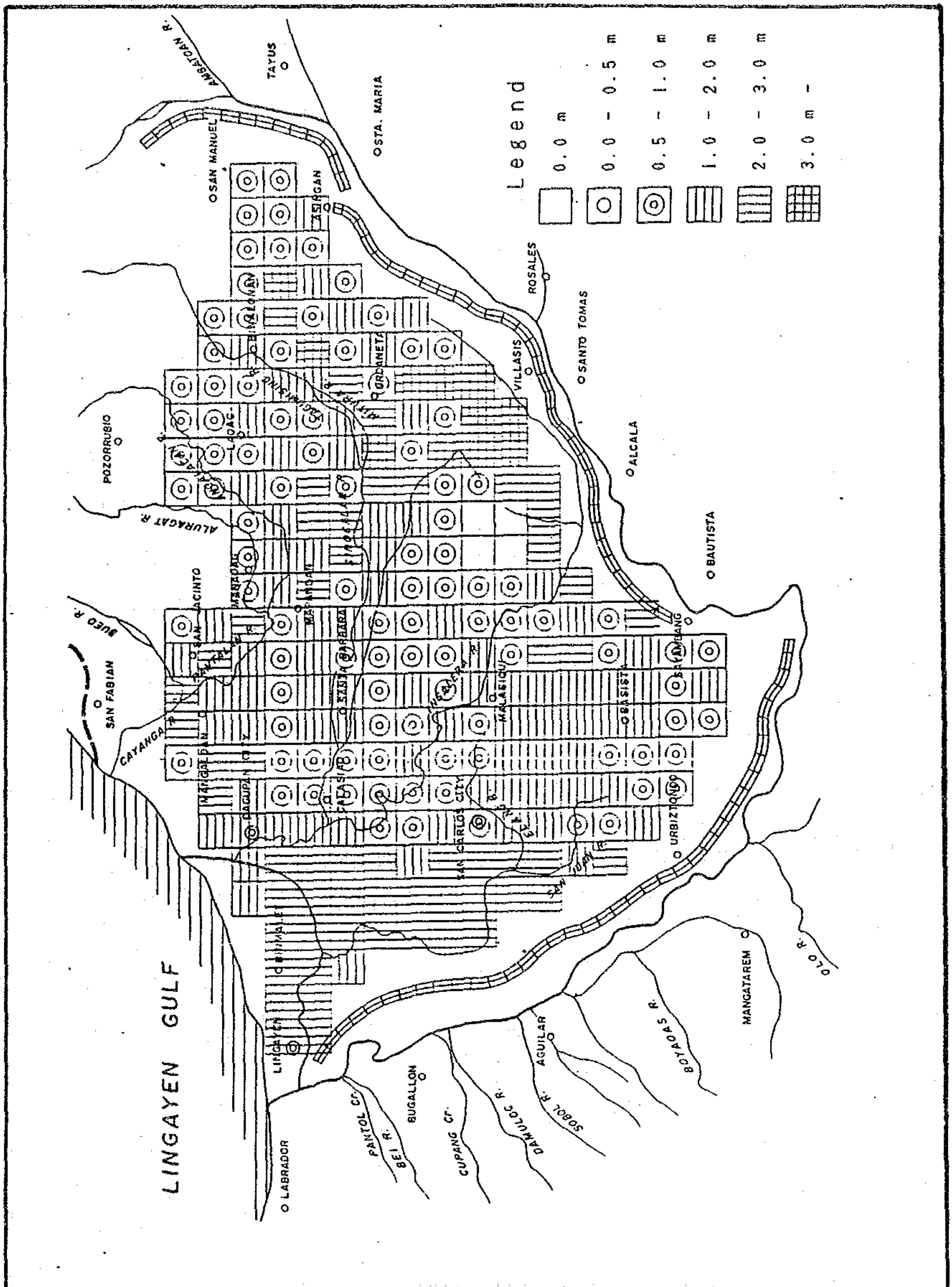
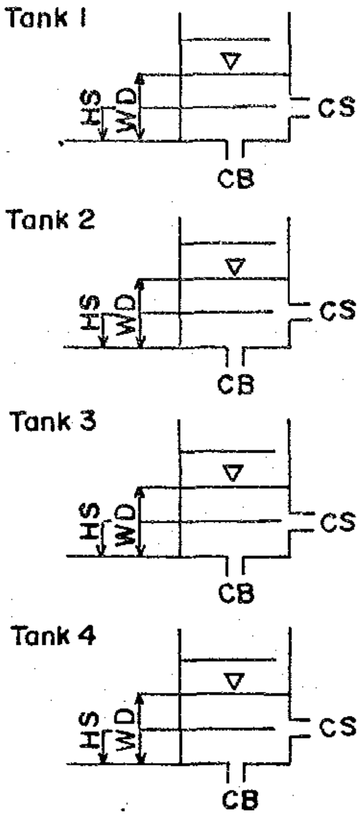


Fig. 4.32 MAXIMUM INUNDATION DEPTH BY 100-YEAR PROBABLE FLOOD



CS : Coefficient of side hole

CB : Coefficient of bottom hole

HS : Height of site hole (mm)

WD : Initial water depth (mm)

	Tank 1	Tank 2	Tank 3	Tank 4
C S	0.2	0.05	0.03	0.005
C B	0.5	0.06	0.02	0.0
H S	10.0	5.0	0.0	0.0
W D	15	10	60	400

Fig. 5.1 **APPLIED TANK MODEL AND CALIBRATED COEFFICIENTS**

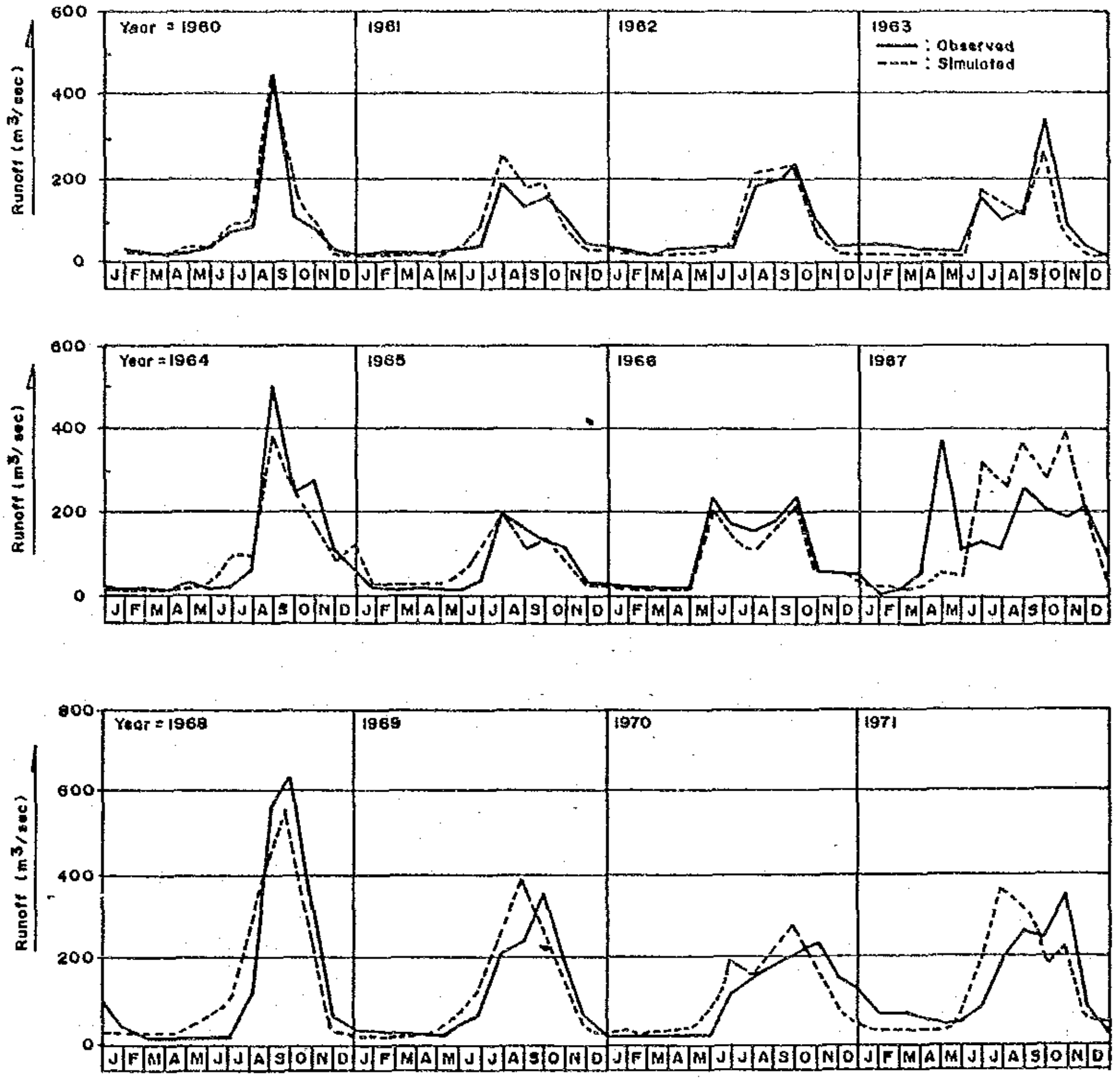


Fig. 5.2 OBSERVED AND SIMULATED MONTHLY RUNOFF HYDROGRAPH

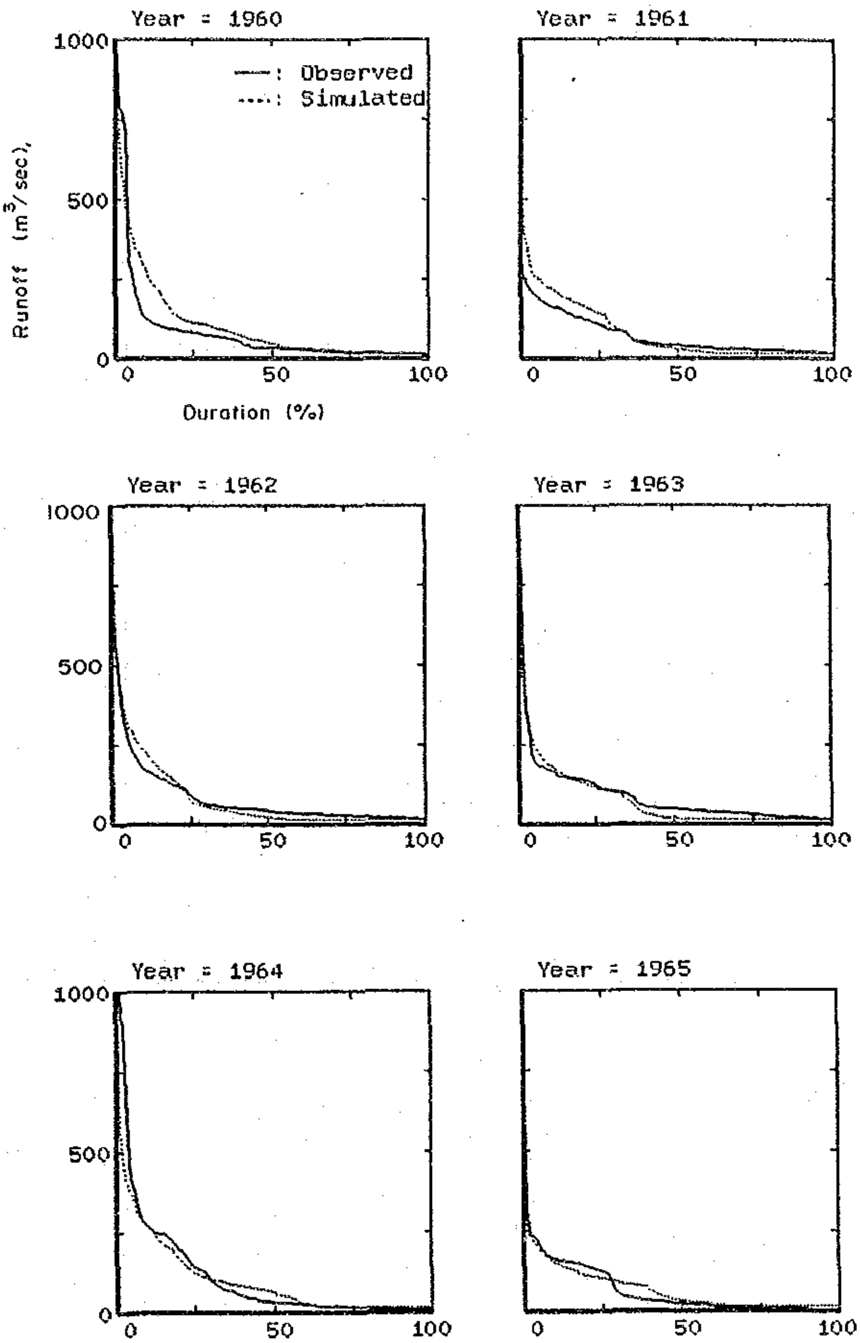


Fig. 5.3 OBSERVED AND SIMULATED FLOW DURATION CURVES AT SAN ROQUE (1/2)

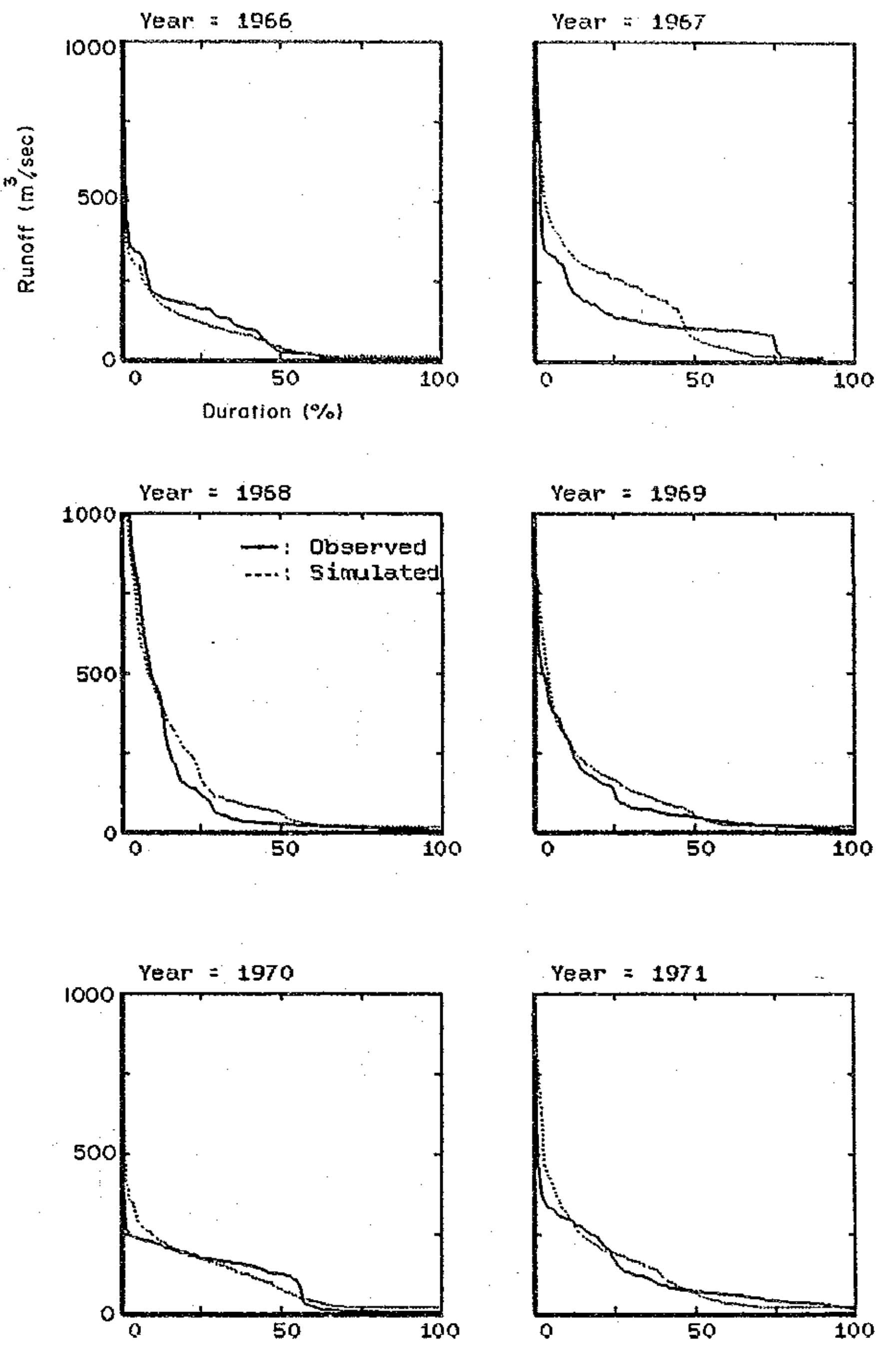


Fig. 5.3 OBSERVED AND SIMULATED FLOW DURATION CURVES AT SAN ROQUE (2/2)

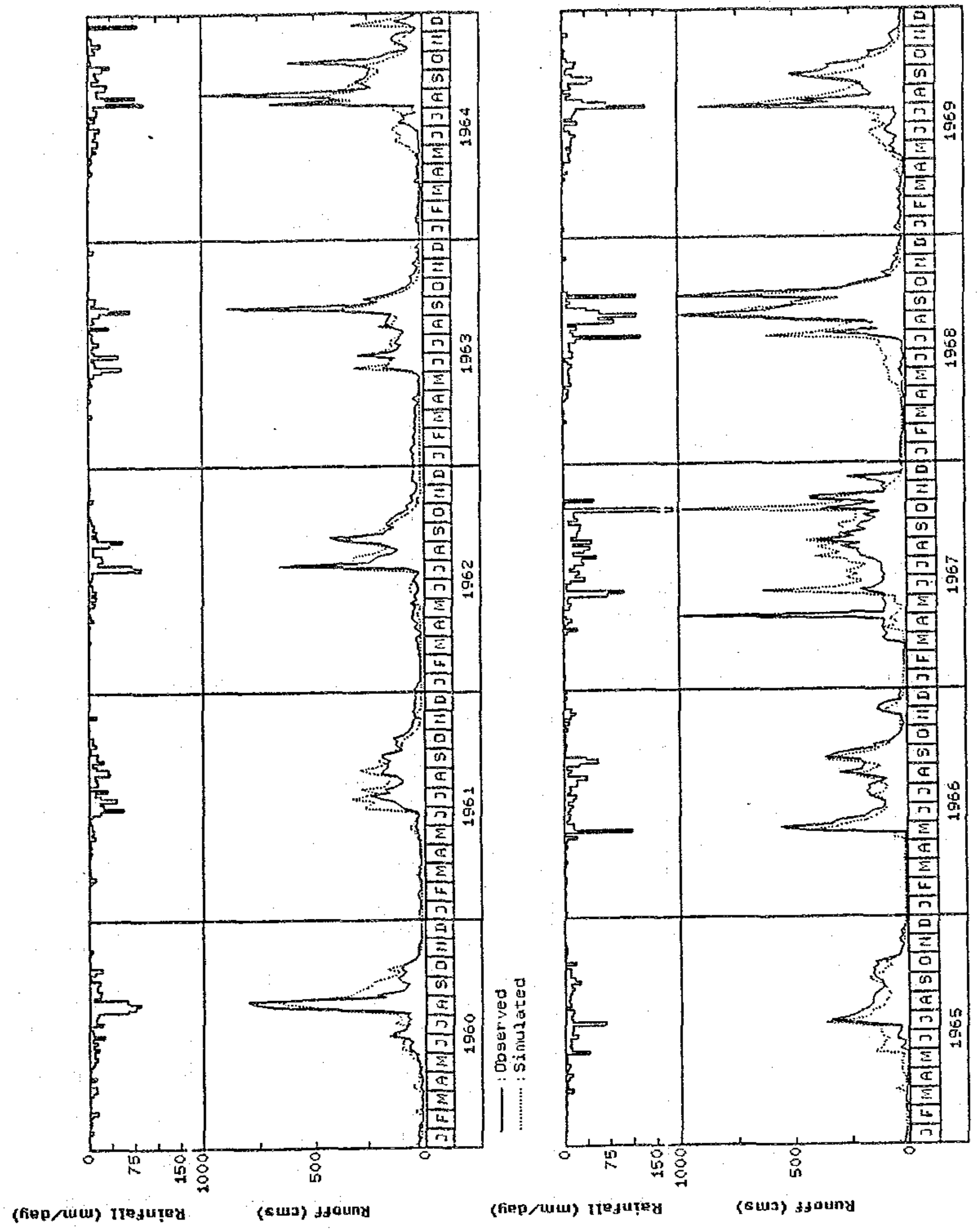


Fig. 5.4 SIMULATED DAILY RUNOFF AT SAN ROQUE (1/3)

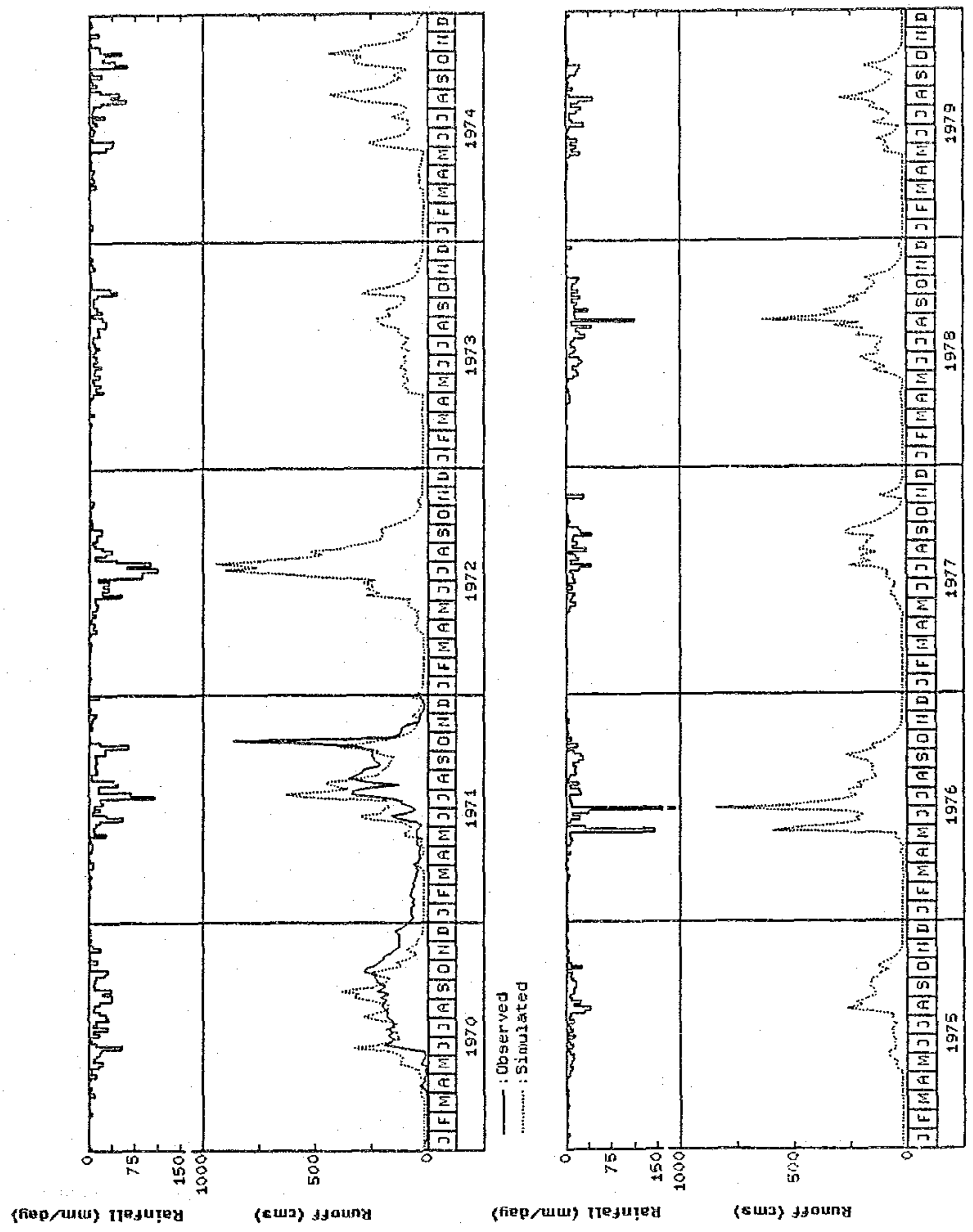


Fig. 5.4 SIMULATED DAILY RUNOFF AT SAN ROQUE (2/3)

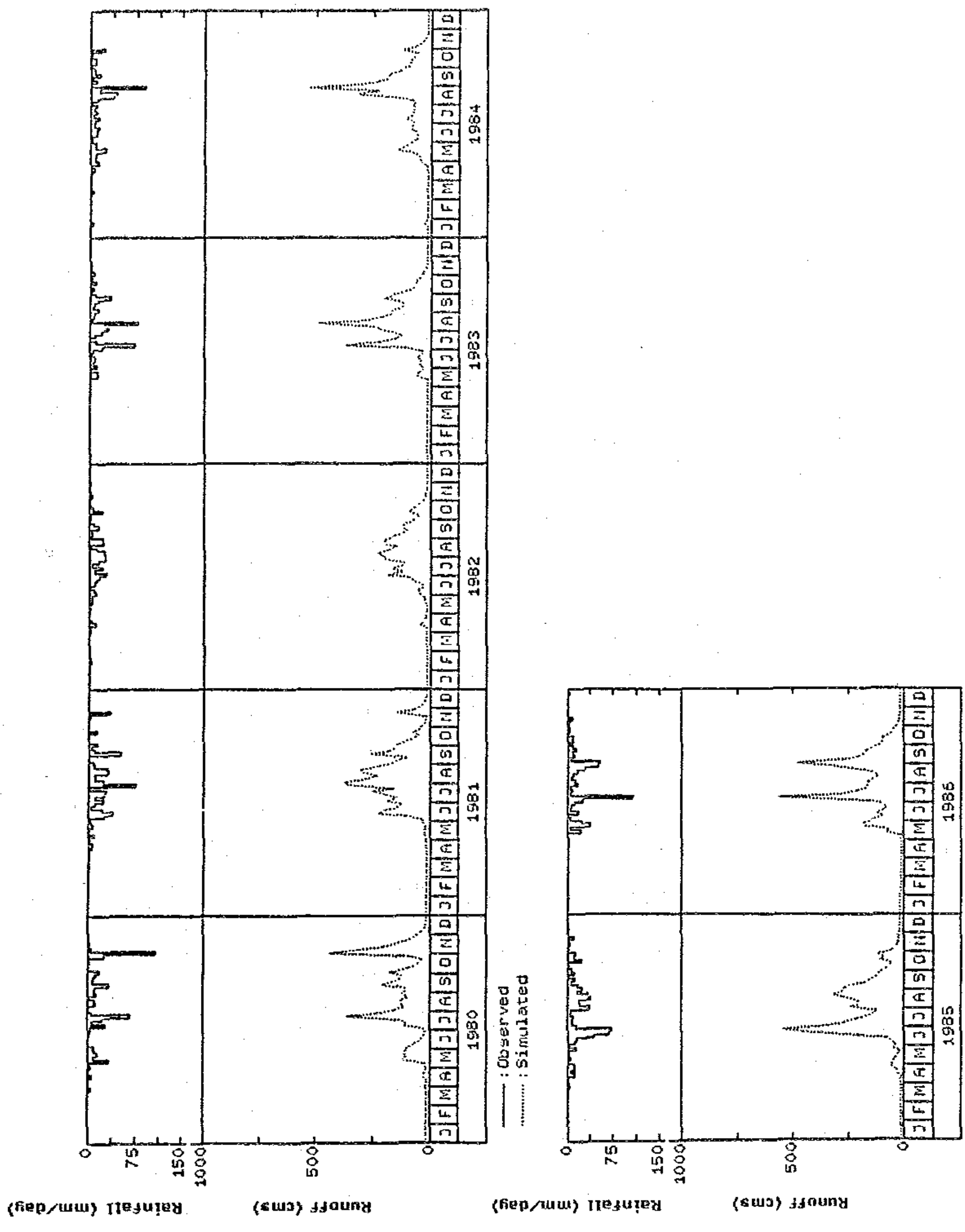


Fig. 5.4 SIMULATED DAILY RUNOFF AT SAN ROQUE (3/3)

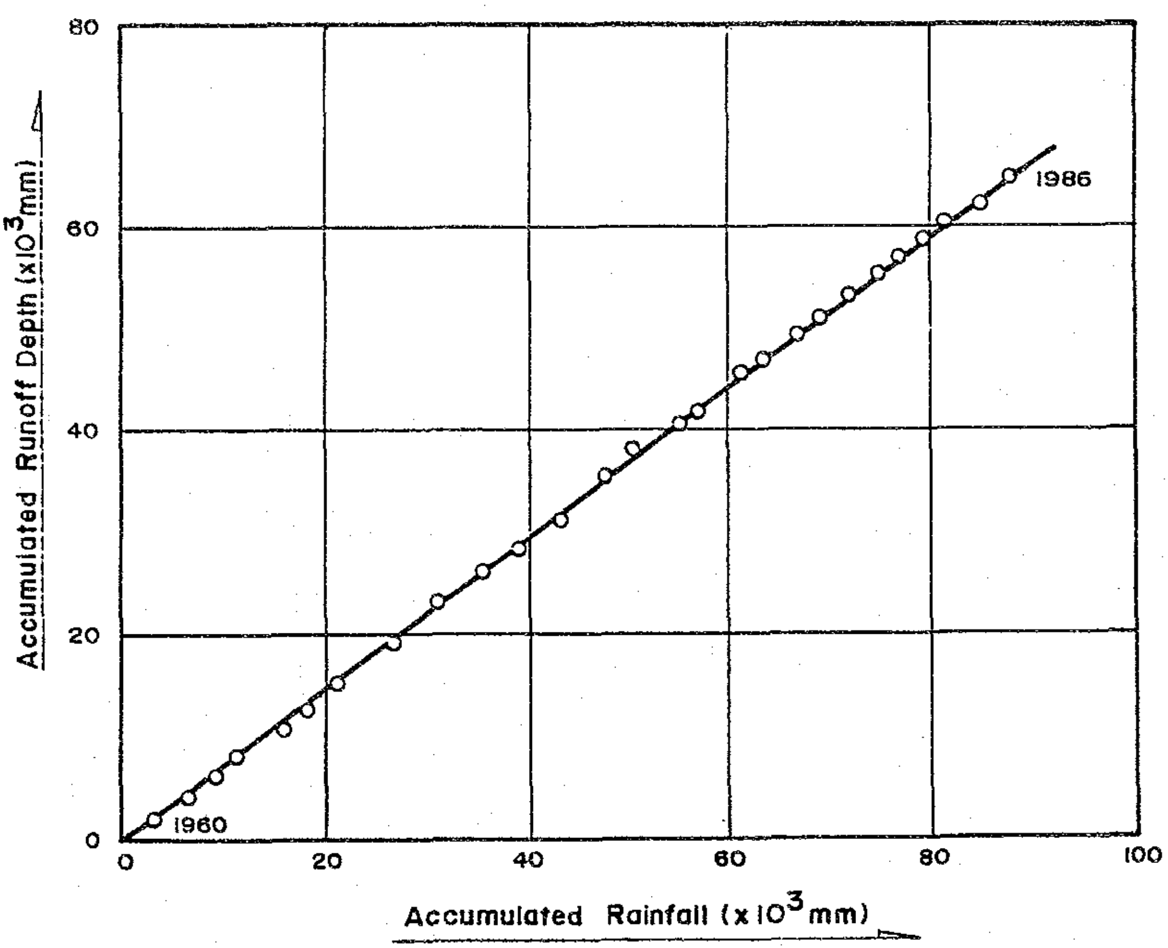


Fig. 5.5 DOUBLE MASS CURVE AT SAN ROQUE

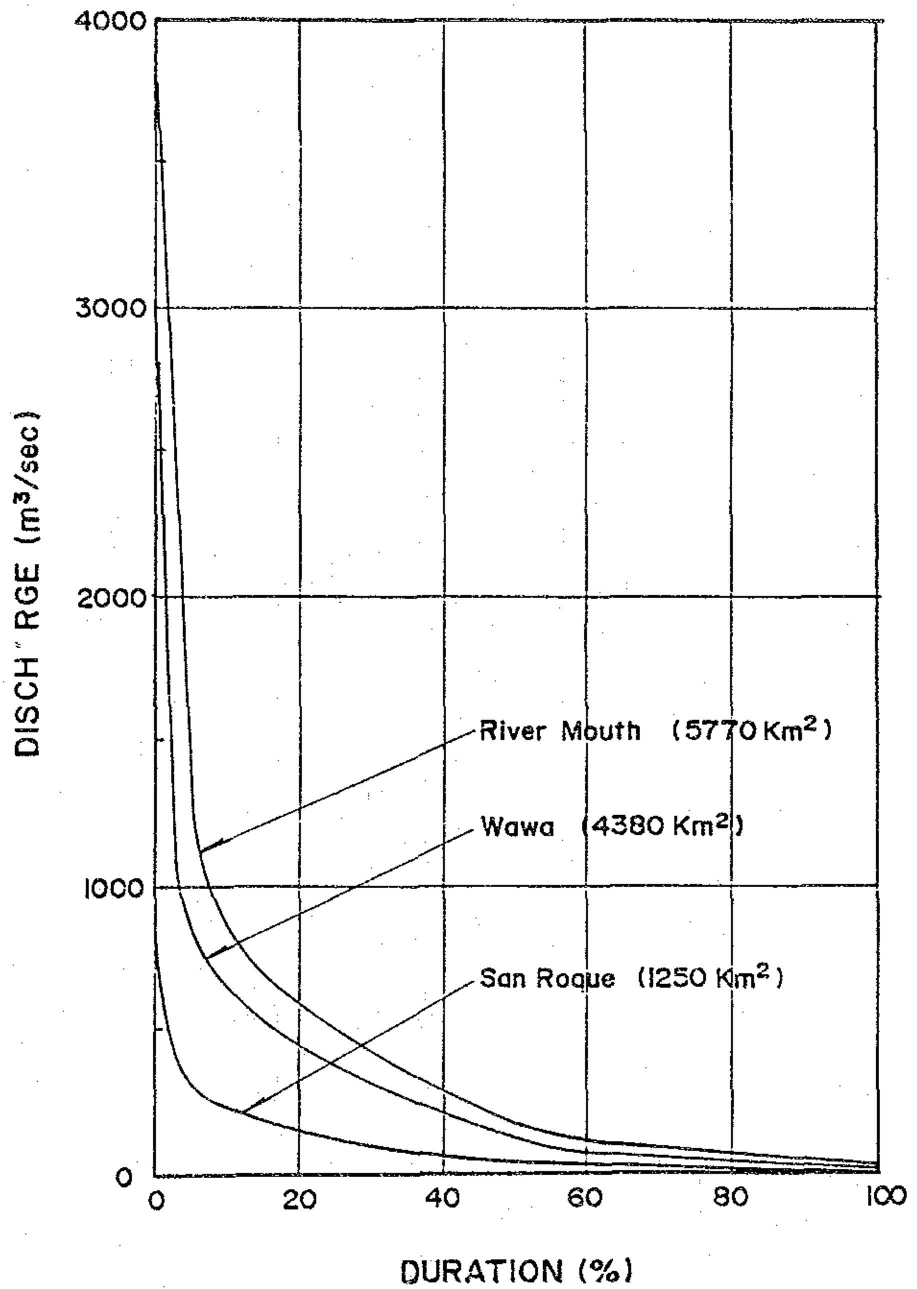


Fig. 5.6 DURATION CURVES

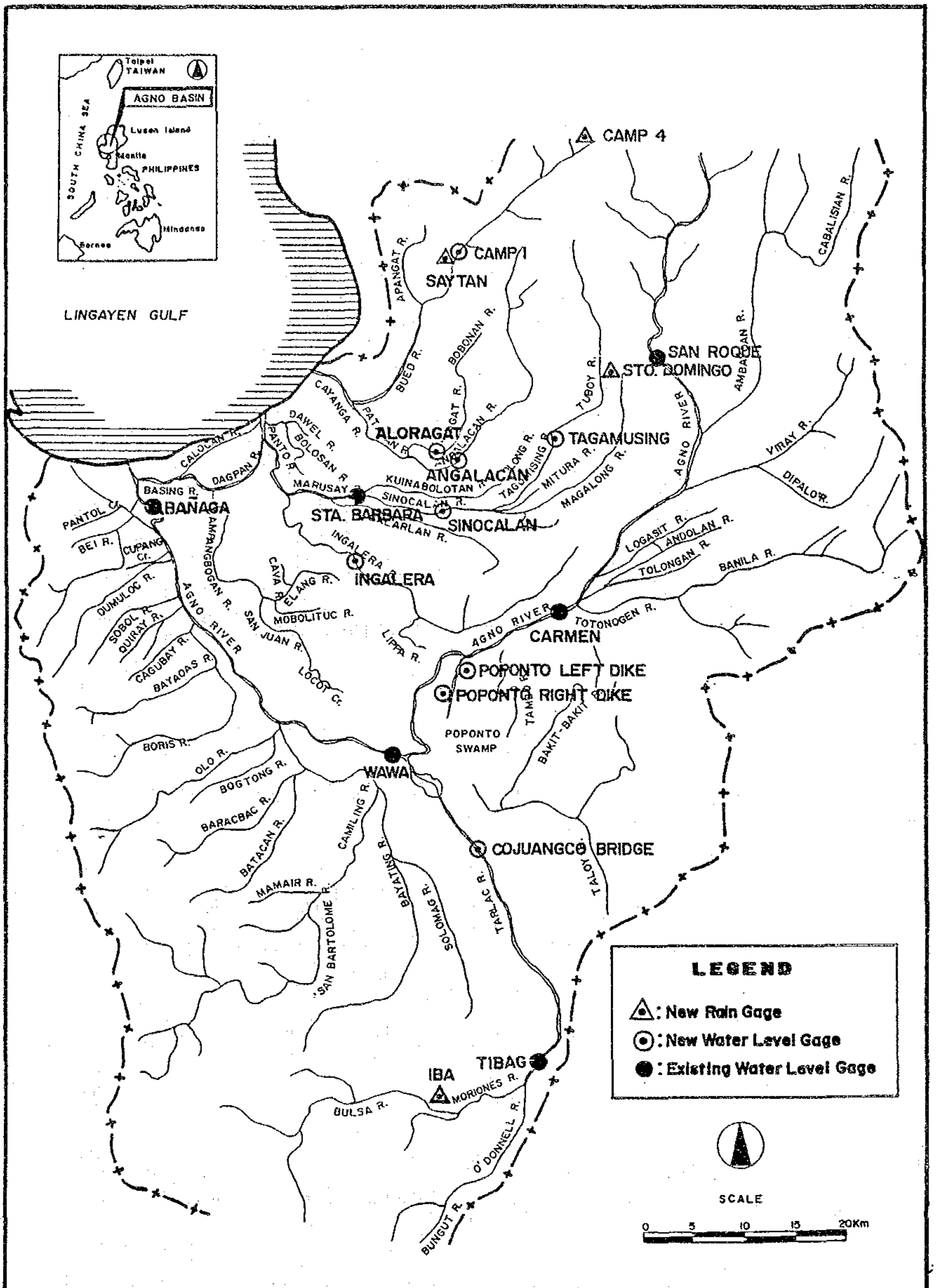


FIG. 6.1 LOCATION MAP OF NEW RAIN GAGES AND WATER LEVEL GAGES

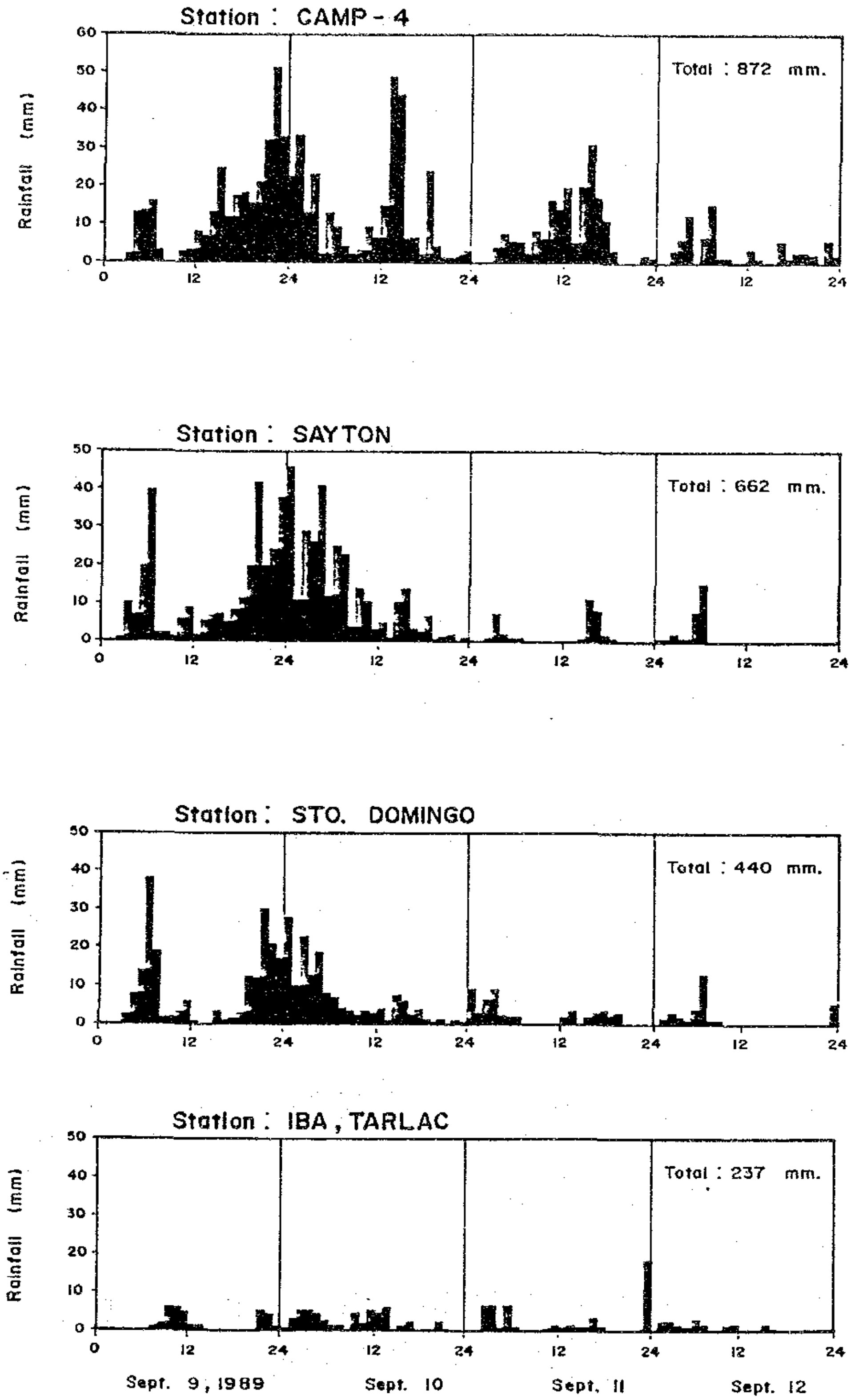


Fig. 6.2 OBSERVED RAINFALL HYETOGRAPHS DURING TYPHOON OPENG

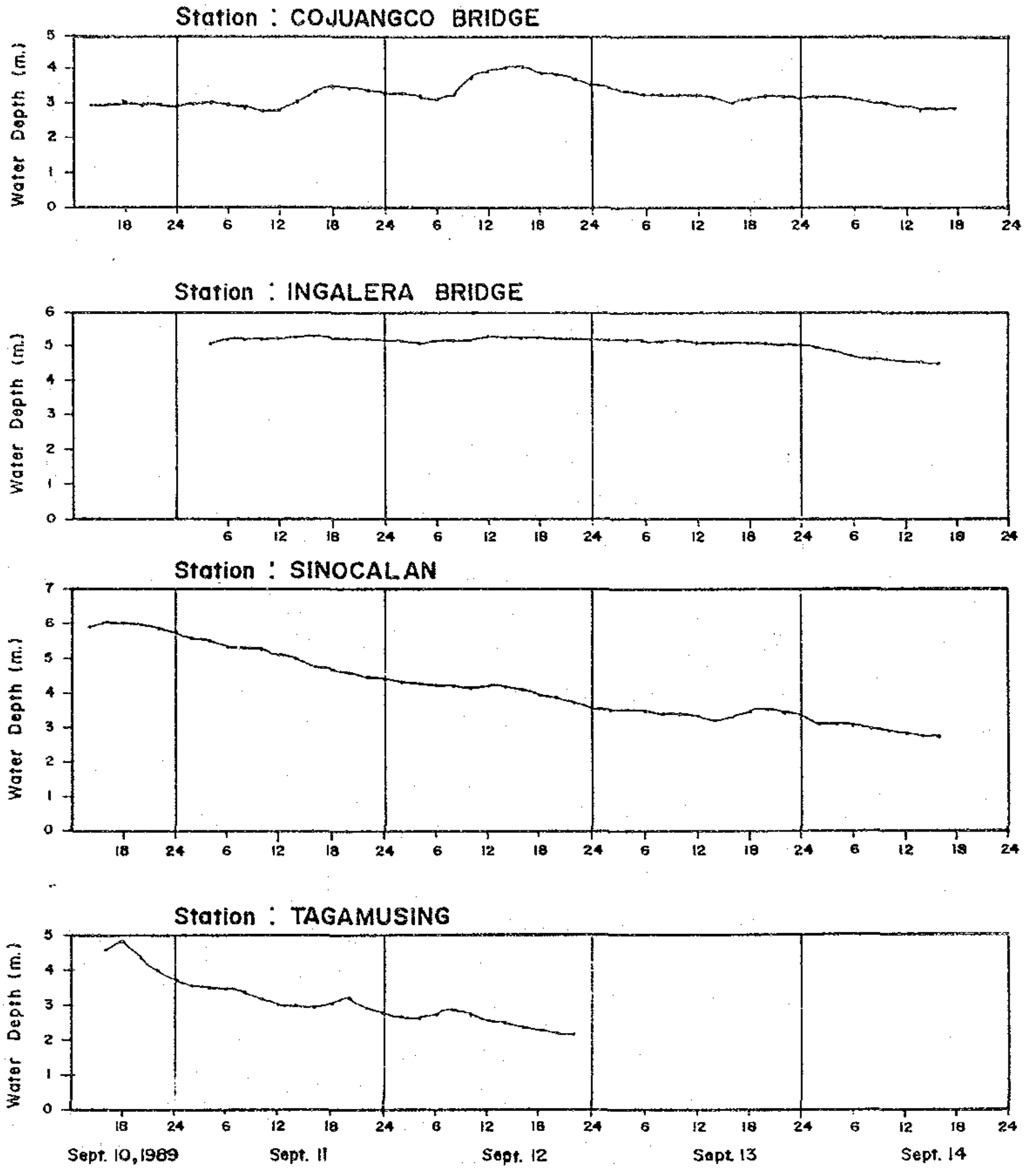


Fig. 6.3 OBSERVED WATER LEVEL HYDROGRAPHS DURING TYPHOON OPENG.

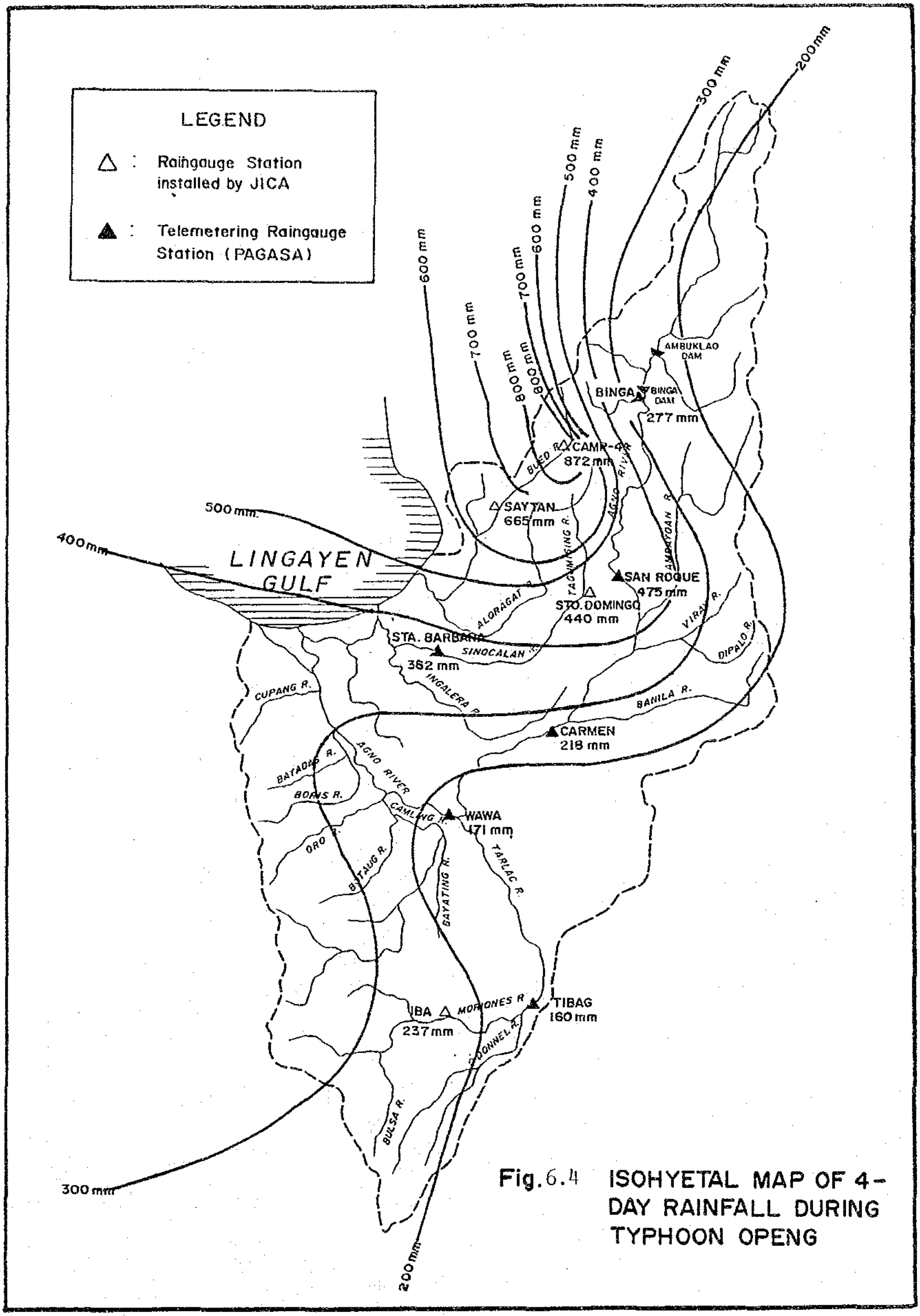
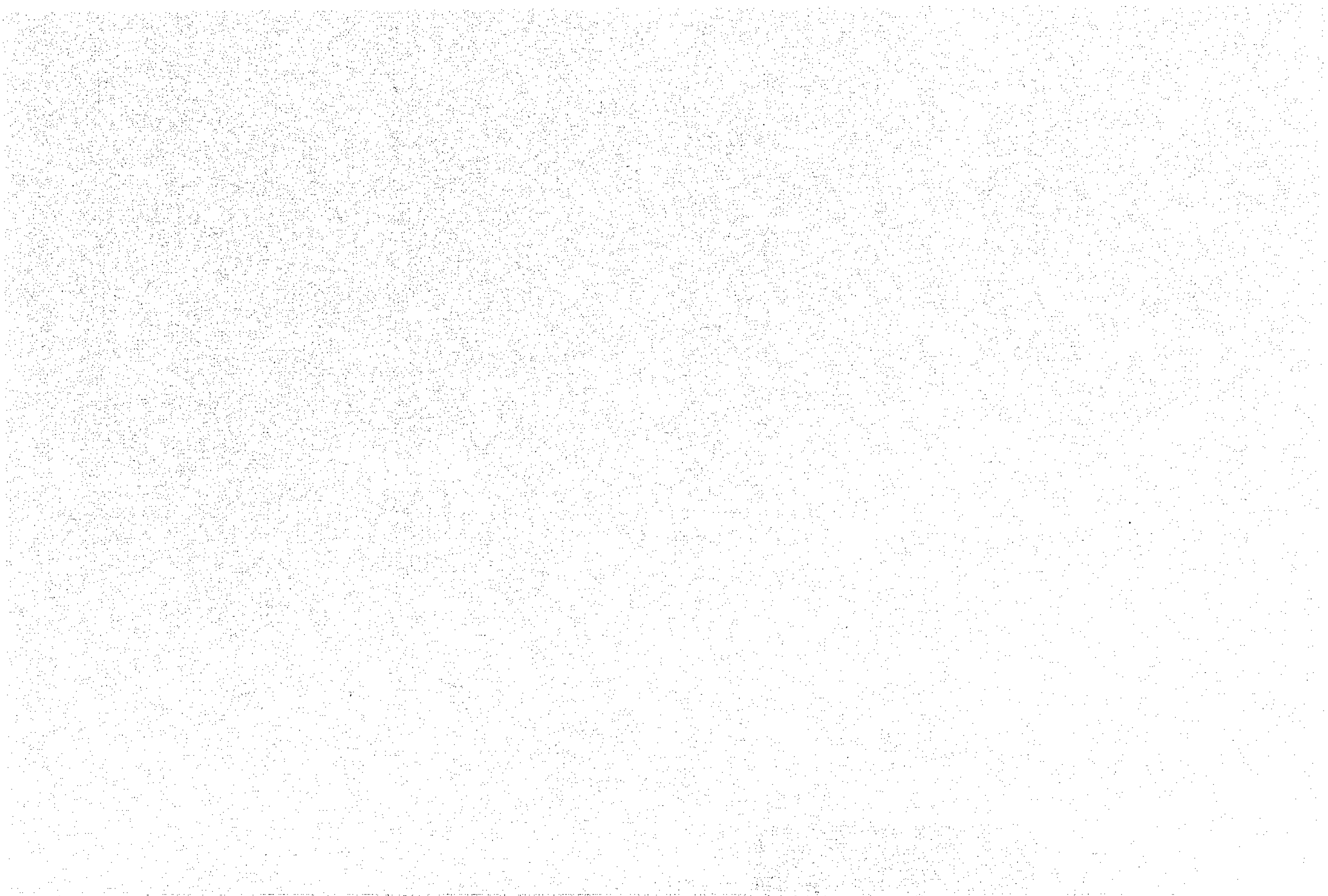


Fig.6.4 ISOHYETAL MAP OF 4-DAY RAINFALL DURING TYPHOON OPENG



3. GL

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SUMMARY

(1) The Agno River basin is generally divided into the following three physiographic provinces.

- Southern Cordillera Mountains (Northeastern mountainous area)
- Central Luzon Plain
- Zambales Mountains (Southwestern mountainous area)

(2) The Agno River basin is underlain by sedimentary rocks, volcanic rocks, intrusive rocks, metasediments and metavolcanics, and its geological ages are from Jurassic to Quaternary. The geological map of the Agno River basin is presented in Fig. 2.1.

(3) Six identified damsites of San Roque, Lower Ambayoan, Lower O'Donnell, Balog-Balog, Moriones and Camiling are studied from the viewpoint of site geology, engineering geology, construction materials and assessments.

(4) The most problem of proposed damsites is water leakage by fault zone. The San Roque and Balog-Balog damsites, which the feasibility study was completed by ELC, are considered to have no problem of water leakage by fault or shear fracture zone, because clay materials constitute impervious zone. Usually the fault zone has a problem of water leakage, so it is difficult to consider the fault zone to be impervious zone. Therefore, further investigations for characteristics of faults are required before design and construction. Damsites such as the Lower Ambayoan, Lower O'Donnell, Moriones and Camiling, are recommended for a geological investigation for rock stability and faults.

(5) The most major problem in the reservoir is water leakage from low ridges. These problems occured in the Lower O'Donnell and Moriones reservoirs. An open low divide which is located between Moriones reservoir and Lower O'Donnell reservoir, is no problem if two damsites are constructed, but a big sub-dam will be required if only one damsite is adopted. Another low ridges in succession of damsite's ridges are located in the both damsites. At least five sub-dams in the Moriones reservoir, and two sub-dams in the Lower O'Donnell damsite, are required. The other reservoirs probably have no problem of water leakage, because rocks in each reservoir are

considered to be watertightness.

(6) Landslides are identified in the Camiling and Lower Ambayoan reservoirs by study of aerial photographs. The Camiling damsite area especially has many obvious and less obvious landslides, and some lower part of them are under water of reservoir. The landslides will occur to slip, because water permeate into landslide masses. Effective countermeasure for landslides is piling works, but it may be difficult from economical viewpoint. One minor landslide is situated in the left bank of the Lower Ambayoan reservoir, and soild removal work for upper part of landslide mass is required for preventive measures.

(7) The Pangasinan Plain is roughly divided into two landscapes, one of which is coastal and the other is alluvial. Coastal landscape is divided into four items, that are active tidal flat, old tidal flat, beach ridges and beach lines. Within this four items old tidal flat is not distributed in the *STUDY* area. Three other items are distributed in the northwestern area of the Pangasinan Plain, near the Lingayen Gulf. The Landform map of the Pangasinan Plain is shown in Fig. 4.1.

(8) The proposed dike along the Agno River, downstream from Wawa, will be constructed on the surface of mainly broad alluvial plain. They are composed of silt with sand and organic clay, therefore, somewhat problem of consolidation settlement will occur in certain area. The foundation of dike in fish pond area at the mouth of the Agno River consists of sandy materials, that may cause quicksand or piping actions.

(9) The granular material that consists of sand and gravel with a negligible content of fines is considered not suitable for dike construction. In order to get well graded soil materials blend of cleyey soils from broad alluvial plain and sandy materials from river terraces will be necessary.

(10) Materials from hilly areas, which are weathered sedimentary rock and terrace deposits are suitable for construction materials except tuffaceous materials. If the ultramafic rocks at the foot of the Zambales mountains are deeply weathered, these may be suitable for dike construction.

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ABBREVIATIONS

BMG	Bureau of Mines and Geo-Sciences
NIA	National Irrigation Administration
ECI	Engineering Consultants Incorporated
BOR	Bureau of Reclamation
DVS	Department of Volcanology and Seismology
NPC	National Power Corporation
BOS	Bureau of Soils
NWRC	National Water Resources Council
MPWH	Ministry of Public Works and Highways
ELC	Electroconsult S.p.A, Italia
IDP	Irrigation Development Plan for Central Luzon by NIA

1. PHYSIOGRAPHY

1.1 General Statement

The Philippines is an archipelago of more than seven thousands of islands and islets. The Luzon Island is the biggest island and situated in the northwestern part of the Philippines. The Agno River basin, the STUDY area, is located in northern part of the Central Luzon.

The Agno River basin is generally divided into three physiographic provinces. First one is the northeastern mountainous area. This area is the southern part of the Cordillera Central Mountains, that is the northwestern mountainous ridge of the Luzon Island.

The second is the Central area which is mostly plain area. This area is called the Central Luzon Plain that opens into Lingayen Gulf on the north and Manila Bay on the south. The STUDY area is the northern part of the Central Luzon Plain, which is separated with a low divide in northeast of Tarlac.

The third is the southwestern mountainous area. This area is called the Zambales Range, most western part of the Luzon Island. The STUDY area is the northeastern area of the Zambales Range.

Physiographic provinces of the STUDY area are summarized as follows:

- Southern Cordillera Mountains (Northeastern mountainous area)
- Central Luzon Plain
- Zambales Mountains (Southwestern mountainous area)

These provinces are shown in Fig.1.1.

1.2 Physiography of Each Province

1.2.1 Southern Cordillera Mountains

The Southern Cordillera Mountains is generally composed of mountains ranging in altitude from 70 to about 2,900 meters. The highest peak in the Basin is Mt. Pulag (2,929 m in height), and also in the Luzon Island. Mount Pulag is situated in near the eastern ridge, 22 kilometers northeast of the Ambuklao Dam. The slope of mountain side in the Basin is steep to very steep, and average degree is about 30^{o} to 45^{o}.

The Agno River has a biggest basin in the central area of this province. The Agno River flows almost southward, assembling many tributaries that flow westward and eastward. The Ambayoan River, one of big tributaries, flows almost southward in the eastern area. The other rivers called allied rivers flow southward or southwestward in the west of the Agno River. The Tuboy River, one of allied rivers, has a basin nearby the Agno River. The Bued River also one of allied rivers, heads in the vicinity of Baguio City and flows southwestward in the western area.

1.2.2 Central Luzon Plain

The Central Luzon Plain of the Basin is widespread plain, with length and width of about 60 kilometers. This area is mostly composed of plains ranging in altitude from 0 to about 100 meters, and partly of hills and small mountains ranging in altitude from 30 to 380 meters. These small mountains are Mounts Amorong, Balungao, Bangcay and Cuyapo. Hills are located in eastern area of Malasiqui and western area of the Tarlac River.

The Agno River in this province flows southward in the vicinity of Tayug, and turns southwestward to almost center of the Central Luzon Plain. Afterward the Agno joins the Tarlac River that flows north to northwestward, and turns northwestward in the vicinity of Wawa. The Agno meanders in the plain assembling the tributaries, and at last flows into the Lingayen Gulf.

A back swamp, called Poponto Swamp, is situated near the confluence of the Agno River and the Tarlac River.

1.2.3 Zambales Mountains

The Zambales Mountains is situated the northeastern area of the Zambales Range that mainly extends from Lingayen Gulf on the north to Bataan Peninsula on the south. This area is composed of mountains and hills ranging in altitude from 20 to about 1,700 meters. The slope of this area is less steep than that of the Southern Cordillera Mountains. The highest peak is Mt. Pinatubo (1,745 m) that stands at the most southern edge of the Basin. And there are some small volcanic cones at several places in the foot of mountains.

The tributaries of this area, are the O'Donnell, Moriones, Camiling, Olo, and Bayaoas River etc., flow eastward or northeastward into the Agno River except two former rivers. The O'Donnell River, the source of which from Mt.Pinatubo, flows north to northeastward, joining Moriones River that flows eastward at 4 kilometers southwest of Tarlac, therefore, becomes the Tarlac River.

2. GEOLOGY OF THE BASIN

2.1 General Statement

The stratigraphy of the north Luzon Island included the Agno River basin is shown in Table 2.1. And the geological map of the Basin is shown in Fig. 2.1.

The Agno River basin is underlain by sedimentary rocks, volcanic rocks, intrusive rocks, metasediments and metavolcanics, and its geological ages are from Jurassic to Quaternary.

2.2 Geology of Each Province

Geology of each physiographic province is mentioned hereinafter.

2.2.1 Southern Cordillera Mountains

This province is mainly underlain by sedimentary rocks, metasediments, metavolcanics and intermediate to acid igneous intrusive rocks.

Sedimentary rocks

Sedimentary rocks, named Zigzag Formation, Kennon Formation, Klondyke Formation, and Rosario Formation in decreasing order of geological age, are identified in this province.

The Zigzag Formation is typically exposed in the upper Bued River Canyon. It consists of massive and well compacted conglomerate, volcanic flows and wackes,tuffaceous shale with interbeds of tuff and pyroclastics. The formation is of Early to Middle Miocene age.

The Kennon Formation is named to the Kennon Limestone and Twin Peaks Sandstone that exposed along the Kennon Road, its type locality at Bued Canyon. Both members are of Middle Miocene age.

The Klondyke Formation is exposed in the southwestern part of this province, typely along the Naguilian Road that extends to the west from

Baguio City. This Formation mainly consists of thick and poor sorted conglomerate, pebble and cobble of which are mainly of diorite and andesite. Conglomerate is frequently associated with thin interbeds of tuffaceous wacke, claystone and siltstone. The Formation is of Late Miocene age.

The Rosario Formation, named for the rocks in the vicinity of Rosario and La Union, is an alternation of brown sandstone, shale and siltstone with minor tuff, sandy limestone and pebble conglomerate. This Formation is of Pliocene to Early Pleistocene age.

Licuan Group, Tineg Formation and Awiden Mesa. Formation are not distributed in the Agno River Basin.

<u>Volcanic rocks</u>

The Zigzag Formation and the klondyke Formation contain not only sedimentary rocks but also volcanic rocks. The former, exposed in the vicinity of Acops Place and Camp 3, mainly consists of andesitic volcanic rocks. The latter,exposed in Mt.Sto.Tomas and Baguio City area, consists of lavas with pyroclastics.

<u>Intrusive rocks</u>

The Agno Batholith is exposed along the Agno River, trending north-south across the eastern half of Baguio district. It consists of diorite, granodiorite and quartz diorite. The intrusion period of quartz diorite as indicated by K-Ar dating is 18 million years or Early Miocene.

<u>Metamorphic rocks</u>

The metamorphic rocks in the Baguio Mineral District are named Dalupirip Schist. *This formation is mainly composed of schists trending* northwest extending from Ambalanga - Liang River on the north to San Nicolas along the Agno River. These schists are apparently of sedimentary parentage, and considered to be the oldest rock type in the Agno River Basin, maybe of Eocene to Cretaceous or Jurassic age.

2.2.2 Central Luzon Plain

This province is underlain by sediments, sedimentary rocks and volcanic rocks.

Sedimentary rocks and sediments

The Aksitero Formation, the basement in the western Central Luzon Plain, consists of an interbedded sequence of sandstone, shale, conglomerate and minor limestone. This Formation is of Late Eocene to Early Oligocene.

The Moriones Formation consists of yellowish brown sandstone, sandy shale and conglomerate, whose type locality is the vicinity of Moriones. This Formation is of Early to Middle Miocene age.

The Malinta Formation consists of principally sandstone in the vicinity of Barrio Marinta, Tarlac. This Formation can be traced from O'Donnell River on the south to about 3.5 kilometers southwest of Sta.Ignacia. This Formation is of Late Middle Miocene age.

The Tarlac Formation consists of interbedded sequence of shale, sandstone and lenticular pebble conglomerate in the vicinity of Tarlac Town. The Tarlac is the most widespread formation that stretches from O'Donnell River on the south to Camiling town, age of which is Late Miocene to Pliocene.

The Sansotero Limestone is named for the limestone that crops out irregularly and disconnectedly in Sansotero,Bigbiga,Mayantoc, and Tarlac. The limestone is massive and porous with inclusions of volcanic and sedimentary rocks. The Sansotero is of Pliocene to Pleistocene age.

The Bamban Formation consists of tuffaceous sandstone and conglomerate and well bedded lapilli tuff, typically exposed in Bamban, Tarlac. The Bamban is of Pleistocene age.

Most of plain is underlain by Quaternary alluvial deposits, composed of sand, gravel, silt and clay.

Volcanic rocks

Quaternary volcanoes are Mts. Amorong, Balungao,Bangcay and Cuyapo, occupying the southeastern part of Pangasinan. These volcanic rocks consists of basalt, andesite and dacite which belongs to the calc-alkali rock suite.

2.2.3 Zambales Mountains

This province is underlain by mainly intrusive rocks and less sedimentary rocks and volcanic rocks.

Sedimentary rocks

The Aksitero Formation consists of limestone and clastic sediments, mainly tuffaceous sandy shale. This Formation is exposed along the Aksitero River in the vicinity of Bigbiga, eastern foothills of Zambales Mountains. The Aksitero is of Late Eocene to Early Oligocene age.

The Zambales Formation and the Sta.Cruz Formation, that are of Middle to Late Miocene age, are exposed in the western part of the Zambales Mountain ridge and not included in the investigation area.

Terrace gravel is identified capping ridges in Zambales and western Pangasinan.

Volcanic rocks

The Zambales Ophiolite consists of massive, spilitic and cherty basalt and basalt rubble breccia, distributed along the Moriones and Camiling River in Tarlac. This Ophiolite is the base of the Aksitero Formation that is dated Late Eocene to Oligocene, therefore, the age of which is probably Eocene.

In the eastern flank of the Zambales Mountains, the older sedimentary rocks, especially the Moriones Formation are intruded by volcanic plugs and dykes. These volcanic rocks are mainly andesite and dacite and minor rhyodacite. Volcanism could have started from the Middle Miocene and continued through the Quaternary.

Quaternary volcanic rock surrounding Mt. Pinatubo belongs to the calc-alkalic series, that are andesite, dacite and basalt. The age of the rock by chemical analysis data is 1.1 ± 0.09 million years.

Intrusive rocks

Intrusive rocks are divided into two rock series as follows:

- Acidic to intermediate rocks A diorite complex called Balog-Balog Diorite, is a dyke system intrusive into the gabbro and diabase dyke swarms of the ophiolite suite. The complex consists of diorite, quartz diorite and pegmatite etc. The intrusion age is considered to be Oligocene.

- Basic to ultrabasic rocks The peridotite - gabbro associations, called the Zambales Ultramafics, consists of mainly peridotite, dunite and layered gabbro. Peridotite and dunite are generally serpentinized. These ultramafics are base rock of the Zambales Range, widespread in an area of 2,700 square kilometers, and considered to be of Cretaceous to Early Eocene age.

2.3 Geologic Structure

2.3.1 Faults

Major faults of the Philippine Island are shown in Fig. 2.3 as crustal fractures.

The Philippine Fault is the greatest transcurrent fault in the Philippines. It is traceable for about 1,200 kilometers, originating Lingayen Gulf on the north, thence along the south border of the Luzon Central Cordillera, Polillo Strait and at last into Davao Gulf on the south. According to the study of the Philippine Fault, present movement is confirmed to be left-lateral, displacing Neogene rocks for at most 8 kilometers.

The Bangui Fault in northwest Luzon, is undoubtedly a major transcurrent fault. And Digdig Fault is traceable further north to join the Bangui Fault in the eastern flank of Luzon Central Cordillera. Both the Bangui and the Philippine Faults die out after they intersect the Digdig Fault.

2.3.2 Fold

The major fold structure (patterns) is shown in Fig. 2.4. The folds may be classified into three distinct sets as follows;

- a NW - SE set
- a NE - SW set
- a N - S set

The classification of fold in the Agno River Basin is a N-S set. The folds included in N-S set are found in the whole northern Luzon from Latitude 14^{o}N up. The folds in the La Union-Ilocos area consist of a series of parallel synclines and anticlines covering the western flank of the Luzon Central Cordillera.

3. GEOLOGY OF PROPOSED DAMS

3.1 Geology of Each Damsite

Six proposed damsites, excluding two existing dams, are screened by Dam and Retarding Basin study. These damsites are San Roque, Lower Ambayoan, Lower O'Donnell, Balog-Balog, Moriones and Camiling. All damsites are under planning stage except Balog-Balog that is under construction.

Geological description of each damsite, concerning site geology, engineering geology, construction materials and assessment, are described hereinafter; geological map and geological data of each damsite is shown at the end of the text.

3.1.1 San Roque Damsite

(1) General description

The San Roque damsite is located on the Agno River about nine kilometers north of San Manuel, Pangasinan. Access to the damsite from San Manuel is by 6.5 kilometers of unpaved gravel road and 2.5 kilometers of foot trail.

Feasibility study of the San Roque Project has been prepared by Electroconsult (ELC) in August 1981.

(2) Site geology

The geological map (1:50,000 in scale) and geological data of the San Roque damsite are shown in Fig. 3.1 and Table 3.1.

Physiography

The San Roque damsite is located in the southern piedmont of the Cordillera Mountains. The damsite is situated in the Agno River valley just before the river fans flow out to the northeastern edge of the Pangasinan Plain.

The mountain slope shows steep to very steep degree, and steeper in the riverbed side. The trend of mountain ridge shows irregular shape. The Agno River meanders in steep mountainous area drawing a large arc, and flows southward on the whole.

Stratigraphy and Lithology

The four lithologic units have been grouped by ELC. The stratigraphic sequence at the site is listed below in order of decreasing age, followed by a lithologic description of these four units.

- Jurassic to Eocene : Metavolcanics-Metasediments
- Oligocene or Early Miocene : Diorite Complex
- Late Miocene : Conglomerate
- Recent : Alluvium, Debris

.Metavolcanics-Metasediments The oldest rocks in the Agno river basin called Dulupirip Schist, are fine to medium grained metavolcanics and metasedimentary formations. These rocks are found to be a rather limited extent on both left and right abutments of damsite, considered to be erosional remnants of the rock formations metamorphosed by the plutonic intrusions.

.Diorite Complex The diorite complex is the most extensive formation and underlies the dam foundation, abutments and most of the reservoir area. This complex consists of granodiorite, quartzdiorite, and related andesite-dacite porphyries. Andesite-dacite porphyries are sporadically distributed along the borders of the pluton, such as a small section on the right bank downstream of the proposed spillway.

.Conglomerate The downstream of the proposed damsite is underlain by a thick sequence of conglomerate with thin lenses of interbedded sandstone and shale. The conglomerate compared with the Klondyke Formation, is generally poorly sorted pebble to boulder of diorite, andesite, limestone and altered volcanic rock fragments with an arkosic sandy matrix.

.Alluvium, Debris The alluvium in the river channel consists of fine sand to boulders about half a meter in diameter. The individual particles are well rounded, consisting of all lithofacies found within the watershed. Debris and residual soil are thick and widespread on all slopes of the valley.

Structure

Three major and several minor faults have been mapped or inferred within the project site. The major faults are Bulangit fault, trends north-south in east of damsite; San Roque fault, runs NE-SW along the left abutment of the dam; and a branch of San Manuel fault which follows the southwestern face of the left bank of Lower Agno River. The minor faults show mainly NE-SW trend, that is subparallel to the San Roque fault.

(3) Engineering geology

Damsite

The San Roque damsite is underlain by mainly diorite complex, diorite to quartzdiorite, and partly metavolcanics and metasediments. Hard and Sound rock exists at around 30 meters depth from the surface in both abutments, and watertightness improves with depth. Therefore, cement grouting will be necessary in both abutments.

The alluvium at the damsite is 19.5 meters thick at maximum. These gravel blanket is considered to be totally pervious and some impermeabilization measures should be taken for the dam foundation.

The damsite is intersected by at least four minor faults. The fault zones are considered to be infilled with clay and silt that constitute impervious screens in the feasibility study report. But the fault zone is generally feared for watertightness, therefore, detail study for faults will be required before construction.

Reservoir

The reservoir will have the shape of a wide lake at the lower part, but follow the shape of a fjord-like artificial lake at upstream. The reservoir is underlain by mainly diorite complex. The rocks of the reservoir area are all impervious.

The reservoir area appears intersected by the main regional faults: San Roque fault, Bulangit fault, Dulong fault, Tayum fault, Tubotob fault, and others of minor importance. In the feasibility study report (Ref. No.), these fault zones considered to form an impervious screen, so the San Roque reservoir will be watertight. The fault zone is generally feared for watertightness so detail study for faults will be necessary.

No landslides or unstable zones were observed along the slopes of the valley. This condition is related and limited to the debris and overburden. Therefore, other consideration will be required for possible instabilities concerning rock masses especially along the fault zones.

(4) Construction materials

Rock for rockfill

The excavations for the spillway where diorite and metavolcanics-metasediments will be produced in large amounts, may provide all the required rock.

Gravel

The alluvial fan, extended in downstream of damsite, consists of gravels with silt from mine tailing. The thickness of the gravel deposit is substantial and unlimited, but water table level is shallow.

Fines for core

Clay deposits have been found in both sides of the Agno valley: Bobon and Bombaya areas on the right side and San Felipe area on the left side. The mother rock of residual soil is the Klondyke Formation, and the thickness of the clayey material is very thin only a few centimeters.

(5) General assessment

The San Roque damsite is comparatively in good condition from physiographical and geological viewpoint, but further investigation for characteristics of faults is required. If the San Roque dam is fill-type dam, further investigation for fine materials is also required, because residual clayey soil is probably a small quantity.

3.1.2 Lower Ambayoan Damsite

(1) General Description

The Lower Ambayoan damsite is located on the Ambayoan River about seven kilometers north-northeast of San Nicolas, eastern Pangasinan. Access to the damsite from San Nicolas is by 2.5 kilometers of paved road and 5 kilometers jeep trail.

This damsite has been considered to be only site inventory in Irrigation Development Plan (IDP).

(2) Site Geology

The geological map (1:50,000 in scale) and geological data of the Lower Ambayoan damsite are shown in Fig. 3.2 and Table 3.2.

<u>Physiography</u>

The Lower Ambayoan damsite area is located in the southern piedmont of the Cordillera Mountains. The damsite is situated in the Ambayoan River valley about four kilometers from the edge of the Pangasinan Plain.

The Ambayoan River flows southward straightly, and the valley shows similar shape. The slope of mountain is comparatively steep. A lot of small tributaries pour into the Ambayoan River from right and left bank.

<u>Stratigraphy and Lithology</u>

The stratigraphic sequence at the site is listed below in order of decreasing age, followed by a lithologic description.

- Jurassic to Eocene : Metavolcanics-Metasediments
- Recent : River deposits, Debris

.<u>Metavolcanics-Metasediments</u> The damsite area is underlain by Dulupirip schist, the oldest rock in the Agno river basin Dulupirip Schist at the damsite consists of schistosed green rock (green schist) and slightly altered diabase. This schistosed green rock is considered to be of diabase origin.

.River deposits, Debris The river deposits consists of mainly gravel with sand. Debris and residual soil are widespread on all slopes of the valley.

Structure

Schistosity of riverbed's rock strikes N70°E, dipping 85° southeastward, and that of right bank's rock strikes N60°W, dipping 82° southwestward. The major fault of N-S trend is inferred along the Ambayoan River.

(3) Engineering geology

Damsite

The Lower Ambayoan damsite is mainly underlain by metavolcanics. This metavolcanics consists of schistosed green rock and diabase that is slightly altered. The former is distributed at the riverbed, and the latter at the riverside. Weathered rock is considered to be about 10 meters thick at the mountainside. River deposits is composed of gravel with sand, and considered to be 20 to 30 meters thick. This river deposits is totally pervious.

The damsite is possibly intersected by a major fault. This fault is inferred along the Ambayoan River, because of the different trend of schistosity at the riverbed and the right bank. Investigation for characteristics of fault would be required.

Reservoir

The reservoir will have the shape of long and narrow lake spread north to south. The reservoir is underlain by mainly metavolcanics and metasediments, and these rocks are considered to be impervious.

The reservoir area is possibly intersected by major fault. This fault is inferred along the Ambayoan River, trending almost N-S.

One landslide was identified by study of aerial photographs and topo map of 1:50,000 in scale. This landslide is situated at the left bank about 1.4 kilometers north of damsite. The landslide mass is in stable condition, but soil removal work for upper part of mass is required for preventive measures.

(4) Construction materials

Rock, coarse aggregates

Aggregates could be extracted from the rock quarry site at the both abutments and/or at the mountain foot near the damsite.

Sand, gravel

Abundant gravel and sand deposits are available in the riverbed both upstream and downstream of the damsite.

Impervious material

There are three potential material sources located near the dam site area. Residual clayey soil may be available at both sides of the abutment ridges and hilly area of right bank about two kilometers downstream of the damsite. The landslide area is also expected to have a deep weathered soil and will be useful for construction materials.

(5) General assessment

The Lower Ambayoan damsite is good condition from physiographical and geological viewpoint. A investigation for damsite and reservoir, especially concerning inferred fault and weathering at the abutments is required, because no investigation has been carried out. It is also necessary to investigate the characteristics of landslide and construction materials.

3.1.3 Lower O'Donnell Damsite

(1) General Description

The Lower O'Donnell damsite is located on the O'Donnell River about twelve kilometers southwest of Tarlac. Access to the damsite from Tarlac is by 2 kilometers of paved road, 3 kilometers of unpaved road, 7 kilometers of dirt road on dike and 3 kilometers of foot trail.

This damsite has been considered to be only site inventory in IDP, as same as the Lower Ambayoan damsite.

(2) Site Geology

The geological map (1:50,000 in scale) and geological data of the Lower O'Donnell damsite are shown in Fig. 3.3 and Table 3.3.

Physiography

The Lower O'Donnell damsite is located in the eastern piedmont of the Zambales Mountains. The damsite is situated at narrow valley in the downstream of O'Donnell River, that is formed by low ridges of cuesta ranging from north to south.

Alluvial plain is widespread both at upperstream and downstream of the damsite. The O'Donnell River gently meanders northeastward in the alluvial plain, jointing the Bangat River about 2.5 kilometers southwest of the damsite.

Two potential saddle dam sites are identified in the reservoir area. An open low divide (ridge) of which elevation is less 100 meters, exists about 4.5 kilometers west-northwest of the damsite. Another low ridge is identified at about one kilometer south of the damsite, based on the reconnaissance by helicopter and study of aerial photographs.

Stratigraphy and Lithology

The stratigraphic sequence at the site is listed below in order of decreasing age, followed by a lithologic description.

- Early Miocene : Interlayered sandstone, siltstone and conglomerate
- Middle Miocene : Interlayered sandstone and siltstone
- Pleistocene : Basaltic to dacitic flows and pyroclastics, Andesitic to dacitic lava domes
- Recent : Alluvium, Debris

. Interlayered sandstone, siltstone and conglomerate This lithofacies called the Moriones Formation, is distributed in southern and western partial area of O'Donnell and near the open low ridge by the Moriones River basin.

.<u>Interlayered sandstone and siltstone</u> This lithofacies called the Marinta Formation, is distributed in the eastern hilly area. The damsite is included in this area, and the formation dips eastward gently.

.<u>Basaltic to dacitic flows and pyroclastics</u> This lithofacies is widespread at northwest and south area of O'Donnell.

.<u>Andesitic to dacitic lava domes</u> These lava domes are distributed near O'Donnell forming isolated mountains or steep mountainous bodies.

.<u>Alluvium, Debris</u> Alluvium, the river deposits, consists of predominantly sand and fine gravel at the surface, but the log of drill hole near O'Donnell indicates that the lower section is predominantly cobbles and boulders. All materials is from volcanic sources. Debris and residual soil are distributed on the foot and the surface of slopes.

<u>Structure</u>

The eastern hills show a 20 to 25 degrees eastwardly dipping homocline that has been eroded into cuestas or hogbacks. No major fault and landslide are identified in the damsite area.

(3) Engineering geology

<u>Damsite</u>

The Lower O'Donnell damsite will be limited to 100 meters in height, owing to the height in hilly areas. The left abutment is composed of sandstone, which is well exposed in a river cut. This sandstone is well-bedded, composed of fine, medium and coarse sandstone. The coarse sandstone partly includes the gravel of 2 to 10 millimeters in diameter.

The bedding strikes N-S to N30^{o}E, and dips 20 to 26 degrees eastward. The bedding of the damsite's cross section is almost horizontal, because it is similar trend to the dam's axis. Weathering of the sandstone is considered to be not so deep, may be 1 to 3 meters deep. Permeability may be rather high along the cracks of sandstone.

Alluvium is considered to be about 20 meters thick, and consists of predominantly sand.

Reservoir

The reservoir is underlain by mainly Alluvium, Morinta Formation and Moriones Formation. No major faults and landslides were identified in the area.

Major problem in the reservoir is water leakage from the low saddles. These low saddles exist at least at two points, one is an open low divide about 4.5 kilometers west-northwest of the damsite, and the other is low ridge about one kilometer south of the damsite. The saddle dams are required at these areas.

(4) Construction materials

Rock, Coarse aggregates

Aggregates could be obtained from the rock quarry sites of isolated small mountains, that are within 3 kilometers north to west of O'Donnell. These rocks are composed of Andesite and dacite.

Sand

Abundant sand deposits are available in the riverbed both upstream and downstream of the damsite.

Gravel

Gravel materials is presumed to be available in the terrace deposits near Santa Juliana, about 13 kilometers southwest of the damsite.

Impervious material

Clay material is surely present in the lowland area extending southwest of the confluence of the O'Donnell and Moriones River, according to the Moriones damsite study in IDP. This lowland area is located about 7 kilometers northeast of the damsite, but more southern close area along the O'Donnell River is supposed to be composed of clay materials. Clay material is of terrace deposits.

(5) General assessment

The Lower O'Donnell damsite is in good acceptable condition from physiographical and geological viewpoint. Maximum height of the dam is limited to 100 meters in elevation, owing to the topography of the damsite area. Major problem in the reservoir is expected reservoir water leakage from the low saddles that show less 100 meters in elevation. At least two saddle dams are required at these area. The geological survey for damsite and reservoir should be investigated in detail.

3.1.4 Balog-Balog Damsite

(1) General description

The Balog-Balog damsite is located on the Bulsa River approximately 30 kilometers west of Tarlac, Tarlac Province. Access to the damsite from Tarlac is by 3 kilometers of paved road, 20 kilometers of rugged unpaved road (partly paved road under construction) and 10 kilometers of new unpaved construction road for the Balog-Balog damsite.

Feasibility study of the Balog-Balog Project has been prepared by ELC in July 1980, and the dam is now under construction.

(2) Site geology

The geological map (1:50,000 in scale) and geological data of the Balog-Balog damsite are shown in Fig. 3.4 and Table 3.4.

<u>Physiography</u>
The Balog-Balog damsite is situated about one kilometer south of Balog-Balog. In the vicinity of the damsite the Bulsa River flows almostly northward, but the Bulsa flows eastward on the whole. One of major tributary that meanders northward joints the main river 2 kilometers south of the damsite, and another small major tributary that flows eastward meets the Bulsa just 200 meters south of the damsite.

Thin mountain ridges and saddleback are often recognized in the damsite area. The trend of mountain ridges shows irregular shape.

Stratigraphy and Lithology

The stratigraphic sequence at the site is listed below in order of decreasing age, followed by a lithologic description.

- Cretaceous to Early Eocene : Gabbro
- Late Oligocene : Quartz diorite, Diorite
- Pleistocene : Andesite, Terrace deposits
- Recent : River deposits, Debris

.Gabbro Gabbro is one of main lithofacies of Zambales Ultramafics, distributed in the western area. No other lithofacies of Ultramafics, such as dunite or peridotite, is identified in the damsite area.

.Quartz diorite, Diorite This lithofacies is the most extensive formation in the area. It underlies the damsite and most part of the reservoir. In general, quartz diorite or diorite is in depth a sound, moderately hard rock.

.Andesite The andesite is distributed in the northeastern part of the reservoir near the damsite. It outcrops on both sides, especially widespread at the right bank. The andesite is light gray, hard and sound rock.

.Terrace deposits The terrace deposits, forming the wide plains along the meanders of the Bulsa River, are mainly composed of well compacted silty sandy gravel with boulders.

.River deposits, Debris River deposits consist of unconsolidated sandy gravel deposits, rich in boulders. This river deposits is on the average five meters thick, along the river channel at the damsite. Debris and residual soil are distributed on the foot and the surface of slopes.

Structure

In the area, the following two main sets of major faults have been identified:

- the NE set which steeply dips to the SE
- the NW set which steeply dips to the NE and SW

And some minor landslides are identified in slopes mainly along the tributaries.

3.1.5 Moriones Damsite

(1) General description

The Moriones damsite is located on the Moriones River about 9 kilometers west of Tarlac, Tarlac Province. Access to the damsite from Tarlac is by 8.5 kilometers of paved road, 1.5 kilometers of dirt road and 1.5 kilometers of foot trail.

This damsite has been evaluated as alternative site for irrigation system in the Balog-Balog feasibility study.

(2) Site geology

The geological map (1:50,000 in scale) and geological data of the Moriones damsite are shown in Fig. 3.5 and Table 3.5.

<u>Physiography</u>

The Moriones damsite is located in the eastern piedmont of the Zambales Mountains, about 5.5 kilometers north of the Lower O'Donnell damsite. The damsite is situated on the narrow valley, that is formed by low ridges of cuesta trending N-S to NW.

Alluvial plane is extremely widespread at upperstream of the damsite. The Moriones River gently flows eastward and meanders near the damsite. The morphology of the reservoir is flat and large with gentle and open slopes, except sporadical isolated steep mountains at the right bank in the upper reservoir.

An open low divide toward the south into the O'Donnell River drainage that shows 100 meters in elevation, exists about 6.5 kilometers southwest of the damsite. And some open ridges of less 100 meters in elevation, are present within one kilometer of the damsite. Furthermore a thin ridge of 100 meters in elevation exists about 1.3 to 2 kilometers south-southwest of the damsite.

Stratigraphy and Lithology

The stratigraphic sequence at the site is listed below in order of decreasing age, followed by a lithologic description.

- Early Miocene : Interlayered sandstone,siltstone and conglomerate
- Middle Miocene : Interlayered sandstone and siltstone
- Pleistocene : Basaltic to dacitic flows and pyroclastics, Andecitic to dacitic lava domes
- Recent : Alluvium, Debris

.Interlayered sandstone, siltstone and conglomerate This lithofacies called the Moriones Formation, is most widespread formation in the area. This formation is overlaid and penetrated with Quaternary volcanics and plugs in the southwestern area, and overlaid with the Marinta Formation, described hereinafter, in the eastern area.

.Interlayered sandstone and siltstone This lithofacies called the Marinta Formation is distributed in eastern to northeastern area. The damsite is situated in this formation's area. The formation dips eastward to northeastward as much more north area.

.Basaltic to dacitic flows and pyroclastics This lithofacies is distributed in the southwestern area, overlying the Moriones Formation.

.Andesitic to dacitic lava domes These lava domes are distributed in the right bank of the Moriones River, forming steep mountainous bodies.

.Alluvium, Debris Alluvium that is widespread along the river, is composed of predominantly sandy materials. No areas of fines are identified, but impervious material is probably present in some rice areas. Recent river deposits are composed of sand to cobble and boulder. Debris and residual soil are distributed on the foot and the surface of slopes.

Structures

The Marinta Formation shows a 20-degree eastwardly (to northeastwardly) dipping homocline that has been deeply eroded into cuestas or hogbacks. The fold structures are identified in the Moriones Formation. No major faults are identified in the damsite area, except in the upper reservoir area.

(3) Engineering geology

Damsite

The Moriones damsite will be limited to 100 meters in elevation, owing to the height of regional mountain ridges. The left abutment is composed of sandstone, which is well exposed in a river cut. A saddle of right bank about 800 meters upperstream of damsite, is underlain by impermeable clay with at least 3 meters thick, that is considered to be Quaternary lake deposit.

Permeability of the weathered bed rock is considered to be rather high along the bedding plane and crack zone of sandstone. It is estimated that the depth of alluvium is about eight meters at the damsite.

Reservoir

The reservoir will have a extremely large lake spread east to west. The reservoir is underlain by mainly marine clastics and partly intrusive rocks, and these rocks are considered to be impervious.

No major faults and landslide are identified, except NE-trend faults in the upper reservoir that may not cause a major problem.

Major problem in the Moriones reservoir is water leakage from some open ridges near the damsite, and an open wide low divide at 6.5 kilometers southwest of the damsite. In these areas saddle dams are required. Blanketing or grouting will be necessary at the thin ridge of 100 meters in elevation that is 1.3 to 2 kilometers south-southwest of the damsite.

(4) Construction materials

Rock, Coarse aggregates

Andesite will be obtained from mountain plug about 2 kilometers west of Moriones. Rock quality is hard to very hard.

Sand and Gravel

The river channel is an abundant source of gravel and sand, whose material is a mixture of ultramafic and mafic igneous rock and volcanic rock.

Impervious material

Clay material is present in the low land area extending southwest of the confluence of the Moriones and O'Donnell River. This low land area is located about 4 kilometers east of the damsite. Clay material is of terrace deposits.

(5) General assessment

The Moriones damsite is good or acceptable condition from physiographical and geological viewpoint. Maximum height of the dam is limited to be 100 meters in elevation, owing to the topography of the damsite area. Major problem in the reservoir is water leakage from low saddles that show less 100 meters in elevation. The saddle dams, at least five dams, are required at these area; and the investigation should be examined in detail. The geological survey for damsite and thin ridge of 100 meters in elevation, located 1.3 to 2 kilometers south-southwest of the damsite, also should be examined.

3.1.6 Camiling Damsite

(1) General description

The Camiling damsite is located on the Camiling River about 19 kilometers southwest of Camiling. Access to the damsite from National Highway No. 13 is by 4.5 kilometers of paved road (under repair), 9 kilometers of unpaved road and 4 kilometers of foot trail.

This damsite is recommended site for development in IDP.

(2) Site geology

The geological map (1:50,000 in scale) and geological data of the Camiling damsite are shown in Fig. 3.6 and Table 3.6.

Physiography

The Camiling damsite is located in the eastern Zambales Mountains. The Camiling River flows northeastward in main Zambales Mountains, and after jointing the major tributary at 3 kilometers upstream of the damsite, it meanders eastward forming comparatively wide valley.
The mountain ridges extend with irregular form, and slopes show steep to very steep degrees. Some major landslides are identified in the slopes along the Camiling River and its tributaries.

Stratigraphy and Lithology

The stratigraphic sequence at the site is listed below in order of decreasing age, followed by a lithologic description.

- Cretaceous Early Eocene : Gabbro, Peridotite, Diabase dyke complex
- Late Oligocene : Quartz diorite, Diorite
- Recent : River deposits, Debris

.Gabbro, Peridotite, Diabase dyke complex This lithofacies called the Zambales Ultramafics is most widely spread in the area. The gabbro is a dense and homogenous mass having a relatively high specific gravity. The gabbro is most common widespread rock in the area. The peridotite is a massive to layered rock, distributed in the western area along the Camiling River. This peridotite is generally serpentinized. The Diabase dyke complex is distributed in the eastern area of the damsite.

.Quartz diorite, Diorite This local lithofacies as same as Balog-Balog diorite is distributed in the limited area about 1.8 kilometers upstream of the damsite.

.River deposits, Debris River deposits is composed of extensive gravel with sand. Debris and residual soil are distributed on the foot and the surface of slopes.

Structure

Some minor faults trending NE are identified by the review of aerial photographs, and a minor E-W trending fault is possibly exist at the ridge of right abutment. Major landslides are also identified at the slopes along the Camiling River and its tributaries by the aerial photographs. These landslides occurred in the Peridotite rock area.

(2) Engineering geology

Damsite
Bedrock at the damsite is a massive gabbro formation. This rock is impermeable and has a high compressive strength. A minor fault trending E-W is inferred at the back ridge of the right abutment.

Reservoir
The reservoir will have a fjord-like lake of about 6.5 kilometers long. The reservoir is underlain by ultramafics, mainly gabbro and peridotite, and these rocks are considered to be impervious. No major faults are identified, except some NE trending minor faults. Some major landslides exist in the reservoir will be subject to preventive measures.

(4) Construction materials

Abundant quantities of sand, gravel and earthfill materials are available in the immediate area of the damsite. Suitable riprap can be obtained by quarrying the nearby site composed of gabbro or quartz diorite.

(5) General assessment

The Camiling damsite is considered to be acceptable condition from physiographical and geological viewpoint. Some major landslides are present in the area, a few of them exist in the reservoir. These will require costly preventive measures, but it maybe be difficult from economical viewpoint. Investigations for geological conditions of damsite and characteristics of landslides and faults, should be reviewed.

3.2 Geological Problems

Geological problems of six proposed damsites are described hereinafter:

3.2.1 Damsite

The most problem of proposed damsites is water leakage by fault zone. The San Roque and Balog-Balog damsites, which the feasibility study was completed by ELC, are considered to have no problem of water leakage by fault or shear fracture zone, because clay materials constitute impervious zone. Usually the fault zone has a problem of water leakage, so it is difficult to consider the fault zone to be impervious zone. Therefore, further investigations for characteristics of faults are required before design and construction.

Damsites such as the Lower Ambayoan, Lower O'Donnell, Moriones and Camiling, are recommended for a geological investigation for rock stability and faults.

3.2.2 Reservoir

Geological problems of reservoir are mainly divided into two items, water leakage and landslides.

(1) Water leakage

The most major problem in the reservoir is water leakage from low ridges. These problems occured in the Lower O'Donnell and Moriones reservoirs. An open low divide which is located between Moriones reservoir and Lower O'Donnell reservoir, is no problem if two damsites are constructed, but a big sub-dam will be required if only one damsite is adopted. Another low ridges in succession of damsite's ridges are located in the both damsites. At least five sub-dams in the Moriones reservoir, and two sub-dams in the Lower O'Donnell damsite, are required.

The other reservoirs probably have no problem of water leakage, because rocks in each reservoir are considered to be watertightness.

(2) Landslide

One of major problem is landslides in the reservoirs. These landslides are identified in the Camiling and Lower Ambayoan reservoirs by study of aerial photographs.

The Camiling damsite area especially has many obvious and less obvious landslides, and some lower part of them are under water of reservoir. The landslides will occur to slip, because water permeate into landslide masses. Effective countermeasure for landslides is piling works, but it may be difficult from economical viewpoint.

One minor landslide is situated in the left bank of the Lower Ambayoan reservoir, and soil removal work for upper part of landslide mass is required for preventive measures.

(3) Others

Other problem is compensation for houses that submerged in the reservoir. The San Roque and Balog-Balog reservoirs have no house, the Camiling and Lower O'Donnell reservoirs have a little houses, and the Lower Ambayoan and Moriones reservoirs have many houses.

4. GEOLOGICAL ASSESSMENT FOR DIKE

4.1 Landform of Pangasinan

4.1.1 Description of Landform

Landform map of the Pangasinan Plain is shown in Fig. 4.1. The Pangasinan Plain is roughly divided into two landscapes, one of which is coastal and the other is alluvial. Coastal landscape is divided into four items, that are active tidal flat, old tidal flat, beach ridges and beach lines. These are shown in Fig. 4.1 as physiographic mapping No. 1 to 4. Within this four items old tidal flat is not distributed in the STUDY area. Three other items are distributed in the northwestern area of the Pangasinan Plain, near the Lingayen Gulf.

Alluvial landscape is divided into nine items, shown in Fig. 4.1 as No. 5 to 13. Within these items, No. 11 and 13 are not distributed in the Study Area. therefore six items are present in the area, that are braided river, river terrace, river levee, abandoned river channel, broad alluvial plain and alluvial fan. The sequence of No. 5, 8, 9, 10, 7, 6, 12 is considered to be an order of high elevation of landform.

4.1.2 Soil Materials of Each Landform

Soil materials that constitute each landform are considered to be as follows:

- Active tidal flat (No. 1)	: sand with minor silt
- Beach ridges (No. 3)	: sand
- Beach lines (No. 4)	: sand
- Braided river (No. 5)	: gravel and sand with minor silt
- River terrace (No. 6)	: gravel and sand
- River levee (No. 7)	: sand
- Abandoned river channel (No.8)	: gravel, sand with silt
- Broad alluvial plain (No. 9a)	: silt with sand
- " (No. 9b)	: silt with minor sand
- " (No. 9c)	: organic clay and silt
- Intermediary valleys (No. 10)	: Sand with gravel and silt

- Alluvial fan (No. 12) : gravel with sand

4.1.3 Foundation of Proposed Dike

Dike system is proposed along the Agno River, Tarlac River and Poponto Swamp.

The proposed dike along the Agno River, upper stream from Bayambang, will be constructed on the surface of braided river or river terrace or river levee. These foundations of dikes are considered to be composed of gravel and sand with minor silt. We anticipate no problem of ground subsidence to occur.

The proposed dike along the Agno River, downstream from Wawa, will be constructed on the surface of mainly broad alluvial plain, number of which are 9b and 9c. They are composed of silt with sand and organic clay, therefore, somewhat problem of consolidation settlement will occur in certain area. The foundation of dike in fish pond area at the mouth of the Agno River consists of sandy materials, that may cause quicksand or piping actions.

The proposed dike in the Popont Swamp will be constructed on the surface of swampy area that is composed mainly of organic clay and silt with little sand. We expect settlement and destruction to occur.

4.2 Broken Dike in Downstream of San Roque

4.2.1 Transition of the Broken Dike

The exesting dike in the downstream of the proposed San Roque damsite was constructed about thirty years ago. The dike location have changed three times. The location of old dike and existing dike only, is shown in Fig. 4.2.

The old dike which was constructed in the early 1960's, was destroyed. The second like location was moved about 150 meters westward, and finally the last existing dike was built about 300 meters west of the old dike.

4.2.2 Geological Description for Broken Dike

This dike which was destroyed so many times is composed of clay with some sand. The cause of the destruction was the swift velocity of the Agno River at flooding time and of narrow width of river channel.

The exesting dike which was partially destroyed in the vicinity of San Vicente and Calanution is composed of mixed sand and gravel, that it is hard to endure the velocity power of the river.

4.3 Dike Construction Materials

4.3.1 Location and Characteristics of Materials

Dike construction materials were located at the following two sources: the plain area and the hilly areas respectively. These are described hereinafter:

(1) Materials of plain area

Materials of braided river and river terrace are mixture of major gravels and sand, and those of broad plain are mainly silt with minor sand and clay. The existing dike material was reported to be taken from the braided river (No. 5) in the plain area, which is a poorly graded mixture of sand and gravel.

(2) Materials of hilly area

Some place in the vicinity of the Agno River are underlain by sedimentary rocks that are sandstone, siltstone and conglomerate. These rocks probably include fine to coarse materials because of weathering. The hilly area west of San Roque (Fig. 4.3) is composed of diluvial terrace deposits. These terrace deposits maybe also include the fines with gravel and sand because of weathering.

4.3.2 Assessment for Construction Materials

The granular material that consists of sand and gravel with a negligible content of fines is considered not suitable for dike construction. In order to get well graded soil materials blend of cleyey soils (broad alluvial plain; 9a, 9b) and sandy materials (river terraces;6 or braided river;5) will be necessary.

Materials from hilly area, which are weathered sedimentary rock and terrace deposits are suitable for construction materials except tuffaceous materials. If the ultramafic rocks at the foot of the Zambales mountains are deeply weathered, these may be suitable for dike construction The proposed hilly borrow areas for construction materials are shown in Fig. 4.3.

TABLES

Table 2.1 STRATIGRAPHY OF NORTH LUZON ISLAND

GEOLOGIC TIME					Luzon Central Cordillera	Luzon Central Plain (West Side)	Zambales Range
MILLION YEARS	ERA	PERIOD	EPOCH	AGE			
	CENOZOIC	QUATERNARY	HOLOCENE		QUATERNARY ALLUVIUM TERRACE GRAVEL	QUATERNARY ALLUVIUM	TERRACE GRAVEL
.01			PLEISTOCENE	LATE	AWIDEN MESA FORMATION / QUATERNARY VOLCANICS	* QUARTENARY VOLCANICS RAMBAN FORMATION	* QUATERNARY VOLCANICS * QUARTENARY PLUGS
				EARLY			
1.8		TERTIARY	PLIOCENE	LATE	ROSARIO FORMATION	SANSOTERO LIMESTONE	
				EARLY			
5.0			MIOCENE	LATE	ANDESITE DIKES KLONDYKE FORMATION	TARLAC FORMATION	STA. CRUZ FORMATION
				MIDDLE	KENNON FORMATION	MALINTA FORMATION	ZAMBALES FORMATION
				EARLY	BALATOC PLUG / BLK. MT. PORPHYRY ZIGZAG FORMATION	MORIONES FORMATION	
22.5			OLIGOCENE	LATE	AGNO BATH. TINES FORMATION		* BALOS-BALOS DIORITE
				EARLY			
38.0			EOCENE	LATE	LICUAN GROUP	AKSITERO FORMATION	AKSITERO FORMATION
				EARLY			** ZAMBALES OPHIOLITE (CHERT-SPILITE)
55.0			PALEOCENE	LATE			
				EARLY	DALUPIRIP SCHIST		** ZAMBALES ULTRAMAFICS (GABBRO, PERIDOTITE DIABASE DYKE)
65.0	MESOZOIC	CRETACEOUS		LATE			
				EARLY			
141		JURASSIC		LATE			
				MIDDLE			
				EARLY			
195							

Source : Refer to No. GL.001 (B.M.G. 1981)

Remarks : (1) The description with "*" is supplemented based on the text of the original source.

(2) The description with "* *" is modified based on the text of the original source.

Table 3.1 Geological Data of San Roque Damsite

Damsite No.	1	Dam's Name	San Roque Damsite
Province	Pangasinan	River	Agno River

Topography				
	Height of Crest	EL. 320 m	Height of River Bed	EL. 100 m
	Width of River Bed	200 m	Dam's Possible Height	200 m
	Location of Dam Axis	(Narrow . [Medium]. Wide .) Valley		
	Reservoir	(Very Large . [Large]. Medium . Small)		
	Notes	. Agno River meanders in Reservoir Area . Mountain slope is steep . Old River Channel can be seen at 2-3km northeast of damsite		

Geological Formation & Age of Damsite	. Dalupirip Schist (Jurassic to Eocene) - Metavolcanics and Metasediments . Agno Batholith (Oligocene or Early Miocene) - Diorite and Quartz diorite . Klondyke Formation (Late Miocene) - Conglomerate with minor Sandstone and Shale

	Damsite	Reservoir	
Rock Type and Age of Bed Rock	. Diorite - Quartz diorite (Early Miocene) - Mainly . Metavolcanics - Metasediments (Cretaceous to Palaeogene)-Partly	Lithology and Age	. Diorite, Quartz diorite (Early Miocene)
Rock Quality	. Hard and slightly weathered rock with thin debris cover - both abutments . Fresh rock exists around 30 m depth	Geologic Structure (Fault Fold Landslide)	. Many major faults (NE - SW, NW - SE trend) . No landslide
Geologic Structure	. Four minor faults (mainly N-S trend, partly E-W trend)	Slope Stability	. Probably stable
Permeability	. High to very high . Cement grouting will be necessary in both abutments	Permeability & Ground Water	. San Roque reservoir will be waterlight
Overburden	. Residual clay deposit at right abutment (3.5 m in thickness) . Thich river deposits (Max.19.5 m in thickness)	Sedimentation	. Less

Construction Materials			
	Rock & Coarse Aggregates	Location	. Large excavations for spillway . Alluvial fan of Pangasinan Plain
		Rock Type	. Diorite - Quartz diorite . Metavolcanics - Metasediments . Gravel
		Quality & Volume	. Hard to very hard
	Sand Material	Location	————
		Quality & Volume	————
	Impervious Material	Location	. Right side of Agno Valley (at foot of hills in bobom and bambdaya areas)
		Soil Type	. Clay deposits
		Quality & Volume	. Residual soil of conglomerate and sandstone

General Assessment						
	Damsite	Good	Reservoir	Good	Dam Construction Materials	Good
	Notes	Further investigation for characteristics of faults will be required.				

Table 3.2 Geological Data of Lower Ambayoan Damsite

Damsite No.	2	Dam's Name	Lower Ambayoan Damsite
Province	Pangasinan	River	Ambayoan River

Topography				
	Height of Crest	EL. 400 m	Height of River Bed	EL. 125 m
	Width of River Bed	280 m	Dam's Possible Height	150 m
	Location of Dam Axis	(Narrow . Medium . [Wide] .) Valley		
	Reservoir	(Very Large . Large . [Medium] . Small)		
	Notes	. Ambayoan River flows southward straightly		

Geological Formation & Age of Damsite	. Dalupirip Schist (Jurassic to Eocene) - Metavolcanics and Metasediments

Damsite		Reservoir	
Rock Type and Age of Bed Rock	. Metavolcanics ... Schistosed green rock (diabase origin) - right bank and river bed . Diabase - left bank	Lithology and Age	. Metavolcanics - Metasediments (Jurassic to Eocene)
Rock Quality	. Hard to very hard with thin debris cover - riverbedside of left bank . Rather hard - riverbed and riverbedside of right bank	Geologic Structure (Fault Fold Landslide)	. Major fault that trends N-S is inferred along Ambayoan River . One minor landslide
Geologic Structure	. Schistosity (river bed) strikes N70 E, and dips 85 southeastward . Schistosity (right bank) strikes N60 W, and dips 82 southwestward . Fault (N-S trend along the river) is inferred	Slope Stability	. Probably stable except landslide area
Permeability	. Probably high to very high	Permeability & Ground Water	. Probably watertight
Overburden	. Residual clay deposits . Thick river deposits	Sedimentation	. Less

Construction Materials			
	Rock & Coarse Aggregates	Location	. Both abutments . Mountain foot near damsite
		Rock Type	. Metavolcanics
		Quality & Volume	. Hard
	Sand Material	Location	. Riverbed both upstream and downstream
		Quality & Volume	. Abundant
	Impervious Material	Location	. Ridges of bothside . Right bank 2 km downstream
		Soil Type	. Clay
		Quality & Volume	. Residual soil of Metavolcanics or terrace deposits

General Assessment						
	Damsite	Good	Reservoir	Good	Dam Construction Material	Good
	Notes	A investigation for damsite and reservoir is required				

Table 3.3 Geological Data of Lower O'Donnell Damsite

Damsite No.	3	Dam's Name	Lower O'Donnell Damsite
Province	Tarlac	River	O'Donnell River

Topography	Height of Crest	EL. 110 m	Height of River Bed	EL. 75 m
	Width of River Bed	200 m	Dam's Possible Height	35 m
	Location of Dam Axis	([Narrow] . Medium . Wide .) Valley		
	Reservoir	([Very Large] . Large . Medium . Small)		
	Notes	. Reservoir is very large alluvial plain . Open low divide at 4.5 km west-northwest of dam (less EL. 100 m) . Low ridge at 1 km southward of dam axes		
Geological Formation & Age of Damsite	. Moriones Formation (Early Miocene) - Interlayered sandstone, siltstone and conglomerate . Malinta Formation (Middle Miocene) - Interlayered sandstone and siltstone . Quaternary Volcanics (Pleistocene) - Basaltic to dacitic flows,and pyroclastics . Quaternary Plug (Pleistocene) - Andesitic to dacitic lava			

Damsite		Reservoir	
Rock Type and Age of Bed Rock	. Bedded sandstone (Middle Miocene)	Lithology and Age	. Interlayered sandstone, siltstone and conglomerate (Early to Middle Miocene) . Basaltic to dacitic flows, pyroclastics Andesitic to dacitic lavas (Pleistocene)
Rock Quality	. Hard and well-bedded . Fine, medium and coarse sandstone with small gravel (at left bank site)	Geologic Structure (Fault Fold Landslide)	. No major fault . No landslide
Geologic Structure	. Bedding strikes NS to N30 E and dips 20 to 26 eastward	Slope Stability	. Probably stable
Permeability	. Probably watertight except crack zone	Permeability & Ground Water	. Probably watertight . Ground water considered to be low level at open low divide
Overburden	. Partly thin debris cover . Thick sandy river deposit	Sedimentation	. Many (Sandy material)

Construction Materials	Rock & Coarse Aggregates	Location	. Isolated small mountains (within 3 km north to west of O'Donnell)
		Rock Type	. Andesitic to dacitic lavas
		Quality & Volume	. Hard to very hard
	Sand Material	Location	. Riverbed of damsite and upper stream
		Quality & Volume	. River deposits (Medium to coarse sand)
	Impervious Materials	Location	. Hilly area about 2 to 3 km northeast of damsite
		Soil Type	. Sandy clay deposits
		Quality & Volume	. Residual soil of siltstone and sandstone

General Assessment	Damsite	Good/Acceptable	Reservoir	Good	Dam Construction Material	Good
	Notes	Sub-dams are required (at least two dams)				

Table 3.4 Geological Data of Balog-Balog Damsite

Damsite No.	4	Dam's Name	Balog-Balog Damsite
Province	Tarlac	River	Bulsa (Moriones) River

Topography	Height of Crest	EL. 260 m	Height of River Bed	EL. 140 m
	Width of River Bed	160 m	Dam's Possible Height	100 m
	Location of Dam Axis	(Narrow . [Medium]. Wide .) Valley		
	Reservoir	(Very Large . [Large]. Medium . Small)		
	Notes	. Major tributary joins Bulsa river at 2 km south of dam		

Geological Formation & Age of Damsite	. Zambales Ultramafics (Cretaceous to Early Eocene) - Gabbro . Balog-Balog Diorite (Late Oligocene) - Quartz diorite, Diorite . Quarternary Plugs (Pleistocene) - Andesite

Damsite		Reservoir	
Rock Type and Age of Bed Rock	. Quartz diorite (Late Oligocene) . Andesite (Pleistocene) - Partly in right abutment	Lithology and Age	. Diorite complex (Late Oligocene) - Quartz diorite, diorite, diorite porphyry . Andesite (Pleistocene) . Gabbro (Cretaceous to Early Eocene)
Rock Quality	. Hard to very hard but deeply weathered (about 10 to 30 m thick)	Geologic Structure (Fault Fold Landslide)	. Two main faults trending NE-SW, NW-SE . Minor landslides at head-waters of creeks (maybe not under water)
Geologic Structure	. Andesite intrudes into diorite complex . Major fault trending NW and dipping eastward at left side of riverbed	Slope Stability	. probably stable, except minor landslide and minor rock slides along steep banks
Permeability	. Almost watertight except weathered zone	Permeability & Ground Water	. Watertightness is expected
Overburden	. Clayey residual soil	Sedimentation	. Less

Construction Materials	Rock & Coarse Aggregates	Location	. Foot of mountain about 2 km northeast of dam . Riverbed of Bulsa River
		Rock Type	. Andesite (Pleistocene) . Gravel
		Quality & Volume	. Hard to very hard
	Sand Material	Location	. Riverbed of Bulsa River
		Quality & Volume	. River deposits (sand, gravel, boulders)
	Impervious Material	Location	. Clay borrow area (hilly and mountainous area at northeastern area and southern area of dam)
		Soil Type	. Clay
		Quality & Volume	. Clayey residual soil

General Assessment	Damsite	Good	Reservoir	Good / Excellent	Dam Construction Material	Good/ Excellent
	Notes	Further investigation for characteristics of faults is required				

Table 3.5 Geological Data of Moriones Damsite

Damsite No.	5	Dam's Name	Moriones Damsite
Province	Tarlac	River	Moriones River

Topography	Height of Crest	EL. 100 m	Height of River Bed	EL. 60 m
	Width of River Bed	240 m	Dam's Possible Height	40 m
	Location of Dam Axis	(Narrow . Medium . Wide .) Valley		
	Reservoir	(Very Large . Large . Medium . Small)		
	Notes	. Reservoir is extremely large alluvial plain . Open low divide at 6.5 km southwest of dam (less EL. 100 m)		

Geological Formation & Age of Damsite	. Moriones Formation (Early Miocene) - Interlayered sandstone, siltstone and conglomerate . Malinta Formation (Middle Miocene) - Interlayered sandstone and siltstone . Quarternary Plug (Pleistocene) - Andesitic to dacitic lavas

Damsite		Reservoir	
Rock Type and Age of Bed Rock	. Interlayered sandstone and siltstone (Middle Miocene)	Lithology and Age	. Interlayered sandstone, siltstone and conglomerate (Early to Middle sandstone) . Basaltic to dacitic lavas (Pleistocene)
Rock Quality	. Probably rather hard to hard	Geologic Structure (Fault Fold Landslide)	. Some syncline and anticline exist in Moriones Formation . Some minor faults exist at upper reservoir (NE-SW, NW-SE trend) . No landslide
Geologic Structure	. Bedding strikes N-S to N10 W and dips 20 to 30 eastward	Slope Stability	. Probably stable
Permeability	. Probably watertight except crack zone	Permeability & Ground Water	. Probably watertight . Ground water considered to be low level at open low divide
Overburden	. Partly thin debris cover . Thick river deposit	Sedimentation	. Less

Construction Materials	Rock & Coarse Aggregates	Location	. Mountain plug about 2 km southwest of Moriones.
		Rock Type	. Andesite
		Quality & Volume	. Hard to very hard
	Sand Material	Location	. Riverbed of Moriones River
		Quality & Volume	. River deposits (sand, gravel)
	Impervious Material	Location	. Hilly area about 2 km east of damsite
		Soil Type	. Sandy clay deposits
		Quality & Volume	. Residual soil of sandstone and siltstone

General Assessment	Damsite	Good / Acceptable	Reservoir	Good	Dam Construction Material	Good
	Notes	. At least five sub-dams are required				

Table 3.6 Geological Data of Camiling Damsite

Damsite No.	6	Dam's Name	Camiling Damsite
Province	Tarlac	River	Camiling River

Topography				
Height of Crest	EL. 460 m	Height of River Bed	EL. 155 m
Width of River Bed	15 m	Dam's Possible Height	103 m
Location of Dam Axis	([Narrow] . Medium . Wide .) Valley		
Reservoir	(Very Large . [Large] . Medium . Small)		
Notes	. Camiling River meanderes almost eastward and forms wide valley after jointing main tributary		

Geological Formation & Age of Damsite	. Zambales Ultramafics (Cretaceous to Early Eocene) - Gabbro, Peridotite, Diabase dyke complex . Balog-Balog Diorite (Late Oligocene) - Quartz diorite, Diorite

Damsite		Reservoir	
Rock Type and Age of Bed Rock	. Gabbro (Cretaceous to Early Eocene)	Lithology and Age	. Gabbro, Peridotite, Diabase (Cretaceous to Early Eocene)
Rock Quality	. Dense and homogenous mass with relatively high specific gravity	Geologic Structure (Fault Fold Landslide)	. Some major landslides A few are in the reservoir . Minor faults trending NE-SW and NW-SE
Geologic Structure	. Minor E-W trend fault is inferred at right abutment	Slope Stability	. Probably stable except landslide areas . Landslide areas are not stable
Permeability	. Probably watertight except fracture zone	Permeability & Ground Water	. Probably watertight
Overburden	. Thin residual soil with thin debris cover	Sedimentation	. Less

Construction Materials			
Rock & Coarse Aggregates	Location	. Mountain ridge about 2 km northwest of dam
	Rock Type	. Diobase, partly micro gabbro
	Quality & Volume	. Hard to very hard
Sand Material	Location	. Riverbed of Camiling River
	Quality & Volume	. River deposits (sand, gravel)
Impervious Material	Location	. Hilly area about 7 km northeast of dam (about 1 km southwest of San Bartolome)
	Soil Type	. Sandy clay deposit
	Quality & Volume	. Residual soil of sandstone and siltstone

General Assessment					
Damsite	Acceptable	Reservoir	Acceptabe / Poor	Dam Construction Material	Good
Notes	Some major landslides exist in reservoir				

FIGURES

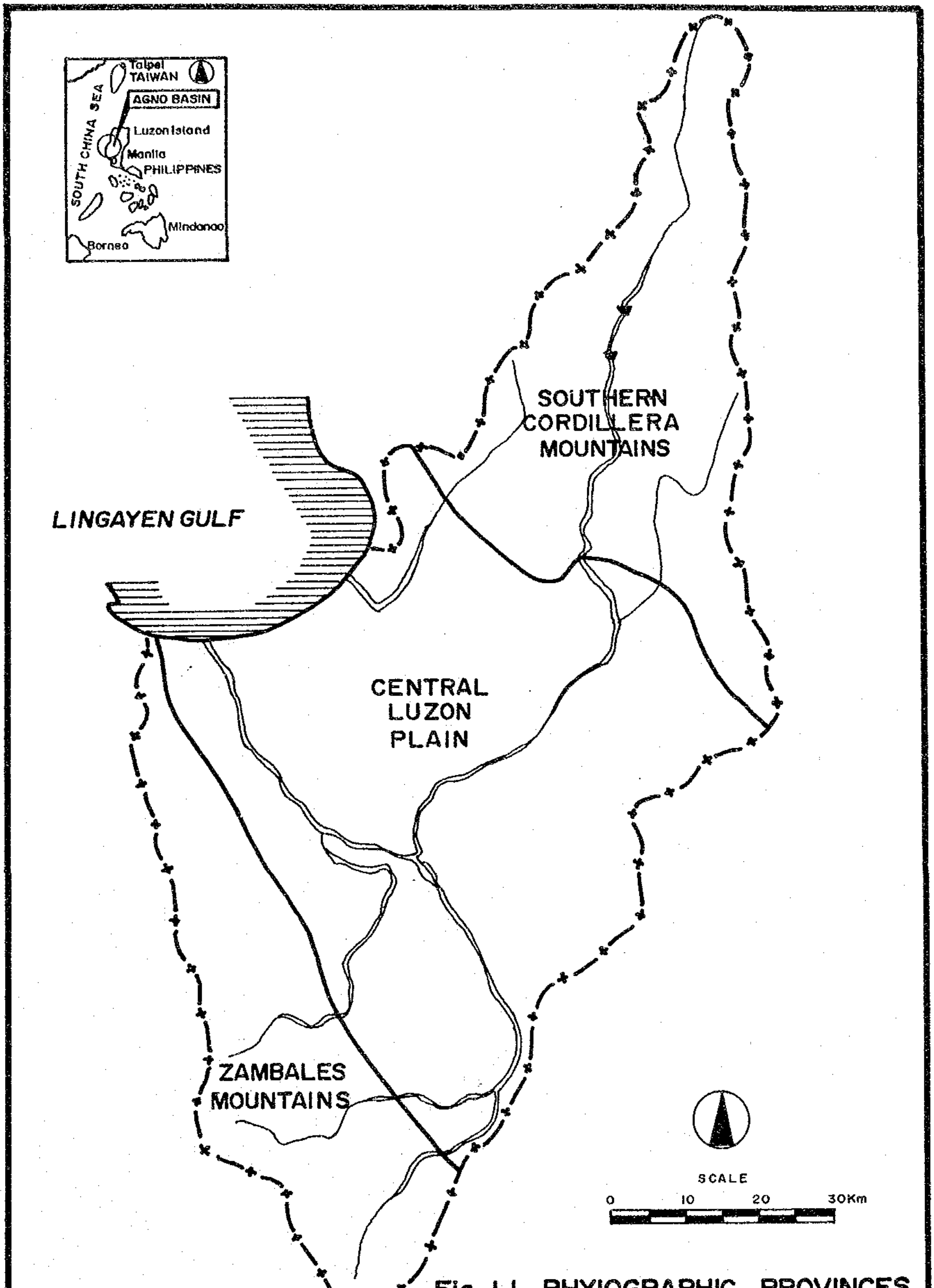

Fig. 1.1 PHYIOGRAPHIC PROVINCES OF THE BASIN

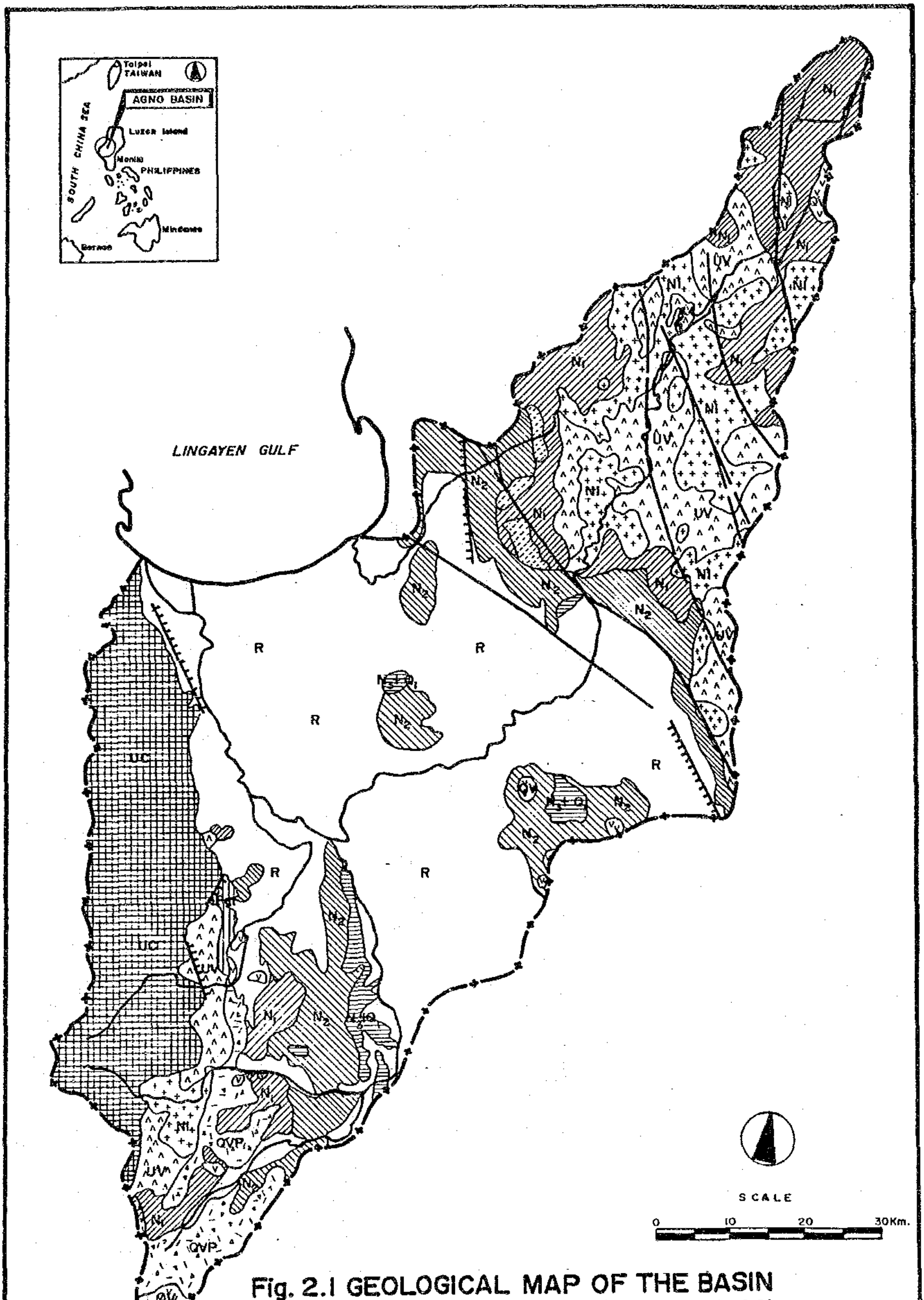

Fig. 2.1 GEOLOGICAL MAP OF THE BASIN

(See Legend in Fig. 2.2)

SEDIMENTARY ROCKS

R	Recent	Alluvium, fluvial and beach deposits.
N_3+Q_1	Pliocene-Pleistocene	Marine and terrestrial sediments, associated with reef limestone.
N_2	Upper Miocene-Pliocene	Largely marine clastics overlain by pyroclastics and tuffaceous sedimentary rocks.
N_1	Oligocene-Miocene	Thick, extensive marine deposits, largely wackes, shales and reef limestone, underlain by conglomerate.
Pg_1	Paleocene-Eocene	Thick, extensive marine deposits largely wackes and shales associated with minor conglomerate and reef limestone.

VOLCANIC ROCKS

QVP	Pliocene-Quarternary	Volcanic plain or volcanic piedmont deposits, chiefly pyroclastics and volcanic debris at foot of volcanoes.
QV	Pliocene-Quarternary	Non-active cones (generally andesite), also dacitic and andesitic plugs.
N_1	Oligocene-Miocene	Mostly submarine andesite and basalt flows, intercalated with pyroclastics and clastic sedimentary rocks.
UV	Undifferen-tiated	Metamorphosed submarine flows, largely spilites and basalts. Often designated as "Metavolcanics". Most units probably Cretaceous and Paleogene.

INTRUSIVE ROCKS

NI	Neogene	Largely Miocene quartz diorite. Mostly batholiths and stocks, include granodiorite and diorite porphyry facies.
UC	Cretaceous-Paleogene	Undefferentiated ultramafic and plutonic rocks. Predominantly peridotite associated with gabbro and diabase dikes.

GEOLOGICAL SYMBOLS

Formational boundary

High angle fault

Normal fault

Fig. 2.2 LEGEND OF GEOLOGICAL MAP (AGNO RIVER BASIN)

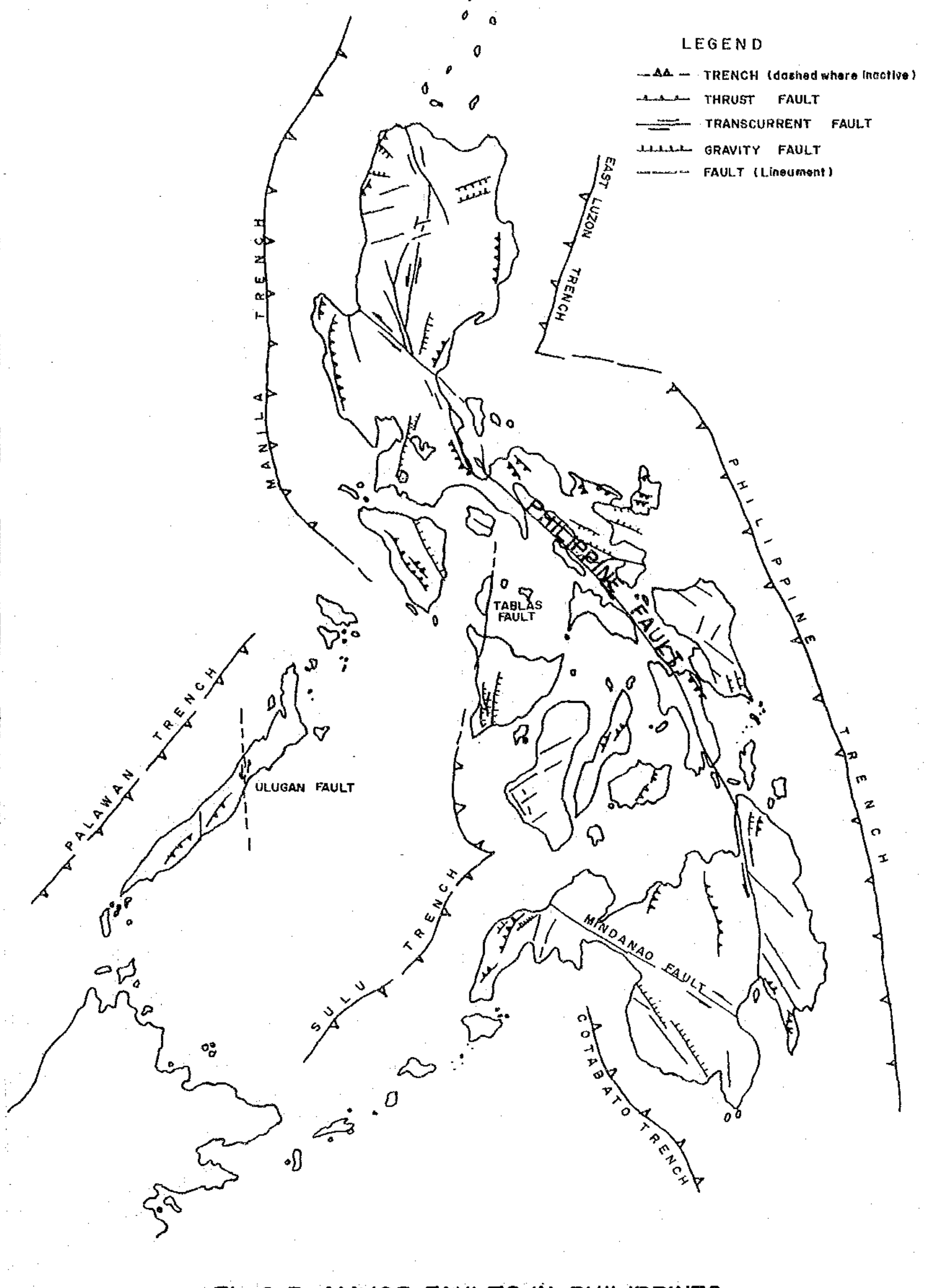

Fig.2.3 MAJOR FAULTS IN PHILIPPINES

Source : Refer to No. GL.001

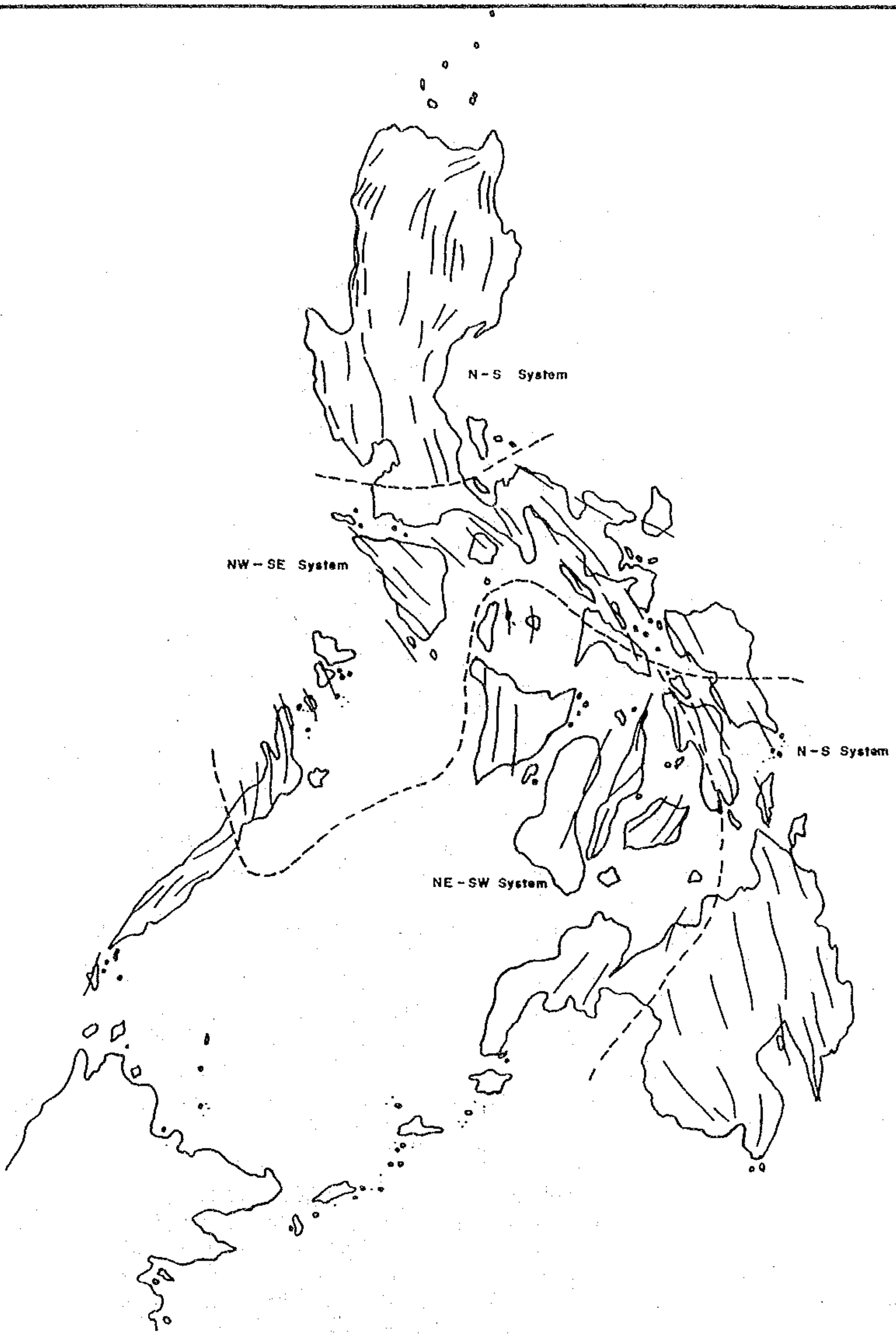

Fig. 2.4 FOLD PATTERNS IN PHILIPPINES

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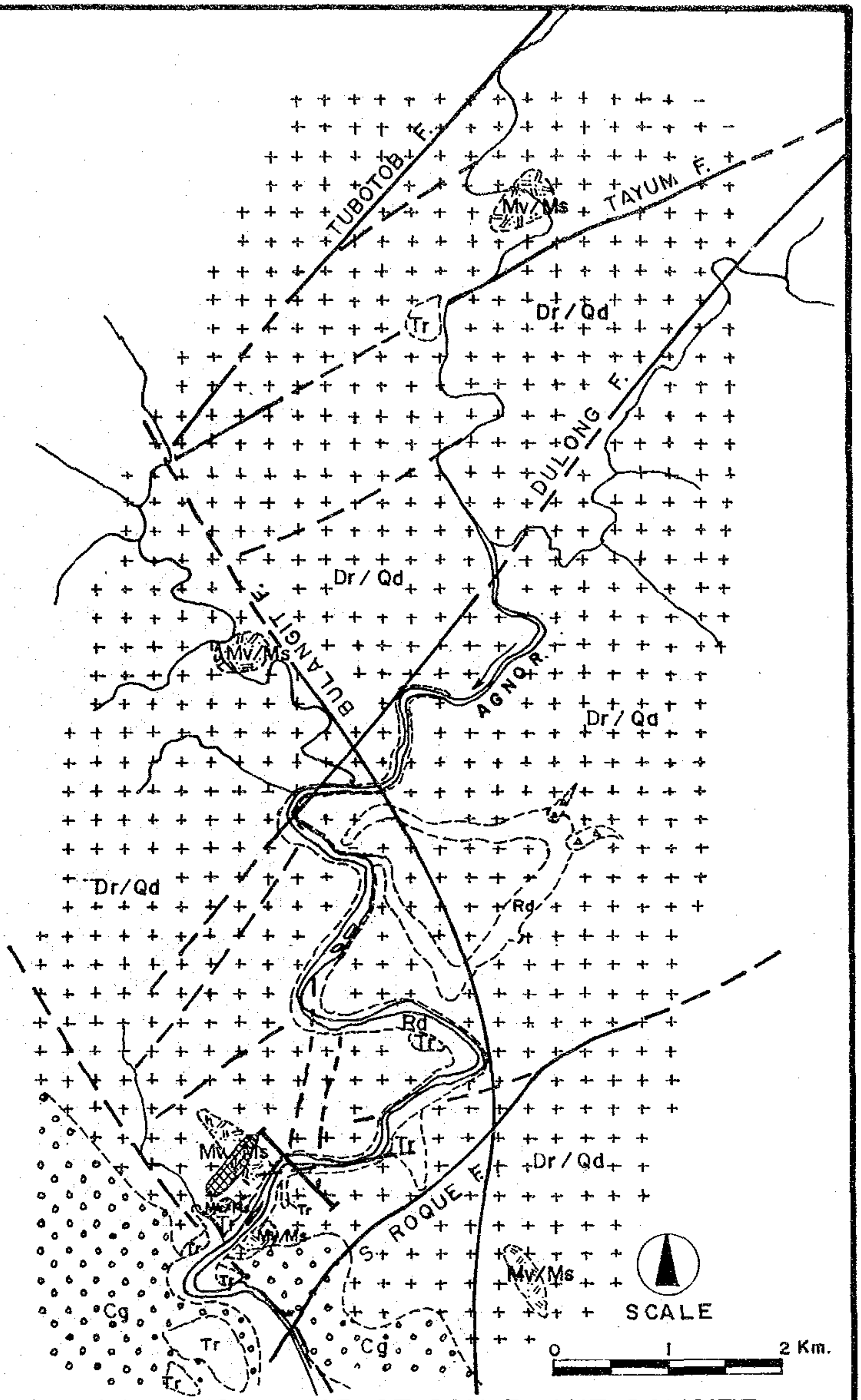

Fig. 3.1 GEOLOGICAL MAP OF SAN ROQUE DAMSITE

(See Legend in Fig. 3.7)

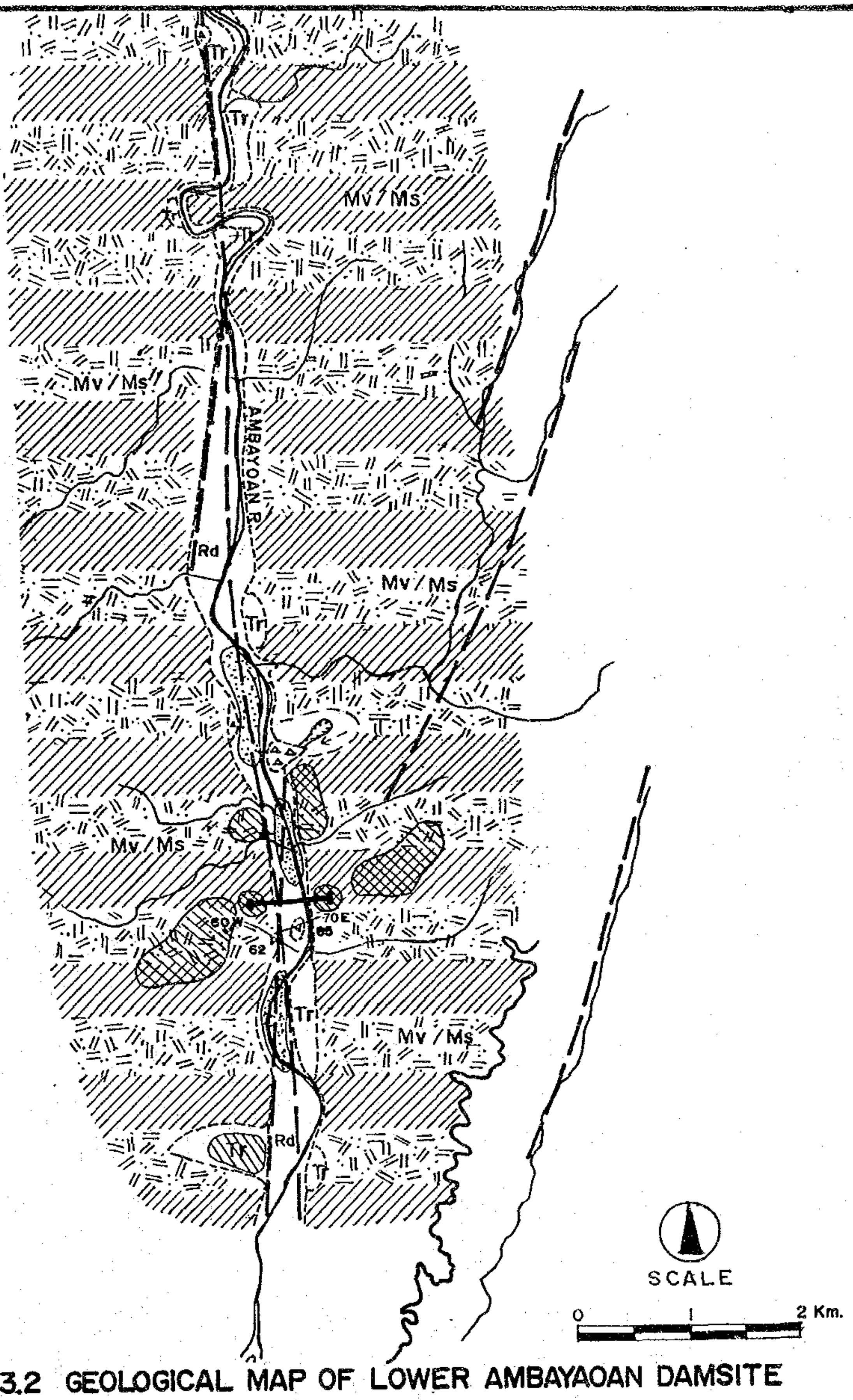

Fig. 3.2 GEOLOGICAL MAP OF LOWER AMBAYAOAN DAMSITE

(See Legend in Fig. 3.7)

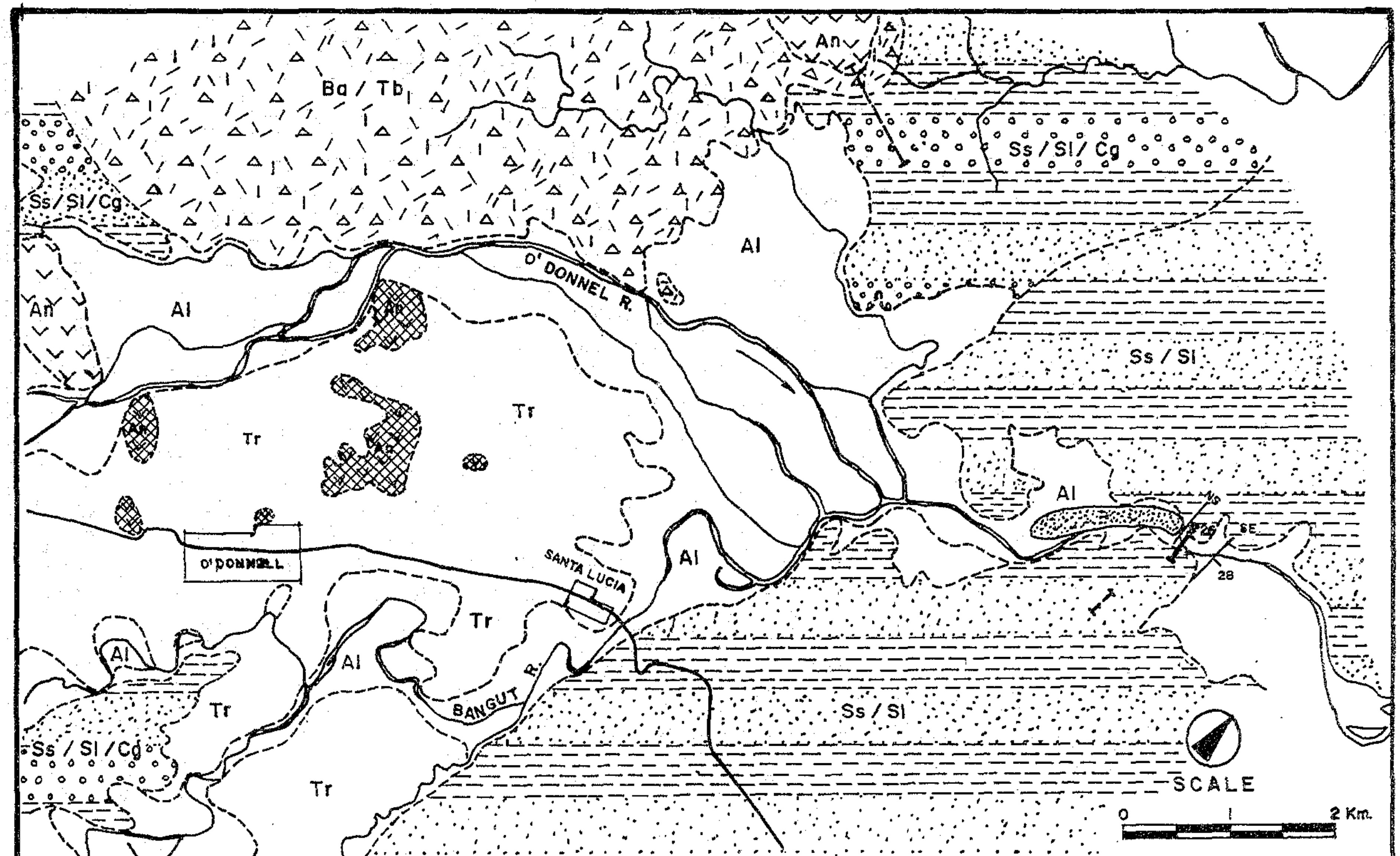

Fig. 3.3 GEOLOGICAL MAP OF LOWER O'DONNELL DAMSITE

(See Legend in Fig. 3.7)

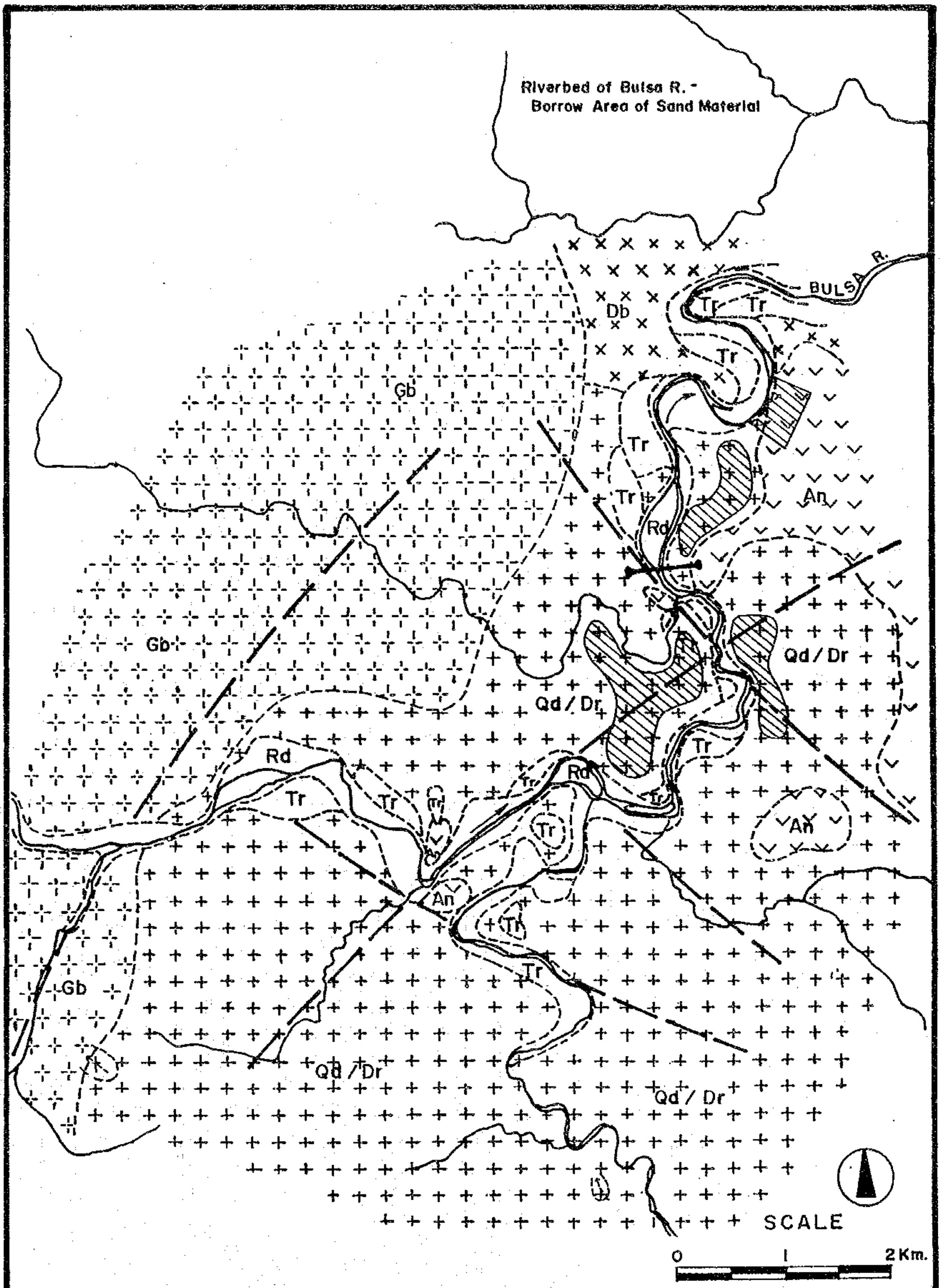

Fig. 3.4 GEOLOGICAL MAP OF BALOG-BALOG DAMSITE

(See Legend in Fig. 3.7)

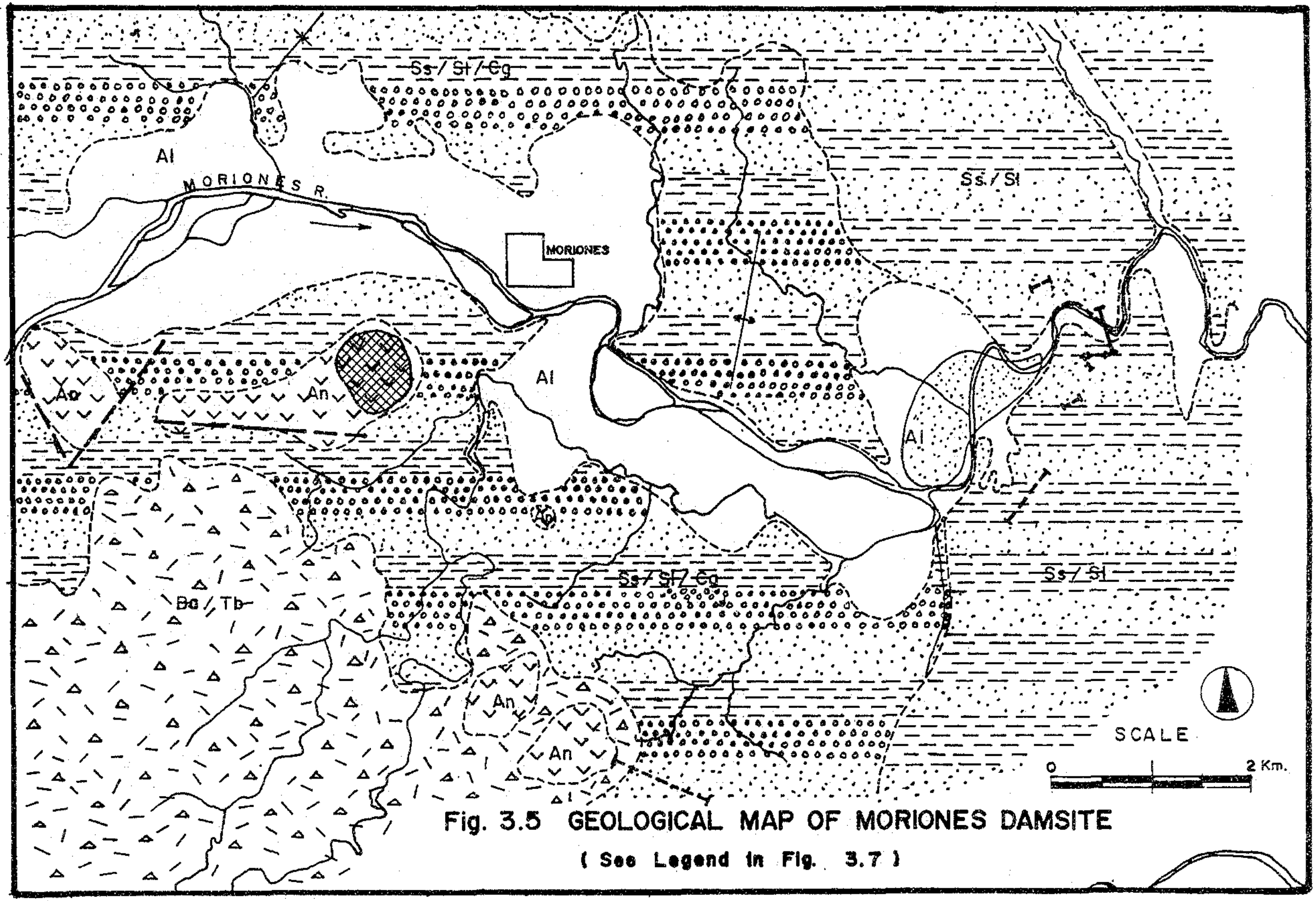

Fig. 3.5 GEOLOGICAL MAP OF MORIONES DAMSITE

(See Legend in Fig. 3.7)

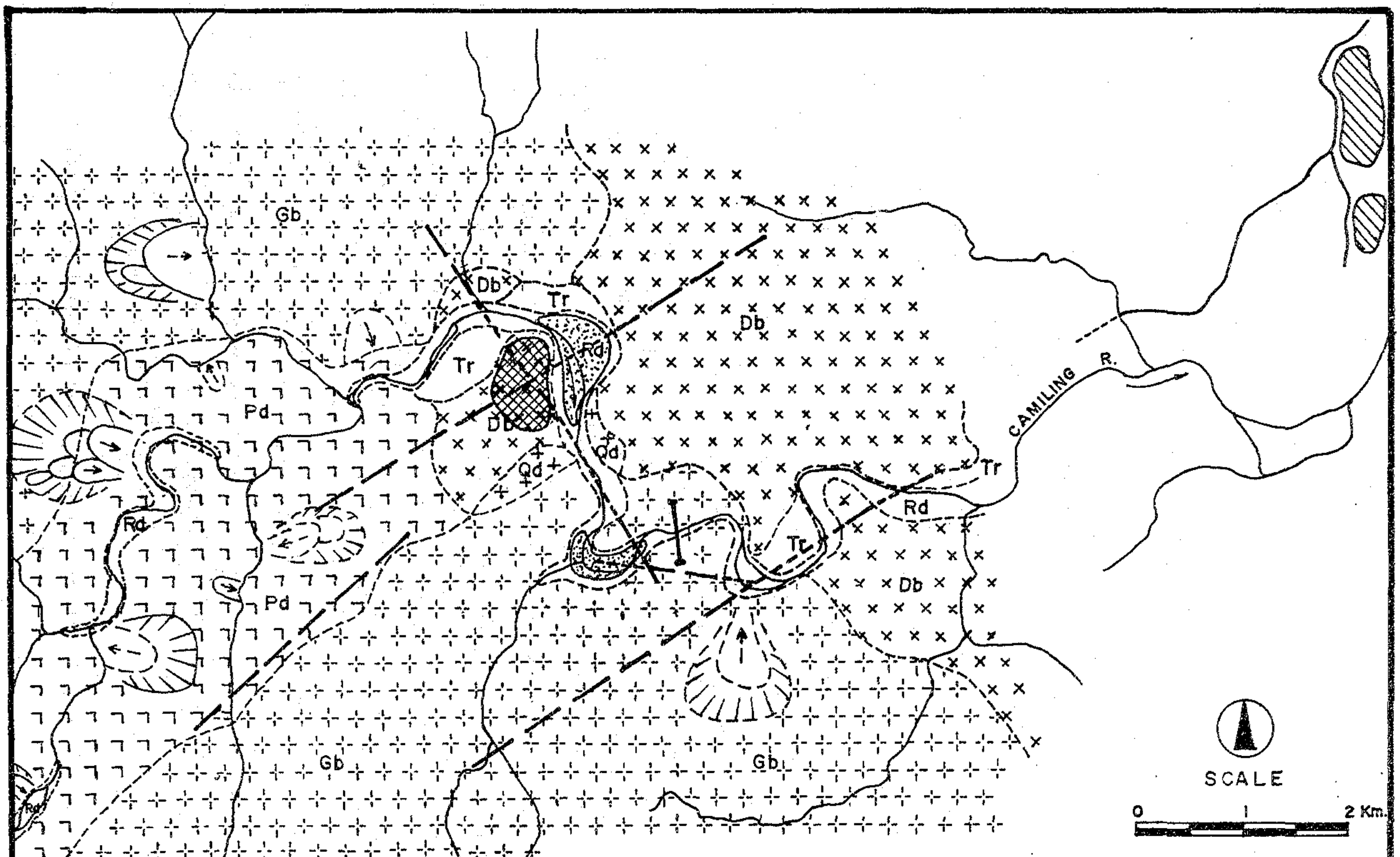

Fig. 3.6 GEOLOGICAL MAP OF CAMILING DAMSITE

(See Legend in Fig. 3.7)

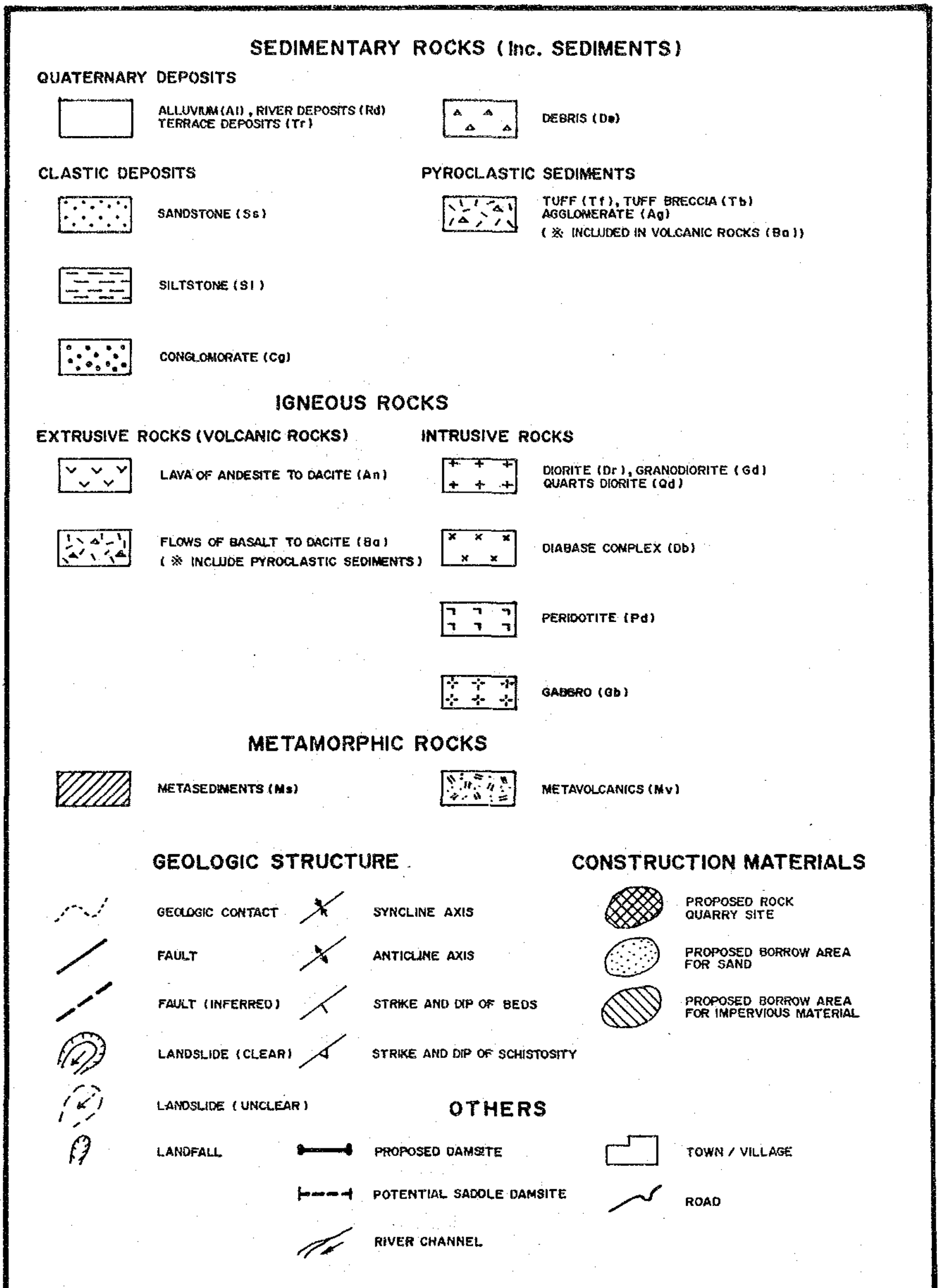

Fig. 3.7 LEGEND OF GEOLOGICAL MAP (DAMSITE)

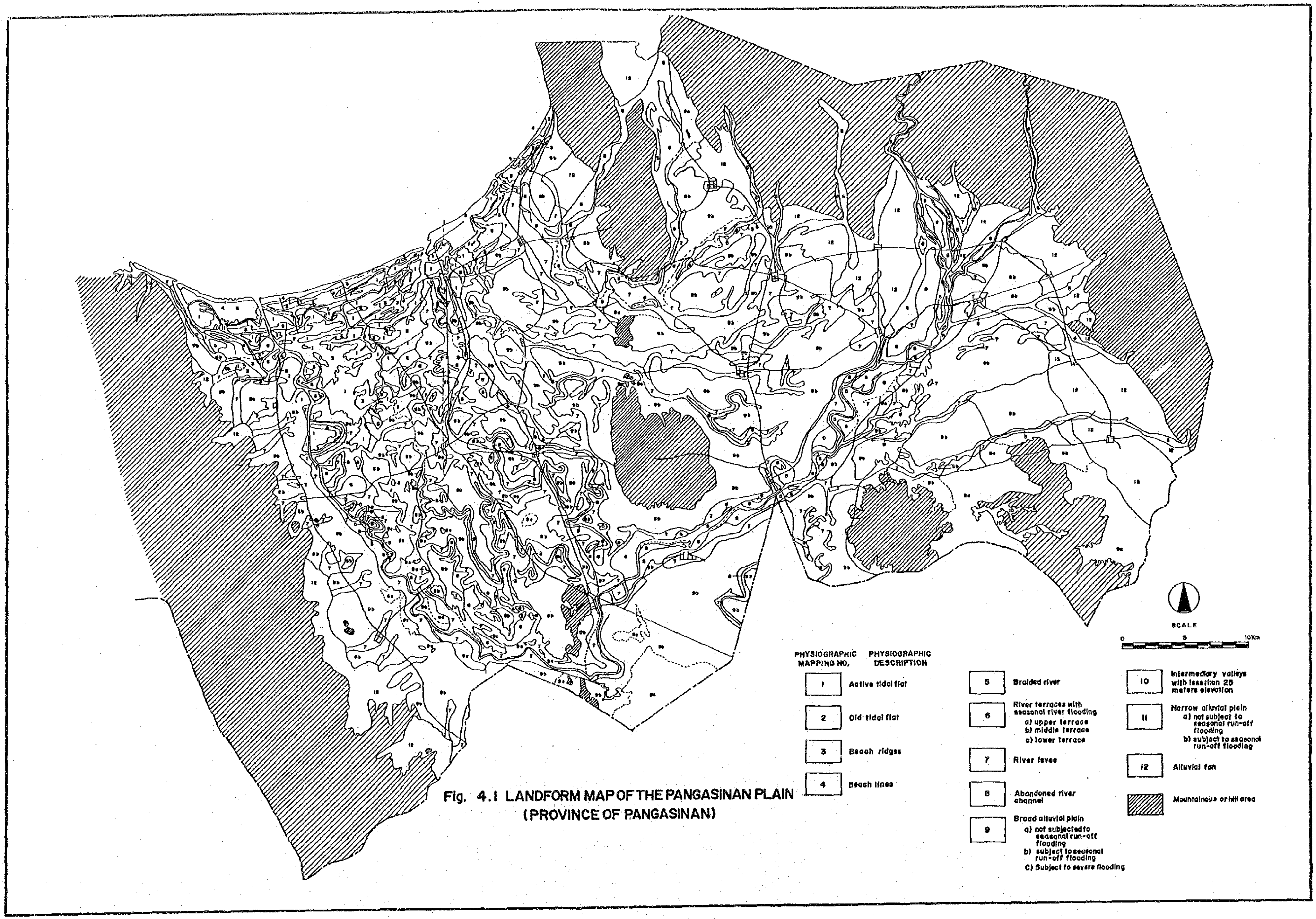

Fig. 4.1 LANDFORM MAP OF THE PANGASINAN PLAIN
(PROVINCE OF PANGASINAN)

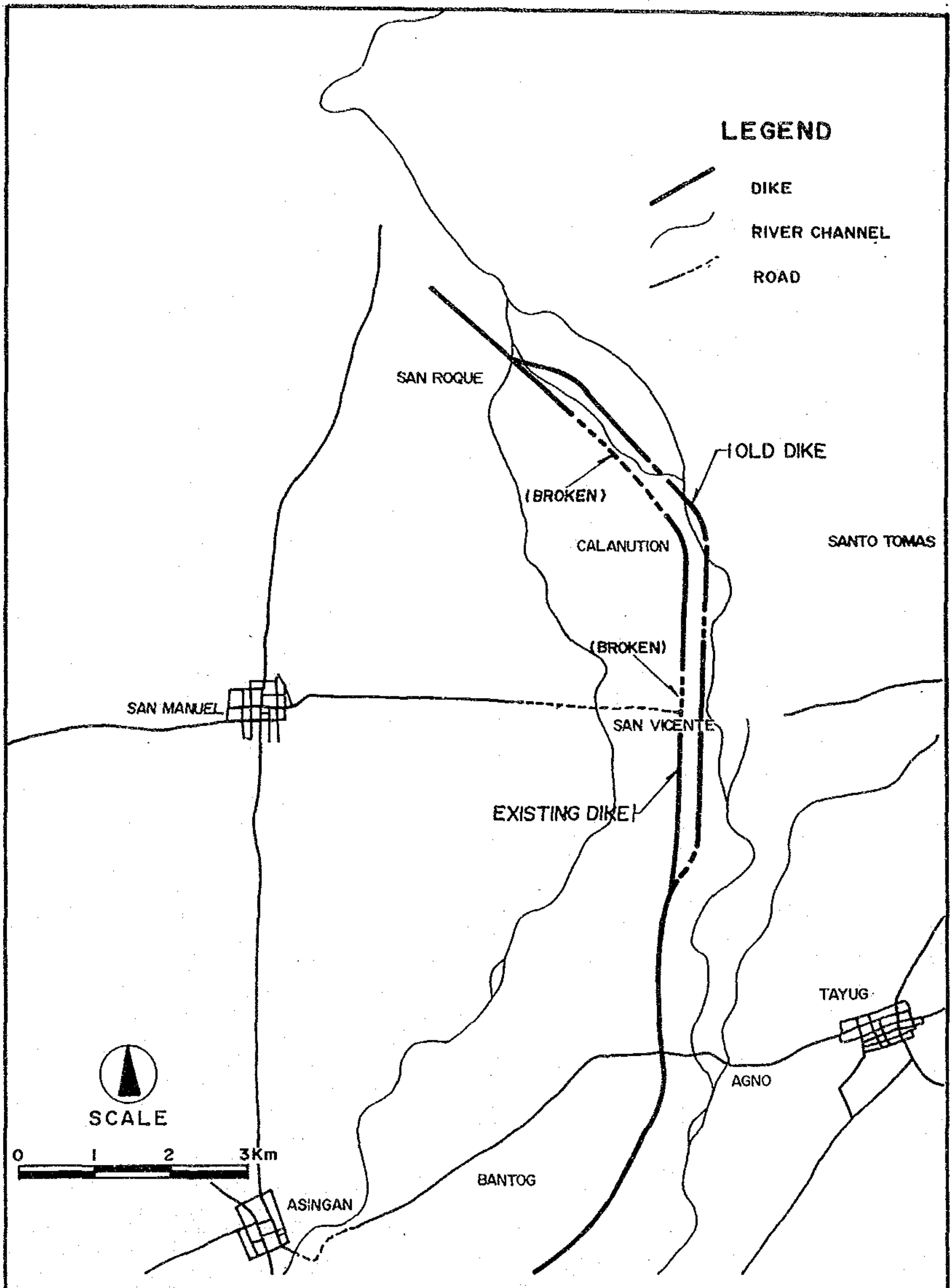

Fig. 4.2 TRANSITION OF DIKE

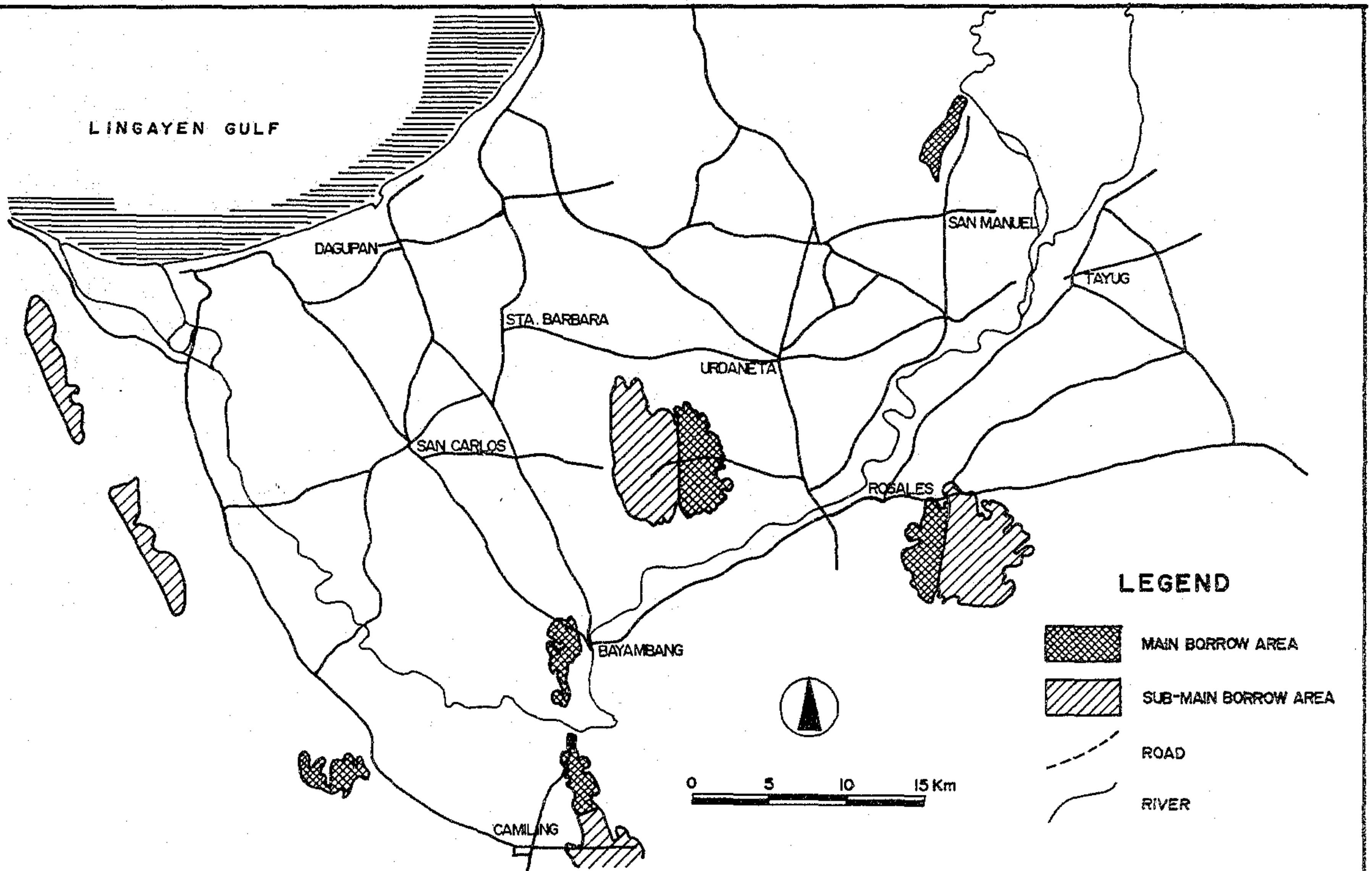

Fig. 4.3 PROPOSED BORROW AREA FOR DIKE CONSTRUCTION MATERIALS

4. SV

4. SV SURVEY

SV : SURVEY

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1. INTRODUCTION

Survey works has been conducted for the period of eleven (11) months from March 1989 to January 1990. Survey works are broadly divided into two (2) stages. Survey works in first stage were field operations which were carried out during the period from March 1989 to July 1989 in the Philippines. Photogrammetric mapping in second stage was carried out in Japan up to January 1990.

Works schedule of survey is shown in Fig. 1.1, and the quantities of survey works are given in Table 1.1. Survey works conducted are described hereunder.

First Stage (March 1989 - July 1989)

(1) Data Collection
(2) Preparation of the specifications on following survey works:
   - Aerial photography
   - Uncontrolled mosaic
   - Leveling
   - Pricking
   - Fiel classification
   - River survey including longitudinal profile and cross section
(3) Contracts with local survey contractors for the above survey works
(4) Supervision of the above survey works
(5) Operation of GPS positioning in the field

Second Stage (August 1989 - January 1990)

Photogrammetric mapping in the Second stage is consisted of following works;

(1) Aerial triangulation
(2) Photogrammetric mapping
(3) Inspection

2. DATA COLLECTION AND THEIR REVIEW

Following data and information related to the survey works were collected.

(1) Ground control point
- Bench mark BC & GS
  Elevations, point descriptions, route maps
- Triangulation BC & GS
  Coordinates, point descriptions, net work maps

(2) Philippines national grid system (Projection and geodetic elements)
- Technical Bulletin No.26 Bureau of Land
- The triangulation of the Philippine Island BC & GS

(3) Sample of map legend and survey result
- Sample of map legend
  Legend of BC & GS (applied to 1/25,000 map)
  Legend of DPWH (applied to 1/25,000 map)
- Sample of river survey
  Cross section DPWH
  Longitudinal profile DPWH

(4) Existing survey results
- Topographic map
  1/250,000 topo-map (the whole project area) BC & GS
  1/50,000 topo-map (the whole project area) BC & GS/NAMRIA
  1/4,000 topo-map (about 50% covered) NIA
- Aerial photography
  1/60,000 aerophoto, 1981(the whole project area) AFPMC
  1/15,000 aerophoto, 1974(about 90% covered) AFPMC
  1/15,000 aerophoto, 1966-67(the whole project area) AFPMC

Geodetic standard considering the above data and information was decided as follows :
- Coordinates Philippines national grid system
- Elevation mean sea level

Map legend and river survey standard were prepared according to the samples of existing survey results.

3. TOPOGRAPHIC SURVEY WORKS

3.1 Survey Works for Photogrammetric Mapping

(1) Aerial photography

F.F.Cruz & Co., Inc. undertook to take aerial photography in accordance with the contract dated April 14, 1989. Aerial photography at a scale of 1:30,000 was proposed to cover the area of 3,400 km^2, however this aerial photography was not completed unfortunately due to unexpected weather condition within the contract period. Finally the 54% of the proposed area was remained untaken.

In order to solve this problem of aerial photography, the following countermeasures were taken for photogrammetric works including uncontrolled mosaic and mapping.

(a) Existing aerial photography

Following existing aerial photography were utilized instead of uncovered mapping area by 1/30,000 scale photos.

- Scale 1:60,000, taken in 1981 (the whole project area)
- Scale 1:15,000, taken in 1974 (about 90% covered)
- Scale 1:15,000, taken in 1966-67 (the whole project area)

(b) 1/8,000 aerial photography

1/8,000 aerial photography was taken from low flight altitude (1,200m in Elevation) in order to cover the intensive area of river channel where the annual transition is expected.

(c) Additional field classification by used of existing aerial photography at a scale of 1/60,000, 1981 was carried out to complete new photographic information in the area where is not covered by the aerial photography of 1/30,000.

These countermeasures were completed on 20th of July, 1989.

(2) Photo Control Survey

Horizontal control survey was carried out adopting Global Positioning System (GPS) to determine geodetic coordinates for aerial triangulation. Field operation of GPS was completed by survey experts of the Study Team with close cooperation of counterparts. Leveling for vertical control including installation of provisional bench mark was