LIST OF FIGURES

ABBREVIATIONS

1. NAME OF PHILIPPINE GOVERNMENT AGENCIES

AFCS	Agno River Flood Control
ARIS	Agno River Irrigation System
DENR	Department of Environment and Natural Resources
DOTC	Department of Transportation and Communications
DPWH	Department of Public Works and Highways
GOP	Government of the Philippines
LATRIS	Lower Agno and Totonogen River Irrigation System
NAPOCOR	National Power Corporation
NAMRIA	National Mapping and Resource Information Authority
NIA	National Irrigation Administration
OCD	Office of Civil Defense
PENRO	Provincial Environment and Natural Resources Office
PM	Project Manager
PMO	Project Management Office
PNR	Philippine National Railways
SMORIS	San Miguel - O'Donnell River Irrigation System

2. NAME OF JAPANESE GOVERNMENT AND OTHER OFFICIAL AGENCIES AND ORGANIZATION

GOJ	Government of Japan
JICA	Japan International Cooperation Agency
MOC	Ministry of Construction, Japan
OECF	Overseas Economic Cooperation Fund, Japan
UN	United Nations

3. MEASUREMENT UNITS

(Length)		(Weight)	
mm	millimeter(s)	gr(grs)	gramme(s)
cm	centimeter(s)	kg(kgs)	kilogramme(s)
m	meter(s)	ton(s)	ton(s),eq'vt to 1,000 kg
km	kilometer(s)		

(Area)		(Time)	
mm^2	square millimeter(s)	sec	second(s)
cm^2	square centimeter(s)	min	minute(s)
m^2	square meter(s)	hr(hrs)	hour(s)
km^2	square kilometer(s)	dy(dys)	day(s)
ha(has)	hectare(s)	mth(mths)	month(s)
		yr(yrs)	year(s)

(Volume)

cm^3	cubic centimeter(s)
m^3	cubic meter(s)
ltr	liter(s)

1. INTRODUCTION

The sediment analysis was performed to grasp the sediment balance and riverbed fluctuation of the Agno River basin. The sediment discharge by sediment sampling records, sediment yield from the upper river basins, and sediment transport capacity in river channels were estimated for the studies on sediment balance.

The study results are to be used as the basic data for the flood control plan and the sediment control plan. The main study items are as follows:

a) Estimation of sediment yield from the upper river basins
b) Construction of sediment discharge rating curves
c) Estimation of sediment transport capacity in river channels
d) Study on sediment balance

2. PRESENT CONDITIONS OF SEDIMENT PROBLEMS AND MEASURES

2.1 Present Conditions of the Basin

2.1.1 Slope Conditions in the Basin

Through the field reconnaissance the present slope conditions were identified and are summarized as follows:

- Slopes in the uppermost stream seem to be stable because of vegetation cover of grass and trees.

- Bare land and slightly vegetated land are observed in the vicinity of the Ambuklao dam and the Binga dam, mainly at the riverside.

- Many erosions occur in National Highway No. 11 called Kennon Road and the Halsema Mountain Highway, since the roads are being widened have no slope protections.

- A large amount of sandy deposits from volcanic sources are distributed along the O'Donnell River.

2.1.2 Vegetative Cover

The vegetative cover of the Basin is not so good and the area of forest land is only 13% of the whole basin. Land use estimated from the aerophotos taken in 1987 is summarized below:

Land Use	Area (km^2)	Percent (%)
Forest <1	980	13
Extensive Land Use <2	3,020	40
Intensive Land Use <3	3,390	44
Fishponds	90	1
Non-Vegetated Land	160	2
Total	7,640	100

Note : <1 : This classification is different from that of Section 3.1.1.
<2 : Cultivated area mixed with brushland and grassland, grass covering >70%.
<3 : Arable land, mainly cereals and sugarcane, crop land mixed with coconut and other plantations.

The distribution of land use is illustrated as Fig. 2.1.

2.2 Sediment Problems and Measures

2.2.1 Dam Reservoirs

There are existing two hydropower dams, Ambuklao dam and Binga dam in the upstream of the Agno River. Large quantities of sediment produced in the watershed flow into the reservoirs, and sedimentation in the dam reservoirs is a serious problem for both dams.

The Ambuklao dam which is situated in the upper reach started operation in 1956, and has the original capacity of 329,000,000 m^3 with a usable storage of 258,000,000 m^3 and a dead storage of 71,000,000 m^3. The Binga dam which is some 10.0 km downstream of Ambuklao started operation in 1960 and has a maximum capacity of 87,443,000 m^3 with a usable storage of 48,200,000 m^3 and a dead storage of 39,443,000 m^3. From the result of the survey in 1986, the remaining volume of 221,000,000 m^3 of the Ambuklao reservoir and 56,119,000 m^3 of the Binga reservoir would be filled up with sediment in about 63 years and 40 years respectively. For the remaining dead storage, it will take around 3 years for Ambuklao and 14 years for Binga to be full of sediment.

The records of sedimentation in the two reservoirs are shown in Table 2.1, and the annual specific sedimentation rate is as high as 5,000 $m^3/km^2/yr$ for Binga dam and 6,000 $m^3/km^2/yr$ for Ambuklao dam.

The inflow of sediment into the power intake of Ambuklao dam causes blocking of the cooling water pipe and abrasion of the turbines. In addition, power generation by the Ambuklao Hydropower Station has been affected due to the rising riverbed at the upstream end of the Binga dam reservoir where the outlet of the power station is installed.

In 1988-1989, the JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) conducted studies to rehabilitate the two dams and proposed the following countermeasures:

- The relevant river course for dredging is proposed for a length of 1,500 m downstream of the outlet of the existing tailrace tunnel, dredging depth of 0.6 m to 1.0 m and dredging width of 25 m to 100 m.

- New intake structure is constructed and operated instead of the existing intake structure.

2.2.2 Irrigation Systems

There are ten national and many communal irrigation systems existing in the Pangasinan plain, and they take water from the Agno River and the tributary and allied rivers. The locations of national irrigation systems are presented in Fig.2.2 and the existing conditions of sedimentation in the systems are tabulated in Table 2.2.

Except for Sinocalan River Irrigation system, which takes in water from the Sinocalan River, desilting in the canals is almost yearly conducted. The desilting volume in Agno River Irrigation System (ARIS) canals, however, is decreasing due to a limitation of budget, consequently the canals became shallow and their flow capacity decreased. Thus, as of 1988 the irrigated area in the wet season was reduced to 2,109 ha from the original design of 18,500 ha. The annual transition of desilting activity and irrigated area for ARIS and Lower Agno and Totonogen River Irrigation System (LATRIS) are shown in Tables 2.3, 2.4 and Fig. 2.3.

(1) Sediment Component

Sediment in the main and lateral canals of ARIS and LATRIS were sampled, and the gradation and specific gravity tests were conducted in the STUDY. The test results are tabulated in Table 2.5, and the sampling sites and the particle size accumulation curves are given in Fig.2.4 and Fig.2.5 respectively.

Sediment in the upper stretches of main canals nearer to the intake dams are mainly composed of coarse sand but in the lower stretches and lateral canals fine sands are main components. Sediment in the canals of ARIS are comparatively coarser than those of LATRIS since ARIS intakes water 20 km upstream from the LATRIS intake dam.

Finer particles such as silt flow into paddy fields through the lateral canals together with irrigation water. In order to control sedimentation, farmers of ARIS area set up a settling basin by reshaping a small portion of their paddy field of which inlet connects directly to farm ditches or lateral canals.

(2) Estimation of Sediment Volume in Irrigation Systems

For ARIS and LATRIS, of which data availability is comparatively good, the volume of sedimentation in the systems is estimated by considering the transition of desilting volume and irrigated area. The annual sediment volume is 480,000 m^3 for ARIS and 60,000 m^3 for LATRIS. The breakdown and process of estimation is presented in Table 2.6.

2.2.3 River Channels

Large quantity of sediment is deposited in the transition portion between the mountain area and the plain, and in the lowest reaches near the river mouth. It causes increasing the river bed and decreasing the flow area of the river channel. Dredging and excavation works has been conducted to widen the river channels and/or construct a new channel, while some of river bed materials such as boulder, gravel and sand are used for construction materials.

(1) Dredging and Excavation of River Channel

Agno Flood Control System (AFCS) has conducted dredging and excavation works since 1981. The location map of dredging and excavation activities is presented in Fig. 2.6, and their volume is tabulated in Table 2.7.

The total volume of dredging and excavation is about two million cubic meters for four years from 1986 to 1989. Dredging works are undertaken in the Agno River, the Panto River and the Tarlac River while excavation are done in the Agno River, the Banila River, the Viray-Dipalo River and the Ambayoan River. In case of the Agno River main course, dredging works are conducted at the river mouth in these years. The annual amount of 200,000 or 300,000 m^3 sediment was dredged in 1988 and 1989.

(2) Riverbed Materials Extraction for Construction Use

The annual volume of extracted riverbed materials amounts to approximately 500,000 m^3 as shown by the survey of AFCS in Table 2.8. The extraction sites are shown in Fig. 2.7.

The annual extraction volume from the Agno River downstream of San Roque in the alluvial fan was recorded at 90,000 m3 of sand and gravel.

(3) Riverbed Fluctuation in the Existing Channel

Cross section survey was conducted in December 1981 and May 1989 for the Agno River main course, the Tarlac River and the Banila River. The tendency of riverbed fluctuation can be verified in terms of sediment deposition volume in each river stretch. The volume is calculated by comparing these cross sections and considering the volume of dredged/excavated and extracted riverbed materials shown in Table 2.9. The deepest riverbed fluctuation and annual sediment volume of existing channels are illustrated in Fig. 2.8. There is no available data showing sediment conditions in other river channels.

The Agno River main course is broadly divided into aggradation section and degradation section according to riparian sedimentation. The former is located from the river mouth to the confluence with the Tarlac River and Santa Maria to San Manuel, and the latter is observed between WaWa and the upper portion of Carmen Bridge in Rosales. Sediment from the Tarlac River has a tendency to deposit abundantly around the Poponto Swamp.

The Banila River is divided into two portions, same as the Agno River. Between the confluence with the Agno River and approximately 10 km upstream lies a sediment transportation section. Toward its upper stream, the riverbed is gradually rising.

2.3 Mining Activities and Disposal Systems

2.3.1 Mining Activities and Disposal Systems

The southern area of the Cordillera Central Mountain Range is the most important mining district in the Philippines and dotted with many copper and gold mines as shown in Fig.2.9. At present there are four (4) mining companies, i.e., Philex Mining Corp., Benguet Corp., Itogon-Suyoc Mines Inc. and Benguet Exploration Inc. are operating in this area.

It has been reported that great quantities of mine tailings yielded by the mining activities flow into the irrigation systems of Pangasinan through the Agno River or the Bued River, cause a blocking of canals and affect the growth of crops. The countermeasures as well as the investigation on the relationship between the mine tailings and sedimentation in the irrigation systems has been a great social problem.

A series of site reconnaissance over the mining area and tailings dams of the four mine companies was conducted in the period June to September, 1989. The inspection results are described below:

- Main disposal systems are provided to impound mine tailings in the tailings dams or ponds.

- A diversion tunnel is provided at the upstream end of each pond, water from the upstream is diverted directly into the downstream of the dam, not flowing into the pond.

- Water discharge in the catchment dam is drained through a penstock or spillway.

The present state of these mining activities and the disposal systems are summarized in Table 2.10.

2.3.2 Government Regulations

Mining activities are regulated by Presidential Decree 463 (" Mineral Resources Development Decree of 1994 ") proclaimed in 1974 and " Consolidated Mines Administrative Order, rules and regulation implementing P.D. No. 463 ".

As for the environmental protection, Section 42-B " Environment Protection in Mining Area " of the administrative order regulates the treatment of abandoned mines, mine wastes, mine tailings and water quality. The summary is as follows:

(i) Surface Mining

- Surface soil before mining shall be saved to be used for re-soiling or as soil cover on waste dumps, slopes, mine tailings covered area.

- Mine waste-dumps shall be located away from major drainage system.

- Appropriate control measures shall be provided in order to prevent spilling, slides and/or washing away of mine wastes.

- Mine waste-dumps, and tailings-covered area shall be prepared to render them suitable either for agriculture, forestry, gardening, cottage industry or human settlement purpose before abandonment.

- Completely mined-out areas shall be rehabilitated before abandonment for possible development into agricultural, industrial, commercial or residential purpose.

- Mine waste-dumps, tailings-covered areas and completely mined-out areas where improvement for agricultural, industrial, commercial or human settlement purposes are not technically feasible shall be revegetated or reforestated.

- For the above purpose all mine/quarry operators shall establish their own vegetable and forest tree nurseries.

(ii) Underground Mining

- All underground opening that had been abandoned shall be filled or developed to prevent subsidences.

(iii) Mill waste and Tailings Disposal and Water Conservation

- All mine/quarry operators are prohibited from directly or indirectly disposing tailings or mill waste into natural drainage systems

- Impounding of mill tailings shall be far from watershed area and free from spillage, slides and/on washing-away of tailings.

- All mine tailings-covered areas must first be resold, cover-cropped or reforested if found not suitable for agricultural, industrial or commercial use.

- Mill effluents shall be treated so that obnoxious odor and poisonous chemicals are removed before disposal.

- Mining Company shall all times conserve water by recycling, developing and maintaining watershed areas, by reforestation and by constructing water reservoirs.

(iv) Forest Conservation

- It shall be the responsibility and duty of all lease holders, claimowners, permittees, licensees, operators and concessionaires to reforest, afforest and protect resources covered by mining claims from encroachment and other forms of destruction.

In accordance with the abovesaid regulation, in September 1989 Department of Environment and Natural Resources (DENR) ordered Benguet Corp. to stop operation of its three major open pit mines (44 Vein, Little Corporal, 3 Vein) of which huge quantity of dissolved solid wastes had been flowing into the Antomok River causing pollution and siltation.

2.4 Existing/On-going Reforestation, Erosion Control and Watershed and Rehabilitation Plans

2.4.1 Reforestation Plans

The Government of the Philippines (GOP) is proceeding reforestation as a measure against sedimentation in dam reservoirs and irrigation systems. The outline of existing and on-going reforestation plans are presented in Table 2.11, and their locations are shown in Fig.2.10.

In 1989 an area of 2,793 ha is being reforestated, while the total remaining area to be planted as of 1988 is as much as 49,000 ha, and it is understood how long term and large budget will be required to cover the whole basin with forest. In addition, even the maintenance and protection of present forest against the damages such as fire, illegal logging and charcoal making and illegal gathering of firewood are still in the difficult condition. According to the research of the Provincial Environment and Natural Resources Office (PENRO), DENR, some 390 ha is annually reforestated but some 570 ha forest is lost due to those damages in Pangasinan.

In 1989 National Power Cooperation (NAPOCOR) made an agreement with DENR to cooperate in reforestation of the upper Agno River basin upstream from the Binga dam. Moreover, National Irrigation Administration (NIA) and DENR agreed to undertake the Balog-Balog Watershed Contract Reforestation Project, in which a total area of 9,165 ha within the watershed of Balog-Balog Dam is proposed to be reforestated in the period of 1989 to 1994.

2.4.2 Erosion Control and Watershed Rehabilitation Plans

As treatment works of bare lands and gullies, such structures as check dam,retaining wall and wattling as well as vegetative measures have been adopted. The existing / on-going erosion control and watershed rehabilitation plans are presented in Table 2.12 and Fig. 2.10.

These projects are all so small due to the limitation of budget that the devastation of watershed seems to be prevailing the progress of those works.

2.5 River Mouth Clogging

Excessive sedimentation at a river mouth may block river flow and be a cause of overbanking. Moreover, it may hinder navigation of fishing boats. Therefore, field investigations and interviews were conducted in this STUDY to know the condition of river mouth clogging for the Agno River and the Allied Rivers.

No serious problem of river mouth clogging has been reported for the Agno River and the Allied Rivers, but sand bars are developing at the river mouths of the left course of the Agno River and the Cayanga River, and this may be a cause of clogging in the future. However, since data such as current, wave, bottom material and coastal topographical map are not available, the cause of development of the sand bars has not been clarified.

The transition of the shoreline along the Study Area is shown in Fig. 2.11 and the following is the result of field investigations for each river mouth.

(1) Agno River Main Course

The Agno River bifurcates into the left and main courses some 5 km upstream from the river mouth. The river mouth of the main course is at present 400 - 500 m wide and is becoming wider through side bank erosion caused by floods and waves as shown in Fig. 2.11. River mouth clogging is not found in this course.

An old resident reported that before 1940 the channel has been narrow with a width of some 50 m and most of the floods had flown into the Lingayen Gulf through the present left course and the Panto River. When dredging and widening of the main course was carried out to make a shortcut to the sea, floods came to flow into the main course and the channel gradually became wider.

Moreover, large quantity of sediment flowing from the upstream seems to extend the the river mouth towards the sea. The annual extension rate estimated by comparing the aerophotos taken in 1964 and 1989 is about 40 m/yr at the left side.

(2) Agno River Left Course

As for the left course, the shoreline near the mouth is coming towards the land since the supply of sediment from the upstream was reduced by the change of main flow to the present main course. Comparing the aerophotos taken in 1964 and 1989, the withdrawal of the shoreline of this left side is about 200 m for 25 years. In order to prevent further erosoin, a breakwater is at present being constructed along the shoreline.

Dredging was conducted from 1981 to 1984 to remove a sand bar that had developed from the left side, but the sand bar from the opposite side, namely the right side is developing and has narrowed the river width to only 10 m at present.

(3) Panto River

The width of the river mouth of the Panto River is stable at some 300 m wide. However, the water depth sometimes becomes shallow due to sedimentation and motorized fishing boats navigate along the deeper portion of the river during the dry season. From 1987 to 1988, 1,500 m of the river channel was dredged from 400 m upstream of the river mouth.

(4) Cayanga River

A sand bar is developing on the right side narrowing the river mouth with a width of about 50 m. It was found through the interview with the residents that there is a big difference of river mouth between the dry season and the wet season. The river width is only 15 m in the dry season, but it becomes 85 m in the wet season. However, no inundation caused by river mouth clogging has yet been experienced because the sand bar is washed out during floods.

3. SEDIMENT YIELD AND BALANCE ANALYSIS

3.1 Estimation of Sediment Yield

3.1.1 Natural Sediment Yield

(1) Sources of Sediment Yield

The sediment yield sources are categorized as set out below:

A. Natural Sediment Yield

a1. erosion of ground surface
a2. landfall, land slide
a3. erosion of river bed and channel

B. Artificial Sediment Yield

b1. agriculture development, deforestation
b2. road construction
b3. mine tailings

In the watershed of the Study Area the main artificial sediment yield sources is presently considered to be mine tailings and the yield from road construction is rather minor.

For estimating the natural sediment yield the sediment yield due to agricultural development and deforestation is treated as existing condition in the mountain area and thus included in a part of natural sediment yield.

(2) Classification of Watershed

The watershed of the Study Area is divided into three, i.e., Southern Cordillera mountains, Central Luzon Plain and Zambales mountains. It is assumed that the sediment yield from the Luzon Plain is negligible and most of the sediment come from the Southern Cordillera mountains and the Zambales mountains. The watershed of these mountain areas is classified into four for assessing the potential sediment yield as shown in the following table.

Classification	Condition of land	Tone in aerial photograph
LANDFALL (La)	landfall/landslide area without vegetation (high yield)	white
BARE LAND (Ba)	bare land with almost no trees and grass (medium yield)	white or light gray
PARTIAL FOREST LAND (Va)	mixed with bare land and forest/grass land (low yield)	light gray or gray
FOREST LAND (Fa)	fully covered with forest and grass (little yield)	dark

(3) Natural Sediment Yield

The watersheds of the Southern Cordillera mountains and the Zambales mountains are divided into 37 (N1-N37) sub-basins and 22 (S1-S22) sub-basins respectively. The sediment yield potential of these sub-basins are assessed in terms of foregoing four classes by use of 1/60,000 scale aerial photographs taken in 1980-1981.

Areas of these four classes are measured for each sub-basins and natural sediment yield is estimated for each sub-basin by use of the formula defined below.

$$Ns = La \times Ld + Ba \times Bd + Va \times Vd + Fa \times Fd$$
$$= (500\ La + 50\ Ba + 5\ Va + Fa) \times Fd$$

Where,

NS	:	Natural sediment yield (m^3/year)
La,Ld	:	Area and yield depth of landfall; assumed Ld = 500 Fd
Ba,Bd	:	Area and yield depth of bare land; assumed Bd = 50 Fd
Va,Vd	:	Area and yield depth of partial forest land; assumed Vd = 5 Fd
Fa,Fd	:	Area and yield depth of forest land

The yield depth of forest land (Fd) for Ambuklao dam and Binga dam is counted backward to be 1.3 mm (Fd) from the recorded annual sediment yield at both reservoirs; 3.71 x $10^6 m^3$/year for Ambuklao and 5.01 x $10^6 m^3$/year for Binga. The record of sediment yield at Ambuklao and Binga dams is shown in Table 3.1.

The estimated natural sediment yield is shown in Table 3.2 for the Southern Cordillera mountains and Table 3.3 for the Zambales mountains. The aerial distribution is shown in Fig. 3.1 and Fig. 3.2 respectively.

The estimated annual average natural sediment yield and sediment yield rate are summarized below:

Site	Catchment* Area (km^2)	Average Sediment Yield ($10^6 m^3$/yr)	Average Sediment Rate (m^3/km^2/yr)
Ambuklao Dam	617	3.3	5,400
Binga Dam	860	5.3	6,100
San Roque Dam	1,250	10.4	8,300
Agno River Basin (N17)	1,310	10.7	8,100
Allied River Basins (N18-N37)	975	7.8	8,000
Southern Cordillera (N1-N37)	2,285	18.5	8,100
Zambales (S1-S22)	1,949	14.4	7,400

* : Mountain area only

3.1.2 Discharge of Mine Tailings

(1) Production of Ore

As described in preceding Section 2.3, there are three major mine companies in the Agno River basin. The annual average production of the ore in the three companies is reported to be 10,837,000 tons, and their main disposal systems are provided to deposit mine tailings in the tailings dams (See Table 2.10). The volume of impounding the tailings dams and that of production of the ore are almost same as presented in Table 3.4.

(2) Monitoring Sediment Yield

The report, "Restudy of San Roque Multi-purpose Project" (JICA, 1985) dealt with flow amount of mine tailings and monitored suspendend load at the downstream of major tailings dams. The annual suspended load at three stations (B, C, D) located downstream of the major three mining area (see Fig. 2.9) is estimated by use of the monitored records as shown in Table 3.5. The total annual suspended load at these sites, which is composed of a part from natural oriented and a part from mine tailings oriented, is estimated at 640,000 m^3/yr (or 1,020,000 tons/yr).

(3) Sediment Deposited in ARIS

The results of the grain size distribution analysis of the sampled sediment in the main and lateral canals of ARIS show that the major component (about 90%) of the sediment is sand (larger than 0.42 mm). Over 60% of the samples taken from the mine tailings dams, on the other hand, is silt and/or clay (smaller than 0.074 mm) as shown in Fig. 3.3.

(4) Tailings Dam and Related Facilities

The inspection results in the STUDY suggest that treatment of mine tailings was done fairly well and no particular defects on tailings dam structures were observed at least during the inspection period.

(5) Preliminary Assessment on Amount of Mine Tailings

In accordance with the findings described in the foregoing sections it is rather difficult to assume that the major source of the sediment deposited in the downstream of San Roque in the Agno River; especially that in ARIS irrigation facilities is mine tailings.

It can be inferred that the discharge of mine tailings will not affect the lower reaches of the Agno river so seriously if the following conditions are held:

1) The amount of ore is not over the present level i.e. order of 10,000,000 m^3/year.

2) The present condition of the disposal system is continued or improved.

3) The amount of ore from illegal mines is not increased.

That is, if the production of ore is increased in the future, it will be necessary to improve the disposal system and to impose legal controls on the illegal mines.

3.2 Sediment Discharge Rating Curve

3.2.1 Sediment Discharge Records

Sediment discharge measurement has been conducted in the STUDY at the water level gauge stations by using the bed load sampler provided by JICA. The results are given as follows:

Station	River	Date of Measurement	Water Discharge (m^3/s)	Bed Load (ton/day)
Cabanbanan, Manaoag	Aloragat	Oct. 13, 1989	1.5	13.1
- Ditto -	-Ditto-	Oct. 20, 1989	29.4	103.7
Polacion, Manaoag	Angalacan	Oct. 10, 1989	63.1	405.2

In addition, suspended load sampling data, which were observed in the Restudy of San Roque Multi-Purpose Project to find the existing condition of mine tailings discharge from the tailing dams were collected. The location of these measurement sites and the records of suspended load are given in Fig. 3.4 and Fig. 3.5, respectively.

3.2.2. Riverbed Materials

A total of 33 sampling sites for riverbed materials were selected along the river course of the Agno River, its major tributaries and the Allied Rivers. Their locations and particle size are presented in Fig.3.6.

The particle size distribution of sampled materials were analyzed by sieving and/or hydrometer analysis. The results are compiled in Table 3.6, and Fig. 3.7 shows the particle size accumulation curves. The distribution of particle size in the Agno River is given in Fig.3.8.

Riverbed materials in the upper reaches of the Agno River down to San Manuel are composed mainly of gravel and coarse sand (2.0-76.2 mm). Main bed materials gradually change into sand from the beginning of the alluvial fan in San Manuel to the confluence with the Tarlac River in WaWa (0.074-0.42 mm). In WaWa and the river mouth, the components of sand and silt increase up to over 50%. In the lowest reaches of the Agno River, the bulk of the sediment are composed of silt (smaller than 0.074 mm).

Riverbed materials in the alluvial fan of tributaries and the Allied Rivers are composed mainly of gravel and coarse sand, similar to that of the Agno River. In the lower reaches of these rivers, however, sand is the dominant component of the riverbed materials.

3.2.3 Sediment Discharge Rating Curve

Sato-Kikkawa-Ashida's formula for the bed load and Lane-Kalinske's formula for the suspended load are employed for the calculation of sediment discharge. Both formulas are widely applied for the estimation of the bed load discharge and the suspended load discharge respectively. Both formulas are expressed by the following equation:

- Sato-Kikkawa-Ashida's formula

$$Q_B = \frac{U*^3}{(Ws/Ww-1)g} \cdot Ps \cdot F \ (to/tc) \qquad \text{------ (3.1)}$$

Where,

Q_B : Volume of bed load per unit width per unit time (tons/day)
$U*$: Friction velocity (m/sec); $U* = \sqrt{gRIe}$
R : Hydraulic mean depth (m)
Ie : Energy gradient
Ws : Density of sand (tons/m^3)
Ww : Density of water (tons/m^3)
g : Acceleration of gravity; $g = 9.8$ m/sec^2
$n > 0.025$: $Ps = 0.623$
$n < 0.025$: $Ps = 0.623 \ (40\ n)^{-3.5}$

Also,

- F : Function of to/tc as shown in Fig. 3.9
- n : Manning's roughness coefficient
- to : Tractive force
- tc : Critical tractive force after Egiazaroff's formula as follows:

$$\frac{U_{*c}^2}{(W_s/W_w-1)g\cdot d_i} = \frac{0.1}{\{\log_{10}(19d_i/d_m)\}^2} \qquad \text{------(3.2)}$$

Where,

U*c : Critical friction velocity of bed materials of gain size "di" (m/sec)

di,dm: Grain size, average grain size of bed materials (m)

- Lane-Kalinske's formula

$$Q_s = Q\cdot C_o\cdot P \qquad \text{------ (3.3)}$$

$$C_o = 5.55\ [1/2(U_*/W_o)\ \exp\{-(W_o/U_*)^2\}]^{1.61} \qquad \text{------ (3.4)}$$

Where,

Qs : Volume of suspended load per unit width per unit time (tons/day)

Q : Flow discharge per unit width (m3/sec)

P : Function of Wo/U*, Karman's constant and Ps = V/U* as shown in Fig. 3.9

Co : Concentration of riverbed (ppm)

Wo : Grain fall velocity (m/sec)

V : Flow velocity (m/sec)

In appling the formulas for bed load and suspended load, the gradation of river bed materials are considered. Sediment discharge of the observed data and the estimation are compared in Fig. 3.10.

As the wash load amount is difficult to be estimated by hydraulics, the following empirical method is applied on the basis of results of sediment discharge measurement:

$$Qws = C \cdot Qw^2 \qquad \text{------- (3.5)}$$

Where,

Qws : Volume of wash load (m^3/day)
Qw : Flow discharge (m^3/sec)
C : Constant

The constant "C" is determined on the following assumptions and equation:

- Wash load produced in the upper reaches flows down the mountain area without sediment deposition on the riverbed but some are deposited on the river mouth.

- According to the actual sedimentation records of Binga dam as shown in Table 3.7, about 50% of the sediment yield from the upper river basin is comprised of 50% silt less than 0.1 mm regarded as wash load. Thus, sediment yield is assumed to be composed of 50% of wash load and 50% of bed material load (bed + suspended loads).

$$C = \frac{0.5 \cdot N \cdot A \cdot Sy}{\sum Qw^2 \cdot T} \qquad \text{------ (3.6)}$$

Where,

N : Period (yr)
A : Catchment area (Km^2)
Sy : Sediment yield rate ($m^3/km^2/yr$)
Qw : Flow discharge (m^3/sec)
T : Unit time (sec)

The grain size distribution of the test results of the sampled river bed materials is used for the calculation. The reference points of sediment discharge rating curves are selected along the Agno River and its major tributaries taking into account the stretches of design river channel, the base points of sediment control and the sampling sites of bed load discharge. The location is shown in Fig. 3.11 and the calculation results are presented in Table 3.8.

3.3 Annual Sediment Transport Capacity

3.3.1 Existing River Channel

The annual sediment transport capacity for bed and suspended loads which affect the riverbed fluctuation is estimated by using the sediment discharge rating curve as presented in Table 3.9. The estimation is based on the daily discharge for twenty seven (27) years from 1960 to 1986 at San Roque.

The transport capacity of the Agno River decreases in transition portion between the mountain area and the alluvial fan, and tends to increase in the narrow stretch from Santa Maria to Wawa. The maximum capacity of the existing channel is estimated at 740,000 m^3/yr.

3.3.2 Design River Channel

The annual sediment transport capacity in the design river channel is estimated based on the design conditions of the Framework Plan.

The capacity of the design channel is mostly larger than that of the existing channel, and the difference is 570,000 m^3/yr at the maximum point of the Agno River as shown in Fig. 3.12. The tendency of the capacity fluctuation between the existing and the design conditions is approximately the same.

3.4 Sediment Balance Analysis

3.4.1 Present Condition

Sediment balance simulation is carried out at 111 reference points in the Agno River System to examine the movement of sediment under the existing river conditions. The simulation is based on the daily discharge for twenty seven (27) years from 1960 to 1986 at San Roque. The applied model is composed of sub-basin, confluence, dam reservoir, river channel, floodway and irrigation system models as shown in Fig. 3.13. Sediment discharge is estimated respectively for each component, namely bed load, suspended load and wash load. Each sediment discharge according to the models is calculated as follows:

Models	Bed Load	Suspended Load	Wash Load
-Sub-basin	Sum of bed material load (bed + suspended load) is equivalent to wash load. <1		$Qs = C \times Qw^2$ Qs : Wash Load Qw : Flow Discharge C : Constant <1
-Confluence	100 % pass	100 % pass	100 % pass
-Dam Reservoir <2	100 % trapped	100 % trapped	Trapped (Trap efficiency by Brune's curve is applied)
-River Channel	Sato-Kikkawa-Ashida's formula	Lane-Kalinske's formula	100 % pass in upper reaches but some % are trapped in lower reaches.
-Flood Way	No inflow	$Qsi = Qsu \times Qwi/Qwu$ Qsi ; Sediment Inflow load Qsu ; Sediment Discharge at Upper Ref. Point Qwi ; Water Inflow Qwu ; Flow Discharge at Upper Ref. Point	Same as suspended
-Irrigation System	No inflow	-Ditto-	-Ditto-

Note: <1 : Refer to Section 3.2.
<2 : Sedimentation in the Poponto Swamp is calculated as dam reservoir model.

The river cross sections surveyed in 1981 and 1989 are the only available records which trace the historical transformation of the riverbed. The simulation results from 1982 to 1986 are, therefore, chosen for comparison from the 27 year simulation of the Agno River main course. The average annual sediment volume of these five year period is compared with the recorded volume estimated from the river cross sections of 1981 and 1989 as shown in Fig. 3.14. The comparison between the simulated and the recorded sediment volume is summarized below:

Reference Stretch/Point	Simulated Sediment Volume ($10^3m^3/yr$)	Recorded Sediment Volume ($10^3m^3/yr$)
(1) River Channel <1		
San Roque - Santa Maria	1,358	1,553
Santa Maria - Wawa	-123	-134
Wawa - River Mouth	2,267	2,542
(2) Dam Reservoir <2		
Ambuklao (for 30 yrs)	98,000	108,000
Binga (for 26 yrs)	45,000	31,320
(3) Retarding Basin <2		
Poponto Swamp	3,705	4,000 <3
(4) Irrigation System <2		
ARIS	396	480
LATRIS	76	60

Note: <1 : Calculation is based on the period from 1982 to 1986.
<2 : Calculation is based on the period from 1960 to 1986.
<3 : This volume is estimated from the interview results with residents.

The above results show that the model well simulates appropriately the movement of sediment under the present conditions of river channel, dam reservoir, retarding basin and irrigation system. The simulated annual sediment balance from 1960 to 1986 is illustrated in Fig. 3.15.

3.4.2 Proposed Condition

The sediment balance under proposed condition was simulated on the following conditions and assumptions:

a. Conditions

1) Proposed Condition (I) : Framework Plan (River improvement only)

2) Proposed Condition (II) : Integrated Framework Plan (River improvement + Retarding basin + Moriones and Lower O'Donnell flood control dams)

3) Proposed Condition (III) : Framework Plan for sediment control (River improvement only + Moriones and Lower O'donnell dams + Sabo dams)

b. Assumptions

1) 50% of the natural sediment yield estimated in Section 3.1 is mitigated by afforestation.

2) Trap efficiency for the dams is considered according to the dams reservoir capacities, but for the sabo dams a trap efficiency of 50% is applied so that only bed material load is trapped.

The annual sediment volume is tabulated in Table 3.10 and the annual sediment balance of each condition, i.e., Proposed Condition (I), (II) and (III) are shown in Figs. 3.16, 3.17 and 3.18, respectively.

3.4.3 Excess Sediment Volume to Be Controlled

The excess sediment volume to be controlled is estimated based on the forgoing calculation results under Proposed Condition (III) and defined below:

1) Design sediment discharge for sediment control : 50% of the present natural sediment yield

2) Design allowable sediment discharge : Sediment transport capacity at the reference point

3) Design excess sediment volume to be controlled : Balance between 1) and 2)

A total of 16 base points of sediment control are selected along the river course of the Agno River, its major tributaries and the Allied Rivers (see Fig. 3.11). The total design sediment discharge and excess sediment volume at the base points are 15,338,000 m^3/yr and 11,731,000 m^3/yr, respectively, as shown in Table 3.11.

4. ALTERNATIVE OF SEDIMENT CONTROL PLANS

In the mountainous area of some 4,200 km^2 which occupies 55% of the study area of 7,640 km^2, natural sediment of as much as 7,800 $m^3/km^2/yr$ are produced, and this large quantity of sediment cause sedimentation in dam reservoirs and the irrigation systems and aggradation of the riverbeds. It is considered that the active yield of sediment is mainly due to poor vegetation. Slope erosions caused by road construction are also observed in the hillsides. In addition, some portions of mine tailings might have been discharged into the rivers.

According to the estimation result of the sediment transport capacity, a remarkable increase of the capacity by the river channel improvement is not expected. Therefore, sediment control measures such as afforestation and the control of mine tailings discharge, slope erosion due to road construction, maintenance of river channel and irrigation canal and sabo works are considered to solve or mitigate the sedimentation problems.

In the STUDY, the sediment control plans were formulated as described below:

a. Afforestation

50% of the sediment yield will be mitigated by afforestation in the future.

b. Mine

Sediment due to mine tailings will be totally controlled (i.e., no tailing discharge in the future).

c. Road

Landslide and soil erosion due to road construction will be totally controlled in the future.

d. Sabo

The remaining part of the sediment yield which will not be controlled by the foregoing three measures (a, b, and c) will be subject to sabo works such as sabo dam.

On the other hand, excess sedimentation in the river channels caused by imbalanced sediment transport capacity is coped with dredging or excavation works.

4.1 Afforestation

Forest vegetation is highly evaluated among nations for its significant effect on prevention of soil erosion. The sediment control plans are formulated in the STUDY on the assumption that 50% of the sediment yield will be mitigated. The area to be afforested to reduce the sediment yield to one-half in the whole basin is estimated at approximately 1,000 km^2 assuming that sediment yield per unit forest land is 1,300 m^3/km^2 (refer to Section 3.1.1), and all of the partial forest land (800 km^2) and about 60% of the bare land (200 km^2) would be totally afforested.

4.2 Control of Mine Tailings

Government regulations prohibit the disposal of mine tailings directly or indirectly immediately into natural drainage systems. However, some portions of the mine tailings may have been discharged into the rivers, although the quantity was estimated to be minimal compared to the natural sediment yield in the STUDY. Moreover, failure of the tailing dams such as the NO.1 tailing dam of Philex Corp. which was washed out during typhoon "Dading" in 1976 will bring catastrophic damage to the downstream.

As for the disposal system of mine tailings, some measures have already been proposed. In 1979, JICA studied the TLP (Tunnel, Launder and Pipeline) System, in which all the mine tailings would be transported to the Lingayen Gulf through a tunnel, pipeline, and open launder. In the San Roque Multi-Purpose Project, all the tailings produced from the mines located in the watershed will be impounded in the San Roque Dam reservoir.

From the reason that the TLP System is not economically feasible and it might contaminate the sea, the idea has been abandoned. On the other hand, GOP has decided not to immediately implement the San-Roque Multi-Purpose Dam Project because of its high cost although this project has been expected as a countermeasure to the sedimentation problem in the irrigation systems.

Under the abovesaid situation, the following on-site conceivable measures are recommended to totally control the discharge of mine tailings.

(i) Diversion Facility

At the upstream end of each of the tailing ponds, a diversion facility shall be provided to prevent water from flowing into the pond from the upstream.

(ii) Spillway

A spillway with enough capacity for excess water not to overtop the tailing dam body shall be provided.

(iii) Improvement of Tailing Dam Body

To prevent the erosion of downstream slope of the tailing dam, stone masonry or gabion, berms and drainage ditches shall be provided.

(iv) Settling of Tailings

For the purpose of settling of tailings in the filled-up pond, surface water shall be drained, and covering with soil and planting shall be done.

4.3 Control of Landslide and Soil Erosion due to Road Construction

Most roads in the mountainous area, whether national, provincial, village, mining or logging roads have poor drainage systems, very steep cut and fill slopes, a small number of culverts and retaining walls, and a few cross drains. For these reasons, road bank erosion, gully erosion and landslides above and below the roads are big problems in the Basin. In particular, along the

Halsema Mountain Highway, of which widening and concreting is at present being done, many landslides were observed.

Treatment of runoff water is the key to control landslides and soil erosion. For this purpose not only a permanent drainage system shall be provided, but drainage during construction is also very important. In addition, slope protection works such as retaining wall, mortar or concrete spraying and planting shall be done in accordance with the topographical and geological conditions.

4.4 Sabo Works

Sabo dam is the most essential component of sabo works. A high and large-capacity sabo dam is effective for regulating sediment discharge. The number of sabo dams is estimated by considering the total storage volume of dams equivalent to the excess sediment volume to be controlled. In general, the height of sabo dam is less than 25 m.

4.5 Maintenance of River Channel and Irrigation Canal

(1) River Channel

Aggradation and degradation of the riverbed occur due to the imbalance of sediment discharge in river channel. Maintenance dredging and excavation shall be done against the aggradation and riverbed protection works such as groundsill and foot protection shall be provided against degradation.

(2) Irrigation Canal

A fair quantity of sediment flows into the irrigation canal. Settling basin shall be provided at the intake as a structural countermeasure, and maintenance dredging shall be continuous for the irrigation systems and river channels.

5. PROPOSED SEDIMENT CONTROL PLANS FOR FRAMEWORK PLAN

5.1 Sabo Dams and Other Facilities

5.1.1 Sabo Dams

The required number of sabo dams for the Framework Plan was estimated for the design life of twenty years. In this estimation the excess sediment volume for the period was assumed to be stored by the dams. The typical design of sabo dam is given in Fig. 5.1, and the construction sites and major dimensions were determined on the basis of the topographical map with a scale of 1:50,000 as presented in Fig. 5.2 and Table5.1, respectively.

The total construction cost of sabo dams for the Framework Plan is estimated at about 2.6 billion pesos and the required construction of sabo dams is summarized below:

Location	Excess Sediment Volume ($10^3m^3/yr$)	Required Number of Sabo Dams for 20 years	Required Number of Sabo Dams for 50 years<1
Ambuklao Dam	1,681	Ambuklao Dam	Ambuklao Dam
Binga Dam	960	Binga Dam	Binga Dam
San Roque Dam	2,550	San Roque Dam	San Roque Dam
Ambayoan	1,126	6	(33)
Dipalo	13	1	(1)
Viray	74	4	(6)
Balog-Balog Dam	1,344	Under const.	Under const.
Moriones Dam	1,042	Moriones and Lower O'Donnell dam	
Lower O'Donnell Dam	1,349	Moriones and Lower O'Donnell dam	
Camiling	373	3	(5)
Olo	376	4	(11)
Bayaoas	191	1	(3)
Tuboy	267	3	(9)
Angalacan	39	2	(3)
Bued	346	8	(33)
Total	11,731	32 plus San Roque, Moriones and Lower O'Donnell	(104)

Note : <1 : The required number of sabo dams for the design life of fifty years was also estimated for reference, on the assumption that sabo dams of 25 m in height are added to the plan of the design life of twenty years.

5.1.2 Other Facilities

(1) Groundsill and Foot Protection

Degradation occur due to imbalance of sediment discharge mainly caused by the decrease of sediment supply from the upper basin due to the construction of a large scale dam such as San Roque. Groundsill and foot protection should be provided at the scouring portion of the low water channel. The stretch to be provided with groundsill and foot protection is proposed as follows:

River	Stretch	Length of Stretch (km)
Agno River	San Roque - San Manuel	5
-Ditto-	Rosales - Urbiztondo	45
Tarlac River	Lower O'Donnell Dam - Confluence of the Tarlac River	25
-Ditto-	Moriones Dam - Confluence of the Tarlac River	5
-Ditto-	Tarlac - Gerona	15
Total		95

(2) Settling Basin

A settling basin shall be provided to trap inflowing sediments in front of the intake of each irrigation system and maintenance dredging in the basin shall also be conducted. The annual sediment inflow to the irrigation systems is estimated from the results of the sediment balance analysis for the Proposed Condition (III) as follows:

Irrigation System	Sediment Inflow Volume (m^3/yr)
ARIS	208,000
LATRIS	22,000
Ambayoan RIS	71,000
Dipalo RIS	11,000
SMORIS	4,000
Tarlac RIS	3,000
Camiling RIS	64,000
Total	383,000

5.2 Non-Structural Measures

5.2.1 River Maintenance

Excess sedimentation in the river channels shall be coped with by dredging or excavation. The total sedimentation volume in the river channels of the Agno River and the tributaries is estimated at 1,400,000 m^3/yr from the result of the sediment balance analysis for the Proposed Condition (III) as follows:

Item	Sediment Volume (10^3m^3/yr)	Remarks
(1) Sediment Yield	15,481	
(2) Sedimentation in Dam Reservoirs	8,823	
(3) Sedimentation in Sabo Dams	2,334	
(4) Sedimentation in Poponto Swamp	244	
(5) Sediment Inflow to Irrigation Systems	383	
(6) Sediment Discharge to Lingayen Gulf	2,291	
(7) Sedimentation in River Channels	1,406	(7)=(1)-(2)-(3)-(4)-(5)-(6)

5.2.2 Dam Maintenance

The remaining dead storage of the existing/ongoing dams, i.e., Ambuklao dam and Binga dam is not enough because of the unexpected huge sediment yield. Maintenance dredging of the dam reservoir should be conducted for the conservation of the design dead storage. The remaining life of the dead storage is estimated at 18 years for the Binga dam while the dead storage of the Ambuklao dam is almost full.

As for the Balog-Balog dam which is under construction, the design dead storage will be filled up in 37 years, less than the design period of 50 years and maintenance dredging shall be necessary. This is the same for Ambuklao and Binga dams.

6. RECOMMENDATION FOR FURTHER STUDY REQUIREMENT

6.1 Sediment Control Plan

In the previous section, the sediment control plan was proposed in the conceptual level as a countermeasure to the sedimentation problem through sediment balance analysis. To improve the sediment control plan from the conceptual level, the following further studies are recommended.

(1) Sediment discharge measurement

The design sediment discharge for formulation of the sediment control plan was estimated from experimental formulas commonly used in Japan, since reliable observed data are not sufficient to determine the specific rating curves in the Agno River basin. In this connection, it is desirable to continue sediment discharge measurement at the hydrological observation stations, together with flow discharge measurement.

(2) Topographical survey

The sites and dimensions of the proposed sabo dams were roughly determined on the basis of the topographical map with a scale of 1 : 50,000 and a contour interval of 20 m. In order to design the Sabo dams more accurately, a topographical map with a scale of about 1 : 3,000 and a contour interval of 2 m is required. For this purpose aerophoto surveys around the proposed dam sites are recommended.

(3) Afforestation

Afforestation is the most effective measure to conserve a watershed. In the Framework Plan for sediment control, a total area of 1,000 km^2 is assumed to be afforested in the whole basin to mitigate 50% of the present sediment yield, but it is predicted that it takes a long time to complete the afforestation of such a wide area. Therefore, it is desirable to select areas to be urgently afforested through field investigation by considering the existing degree of devastation and the effect to be expected by afforestation. In addition, a study on suitable plant selection is also required.

(4) Monitoring of mine tailings discharge

The control of mine tailings discharge is very important since they may inflict catastrophic damage to the downstream if they are washed away, although the mine tailings discharge was estimated to be minimal compared to the natural sediment yield in this STUDY. In this connection, monitoring of mine tailings discharge is recommended to be continued, and it shall include inspection of the mine tailings disposal systems, sediment discharge measurement and patrol against illegal mining.

6.2 River Mouth Clogging

As mentioned in Section 2.5, a developing sand bar, which may be a cause of river mouth clogging has been observed at the river mouths of the Agno River left course and the Cayanga River. However, because of unavailability of data such as current wave, bottom material and coastal topographical map the cause of the sedimentation around the river mouths has not been determined.

A river mouth survey is strongly recommended not only to collect these data but also to formulate the river mouth treatment plan. The survey area shall include not only the river mouths of the Agno River left course and the Cayanga River but also those of the Agno River main course and the Panto River since the sand drift along the Lingayen Gulf may be influenced by the water and sediment discharge of these rivers.

The required survey items are given as follows:

(1) Wave height and direction

Wave is a main cause of sand drift, and it is very important to know the characteristics of wave such as wave height and direction. For this purpose a wave gauge shall be installed at a place of more than 10 m depth, where reflection waves do not affect.

(2) Tidal Level

Tidal level data are required to determine the design high tide level, the tidal reach and tidal prizm. The observation records and tide tables of the San Fernando Harbor are available.

(3) Current

Velocity and direction of coastal current are required to know the direction of sand drift. Current observation shall be carried out along the shoreline.

(4) Wind Velocity and Direction

Wind data is used to interpolate wave height and direction data. All the recorded data of the Dagupan Meteological Station shall be collected.

(5) Littoral Sand Drift

Littoral sand drift survey shall be performed to find prevailing direction and relation between external forces and amount of littoral sand drift. For this purpose a survey using tracers of fluorescent sands are recommended. During the littoral sand survey, the wave and current survey shall also be conducted continuously.

(6) Bottom Material

Bottom material survey shall be performed to know the gradation of the bottom materials. The results will be the basic data needed for estimation of the process of sand bars. Sampling of bottom materials shall be done at both of the river mouths and the sea area.

(7) Water Level and Water Discharge at River Mouth

River mouth water level survey is performed to find the degree of obstruction of flood flow by sand bar and of flush of sand bar by floods by observation of water level at river mouth. The purpose of river mouth discharge survey is to distinguish the intrinsic river discharge and tidal discharge. A water level gauge station shall be installed at each river mouth.

(8) River and Coast Topography

Results of river and coast topography survey will be a basic data for analysis of the transition of the river mouths. The survey shall consist of longitudinal and cross sectional survey of the river channels, sounding survey around the river mouths, beach survey, shoreline survey and topographical survey around the river mouths.

TABLES

Table 2.1 SEDIMENT DEPOSIT RECORD IN AMBUKLAO AND BINGA DAM RESERVOIR

(1) Ambuklao Dam Reservoir (CA = 617 km2)

Year	Period	Accumulative Deposit Volume (mill. m3)	Specific Annual Deposit Rate (m3/km2/yr)
1956	0	0.00	0
1967	11	27.00	3,978
1980	24	91.70	6,193
1986	30	108.00	5,835

(2) Binga Dam Reservoir (CA = 860 km2)

Year	Period	Accumulative Deposit Volume (mill. m3)	Specific Annual Deposit Rate (m3/km2/yr)
1960	0	0.00	0
1967	7	5.55	3,263
1979	19	22.60	4,895
1986	26	31.32	4,957

Data Source: Sedimentation Studies of Ambuklao and Binga Reservoir, NAPOCOR, 1986

Table 2.2 SILTATION CONDITION IN NATIONAL IRRIGATION SYSTEMS

Where a cell holds two values, the upper one is given first. Length of Canals: Upper = Original Design, Lower = Operational as of 1988. Actual Irrigated Area: Upper = Wet Season (MAY-OCT), Lower = Dry Season (NOV-APR). Desilting Quantity: Upper = Main Canal, Middle = Lateral Canal, Lower = Total.

No.	Name of Irrigation System	Service Irrigation Area (ha)	Source of Water	Design Discharge (m3/s)	Length of Canals (km): Main	Length of Canals (km): Lateral	Length of Canals (km): Total	Actual Irrigated Area for Last Three Years (ha): 1986	1987	1988	Desilting Quantity for Last Three Years (m3): 1986	1987	1988	Accumulated Quantity of Siltation in Canals (m3): Date of Surveying	Main Canal	Lateral Canals	Total	Silting Materials: Main Canal	Lateral Canals	Agricultural Field	Remarks
1	Agno River Irrigation System	18,509	Agno River	38	39.82 39.82	208.012 144.88	247.832 188.700	9,162 4,337	6,749 6,101	2,109 3,018	NO DATA NO DATA 32,639	NO DATA NO DATA 30,714	NO DATA NO DATA NO DATA	May, 1988	No Data	No Data	307,715	Sand	Fine Sand	Fine Sand	
2	Lower Agno and Toto-nogen River Irrigation System	10,000	Agno River	19	36.981 28.311	179.743 150.003	210.724 178.314	4,436 2,725	4,489 2,741	4,844 2,887	Only in the stretch from Intake to 500 m upstream desilting was conduct		65,200 120,100 185,300	1986-1987	169,100	166,100	335,200	Fine Sand	Fine Sand	Fine Sand, Siltation is very slight	No Desilting Activity before the year 1984
3	Ambayaoan River Irrigation River	4,050	Ambayaoan River	6	15.980 15.980	70.57 58.91	86.55 84.89	3,134 746	2,322 751	3,855 442	1,400 - 1,400	1,400 - 1,400	1,400 - 1,400	1987	80,813	88,138	168,951	gravel sand	fine sand silt clay	Siltation is very slight	
4	Pepalo River Irrigation System	1,963	Depalo River	4	11.58 11.58	25.000 25.000	36.580 36.580	1,540 163	1,513 100	1,503 100	NO DATA NO DATA NO DATA	NO DATA NO DATA NO DATA	NO DATA NO DATA 38,038	1987	No Data	No Data	38,038	gravel sand	gravel sand	Siltation is very slight	
5	Sinocalan River Irrigation System	1,650	Sinocalan River	2.10	6.92 6.92	20.404 14.849	27.324 21.769	- 541	193 523	163 555	No Desilting Activity			No Data				Siltation is slight			Designed to Irrigate only in Dry Season
6	San Fabian (Bued) River Irrigation System	2,765	Bued River	4.785	16.305 15.499	39.66 36.352	55.965 51.851	1,882 1,383	1,595 1,419	1,742 1,280	NO DATA Small Scale Desilting	4,430 8,780 13,210	1,820 6,658 8,478	Jan. 1987	10,622	18,789	29,411	sand	sand	Siltation is very slight	
7	Dumoloc River Irrigation System	3,500	Dumoloc River	2	10.239 9.478	27.228 21.737	37.467 31.215	1,104 160	890 169	888 99	NO DATA Small Scale Desilting	1,815 5,377 7,192	4,619 6,298 10,917	Jan. 1987	6,534	11,864	18,398	sand	sand	Siltation is very slight	
8	Camiling River Irrigation System	8,580	Camiling	No Data	27.89 27.89	165.60 151.00	193.49 178.89	6,959 2,718	7,012 2,649	5,400 2,574	Yearly Desilting was conducted but NO DATA		41,493 - 41,493	No Data				gravel, sand	sand	Siltation is very slight	
9	Tarlac River Irrigation System	3,662	Tarlac	21.6	20.64 20.64	100.12 -	120.76 20.64	No Data			No Data			No Data				sand	sand	Siltation is very slight	
10	San Miguel and O'donnell River Irrigation System	10,412	O'donnell	18	27.50 -	116.00 -	143.50 -	No Data			No Data			No Data				sand	sand	Siltation is very slight	

Table 2.3 ACTUAL IRRIGATED AREA AND DESILTING ACTIVITIES IN ARIS

YEAR	ACTUAL IRRIGATED AREA (ha) Wet Season	ACTUAL IRRIGATED AREA (ha) Dry Season	DESILTED VOLUME (mill. m3)	ACCUMULATIVE DEPOSIT VOLUME (mill. m3)
1975	13,545	4,505	No Data	No Data
1976	16,271	5,212	No Data	No Data
1977	16,593	3,978	No Data	No Data
1978	12,394	4,409	148	No Data
1979	13,742	4,498	108	No Data
1980	13,095	4,290	133	No Data
1981	9,689	4,018	70	No Data
1982	10,037	4,786	67	No Data
1983	10,318	3,932	46	No Data
1984	7,573	551	37	No Data
1985	9,367	3,072	33	No Data
1986	9,162	4,337	33	No Data
1987	6,749	4,101	31	No Data
1988	2,109	2,010	No Data	908<1
Total	150,644	53,699	706	908
Average	10,760	3,836	71	908

Data Source : ARIS, NIA

Note: <1 : Estimated from the result of cross section survey.

Table 2.4 ACTUAL IRRIGATED AREA AND DESILTING ACTIVITIES IN LATRIS

YEAR	ACTUAL IRRIGATED AREA (ha)		DESILTED VOLUME (mill. m3)	ACCUMULATIVE DEPOSIT VOLUME (mill. m3)
	Wet Season	Dry Season		
1980	7,515	3,634	No Desilting	No Data
1981	6,783	3,335	No Desilting	No Data
1982	No Data	No Data	No Desilting	No Data
1983	5,527	3,151	No Desilting	No Data
1984	5,211	3,308	No Desilting	No Data
1985	5,012	3,098	No Data < 2	No Data
1986	4,436	2,725	No Data < 2	No Data
1987	4,449	2,747	No Data < 2	335 < 1
1988	4,644	2,887	62 <3	No Data
Total	43,577	24,885	62	335
Average	5,448	3,110	62	335

Data Source : LATRIS, NIA

Note: <1: *Estimated from the result of cross section survey*
<2: Only in the streach of main canal from the intake + 0 + 500 m upstream desilting was conducted, but the desilted volume was unknown.
<3: The total desilting volume will be 185 cu.m for three years after 1988.

Table 2.5 RESULTS OF GRADATION AND SPECIFIC GRAVITY TESTS IN IRRIGATION CANALS

Sample No.	River/Canal	Location	Distance from Rivermouth or Confluence (km)	Specific Gravity: Smaller than 0.074 mm	Specific Gravity: 0.074 mm - 9.52 mm	Specific Gravity: Greater than 9.52 mm	Particle Size Components (%): Cobble 76.2mm - 300mm	Gravel 2.0mm - 76.2mm	Coarse Sand 0.42mm - 2.0mm	Fine Sand 0.074mm - 0.42mm	Silt 0.005mm - 0.074mm	Clay 0.001mm - 0.005mm	Maximum Particle Size (mm)	60% Particle Size D60 (mm)	50% Particle Size D50 (mm)	10% Particle Size D10 (mm)	Uniformity Coefficient UC UC=D60/D10	Remarks
AR-1	ARIS Main	Sn. Roque, San Manuel, Pang.	<1 2	-	2.79	-	0	1.14	58.37	40.0	-	-	19.1	0.70	0.50	0.21	3.33	
AR-2	-Ditto-	Sn. Manuel, Pang.	<1 6	-	2.69	-	0	25.60	50.30	23.80	-	-	19.1	1.1	0.87	0.30	3.67	
AR-3	-Ditto-	Sobol, Asingan	<1 13	-	2.68	-	0	1.82	62.08	36.10	-	-	9.52	1.4	0.90	0.30	4.67	
AR-4	-Ditto-	Yatyat, Binalonan Pangasinan	<1 21	-	2.71	-	0	0	6.52	92.85	-	-	2.00	0.31	0.30	0.16	1.94	
AR-5	-Ditto-	Catablan, Sta. Barbara, Pang.	<1 33	-	2.68	-	0	0.05	1.01	96.49	-	-	4.76	0.31	0.30	0.15	2.09	
AR-6	ARIS Lateral	Binalonan, Pang.	<2 7															No Siltation Abandoned Canal
AR-7	-Ditto-	Bactad, Urdaneta Pangasinan	<2 5	-	2.69	-	0	0.04	7.51	92.20	-	-	4.76	0.31	0.30	0.16	1.94	
AR-8	ARIS Lateral	Sumabnit, Binalonan Pangasinan	<2 7															No Siltation Abandoned Canal
AR-9	-Ditto-	Calbeg, Malasique, Pangasinan	<2 6															No Sediment Desilted Canal
AR-10	-Ditto-	Jimenez, Mapandan, Pangasinan	<2 4	2.66	-	-	0	6	0	79	15	-	-	0.24	0.18	0.065	3.69	
LA-1	LATRIS Main	Sta. Maria, Pang.	<1 5	-	2.59	-	0	0.08	3.46	95.30	-	-	4.76	0.31	0.29	0.15	2.10	
LA-2	- Ditto -	Carmen, Rosales Pangasinan	<1 16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Note : <1 : Distance from the (Main Canal) Intake
<2 : Distance from the Main Canal

Table 2.6 ESTIMATION OF SEDIMENT VOLUME IN ARIS/LATRIS

No.	Item	Unit	ARIS	LATRIS	Remarks
1.	Design Irrigation Area	ha	18,509	10,000	
2.	Actual Irrigated Area				in the wet season
	in the year of 1988	ha	2,109	-	
	1987	ha	-	4,449	
3.	Actual Irrigated Area				in the wet season
	in the year of 1978	ha	12,394	-	
	1980	ha	-	7,515	
4.	Calculation Period	yr.	10(1988-1978)	7(1987-1980)	
5.	Accumulative Sediment Volume				
	in Canals as of 1988	m^3	908,000	-	
	1987	m^3	-	335,000	
6.	Accumulative Sediment Volume				[(1)-(3)]/(7)
	in Canals as of 1978	m^3	340,000	-	
	1980	m^3	-	146,000	
7.	Constant		0.018	0.017	[(1)-(2)]/(3)
8.	Desilting Volume	m^3	706,000	0	in the calculation period
9.	Annual Sediment Volume in Canals	m^3	127,000	27,000	[(5)-(6)+(8)]/(4)
10.	Annual Sediment Volume Rate in Paddy Fields	ton/ha/yr.	56.5	9.6	< 1
11.	Average Irrigated Area	ha/yr.	10,000	5,500	
12.	Unit Weight of Sediment	ton/m^3	1.6	1.6	
13.	Annual Sediment Volume in Paddy Fields	m^3	353,000	33,000	(10)*(11)/(12)
14.	Annual Sediment Volume in Irrigation Systems	m^3	480,000	60,000	(9)+(13)

Data Source : ARIS, NIA and LATRIS, NIA (Refer to Tables 2.2, 2.3 and 2.4)
Note : < 1 : Source; Industrial Pollution of Irrigation Water and Effect on Riceland Productivity, A.R. Castaneda and S.I. Bhuiyan (SD513)

Table 2.7 (1/2) RECORDS OF DREDGING/EXCAVATION ACTIVITIES

No.	River	Location	Stretch	Length of Dredging Stretch (m)	Quantity of Dredging (cum)	Period of Work	Description of Work
1	Agno	Anulid, Poponto Pangasinan	Sta. 3 + 210 to Sta. 4 + 264.30	1,054	30	1989	River Improvement by Bulldozing
2	-Ditto-	Balococ, Lingayen Pangasinan	Sta. 0 + 280 to Sta. 1 + 660	1,380	329,000	-Ditto-	Dredging, Cut-off-Channel
3	-Ditto-	-Ditto-	Sta. 0 + 000 to Sta. 1 + 660	1,680	224,522	1988	-Ditto-
4	-Ditto-	Anulid, Poponto Pangasinan	Sta. 1 + 440 to Sta. 2 + 105.40	665	53,863	-Ditto-	Pilot Channel Improvement by Bulldozing
5	-Ditto-	-Ditto-	Sta. 1 + 420 to Sta. 1 + 814 and Sta. 0 + 360 to Sta. 1 + 346.20	1,380	35,650	1987	-Ditto-
6	-Ditto-	Sn. Patricio, Sta. Maria Pangasinan	Sta. 0 + 000 to Sta. 1 + 300	1,300	54,279	-Ditto-	River Improvement by Bulldozing
7	-Ditto-	-Ditto-	Sta. 1 + 400 to Sta. 0 +280 and Sta. 4 + 264.3 to Sta. 4 + 475.12	481	88,600	1986	-Ditto-
8	-Ditto-	Urbiztondo, Pangasinan	Sta. 0 + 000 to Sta. 0 + 738	738	109,434	-Ditto-	Cut-off-Channel
9	-Ditto-	Sabangan, Labrador, Pangasinan	River Mouth to 1 Km. Upstream	1,000	No Data	1981-1984	Dredging, Removing Sand bar Deepening River Bed
	Sub-Total (1)			9,678	895,378		
10	Bued	Binday, San Fabian Pangasinan	Sta. 0 + 000 to Sta. 1 + 900	900	44,740	1989	Cut-off-Channel by Bulldozing
11	-Ditto-	Cabaritan, Sison Pangasinan	Sta. 0 + 000 to Sta. 1 + 040	1,040	31,318	-Ditto-	-Ditto-
12	-Ditto-	Villegas, Pozorrubio Pangasinan	Sta. 0 + 000 to Sta. 0 + 800	800	9,670	1987	River Improvement by Bulldozing
	Sub-Total (2)			2,740	85,728		

Table 2.7 (2/2) RECORDS OF DREDGING/EXCAVATION ACTIVITIES

No.	River	Location	Stretch	Length of Dredging Stretch (m)	Quantity of Dredging (cum)	Period of Work	Description of Work
13	Banila	Kita-Kita, Balungo Pangasinan	Sta 0 + 000 to Sta. 1 + 020	1,020	11,406	1989	River Improvement by Bulldozing
14	-Ditto-	Usiagan, Pangasinan	Sta. 0 + 440 to Sta. 1 + 480	1,040	32,100	-Ditto-	-Ditto-
	Sub-Total (3)			2,060	43,506		
15	Viray, Dipalo	Tayug, Pangasinan	Sta. -(1 + 300) to Sta. -(2 + 300)	1,000	26,643	1989	River Improvement by Bulldozing
16	-Ditto-	Magallanes, Tayug Pangasinan	Sta. 5 + 380 to Sta. 6 + 572	1,192	28,310	1988	-Ditto-
	Sub-Total (4)			2,192	54,953		
17	Panto	Pantal, Dagupan Pangasinan	Sta. 0 + 626.46 to Sta. 1 + 180	554	125,485	1989	
18	-Ditto-	-Ditto-	Sta. -(0 + 700) to Sta. 0 + 100	800	99,288	1988	Dredging Deepening River Bed
19	-Ditto-	-Ditto-	400 m upstream fro River mouth to 1.5 km. upstream	1,500	343,000	1987-1988	-Ditto-
	Sub-Total (5)			2,854	567,773		
20	Tarlac	Tibag, Tarlac Tarlac	Bridge to 30 m Downstream <1	30 (as of June, 1989)	18,432.00 (as of June, 1989)	Apr., 1989- (on-going)	Dredging, Deepening River Bed
21	-Ditto-	No Data	No Data	No Data	148,500	1989	
22	-Ditto-	Pantal, Moncada Tarlac	Sta. 0 + 000 to Sta 3 + 396	3,396	73,150	1988	River Improvement By Bulldozing
	Sub-Total (6)			3,426	240,082		
23	Ambayoan	Sn. Nicolas, Pangasinan	Sta. -(2 + 970) to Sta. -(3 + 470)	500	13,126	1988	River Improvement by Bulldozing
	Sub-Total (7)			620	13,126		
24	Marusay	Malsian, Calasiao Pangasinan	Sta. 0 + 000 to Sta. 0 + 620	620	15,307	1987	Cut-off-Channel Improvement by Bulldozing
	Sub-Total (8)			620	15,307		
	Total (1)-(8)			24,070	1,915,853		

Source : AFCS, DPWH, July 1989

Note : <1 : The total length of 5 km downstream from the bridge is proposed to be dredged for three years (Three years program)

Table 2.8 (1/2) ESTIMATED QUANTITY OF RIVER BED MATERIALS ANNUALLY EXTRACTED FROM RIVERS AS CONSTRUCTION MATERIALS

No.	River	Location	Quantity Extracted From River (m3)				Remarks
			Boulder Cobble	Gravel	Sand	Total	
1	Agno	Cabalitan Asingan, Pangasinan	-	3,240	12,960	16,200	
2	- Ditto -	Camplasan, Sta. Maria, Pangasinan	-	960	3,840	4,800	
3	- Ditto -	San Vicente, Sta. Maria, Pangasinan	-	5,520	22,080	27,600	
4	- Ditto -	Sta. Ana, Asingan, Pangasinan	-	7,440	29,760	37,200	
5	- Ditto -	San Vicente East, San Manuel, Pang.	-	1,440	6,480	7,920	
6	Bei	Guiset, Bugallon, Pangasinan	-	5,880	-	5,880	
7	Olo	Cacam Posan, Mangatarem, Pang.	2,400	-	6,000	8,400	
8	Baracbac	Baracbac, Mangatarem, Pangasinan	-	-	600	600	
9	Mayantoc (Camiling)	Mayantoc, Tarlac	6,000	-	-	6,000	
10	Tarlac	Aguso, Tarlac, Tarlac	-	-	39,000	39,000	
11	Moriones (Tarlac)	Polougawi, Tarlac, Tarlac	-	13,680	54,720	68,400	
12	Banila	Flores, Umingan, Pangasinan	-	960	5,040	6,000	
13	- Ditto -	Esperanza, Umingan, Pangasinan	-	1,440	6,960	8,400	
14	- Ditto -	Nancalubasan Umingan, Pang.	2,400	1,440	11,760	15,600	
15	Dipalo (Viray-Dipalo)	San Pedro Natividad, Pangasinan	-	480	1,680	2,160	
16	Viray	Luanca Natividad, Pangasinan	12,000	480	2,160	14,640	

Table 2.8 (2/2) ESTIMATED QUANTITY OF RIVER BED MATERIALS ANNUALLY EXTRACTED FROM RIVERS AS CONSTRUCTION MATERIALS

No.	River	Location	Quantity Extracted From River (m3)				Remarks
			Boulder Cobble	Gravel	Sand	Total	
17	Ambayoan	Poblacion, San Nicolas, Pang.	1,920	840	3,600	6,360	
18	Cabalisian (Ambayoan)	Sta. Maria, San Nicolas, Pang.	-	-	1,920	1,920	
19	Tuboy	Tacnien San Manuel, Pangasinan	240	-	1,680	1,920	
20	Aloragat	Bugayong, Binalonan, Pangasinan	-	11,520	46,560	58,080	
21	- Ditto -	Macao, Sison, Pang.	-	5,040	20,160	25,200	
22	- Ditto -	Lipit, Manaoang, Pangasinan	-	720	3,360	4,080	
23	- Ditto -	Malasin, Pozzorobio, Pangasinan	-	-	720	720	
24	Abeloleng (Bued)	Anonang, San Vicente San Jacinto, Pang.	12,000	11,400	45,600	69,000	
25	Bued	Binday, San Fabian, Pangasinan	4,800	1,800	8,160	14,760	
26	- Ditto -	Agat, Sison Pang.	25,200	1,920	9,120	36,240	
		Total	66,960	76,200	343,920	487,080	

Data Source : Survey Conducted by AFCS,DPWH, 1989

Table 2.9 ANNUAL SEDIMENT VOLUME IN EXISTING CHANNEL (1982-1988)

River	Stretch <1	(1) Length (m)	(2) Fluctuation Volume of Low Water Channel (m3/yr)	(3) Quantity of Extracted River Bed Materials (m3/yr)	(4) Quantity of Dredging/Excavation (m3/yr)	Annual Sediment Volume <2 (5): (2)-(3)-(4) (m3/yr) (6): (5)/(1) (m3/yr/m)
Agno	AG 23-65	15,500	1,291,314	0	79,075	1,370,389 88
	AG 65-109	19,000	965,225	0	15,633	980,858 52
	AG 109-141	8,500	191,355	0	0	191,355 23
	AG 141-309	18,600	(77,237)	0	0	(77,237) (4)
	AG 309-359	18,150	(57,272)	0	0	(57,272) (3)
	AG 359-367	3,700	68,019	0	0	68,019 18
	AG 367-416	8,850	229,960	48,600	7,754	286,314 32
	AG 416-459	7,050	330,474	45,120	0	375,594 53
	AG 459-473	6,600	822,850	0	0	822,850 125
Tarlac	TA 183-194	5,550	5,977	0	10,450	16,427 3
	TA 194-215	8,550	148,499	0	0	148,499 17
	TA 215-227	5,850	24,656	0	0	24,656 4
Bamila	BN 372-385	13,250	(36,376)	0	1,629	(34,746) (3)
	BN 385-401	12,450	285,868	30,000	0	315,868 25

Note : <1 : This stretch shows the station number as of 1989.
<2 : Figures in parenthesis are negative.

Table 2.10 SUMMARY OF OPERATING MINES ALONG AGNO AND BUED RIVERS

M I N E	Production of Ore <1 (1000DMT)	Daily Milling Capacity(MT)	Tailing Dam Capacity (MT)	Start of Use	Present Dam Status	Cost	R E M A R K S
A. AGNO RIVER							
1. Philex Mines	9,521	27,500 Copper ore	Dam #1 85,375,342	1969	Completely filled-up (Dec. 1988)	P10 M	in 1976, the dam was washed out due to typhoon "Dading". It was re-built the same year.
			Dam #2 57,417,615	1981	51% full (good until Feb. 1991)	P38 M	
			Dam #3 142,596,768	Jan. 1990	under construction	P84.8 M (initial construction cost)	
2. Benguet Corp.	1,199	3,500	Dam #1 6,121,000	Mar. 1969	Completely filled-up June, 1986	P6.33 M	of the total mill tailings produced, 16% is recovered as sandfill for underground openings and the remaining volume is impounded in the dams.
			Dam #2 7,075,000	June 1977	Completely filled-up Nov. 1986	P56.03 M	underground openings and the remaining volume is impounded in the dams.
			Dam #3 3,930,000	Nov. 1986	10% filled-up as of May, 1988	P35.36 M	This dam will be constructed in two stages.
3. Itogon-Suyoc Mines	117	350	1,091,724	1981	76% filled	P1326 M	Dam construction is still going on
Sub-total	10,837						
B. BUED RIVER							
1. Benguet Explo. Inc.	62	150					Tailings are being dumped into their underground opening. Surface ponds are used as contingency meas.

Data Source : Memorandum Report on Technical Data needed by DPWH and JICA
Note : <1: Average from 1985 to 1988

Table 2.11 (1/4) LIST OF EXISTING/ON-GOING REFORESTATION PROJECT

No.	Name of Project	Present Status	Period of Project	Agency	Project Area (ha) (1) Total Proj. Area	(2) Total Area to be Planted	(3) Accomplishment as of 1988	(4)=(2)-(3) Remaining to be planted as of 1988	(5) Area to be planted in 1989
1	Upper Agno Watershed <1 Reforestation Project	On-going	Started in 1977	CENRO, Baguio DENR	26,000	16,979	8,147	8,832	165
2	Upper Agno Watershed Reservation	On-going	Started in 1980	NPC-WMD (DENR)	3,247	3,247	2,233	1,014	114
3	Kennon Road Reforestation Project	On-going	Started in 1938	CENRO, Tublay DENR	11,800	2,446	1,101	1,345	90
4	Family Approach Reforestation Project	Completed	1986 -Mar.1989	CENRO, Tayug DENR	550	550	550	-	-
5	Simultaneous Reforestation and Protection Project Phase I	Completed	1986-1989	-Ditto-	300	300	300	-	-
6	Simultaneous Reforestation and Protection Project Phase II	On-going	1988-1992	-Ditto-	100	100	-	-	-
7	Simultaneous Reforestation and Protection Project Phase III	Proposed		-Ditto-	700	700	-	-	-
8	San Nicolas Reforestation Project	On-going	Started in 1961	-Ditto-	8,596	6,166	2,678	3,488	45
9	Villaverde Trail Revegetation Project	On-going	Started in 1980	-Ditto-	11,843	2,689	950	1,739	60
10	Contract Reforestation Project <2 Sta.Maria East, San Nicolas (ADB)	On-going	1989-1991	-Ditto-	96	96	-	-	96

Table 2.11 (2/4) LIST OF EXISTING/ON-GOING REFORESTATION PROJECT

No.	Name of Project	Present Status	Period of Project	Agency	Project Area (ha)				
					(1) Total Proj. Area	(2) Total Area to be Planted	(3) Accomplishment as of 1988	(4)=(2)-(3) Remaining to be planted as of 1988	(5)Area to be planted in 1989
11	Contract Reforestation Project Sta.Maria East,San Nicolas (ADB)	On-going	1989-1991	CENO, Tayug DENR	25	25	-	-	25
12	Contract Reforestation Project Villaverde	On-going	1989	-Ditto-	50	50	-	-	50
13	Contract Reforestation Project Villaverde Trail Revegetation	Completed	1988	-Ditto-	90	90	90	-	90
14	Contract Reforestation Project <3 San Roque	On-going	1989-1991	-Ditto-	75	75	-	-	75
15	Contract Reforestation Project San Manuel	On-going	1989-1991	-Ditto-	80	80	-	-	80
16	Ayaman Reforestation Project	On-going	1989	-Ditto-	75	75	-	-	75
17	Contract Reforestation Project Bongel	Completed	1988	-Ditto-	101	101	101	-	101
18	Contract Reforestation Project San Quintin	On-going	1989-1991	-Ditto-	150	150	-	-	150
19	Manleluag Reforestation Project	On-going	Started in 1939	CENRO, Dagupan,DENR	13,693	13,693	4,491	9,202	20
20	Contract Reforestation Project Mangatarem, Pangasinan	On-going	1989-1991	-Ditto-	40	40	-	-	40

Table 2.11 (3/4) LIST OF EXISTING/ON-GOING REFORESTATION PROJECT

No.	Name of Project	Present Status	Period of Project	Agency	Project Area (ha)				
					(1) Total Proj. Area	(2) Total Area to be Planted	(3) Accomplishment as of 1988	(4)=(2)-(3) Remaining to be planted as of 1988	(5)Area to be planted in 1989
21	Contract Reforestation Project Mangatarem, Pangasinan	On-going	1989-1991	CENR, Dagupan, DENR	50	50	-	-	50
22	Contract Reforestation Project Mangatarem, Pangasinan	On-going	1988-1991	-Ditto-	156	156	-	-	156
23	Contract Reforestation Project Labrador, Pangasinan	On-going	1988-1991	-Ditto-	152	152	-	-	152
24	Bamboo Pilot Project	On-going	1986	-Ditto-	50	-	29	-	5
25	PIADP Project	On-going	1986	-Ditto-	50	-	41	-	5
26	Urban Forestry Dev. Pilot Project, Bonoan	On-going	1986	-Ditto-	100	-	36	-	15
27	Contract Reforestation Project Anguilan, Pangasinan	On-going	1988-1991	-Ditto-	151	-	-	-	151
28	Contract Reforestation Project Bugallon, Pangasinan	On-going	1989-1991	-Ditto-	50	-	-	-	50
29	Corporate Reforestation Contract	On-going	1988-1991	-Ditto-	150	150	-	-	150
30	Mangrove Revegetation Project Binmaley, Pangasinan	On-going	Started in 1989	-Ditto-	34	-	-	34	34

Table 2.11 (4/4) LIST OF EXISTING/ON-GOING REFORESTATION PROJECT

No.	Name of Project	Present Status	Period of Project	Agency	Project Area (ha) (1) Total Proj. Area	(2) Total Area to be Planted	(3) Accomplishment as of 1988	(4)=(2)-(3) Remaining to be planted as of 1988	(5) Area to be planted in 1989
31	Mangrove Revegitation Project Dagupan City	On-going	1989	CENR, Dagupan, DENR	10	-	-	-	10
32	Labney Reforestation Project	On-going	Started in 1959	CENRO, Sta. Ignacia, DENR	6,104.0	2,993.5	694.5	2,299	36
33	Calao Quick Forest Development Project System	Completed	Completed in 1988	-Ditto-	520	520	432.2	87.8	0
34	Maamot Reforestation Project	On-going	Started in 1958	CENRO, Capas DENR	4,200	3,622	2,288	1,334	44
35	Capas, Reforestation Project	On-going	Started in 1973	-Ditto-	11,784	11,784	902	10,882	9
36	Regional Special Reforestation Project	On-going	Started in 1988	-Ditto-	50	50	50	-	50
37	Community Based Reforestation Project	On-going	1989	ADB	100	100	-	-	100
38	Balog-Balog Reforestation Project	On-going	1989-1994	NIA	28,025	9,165	-	9,165	500
39	Lilay-Kulabnao Rehabilitation Project	On-going	1989	DPWH	1,802	-	-	-	-
	Total				131,149	76,394.5	25,113.7	49,421.8	2,793

Note: (1: Part of Itogon Reforestation Project and All of Bokod Reforestation Project
(2: No. 9 - No. 12 Carabollo Mountain Ranges
(3: No. 13 - No. 16 Lower Agno River Basin

Table 2.12 (1/2) LIST OF EXISTING/ON-GOING EROSION CONTROL AND WATERSHED REHABILITATION PROJECT

Location No.	Name of Project	Present Status	Project Period	Agency	Project Area	Description of Works
1	Km 24 Atok Erosion Control Project	Completed	<1 1988	BFD/UNDP/ FAO	6 ha	.Gabion Check Dam .Gabion Retaining Work .Loose Rock Check Dam .RIP-RAP Retaining Wall .Wattling .Bushwood Check Dam
2	Halseb Road Erosion Control Project	Completed	<1 1988	BFD/UNDP	3.8 km	.Gabion Check Dam .RIP-RAP Retaining Wall .Loose Rock Check Dam
3	SWIM Bangao Project	Completed	<1 1988	SWIM/DPWH	291 ha	.Gabion Check Dam .Loose Rock Check Dam .RIP-RAP (Diversion Wall) .Wattling .Stone Terrace .Plantation
4	MT Palansa Soil Erosion Control Project	Completed	<1 1983	BFD/UNDP	17 ha	.Loose Rock Check Dam .Log Check Dam .Gabion Check Dam .Wattling .Plantation
5	Baguio Luacan Road Erosion Control Project	On-going	1988-1989	CENRO, Baguio, DENR	2.5 ha	.Gabion .RIP-RAP Retaining Wall .Loose Rock Check Dam .Plantation
6	Tocok Erosion Control Project	On-going	Started in 1989	-Ditto-	600 ha	.RIP-RAP Retaining Wall .Plantation (1.8 ha) .Check Dams
7	Kennon Road Watershed Rehabilitation Project	On-going	1989	CENRO, Tublay, DENR	3 ha	.Loose Rock Check Dam

Note : <1: Year of Completion

Table 2.12 (2/2) LIST OF EXISTING/ON-GOING EROSION CONTROL AND WATERSHED REHABILITATION PROJECT

Location No.	Name of Project	Present Status	Project Period	Agency	Project Area	Description of Works
8	Watershed Rehabilitation Project within Villaverde Revegetation Project	On-going	1988-1992	CENRO, Tayug, DENR	105 ha	.Gabion Check Dam .Wattling .Bench-Brush Layering .Vegetative Measures
9	Watershed Rehabilitation Project within San Nicolas Reforestation Project	On-going	Started in 1989	-Ditto-	6 ha	.Gabion Check Dam .Wattling .Bench-Brush Layering .Vegetative Measure
10	Watershed Rehabilitation and Erosion Control Project Mangatarem,Pangasinan	On-going	Started in 1987	CENRO, Dagupan, DENR	2 ha	.Loose Rock Check Dam .Wattling .Planting .Cutting .Seedling
11	Watershed Component within Manleluag Reforestation Project	On-going	Started in 1989	-Ditto-	5 ha	.Loose Rock Check Dams .Wattling .Planting .Cutting .Seedling
12	Tangbao Sub-Watershed Rehabilitation Project	On-going	Started in 1986	CENRO, Sta. Ignacia, DENR	240 ha	.Loose Rock Check Dam .Gabion Check Dam .Log Retaining Wall .Loose Rock Retaining Wall .Wattling
13	Tangbao-FMB-SWIM Watershed Rehabilitation Project	On-going	Started in 1988	-Ditto-	1,572 ha	-Ditto-
14	Balog-Balog Watershed Rehabilitation Project	On-going	Started in 1986	CENRO, Capas, DENR	28,025 ha	.Structural Measures (Store Check Dams) .Vegetative Measures

Table 3.1 SEDIMENT YIELD AT AMBUKLAO AND BINGA DAM SITES

No.	Item	Unit	Ambuklao	Binga	Remarks
1.	Drainage Area	km2	617	860	
2.	Sedimentation record	mil.m3/yr.	3.60	1.20	(2) = (4)/(3)
3.	Period	yrs.	30(1956-1986)	26 (1960-1986)	
4.	Sediment volume	mil.m3	108.00	31.32	
5.	Trap Efficiency	%	97	85	by Brune's Diagram
6.	Annual Inflow	mil. m3	1287 <1	1807 <1	
7.	Annual Runoff	mm/yr.	2,086	2,101	(7) = (6)/(1)
8.	Reservoir Capacity	mil.m3	329.0	87.4	
9.	Capacity/Inflow	-	0.26	0.048	(9) = (8)/(6)
10.	Sediment Yield Rate	m3/km2/yr.	6,143	5,917	(10) = (12)/(1)
11.	Sediment Trapped by Upper Dam	mil.m3/yr.	-	3.60	
12.	Sediment Yield	mil.m3/yr.	3.71	5.01	(12) = (2)/(5)+(11)

Data Source : Sedimentation Studies of Ambuklao & Binga Reservoir, NAPOCOR, 1988
Note : <1: Re-Study of the San Roque Multi-Purpose Project Final Report, JICA, 1985

Table 3.2 (1/2) NATURAL SEDIMENT YIELD IN SOUTHERN CORDILLERA MOUNTAINS

Sub-Basin Unit No.	Area of Sub-Basin (Km^2)	(1) Mountain Area of Sub-Basin (Km^2)	Area of each Land (Km^2): Land Fall (La)	Bare Land (Ba)	Slight Vegitation Land (Va)	Forest (Fa)	(2) Annual Sediment Yield (10^6 m^3/yr) (MS)	(3) Sediment Yield Rate (m^3/Km^2/yr)	Remarks Mountain Area in Sub-Basin (MA:%)
M1	48	48	0.023	0.24	21.03	26.71	0.20	4208	
M2	56	56			13.03	42.97	0.14	2510	
M3	60	60	0.018	1.54	41.77	16.67	0.40	6750	
M4	33	33	0.015	0.27	8.62	24.10	0.11	3474	
M5	55	55	0.048	1.78	16.17	37.00	0.30	5457	
M6	68	68	0.110	2.29	19.62	45.98	0.41	5995	
M7	41	41	0.030	1.52	10.14	29.31	0.22	5422	
M8	72	72	0.009	4.37	16.92	50.70	0.47	6469	
M9	103	103	0.086	2.98	19.33	80.60	0.48	4660	
M10	81	81	0.187	4.10	21.92	54.79	0.60	7429	
Sub-Total (M1-M10)	617	617	0.526	19.09	188.55	408.83	3.34	5413	Ambuklao Dam Basin Sediment Yield Data 3.71 x 10^6 m^3/yr
M11	143	143	0.122	7.48	24.48	110.92	0.87	6076	
M12	100	100	0.117	10.67	32.72	56.49	1.06	10557	
Sub-Total (M1-M12)	860	860	0.765	37.24	245.75	576.25	5.26	6121	Binga Dam Basin Sediment Yield Data 5.01 x 10^6 m^3/yr
M13	80	80	0.125	2.07	41.00	36.81	0.53	6627	
M14	111	111	0.043	44.90	20.53	45.53	3.14	28280	(Tanu Planning Dam)
M15	94	94	0.036	2.63	18.63	72.70	0.41	4361	
M16	105	105	0.043	11.97	19.22	73.77	1.03	9779	
Sub-Total (M1-M16)	1250	1250	1.012	98.81	345.13	805.05	10.37	8296	San Roque proposed Dam Basin
M17	85	60		1.17	25.88	32.95	0.29	4785	(MA: 70%)
Sub-Total (M1-M17)	1335	1310	1.012	99.98	371.01	838.00	10.66	8135	Agno River Basin

Table 3.2 (2/2) NATURAL SEDIMENT YIELD IN SOUTHERN CORDILLERA MOUNTAINS

Sub-Basin Unit No.	Area of Sub-Basin (Km^2)	(1) Mountain Area of Sub-Basin (Km^2)	Area of each Land (Km^2) Land Fall (La)	Bare Land (Ba)	Slight Vegitation Land (Va)	Forest (Fa)	(2) Annual Sediment Yield (10^6 m^3/yr) (NS)	(3) Sediment Yield Rate (m^3/Km^2/yr)	Remarks Mountain Area in Sub-Basin (MA:%)
N18	151	151	0.020	13.50	50.00	87.48	1.33	8803	
N19	119	119		28.94	30.11	59.95	2.15	18107	Lower Ambayoan
N20	40	40		8.20	1.76	30.04	0.58	14587	proposed Dam
N21	53	53		11.34	4.00	37.66	0.81	15322	
N22	50	50		1.30	1.25	47.45	0.15	3086	(MA: 20%)
N23	39	39	0.047	0.54	4.10	34.31	0.14	3510	
N24	29	6	0.018	0.27	0.81	4.90	0.04	6815	(MA: 20%)
N25	69	66	0.077	3.38	9.68	52.86	0.40	6082	(MA: 95%)
N26	73	44	0.112	1.17	10.58	32.14	0.26	5895	(MA: 60%)
N27	93	14	0.016		3.24	10.74	0.05	3245	(MA: 15%)
N28	75	75		7.04	9.88	58.08	0.60	7964	
N29	15	15		1.27	4.01	9.72	0.12	8083	
N30	16	8		0.09	1.62	6.29	0.02	3070	(MA: 50%)
N31	21	17			12.58	4.42	0.09	5148	(MA: 80%)
N32	66	10		0.23	2.93	6.84	0.04	4289	(MA: 15%)
N33	66	56		0.32	5.49	50.19	0.12	2174	(MA: 85%)
N34	44	13		0.38	2.30	10.52	0.04	3102	(MA: 30%)
N35	80	80	0.034	1.94	21.24	56.79	0.36	4501	
N36	102	92	0.016	3.65	12.05	76.28	0.43	4621	N 35.36 Bued River Basin (MA: 90%)
N37	67	27		0.45	6.71	19.84	0.10	3654	(MA: 40%)
Sub-Total (N18-N37)	1268	975	0.340	83.81	194.34	696.51	7.84	8038	Allied River Basin
Total (N1-N37)	2603	2285	1.352	183.79	565.35	1534.51	18.49	8094	North Area

Table 3.3 NATURAL SEDIMENT YIELD IN ZAMBALES MOUNTAINS

Sub-Basin Unit No.	Area of Sub-Basin (Km^2)	(1) Mountain Area of Sub-Basin (Km^2)	Area of each Land (Km^2): Land Fall (La)	Bare Land (Ba)	Slight Vegitation Land (Va)	Forest (Fa)	(2) Annual Sediment Yield (10^6 m^3/yr) (MS)	(3) Sediment Yield Rate (m^3/Km^2/yr)	Remarks Mountain Area in Sub-Basin (MA:%)
S1	119	119	0.054	16.43	15.63	84.89	1.44	12143	
S2	39	39	0.025	7.67	6.85	24.46	0.59	15157	
S3	121	121		7.02	11.12	102.86	0.66	5474	Lower O'Donnel proposed Dam Site
S4	29	17				17.00	0.02	1380	(MA: 75%)
S5	283	283	0.304	32.21	12.98	238.41	2.68	9469	Balog-Balog Dam Site
S6	254	254	0.104	24.37	25.89	203.64	2.08	8207	Moriones proposed Dam
S7	34	34			0.86	33.14	0.05	1432	
S8	138	104			0.32	103.68	0.14	1316	(MA: 75%)
S9	221	221	0.284	13.73	13.13	193.86	1.41	6400	Camiling proposed Dam
S10	20	20		1.08	1.80	17.12	0.10	5208	
S11	42	21		0.32	2.57	18.11	0.06	2907	(MA: 50%)
S12	190	114		2.03	13.85	98.12	0.35	3066	(MA: 60%)
S13	105	63	0.050	2.87	5.21	54.87	0.32	5147	(MA: 60%)
S14	146	124	0.190	10.06	10.41	103.34	0.98	7898	(MA: 85%)
S15	130	130	0.074	16.26	27.54	86.13	1.40	10738	
S16	21	13	0.036	2.00	0.51	10.45	0.17	13100	(MA: 60%)
S17	78	31		5.27	7.38	18.35	0.41	13367	(MA: 40%)
S18	64	64	0.034	8.57	21.54	33.86	0.76	11925	
S19	8	8		0.15	0.25	7.60	0.02	2657	
S20	54	43		1.13	12.19	29.68	0.19	4448	(MA: 80%)
S21	72	61		0.5	22.99	37.51	0.23	3782	(MA: 85%)
S22	129	65	0.022	1.31	19.35	44.32	0.28	4351	(MA: 50%)
Total (S1-S22)	2297	1949	1.177	154.98	231.47	1561.37	14.37	7375	

Table 3.4 COMPARISON BETWEEN VOLUMES DEPOSITED IN TAILINGS DAMS AND PRODUCTION OF ORE

Mining Company	Tailings Dam	Period of Ponding (yrs)	(1) Deposited Vol. in Tailings Dams (mil. ton)	(2) Total Vol. of Production of Ore during ponding (mil. ton)	(3): (2)-(1) Gap
Philex Mines	No. 1	11 (1977 - 1988)	85.4 <1		
	No. 2	7 (1981 - 1988)	29.3		
	Sub-Total	11 (1977 - 1988)	114.7	104.7	-10.0
Benguet-Corp.	No. 1	8 (1969 - 1977)	6.1		
	No. 2	9 (1977 - 1986)	7.1		
	No. 3	2 (1986 - 1988)	0.4		
	Sub-Total	19 (1969 - 1988)	13.6	22.8	9.2
Itogon-Suyoc Mines	No. 1	7 (1981 - 1988)	0.8	0.8	0.0
Total			129.1	128.3	-0.8

Data Source : Memorandum Report on Technical Data needed by DPWH and JICA

Note : <1 : No. 1 Tailings Dam was washed out due to Typhoon "Dading" in 1976.

Table 3.5 ANNUAL SUSPENDED LOAD DISCHARGE OF FIXED POINT B-E

Fixed Point	Location	Annual Suspended Load Discharge (1000 Ton/Yr)	(1000 cu. m/Yr) <1
B	Ambalanga River, Downstream of Benguet Corp. and I.S.M.I. mines	198	124
C	Albian Creek, Downstream of Tailing's Dam No. 1 of Philex	661	413
D	Manaa Creek, Downstream of Tailing's Dam No. 2 of Philex	159 <2	99 <2
	Sub-Total	1,018	636
E	Agno River, Downstream of San Roque Dam Site	5,163	3,227

Note : <1: Unit weight of 1.6 Ton/cu. m was assumed.
<2: Since the corelation between discharge and suspended load is not observed, the average load of 455 Ton/day was used for the estimation.

Table 3.6 (1/3) RESULTS OF GRADATION AND SPECIFIC GRAVITY TESTS

Sample No.	River/Canal	Location	Distance from Rivermouth or Confluence (km)	Specific Gravity: Smaller than 0.074 mm	Specific Gravity: 0.074 mm -9.52 mm	Specific Gravity: Greater than 9.52 mm	Particle Size Components (%): Cobble 76.2mm - 300mm	Gravel 2.0mm - 76.2mm	Coarse Sand 0.42mm - 2.0mm	Fine Sand 0.074mm - 0.42mm	Silt 0.005mm - 0.074mm	Clay 0.001mm - 0.005mm	Maximum Particle Size (mm)	60% Particle Size D60 (mm)	50% Particle Size D50 (mm)	10% Particle Size D10 (mm)	Uniformity Coefficient UC UC=D60/D10	Remarks
A-1	Agno	Banaga, Bugallon Pangasinan	<1 6	2.69	-	-	0	1	1	8	85	4	-	0.046	0.037	0.0095	4.84	
A-2	- Ditto -	Salinap-Bocboc, Aguilar, Pangasinan	<1 21	2.86	-	-	0	0	0	33	66.5	0.5	-	0.067	0.055	0.018	3.72	
A-3	- Ditto -	Urbiztondo, Pang.	<1 34	2.71	-	-	0	0	0	81	19	-	-	0.20	0.16	0.055	3.64	
A-4	- Ditto -	Wawa, Bayambang, Pangasinan	<1 54	-	2.68	-	0	0	69.42	29.00	-	-	2.00	0.70	0.60	0.30	2.33	
A-5	- Ditto -	Laoac, Alcala, Pangasinan	<1 68	-	2.71	-	0	0.05	36.31	62.64	-	-	4.76	0.40	0.36	0.18	2.22	
A-6	- Ditto -	Carmen, Rosales, Pangasinan	<1 85	-	2.68	-	0	0.23	23.35	75.55	-	-	9.52	0.40	0.36	0.30	1.33	
A-7	- Ditto -	Brgy. Sanchez, Asingan, Pang.	<1 98	-	2.67	-	0	4.30	79.10	16.20	-	-	9.52	0.86	0.72	0.33	2.60	
A-8	- Ditto -	Magallanes, Tayug Pangasinan	<1 108	-	2.81	2.76	0	55.13	39.27	5.44	-	-	100	4.0	2.6	0.51	7.84	
A-9	- Ditto -	San Roque, San Manuel, Pangasinan	<1 118	-	2.73	2.68	26.00	51.98	15.38	5.95	-	-	140	50	33	0.60	83.33	
A-10	Ambalanga	Baloy, Itogon Benguet	<2 0.6	-	2.74	2.65	3.00	77.08	9.51	9.83	-	-	100	20	13	0.38	52.63	
O-1	Olo	Olo, Mangatarem, Pangasinan	<2 6	-	2.79	-	0	36.02	57.25	6.02	-	-	9.52	2.0	1.5	0.50	4.00	
C-1	Camiling	Bilad, Camiling, Tarlac	<2 17	-	2.85	-	0	0.08	39.26	60.05	-	-	4.76	0.40	0.36	0.20	2.00	
C-2	- Ditto -	Mayantoc, Tarlac	<2 39	-	2.80	2.85	30.0	48.00	15.10	6.90	-	-	140	50	32	0.60	83.3	

Note : <1 : Distance from the rivermouth of Agno River
<2 : Distance from the confluence with Agno River

Table 3.6 (2/3) RESULTS OF GRADATION AND SPECIFIC GRAVITY TESTS

Sample No.	River/Canal	Location	Distance from Rivermouth or Confluence (km)	Specific Gravity: Smaller than 0.074 mm	Specific Gravity: 0.074 mm - 9.52 mm	Specific Gravity: Greater than 9.52 mm	Particle Size Components (%): Cobble 76.2mm - 300mm	Gravel 2.0mm - 76.2mm	Coarse Sand 0.42mm - 2.0mm	Fine Sand 0.074mm - 0.42mm	Silt 0.005mm - 0.074mm	Clay 0.001mm - 0.005mm	Maximum Particle Size (mm)	60% Particle Size D60 (mm)	50% Particle Size D50 (mm)	10% Particle Size D10 (mm)	Uniformity Coefficient UC UC=D60/D10	Remarks
T-1	Tarlac	Kang-ayan Paniqui, Tarlac	<2 22	-	2.68	-	0	1.10	38.19	60.41	-	-	19.1	0.40	0.35	0.15	2.70	
T-2	- Ditto -	Ayson, Gerona, Tarlac	<2 30	-	2.86	-	0	0.23	22.84	76.60	-	-	9.52	0.34	0.31	0.16	2.13	
T-3	- Ditto -	Tibag, Tarlac	<2 46	-	2.69	-	0	1.85	70.85	27.18	-	-	9.52	0.80	0.63	0.30	2.66	
T-4	Moriones	Villa Aglipay, Capas, Tarlac	<3 18	-	2.82	2.85	0	79.60	11.00	8.80	-	-	100	23	16	0.60	38.3	
T-5	O'donnell	Umbac, Capas, Tarlac	<3 21	-	2.70	-	0	44.00	42.60	13.10	-	-	38.1	2.5	1.7	0.38	6.58	
Ba-1	Banila	Pugaro-San Miguel Balungao, Pang.	<2 8	-	2.84	-	0	85.20	12.40	2.20	-	-	38.1	6.4	5.0	1.6	4.00	
Am-1	Ambayoan	San Nicolas, Pang.	<2 5	-	2.72	2.75	22.0	58.30	14.80	4.30	-	-	220	30	21	0.80	37.5	
Am-2	Ambayoan	Ambayoan, San Nicolas, Pangasinan	<2 33	-	2.68	2.73	12.90	68.00	17.80	2.10	-	-	100	30	21	1.1	27.3	

Note : <2 : Distance from the confluence with Agno River
<3 : Distance from the confluence with Tarlac River

Table 3.6 (3/3) RESULTS OF GRADATION AND SPECIFIC GRAVITY TESTS

Sample No.	River/Canal	Location	Distance from Rivermouth or Confluence (km)	Specific Gravity: Smaller than 0.074 mm	Specific Gravity: 0.074 mm -9.52 mm	Specific Gravity: Greater than 9.52 mm	Particle Size Components (%): Cobble 76.2mm - 300mm	Gravel 2.0mm - 76.2mm	Coarse Sand 0.42mm - 2.0mm	Fine Sand 0.074mm - 0.42mm	Silt 0.005mm - 0.074mm	Clay 0.001mm - 0.005mm	Maximum Particle Size (mm)	60% Particle Size D60 (mm)	50% Particle Size D50 (mm)	10% Particle Size D10 (mm)	Uniformity Coefficient UC UC=D60/D10	Remarks
I-1	Ingalera	Malabago-Magsaing Calasiao, Pang.	<4 17	-	2.69	-	0	0.85	88.00	10.84	-	-	4.76	0.81	0.70	0.40	2.03	
I-2	-Ditto-	Talos Pataag, Malasique, Pang.	<4 36	-	2.67	-	0	10.10	62.50	26.17	-	-	4.76	0.88	0.70	0.20	4.40	
Ta-1	Marasay (Tuboy)	Calasiao, Pang.	<4 17	-	2.68	-	0	0.37	74.05	24.96	-	-	4.76	0.72	0.60	0.30	2.40	
Ta-2	Kitara (Tuboy)	Canantiles, Urdaneta, Pang.	<4 46	-	2.65	-	0	1.70	55.16	41.01	-	-	4.76	0.61	0.50	0.20	3.05	
Ta-3	Tuboy	Lapalo, Sn, Manuel, Pangasinan	<4 67	-	2.76	2.66	5.00	58.17	26.16	10.32	-	-	100	11	8.0	0.40	27.5	
Al-1	Patalan (Aloragat)	Mapandan, Pang.	<4 17	-	2.67	-	0	0.02	42.94	56.55	-	-	4.76	0.50	0.40	0.19	2.63	
Al-2	Inamduyan (Aloragat)	Talogtog,Laoac Pangasinan	<4 30	-	2.73	2.80	0	69.52	19.24	11.16	-	-	38.1	10	6.0	0.38	2.63	
Al-3	Aloragat	Bugayong, Poz. Pangasinan	<4 37	-	2.75	2.69	6.00	69.48	15.74	6.69	-	-	100	21	13	0.60	35.0	
Al-4	-Ditto-	Sugcong, Poz. Pangasinan	<4 45	-	2.65	2.60	14.00	62.70	16.50	6.54	-	-	130	30	17	0.60	50.0	
Bu-1	Cayanga (Bued)	Cayanga, San Fabian, Pang.	<4 3	2.81	-	-	0	1	3	42	48	6		0.085	0.070	0.012	7.08	
Bu-2	Bued	San Vicente, San Jacinto, Pang.	<4 15	-	2.74	2.69	14.00	60.53	17.84	7.45	-	-	100	31	20	0.50	62.0	
Bu-3	-Ditto-	Camp 1, Dongos Benguet	<4 37	-	2.73	2.75	11.00	69.78	16.03	2.94	-	-	100	40	30	0.85	47.1	

Note : <4 : Distance from the sea.

Table 3.7 SEDIMENT YIELD IN BINGA DAM BASIN (1967-1986)

Component	(1) Deposit Vol. in Binga Dam (10^6 m^3)	(2) Sediment Inflow From Ambuklao Dam (10^6 m^3)	(3) Sediment Outfow From Binga Dam (10^6 m^3)	(4) : (1) -(2)+(3) Sediment Yield Vol. (10^6 m^3)	Percent (%)
Sand, Gravel	12.7	-	-	12.7	44
Silt	13.3	2.4	5.0	15.9	56
Total	26.0	2.4	5.0	28.6	100

Data Source : Report on Study of Ambuklao Dam Rehabilitation Project, JICA, 1988

Report on Study of Binga Dam Rehabilitation on Project, JICA, 1989

Note: Sediment discharge from dam reservoirs was estimated by assuming that all of the sand and gravel were trapped in the reservoir but some silt were discharged to downstream. Trap efficiencies of 97% for Ambuklao Dam and 85% for Binga Dam obtained from Brune's Diagram was used.

Table 3.8 CONSTANTS FOR SEDIMENT DISCHARGE RATING CURVE

Reference Point	EXISTING CHANNEL Bed Load (Ton/day) ALPHA	BETA	Suspended Load (Ton/day) ALPHA	BETA	DESIGN CHANNEL Bed Load (Ton/day) ALPHA	BETA	Suspended Load (Ton/day) ALPHA	BETA
AGNO								
P-1	1.124	1.358	0.357	1.510	0.058	1.851	0.127	1.715
P-2	0.485	1.346	0.633	1.322	0.120	1.607	0.064	1.714
P-3	0.137	1.386	0.025	1.676	0.260	1.387	0.028	1.749
P-4	0.401	1.224	0.006	1.871	0.909	1.145	0.016	1.773
P-5	0.122	1.377	0.086	1.707	0.376	1.254	0.176	1.637
P-6	1.458	0.961	0.516	1.403	0.575	1.145	0.250	1.547
P-7	0.554	1.156	0.237	1.559	0.311	1.266	0.159	1.638
P-8	1.113	1.042	0.401	1.471	0.512	1.131	0.184	1.678
P-9	0.150	1.128	0.035	1.714	0.230	1.131	0.060	1.701
P-10	0.452	0.868	0.031	1.451	0.056	1.208	0.002	1.857
AMBAYOAN								
P-11	0.009	2.215	0.128	1.809	3.963	1.295	0.382	1.649
P-12	0.007	2.143	0.414	1.571	0.303	1.567	0.252	1.668
VIRAY-DIPALO								
P-13	1.634	1.685	1.063	1.596	16.256	1.477	2.483	1.562
P-14	1.184	1.718	0.631	1.687	4.250	1.662	2.009	1.555
P-15	0.111	1.461	0.127	1.785	0.053	1.913	0.113	1.868
BANILA								
P-16	5.320	1.364	0.240	1.561	70.949	1.070	0.871	1.717
P-17	0.037	1.907	0.121	1.449	1.177	1.500	0.064	1.806
P-18	0.752	1.146	0.058	1.463	0.082	1.789	0.020	1.576
TARLAC								
P-19	0.369	1.250	0.281	1.654	1.293	1.178	0.884	1.576
P-20	1.318	1.029	1.174	1.452	0.866	1.123	0.779	1.537
O'DONNELL								
P-21 <2	0.688	1.374	0.280	1.727	0.688	1.374	0.280	1.727
MORIONES								
P-22 <2	0.000	3.200	0.414	1.418	0.000	3.200	0.414	1.481
CAMILING								
P-23	0.472	1.330	0.100	1.753	0.007	2.325	0.135	1.815
P-24	0.458	1.418	0.013	1.780	0.059	1.858	0.006	2.017
OLO								
P-25 <2	0.311	1.862	0.030	1.930	0.311	1.862	0.030	1.930
BAYAOAS								
P-26 <2	1.215	1.535	0.026	1.937	1.215	1.535	0.026	1.937
TUBOY								
P-27 <2	4.507	1.349	3.725	1.626	4.507	1.349	3.725	1.626
ANGALACAN								
P-28 <2	6.532	1.448	0.920	1.530	6.532	1.448	0.920	1.530
BUED								
P-29 <2	0.479	1.747	2.388	1.425	0.479	1.747	2.388	1.425

Note: <1 : $Qs = ALPHA * Q^{BETA}$

Where, Q : Flow Discharge (m3/s)

Qs : Sediment Discharge (m3/s)

<2 : River improvement is not carried out.

Table 3.9 CALCULATION OF ANNUAL SEDIMENT TRANSPORT CAPACITY

Base Point	Annual Discharge (1000 cu.M)	EXISTING CHANNEL Bed Load (1000 cu.M)	EXISTING CHANNEL Suspended Load (1000 cu.M)	EXISTING CHANNEL Total (1000 cu.M)	DESIGN CHANNEL Bed Load (1000 cu.M)	DESIGN CHANNEL Suspended Load (1000 cu.M)	DESIGN CHANNEL Total (1000 cu.M)
AGNO							
P-1	3,024	169.58	127.14	296.72	152.94	148.92	301.86
P-2	3,188	73.47	83.81	157.28	81.36	81.65	163.01
P-3	4,416	40.86	43.96	84.82	78.01	77.86	155.87
P-4	4,712	49.75	40.92	90.67	17.06	58.08	129.14
P-5	5,238	43.61	245.70	289.31	63.59	320.92	384.51
P-6	5,272	45.28	218.44	263.72	51.12	260.10	311.22
P-7	8,508	91.41	560.99	652.40	104.49	645.84	750.32
P-8	9,701	104.07	635.03	739.10	83.52	1226.88	1310.40
P-9	10,771	27.00	359.89	386.89	42.23	562.08	604.31
P-10	11,208	15.68	52.79	68.47	18.01	62.27	80.29
AMBAYOAN							
P-11	713	9.10	19.24	28.34	64.94	28.08	93.02
P-12	726	5.19	22.24	27.43	16.00	20.73	36.73
VIRAY-DIPALO							
P-13	69	2.74	1.48	4.22	17.95	3.24	21.18
P-14	129	6.27	3.07	9.33	19.33	6.87	26.20
P-15	251	0.78	2.65	3.43	1.74	3.15	4.89
BANILA							
P-16	129	11.20	0.83	12.03	76.46	2.42	78.88
P-17	450	3.62	1.93	5.55	22.75	2.89	25.64
P-18	526	4.79	0.78	5.57	6.53	1.71	8.24
TARLAC							
P-19	1,587	13.69	79.23	92.92	33.98	166.53	200.51
P-20	1,587	17.27	117.80	135.07	17.55	120.19	137.75
O'DONNELL							
P-21 <1	528	10.33	17.32	27.65	10.33	17.32	27.65
MORIONES							
P-22 <1	975	0.00	23.36	23.36	0.00	23.36	23.36
CAMILING							
P-23	591	6.95	8.39	15.34	7.82	14.82	22.64
P-24	1,150	24.57	4.01	28.58	26.94	6.18	33.12
OLO							
P-25 <1	290	11.15	1.38	12.54	11.15	1.38	12.54
BAYAOAS							
P-26 <1	149	4.94	0.34	5.28	4.94	0.34	5.58
TUBOY							
P-27 <1	156	11.89	20.98	32.87	11.89	20.98	32.87
ANGALACAN							
P-28 <1	132	17.60	3.06	20.66	17.60	3.06	20.66
BUED							
P-29 <1	627	43.40	55.70	99.10	43.40	55.70	99.10

Note : <1 : River improvement is not carried out.

Table 3.10 ANNUAL SEDIMENT VOLUME OF EACH CONDITION

Unit : ($10^3 m^3/yr$)

Reference Point/Stretch	Proposed Condition (I)	Proposed Condition (II)	Proposed Condition (III)	Present Condition <1
(1) River Channel				
Agno				
San Roque - Santa Maria	-209	-209	-209	2,514
Santa Maria - Wawa	-146	-110	-146	-173
Wawa - River Mouth	1,761	1,025	1,728	3,917
Ambayoan	1,185	1,185	-35	2,413
Dipalo (Viray)	138	138	5	285
Banila	69	69	69	149
Tarlac	1,070	-126	-126	3,669
Camiling	532	532	136	1,099
Olo	376	376	-14	766
Bayaoas	191	191	-5	386
(2) Dam Reservoir				
Ambuklao	1,597	1,597	1,597	3,262
Binga	835	835	835	1,717
San Roque	2,704	2,704	2,704	-
Balog-Balog	1,338	1,338	1,338	-
Moriones/Lower O'Donnell	-	2,349	2,349	-
(3) Sabo Dam				
Ambayoan	-	-	1,219	-
Dipalo (Viray)	-	-	134	-
Camiling	-	-	395	-
Olo	-	-	390	-
Bayaoas	-	-	196	-
(4) Retarding Basin				
Poponto Swamp	1,216	1,834	244	3,705
(5) Irrigation System				
ARIS	208	208	208	396
LATRIS	22	22	22	76
Ambayoan RIS	71	71	71	140
Dipalo RIS	11	11	11	20
SMORIS	49	4	4	97
Tarlac RIS	31	3	3	97
Camiling RIS	64	64	64	124

Note: <1: Calculation is based on the period from 1960 to 1986.

Table 3.11 EXCESS SEDIMENT VOLUME TO BE CONTROLLED

Base Point of Sediment Control	Reference Point Number	(1) Design Sediment Discharge ($10^3 m^3/yr$)	(2) Design Allowable Sediment Discharge ($10^3 m^3/yr$)	(3): (1)-(2) Design Excess Sediment Volume to be Controlled ($10^3 m^3/yr$)	Remarks
AGNO					
BP-1	-	1,681	-	1,681	Ambuklao Dam
BP-2	-	960	-	960	Binga Dam
BP-3	-	2,550	-	2,550	San Roque Proposed Dam
AMBAYOAN					
BP-4	P-11	2,439	1,313	1,126	
VIRAY-DIPALO					
BP-5	P-13	68	55	13	
BP-6	P-14	200	126	74	
BANILA					
BP-7	P-16	131	145	0	
TARLAC					
BP-8	-	1,344	-	1,344	Balog-Balog Dam
BP-9	-	1,042	-	1,042	Moriones Proposed Dam
BP-10	-	1,349	-	1,349	Lower O'Donnell Proposed Dam
CAMILING					
BP-11	P-23	791	418	373	
OLO					
BP-12	P-25	781	405	376	
BAYAOAS					
BP-13	P-26	392	201	191	
TUBOY					
BP-14	P-27	600	333	267	
ANGALACAN					
BP-15	P-28	120	81	39	
BUED					
BP-16	P-29	890	544	346	
Total		15,338	3,621	11,731	

Table 5.1 (1/2) MAJOR DIMENSION OF PROPOSED SABO DAM

Dam No.	Name of River	Height (m)	Width (m)	River Bed Gradient	Construction Cost (mil. peso)	Total Dam Volume (m3)	Remarks
D-1	Ambayoan	20	100	1/35	70	1,190,000	Upper Ambayoan Dam Site
D-2	- ditto -	20	100	1/35	70	1,190,000	
D-3	- ditto -	20	200	1/65	140	4,810,000	Upper Sapinit Dam Site
D-4	- ditto -	20	100	1/70	70	2,380,000	
D-5	- ditto -	20	300	1/100	210	11,400,000	
D-6	- ditto -	20	150	1/30	105	1,620,000	
Sub - Total (Ambayoan)					665	22,590,000	
D-7	Dipalo	20	100	1/20	70	680,000	
D-8	Viray	20	100	1/5	70	170,000	
D-9	- ditto -	20	100	1/12	70	425,000	
D-10	- ditto -	20	100	1/20	70	680,000	
D-11	- ditto -	10	100	1/15	40	205,000	
Sub - Total (Viray)					320	1,480,000	
D-12	Camiling	20	180	1/75	125	4,950,000	Camiling Dam Site
D-13	- ditto -	15	140	1/25	77	935,000	
D-14	- ditto -	10	140	1/75	56	1,875,000	
Sub - Total (Camiling)					258	7,760,000	
D-15	Olo	25	150	1/60	126	4,050,000	Pila Dam Site
D-16	- ditto -	20	100	1/35	70	1,190,000	
D-17	- ditto -	20	100	1/35	70	1,190,000	
D-18	- ditto -	20	100	1/35	70	1,190,000	
Sub - Total (Olo)					336	7,620,000	

Table 5.1 (2/2) MAJOR DIMENSION OF PROPOSED SABO DAM

Dam No.	Name of River	Height (m)	Width (m)	River Bed Gradient	Construction Cost (mil. peso)	Total Dam Volume (m3)	Remarks
D-19	Bayaoas	20	180	1/75	125	4,950,000	Bayaoas Dam Site
D-20	- ditto -	20	150	1/65	105	3,510,000	Kalipkip Dam Site
D-21	- ditto -	15	100	1/40	55	1,020,000	
D-22	- ditto -	15	140	1/25	77	935,000	
Sub - Total (Tuboy)					362	5,465,000	
D-23	Angalacan	15	80	1/25	44	485,000	
D-24	- ditto -	15	100	1/15	55	380,000	
Sub - Total (Angalacan)					99	865,000	
D-25	Bued	20	100	1/45	70	1,530,000	
D-26	- ditto -	20	100	1/45	70	1,530,000	
D-27	- ditto -	20	100	1/45	70	1,530,000	
D-28	- ditto -	20	100	1/15	70	510,000	
D-29	- ditto -	20	100	1/25	70	850,000	
D-30	- ditto -	20	100	1/15	70	510,000	
D-31	- ditto -	20	100	1/10	70	340,000	
D-32	- ditto -	20	100	1/10	70	340,000	
Sub - Total (Bued)					560	7,140,000	
Total					2,600		

Note: The construction cost of each dam was estimated in proportion to the volume of dam, based on the estimation that the cost of dam of 20 m in height and 100 m in width was 70,000,000 pesos.

FIGURES

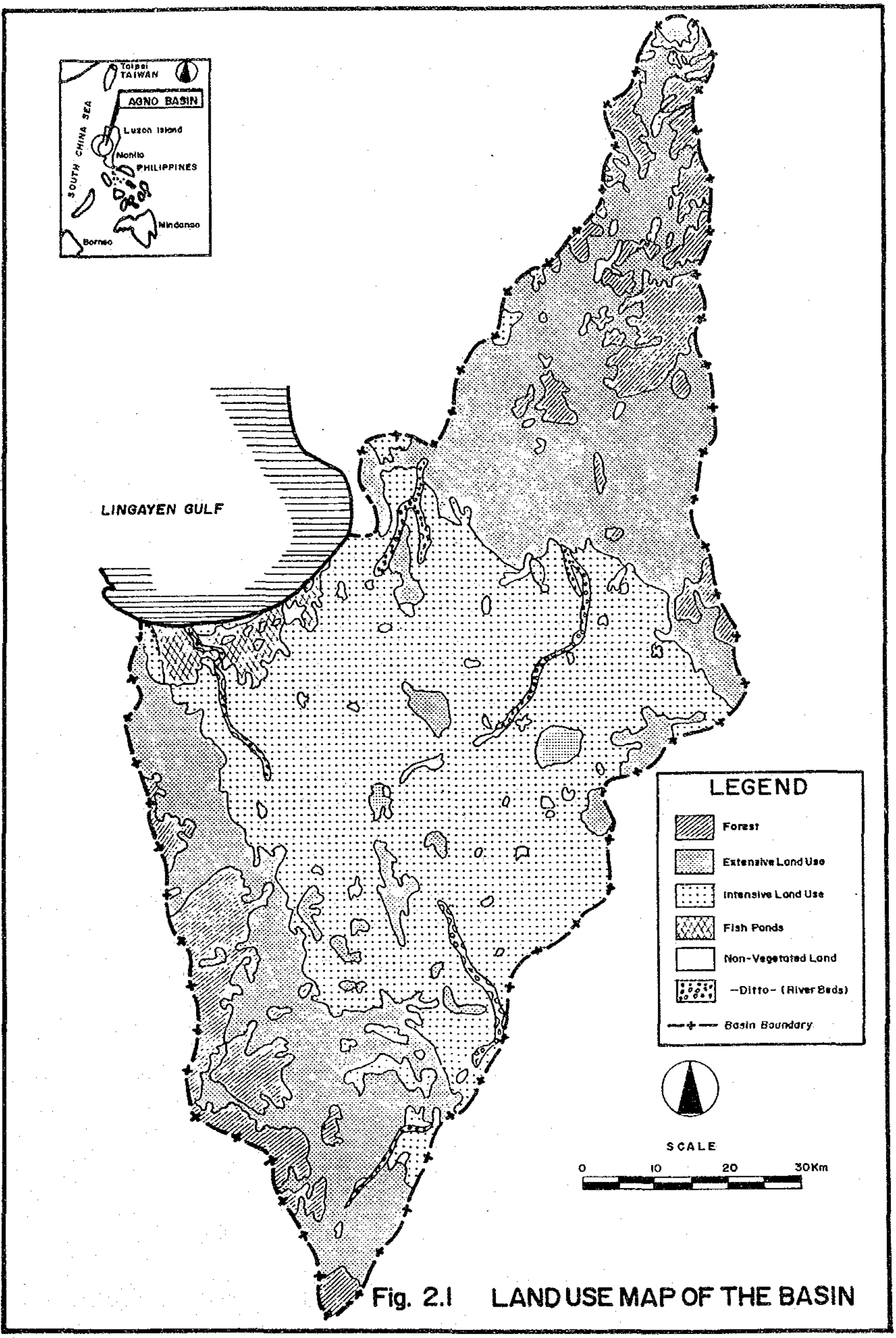


Fig. 2.1 LAND USE MAP OF THE BASIN

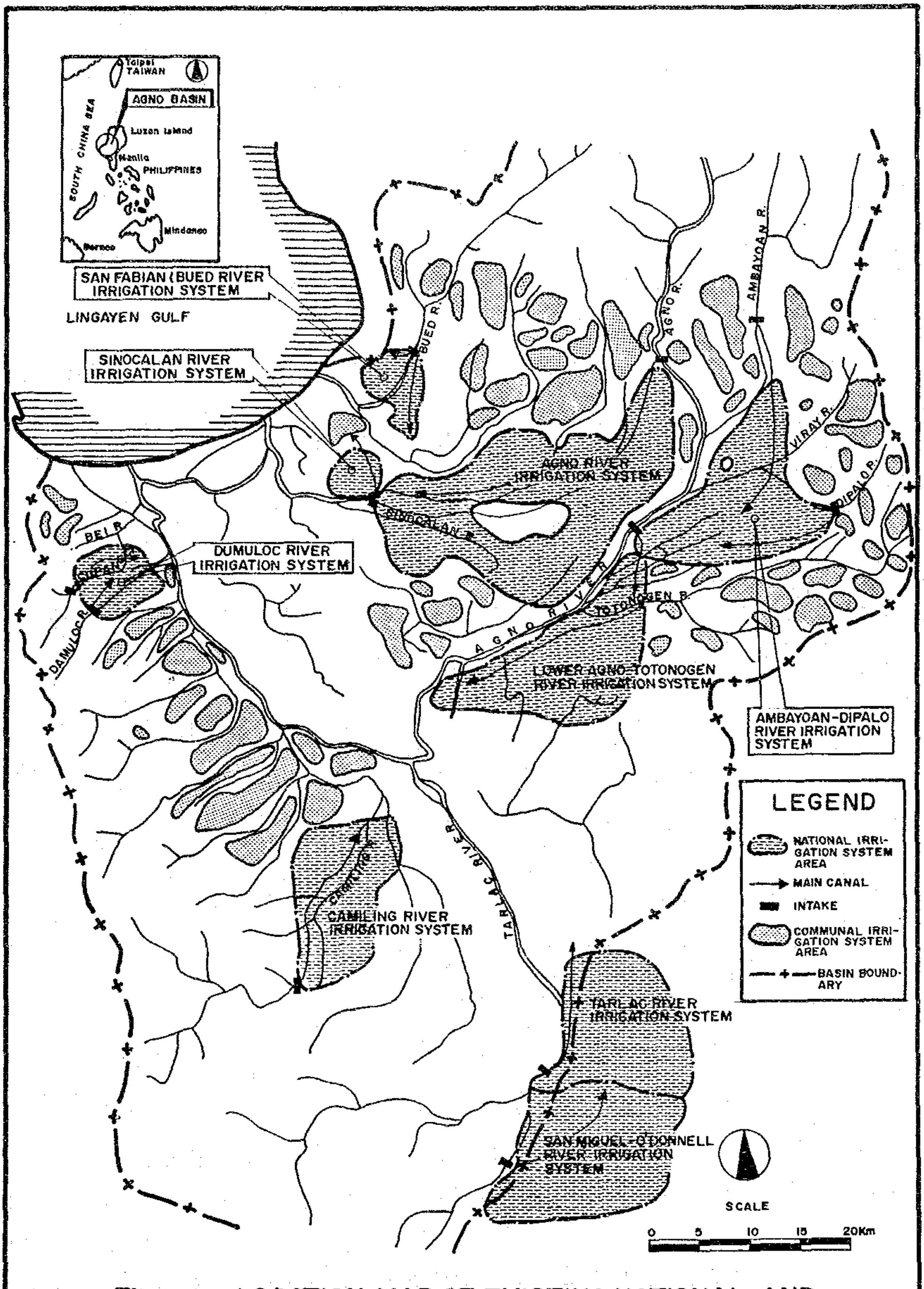


Fig 2.2 LOCATION MAP OF EXISTING NATIONAL AND COMMUNAL IRRIGATION SYSTEMS

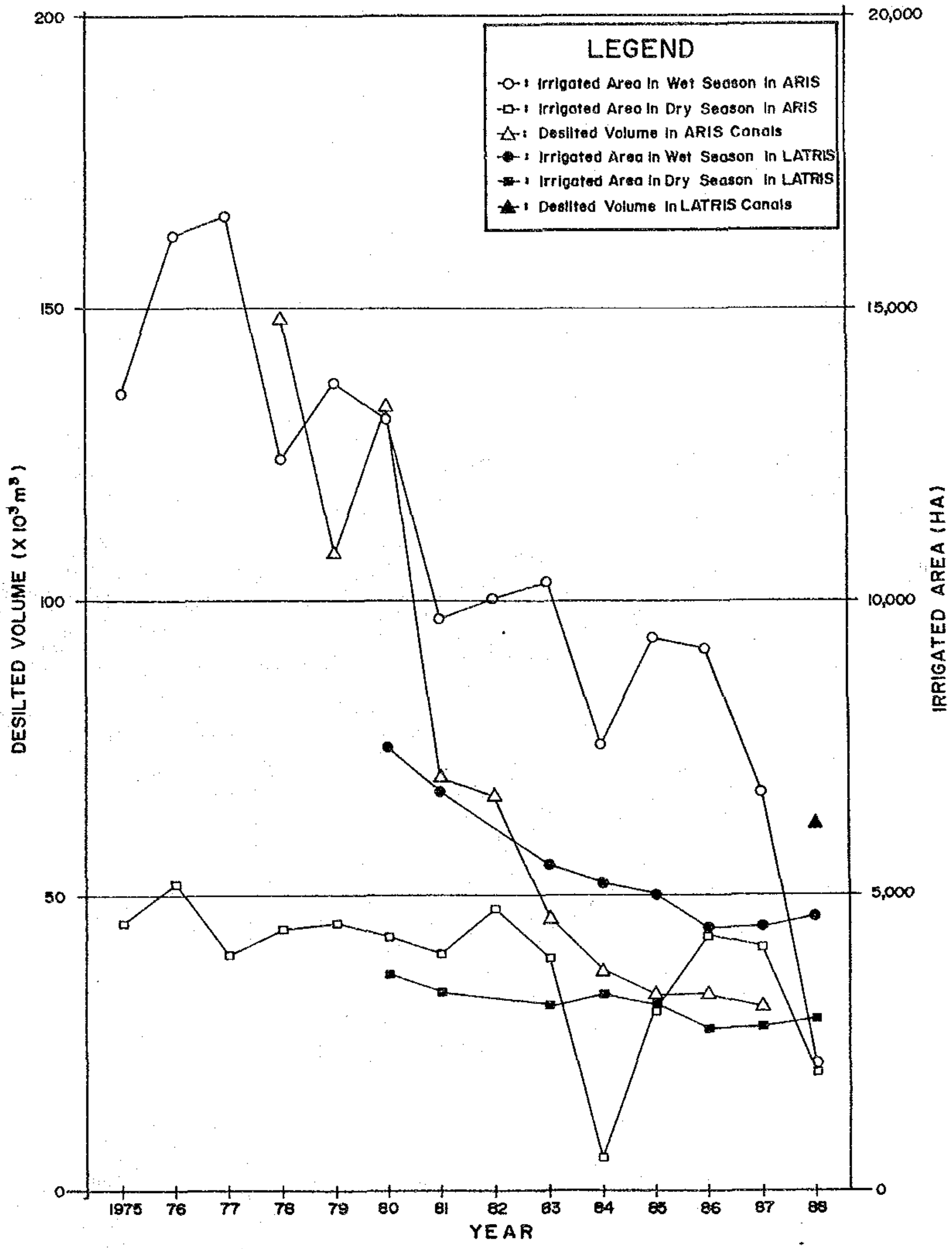


Fig. 2.3 ACTUAL IRRIGATED AREA AND DESILTED VOLUME IN ARIS AND LATRIS

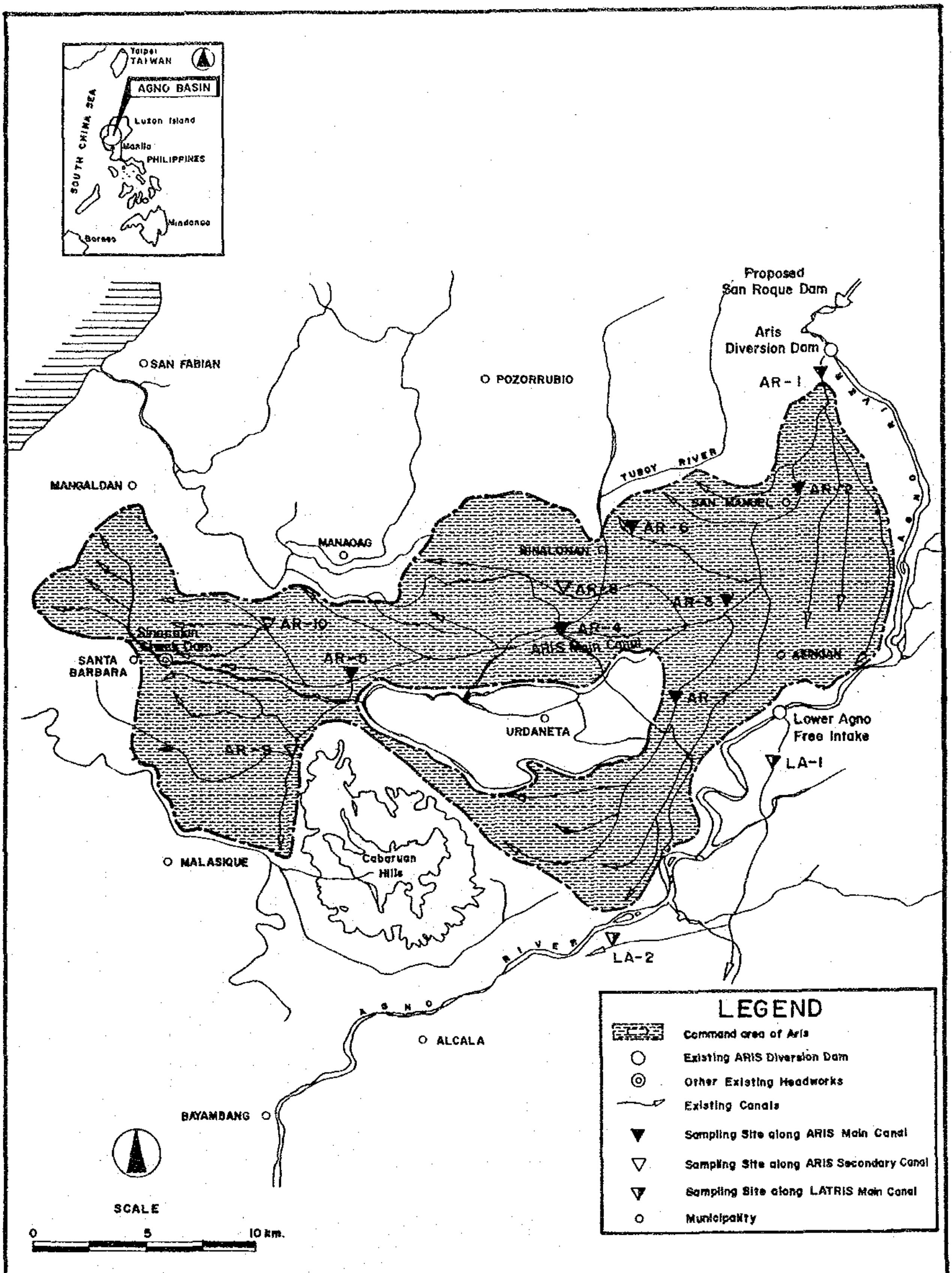
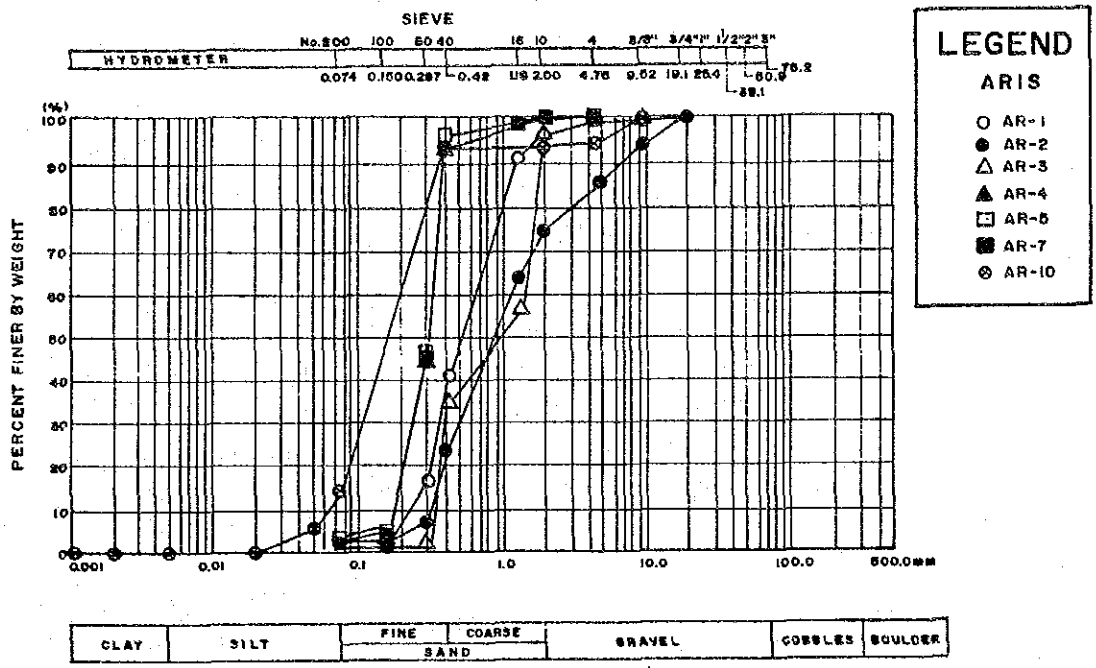


Fig. 2.4 LOCATION MAP OF SAMPLING SITES FOR IRRIGATION CANALS



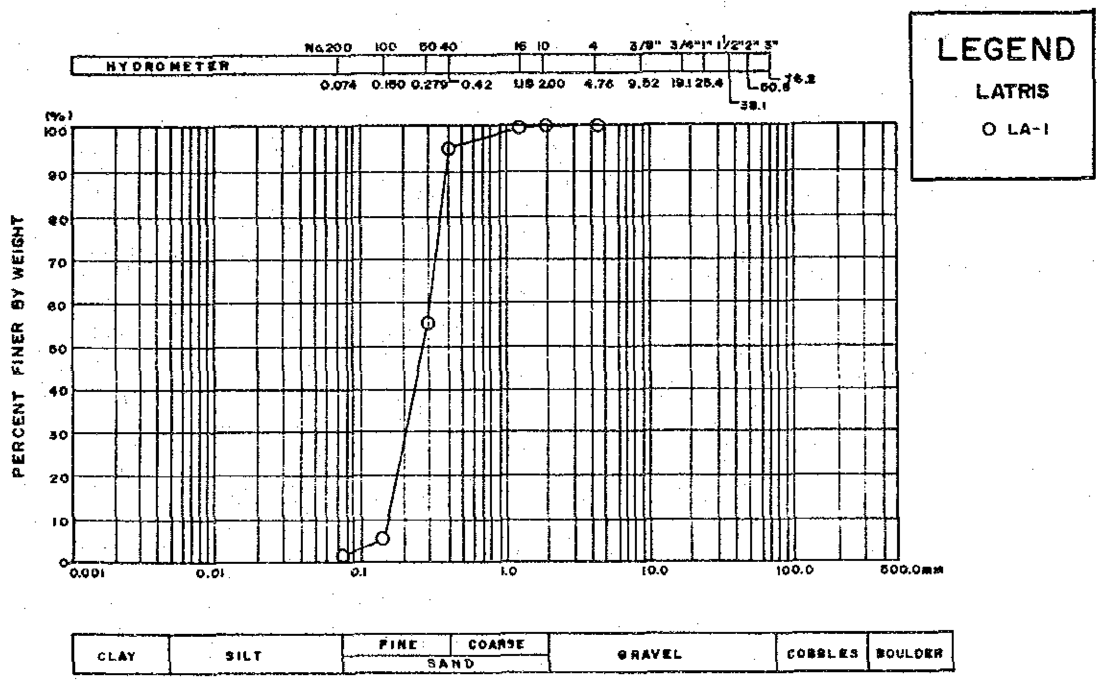


Fig. 2.5 PARTICLE SIZE ACCUMULATION CURVES OF SEDIMENT IN IRRIGATION CANALS

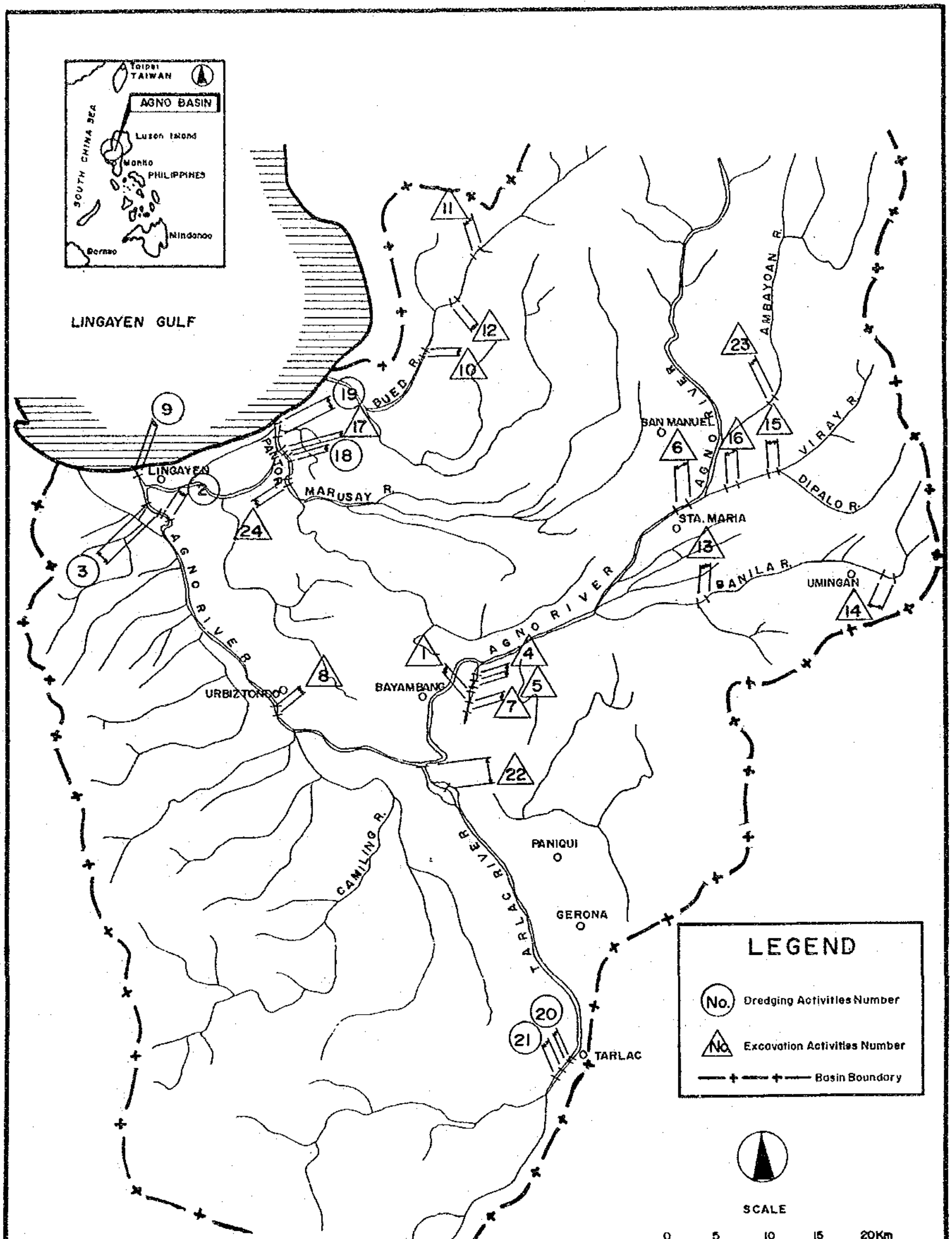


Fig. 2.6 LOCATION MAP OF DREDGING/EXCAVATION ACTIVITIES

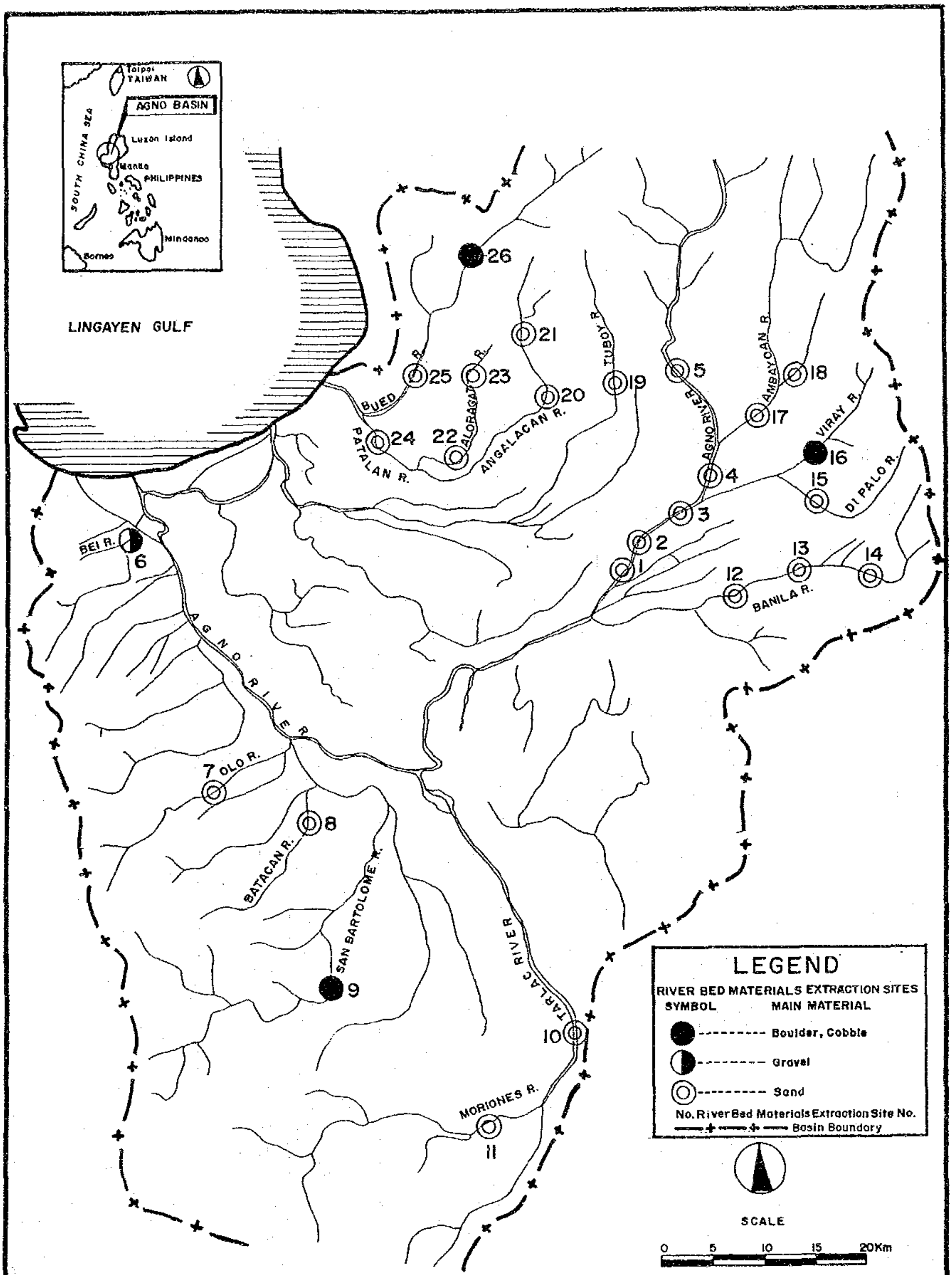


Fig. 2.7 LOCATION MAP OF RIVER BED MATERIALS EXTRACTION FOR CONSTRUCTION MATERIALS

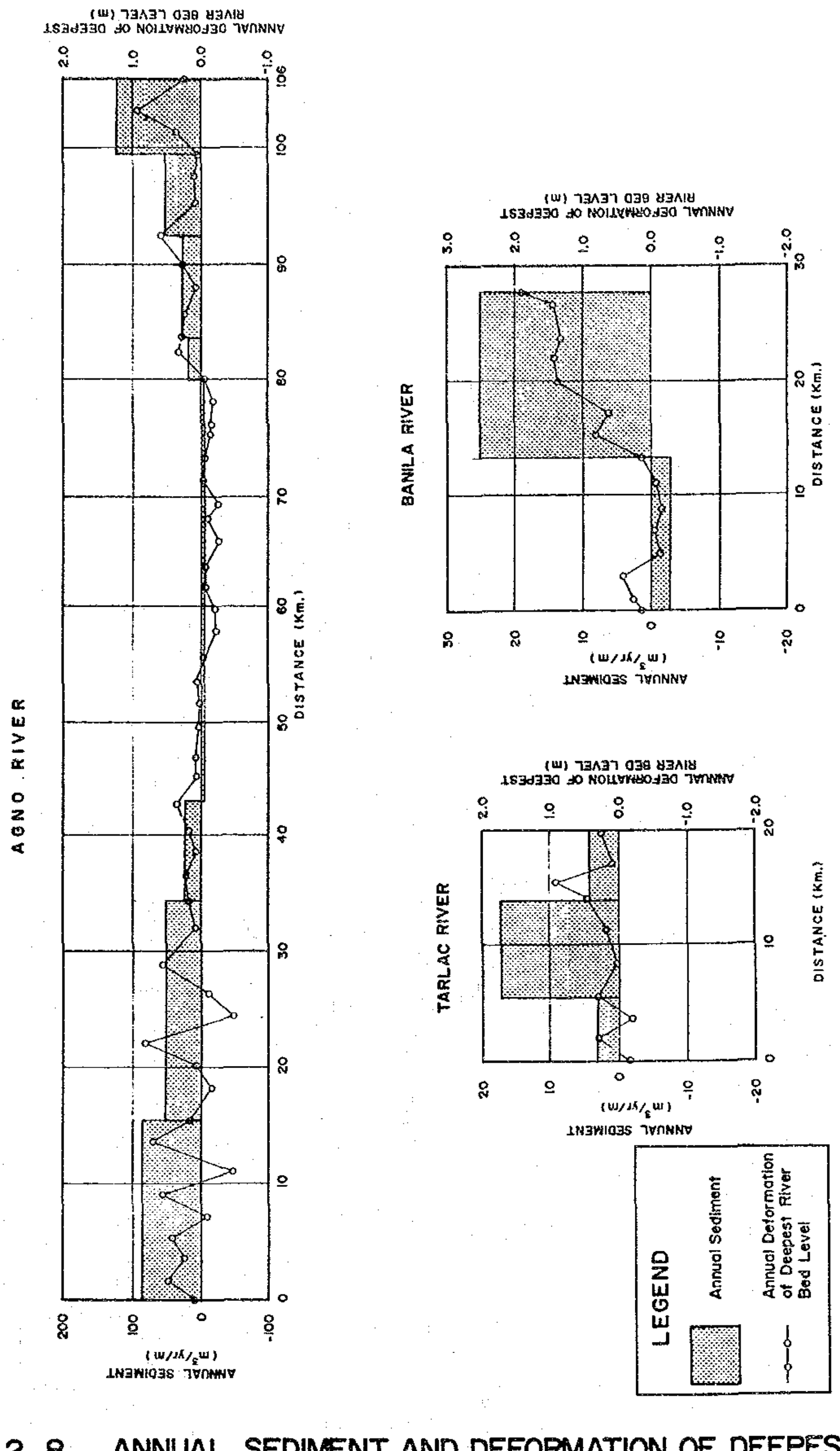


Fig. 2.8 ANNUAL SEDIMENT AND DEFORMATION OF DEEPEST RIVER BED LEVEL OF EXISTING CHANNEL

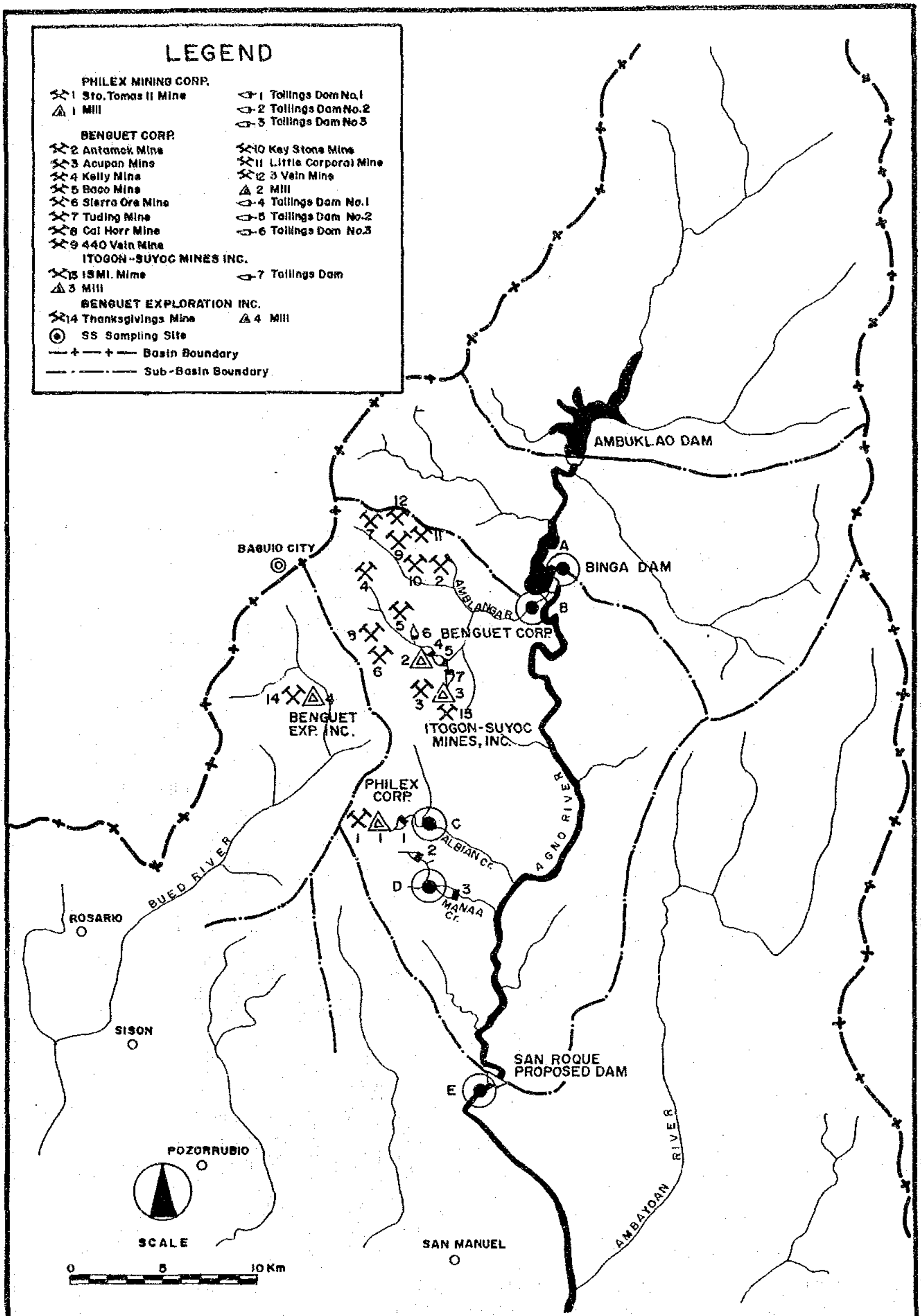


Fig. 2.9 LOCATION MAP OF MINES INDUSTRY AREA

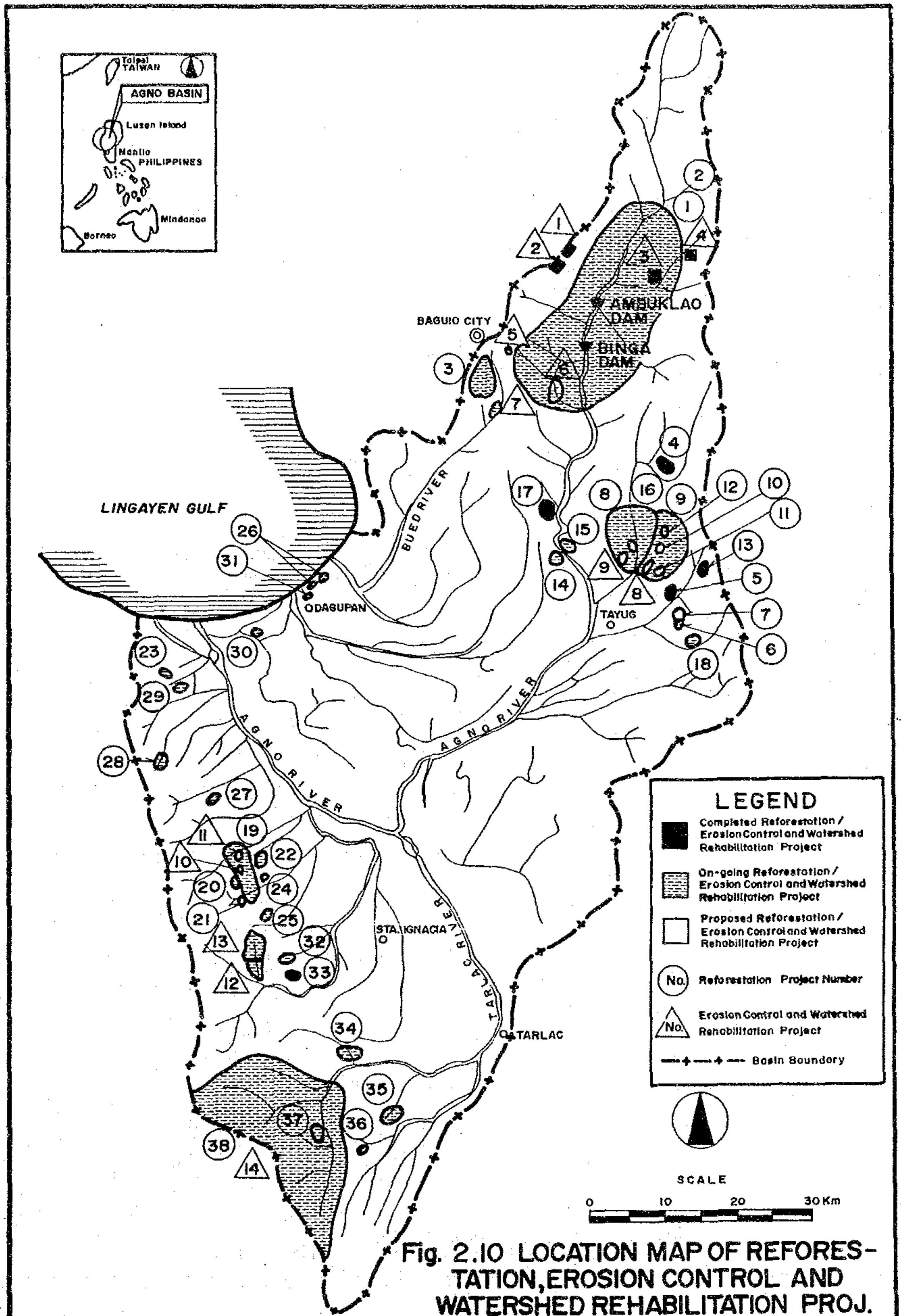


Fig. 2.10 LOCATION MAP OF REFORESTATION, EROSION CONTROL AND WATERSHED REHABILITATION PROJ.

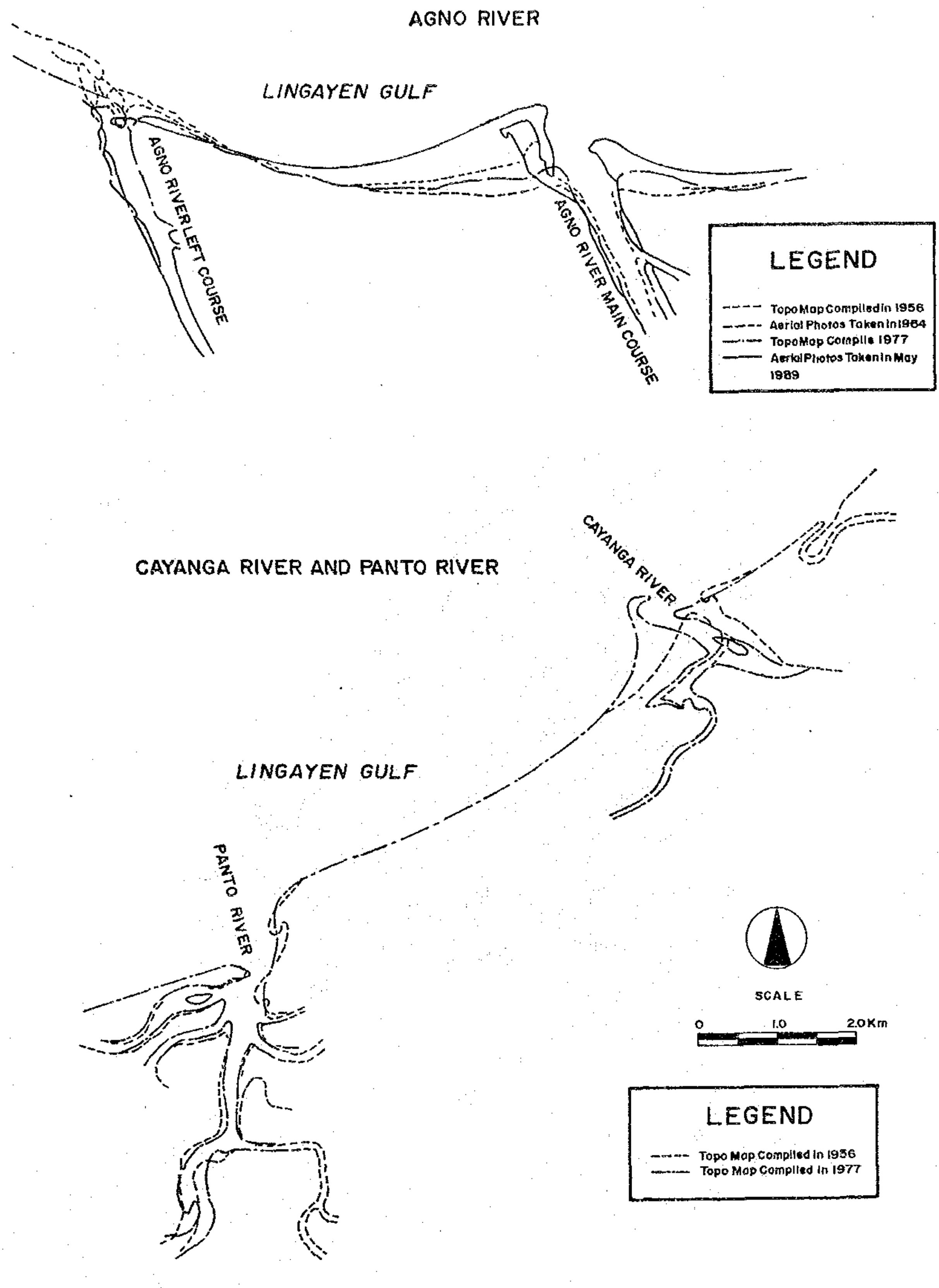


Fig 2.11 TRANSIT OF SHORELINE

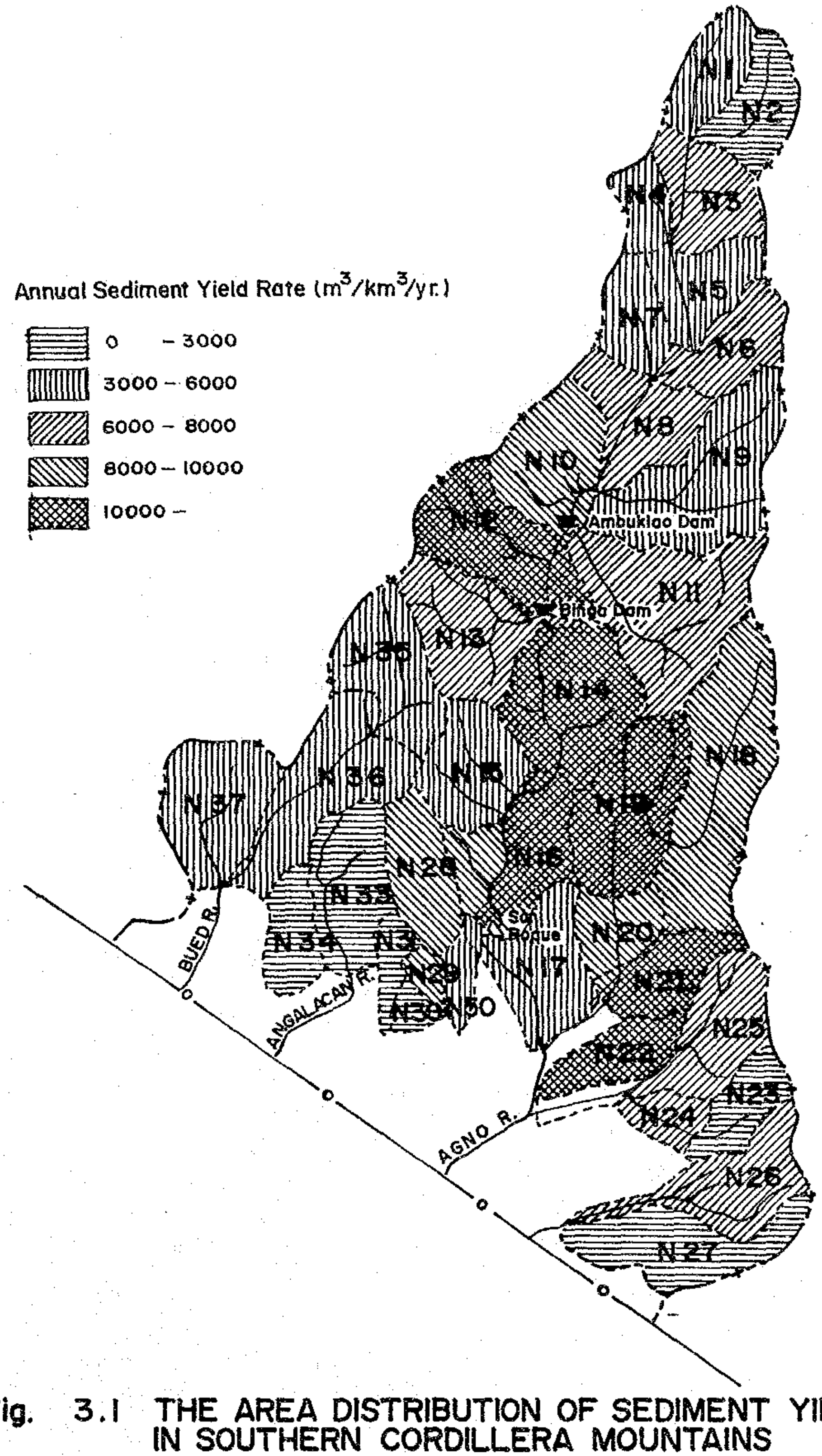


Fig. 3.1 THE AREA DISTRIBUTION OF SEDIMENT YIELD IN SOUTHERN CORDILLERA MOUNTAINS

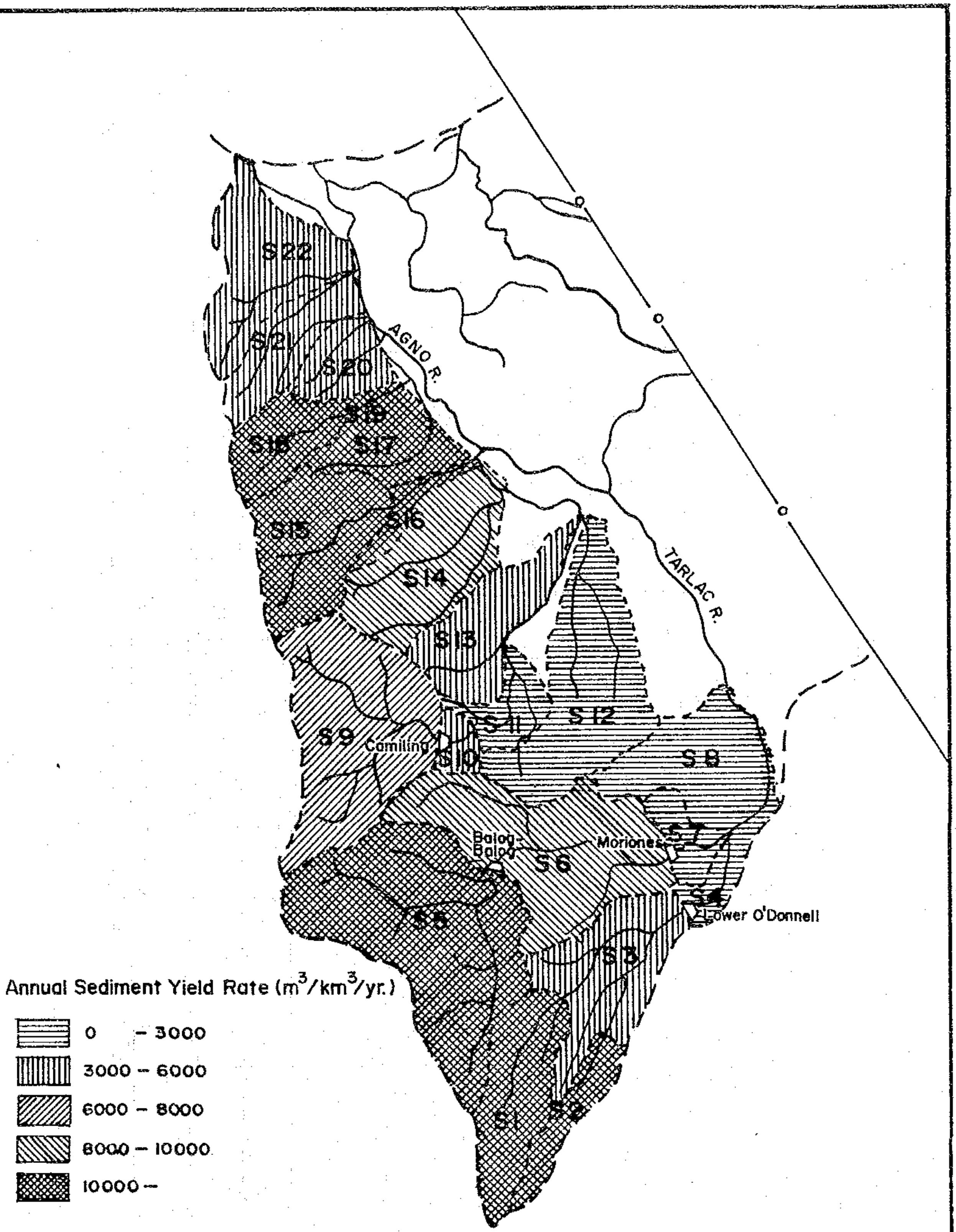


Fig. 3.2 THE AREA DISTRIBUTION OF SEDIMENT YIELD IN ZAMBALES MOUNTAINS

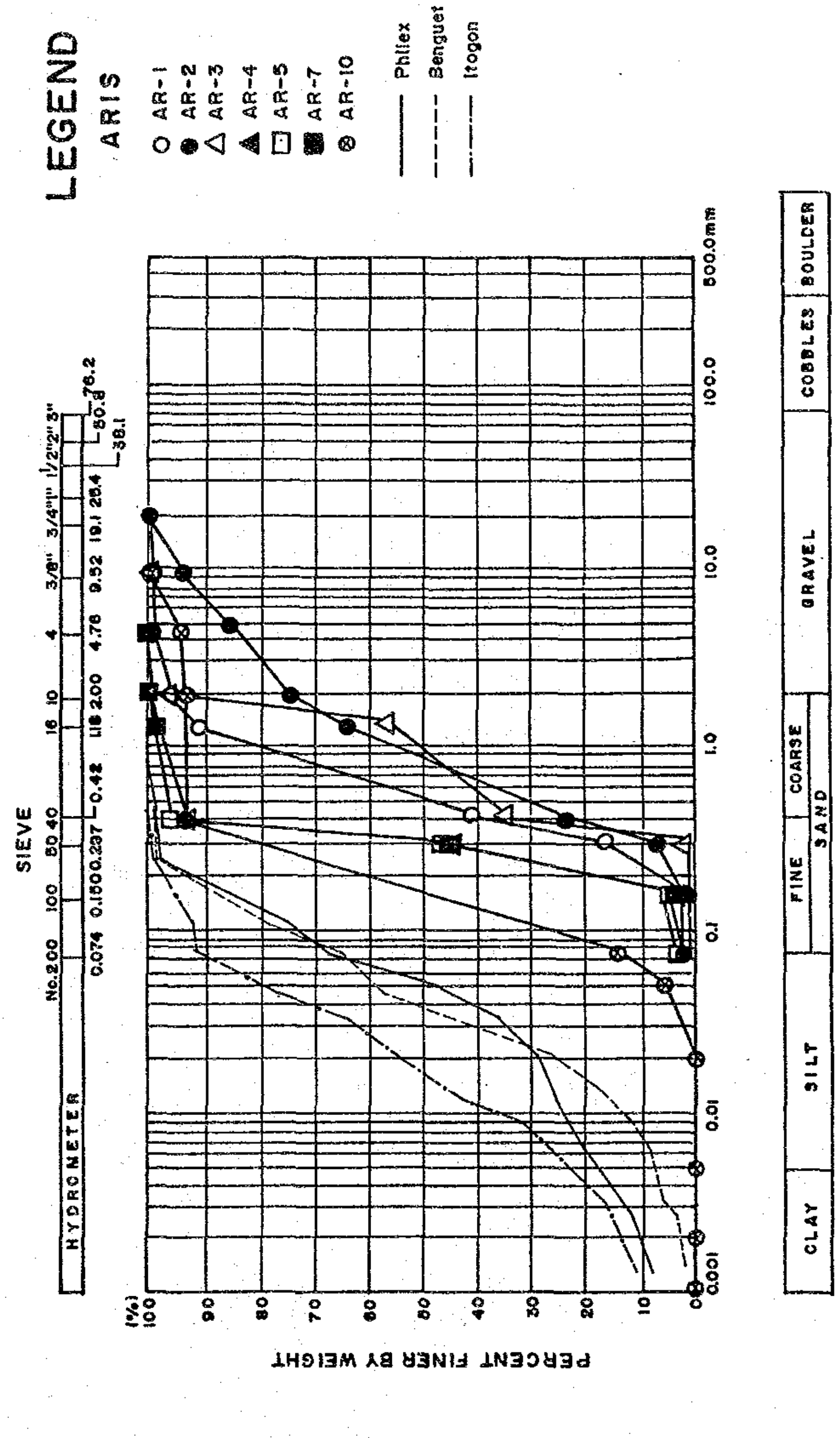
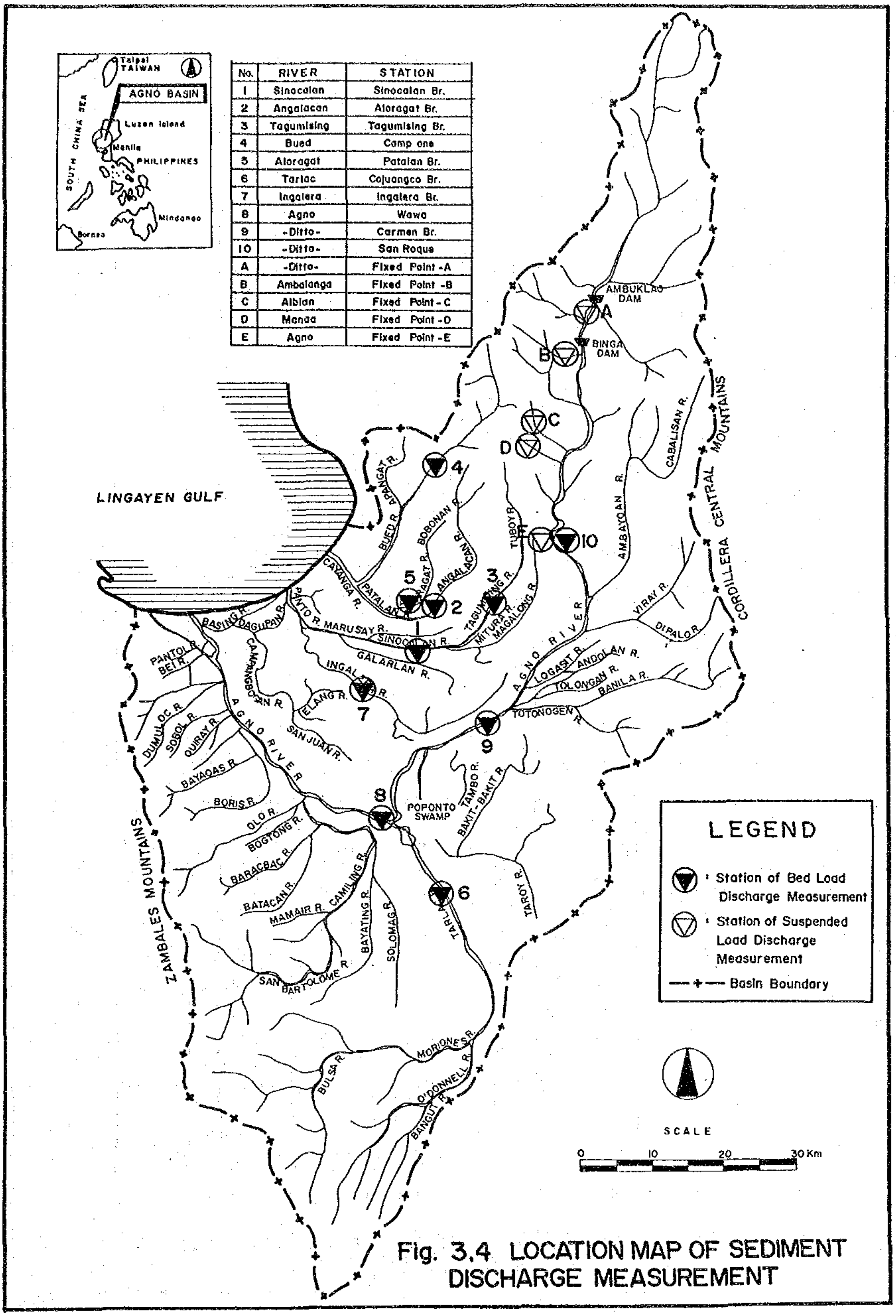


Fig. 3.3 PARTICLE SIZE ACCUMULATION CURVES OF SEDIMENT / MINE TAILINGS



No.	RIVER	STATION
1	Sinocalan	Sinocalan Br.
2	Angalacan	Aloragat Br.
3	Tagumising	Tagumising Br.
4	Bued	Camp one
5	Aloragat	Patalan Br.
6	Tarlac	Cojuangco Br.
7	Ingalera	Ingalera Br.
8	Agno	Wawa
9	-Ditto-	Carmen Br.
10	-Ditto-	San Roque
A	-Ditto-	Fixed Point-A
B	Ambalanga	Fixed Point-B
C	Alblan	Fixed Point-C
D	Manaa	Fixed Point-D
E	Agno	Fixed Point-E

Fig. 3.4 LOCATION MAP OF SEDIMENT DISCHARGE MEASUREMENT

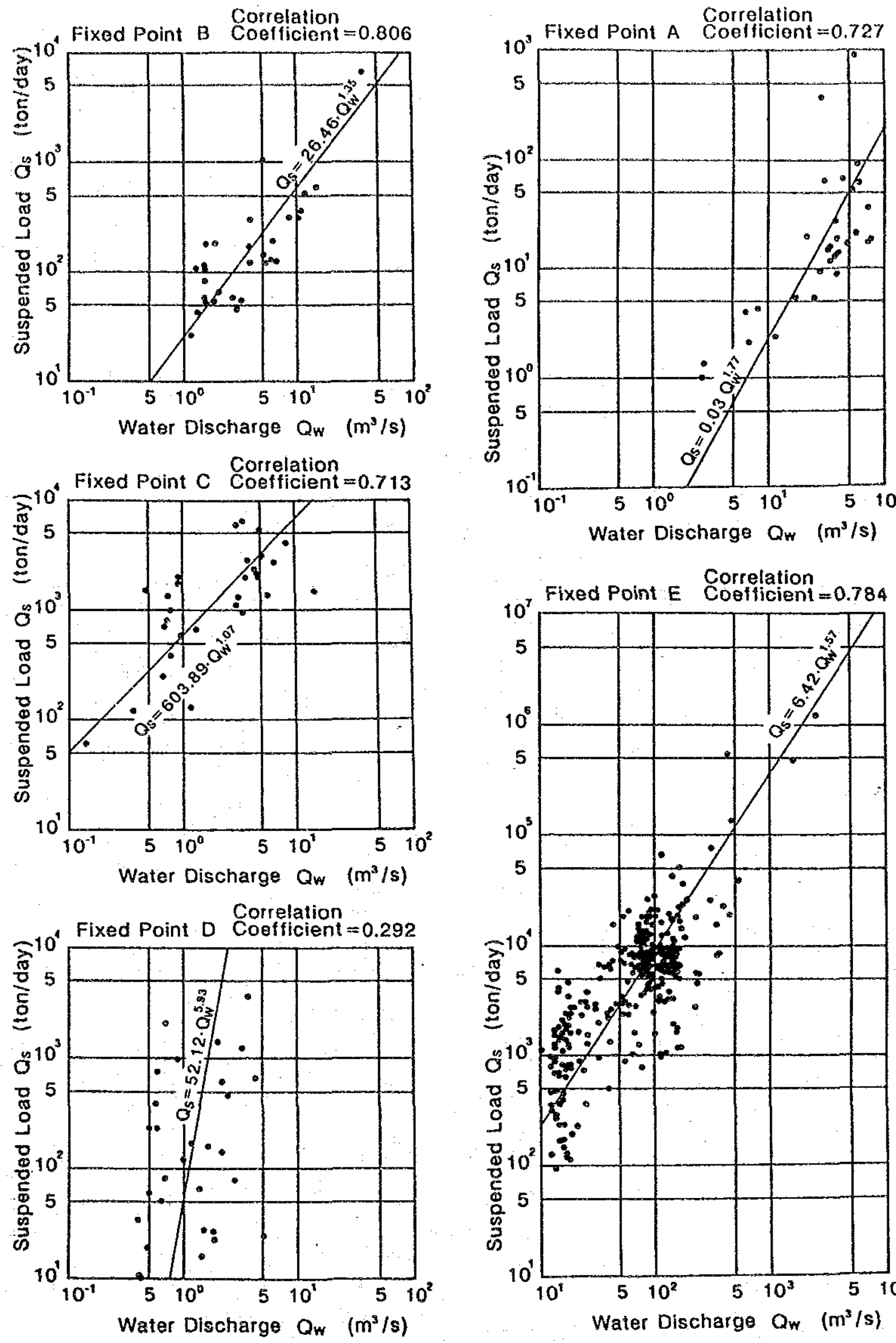


Fig. 3.5 RESULT OF SUSPENDED LOAD MEASUREMENT AT FIXED POINTS A-E

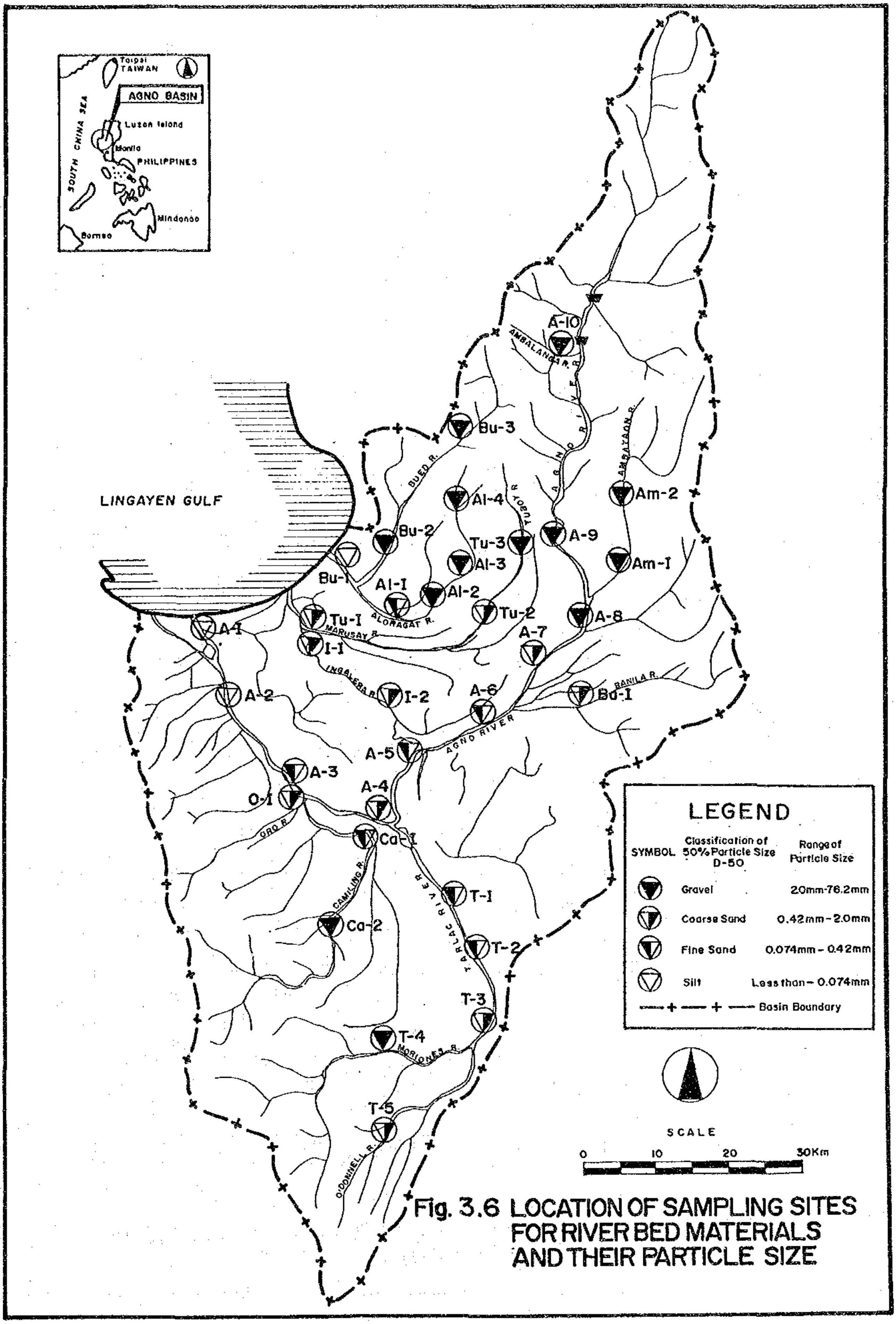
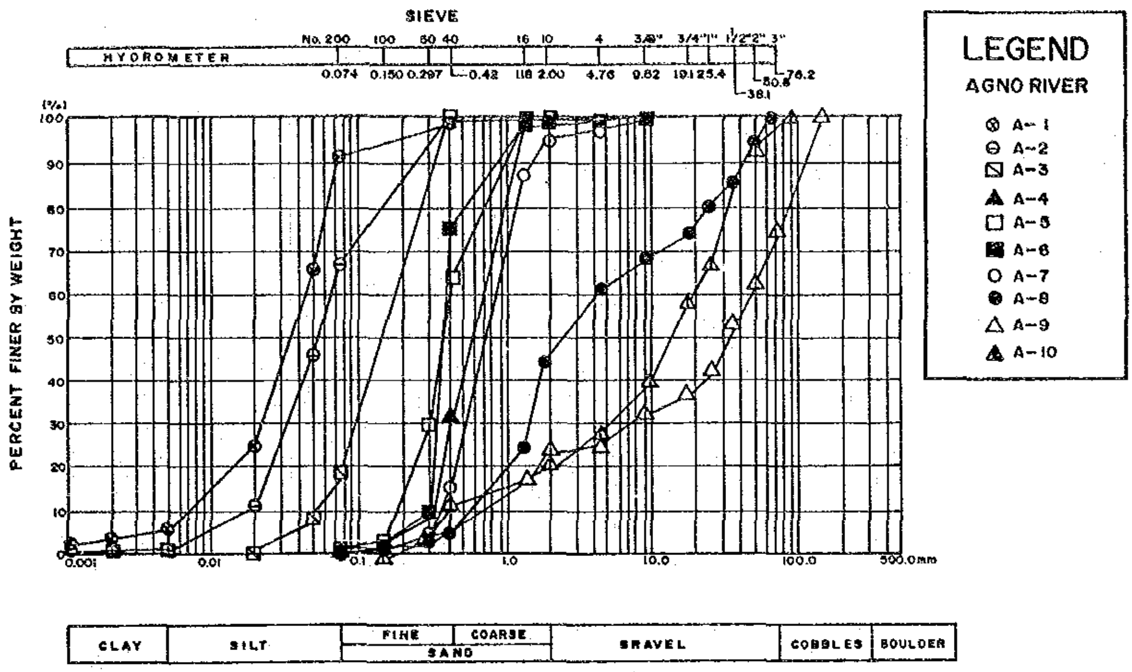


Fig. 3.6 LOCATION OF SAMPLING SITES FOR RIVER BED MATERIALS AND THEIR PARTICLE SIZE



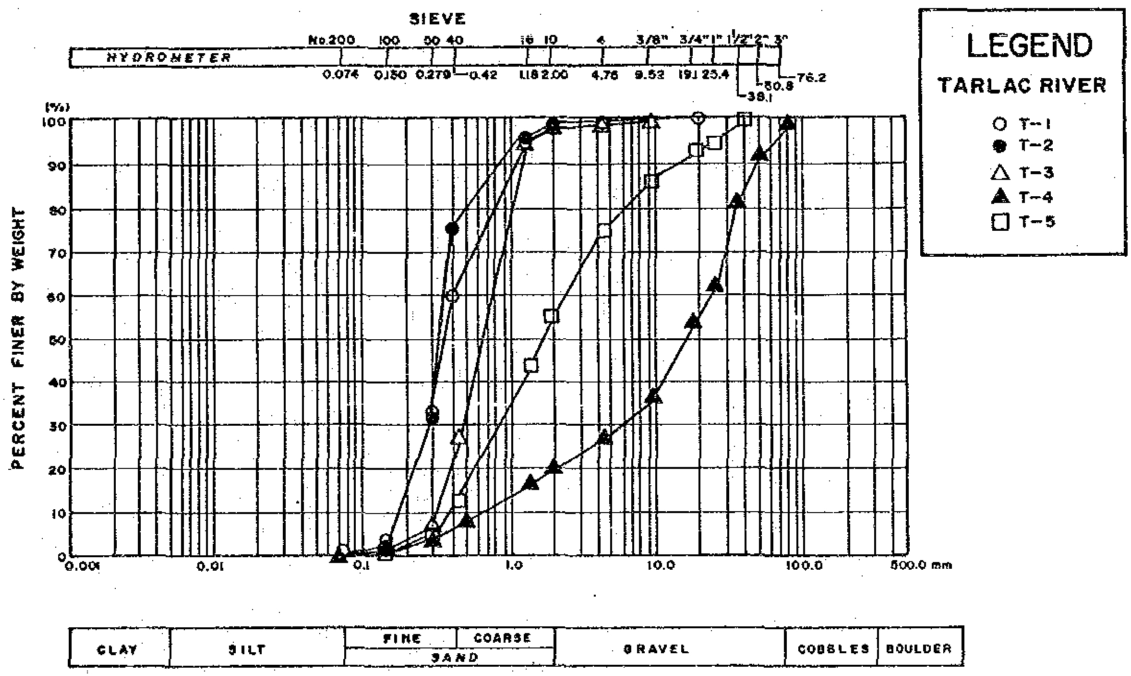
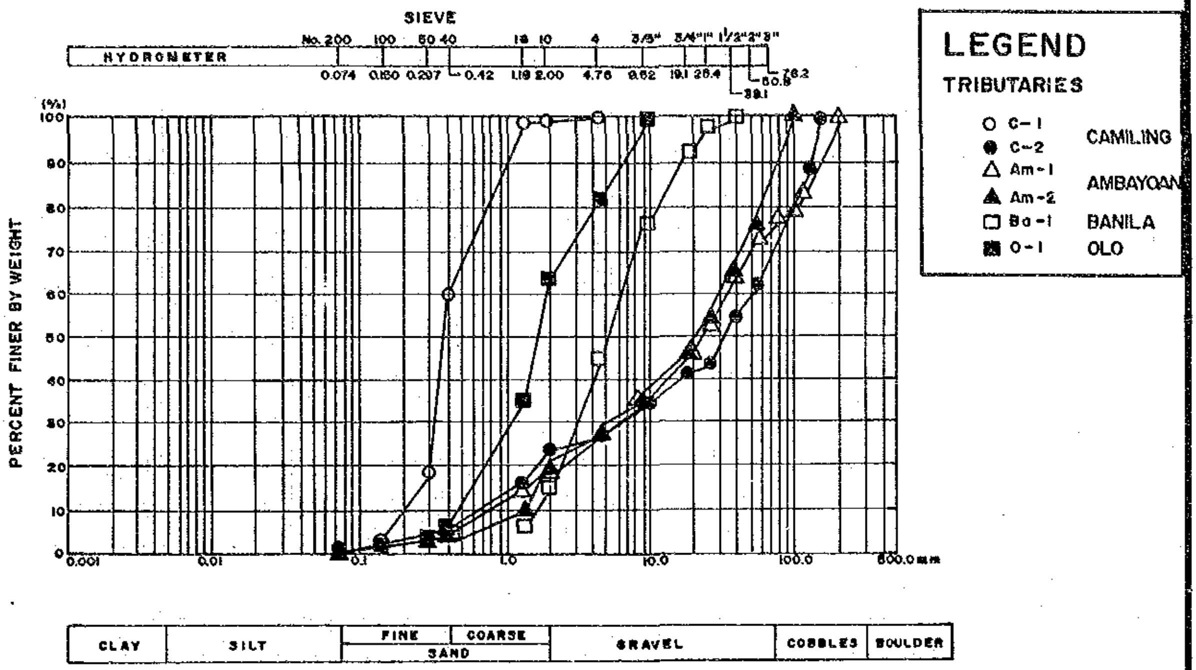


Fig. 3.7 (1/4) PARTICLE SIZE ACCUMULATION CURVES OF RIVER BED MATERIALS



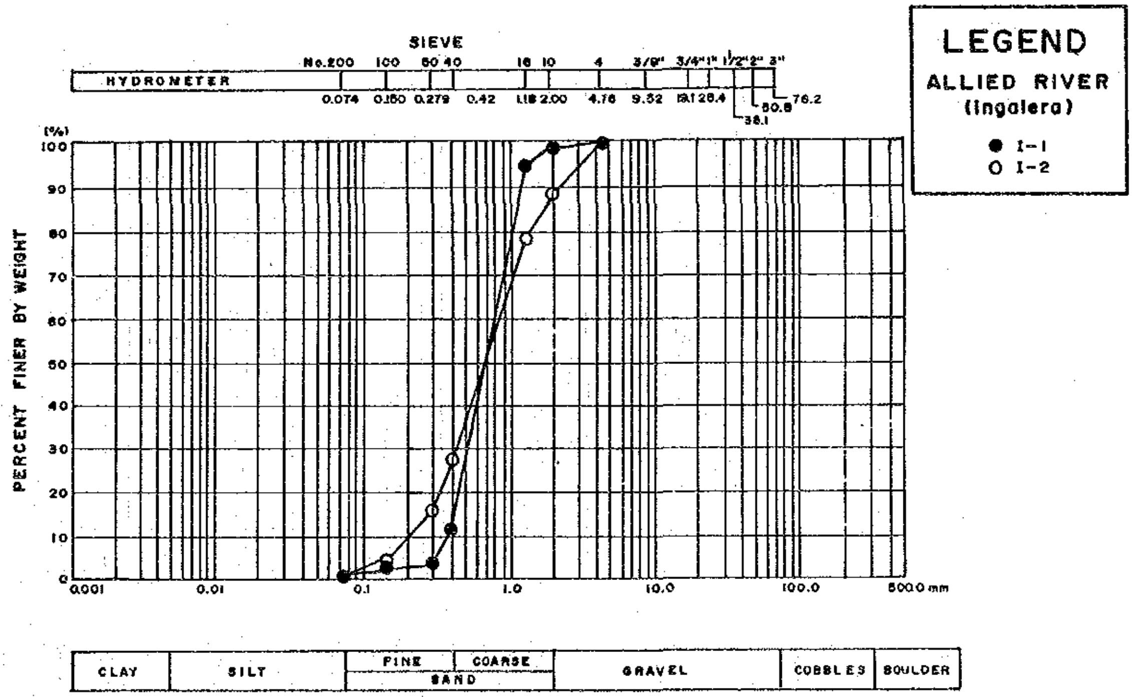
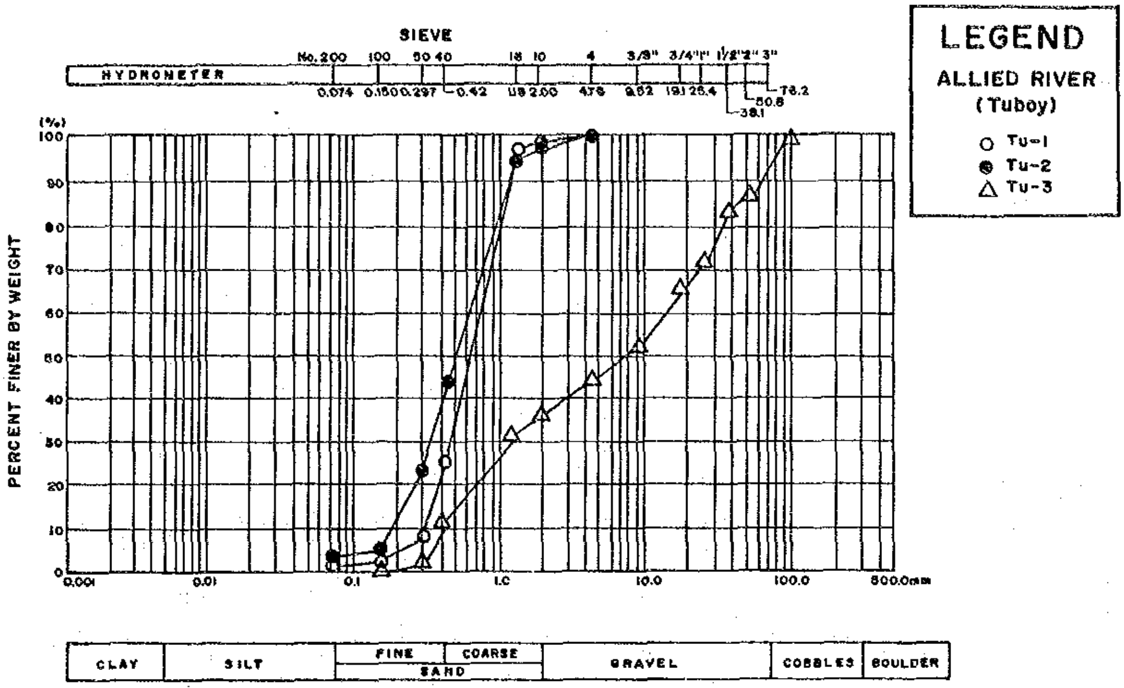


Fig.3.7 (2/4) PARTICLE SIZE ACCUMULATION CURVES OF RIVER BED MATERIALS



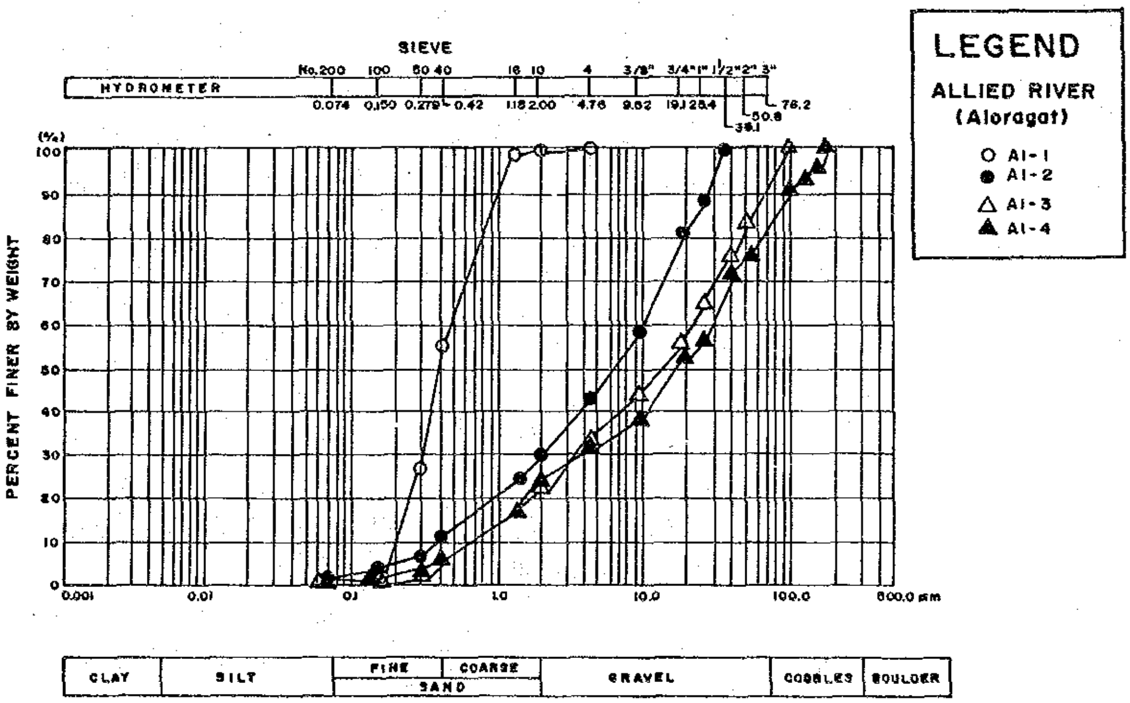


Fig.3.7 (3/4) PARTICLE SIZE ACCUMULATION CURVES OF RIVER BED MATERIALS

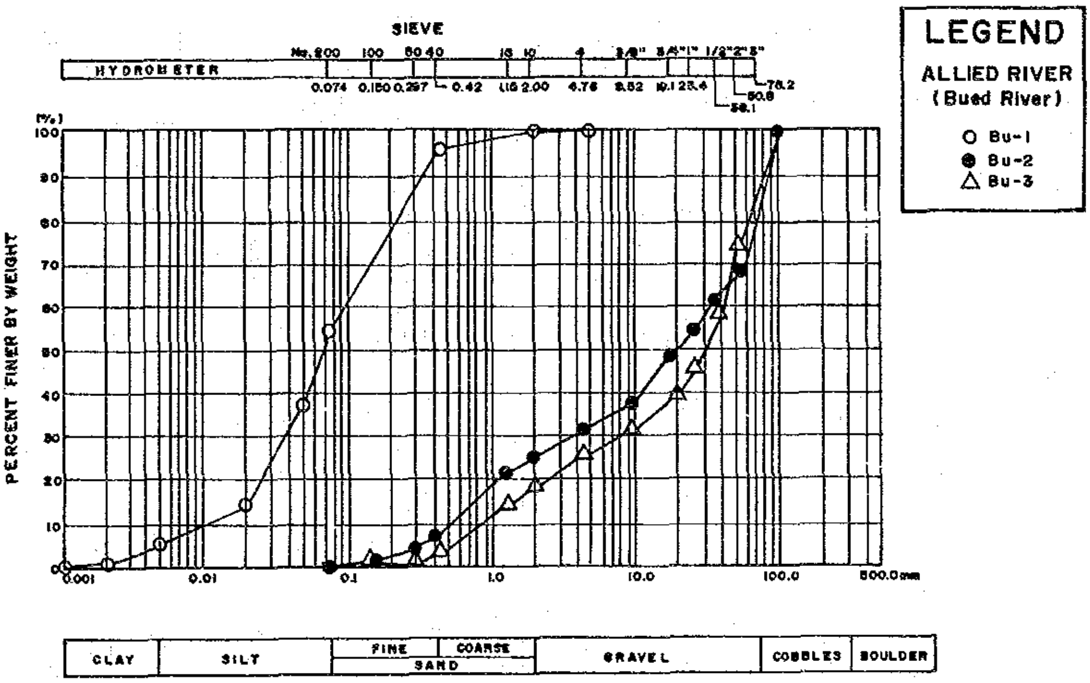


Fig.3.7 (4/4) PARTICLE SIZE ACCUMULATION CURVES OF RIVER BED MATERIALS

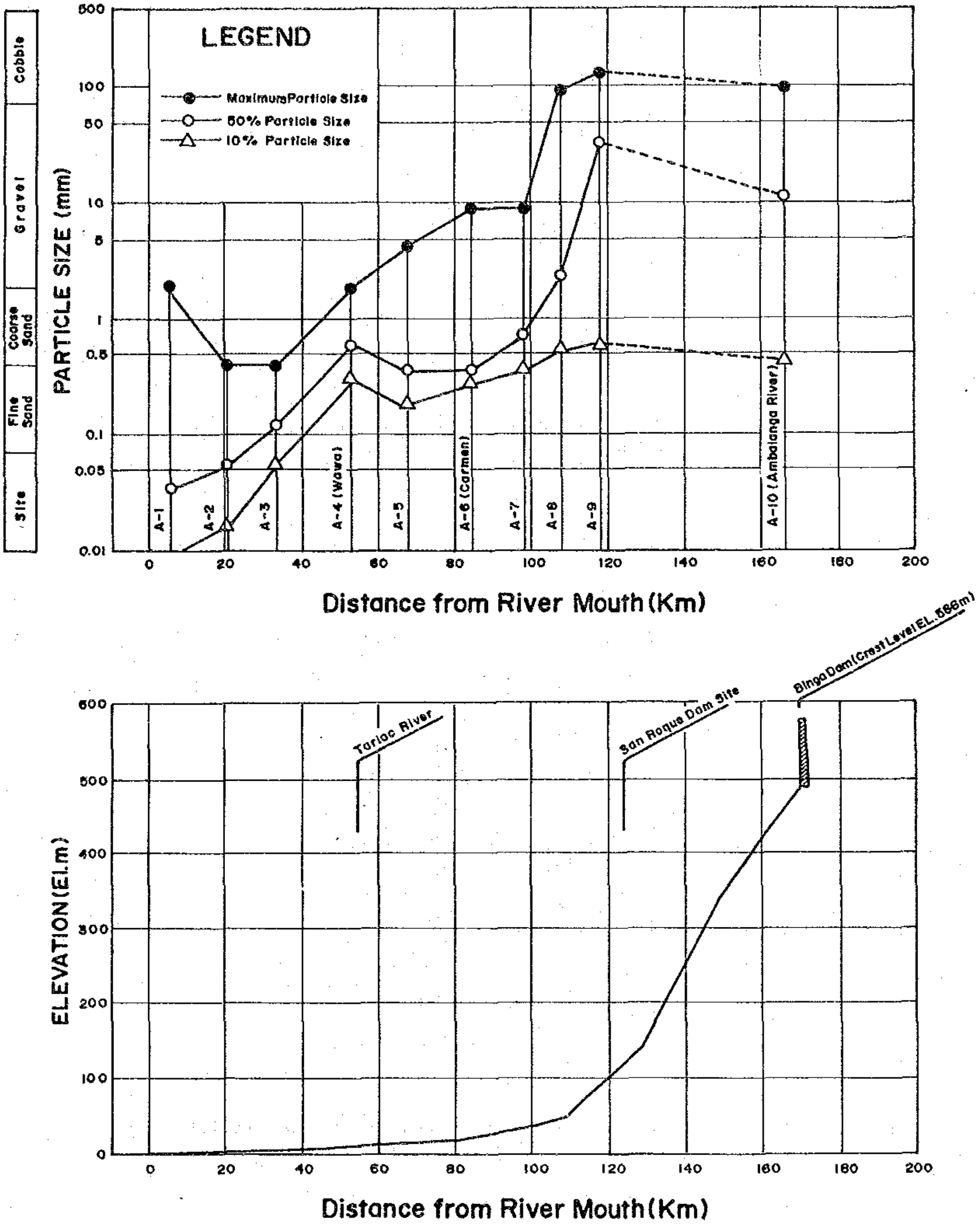
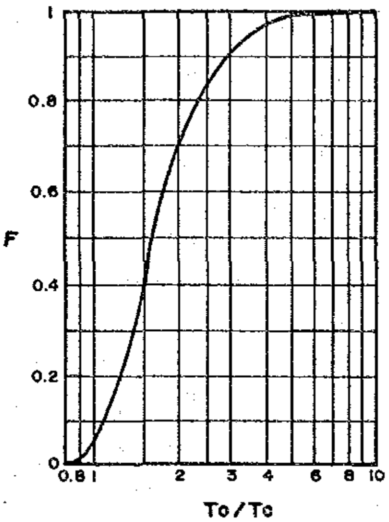
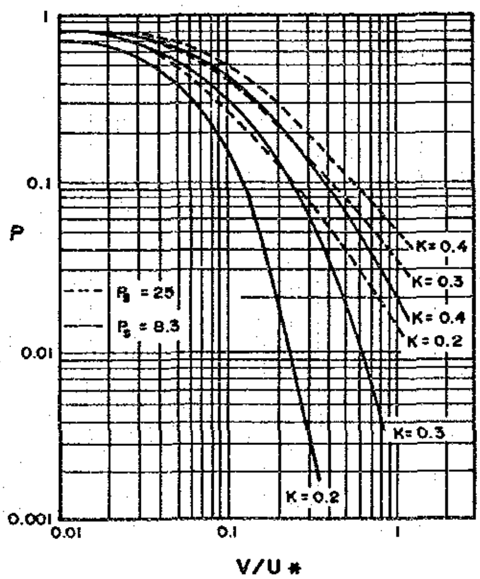


Fig. 3.8 DISTRIBUTION OF PARTICLE SIZE OF RIVER BED MATERIALS IN AGNO RIVER

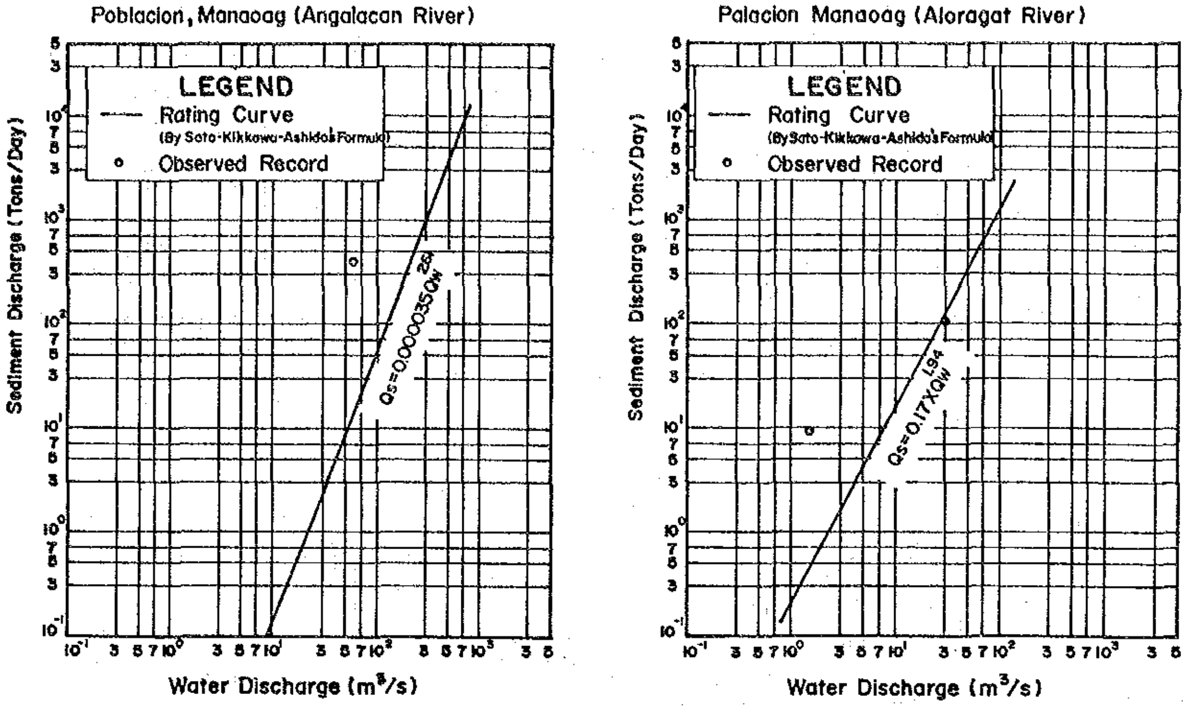


RELATION BETWEEN F AND To/Tc IN SATO-KIKKAWA-ASHIDA'S FORMULA

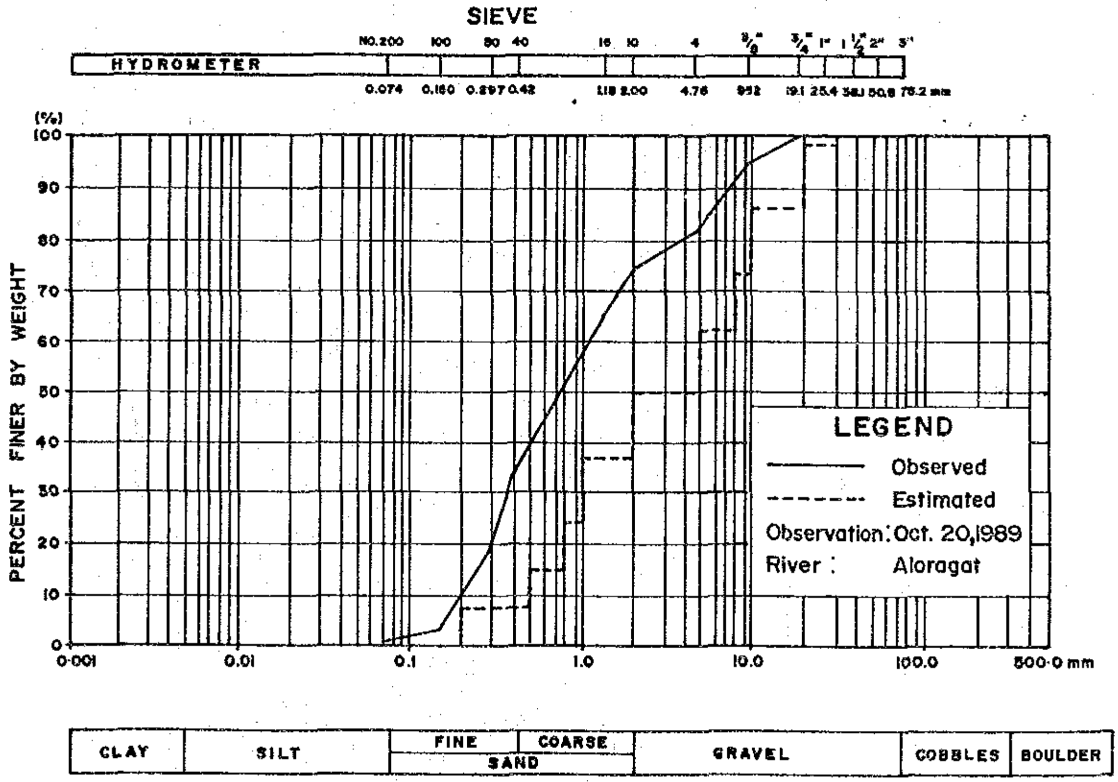


VALUE OF P IN LANE-KALINSKE'S FORMULA (BY ASHIDA)

Fig. 3.9 DIAGRAMS FOR SEDIMENT FORMULAS



(1) Sediment Discharge



(2) Gradation of Bed Load

Fig. 3.10 COMPARISON OF BED LOAD DISCHARGE BETWEEN OBSERVED AND ESTIMATED