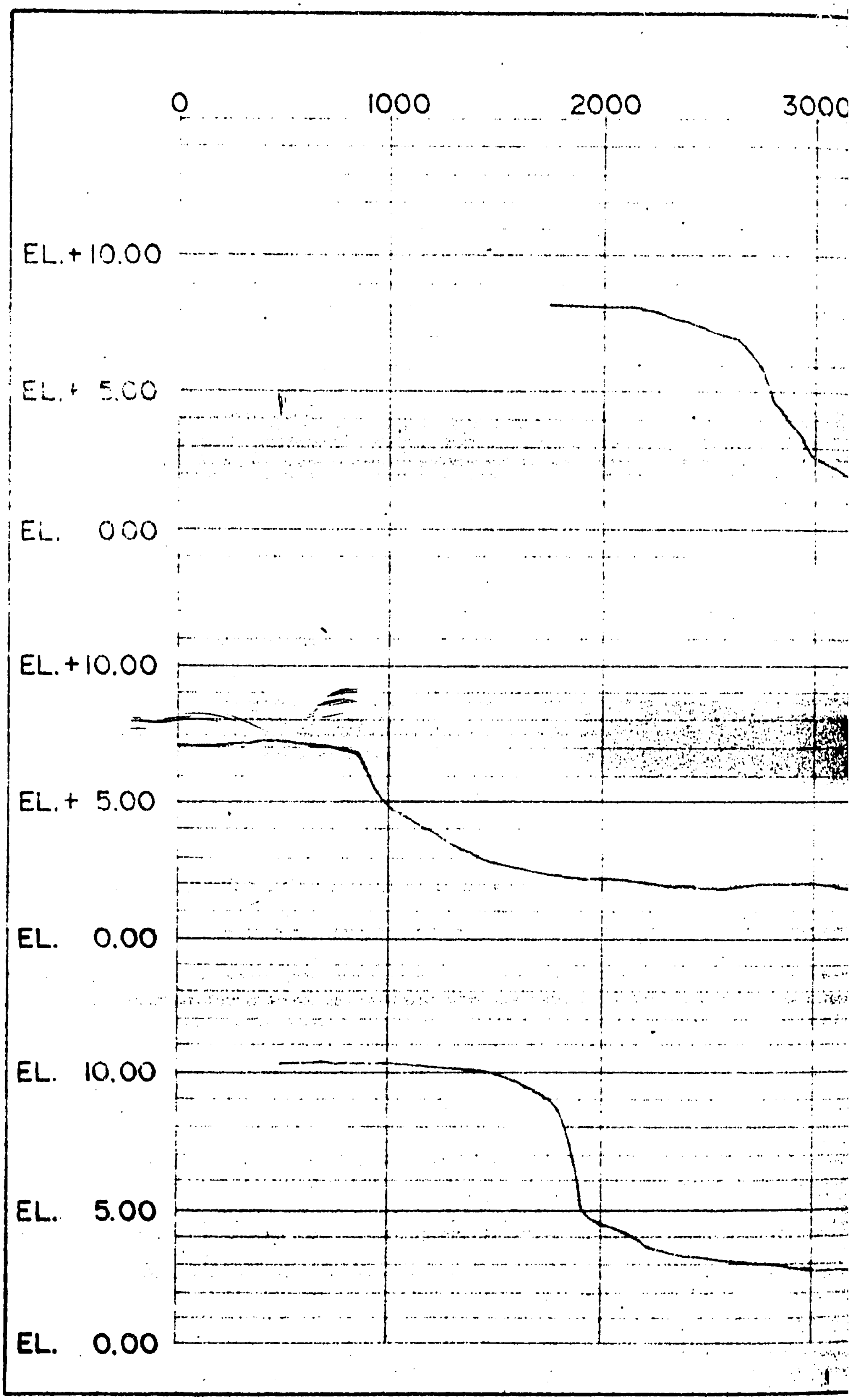
RINCONADA INTEGRATED AREA DEVELOPMENT

FEASIBILITY STUDY

SHEET TITLE:

CROSS-SECTION AND MAP OF LAKE BATO

FIG. II-3b


0
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3000
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EL. + 5.00
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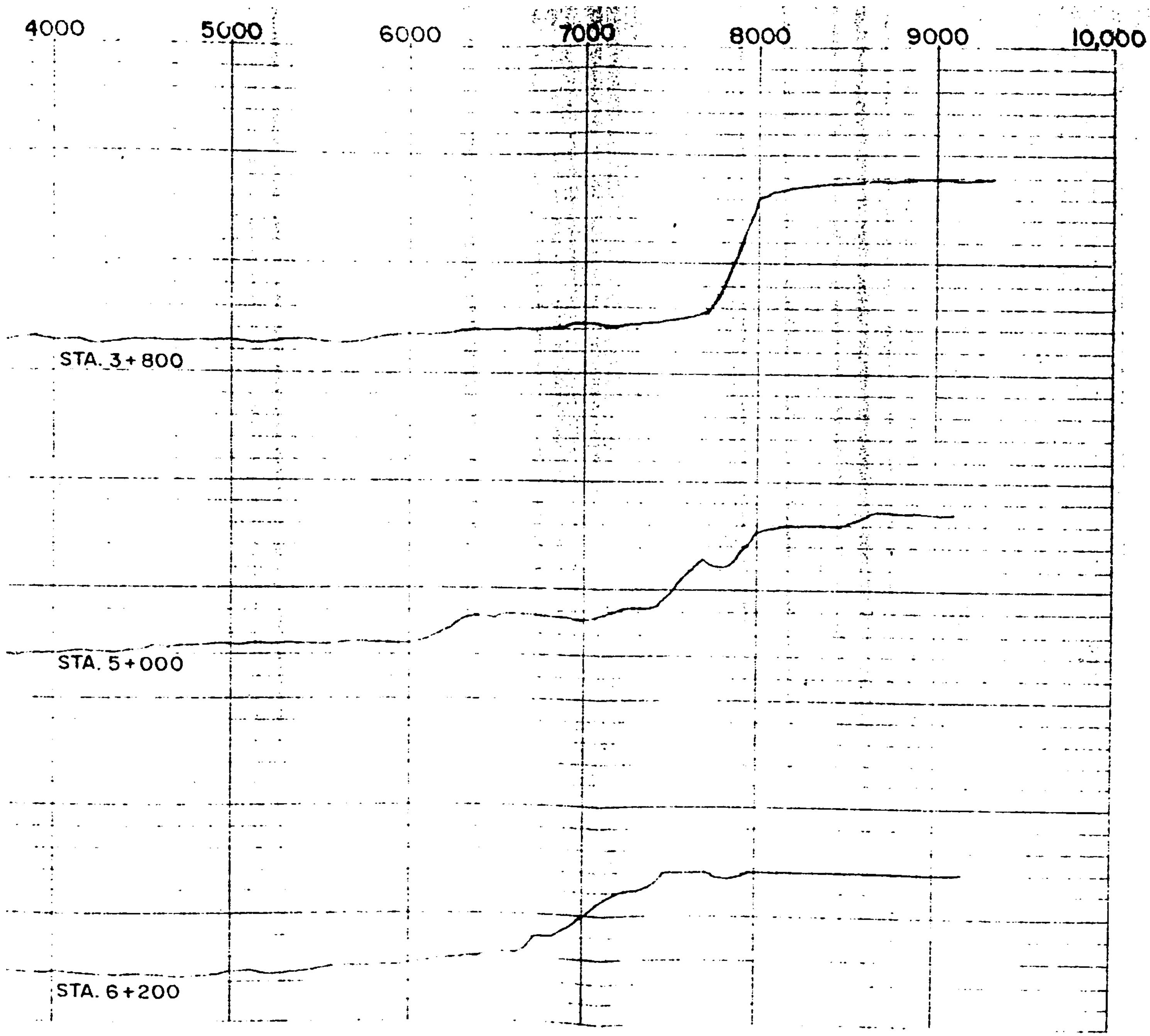
EL. 10.00
EL. 5.00
EL. 0.00

B-1


4000
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7000
8000
9000
10,000
STA. 3+800
STA. 5+000
STA. 6+200

B-2

The Bicol River originates at the outlet of Lake Bato and has an overall length of 95 km. to its outlet in San Miguel Bay. The Bicol River is a meandering river with a very flat gradient and at low flows the entire reach is influenced by tidal effects. Some typical cross-sections of this river from Lake Bato downstream to Ombao at km. 67 are shown on Figs. 4a, b, c.

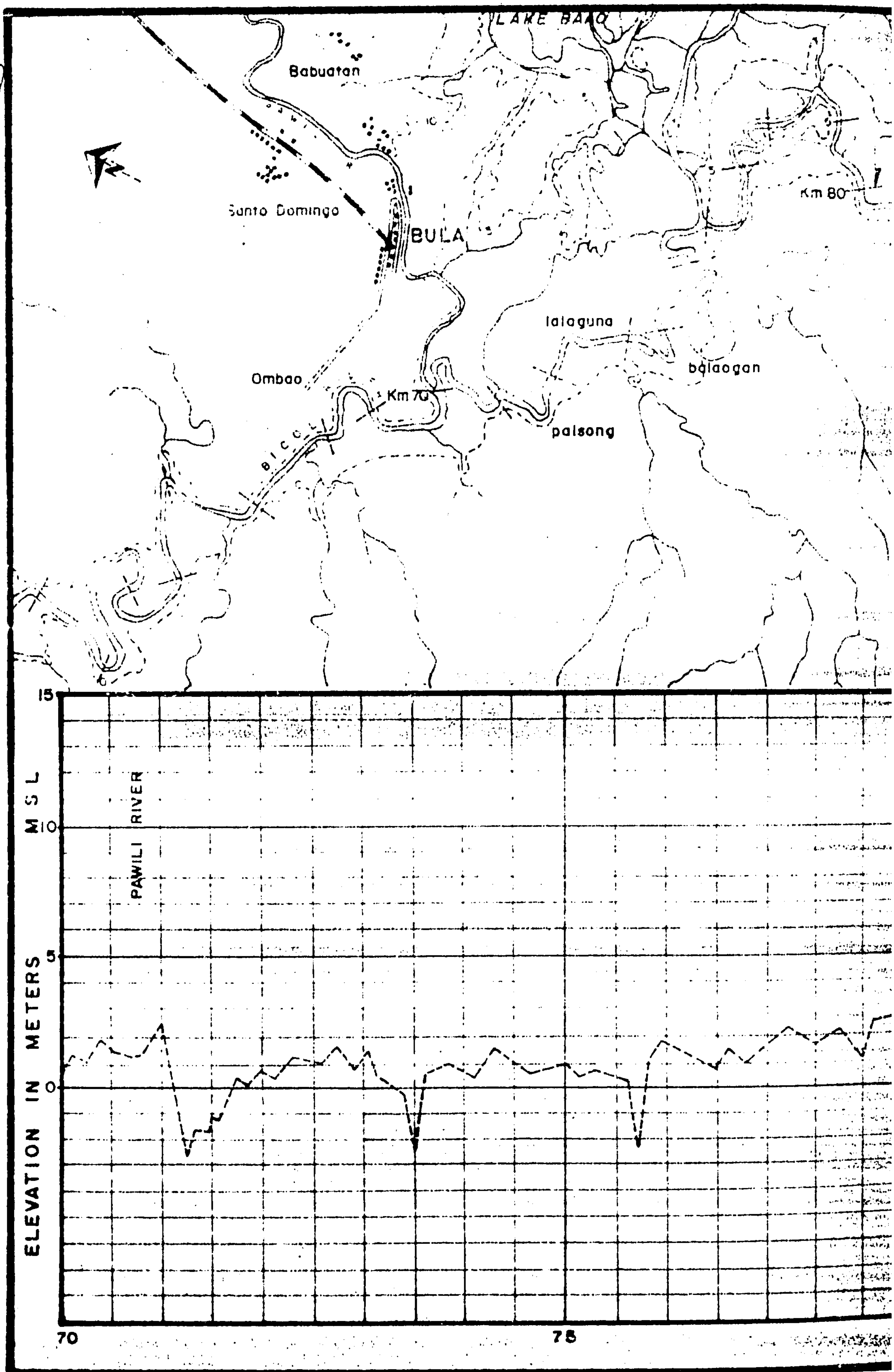
Lake Baao is a shallow stretch of open water in a marshy depression upstream of the confluence of the Bicol and Pawili Rivers. This low-lying area is interlaced with natural spill channels of the Waras and Barit which have become filled with sediments and are almost totally obliterated. During the dry periods, the lake has a surface area of approximately 6 $km.^2$ but increases in area to approximately 40 $km.^2$ during the wet season. During the wet season, this area is flooded both from the upstream by the Waras and Barit Rivers and from the downstream by spill from the high water levels in the Bicol and Pawili Rivers. The cross-sections of this lake are shown on Figs. 5a, b.

The Ragay Hills to the west of Lake Bato range in elevation up to 300 meters above MSL. The diversion alignment crosses these hills through a deep canyon and a low saddle with a crest elevation of 85 meters above MSL. The profile and cross-sections of this alignment are shown on Figs. III-4 and III-5.

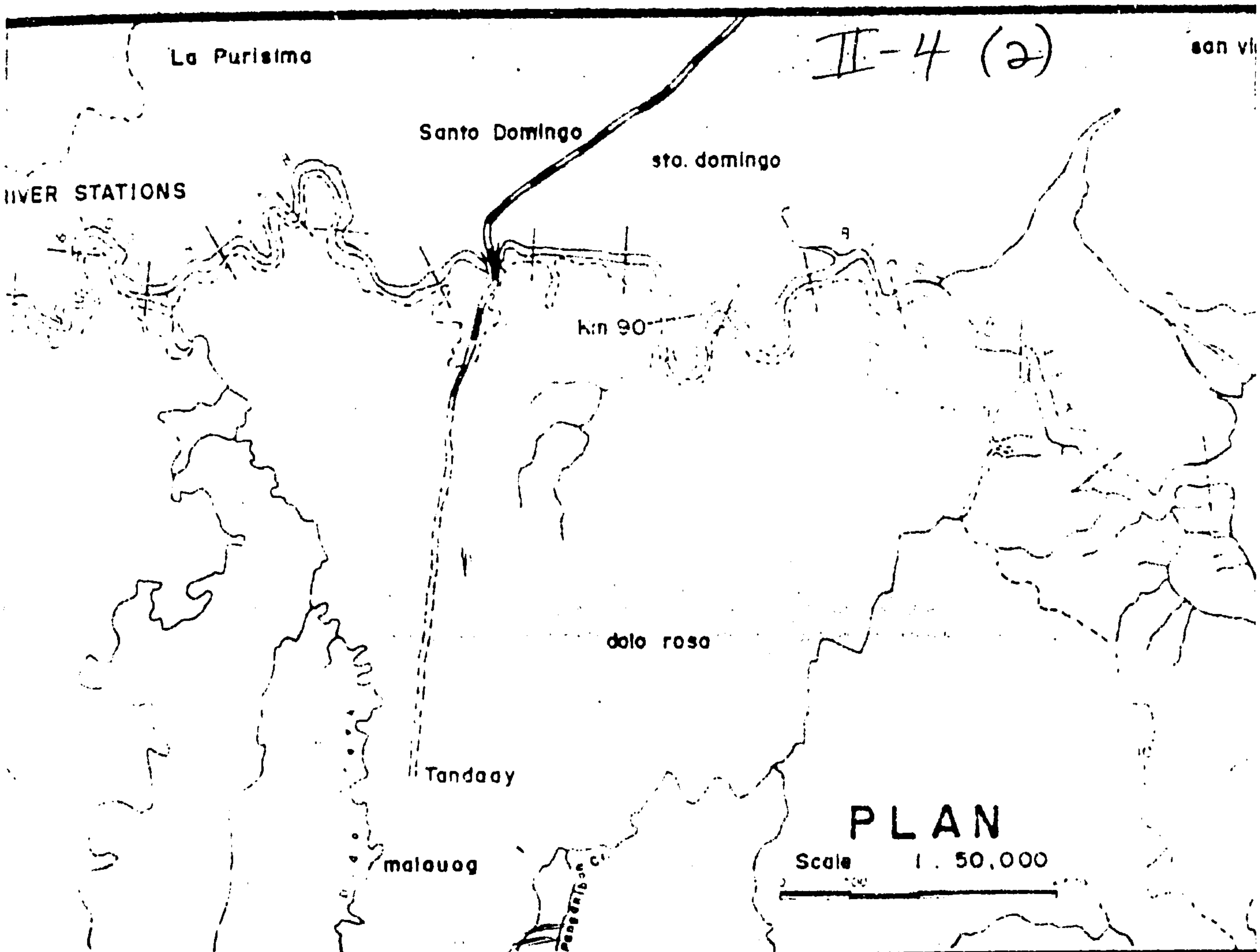
C. SOILS

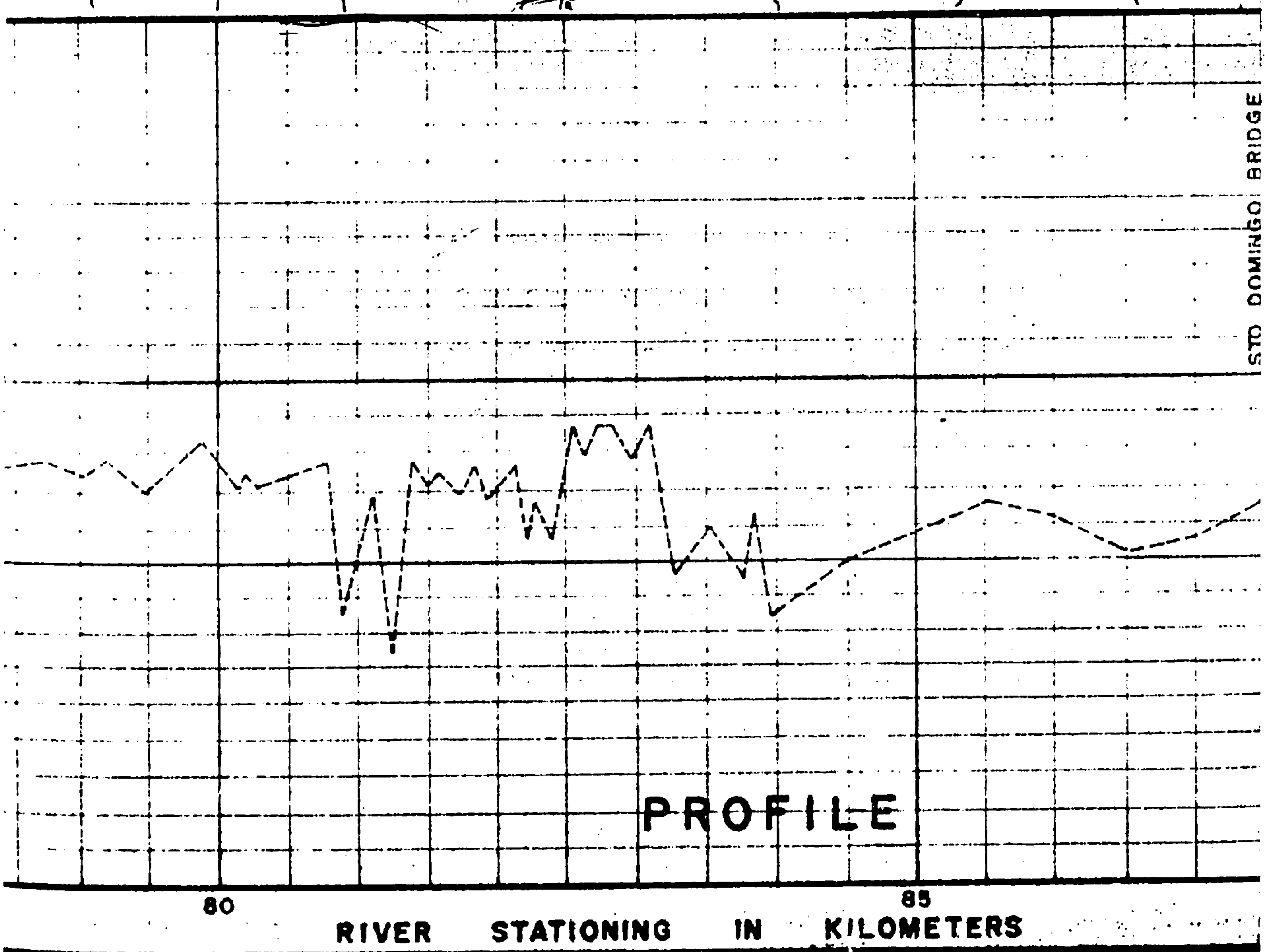
1. General

The project area is bounded on the northeast by the Bicol Cordillera which consists of a chain of volcanic mountains including Isarog, Iriga, Malinao, Masaraga and the active Mayon Volcano. On the southwest are the Ragay Hills which consist of folded and faulted sedimentary formations of limestone, siltstone, II-4 (1)

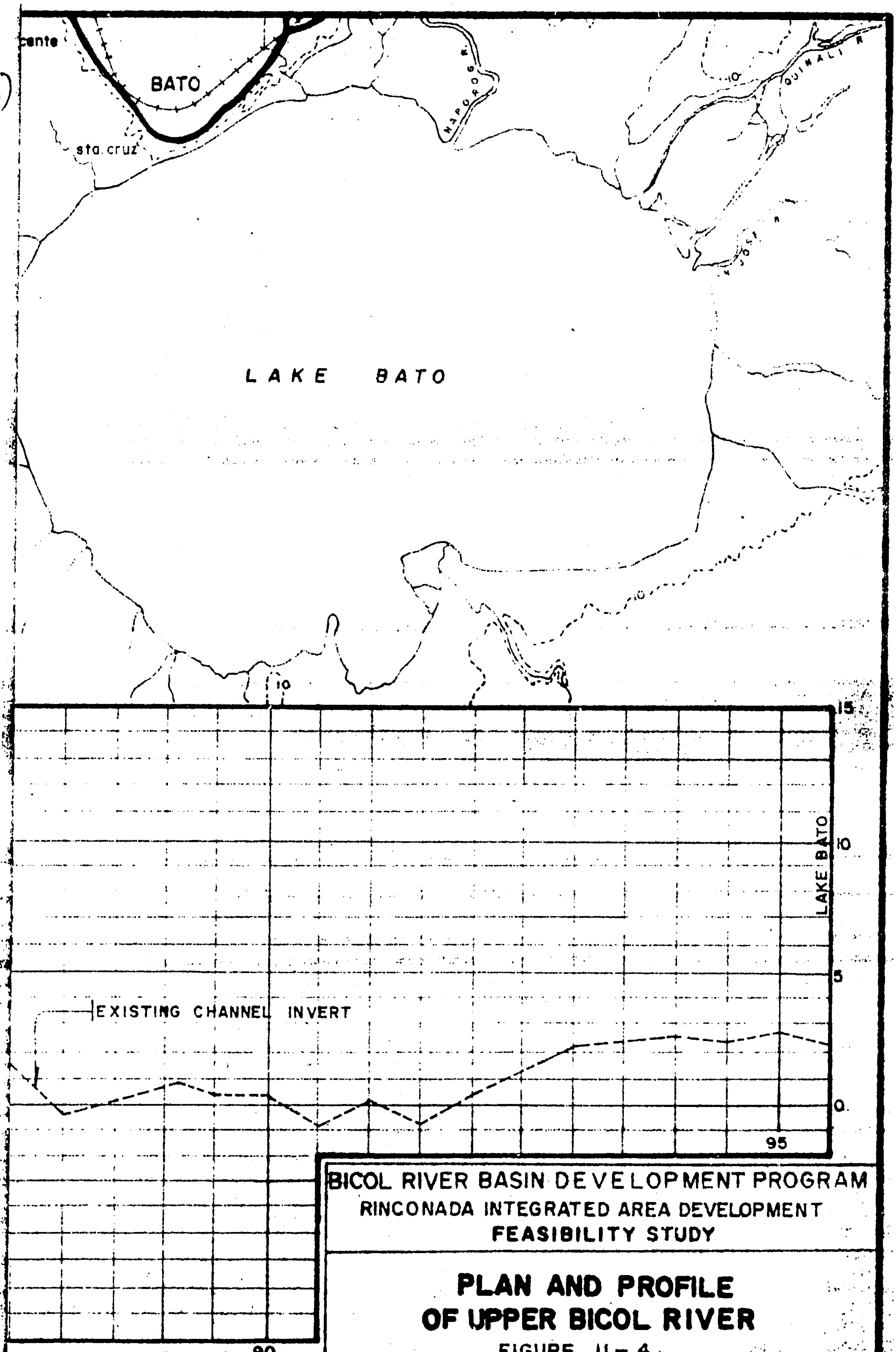

LAKE BAAO
Babuatan
Santo Domingo
BULA
Km 80
lalaguna
balaogan
Ombao
Km 70
palsong
BICOL
PAWILI RIVER
ELEVATION IN METERS MSL
15
10
5
0
70
75

II-4 (2)


La Purisima
Santo Domingo
sto. domingo
san vi
IIVER STATIONS
km 90
dolo rosa
Tandaay
malauog
PLAN
Scale 1 . 50,000


STO DOMINGO BRIDGE
PROFILE
80
85
RIVER STATIONING IN KILOMETERS

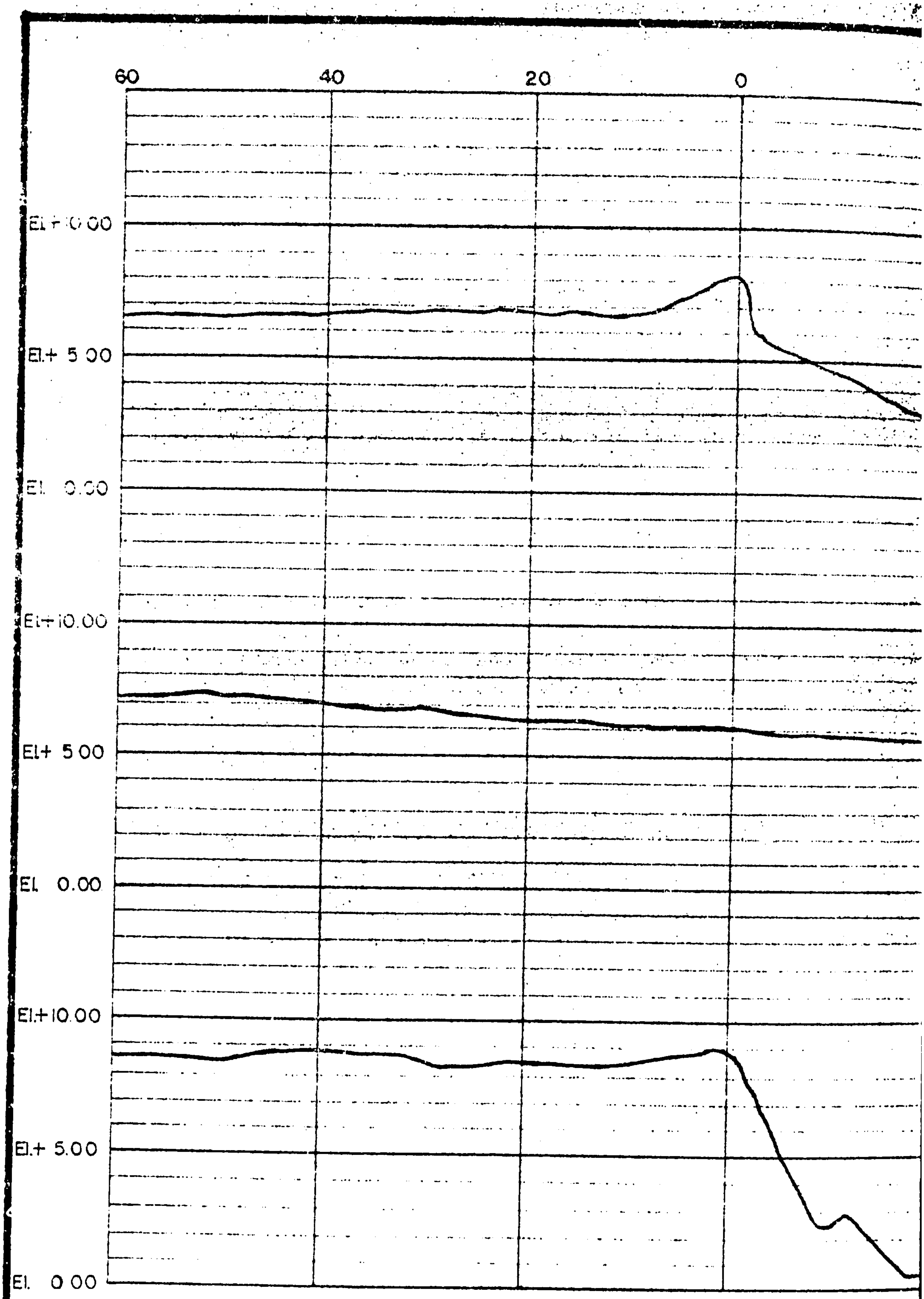
II 4(3)



BICOL RIVER BASIN DEVELOPMENT PROGRAM
RINCONADA INTEGRATED AREA DEVELOPMENT
FEASIBILITY STUDY

PLAN AND PROFILE OF UPPER BICOL RIVER

FIGURE II – 4



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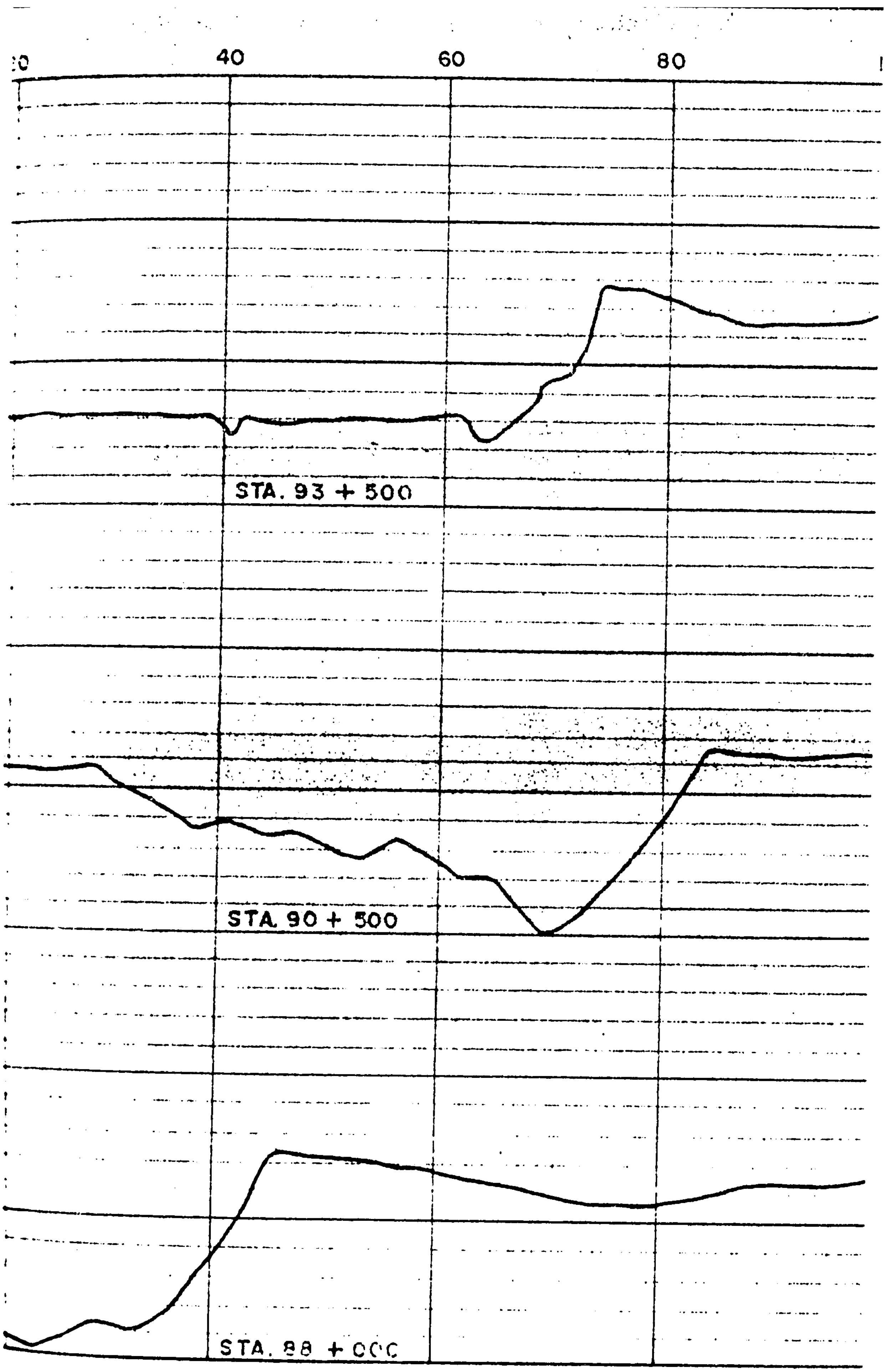
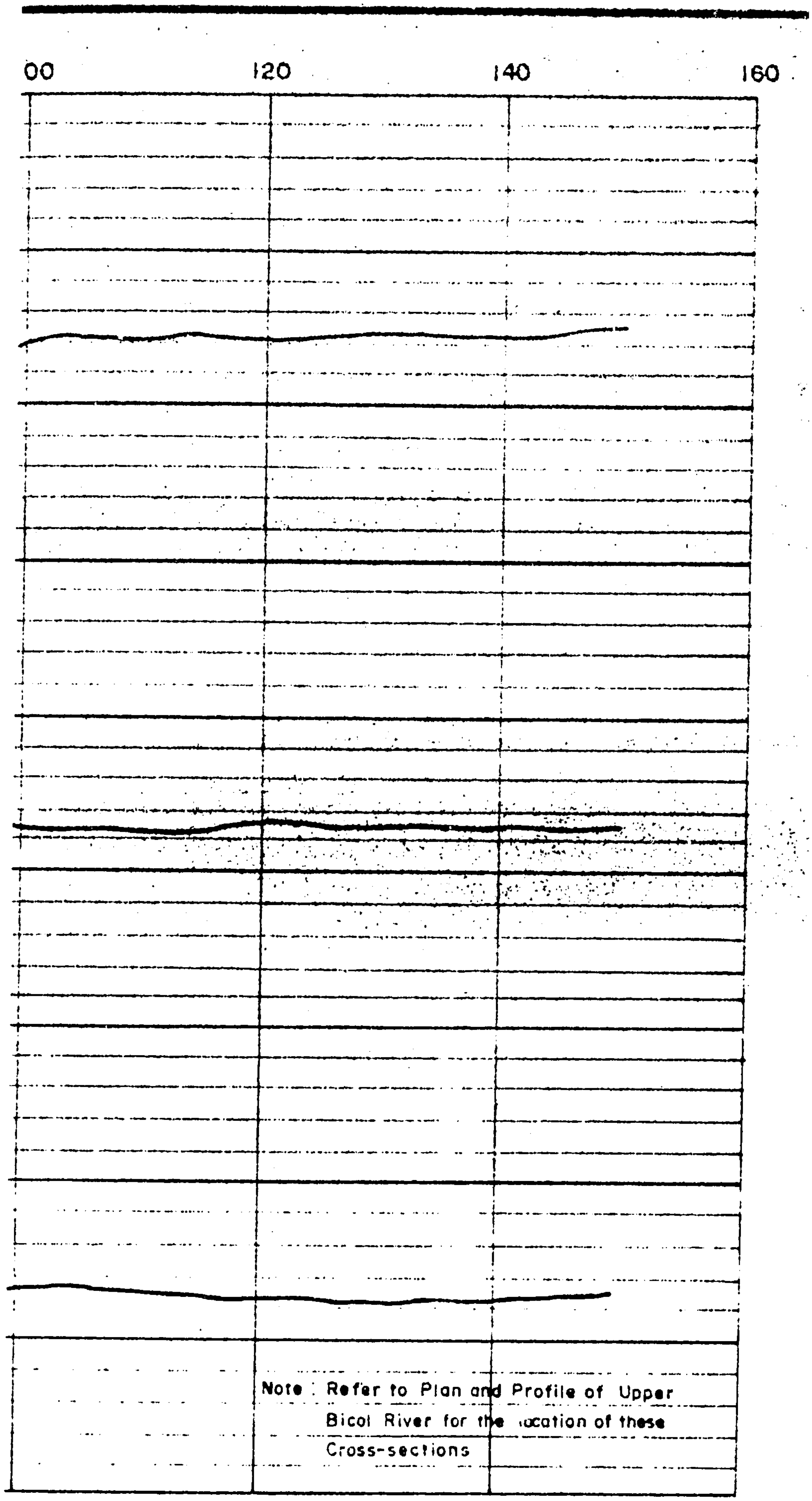
II-4-a (1)

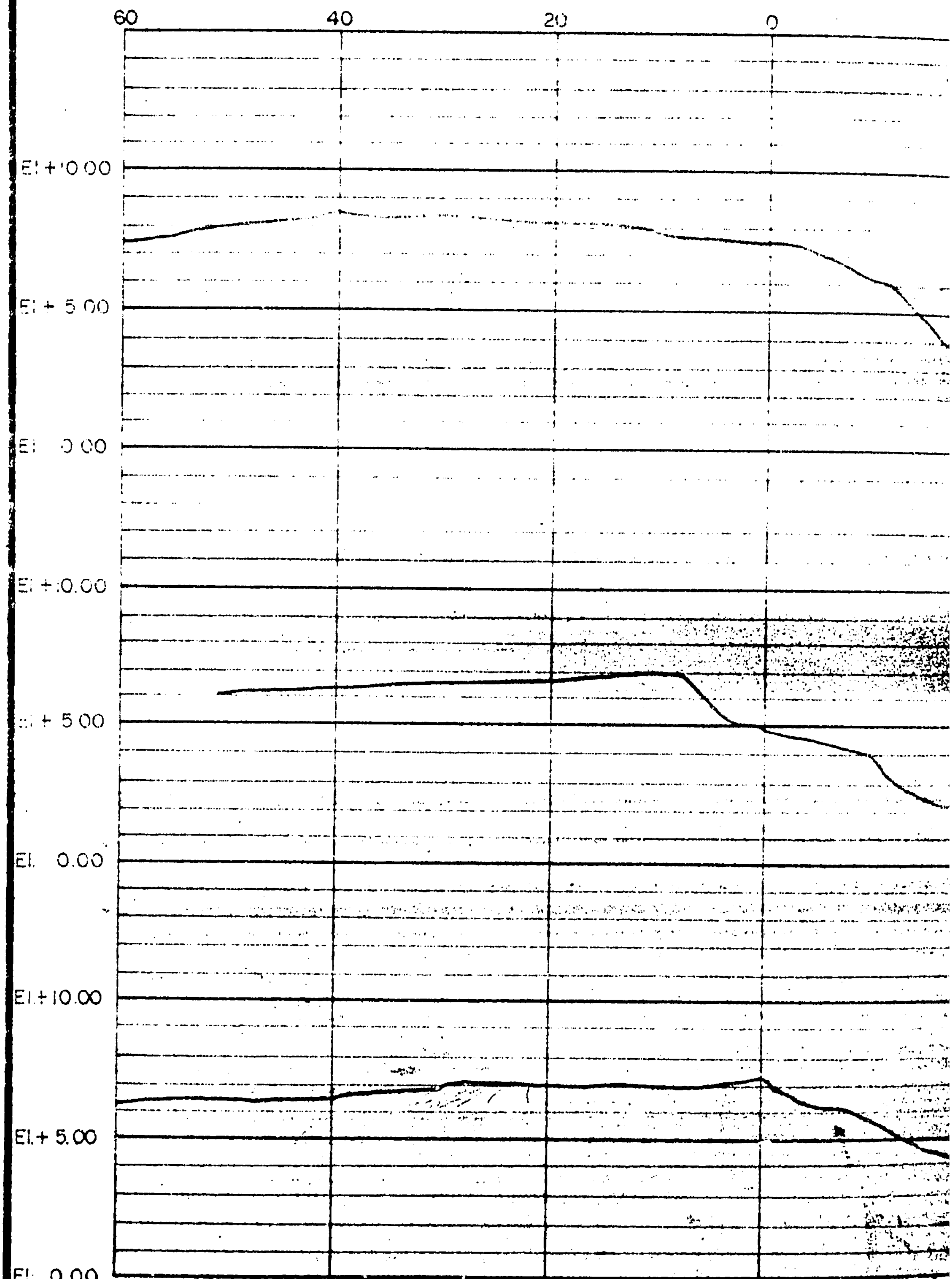


II-4 a (2)



SCALES:
1 Cm. = 5 M. Horizontal
1 Cm. = 2 M. Vertical

FIGURE II – 4a



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El +10.00
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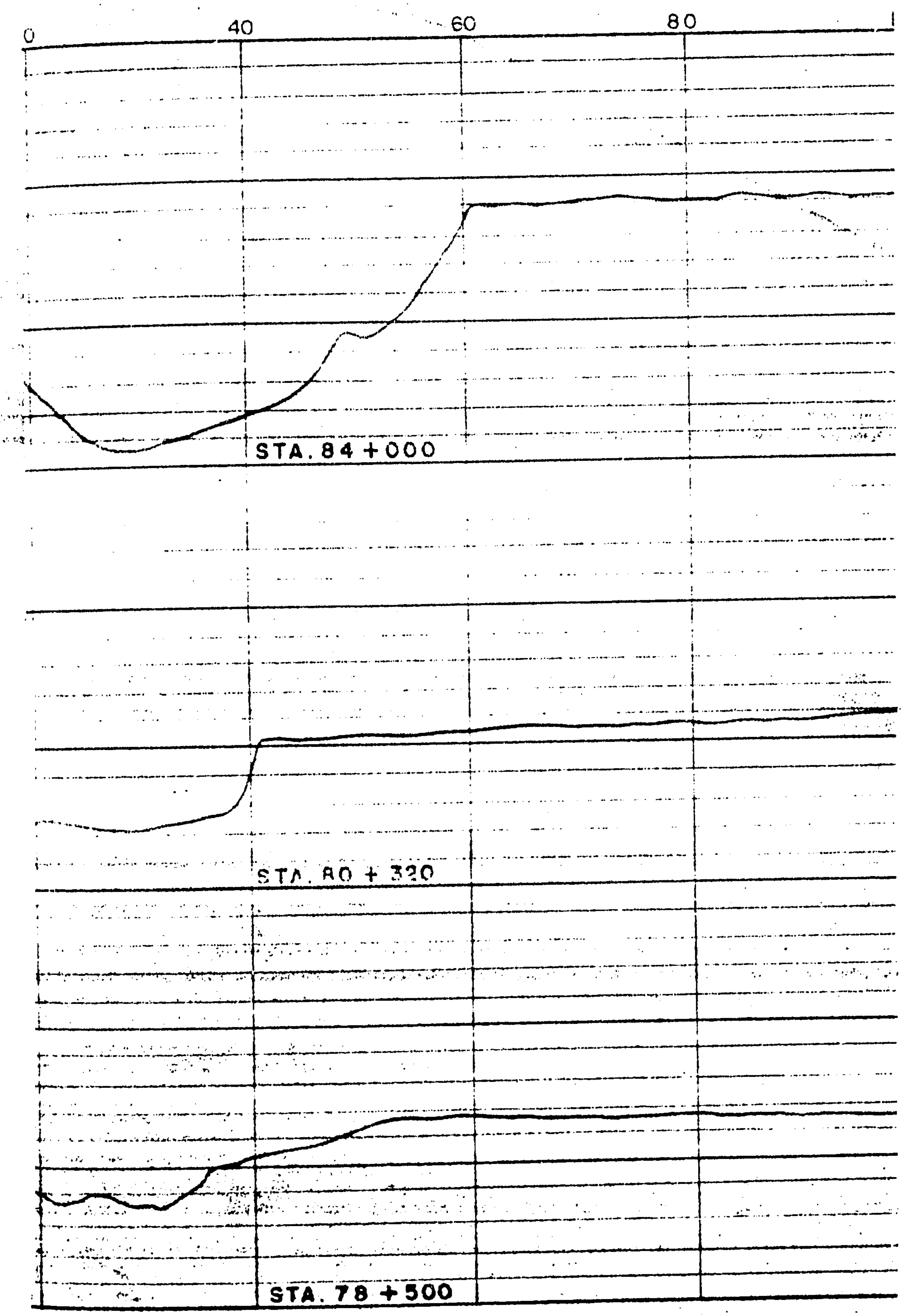
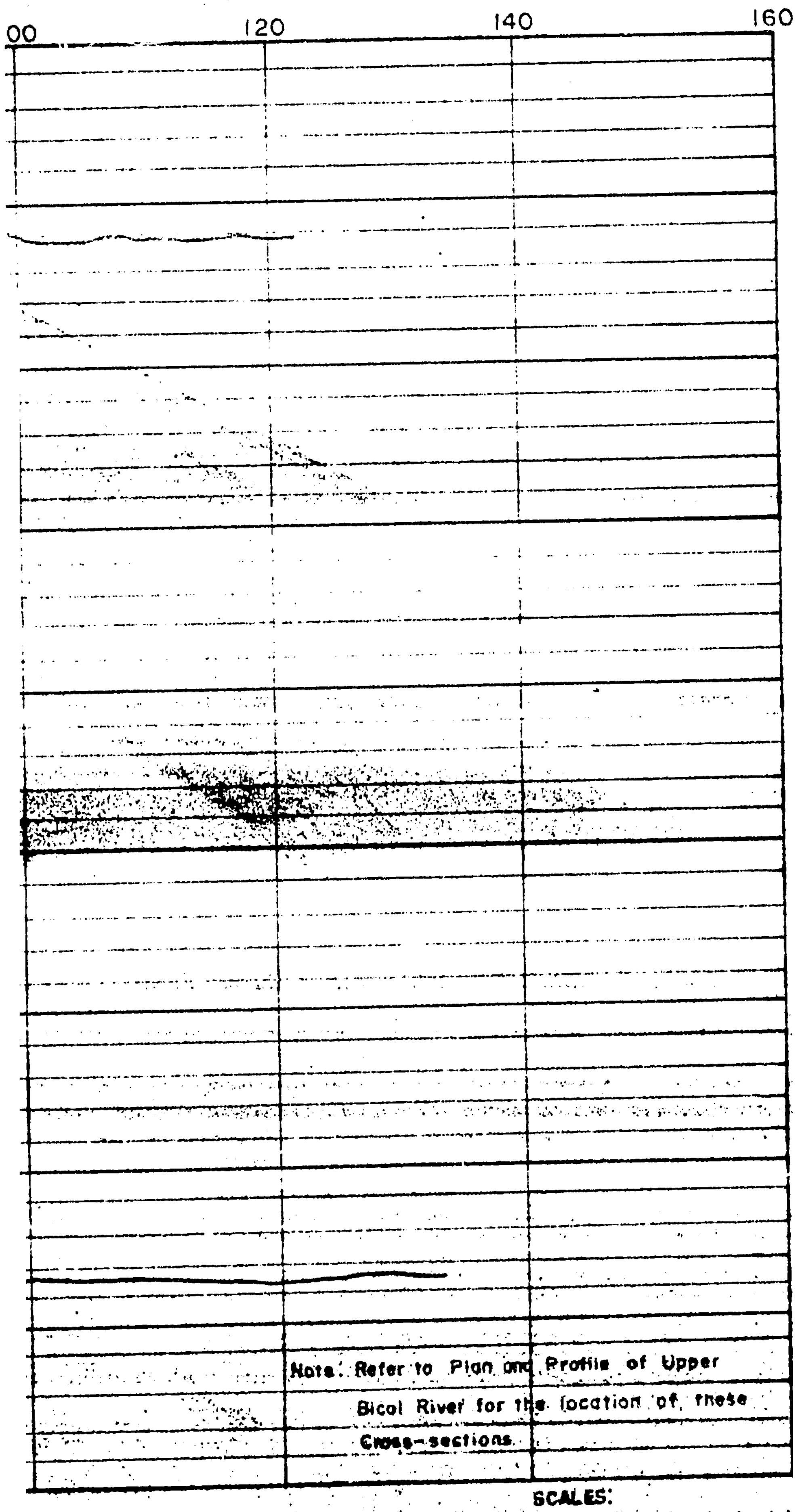
El 0.00

II-4 b (1)



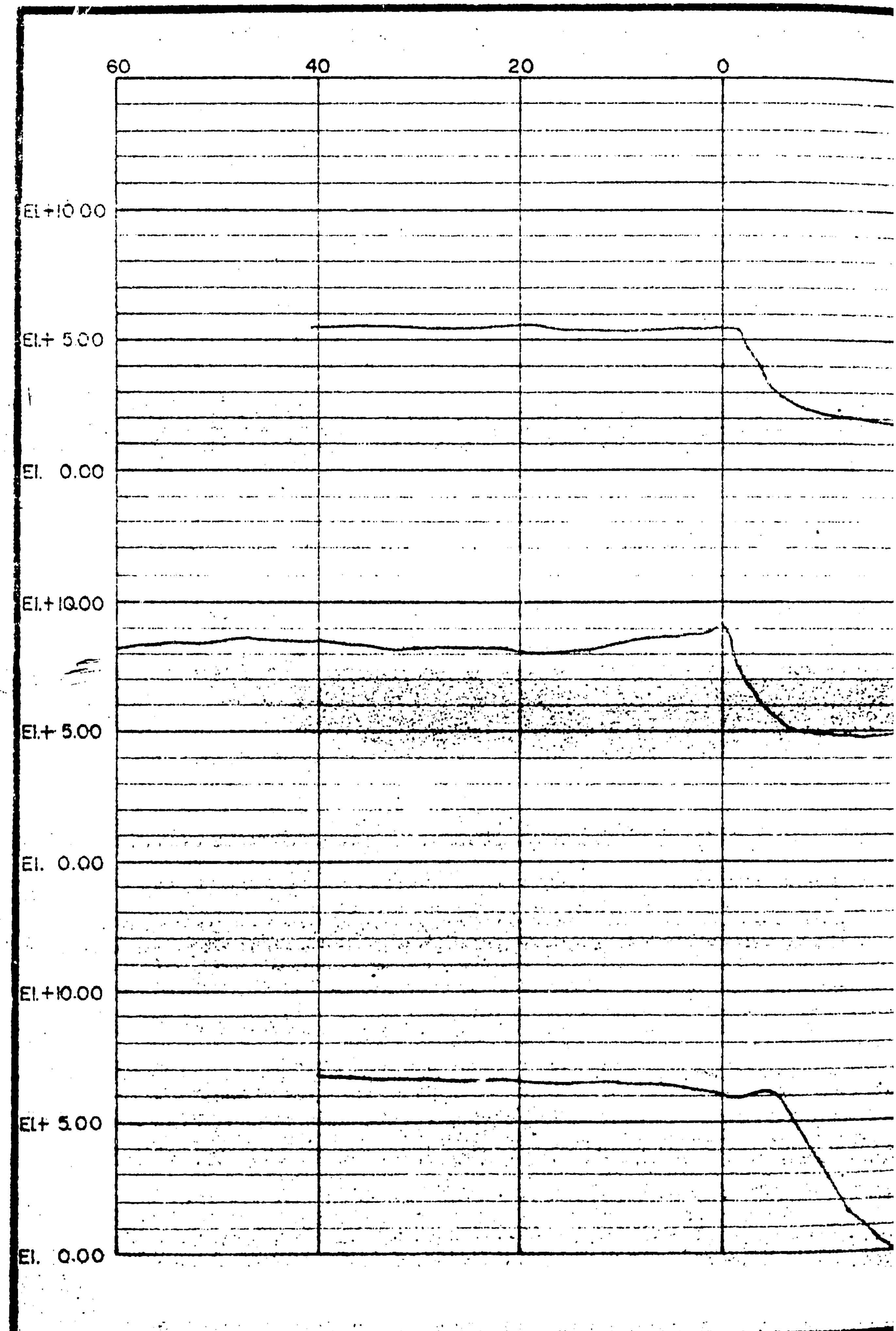
II-4b (2)



SCALES:
1 Cm. = 5 M. Horizontal
1 Cm. = 2 M. Vertical

FIGURE II – 4b

Sheet 3/4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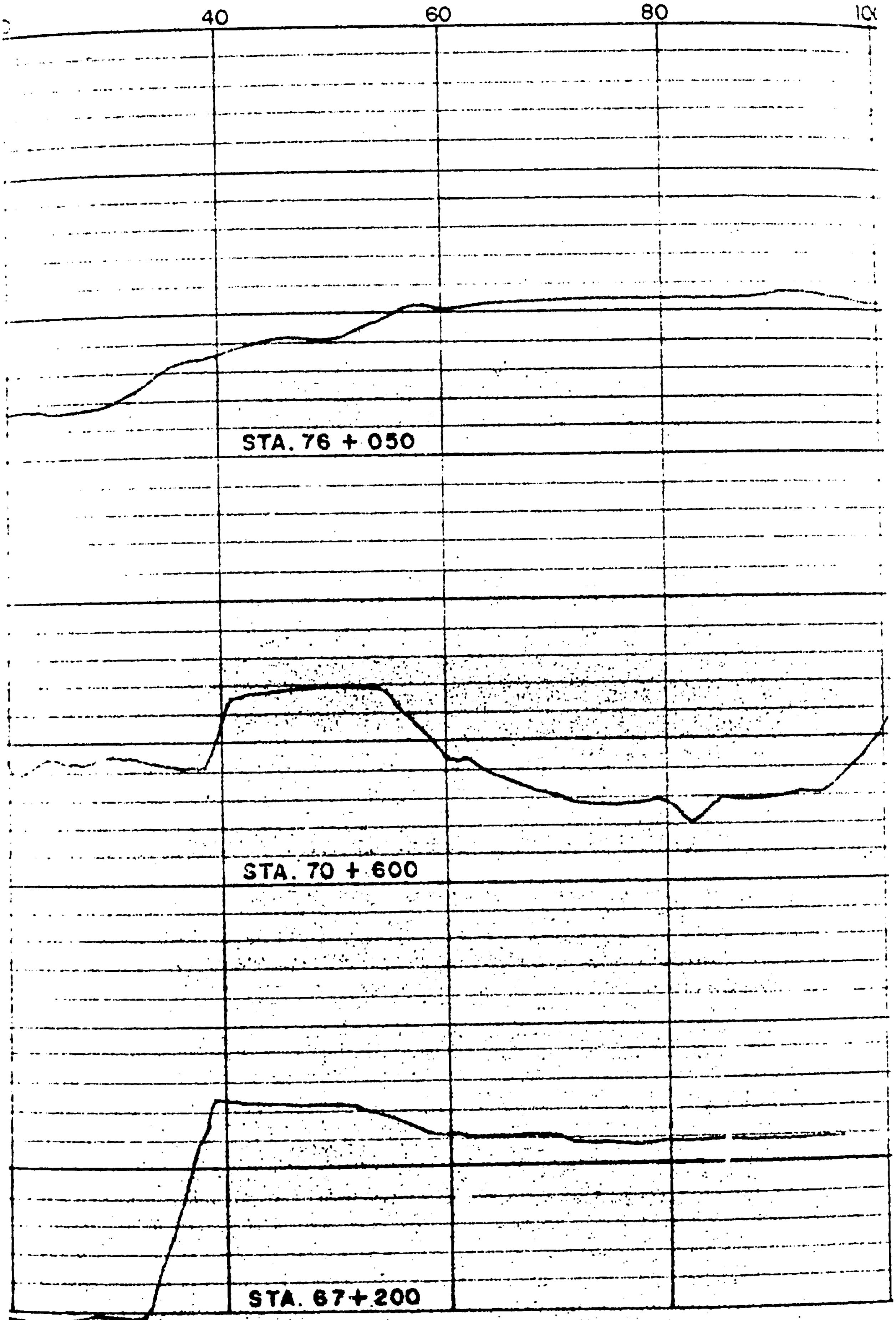
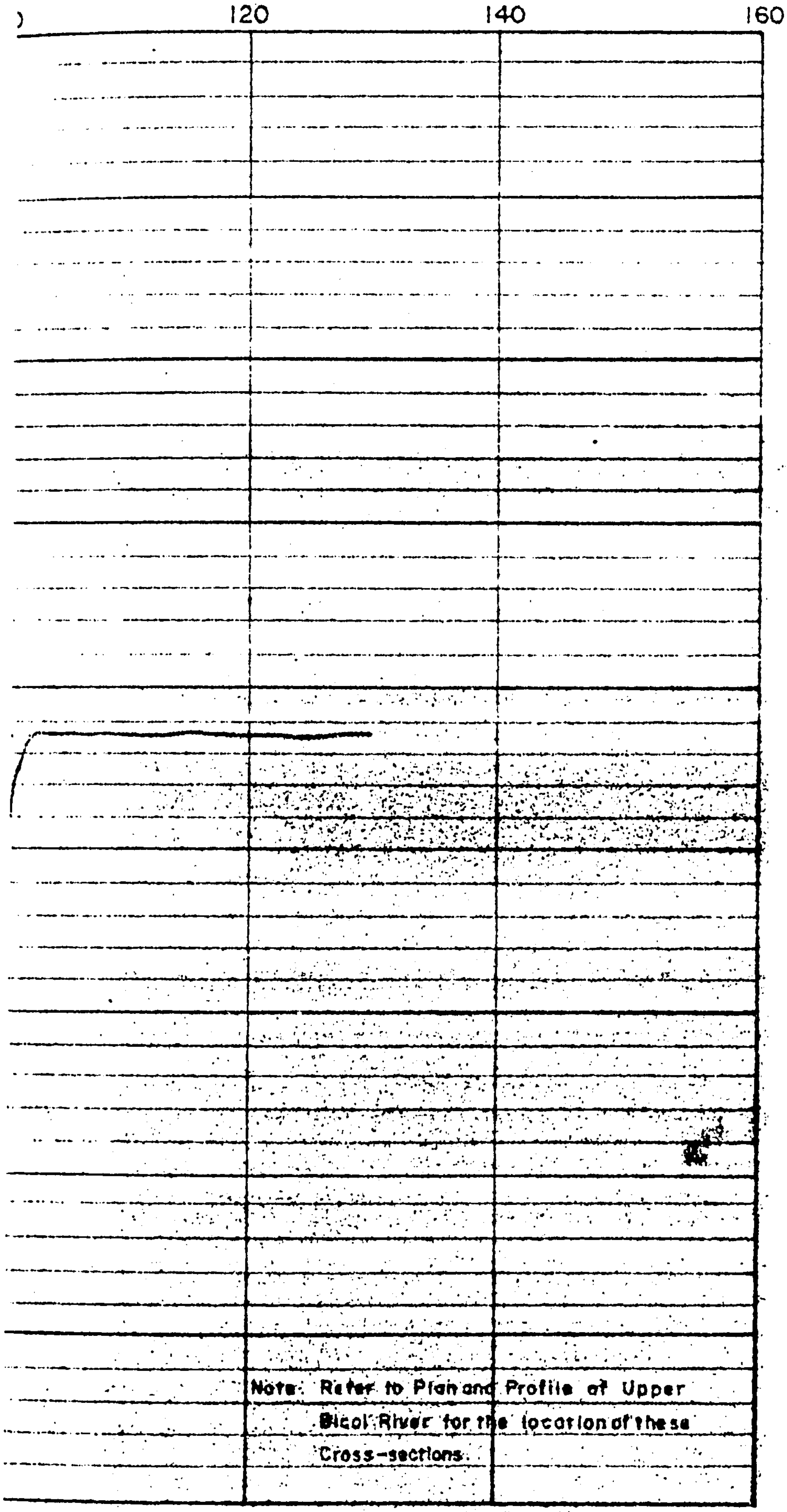


II-4-c (2)



SCALES:

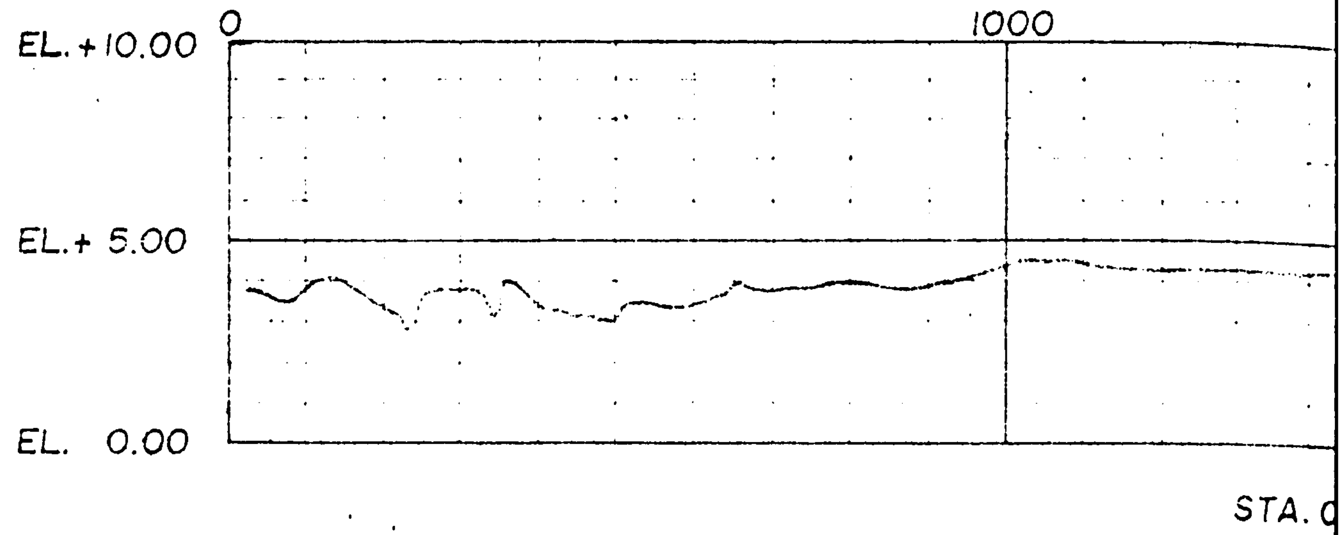
1 Cm.= 5 M. Horizontal

1 Cm.= 2 M. Vertical

FIGURE II – 4c

Sheet 4/4

II-4c-(3)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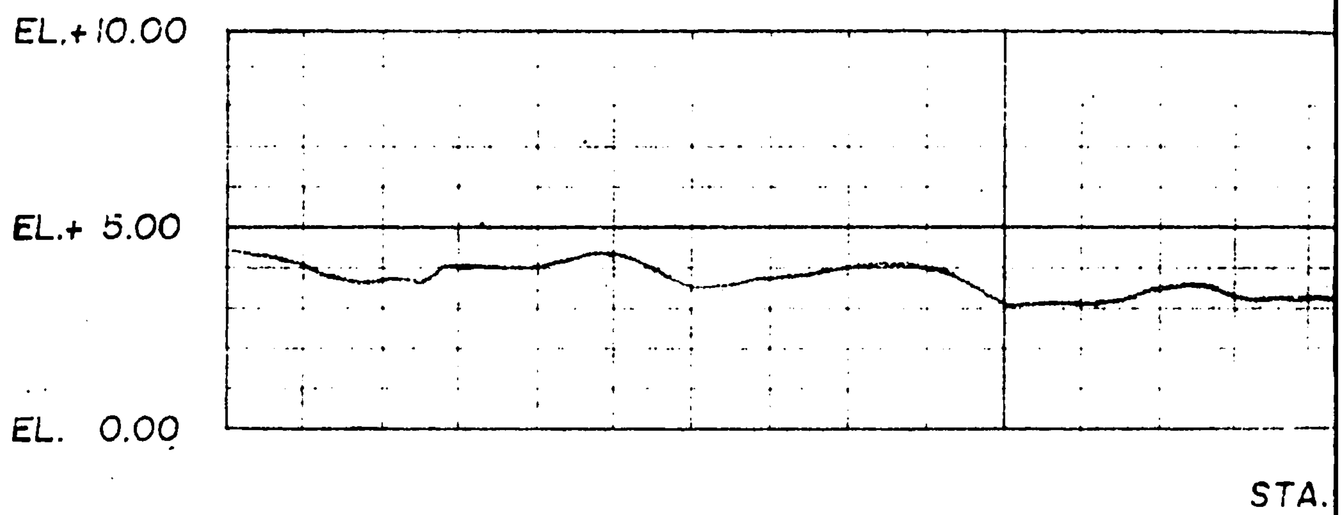
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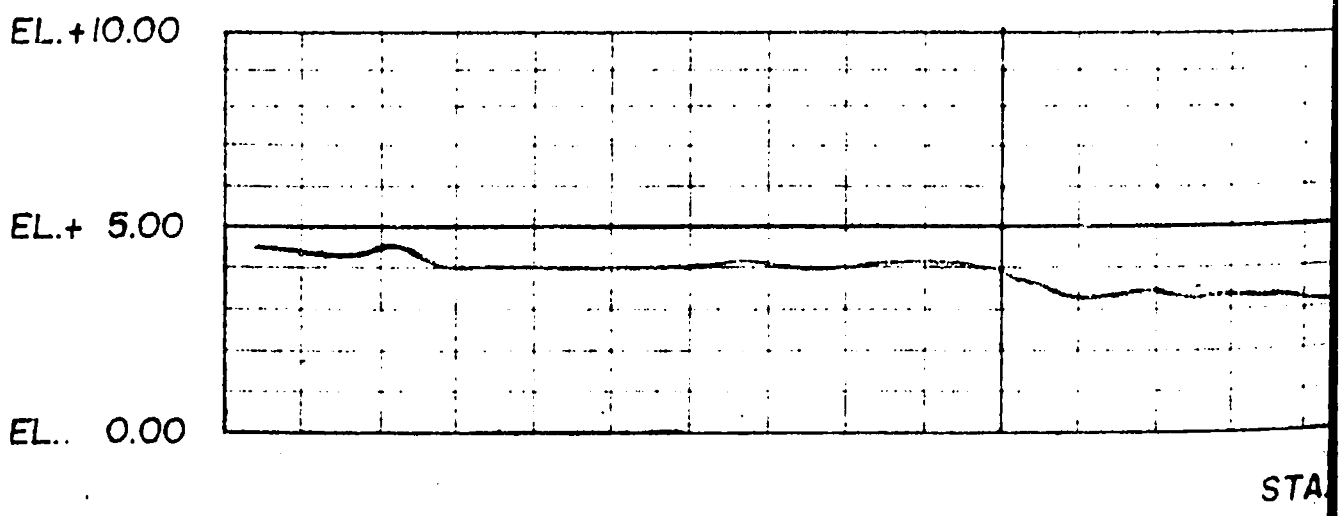
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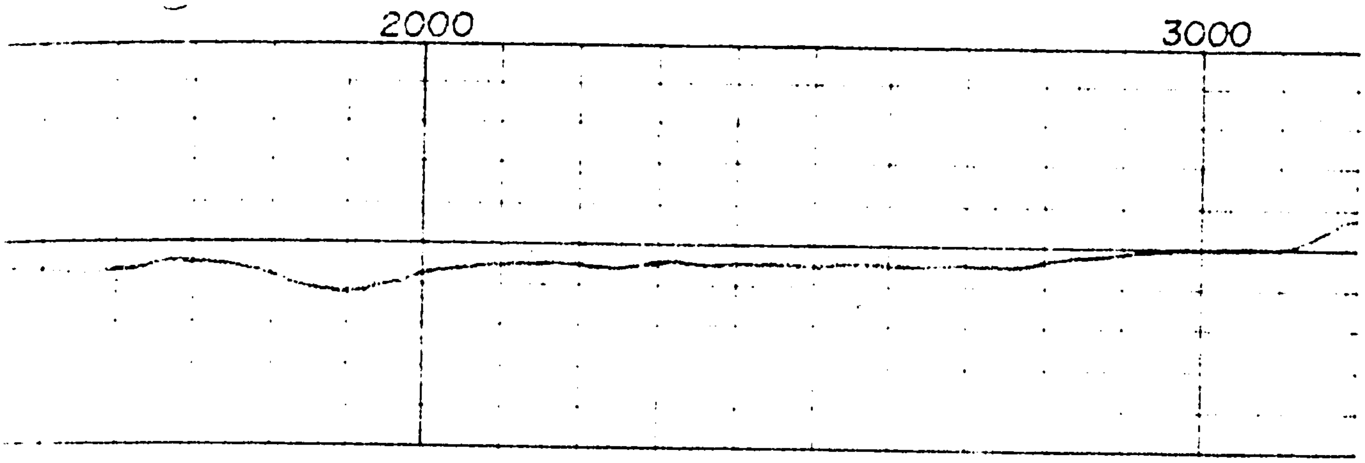

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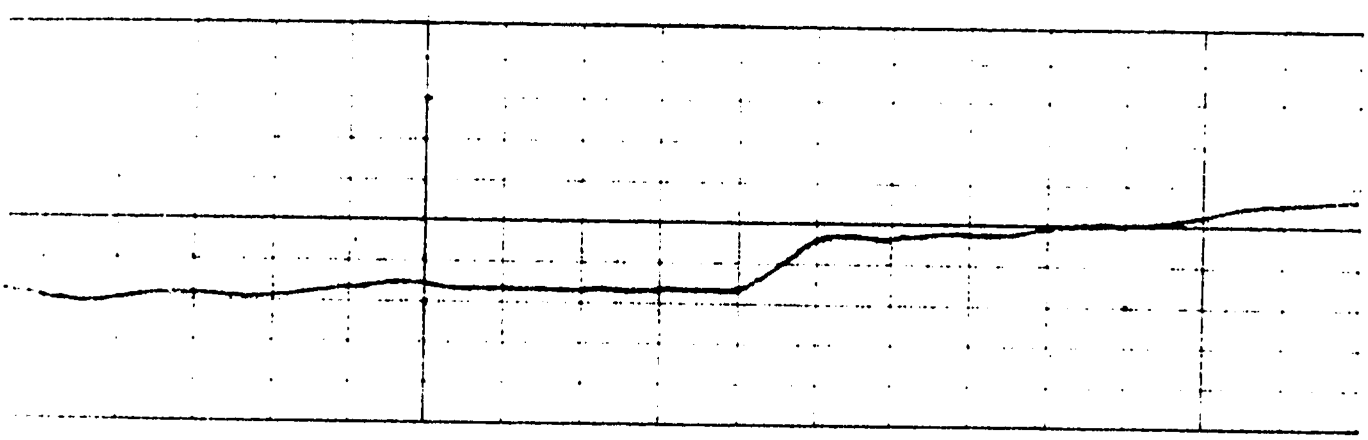
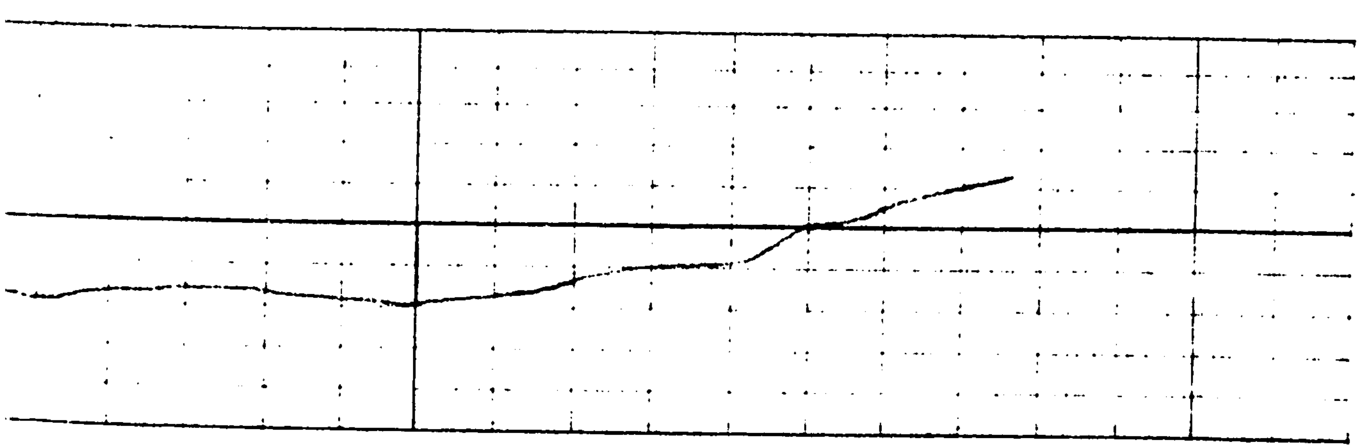


0+800



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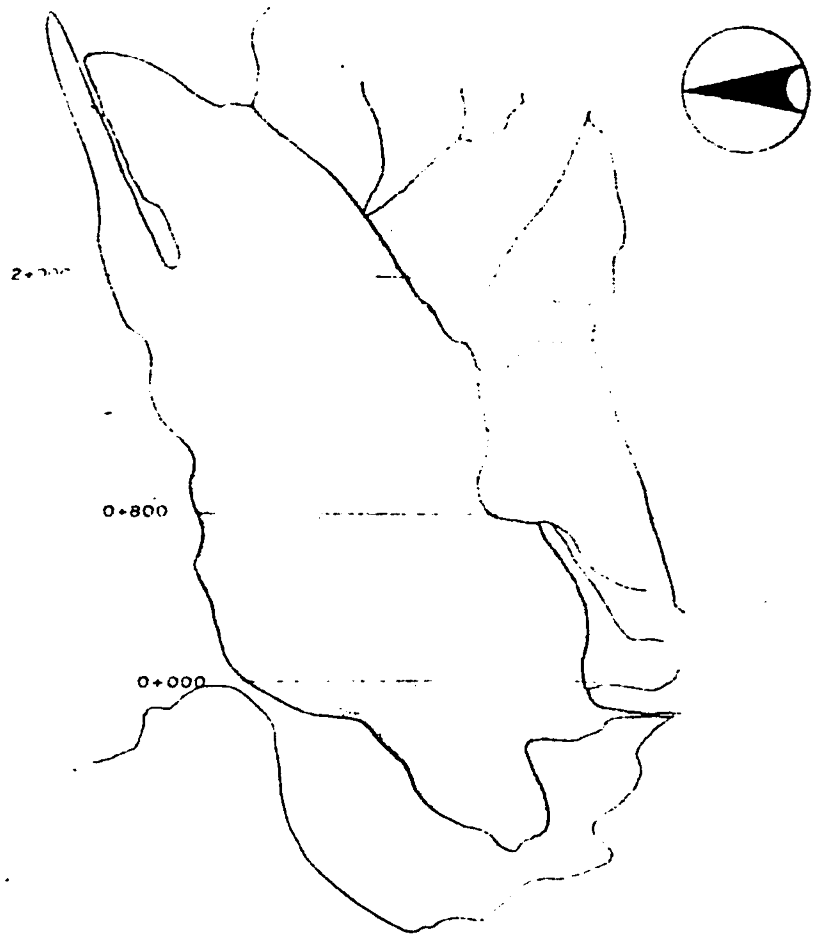


MAP OF LAKE BAAO

LEGEND

- SHORELINE
- RIVER
- CREEK

SCALES

(MAP)

500 0 500 1000 1500 2000

SCALE 1:25,000

(CROSS-SECTION)

Vertical Scale

5 0 5 10 15

SCALE 1:200

Horizontal Scale

100 0 100 200 300 400 500 1000

SCALE 1:10,000

II-5-(3)

BICOL RIVER BASIN DEVELOPMENT PROGRAM

RINCONADA INTEGRATED AREA DEVELOPMENT

FEASIBILITY STUDY

PLAN AND CROSS-SECTION OF LAKE BAAO

FIG II-5

sandstone, conglomerate, and shale. In between these higher areas lie extensive plain areas with alluvial deposits of sand, silt, and clay.

The geology of this area, as described herein, is based on the mapping and description of several earlier investigators and on field reconnaissance and borings made for the Bicol River Basin Comprehensive Water Resources Study (CWRS) and for the current Rinconada IAD groundwater and geotechnical studies. The following publications have served as primary sources of information:

CORBY, G.W. et. al., Geology and Oil Possibilities of the Philippines, Republic of the Philippines, Department of Agriculture and Natural Resources, Technical Bulletin No. 21, 1951.

DUMAPIT, P.T., Groundwater Geology of the Bicol Region, Republic of the Philippines, Department of Agriculture and Natural Resources, Bureau of Mines, 1970 (Unpublished).

TRAVAGLIA, C. and BAES, A., Descriptive Notes of the Geological Map of the Bicol River Basin, United Nations Development Project, Soils and Land Resources Appraisal and Training Project Phi/74003, 1975 (Unpublished).

NONINI, LEWIS G., Prefeasibility Assessment of the Groundwater Potential of the Bicol River Basin, Comprehensive Water Resources Development Study, Bicol River Basin Council, January 30, 1976.

2. Eastern Bicol Cordillera

The Cordillera, which parallels the trend of the Basin, is a volcanic chain comprising five volcanos with peaks ranging in elevation from 1196 to 2421 meters. Commencing at the southern end of the chain and proceeding northward, these volcanos are as follows:

Name	Elevation (m)	Status
Mt. Mayon	2421	Active
Mt. Masaraga	1339	Extinct
Mt. Malinao	1657	Dormant
Mt. Iriga	1196	Extinct
Mt. Isarog	1976	Extinct

These volcanos are the result of explosive volcanism from Pliocene to Recent Time. They are superimposed on alternating layers of andesitic lava and agglomerate formed during Upper Miocene and Pleistocene Time. Large exposures of the lava and agglomerate, which are the oldest rocks that outcrop in the Basin, are found in the hills north of Polangui and the hills between Mt. Isarog and Mt. Iriga. It is probable that the volcanos developed along lines of weakness caused by folding and faulting of these older rocks. The volcanos are reported to consist, in general, of a steep-sloped central cone of interbedded pyroclastic ejecta and lava flows surrounded by larger flatter-sloped piedmont bases of almost all types of pyroclastic materials including volcanic ash and sand, lapilli, and blocks. The most common type of rock found in the volcanic cones is pyroxene-hornblende andesite. However, rhyolites and dacites also are found at Mt. Malinao, dacite at Mt. Masaraga and basaltic andesite at Mt. Iriga and Mt. Mayon. Among the rock types found in the pyroclastics of the volcanic piedmont are breccias, tuffs, agglomerates, pumice, basaltic andesite and rhyolite-pumicites. The rock types found within specific areas of the volcanic piedmont are dependent on the volcano from which they originated. Basaltic andesite is found around Mt. Mayon and rhyolite and pumice around Mt. Iriga.

3. Ragay Hills

The Ragay Hills, which form the southwestern boundary of the Basin, parallel the general northwest-southeast trend of the Basin in similar manner as the Eastern Bicol Cordillera. However, unlike the Cordillera which is of volcanic origin, the Ragay Hills and their extensions to the south (the Pantao Mountains and the Talisay, Oas and Ligao Ranges) are composed of folded and faulted sedimentary rocks. The formations that are present are known as the Bicol Coal Measures, the Talisay Limestone, the Clastic Formation and the Coralline Limestone. The oldest sedimentary rocks which outcrop in the Basin are the Bicol Coal Measures which are Lower to Middle Miocene in age. This formation, which is estimated to be about 1000 meters in thickness, consists of conglomerates, sandstone, shale and calcareous lenses. It is reported to be exposed only in a limited area in the southwestern portion of the Basin where the exposure is due to faulting.

The Bicol Coal Measures are unconformably overlain by the Talisay Limestone, an uplifted formation which is Upper Miocene in age. This formation, estimated to be about 300 meters thick, is composed predominantly of thin beds of whitish coralline limestone with some layers of crystalline limestone. The thickest exposure of these beds, which dip moderately to the southwest, is found in an escarpment of the Talisay Range west of Oas.

The Talisay Limestone is overlain by the Clastic Formation, which is reported by Travaglia to be a transgressive series of sediments deposited in a shallow to moderately deep marine environment from Upper Miocene to Pliocene time. These rocks have been folded and the axes of the synclines and anticlines of the formation parallel the general trend of the Bicol River Basin. The formation consists of the members classified separately by Corby as the Aliang Silt, Paulba Sandstone, Malama Silt and Nabria Formation. The maximum thickness of each of these members is reported to be 350,600,1850(?) and 150 meters respectively. Together they constitute the major and most widely distributed group of sedimentary rocks within the Bicol River Basin. Outcrops of these rocks are found in the Ragay Hills on the southwestern side of the basin from the vicinity of Lupi in the north to the southern boundary of the basin. Travaglia reports the formation to consist of sandstone, siltstone, claystone, shale and conglomerates all of which can be tuffaceous to calcareous. Shales are present throughout the formation and are reported to contain an abundance of shells when found in the northern portion of the basin but few shells when found in the south. The most predominant type of rock within the formation is a marly, tuffaceous and highly fossiliferous shale. Medium-to coarse-grained sandstone composed of subangular to rounded particles of volcanic origin is found in localized areas. The siltstone occurs in massive layers and contains many shells. The conglomerates found are predominantly composed of volcanic materials. However, Travaglia reports the presence of a conglomerate of flat pebbles of Eocene limestone in the shale outcropping in the San Jose River Valley on the Libon-Pantao road.

The Clastic Formation described above is overlain conformably by the Coralline Limestone which was deposited in a reef and fore reef environment from Pliocene to Pleistocene time. In the northern portion of the Bicol River Basin this formation outcrops almost continuously near the crest of the Ragay Hills from the vicinity of Lupi to Lake Bato. In the south it again outcrops in the Ligao Range. The formation, which is shown by the outcrops to have been subjected to principal and secondary faulting, includes porous reef limestone; very porous bioclastic limestone composed of reef fragments mixed with quartz sand and sometimes with pyroclastics; cyrstalline limestone; conglomeratic limestone; and more. Travaglia reports outcrops of the conglomeratic limestone south of Ligao and outcrops of the marl in the northern part of the Basin. The formation is estimated to have a mximum total thickness of 350 meters. However, because of the mode of formation the thickness is thought to vary widely throughout the Basin.

In the Ligao Range in the southern portion of the Basin, the corraline limestone is overlain by 3 to 10 meters of pyroclastic materials ejected from Mt. Mayon during Pleistocene and Recent Time. The pyroclastics in this area also have been reported to be interbedded with the limestone.

4. Bicol Plain

The flat central lowland known as the Bicol Plain is an alluvium-filled trough which separates the volcanic hills of the Eastern Bicol Cordillera from the sedimentary Ragay Hills. The two basin-forming structures meet in the vicinity of Lake Bato and that at one time, a continuous trough about 200 meters deep extended from San Miguel Bay to the Albay Gulf. Early investigators considered this trough to be the result of geosynclinal folding. However, recent studies indicate that at least a portion of this trough may be a down-faulted graben block which resulted from the collapse of areas that had been undermined and weakened by the emission of molten rock and clastic materials through volcanic fissures and vents. It appears likely that the portion of the trough from Lake Bato to the Albay Gulf is such a graben.

The volcanic rocks on the northeastern side of the Basin and the sedimentary rocks on the southwestern side of the Basin dip beneath the alluvium of the Bicol Plain. Since the sedimentary rocks and some of the volcanic rocks are of the same geological age, it is probable that they are intercalated over limited areas beneath the alluvium.

The alluvial material which fills this trough is derived partly from the weathering of the sedimentary rocks of the Ragay Hills but predominantly from weathering and erosion of the volcanic rocks of the Eastern Bicol Cordillera. Some of these alluvial materials have been found to contain sea shells and shell fragments which are indicative of deposition under marine or deltaic conditions. In general, the alluvium is considered to consist of flood plain deposits overlying marine or deltaic deposits. However, it is not unlikely that the alluvium is interbedded with pyroclastics. In areas such as the vicinity of Mt. Mayon pyroclastics may even overlie recent alluvium.

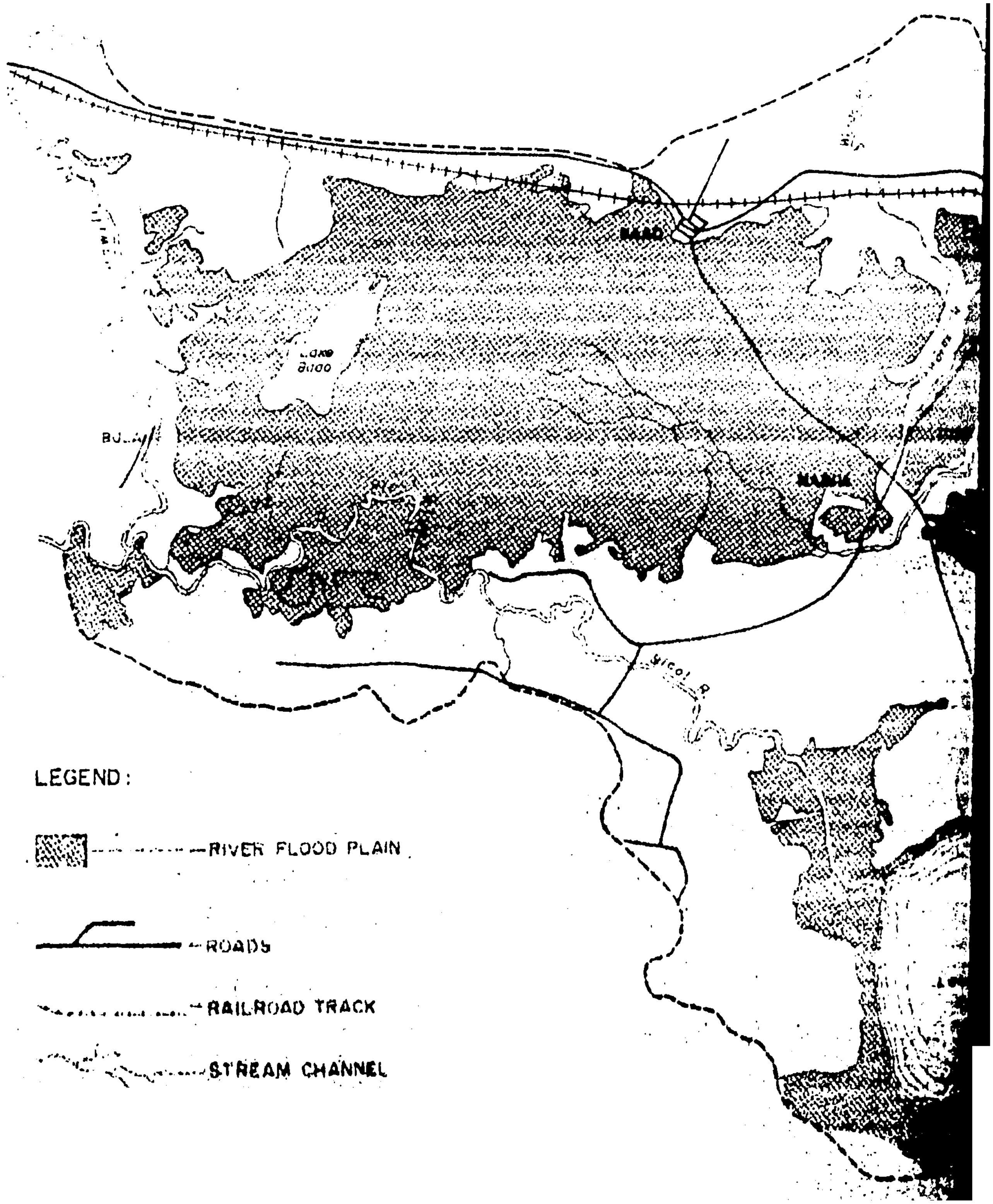
The flood plain deposits consist of mixed clayey river and/or lake alluvium mainly from pyroclastics and the weathered products of andesitic rock. These soils are generally well suited for irrigation of paddy rice. They are deep, fertile, easy to puddle, and there will be little water loss to deep percolation. However, these soils are in low-lying depressed areas which are subject to frequent flooding and have inadequate drainage outlets.

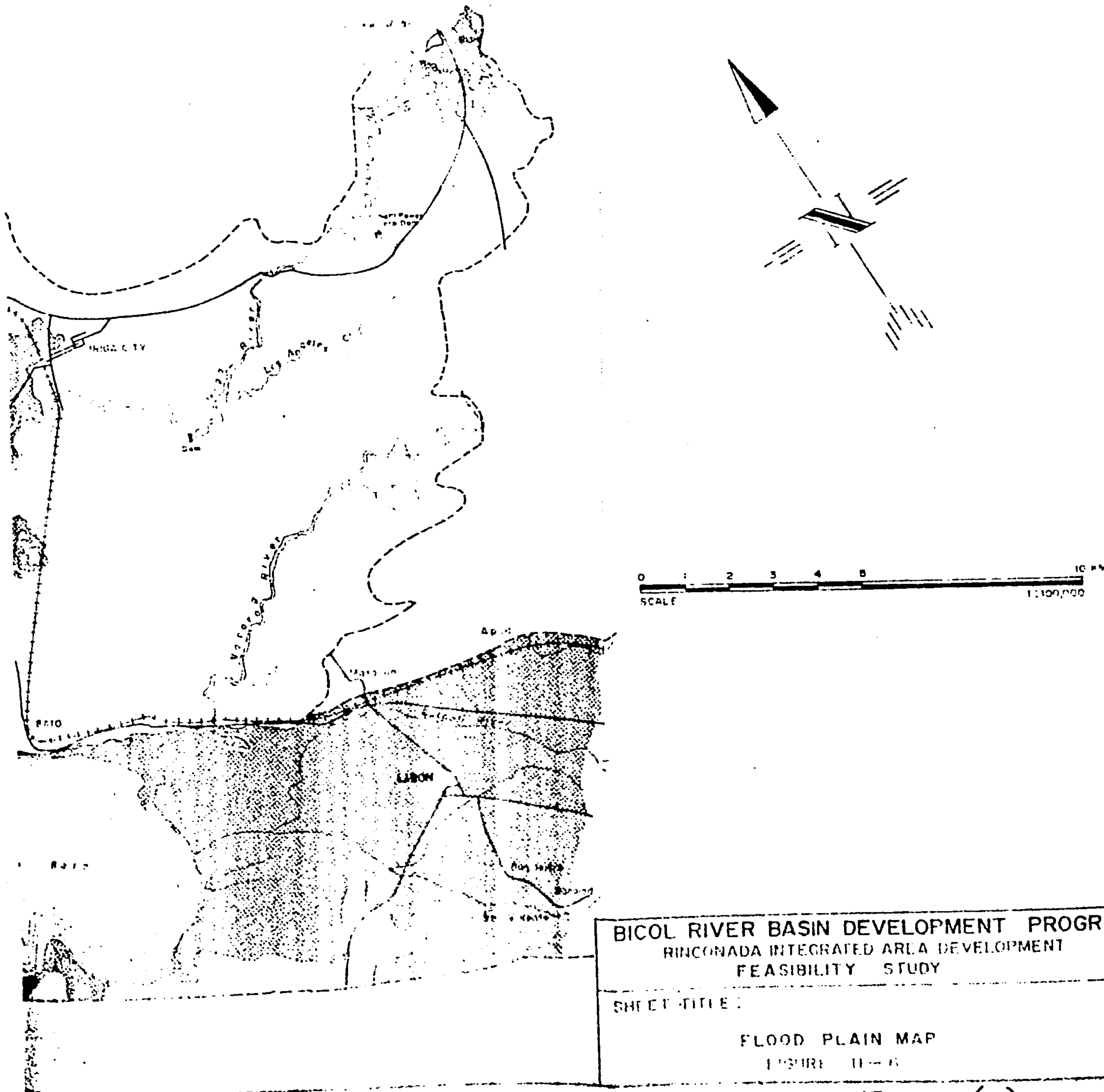
Piedmont plains occupy the remaining, and major portion of the Bicol Plain. The piedmont plain between Nabua, Sto. Domingo and Bula adjoining the Bicol River are nearly level, slightly dissected and consist of mixed clayey river and piedmont alluvium with some volcanic ash deposits. The piedmont plain at the foot of the Ragay Hills consists of fine clayey alluvium and colluvium derived from limestone and shale in the hills and from the underlying clastic formation.

Figure 6 shows the location and extent of the flood plain.

5. Geologic Structures

The Bicol River Basin has been subjected to both folding and faulting. As indicated by Travaglia, the entire Bicol Peninsula is an intermediate land mass between the two dominant structural elements of the archipelago, the Philippine Deep Zone to the east and the Philippine Fault Zone to the west. The latter, which extends for 1200 kilometers from south of the Polilio Islands through Leyte and into the Agusan depression in Mindanao exerts the stronger influence on the Basin. This fault is a zone of variable width with


LEGEND:
RIVER FLOOD PLAIN
ROADS
RAILROAD TRACK
STREAM CHANNEL



BICOL RIVER BASIN DEVELOPMENT PROGRAM
RINCONADA INTEGRATED AREA DEVELOPMENT
FEASIBILITY STUDY

SHEET TITLE :

FLOOD PLAIN MAP
FIGURE II-6

numerous branches and several smaller parallel faults. The San Vicente-Ligao Fault, which cuts the Bicol Region and which Travaglia calls "the most important structural element of the southwestern part of the Basin," is one of the inland splays of the Philippine Fault. It extends from Legaspi City along the southwest side of the Bicol River Basin, crosses the Ragay Hills and passes into the sea north of Balatan. Travaglia reports the probable throw of this fault to be "several hundred of meters" and states that "This structure has elevated the sedimentary rocks and has given origin to the depression occupied today by Lake Bato and the Bicol Plain. Many secondary faults parallel the San Vicente-Ligao Fault and there are many faults with a southeast-northwest trend between Banga and Bula.

Anticlines and synclines are reported by Travaglia to occur east of Pasacao and east of Pantao. The most important of these is the Talisay syncline which occurs in the southwestern part of the Bicol River Basin and extends northwestward with the Talisay Anticline. The Clastic Formation in this area is broadly folded.

6. Seismicity

The Philippine Islands lie along the Circum-Pacific Belt, one of the world's zones of major seismic activity. Gutenberg and Richter in their book "Seismicity of the Earth and Associated Phenomena" state that seismicity is high in the region of the Mindanao Trench, moderate in the vicinity of Luzon and low elsewhere in the Philippines. Travaglia reports that the Bicol Region is subject to frequent earthquakes. A search of the records in Gutenberg and Richter's book and in "The Seismicity of the Earth 1953-1965" by J.P. Rothe reveals that in the period from 1907 to 1965 the epicenters of six earthquakes were located near to but not within the Bicol River Basin. Three of these were located offshore in the vicinity of the Philippine Fault; the remainder were located in the vicinity of Culasi Peak. All shocks were shallow and registered instrumental magnitudes ranging from 5.9 to 7.6. These values correspond to values of 8 to 10 on the Modified Mercalli Scale. Several of the more recent readings reported by Rothe indicate intensities of IV to VI on the Rossi-Forel Scale have been experienced in Camarines as a result of earthquakes with epi centers outside of the Basin area. These intensities correspond to instrumental intensities of 4 to 6 on the Modified Mercalli Scale.

D. HYDROLOGY

1. General

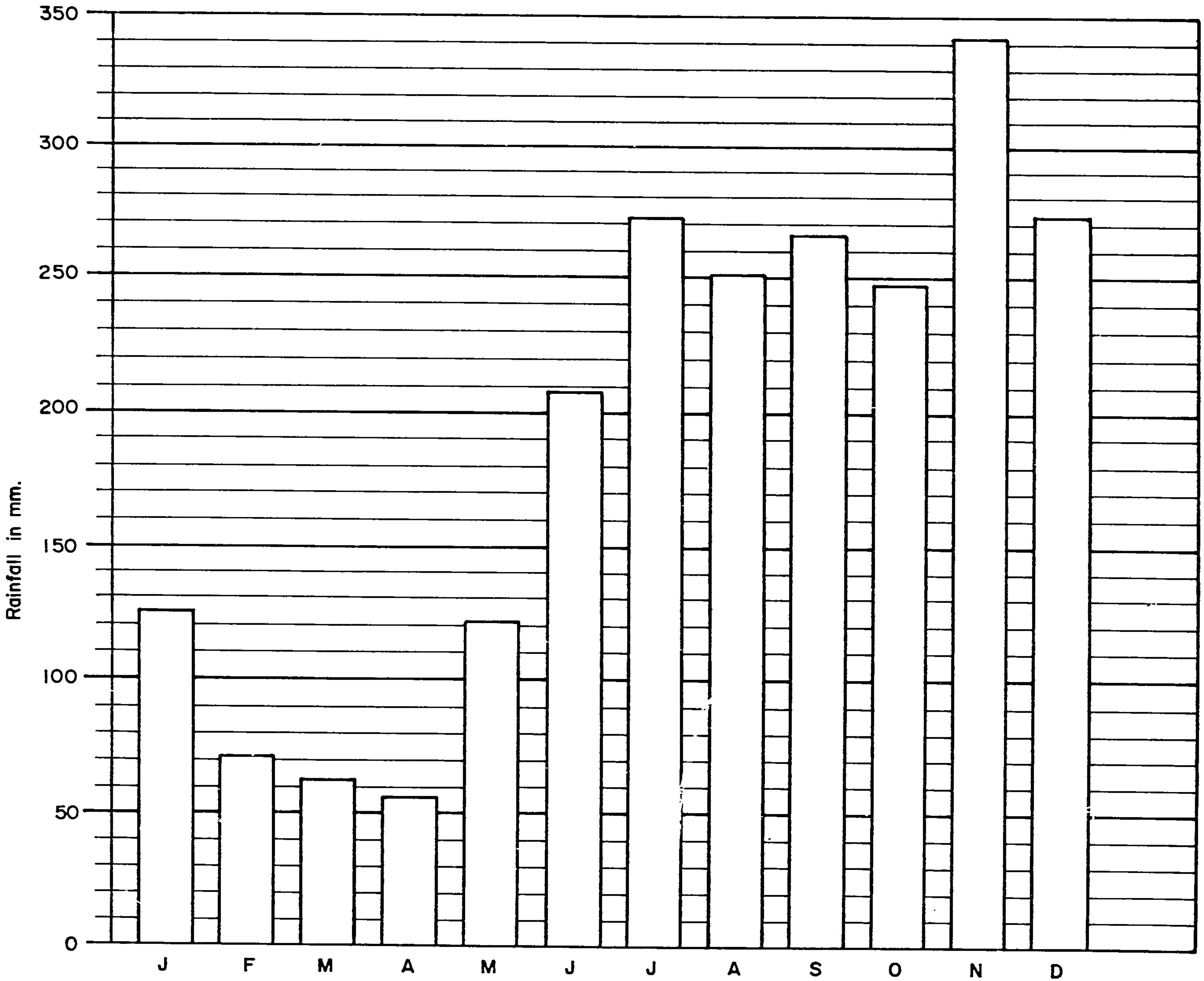
The project area has a tropical climate with a relatively high humidity and constant temperature throughout the year.

2. Rainfall

The rainy season extends from May through December with the maximums occurring in July and November. The two maximum periods are caused by the two air stream systems which dominate the climatic pattern over the region. The northeast monsoon, associated with the northern hemisphere winter, extends from October to March. The southwest monsoon, originating in the Indian Ocean, affects the area from May through September.

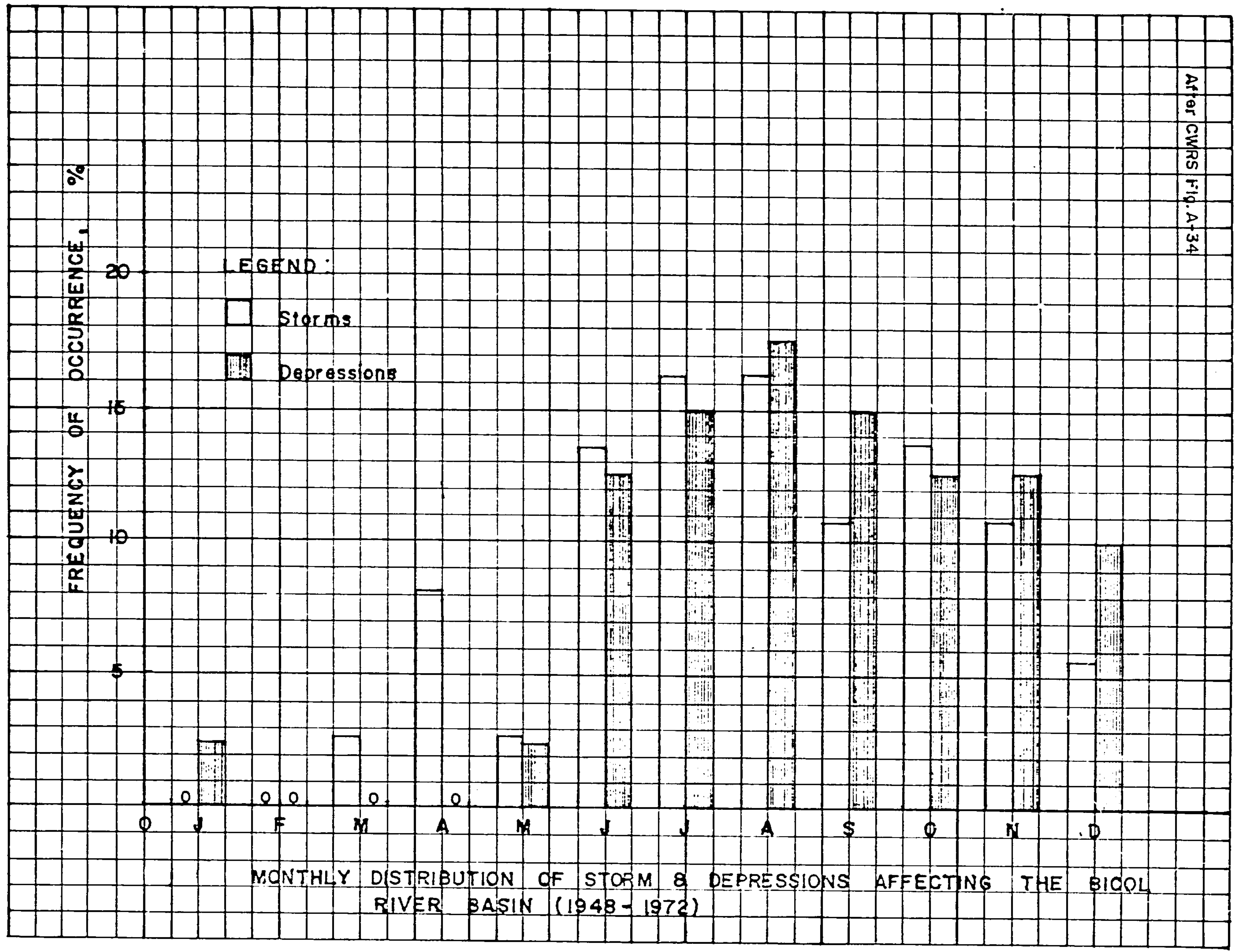
The mean annual rainfall of the region varies from 1,100 mm. along the coast west of Lake Bato to an excess of 3,000 mm. on the slopes of Mt. Mayon and adjacent volcanic peaks. The Mean Annual Rainfall Distribution for Guinobatan upstream of Lake Bato, is shown on Fig. 7.

Very intense rainfall occurs with the tropical cyclones which frequently affect the area. These tropical cyclones can occur at anytime during the year, but particularly during the period from June through December. The Monthly Distribution of Storms and Depressions Affecting the Bicol Region is shown on Fig. 8.



Mean Monthly Distribution of Rainfall at Guinobatan, Albay

Fig.II-7



MONTHLY DISTRIBUTION OF STORM & DEPRESSIONS AFFECTING THE BICOL RIVER BASIN (1948 - 1972)

Fig.II-8

From January through May, the rainfall is relatively light with extended periods of drought. The Low Rainfall Drought Severity at San Jose, Bula is shown on Fig. 9. This analysis reflects the conditions in the downstream service area which could be irrigated during the dry season by storage from Lake Bato.

3. Evaporation

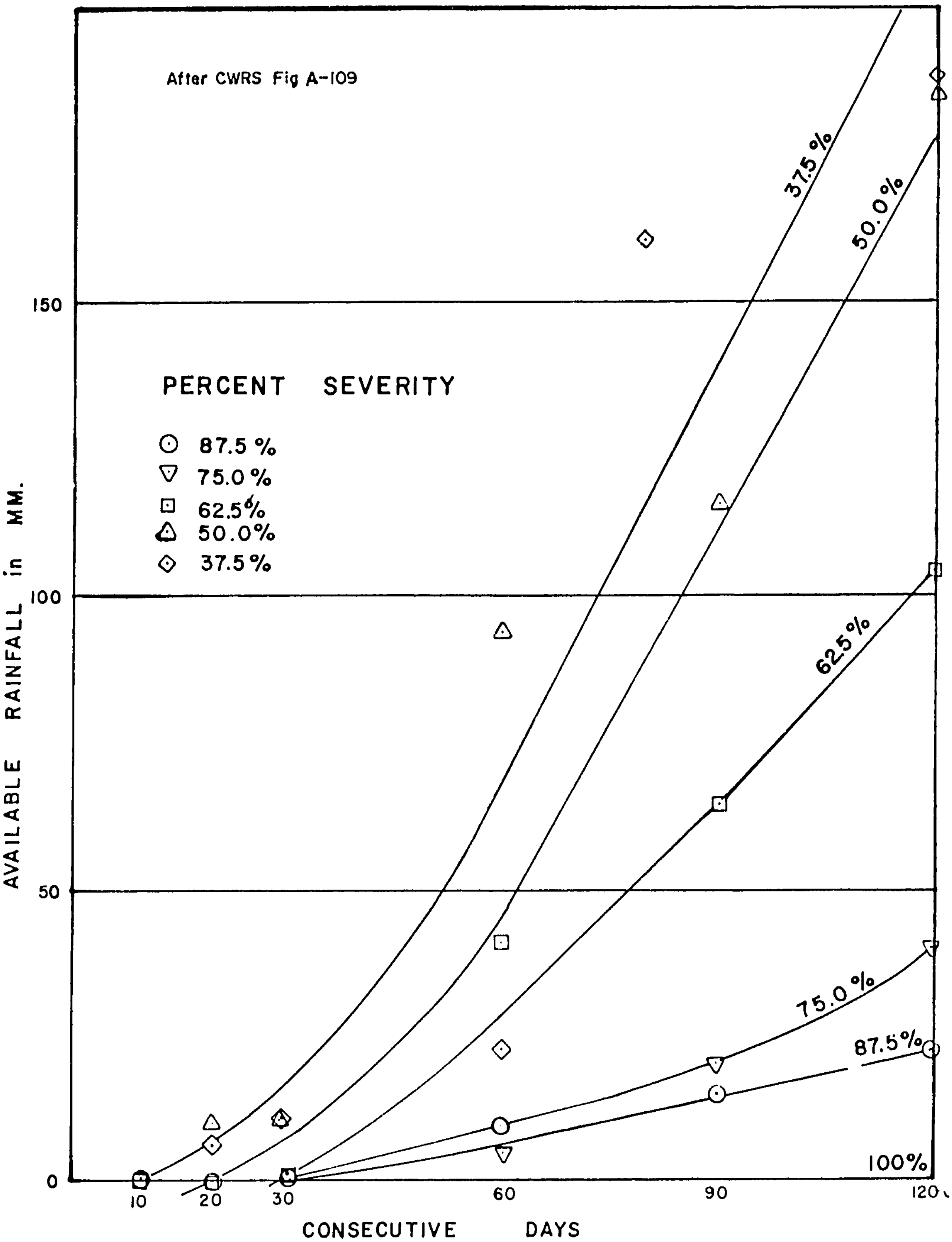
There are few available records on evaporation in the Basin, and the only continuous, long term record is for the station at Naga City. Since evaporation is not expected to vary significantly within the lower elevations of the Basin, the records at Naga City has been used for reservoir routing studies. The monthly evaporation at Naga City is shown on Fig. 10. These observations were made with an open rim type pan with a recommended adjustment coefficient of 0.60.

4. Stream Flows

The major stream of the region is the Bicol River which originates at Lake Bato. The discharge from this lake is measured by the Bicol River gage at Sto. Domingo. The Frequency Analysis of the peak flows at Sto. Domingo is shown on Fig. 11, the Low Flow Analysis on Fig. 12, and the Rating Curve on Fig. 13. As noted from these curves, the discharge from Lake Bato varies from a high of 300 cms. to a low of 2 cms.

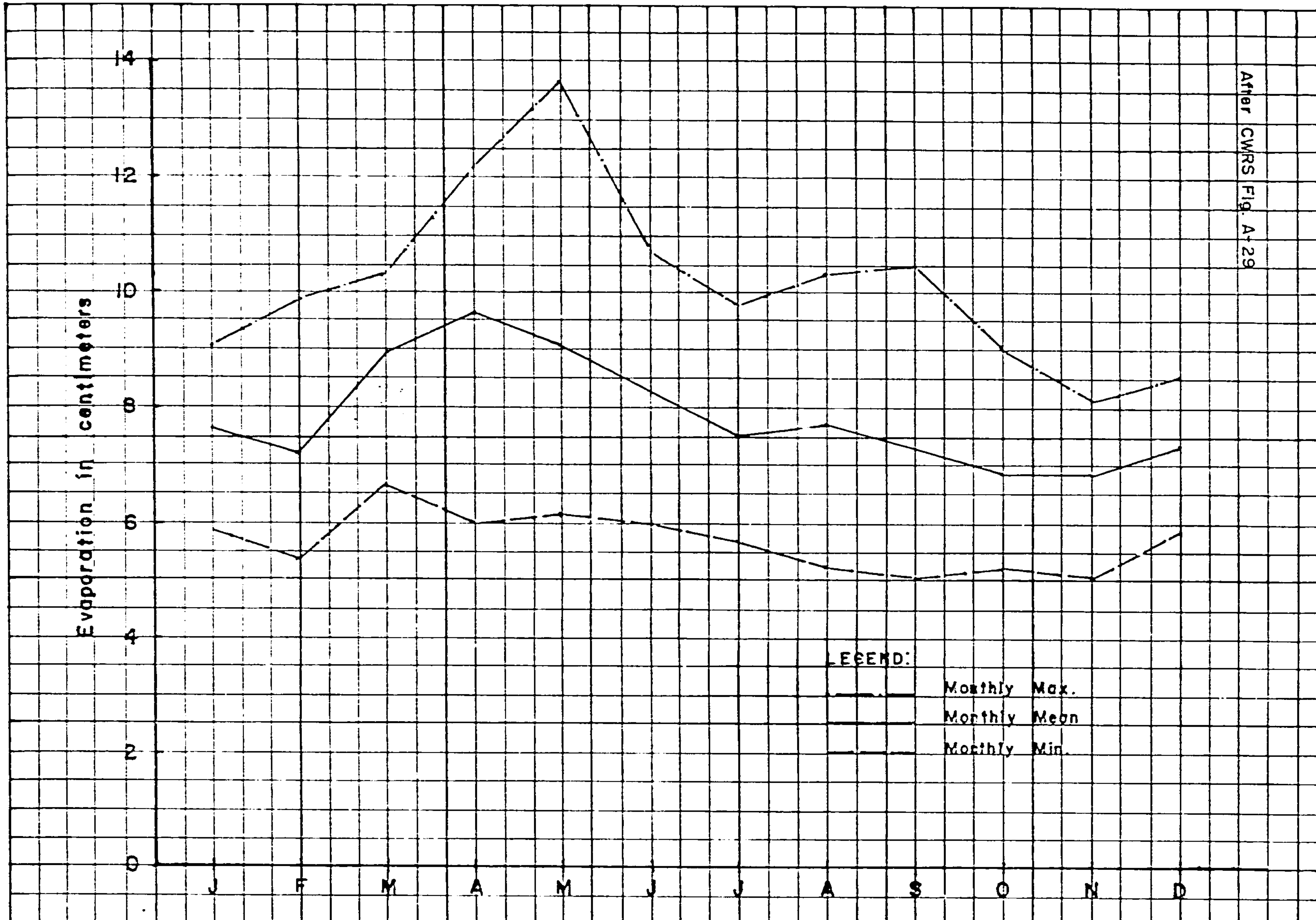
For Lake Bato, the Frequency Analysis of peak water levels is shown on Fig. 14, and the Low Level Analysis on Fig. 15. The level of this lake varies from a peak of 10.5 meters MSL to a low of 4 meters MSL.

The major streams discharging into Lake Bato are the Naporong, Quinali, and Talisay Rivers. These rivers have considerable overbank flow during flood periods and the peak discharge records of these streams do not reflect the actual inflows to the



LOW RAINFALLS, SAN JOSE, BANASI, BULA - Drought Severity

Fig. 9



MONTHLY EVAPORATION RATES AT NAGA CITY (1956 - 1973)

Fig. II-10

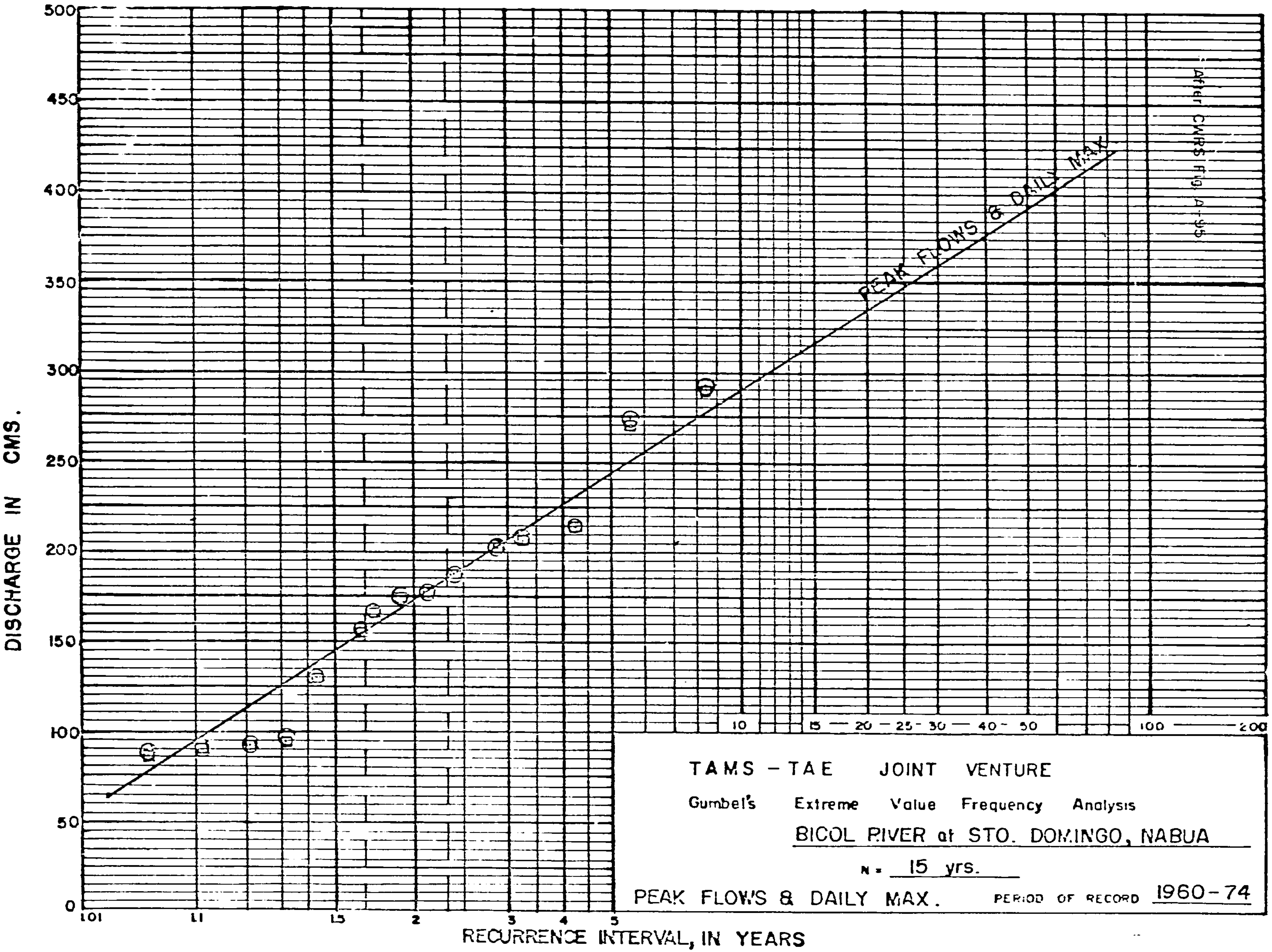
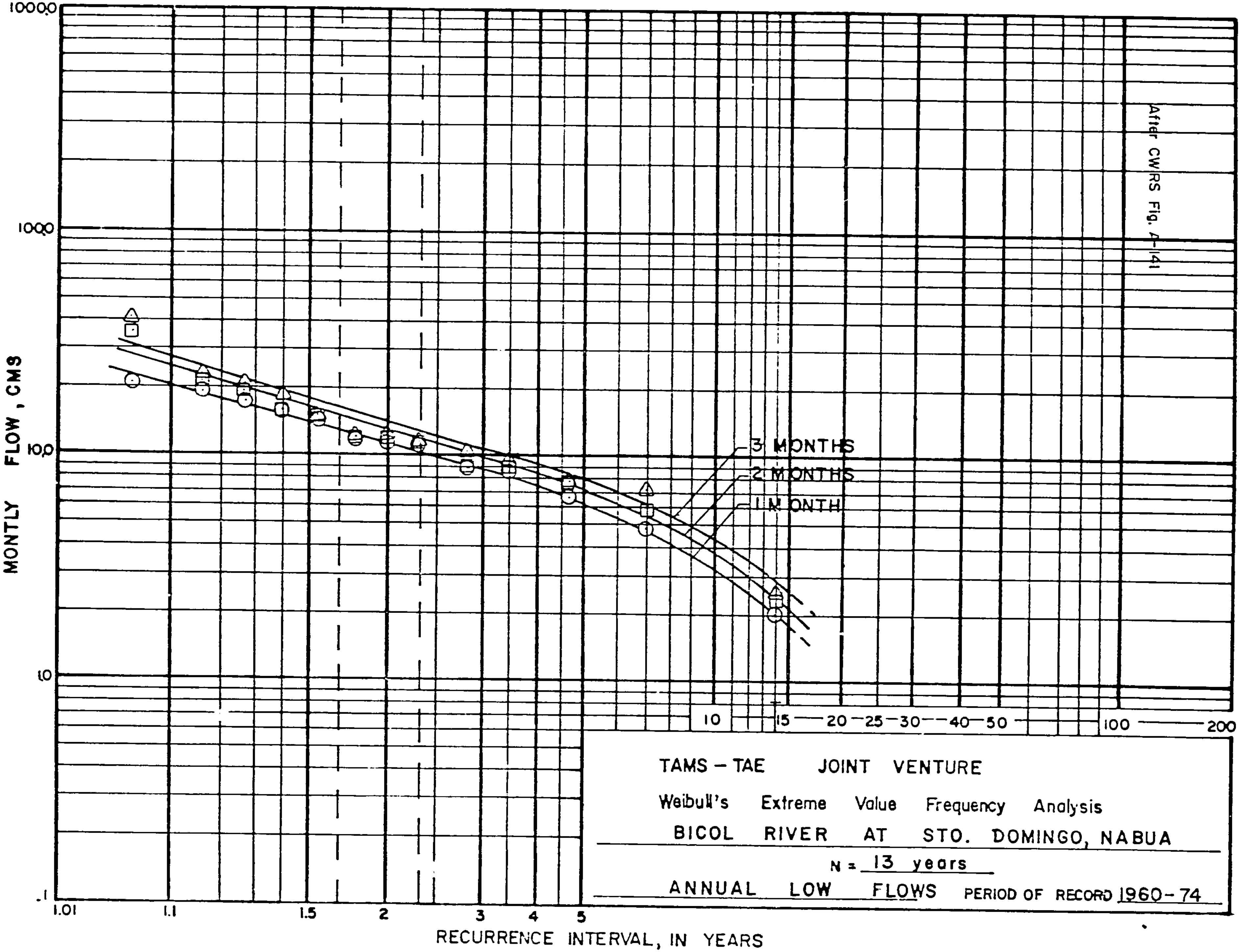

DISCHARGE IN CMS.
RECURRENCE INTERVAL, IN YEARS
500
450
400
350
300
250
200
150
100
50
0
1.01
1.1
1.5
2
3
4
5
10
15 — 20 — 25 — 30 — 40 — 50
100 — 200
PEAK FLOWS & DAILY MAX.
After CWRS Fig. A-95
TAMS - TAE JOINT VENTURE
Gumbel's Extreme Value Frequency Analysis
BICOL RIVER at STO. DOMINGO, NABUA
N = 15 yrs.
PEAK FLOWS & DAILY MAX.
PERIOD OF RECORD 1960-74

Fig.-11



TAMS – TAE JOINT VENTURE

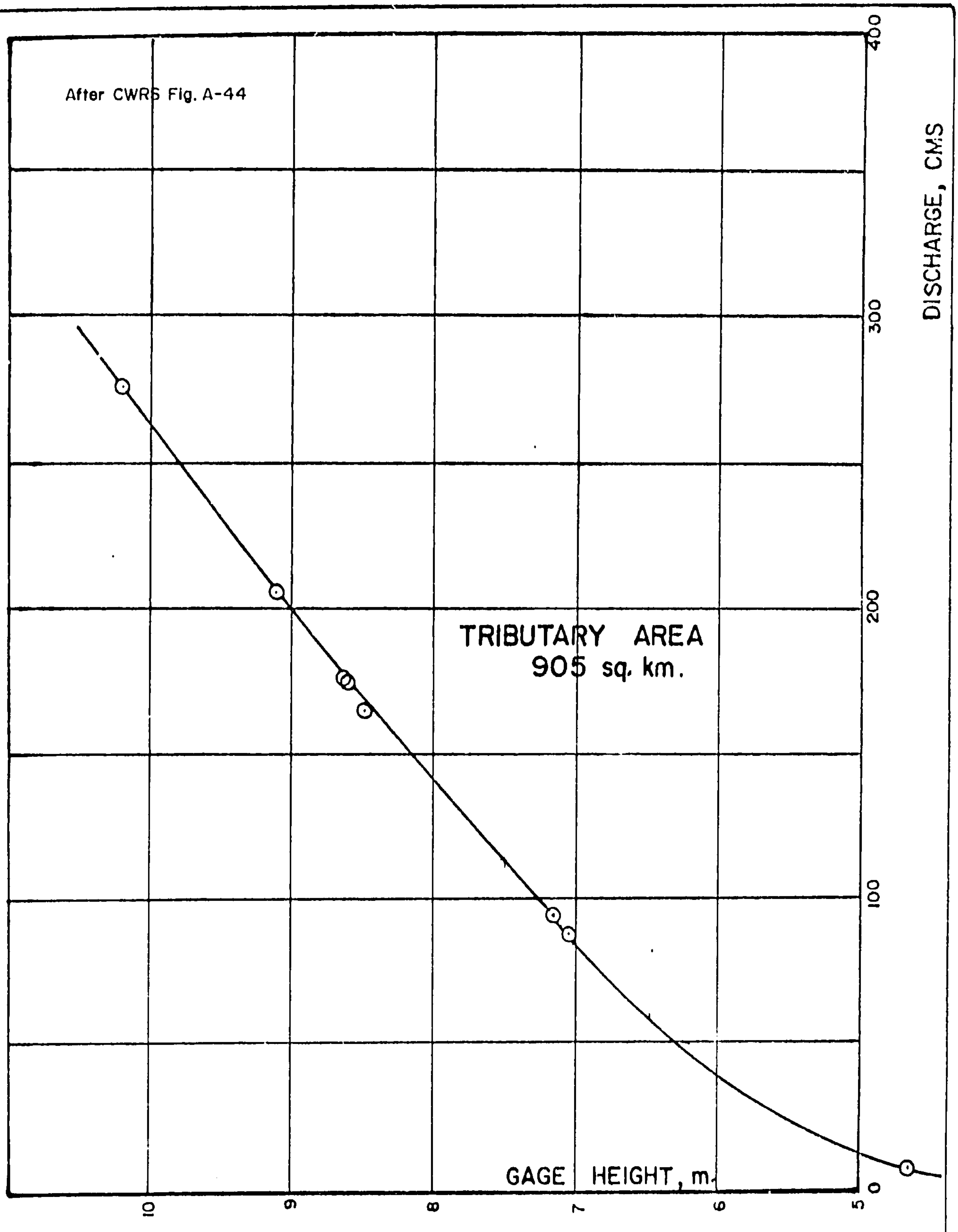
Weibull's Extreme Value Frequency Analysis

BICOL RIVER AT STO. DOMINGO, NABUA

N = 13 years

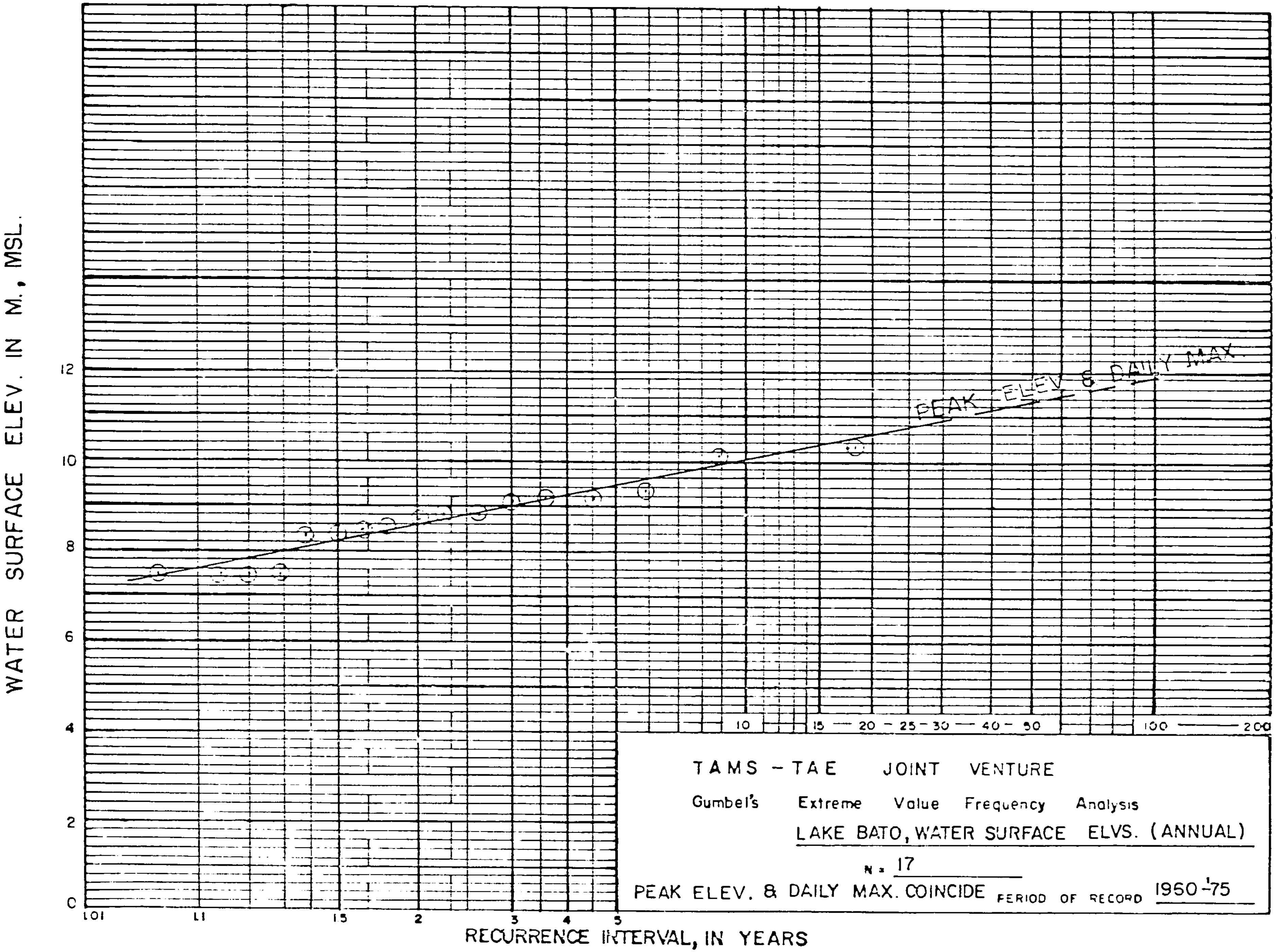
ANNUAL LOW FLOWS PERIOD OF RECORD 1960-74

Fig.-12



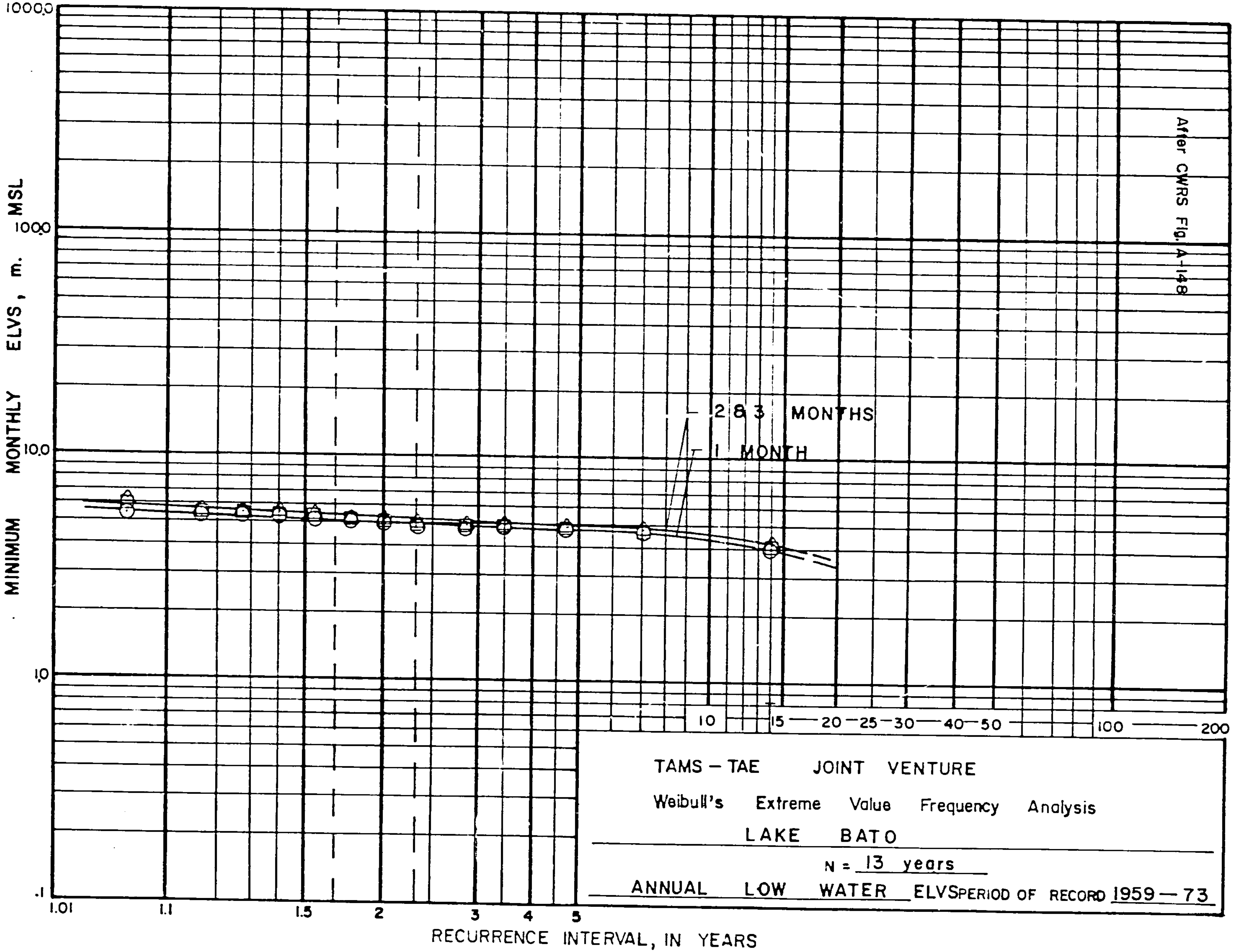
Rating Curve for Bicol River, Sto. Domingo

Fig.- 13



After CWRS Fig. A-103

Fig. 14



MINIMUM MONTHLY ELVS, m. MSL
1000.0
100.0
10.0
1.0
.1
After CWRS Fig. A-148
2 & 3 MONTHS
1 MONTH
1.01
1.1
1.5
2
3
4
5
10
15
20
25
30
40
50
100
200
RECURRENCE INTERVAL, IN YEARS
TAMS – TAE JOINT VENTURE
Weibull's Extreme Value Frequency Analysis
LAKE BATO
N = 13 years
ANNUAL LOW WATER ELVS PERIOD OF RECORD 1959 – 73

Fig. 15

lake. The peak discharge into Lake Bato was computed from a reservoir routing study. For Typhoon Sening the peak inflow was calculated to be 1190 cms.

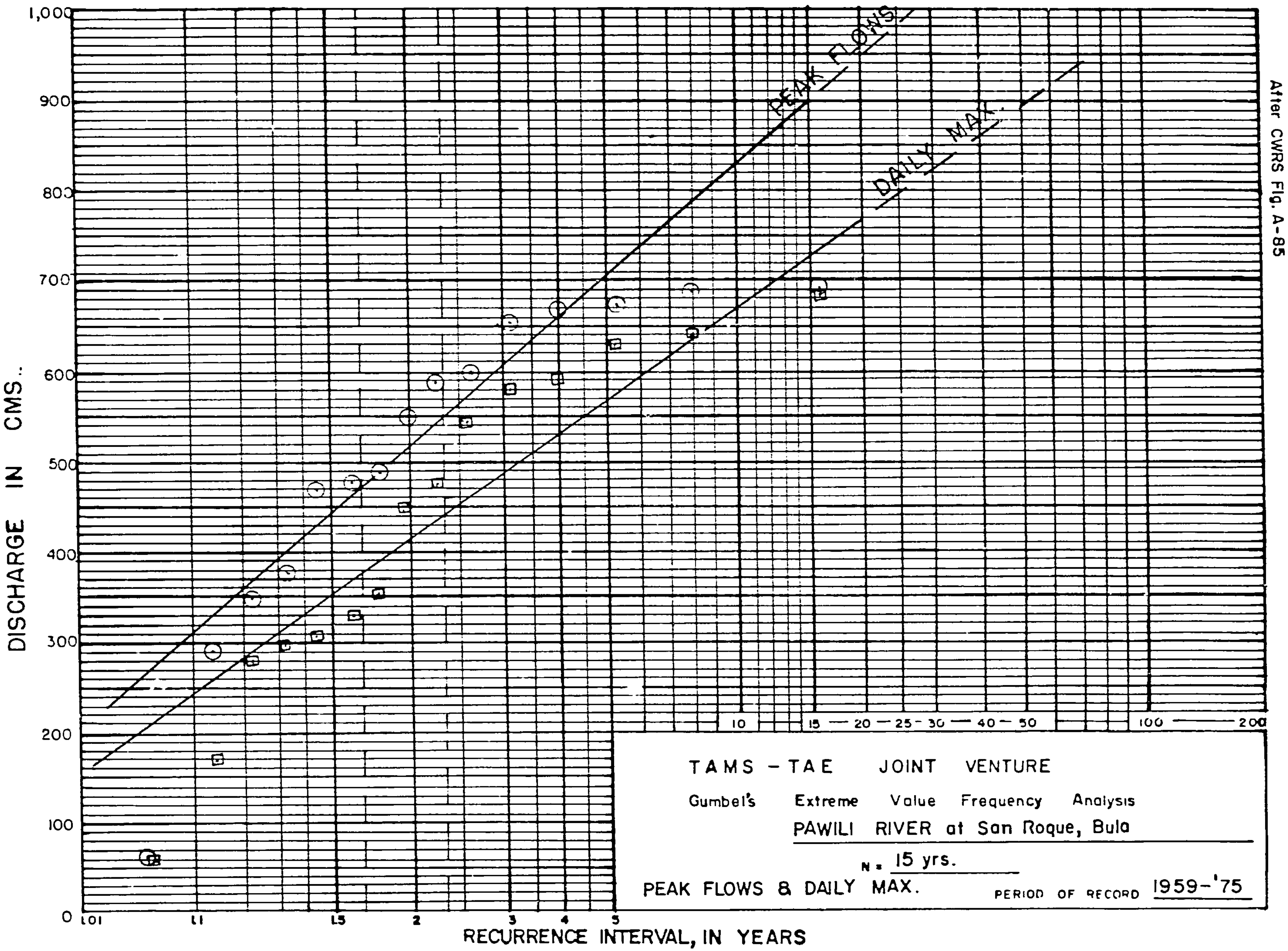
Other stream flows which are significant to the study are the Pawili River which has a drainage area of 240 $km.^2$, and the Waras and Barit Rivers which has a combined drainage area of approximately 300 $km.^2$. For the Pawili River, the Frequency Analysis of peak flows is shown on Fig. 16, the Low Flows on Fig. 17, and the Rating Curve on Fig. 18. The flow of this river varies from a peak of 700 cms. to a low of 0.15 cms. At flood times, the discharge from this river reverses the flow in the Bicol River and spills upstream into Lake Baao.

For the Waras and Barit Rivers, there are no gaging stations to measure their combined flows, and synthetic run-off hydrographs were developed for use in the flood routing analysis.

The total flow from the project area is measured by the Bicol River gage at Ombao. The Frequency Analysis of peak elevations at this station is shown on Fig. 19, the Low Flows on Fig. 20, the Low Flows by Months on Fig. 21, and the Rating Curve on Fig. 22. The flows at this station vary from a peak of 400 cms. to a low of 2.5 cms. There are strong tidal effects at this station and these discharge records are subject to review.

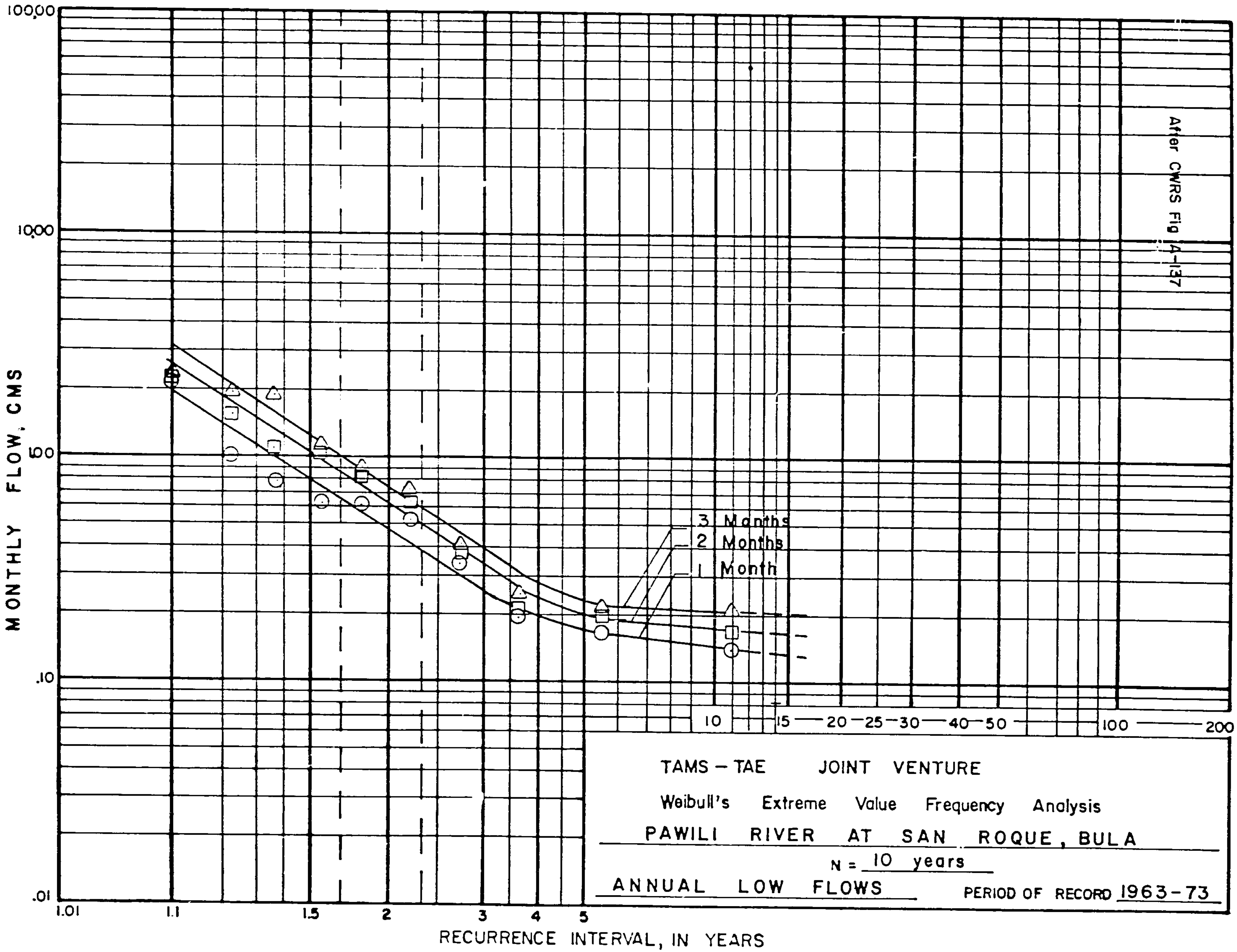
E. SEDIMENTATION

There are three major sources of sediment transport into Lake Bato. These are the Naporong River which originates on the slopes of Mt. Malinao and has a drainage area of 150 $km.^2$, the Quinali River which originates on the slopes of Mt. Masaraga and Mt. Mayon and has a drainage area of 365 $km.^2$, and the Talisay River which originates on the slopes of the Ragay Hills and has a drainage area of 250 $km.^2$.



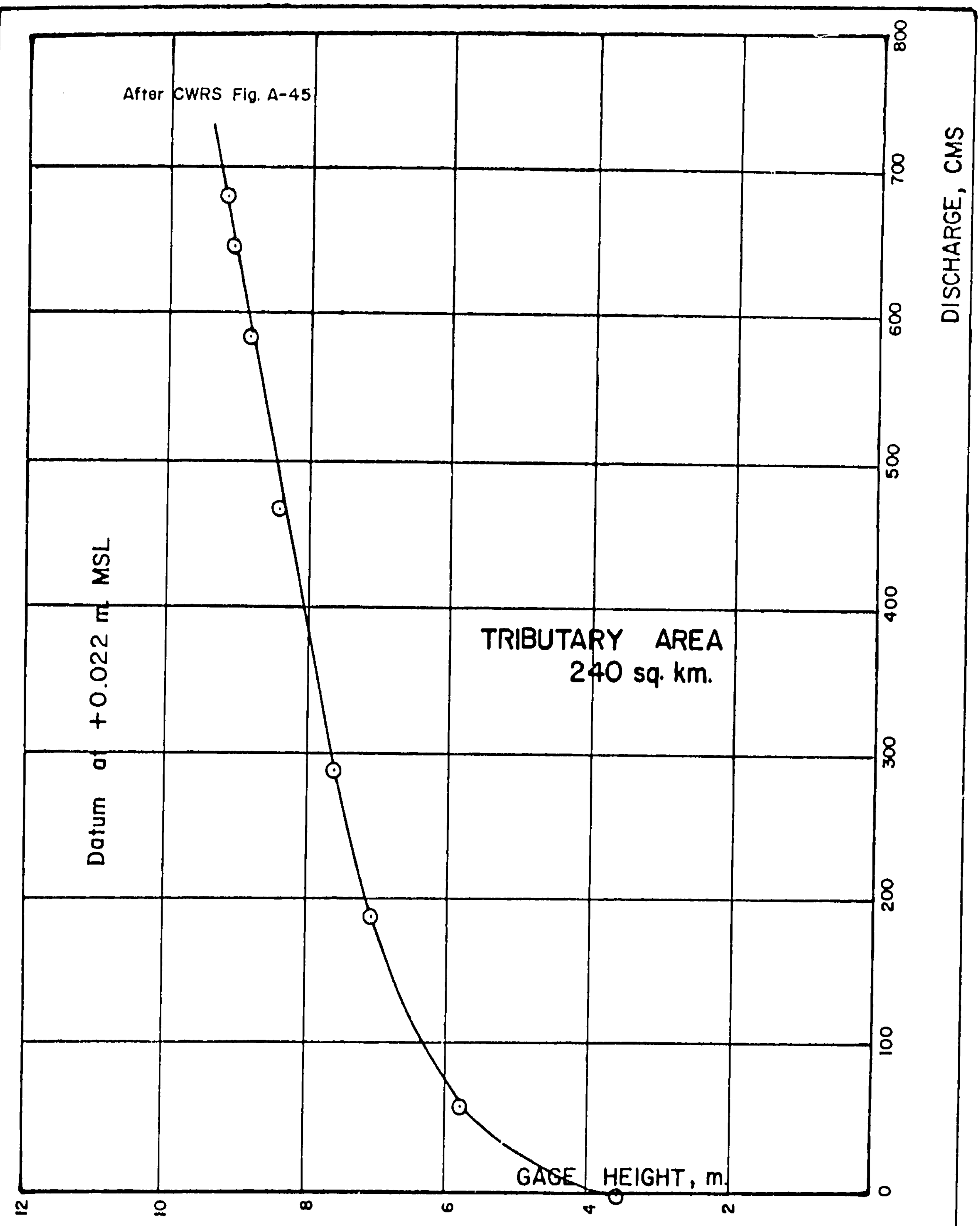
DISCHARGE IN CMS.
1,000
900
800
700
600
500
400
300
200
100
0
1.01
1.1
1.5
2
3
4
5
10
15 — 20 — 25 – 30 — 40 — 50
100 — 200
RECURRENCE INTERVAL, IN YEARS
PEAK FLOWS
DAILY MAX.
After CWRS Fig. A-85
TAMS – TAE JOINT VENTURE
Gumbel's Extreme Value Frequency Analysis
PAWILI RIVER at San Roque, Bula
N = 15 yrs.
PEAK FLOWS & DAILY MAX.
PERIOD OF RECORD 1959–'75

Fig. 16



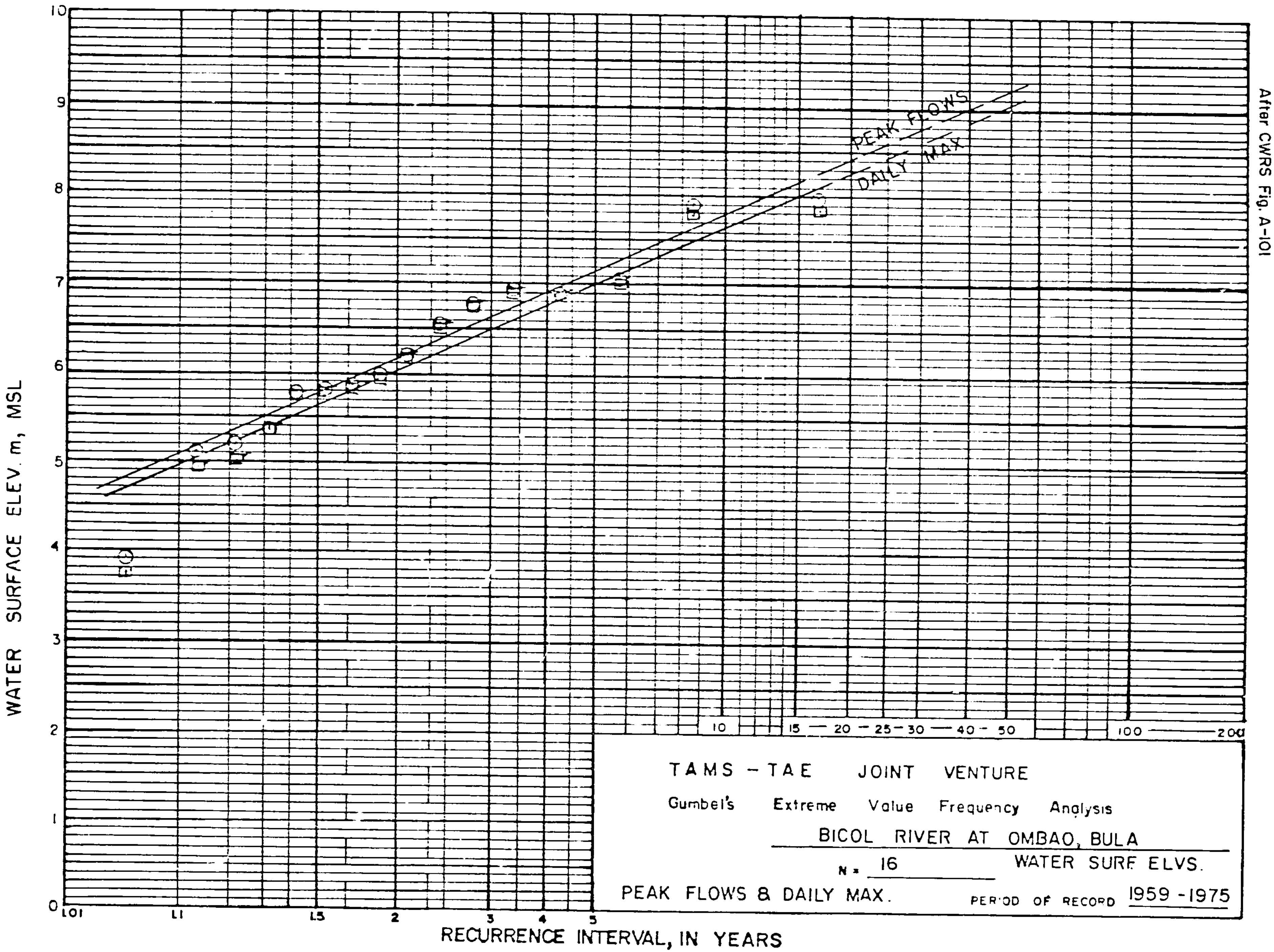
MONTHLY FLOW, CMS
100.00
10.00
1.00
.10
.01
RECURRENCE INTERVAL, IN YEARS
1.01
1.1
1.5
2
3
4
5
10
15
20
25
30
40
50
100
200
3 Months
2 Months
1 Month
After CWRS Fig. A-137
TAMS – TAE JOINT VENTURE
Weibull's Extreme Value Frequency Analysis
PAWILI RIVER AT SAN ROQUE, BULA
N = 10 years
ANNUAL LOW FLOWS
PERIOD OF RECORD 1963-73

Fig. 17



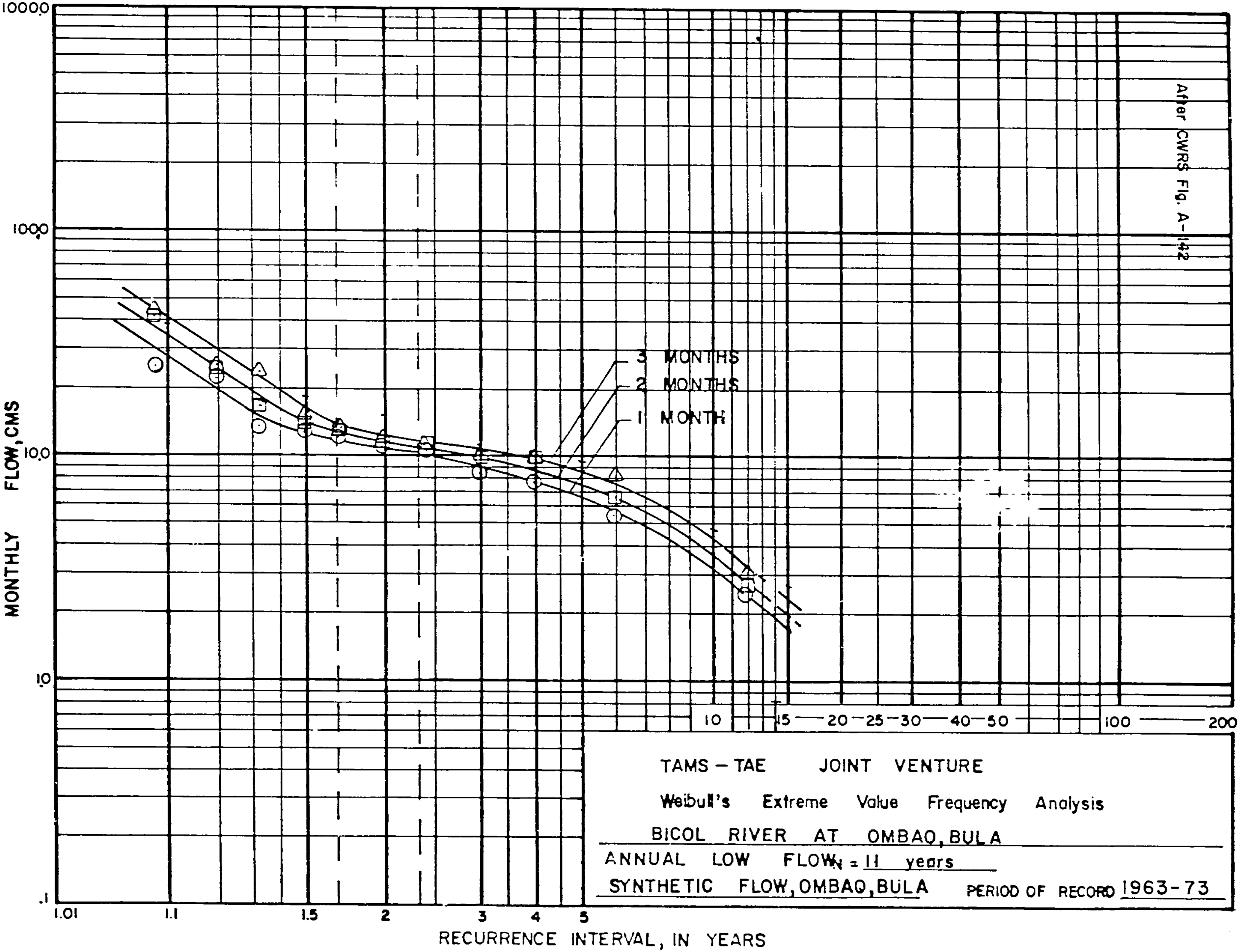
Rating Curve for Pawili River, San Roque Buia

Fig. 18



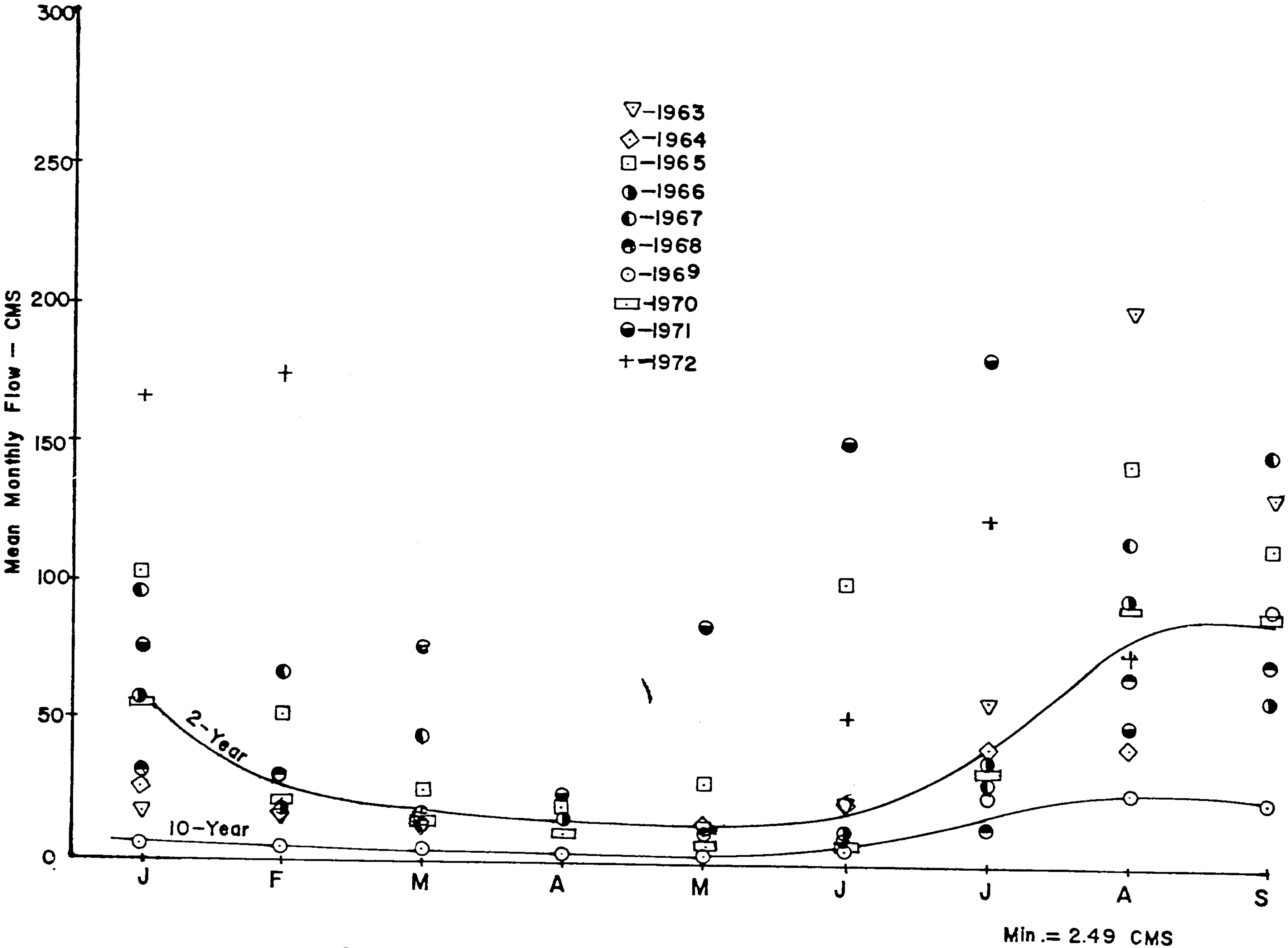
WATER SURFACE ELEV. m, MSL
RECURRENCE INTERVAL, IN YEARS
PEAK FLOWS
DAILY MAX
After CWRS Fig. A-101
TAMS - TAE JOINT VENTURE
Gumbel's Extreme Value Frequency Analysis
BICOL RIVER AT OMBAO, BULA
N = 16
WATER SURF ELVS.
PEAK FLOWS & DAILY MAX.
PERIOD OF RECORD 1959 - 1975

Fig. 19



1000.0
100.0
10.0
1.0
.1
MONTHLY FLOW, CMS
3 MONTHS
2 MONTHS
1 MONTH
After CWRS Fig. A-142
1.01
1.1
1.5
2
3
4
5
10
15
20
25
30
40
50
100
200
RECURRENCE INTERVAL, IN YEARS
TAMS – TAE JOINT VENTURE
Weibull's Extreme Value Frequency Analysis
BICOL RIVER AT OMBAO, BULA
ANNUAL LOW FLOW N = 11 years
SYNTHETIC FLOW, OMBAO, BULA
PERIOD OF RECORD 1963-73

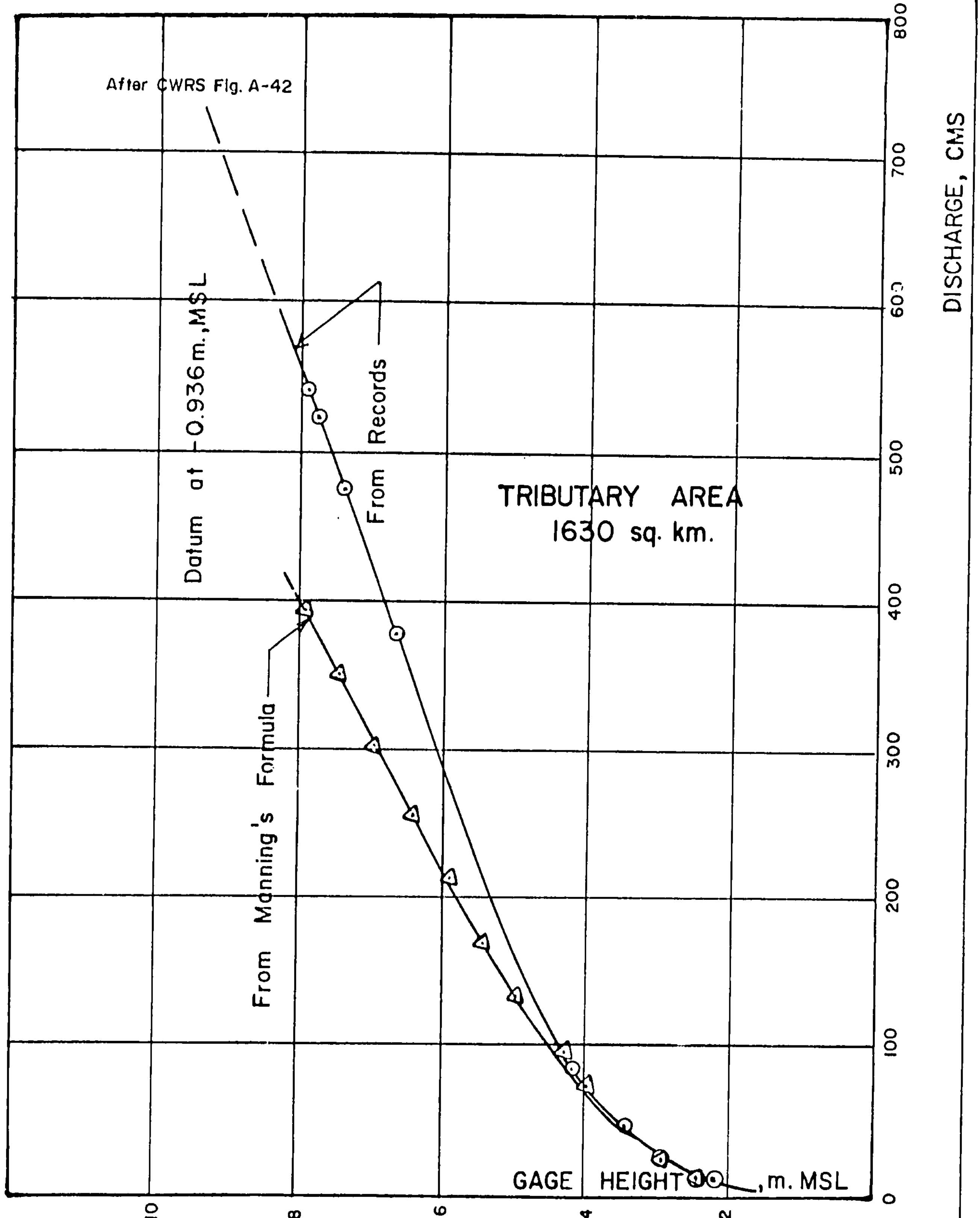
Fig. 20



BICOL RIVER, Ombao, Bula (Synthetic Flow Record)

After CWRS Fig. A-125

Fig. 21



Rating Curve for Bicol River, Ombao, Bula.

The delta formations where these streams discharge into Lake Bato are minor or inactive, and the rate of shoreline accretion is insignificant. These streams contribute very little coarse, or bed load material to the siltation of Lake Bato.

The siltation of Lake Bato is primarily of fine silts and clays which are eroded from alluvial river banks in the upstream flood plains. These fines are distributed uniformly over the lake at a rate of approximately 5 cm. per year. The siltation rate of these fine materials in suspension will not be materially affected by any of the proposed lake developments. The general pattern of siltation will not change, and Lake Bato will continue as an active, productive lake for the foreseeable future.

The CWRS estimated that the rate of siltation of Lake Bato is approximately 400,000 M^3 per year which is equivalent to a uniform distribution of 4 cm per year. Subsequent comparison of historical bathymetry obtained from local residents and from lake soundings taken by BRBDP indicate that a more appropriate rate would be the 5 cm. per year.

Core sampling of the lake bottom confirmed that there is very little coarse, bed material, in the lake deposits. These samples showed very soft silts, clays and colloids with approximately 5% fine sand.

III. PRELIMINARY PLANNING AND DESIGN

A. PROBLEM DEFINITION

1. General

The basic problems of the area are an inequitable distribution of income to the rural poor, a lag in economic development, and an average income level that is below the national average and the gap is widening. There are numerous problems that are the contributory causes of these inadequate social and economic conditions. Those problems which would be ameliorated by the Lake Bato Regulation and Diversion would be:

- flooding
- poor drainage
- inadequate water supply

2. Flooding

This is a major problem throughout the low-lying flood plains within the project area. Annually, 11,000 hectares of the areas surrounding Lake Bato and Lake Baao, and the areas within the municipalities of Baao, Nabua, Bula and Bato are inundated. These flooded areas are shown on the Map of Fig. II-6.

This flooding is the aftermath of the heavy rainfalls associated with tropical depressions, storms and typhoons. These heavy rains can occur at anytime during the year, but particularly during the period from July through December.

Lakes Bato and Baao serve as natural detention reservoirs for the large runoff from Mt. Mayon and the Quinali Valley. This detention tends to reduce downstream flooding but increases the surface area and extends the flooding around the periphery of the lakes. The extent of this flooding is a partial function of the pre-storm level (available storage) of Lake Bato. The lake level is generally high during the rainy season and the beneficial storage is limited. At present, the lake water level cannot be rapidly lowered prior to, or in anticipation of a storm because of the constricted outlet and the lack of control facilities. The lake's outlet is the Bicol River which has a very flat gradient and there is no viable means of significantly increasing its discharge capacity.

3. Poor Drainage

This is another major problem in the urban areas of Nabua and Baao, and in the adjacent agricultural areas of the Barit and Waras Irrigation Systems. The main drainage channels in these areas are the Barit and Waras Rivers. These rivers discharge into Lake Baao which, during flood times, extends into the above areas and restricts the outlets of the two rivers. At the point of discharge into the lake, the river velocities are reduced and sediment deposition is induced. These depositions tend to clog the channels and severely restrict the drainage. In some reaches, the river channels have been essentially obliterated.

4. Inadequate Water Supply

A supply for both municipal and agricultural needs is also a problem in the region. Recent studies indicate that most of the municipal needs can best be served from groundwater, and additional surface supplies will be required primarily for agricultural, fisheries and related needs. In the Rinconada IAD, there is a very limited agricultural area that could be benefitted by Lake Bato storage. However, there are extensive downstream areas in the Bula, the Baliwag-San Vicente, and the Naga-Calabanga projects that could be developed to utilize any additional irrigation supply that would become available from Lake Bato Regulation.

B. GENERAL ALTERNATIVES

1. General

There are various alternative methods of resolving the previously defined problems. The planning process identifies these alternatives, evaluates their potential, and selects those alternatives that warrant further consideration. Following is a description and an evaluation of the identified alternatives.

2. Flood Control

Floodproofing would reduce damages to structures and similar developments by such local protection methods as flood walls or levees around the threatened facility, closure of structural openings below flood levels, and raising the facility above flood levels. This latter method has been extensively used in the flood areas by elevating the floor level of buildings. This method minimizes the flood damages to the particular structure, but there remains the problem of access during flood periods and the debris and unsanitary conditions after the flood recedes.

Removal or relocation of structures to flood-free areas can be a viable alternative for specific conditions. However, this method is not considered socially applicable to the project conditions.

Dredging or enlargement of the outlet channel would tend to lower the flood levels. However, the Bicol River has a very flat gradient with tidal influence, and the hydraulic analysis completed during the CWRS indicated that the proposed dredging of the Bicol River would not significantly lower the flood levels.

Detention of flood waters in a lake or reservoir would tend to reduce downstream flooding. Lakes Bato and Baao serve as natural detention areas and are very effective in minimizing downstream flooding. However, this detention increases the surface area of the lakes and is the cause of extensive flooding in the project area. It has been suggested that dredging of Lake Bato would increase the Lake's capacity and thereby reduce the flood levels. However, to affect a one (1) meter lowering of the flood level would require that the lake capacity be increased by approximately 50 million cubic meters. The cost and disposal problem of dredging the lake would be immense and this method is not considered a viable alternative.

It has also been suggested that levees be constructed to confine Lake Bato for flood protection. Such levees would tend to protect some of the adjacent urban areas, but there could be no increase in the detention capacity of the lake without raising the water levels and encroaching on the upstream agricultural areas and on the municipality of Libon. These protective levees would limit access to the lake, would restrict interior drainage, would be relatively high considering freeboard above maximum flood levels, and would be inordinately costly to construct because of a soft foundation and an unstable soil. This is not considered a viable alternative for flood protection.

Levees would confine the flood flows to the channel and limit flooding of the adjacent lands. Much of the flooding of the Lake Baao area is caused by backflows from the Bicol and Pawili Rivers. Levees and a control structure would prevent these backflows and limit the flooding to that caused by interior runoff. It is expected that this reduced flooding would significantly benefit the municipalities of Nabua, Bula and Baao, and the irrigated areas of the Barit and the Waras projects. This is an alternative to be considered for further analysis.

Diversion of flood flows directly to the sea could significantly lower the flood levels particularly in the immediate area. Numerous diversion plans were considered in the CWRS and the most cost-effective alternative was the Lake Bato-Pantao Bay Diversion.

This alternative is considered for further analysis both for an open channel and for a combination tunnel and open cut.

3. Drainage

The major drainage problem is caused by the flooding from Lake Baao. The drainage alternative cannot be fully considered until after the initial appraisal of the flood control plans for the area. Following are some of the alternative plans that will be considered at that time:

An alternate outlet directly to the Bicol River has been suggested as a means of relieving the drainage problem in the Nabua area. This alternative will be considered.

Dredging will be required to open up the presently clogged channels, and it is an alternative for maintaining the drainage outlets in the future. This alternative has the inherent problems of continual maintenance and disposal of the excavated material, but it may be the only viable means of relieving the drainage problem and it has to be considered.

Erosion control would minimize the sediment transport and reduce the accumulation and clogging of the channels. There is little evidence of watershed deterioration in the Waras watershed, and Lake Buhi serves as a sediment trap for the Barit watershed. It is doubtful that the projected recommendations for watershed protection would significantly improve the drainage outlets but it is a factor to be considered.

Reduced water levels at the outlet (Lake Baao) would permit the sediments to be transported further into the lake before deposition. This could significantly improve the drainage conditions in the Nabua area and will be a considered factor in the flood control study.

4. Agricultural Water Supply

There is a very limited area in the Rinconada IAD that would be benefitted from Lake Bato Regulation, but there are large downstream areas that are in the development phase. These areas could use any additional water that would be available during the dry season. There are numerous non-structural means of improving the water supply such as cloud seeding, watershed management, and on-farm water management. These alternatives have all been considered, and each method would tend to improve the supply. Even if these methods were fully successful, there would still be geographic areas and time periods of the year when a supplemental supply would be required. This supplemental supply must come either from groundwater or from surface storage.

Groundwater could provide a supplemental supply for specific areas and will be considered to the fullest extent possible consistent with the demands for municipal supplies. This supply is not adequate for any extensive coverage, and a surface supply will also be required.

Surface storage in Lake Bato was considered in the CWRS as the most appropriate storage site for service to the lower Bicol River. This storage can be developed independently of flood control except for common use of the control structure, and the operating limitations dictated by flood control requirements. These limitations will be a considered factor in this flood control study.

C. CONSIDERED ALTERNATES

1. General

The specific problems that could be ameliorated by the Lake Bato Regulation and Diversion would be poor drainage, inadequate water supply and flooding. The drainage alternative will be reviewed and fully considered after the flood control aspects of this Interim Report have been evaluated. The water supply problem is primarily one of regulation and control of Lake Bato. This regulation will be a consideration in the planning of Lake Bato flood control. The flooding problem is the primary concern of this Interim Report and only thesc alternatives are considered herein.

2. Planning

The only apparent means of reducing the flood damages in their respective areas is by lowering the flood levels in Lake Bato and Lake Baao. In Lake Bato, the only means of lowering the levels is by diverting the flood flows directly to Pantao Bay.

In Lake Baao, the flood levels could be lowered by (1) the above diversion which would lower the flood levels in the Bicol River; by (2) levees along the right bank of the Bicol River which would prevent backflow from the Bicol River into the Baao area; and by (3) a combination of above. The layout of these alternatives are shown on the map of Fig. III-1.

The Diversion would be approximately 10 kilometers in length and could be either a tunnel or an open channel through a low saddle in the coastal hills. The preliminary cost estimates indicate that an open channel would be the least costly and has been the type of diversion considered in the hydraulic planning.

The channel would be unlined with a bottom width of 22 meters. The invert elevation at the inlet would be 3 meters above MSL and the channel slope would be 0.0009.

An Influent Control Structure, in the upstream reach of the diversion, would regulate the water level in the lake depending on the needs for water supply or for flood control regulation. For the hydraulic routing study, it was assumed that the lake level had been lowered to elevation 5 MSL in an anticipation of a typhoon.

There would also be a gated control structure at the Bicol outlet of Lake Bato. Even without the diversion, this structure would be necessary for developing the water supply storage in the lake.

<u>The Levees</u> along the right bank of the Bicol River would be approximately 8 kilometers in length and would have a top elevation of 11 meters above MSL. The maximum height of these levees would exceed 6 meters.

A gated control structure at the river outlet of Lake Baao would regulate the drainage of Lake Baao and prevent backflow from the Bicol River. This structure, at a lesser height, would be necessary for water control of the Baao areas even without the flood levees.

A combination of the above would have the same components except that the top of the levees would be at elevation 9 MSL. There is also a consideration of a gated control structure on the Bicol River at Ombao. This structure would limit the river discharge to protect downstream areas and would check the water level to divert the peak flow of the Pawili River upstream to Lake Bato. For the hydraulic routing study, it was assumed that the downstream discharge was limited to a maximum of 200 cubic meters per second (CMS). This structure could also be used as a check during the dry season to back water upstream into the lower Pawili River and provide an additional source of irrigation water.

A vehicular bridge would be included on all control structures, and the access roads would be coordinated with the Bicol Secondary and Feeder Road Project.

3. Hydraulic Effects

The hydraulic effects of each of the alternatives have been determined with the use of a mathematical computer model designated "LATIS." For this model, Typhoon Sening conditions were used as a basis of comparison. These determined flood levels at selected locations for these conditions have been tabulated in Table III-1.

Typhoon Sening occurred during October 11-15, 1970, and caused extensive damage and flooding in the basin. This typhoon was selected as a basis of comparison because the hydrologic data and flood levels were well documented and could be used in the calibration of the mathematical model. This typhoon was relatively severe but not of an uncommon occurrence. It had been calculated that the maximum flood level in Lake Bato during the typhoon was of an 18-year frequency. Subsequently, however, that flood level was exceeded during the floods of December 1975.

It is to be noted that these alternatives do not materially effect the maximum flood levels at Naga City. The maximum flood levels in the Lower Bicol River are more effected by the tidal surge from San Miguel Bay than from fluvial flooding. After 4 days, the effects of the surge have been dissipated and the effects of the upstream controls is then evident by the lowered water levels.

It is also to be noted that the Baao Levees would cause a significant increase in the flood levels in the Bicol River. During Typhoon Sening, approximately 50 million M^3 of water spilled into the Lake Baao area from the Bicol and Pawili Rivers. The levees would eliminate this natural detention area with the resulting increase in flood levels.

The flooded areas for each of the alternatives is shown on the map of Fig. III-1. The Bato Diversion would eliminate the flooding from approximately 1500 hectares around Lake Bato and 2500 hectares in the Lake Baao area. The combination diversion and levees would eliminate the flooding for the same area around Lake Bato but would increase the benefitted area in Lake Baao to 3500 hectares. The Baao levees would eliminate the flooding from the same 3500 hectares but would cause additional flooding elsewhere.

TABLE III-1

CALCULATED FLOOD LEVELS FOR CONSIDERED ALTERNATIVES

Selected Locations.	Existing Conditions	ALTERNATIVES (1) Bato Diversion	(2) Baao Levees	(3) Diversion Levees & Ombao Control
		Maximum Flood Levels - M.S.L. for Typhoon Sening		
Bicol River:				
Naga City	2.96	2.94	3.01	2.92
Ombao	7.74	7.03	8.69	6.20
Outlet of Lake Baao	9.33	7.65	10.61	8.96
Sto. Domingo	10.36	7.67	11.05	8.95
Lake Baao:				
Nabua	10.5±	8.23	7.02	7.00
Lake Bato	10.52	8.94		8.94
		Flood Levels After 4 Days		
Naga City	2.70	2.41	2.90	2.08
Ombao	7.70	6.49	8.41	5.15
Outlet of Lake Baao	9.33	7.56	10.40	8.82
Sto. Domingo	10.13	7.58	10.85	8.82
Lake Baao at Nabua	10.5±	8.19	7.02	7.00
Lake Bato	10.52	8.93		8.93

4. Design

The only important factor which will significantly affect the structural designs of this study would be the soil and foundation conditions. These are the only design considerations considered herein.

a) Field Investigations

The field investigations for this study consisted of a geological reconnaissance which was performed in connection with the groundwater hydrology studies being performed concurrently with this study; a field inspection of proposed structures sites, quarries and borrow areas by the Project Manager, Geologist and Soils Engineer; and a limited subsurface exploratory program. The subsurface exploratory program consisted of 12 NX-size borings. These included 3 borings of 19.5, 30.0 and 40.5 meters depth at the proposed site of the Lake Bato outlet control structure on the Bicol River; 3 borings of 19.5, 30.0 and 40.5 meters depth at the proposed site of the influent control structure for the Lake Bato-Pantao Bay Diversion; and 6 borings of 12.0, 16.5, 30.0, 34.5, 49.5 and 60 meters depth along the proposed alignment of the diversion. Split spoon samples of 1-3/8 inch diameter were taken every 1.5 meters of depth throughout the overburden in each hole except at those 1.5 meters intervals where 2.0-inch diameter Shelby tube samples were substituted to obtain undisturbed samples for laboratory testing. Rock cores were taken only from the Borings Nos. BH-1 through BH-5 inclusive along the proposed channel alignment, BX-size cores were taken in Boring No. BH-1; BX- and NX- size cores were taken in Borings Nos. BH-2 BH-3 and BH-5; and BX- and AW- size cores were taken in Boring No. BH-4. The locations of the borings and the boring profiles for the proposed diversion and for the outlet control structure are shown on Figs. III-3, III-5, and III-8.

b) Lake Bato-Pantao Bay Diversion

General

Subsurface conditions along the alignment of the proposed diversion are shown by the graphical boring logs on Fig. III-5. Included are the logs of the 6 borings drilled along the diversion alignment and 1 boring drilled at the proposed site of the influent control structure (Station 0+360). The boring for the influent control structure was drilled in the flat rice paddy area immediately adjacent to Lake Bato. This boring penetrated alluvium to a depth of 40.5 meters. The upper 24 meters consists of soft to medium clay; below this depth layers of sand and clayey sand alternate with layers of clay and silty clay. The sands range from medium to dense and the clays from medium to stiff. A somewhat similar condition exists in the low area at the Pantao Bay end of the channel. Boring No. BH-6 at Station 8+912 penetrated approximately 11 meters of very soft to soft clay followed by about 1 meter of medium to stiff clay before being terminated. The remaining borings along the alignment were done at higher elevations. These borings show 1.5 to 7.5 meters of overburden which, in general, is composed of residual soil but which may be alluvial when, as in the case of Boring No. BH-1, a hole was drilled in proximity to a stream. The alluvial overburden consists primarily of very loose to medium sand and silty sand. The residual overburden is predominantly stiff to hard silty clay and clay and medium to dense silty sand and clayey silt. This overburden rests upon the Clastic Formation which has been described in the section on soils. The rock types encountered in the borings include siltstone, sandstone and conglomerate. The logs of some holes also show a very hard silty clay between layers of siltstone. On the basis of observations of outcrops during a field inspection of the alignment, this material is considered to be an indurated clay. Core recovery was highest in the sandstone where, in general, it ranged from 50 to 98 percent. Values as low as 10 percent were obtained but these were encountered in localized areas. Near-vertical outcrops rising to heights of 30 meters and more and containing the sandstone material were encountered during field reconnaissance and confirm the quality of this rock. Core recovery was the lowest in the conglomerate where values ranged from approximately 7 to 19 percent. However, this conglomerate was also observed in the same near-vertical outcrops as the sandstone. It is considered that the low recovery is due to difficulties in coring and the quality of the conglomerate is much better than the percent recovery would indicate. Recovery in the siltstone ranged from 16 to 100 percent when all cores are considered regardless of size. However, if values are tabulated based on core size, the recovery range is as follows: NX-size, 67 to 100 percent; BX-size, 16 to 100 percent; and AW, 19 to 53 percent. Examination of the rock core combined with field observations indicate that the material designated as siltstone contains many hairline cracks and is a firmly compacted silt or clay rather than a rock. Slickensiding was observed in the cores and material from outcrops, and in several instances, this material could be easily broken. Other material designated as siltstone was found to be a true rock.

The borings which were made at intervals from 900 to 1600 meters. Measurements made during the field reconnaissance indicate that the rocks encountered in these borings dip 10 to 15 degrees in a south to southwest direction. Because of the spacing, the dip and the depths of each boring relative to adjacent borings, it was not possible to join strata in one hole to those in another. It is then difficult to predict the type of rock which would be encountered throughout the alignment. However, information obtained from each boring was projected along the alignment to the maximum extent possible. Conditions in intermediate areas were estimated on the basis of the distribution of the various types of rock in those zones where data were available. There is no information available on seepage through the overburden and rock since no seepage or pressure tests were performed.

Channel Alternative

The channel would be excavated through four basic categories of material: alluvium, residual soils, indurated silts and clays, and fresh, closely to widely jointed rock. The bottom width of the channel was considered to be 22 meters, and the width of the lowest berm on the east side of the channel was considered to be 10 m to accomodate a roadway along the channel. The design of the cut slopes is based upon the results of the subsurface exploratory program; on the observations ofthe rock quality and natural slopes during the field reconnaissance; and on empirical design procedures. Slopes in the soft alluvium at each end of the channel have been established as 1 vertical on 6 horizontal. Throughout the remainder of the channel, slopes in alluvial and residual soils have been established as 1 vertical and 2 horizontal; slopes in the siltstone as 1 vertical and 2 horizontal; and slopes in the sandstone and conglomerate as 1 vertical on 1/2 horizontal. Berms have been provided at 10 meter vertical intervals and at the interface between overburden and soil. The purpose of these berms is to (1) protect the channel against reduced capacity due to the accumulation of weathered material or debris from rock falls which cannot be economically avoided in new rock-cut construction; and (2) provide for periodic removal of water or checking of water flow accross the face of the slope thereby reducing erosion. Except for the 10-meter wide berm for the roadway, all berms are to be 5 meters wide. Typical channel cross-sections are shown on Figure III-6.

Excavation of the earth and rock is expected to be accomplished by conventional earth and rock excavation techniques. It is expected that scrapers would be used for removal of the overburden. Rippers could be used for the indurated clay and silt and for the closely jointed upper portion of the rock. However, it is expected that blasting will be required for the major portion of the rock and that cushion blasting will be used to obtain smooth cut slopes.

It is anticipated that the excavated material can be deposited in the undeveloped areas adjacent to the cut and provide terraced level areas for development and beneficial use. The specific disposal areas and details for the filling of such areas cannot be defined until detailed topographic maps are available. The approximate quantity of material for disposal in the channel alternative is 30,000,000 cubic meters.

Channel-Tunnel Alternative

The relative length of tunnel and channel were determined on the basis of subsurface conditions as shown on Fig. III-5. The tunnel portals were established so that a minimum rock cover of one tunnel diameter above the tunnel crown would be maintained throughout the length of the tunnel. The tunnel would be excavated through the sedimentary rocks of the Clastic Formation (see Section on Soils). This would include sandstone, conglomerate siltstone and indurated clay and silt. On the basis of information provided by the borings and modified by field reconnaissance, it is expected that the sandstone and conglomerate would result in tunnel loads similar to those given by Terzaghi for moderately blocky and seamy rock (See "Rock Tunneling with Steel Supports" by R. V Proctor and T.L. White). The nature of the siltstone, on the other hand, is such that the possibility of the development of loads equal to those for squeezing rock must be taken into consideration. This results from the fact that many indurated materials tend to increase in volume in the presence of water after the confining force has been removed. Since this will have a significant effect on the cost of the tunnel, it is necessary to determine the swelling potential of several samples of the indurated materials. No cores from the initial borings were preserved in their natural state. Therefore, it will not be possible to test for volume change until new samples are obtained. Additional borings have been proposed for the feasibility study if this alternative is pursued. For the purpose of the current study, it has been assumed, on the basis of available data, that 55 percent of the tunnel will be in the conglomerate and sandstone and 45 percent in the indurated clay and silt. Cross sections for zones have developed and are designated as medium rock section and bad rock section respectively. Sections have been developed for each zone and are shown on Fig. III-7. For purposes of cost estimation, it was further assumed that (1) 100-feet long zone immediately inside of each portal would require heavy reinforcement; (2) the entire length of the tunnel will require a reinforced concrete lining; and (3) construction will be by the top heading and bench method. Since pressure tests were not performed in the initial borings, it also was necessary to assume, on the basis of field observations of outcrops, that only a moderate amount of pumping would be required for dewatering and that grouting takes would be moderate. Pressure tests will be necessary in the feasibility stage borings in order to permit a closer approximation of these costs.

In general, it is expected that excavation will be done primarily by drilling and blasting although it is possible that Alpine excavators could be used for the indurated materials and the more fractured fresh rock. The use of smooth wall blasting should be required to limit overbreak. Disposal of excavated material would be made in the manner outlined for the channel alternative. The amount of excavated material from the channel-tunnel alternative is estimated to be 6,200,000 cubic meters.

Influent Control Structure

Subsurface explorations at the proposed site of this structure revealed the presence of soft to medium clay to a depth of approximately 30 meters. Below this depth, medium to stiff clay is interlayered with medium to dense sand and silty sand. The control structure at this site would require piles having minimum lengths of about 30 meters. The consistency of surface materials would pose an operational problem for heavy equipment. It is anticipated that better foundation conditions are present once the alignment passes out of the lowlands immediately adjacent to Lake Bato.

For this prefeasibility study, it has been assumed that the influent control structure will be constructed at this alternate site and that the foundation will be of firm residual material or rock. Additional borings will be required in the feasibility stage in order to verify this assumption.

c) Lake Bato - Outlet Control Structure

The proposed site for this structure is on the Bicol River a short distance from Lake Bato. Ground surface in the area immediately outside of the river channel in this area ranges, in general, between El. 8 m. and El. 10 m. Localized low spots are encountered in the form of drainage channels and swamp areas, particularly on the right side of the river. There would be some filling at these low spots to accommodate an access road to the structure.

Two heights of structure would be considered. The higher structure would be used only if the diversion channel or channel-tunnel is not constructed. In this case the maximum water surface would be at El. 11 m. The lower control structure would be used if the diversion channel is constructed. In this case the maximum water surface would be El. 9.

Sub-surface conditions at the proposed site of the outlet control structure are shown on Fig. III-8. The surface soils on both sides of the river are silty clays and that in the river is a fine sand. The profile on the right side of the river shows layers of very soft to medium silty clay and clay alternating with very loose to dense silty fine sand in the upper 15 meters. From 15 to 30 meters, the silty clay is stiff to very stiff and the sand varies from loose to dense. The profile on the left side of the river shows, in general, soft to medium silt-clay mixtures alternating with very loose to medium dense silt to a depth of 15 meters. From 15 to 19.5 meters, the material consists of medium dense silty fine sand and coarse to fine sand. The river boring showed layers of silty fine sand, clayey sand and coarse to fine sand alternating with layers of silty clay and clay. From ground surface to a depth of 28 meters, the sands, in general, are loose to medium dense. Layers of very loose sand are found at the surface and at depth of about 28 meters. The clays range from medium to stiff in the same depth range. From 28 to 40.5 meters, the sands and a silt encountered are medium dense to dense and the clay is very stiff.

Soil conditions at the site are variable. In general, soft to medium clays and very loose to loose sands can be found to depths of 28 meters. Thus, piles will be required to carry the structural loads to the firmer and/or denser materials below this depth. Since the project is located in a seismically active area, the possibility of liquefaction of the loose sand layers must be considered. The soft clay deposits pose the problem of settlement, and, since the profile is erratic, the problem of differential settlement is significant. For this condition, concrete-filled steel pipe piles would be required with tips driven below the level of loose sand. A concrete apron would be required upstream and downstream of the control structure to avoid piping of the foundation sand in the river. Sheet piling would also be required to prevent erosion of foundation material. These would be installed to a depth of 10 meters around the periphery of each structural foundation element.

This is a very difficult construction site! It is anticipated that there are much more favorable sites downstream, and it has been proposed that additional exploratory borings be done to evaluate these alternate sites.

d) Baao Levees

The levees would be founded on clay and silty-clay alluvial deposits which range from soft to medium. These foundation materials will have to be preconsolidated to support the embankment or the embankment would require (1) extremely flat slopes or (2) large stabilizing berms. Preconsolidation can be conveniently done by stage construction as discussed in the implementation schedule. The plan, profile, and typical section of the levee is shown on Figs. III-9 and 10.

The Control Structure would be founded on very soft to medium silty-clays similar to the previously described conditions for the Lake Bato Outlet Structure. Similarly, a foundation of concrete piles and sheet piles would also be required. It is expected that the foundation conditions would be similar throughout the area. However, alternate sites will be reviewed when the proposed additional borings are taken along the levee alignment.

Construction Materials

The proposed sources of impervious fill, sand and gravel, and rock for aggregate and slope protection have been located through the use of aerial photographs and field reconnaissance. A subsurface exploration program to verify the availability of adequate quantities of suitable materials will be required and has been proposed. Impervious borrow consisting of silty clay and clay is to be obtained from the Tandaay-Malaway area. The average haul distance is estimated to be about 8 km. Sand and gravel borrow is available from the Waras River which is an approved source of highway aggregate. Stone for slope protection and concrete aggregate is available by quarrying near the crest of the Ragay Hills on the Tandaay-Balatan Road. The material is expected to be crystalline limestone and possibly some sandstone. The estimated average haul distance is 7 kilometers.

D. COST ESTIMATES

1. General

The following cost estimates were based primarily on unit price developed for the "Comprehensive Water Resources Development Study for the Bicol River Basin." These were escalated at a rate of 8 percent per year compounded, or 17% for the two year periods between 1976 and 1978.

The one major exception to this is the tunnel alternate for the Lake Bato-Pantao Bay Diversion Channel. This was based on current tunnel prices in the United States modified to reflect local Philippine conditions.

The availability of soils boring data as well as field topography affected the estimated cost of the Lake Bato-Pantao Bay Diversion Channel substantially. The excavation quantity increased from 17,000,000 cubic meters to 29,100,000 cubic meters, and the estimated quantity of material requiring drilling and blasting increased from 3,000,000 cubic meters to an estimated 12,470,000 cubic meters.

2. Lake Bato-Pantao Bay Diversion Channel

Two alternates have been considered for the diversion channel, an open channel from Lake Bato to Pantao Bay and an open channel-tunnel combination. The plan, profile, typical open channel sections, and typical tunnel section are shown in Figures III-3 to III-4 respectively. The cost for each alternate is listed below:

Open Channel Throughout

This will consist of an unlined open channel with a bottom width of 22 meters and varying side slopes. The length of the channel will be approximately 9700 meters.

a)	Channel Excavation 29,100,000 m^3 @ ₱6.0	=	₱ 174,600,000
b)	Control Structure	=	3,565,000
c)	Bridge Superstructure 88 m^3 @ ₱2,400	=	211,000
	Construction Sub-Total	=	₱ 178,376,000
	10% Contingencies	=	17,838,000
	Total	=	₱ 196,214,000
	Say	=	₱ 200,000,000

As was done for the CWRS study, this estimate assumes a 5-year construction schedule using two 10-hour shifts per day. The excavation output required would be approximately 1100 cubic meters per hour. Excavated material would be disposed of by creating spoil areas alongside the channel alignment. Haul distances should not exceed an average of 500 meters.

Open Channel-Tunnel Combination

This will consist of 5900 meters of open channel with a bottom width of 22 meters and a 3400-meter long tunnel approximately 9 meters in diameter.

a)	Channel Excavation 5,800,000 m^3 @ ₱6.0	=	₱ 34,800,000
b)	9-meter diameter tunnel 3400 m @ ₱120,000	=	408,000,000
c)	Control Structure	=	3,565,000
d)	Bridge Superstructure	=	211,000
	Construction Total	=	₱ 446,576,000
	10% Contingencies	=	44,658,000
	Total	=	₱ 491,234,000
	Say	=	₱ 500,000,000

The estimate assumes the following:

1. The unit cost for channel excavation will be comparable to that of the alternate using open channel throughout, which is ₱6.0 per Cubic meter.

2. The cost for the tunnel is based on 80% of estimated U.S. prices to reflect local Philippine conditions.

Details of Estimate for Open Channel Throughout

1.	Mobilization & Demobilization	=	₱ 12,066,000
2.	Equipment including spare parts, tires, fuel	=	51,752,000
3.	Labor	=	15,575,000
4.	Drilling and Blasting 12,470,000 m^3 @ ₱4.40	=	54,868,000
	Sub-Total	=	₱ 134,261,000
	25% overhead & profit	=	33,565,000
	Construction Total	=	₱ 167,826,000
	10% Contingencies	=	16,783,000
	Total		₱ 184,609,000

Unit construction cost for channel excavation including labor, equipment, 25% overhead and profit is ₱167,826,000/29,100,000 cubic meters or approximately ₱6.0/m^3. See Tables III-2, III-3 and III-4 for breakdown of the above.

TABLE III-2

COST ESTIMATE
MOBILIZATION & DEMOBILIZATION

	Item	Unit Cost ₱	Quantity	Total Cost ₱
1.	Temporary Pier 27 m x 15 m	1,400/m^2	405 m^2	567,000
2.	Staging Area	47/m^2	50,000 m^2	2,350,000
3.	Fuel Storage	88/BBL	10,000 BBL	880,000
4.	Office & General Warehouse	878/m^2	500 m^2	440,000
5.	Parts Warehouse & Shops	585/m^2	500 m^2	293,000
6.	Temporary Road	468,000/Km	5 Km	2,340,000
7.	Water Supply & Distribution	L.S.		235,000
8.	Sanitary System	L.S.		235,000
9.	Temporary Power & Distribution	1,750/KVA	300 KVA	525,000
10.	Camp Facilities	47/m^2	500 m^2	25,000
11.	Fencing	18/m	10,000 m	180,000
12.	Housing & Medical Facilities	1,170/m^2	200 m^2	235,000
13.	Fixtures & Supplies	L.S.		470,000
			Sub-Total ----	₱ 8,775,000
14.	Misc. Small Tools, Supplies, Office Equipment	10%		878,000
			Sub-Total ----	₱ 9,653,000
15.	Demobilization	25%		2,413,000
			TOTAL ----	₱ 12,066,000 *

(*) CWRS 1976 figures escalated to 1978 by 17%.

TABLE III-3

COST ESTIMATE
CONTRACTOR'S ORGANIZATION AND LABOR

Item	Quantity	Unit Cost ₱	Total Cost ₱
Labor			
Project Manager	1	₱ 875/day	
Chief Engineer	1	875/day	
Surveyors (2 parties)	6	120/day	
Construction Engineer	2	47/day	
Reports and Drafting	2	35/day	
	12 men	₱ 1,952/day	
Construction Supt.	1		
Earthwork	2		
Roads	2		
Master Mechs.	2		
Fuel Dept.	2		
Harbor Chief	2		
	11 men	₱ 350/day	
Purchasing Agent	1		
Comptroller	1		
Accounts	4		
Payroll	2		
Timekeepers	2		
Camp. Mgr.	1		
Clerks, janitors & drivers	25		
	36 men	₱ 585/day	
Field Crews			
Operators	60		
Mechanics	38		
Helpers	38		
Service Mechanics	14		
	150 men	₱ 3,510/day	
Common Labor	150 men	2,632/day	
		₱ 9,029/day	
Total Labor: 1,500 days @₱9,029/day			₱ 13,543,500
Insurance, Taxes, Severance, Vacations, 15%			2,031,500
		TOTAL ----	₱ 15,575,000

*CWRS rates escalated 17% to reflect 1978 costs.

TABLE III-4

COST ESTIMATE
EQUIPMENT

	Item	(*) Unit Cost ₱	Quantity	Total Cost* ₱
1.	Crane, 50T for Pier	3,075,000	1 each	3,075,000
2.	Crawler Tractor	1,320,000	9 ea.	11,880,000
3.	Power Shovels, 3.2 yd.	1,755,000	3 ea.	5,265,000
4.	Front end Loader, Track 4 yd.	1,170,000	3 ea.	3,510,000
5.	Elevating Loader	470,000	2 ea.	1,410,000
6.	Skidder, 518	470,000	2 ea.	1,410,000
7.	Motor Grader, 12 G	585,000	3 ea.	1,755,000
8.	Dump Trucks, 5 yd.	235,000	9 ea.	2,110,000
9.	Scrapers 621	1,170,000	9 ea.	10,530,000
10.	Conveyor Line, 500 meters	1,055,000	-	1,055,000
11.	Dragline 8 yd.	2,340,000	1 ea.	2,340,000
12.	Fuel Truck, 3000 Gal.	295,000	3 ea.	885,000
13.	Service Truck	235,000	2 ea.	470,000
14.	Pickup	60,000	6 ea.	360,000
15.	Jeeps	60,000	6 ea.	360,000
16.	Compresser with drills	117,000	9 ea.	1,055,000
17.	Manhauls	235,000	15 ea.	3,525,000
			Sub-Total ---	₱ 50,995,000
18.	Spare parts, Tires & P.O.L.	37.5%		13,695,000
			Sub-Total	₱ 64,690,000
19.	Salvage, 20%		Less	12,938,000
			Construction Total ---	₱ 51,752,000

(*) Equipment Costs per CWRS 1976
escalated by 17% to reflect 1978 costs.

3. Levee near Lake Baao along northeast bank at the Bicol River

The levee will generally follow the northeast bank of the Bicol River between Palsong and the proposed control structure. From there it will take a direct route to the Pawili River just north of Bula. The total levee length is approximately 8,000 meters. The plan is shown in Figure III-9 and the typical levee section and profile is shown in Figure III-10. Costs have been developed for two top of levee elevations 9 and 11 meters, and these are as listed below:

Top of Levee at Elevation 9 Meters M.S.L.

a)	Excavation 150,400 m^3 @ ₱5.8	=	₱	872,000
b)	Seeding 152,700 m^2 @ ₱3.2	=		489,000
c)	Impervious Fill 639,200 m^3 @ ₱11.7	=		7,479,000
d)	River Run Gravel 4,600 m^3 @ ₱23.3	=		107,000
	Construction Total	=	₱	8,840,000
	10% Contingencies	=		884,000
	Total	=	₱	9,724,000
	Say	=	₱	10,000,000

Based on a total length of 8,000 meters, the cost per linear meter is ₱10,000,000/8,000 meters or ₱1,250 per meter. The average levee height is 3.7 meters.

Top of Levee at 11 Meters M.S.L.

a)	Excavation 214,400 m^3 @ ₱5.8	=	₱	1,244,000
b)	Seeding 218,600 m^2 @ ₱3.2	=		700,000

c)	Impervious Fill 1,348,000 m^3 @ ₱11.7	=	₱	15,772,000
d)	River Run Gravel 4600 m^3 @ ₱23.3	=		107,000
	Construction Total	=	₱	17,823,000
	10% Contingencies	=		1,782,000
	Total	=	₱	19,823,000
	Say	=	₱	20,000,000

Based on the total length of 8,000 meters, the cost per linear meter is ₱20,000,000/8,000 meters or ₱2,500/meter. The average levee height is 5.7 meters.

Control Structure for Levee at Lake Baao

a)	Mobilization Lump Sum	=	₱	100,000
b)	Concrete Piles 880 m @ ₱93.6	=		82,000
c)	Sheet Piling 360 m^2 @ ₱527	=		190,000
d)	Mass Concrete 40 m^3 @ ₱386	=		15,000
e)	Structural Concrete 90 m^3 @ ₱772	=		70,000
f)	Reinforcing Steel 9,000 kg. @ ₱5.56	=		50,000
g)	Vertical Lift Gates 37,000 kg. @ ₱29.3	=		1,084,000
h)	Bridge Superstructure 50 m^2 @ ₱2400	=		120,000
	Construction Cost	=	₱	1,711,000
	10% Contingencies	=		171,000
	Total	=	₱	1,882,000

E. MOST COST-EFFECTIVE PLAN

Basically, the most cost-effective plan is that plan which would provide the greatest benefits at the least cost.

The potential benefits were not quantified for this Phase I Study. However, these benefits would include increased agricultural production, improved drainage, improved transportation, reduction in losses and damages due to flooding, and the intangible benefits to health and social welfare. The benefits per hectare would be comparatively greater around Lake Baao where these are extensive urban and irrigated developments as compared to Lake Bato where the areas are primarily undeveloped agriculture or fallow land. For this study, only the benefitted gross area and the project construction costs were the basis for comparing alternatives.

The Diversion Channel with Baao Levees would be the most cost-effective plan of those considered. The estimated construction cost of this plan is ₱210 million and it would eliminate flooding of 5,000 hectares (1,500 has. around Lake Bato and 3,500 has. at Lake Baao) at a cost per hectare of ₱42,[illegible]

The levee and control structure would also provide some benefits by the dry season regulation of Lake Baao. The Ombao control structure would provide benefits by reduction in downstream flood levels, in irrigation storage and regulation, and in a transportation crossing of the Bicol River. However, it is not an essential component of the plan, and its cost effectiveness is subject to review.

The Diversion Channel alone has an estimated construction cost of ₱200 million and it would eliminate flooding of 4,000 hectares at a cost per hectare of ₱50,000. A Diversion Tunnel would have the same benefits but at an estimated cost of ₱490 million. Neither plan is considered to be competitive.

The Baao Levee alone would cause significant increase in the Bicol River flood levels and would increase flooding along extensive reaches of the river. The high river levels would also restrict the interior drainage of the Baao area with inherent problems. The Baao Levee alone is considered an unacceptable alternative.

F. IMPLEMENTATION SCHEDULE

The Diversion will take approximately 5 years to construct and would have the first priority.

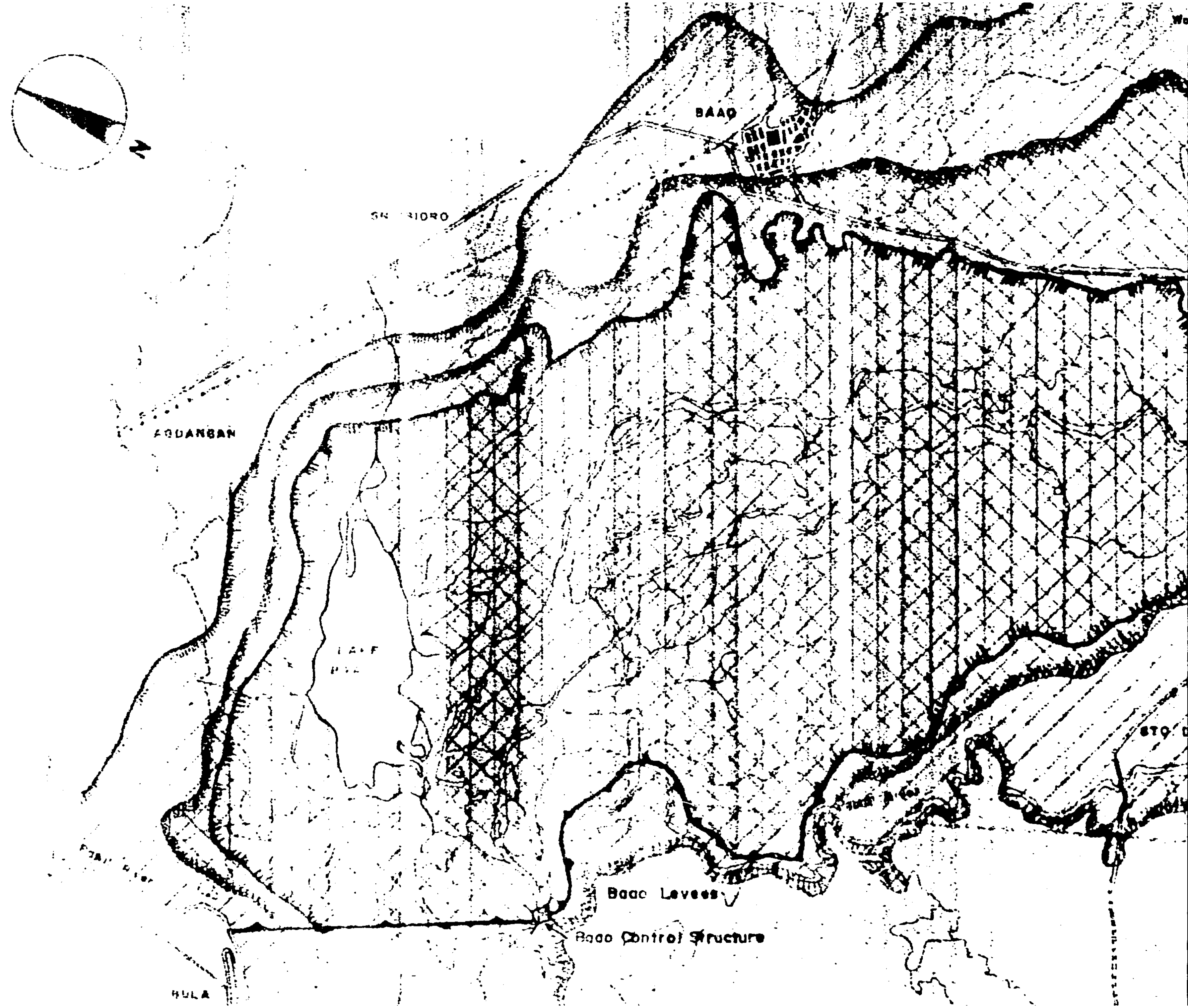
The Lake Bato Outlet Structure could operate independently of the Diversion but at a probable lower lake level to provide some flood storage. Some of the additional dry season water supply which would be available from Lake Bato Regulation could be utilized immediately. This structure should also have a high priority.

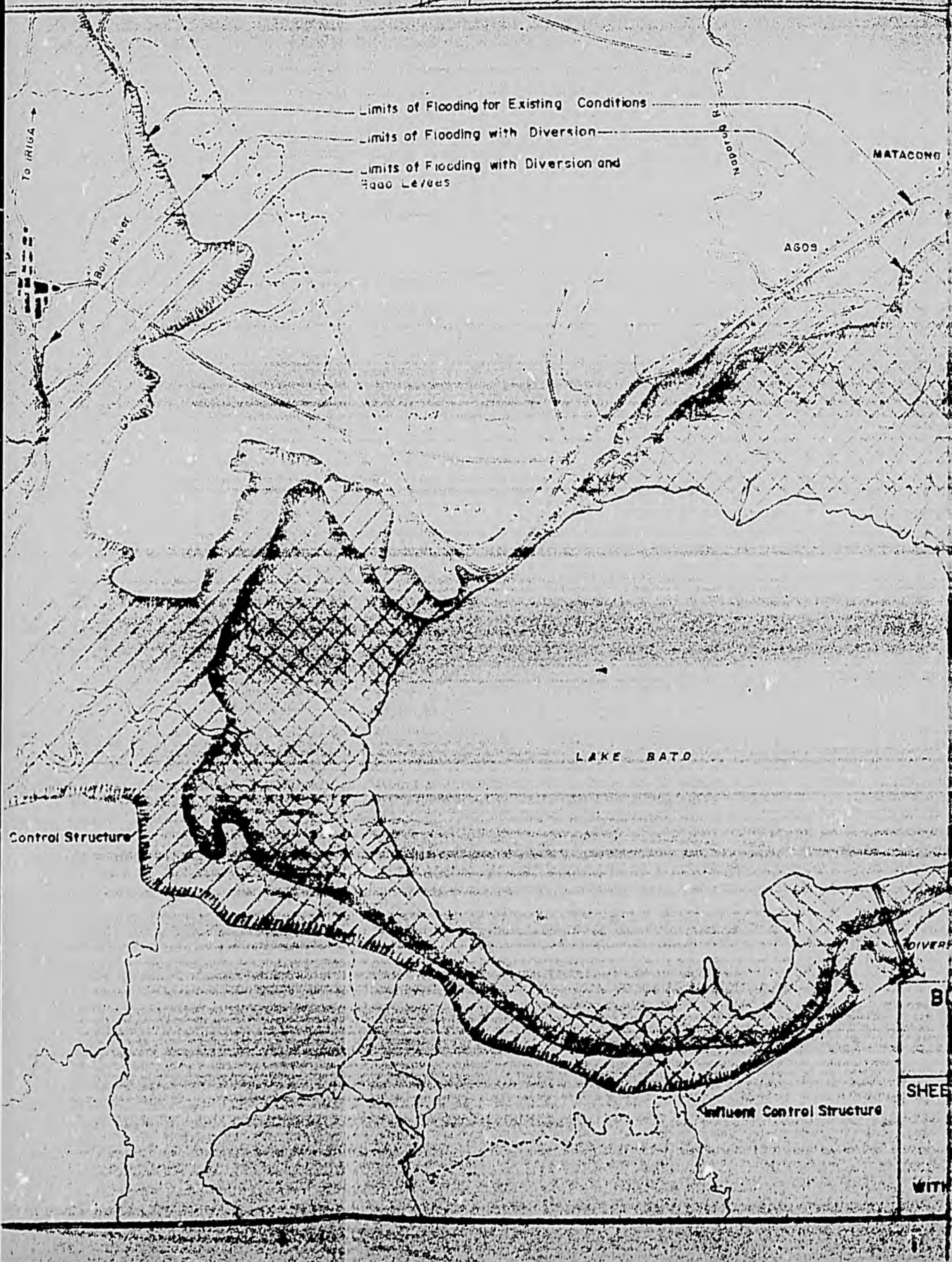
The specifics of the Lake Baao Regulation has not yet been defined. However, it is expected that those will include a low levee and a control structure to regulate the water level during the dry season. A preconsolidation of the levee alignment would be required and this could be achieved by the initial construction of a low levee. The control structure could also be initially constructed. However, the higher levees cannot be completed until the Diversion is operational.

The operation of the Ombao Control Structure, if it is deemed feasible, is dependent upon the Diversion and should be the last element constructed.

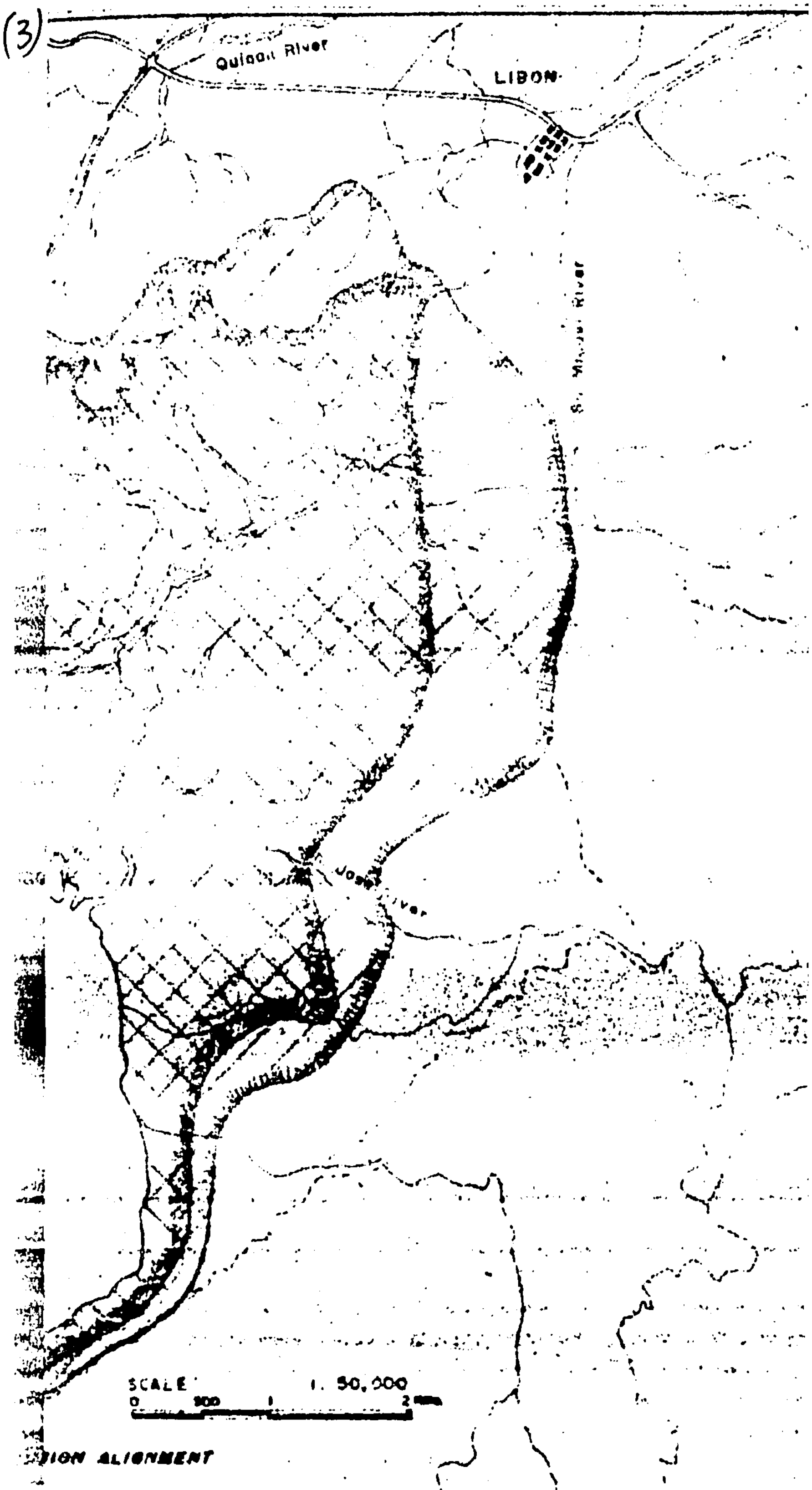
It has been assumed that any dredging will be done by a portable dredge, and that channel closures as scheduled above would not conflict with the dredging schedule.

III-1-(1)





Limits of Flooding for Existing Conditions
Limits of Flooding with Diversion
Limits of Flooding with Diversion and
To IRIGA
MATACONG
AGOS
LAKE BATO
Control Structure
Influent Control Structure
B
SHEE
WITH



COL RIVER BASIN DEVELOPMENT PROGRAM

RINCONADA INTEGRATED AREA DEVELOPMENT

FEASIBILITY STUDY

T TITLE:

LAKE BATO REGULATION AND DIVERSION

LAYOUT MAP

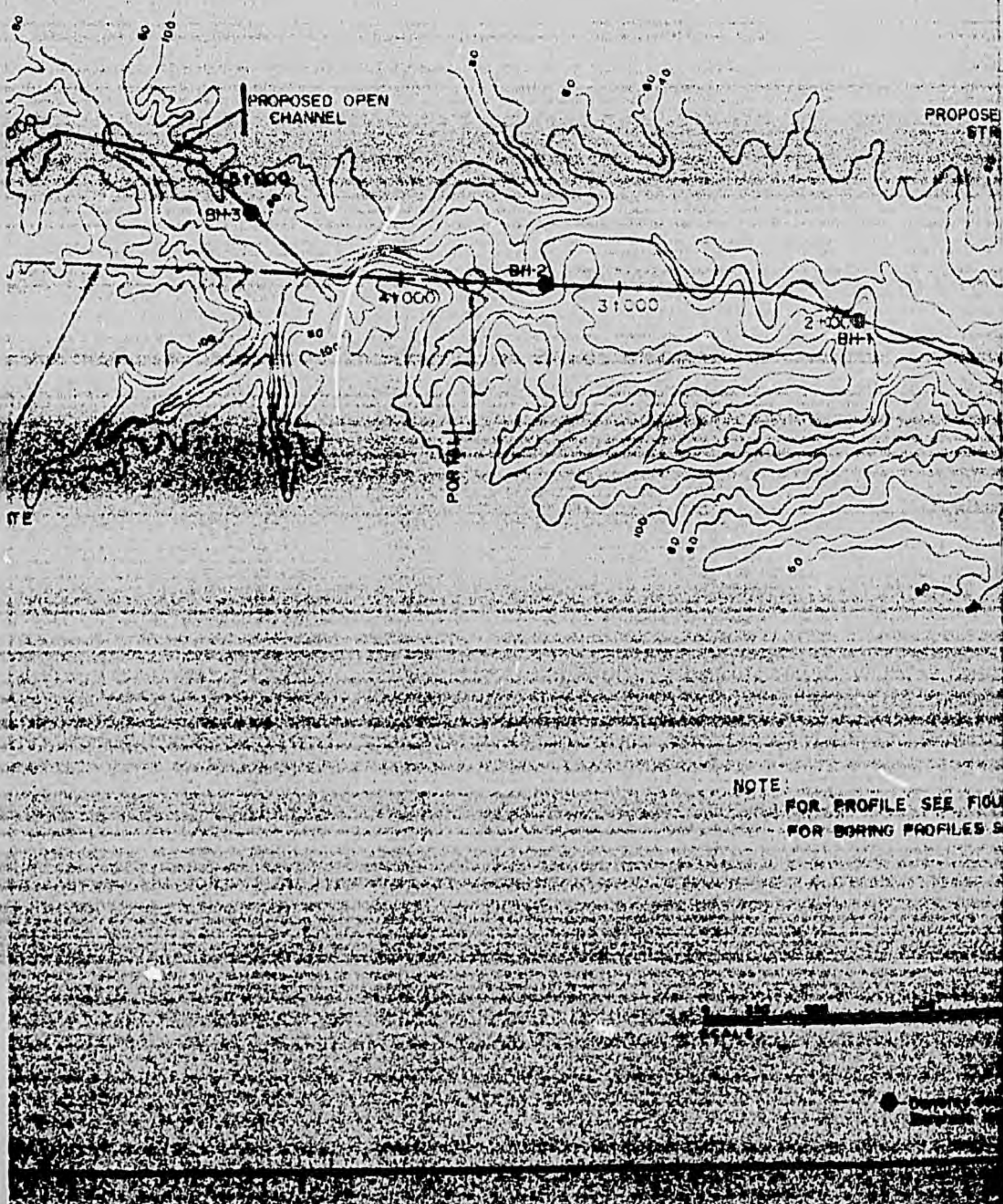
LIMITS OF FLOODING FOR CONSIDERED ALTERNATIVES

Figure III-1

III-3 (1)

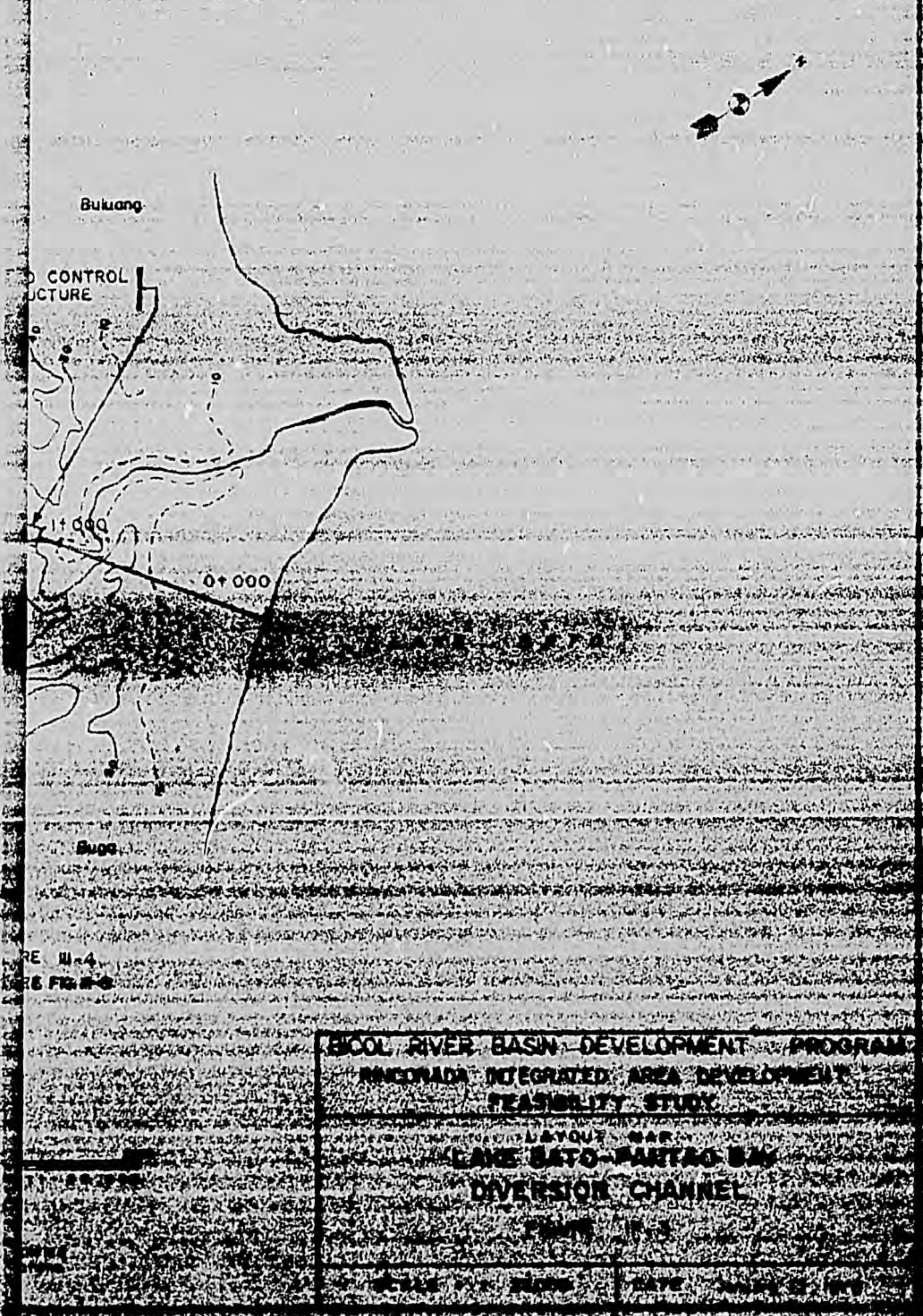
PANTAO BAY
9+700
9+000
BH-6
Macabugos Creek
8+000
BH-5
7+000
PORTAL
20
40
60
80
100

III - 3 - (2)

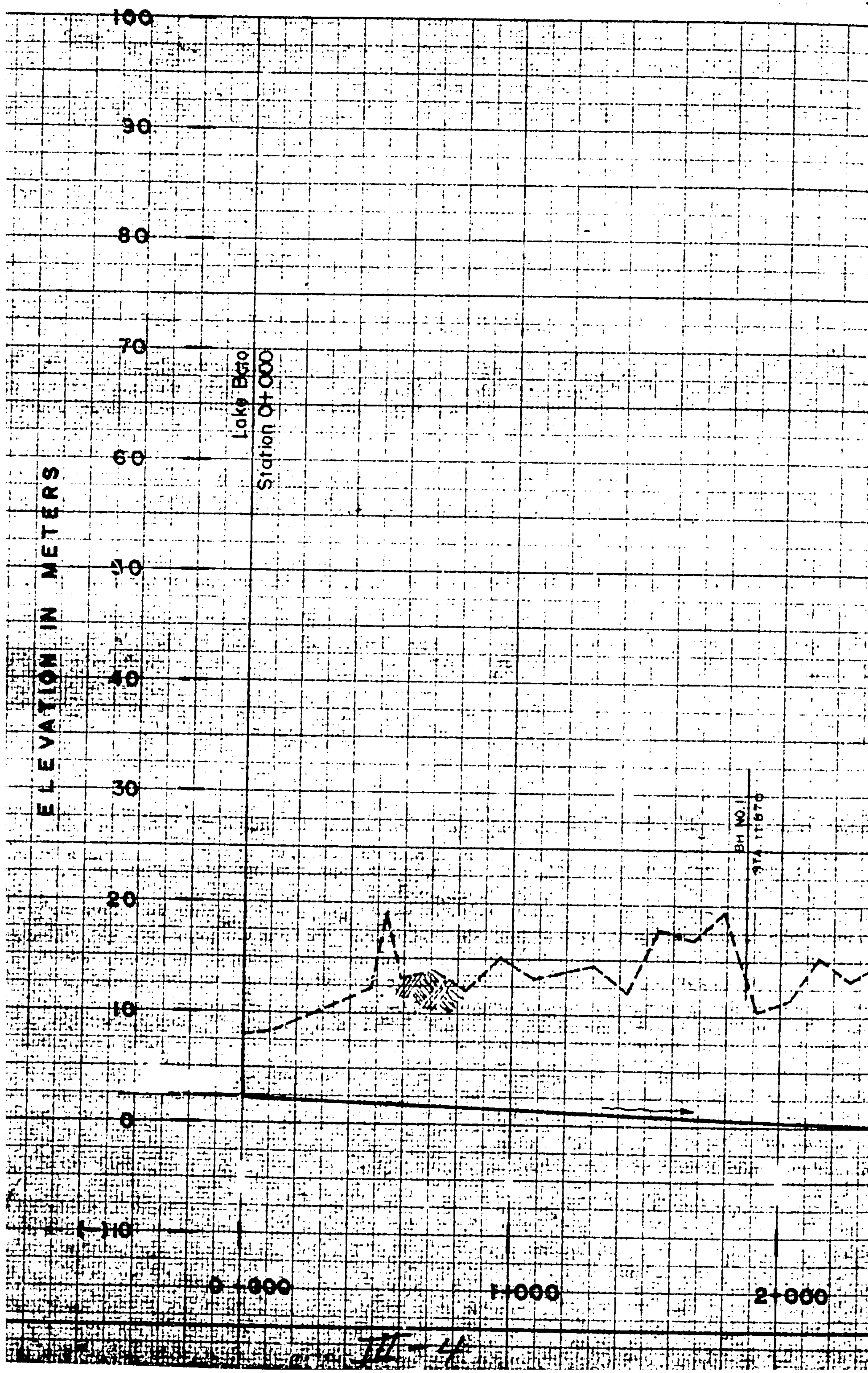


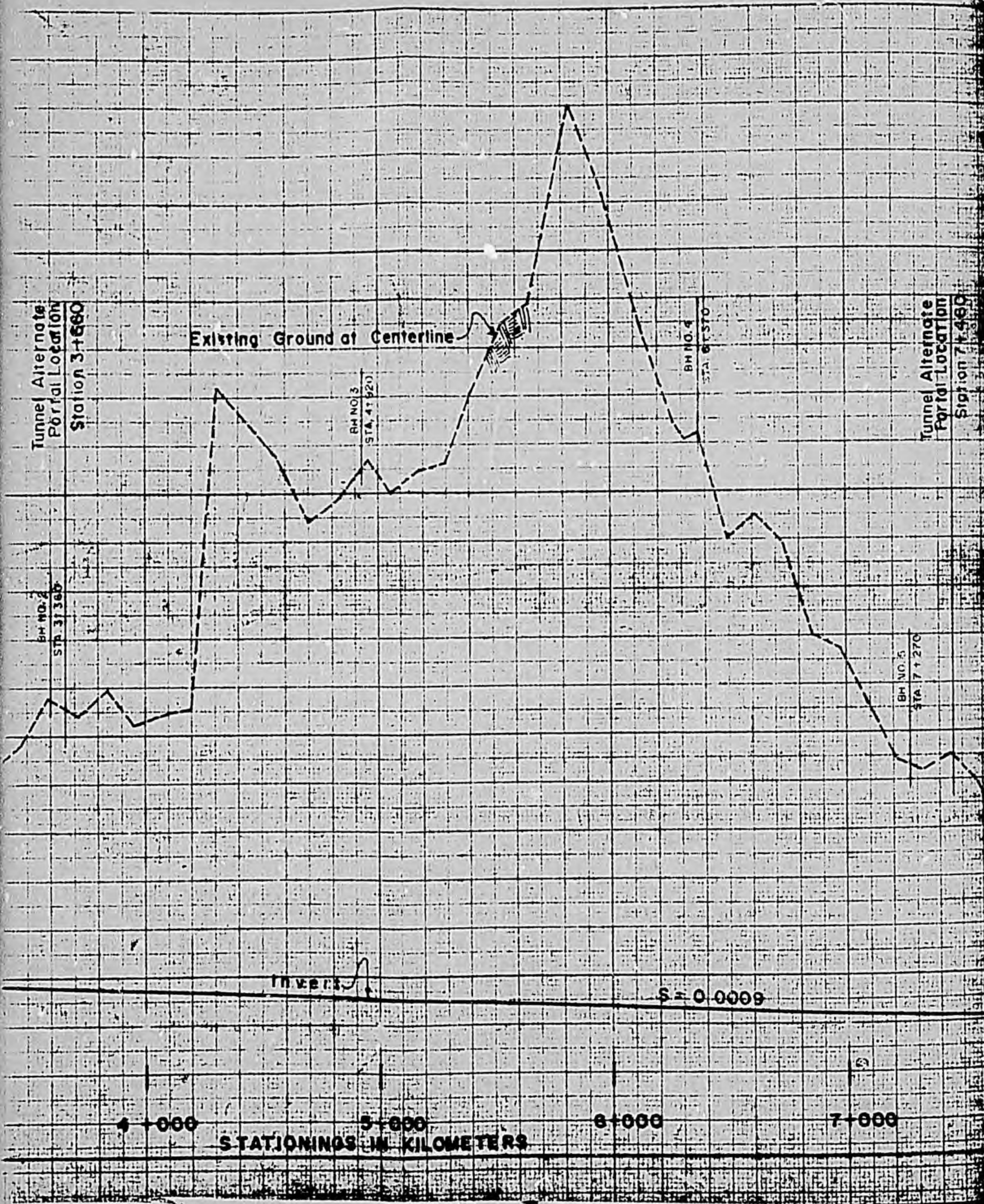
PROPOSED OPEN CHANNEL
PROPOSE
STR
BH-3
BH-2
BH-1
4+000
3+000
2+000
PORTAL
NOTE:
FOR PROFILE SEE FIGU
FOR BORING PROFILES S
SCALE

III-3-(3)



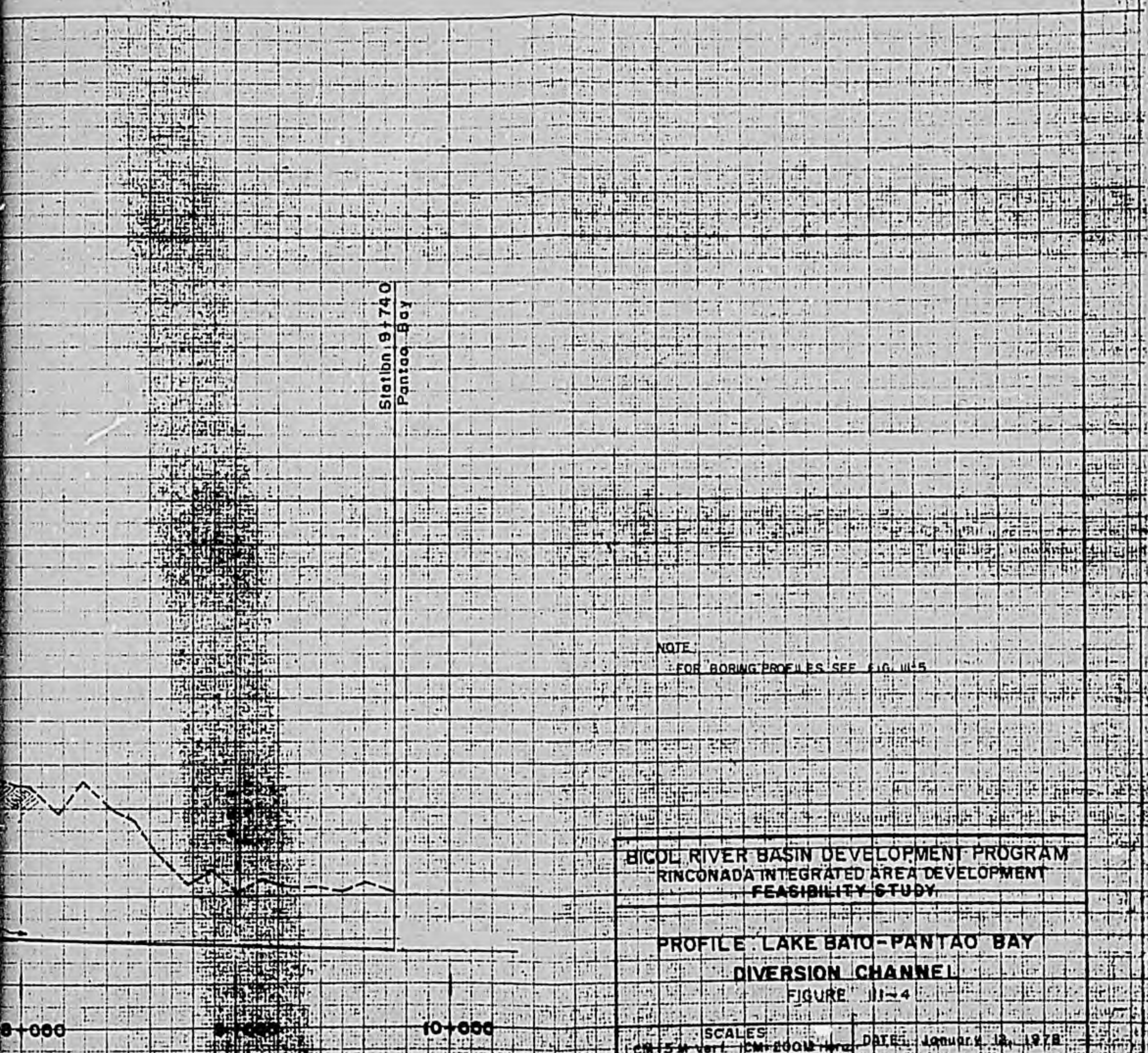
Buluang
CONTROL
UCTURE
1+000
0+000
Buga
BICOL RIVER BASIN DEVELOPMENT PROGRAM
RINCONADA INTEGRATED AREA DEVELOPMENT
FEASIBILITY STUDY
LAYOUT MAP
LAKE BATO-PANTAO BAY
DIVERSION CHANNEL


ELEVATION IN METERS
100
90
80
70
60
50
40
30
20
10
0
-10
Lake Bato
Station 0+000
BH No.1
0+000
1+000
2+000



Tunnel Alternate Portal Location Station 3+660
BH NO. 2 STA. 3+360
Existing Ground at Centerline
BH NO. 3 STA. 4+920
BH NO. 4 STA. 6+570
Tunnel Alternate Portal Location Station 7+460
BH NO. 5 STA. 7+270
Invert
S = 0.0009
4+000
5+000
6+000
7+000
STATIONINGS IN KILOMETERS

III-4 - (3)

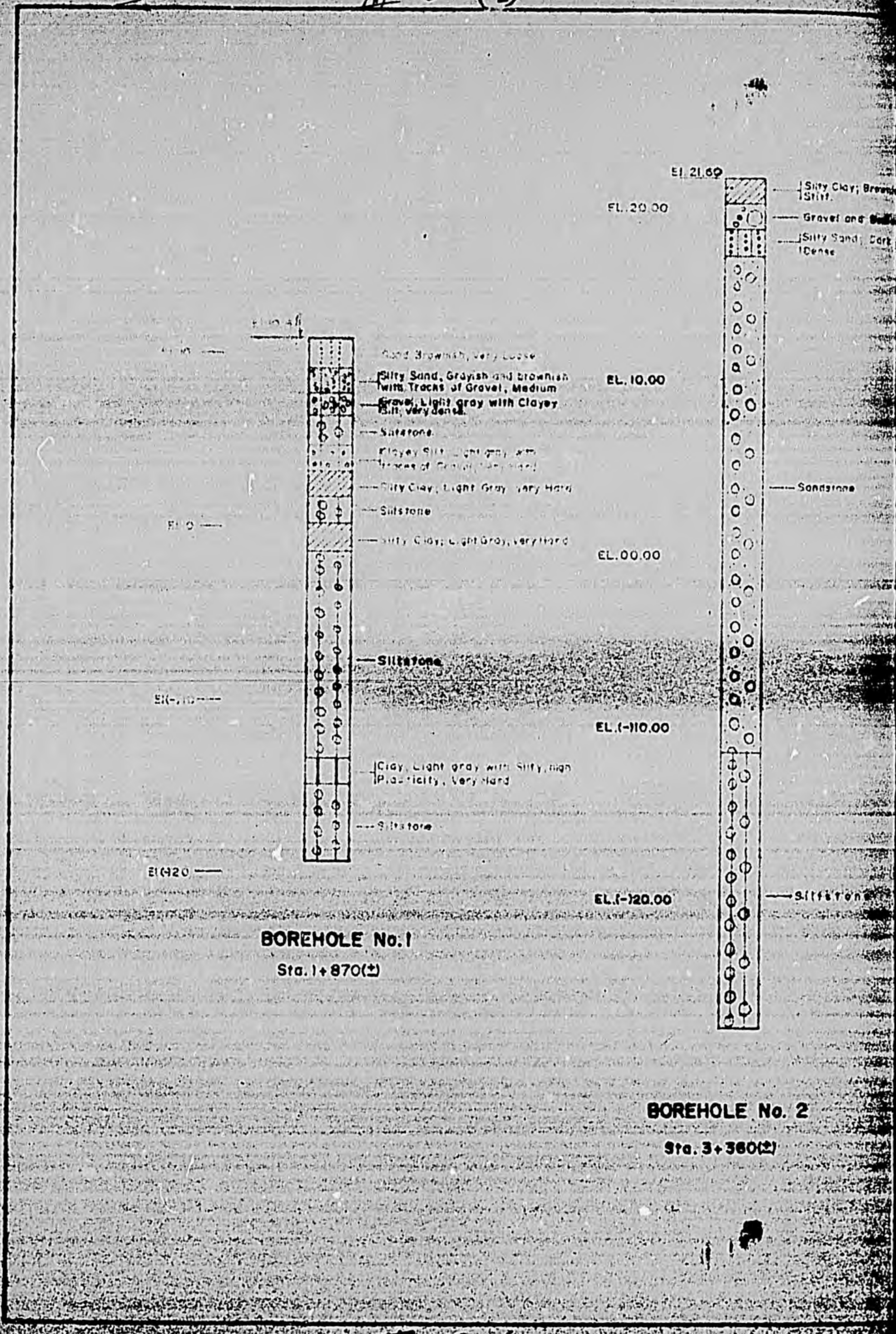


BICOL RIVER BASIN DEVELOPMENT PROGRAM
RINCONADA INTEGRATED AREA DEVELOPMENT
FEASIBILITY STUDY

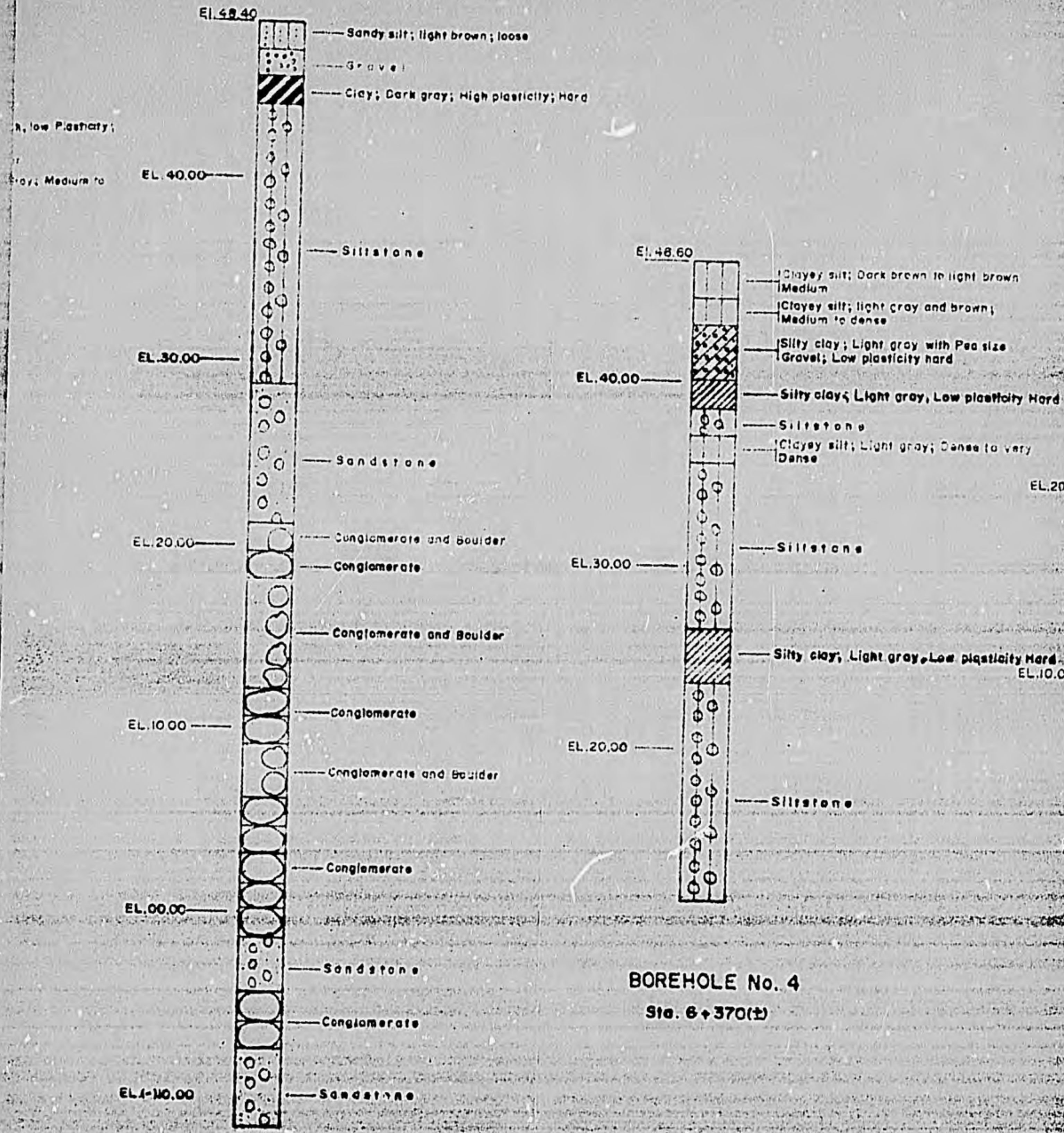
PROFILE : LAKE BATO - PANTAO BAY
DIVERSION CHANNEL
FIGURE III-4

SCALES: 1 CM = 5 M vert. 1 CM = 200 M horiz. DATE: January 12, 1978

III-4 - (3)



EL.21.69
Silty Clay; Brown, Stiff.
EL.20.00
Gravel and
Silty Sand; Dark, Dense
EL.10.00
Sand Brownish, Very Loose
Silty Sand, Grayish and brownish with Traces of Gravel, Medium
Gravel, Light gray with Clayey Silt, very dense.
Siltstone
Clayey Silt, Light gray, with Traces of Gravel, Very Hard
Silty Clay, Light Gray, Very Hard
Siltstone
Silty Clay; Light Gray, very Hard
Sandstone
EL.00.00
Siltstone
EL.(-)10.00
Clay, Light gray with Silty, high Plasticity, Very Hard
Siltstone
EL.(-)20.00
Siltstone
BOREHOLE No.1
Sta. 1+870(±)
BOREHOLE No. 2
Sta. 3+360(±)

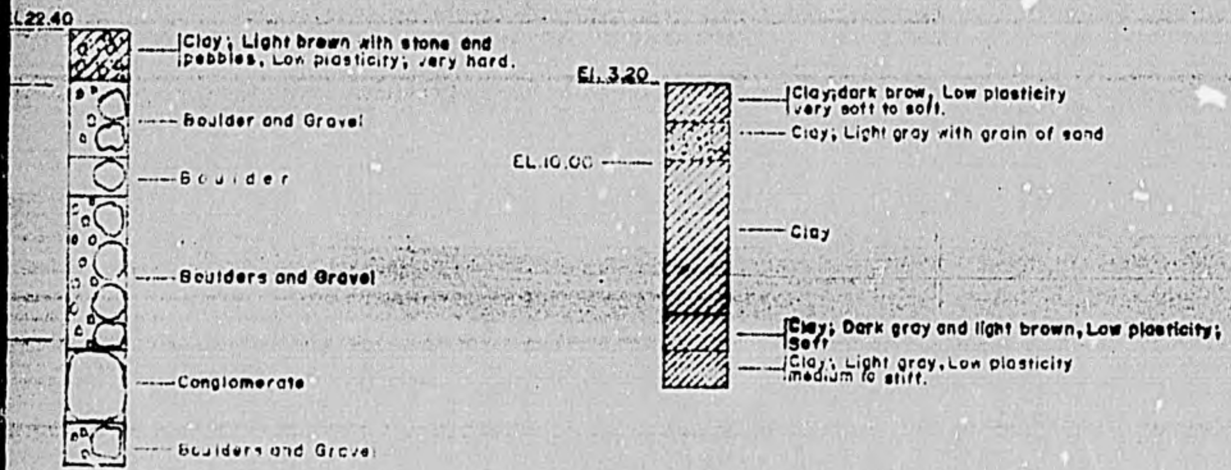


BOREHOLE No. 3

Sta. 4+920(±)

BOREHOLE No. 4

Sta. 6+370(±)



BOREHOLE No. 6
Sta. 9+020(±)

OREHOLE No. 5
Sta. 7+270(±)

NOTE: HORIZONTAL
EXAGGERATE

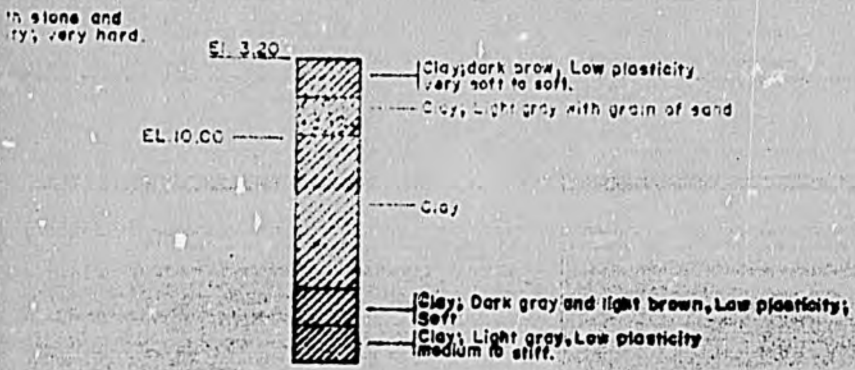
BICOL RIVER BASIN DEVELOPMENT
RINCONADA INTEGRATED AREA DEVEL
FEASIBILITY STUDY

LAKE BATO-PANTAO BAY DIVER
BORING PROFILES

Figure III - 5

SCALE: 1 Cm.= 3 M. Vertical	DATE: Januar

III-5 (4)



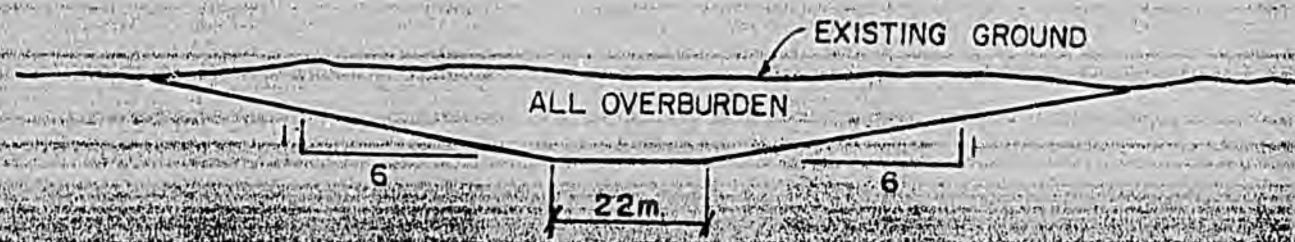
BOREHOLE No. 6

Sta. 9+020(±)

NOTE: HORIZONTAL SCALE EXAGGERATED

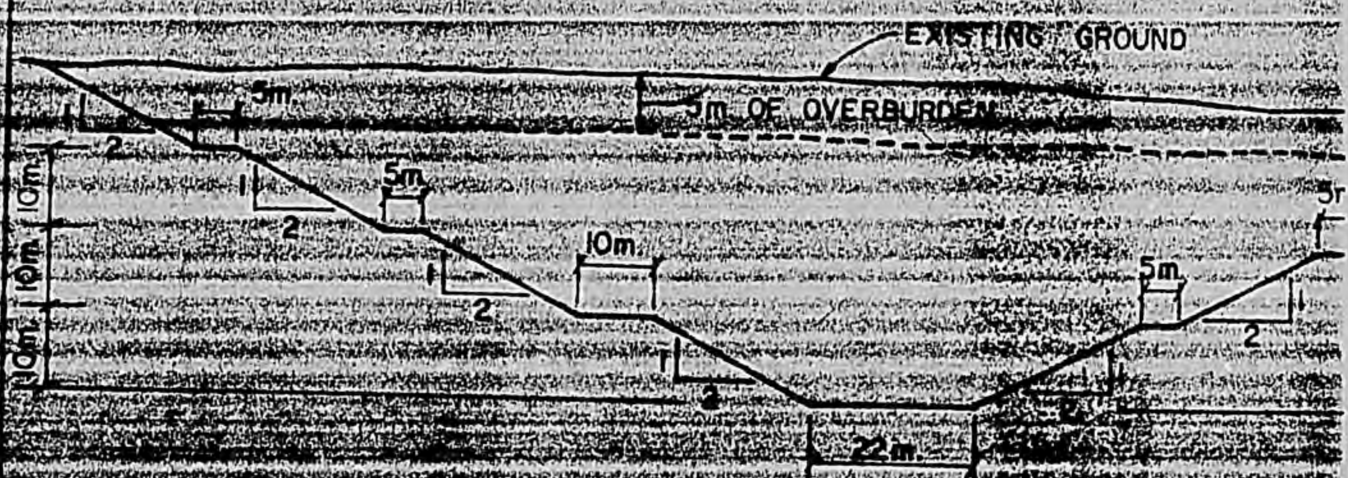
BICOL RIVER BASIN DEVELOPMENT PROGRAM RINCONADA INTEGRATED AREA DEVELOPMENT FEASIBILITY STUDY	
LAKE BATO-PANTAO BAY DIVERSION **BORING PROFILES** Figure III-5	
SCALE: 1 Cm.= 5 M. Vertical	DATE: January 12, 1978

III-6 (1)



STA. 0+000 TO 0+540
STA. 8+640 TO END

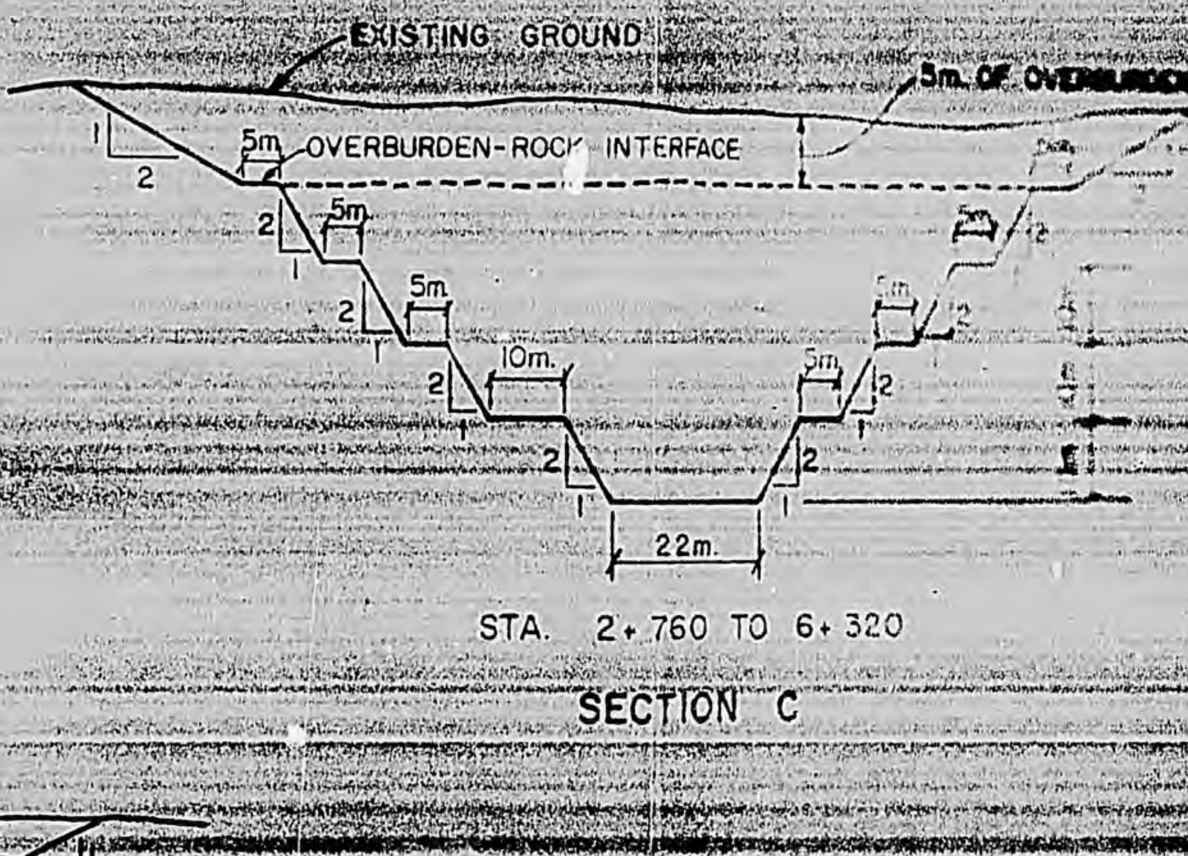
SECTION A



STA 0+600 TO [illegible]
STA. 6+320 TO [illegible]

SECTION B

III-6 (2)

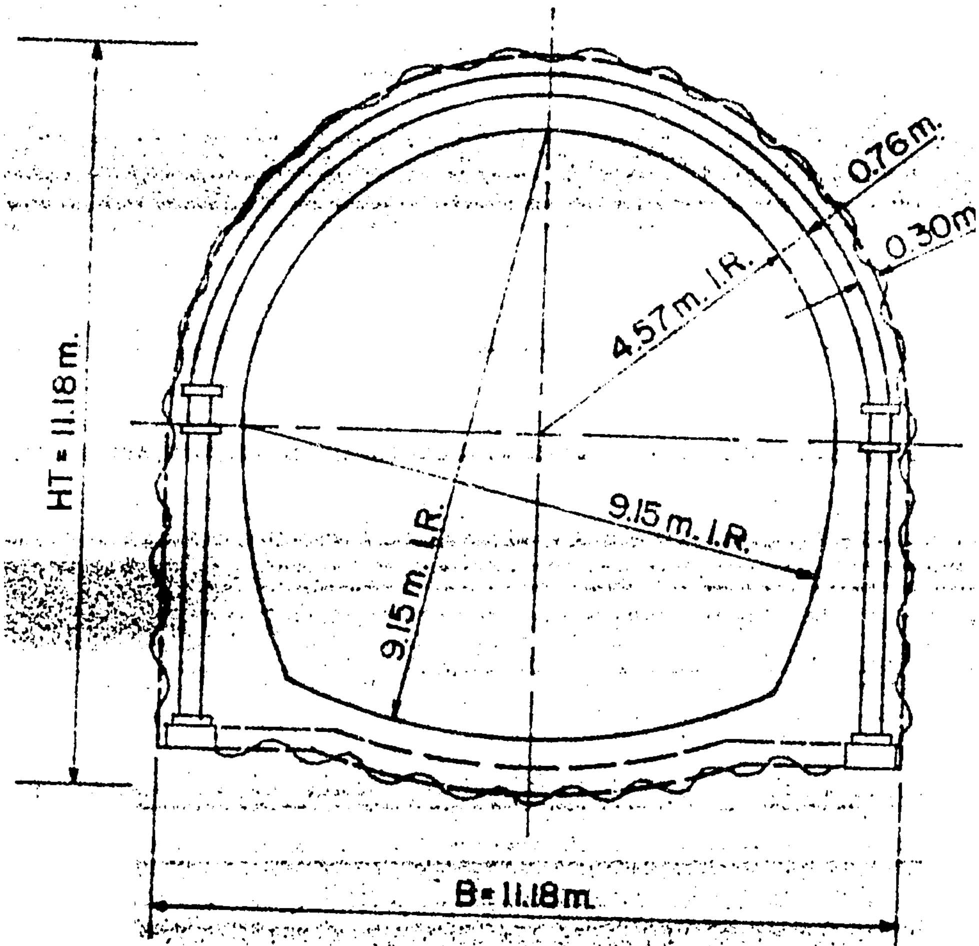


STA. 2+760 TO 6+320

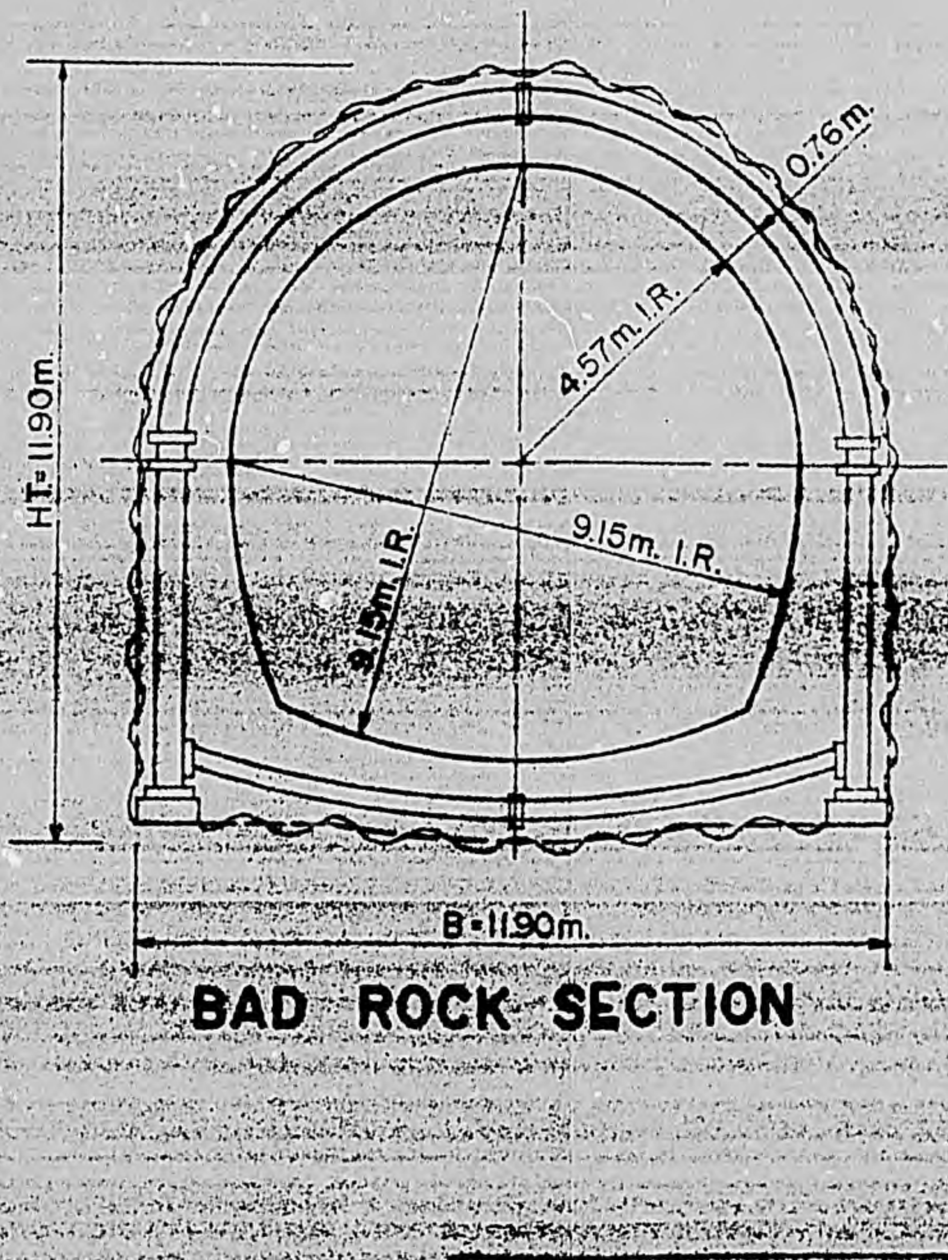
SECTION C

BICOL RIVER BASIN DEVELOPMENT PROGRAM
RINCONADA INTEGRATED AREA DEVELOPMENT
FEASIBILITY STUDY

TYPICAL OPEN CHANNEL SECTIONS
LAKE [illegible] PANTAO BAY DIVERSION CHANNEL
FIGURE III-6



MEDIUM ROCK SECTION



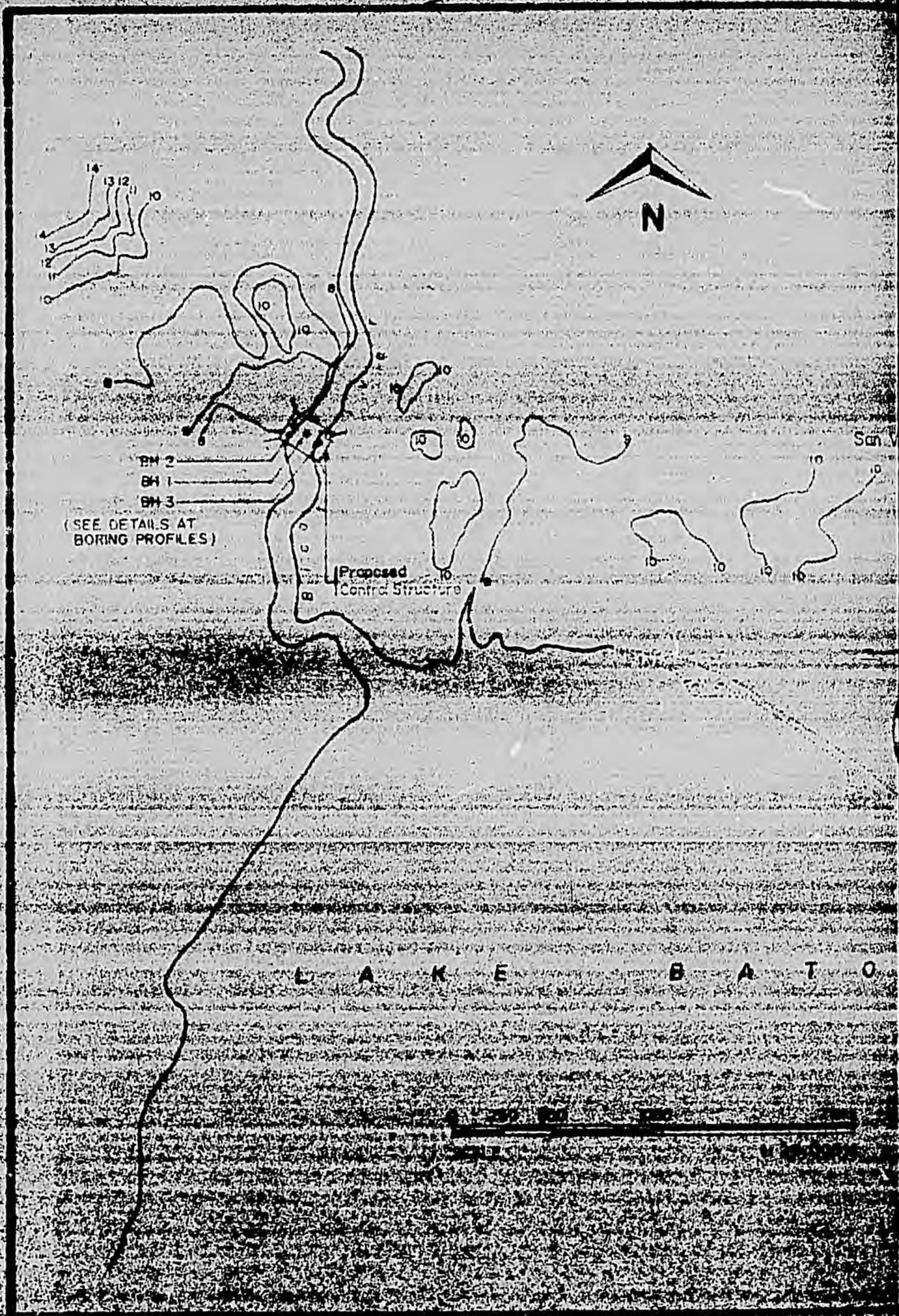
BAD ROCK SECTION

BICOL RIVER BASIN DEVELOPMENT PROGRAM
RINCONADA INTEGRATED AREA DEVELOPMENT
FEASIBILITY STUDY

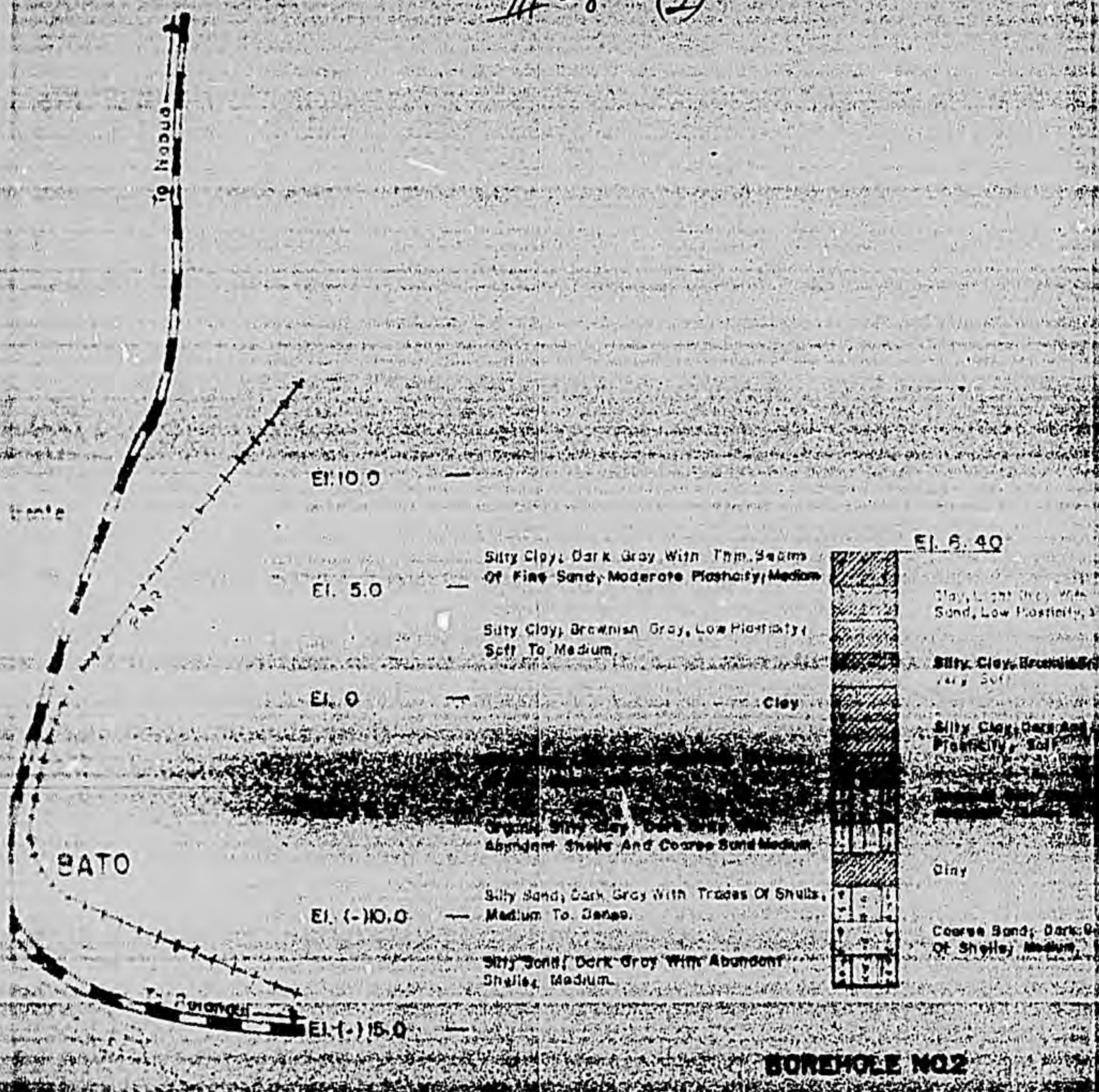
TYPICAL TUNNEL SECTION
LAKE BATO-PANTAO BAY DIVERSION

FIGURE III-7

SCALE [illegible] DATE [illegible]

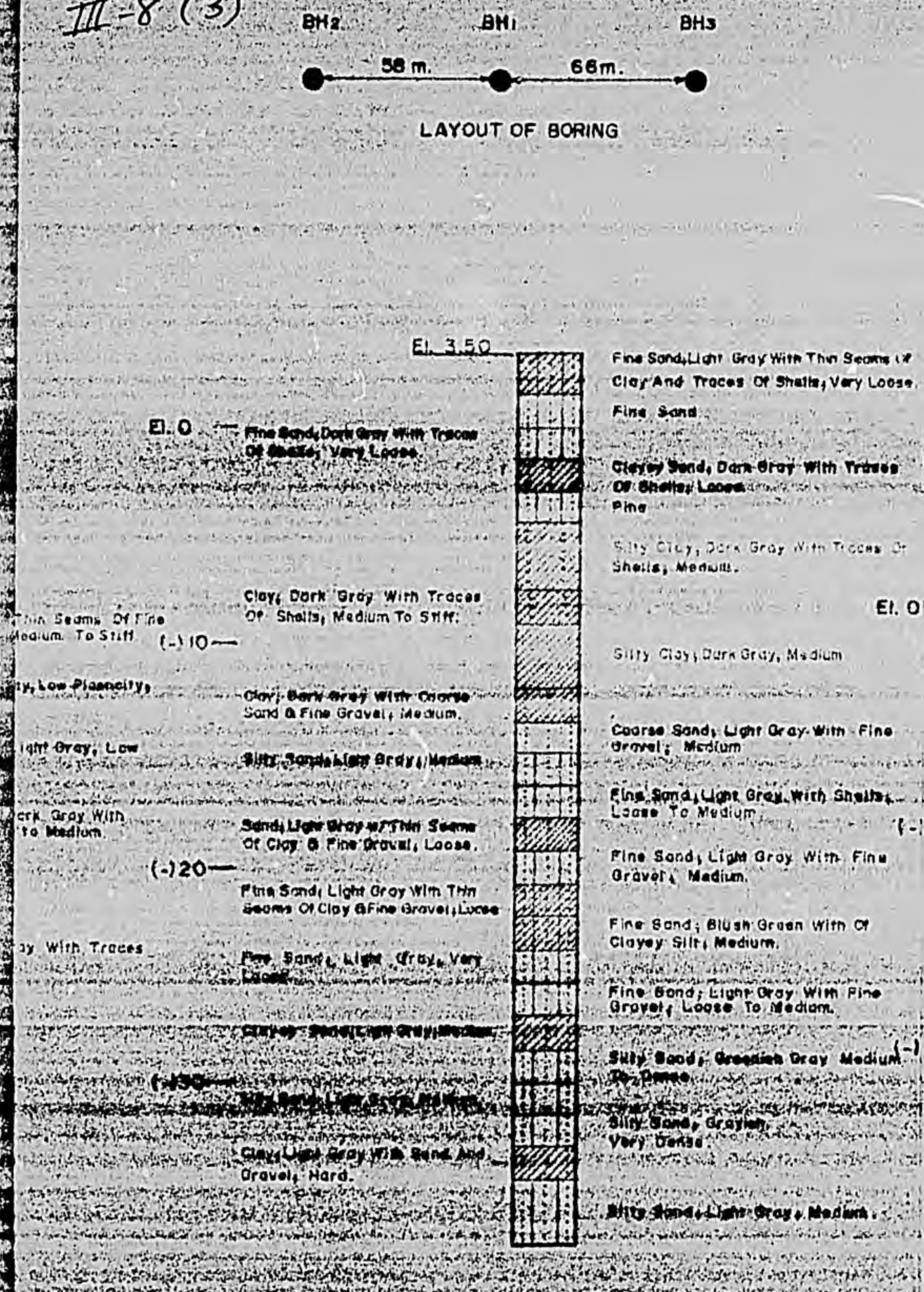

N
BH 2
BH 1
BH 3
(SEE DETAILS AT
BORING PROFILES)
Proposed
Control Structure
L A K E B A T O

III-8 (2)



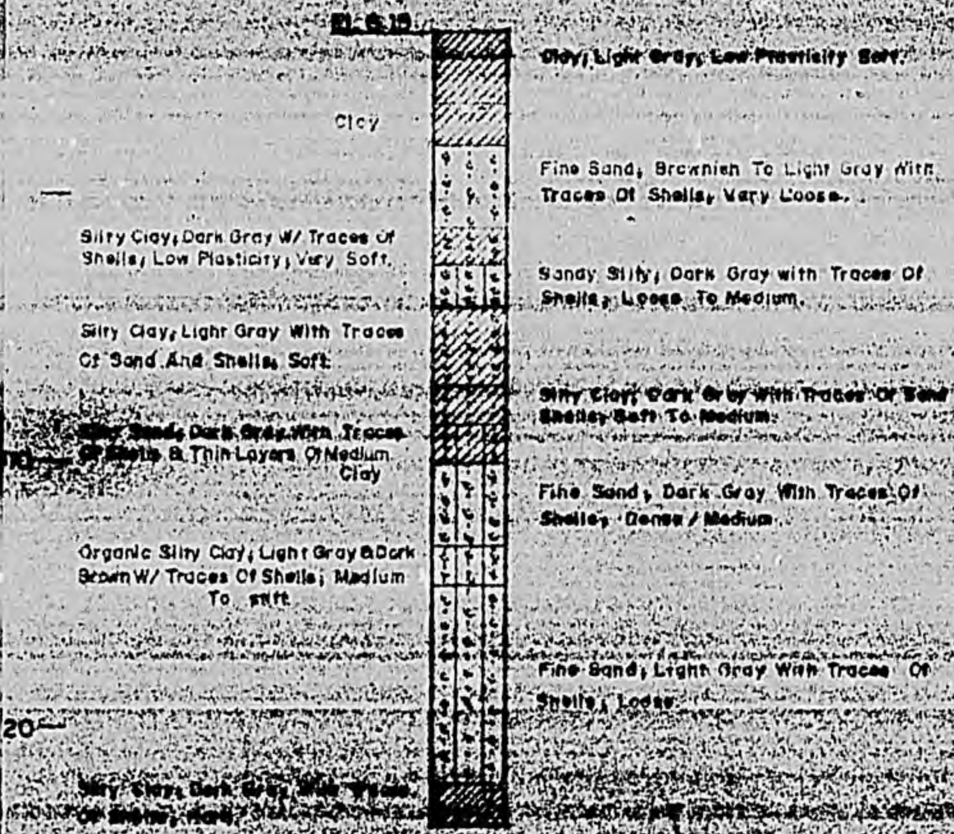
To Naga
BATO
El. 10.0
El. 5.0
El. 0
El. (-)10.0
El. (-)15.0
El. 6.40
Silty Clay; Dark Gray With Thin Seams Of Fine Sand, Moderate Plasticity, Medium
Silty Clay; Brownish Gray, Low Plasticity, Soft To Medium.
Clay
Abundant Shells And Coarse Sand Medium.
Silty Sand; Dark Gray With Traces Of Shells, Medium To Dense.
Silty Sand; Dark Gray With Abundant Shells, Medium.
Clay
BOREHOLE NO.2

III-8 (3)



BOREHOLE NO.1

III-8-(4)

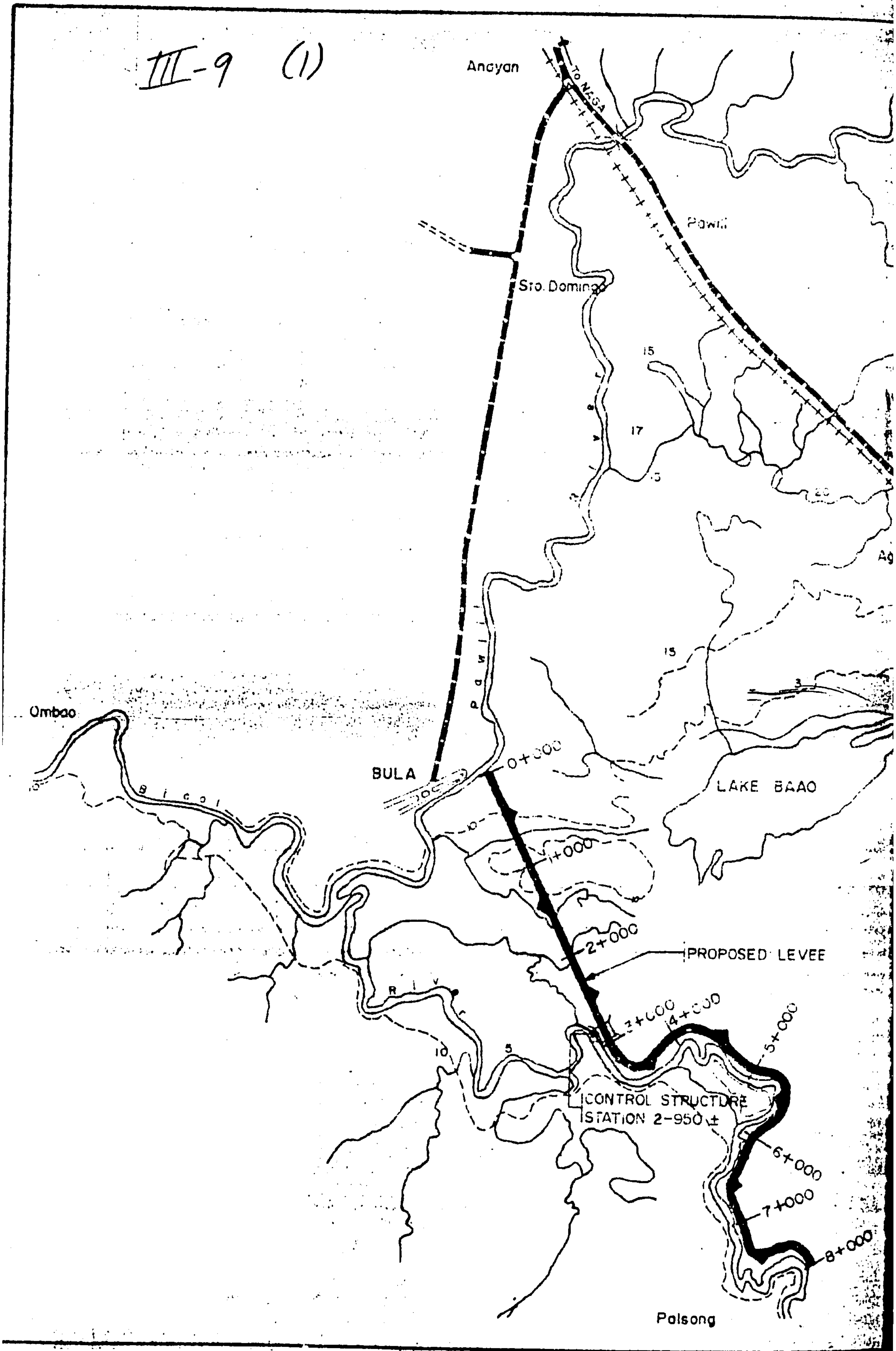


BOREHOLE NO.3

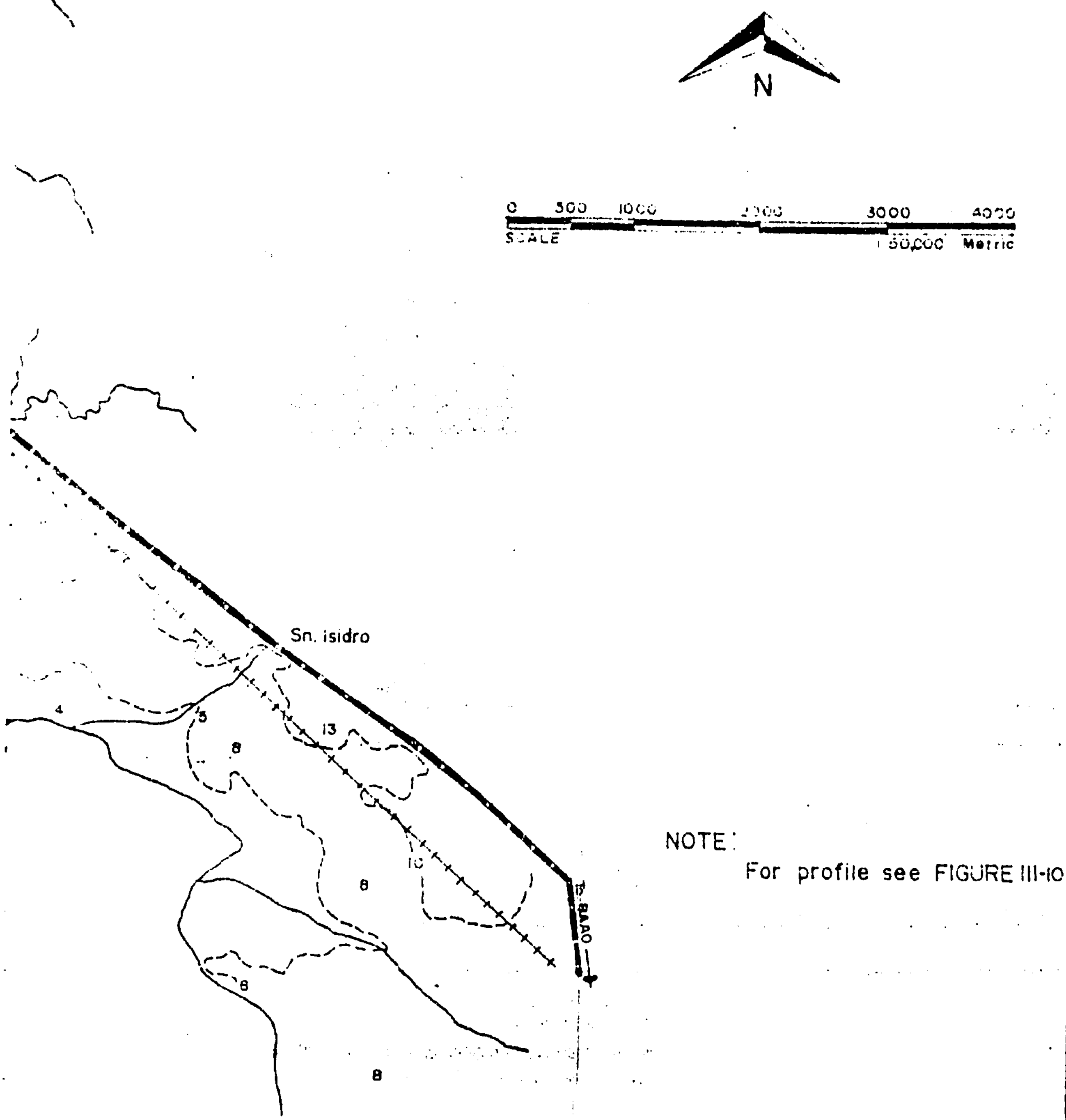
BICOL RIVER BASIN DEVELOPMENT PROGRAM **RINCONADA INTEGRATED AREA DEVELOPMENT** **FEASIBILITY STUDY**
LOCATION MAP AND BORING PROFILE **OF LAKE BATO CONTROL STRUCTURE** **FIGURE III-[illegible]**

SCALE FOR BORING PROFILE [illegible] VERTICAL	DATE: [illegible] 12, [illegible]

III-9 (1)


Anayan
To NAGA
Pawili
Sto. Domingo
15
17
15
LAKE BAAO
Ombao
Bicol
Pawili
BULA
0+000
1+000
2+000
PROPOSED LEVEE
3+000
4+000
5+000
6+000
7+000
8+000
River
10
5
CONTROL STRUCTURE
STATION 2-950 ±
Palsong

III-9 (2)



BICOL RIVER BASIN DEVELOPMENT PROGRAM

RINCONADA INTEGRATED AREA DEVELOPMENT

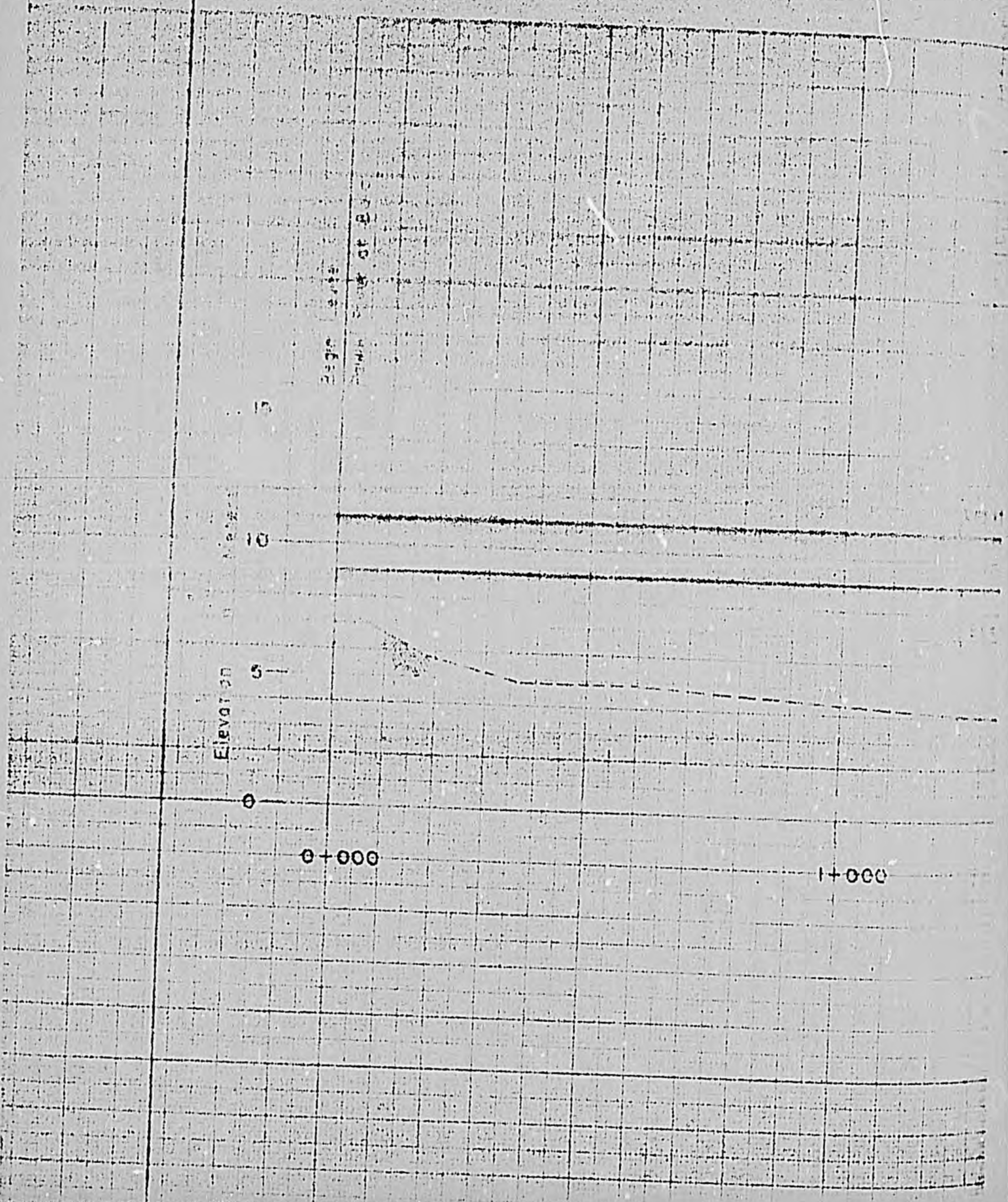
FEASIBILITY STUDY

PROPOSED LEVEE N.E. BANK OF BICOL RIVER BETWEEN BULA AND PALSONG

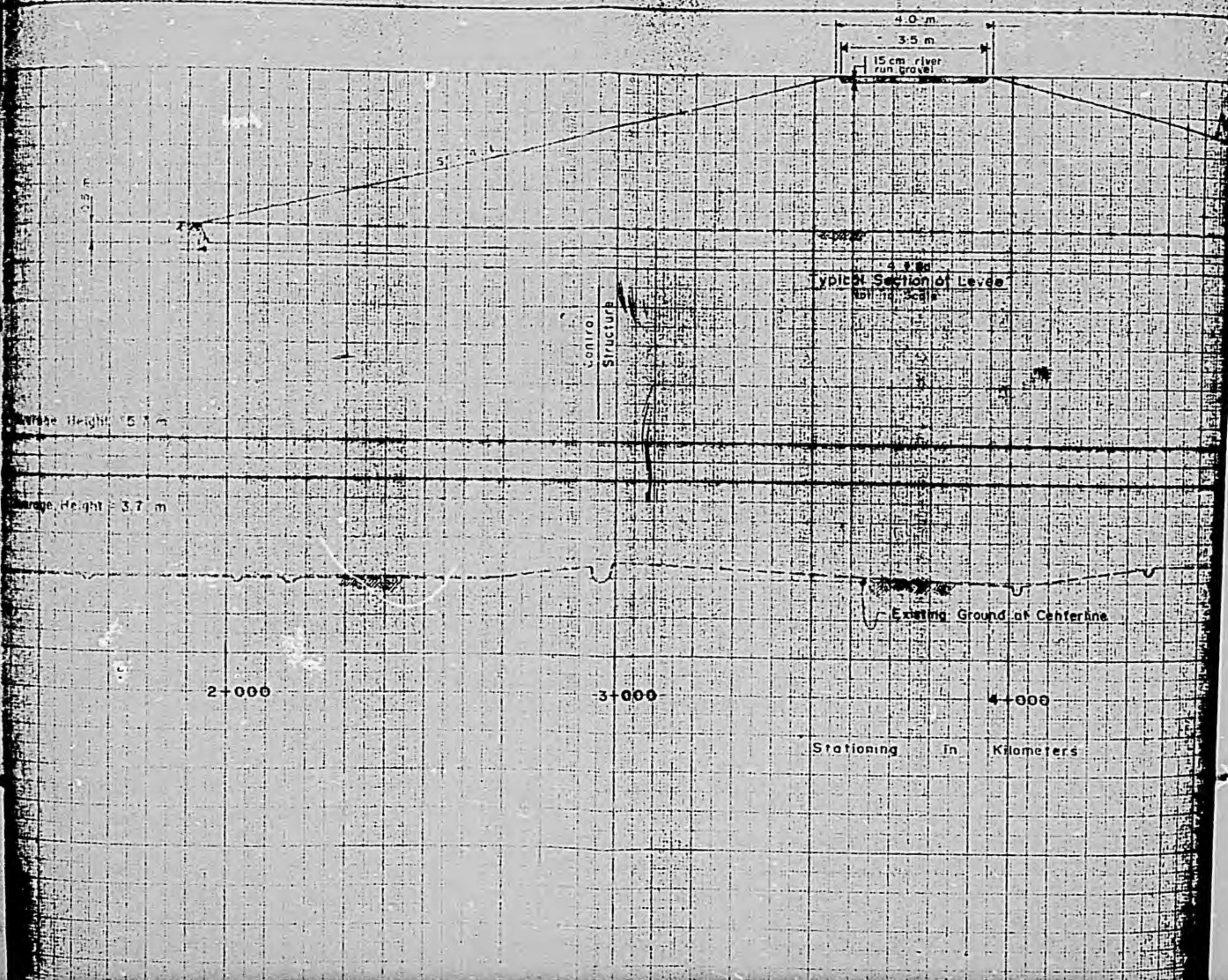
FIGURE III—9

SCALE 1 : 50,000	DATE: JAN. 12, 1978

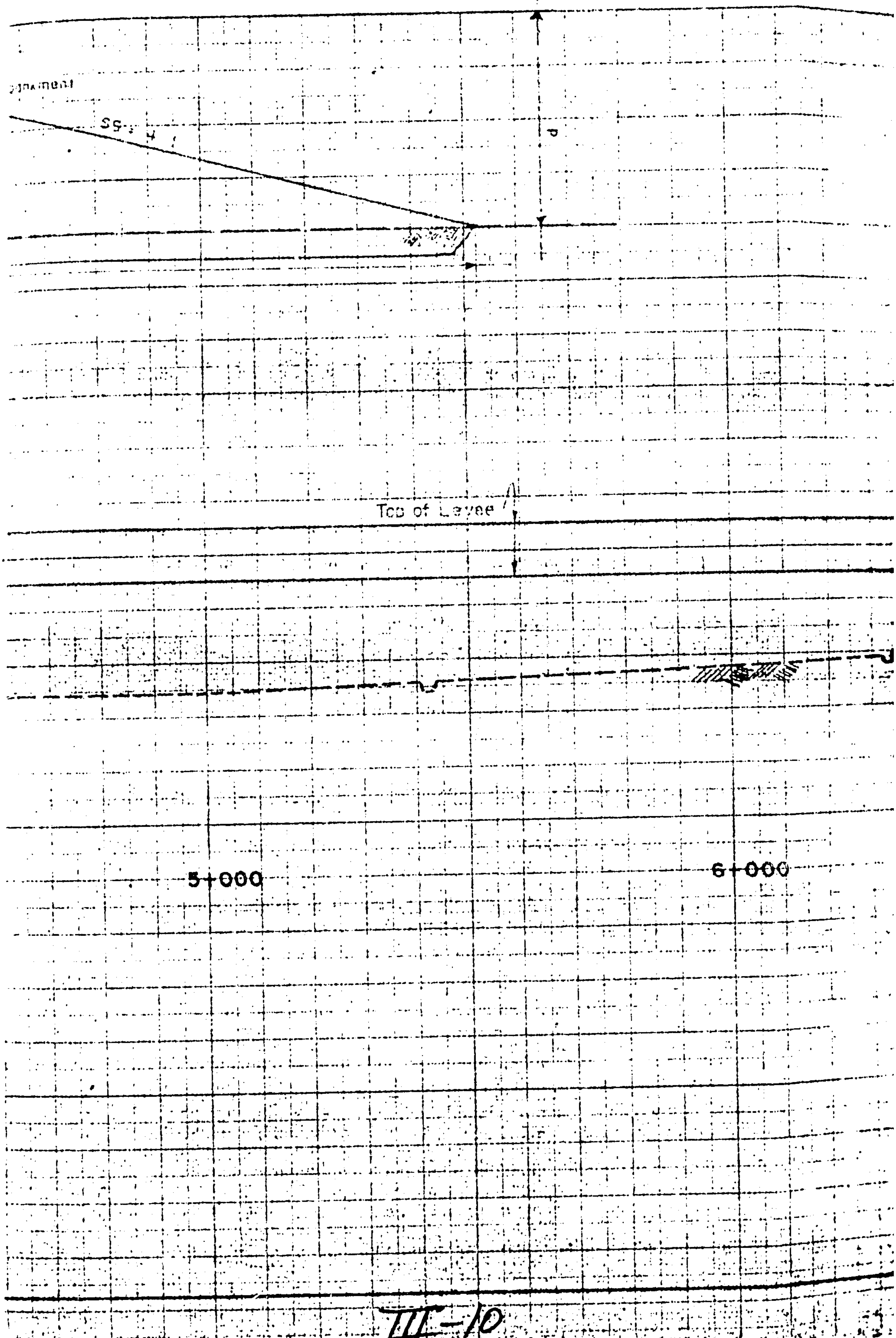
III-10 (1)

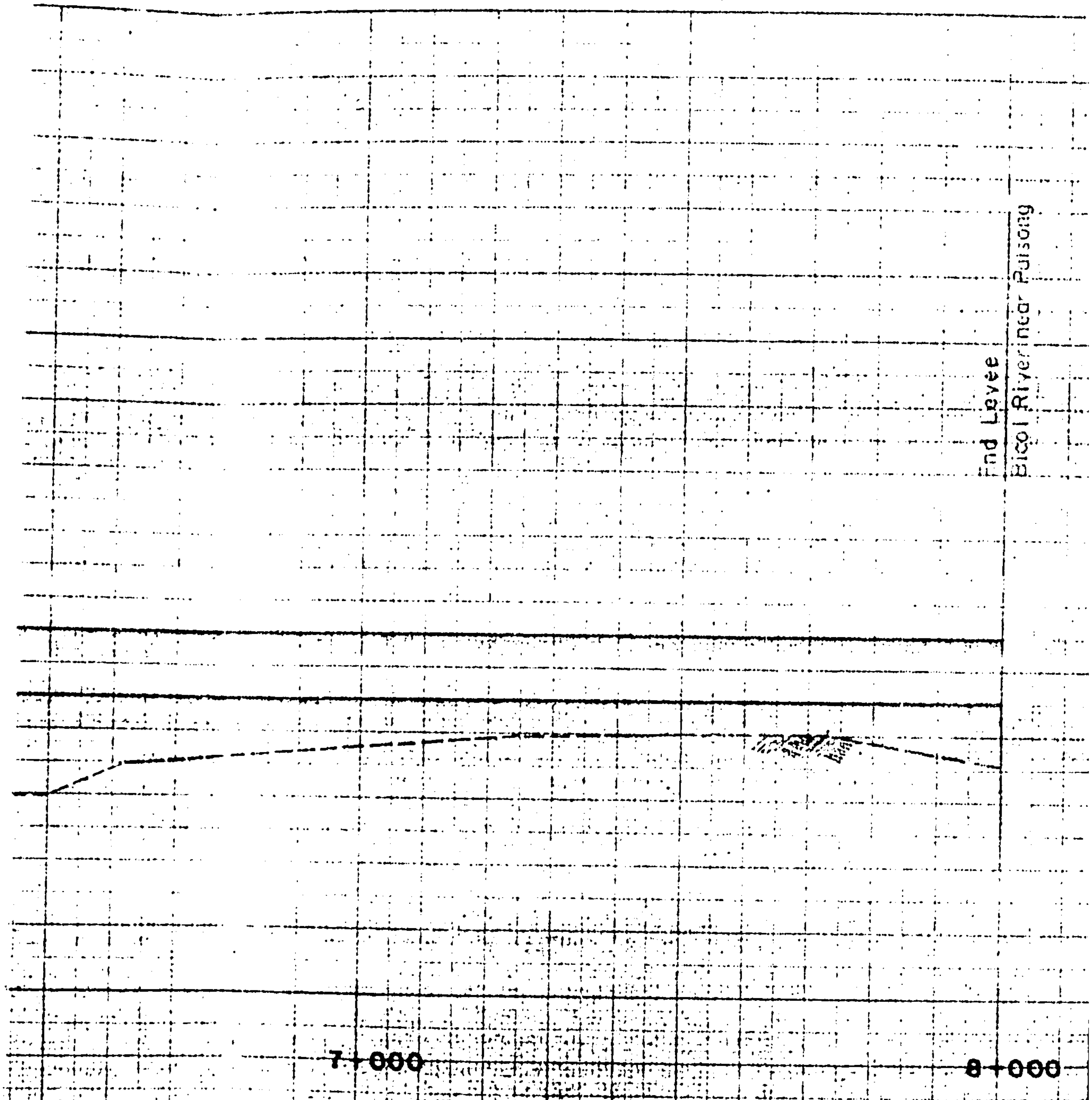


III-10 (2)



4.0 m
3.5 m
15 cm river run gravel
Typical Section of Levee
Not to Scale
Control Structure
Height 5.1 m
Height 3.7 m
Existing Ground at Centerline
2+000
3+000
4+000
Stationing in Kilometers


Top of Levee
5+000
6+000



BICOL RIVER BASIN DEVELOPMENT PROGRAM
RINCONADA INTEGRATED AREA DEVELOPMENT
FEASIBILITY STUDY

PROFILE AND TYPICAL SECTION - LEVEE ALONG NORTHEAST BANK OF BICOL RIVER BETWEEN BULA AND PALSONG

FIGURE III-10

SCALES 1CM=2M Vert. 1CM=100M Horiz.	DATE: January 12, 1978

IV. CONCLUSIONS AND RECOMMENDATIONS

The Lake Bato Regulation and Diversion are inter-related, but not inter-dependent projects. Lake Bato could be regulated for dry season storage, at levels considerably below flood levels and this low level regulation could be achieved without the Diversion. However, the Diversion is required for any flood control development in the Lake Bato-Lake Baao area.

The Diversion would be very effective in lowering the flood levels in the urban and agricultural areas of Bula, Baao, Nabua and Bato, and it is the only apparent means of improving the flooding conditions in these areas. It could be constructed with no unusual difficulties but it would require an inordinately large excavation. The estimated construction cost would be approximately ₱200 million.

This Phase I Study did not include an economic or benefit analysis of the Diversion. It is apparent, however, that the direct benefits from increased agricultural production and from reduction in flood damages would not be enough to justify an expenditure of ₱200 million for the project.

There are the associated benefits of increased development and land use, and improvements in drainage, transportation, and in the general health and welfare of the area. These benefits may be significant and should be considered in the analysis. It is recommended that these benefits be defined before any decision is made on the diversion channel.