Report on

REVIEW OF PLANS for

FLOOD CONTROL and RECLAMATION on the PAMPANGA RIVER in CENTRAL LUZON

For the GOVERNMENT of the
REPUBLIC OF THE PHILIPPINES
and the
AGENCY FOR INTERNATIONAL DEVELOPMENT

by the

U. S. BUREAU OF RECLAMATION

Vaud Larson
CIVIL ENGINEER

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Dr. William Gardner
GEOLOGIST

MANILA, PHILIPPINES DECEMBER, 1962

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SUMMARY

As requested by the Philippine Government, and arranged through the Agency for International Development, three technicians of the Bureau of Reclamation spent a short period in Luzon for purposes of examining the geology of dam sites and recommending a drilling program therefor, and reviewing the flood control and reclamation plans for Candaba and San Antonio Swamps.

This report is confined to the flood control and reclamation plans, together with other pertinent discussions, for the Pampanga River Basin as found by Engineer Vaud Larson, Hydrologist Phil Gibbs, and Geologist, Dr. William Gardner. A separate report on the geology and exploration programs is being prepared by Dr. Gardner.

We have found that Scheme I and Scheme II are not practical plans. They both accomplish adequate reclamation of the Candaba and San Antonio Swamps, but the cost of doing so is too great to warrant further consideration under present conditions. Not only the large construction cost, but also the expensive and difficult maintenance costs associated with keeping the systems in good operating condition further substantiates our recommended disapproval of Schemes I and II.

Scheme III is primarily a flood protection plan for much of the Pampanga overflow plain, but also accomplishes a substantial amount of reclamation. It lends itself to an orderly program of construction and the features of the plan are such that reasonable modifications can

be made as found desirable from changing conditions and as future data becomes available.

Our preliminary examination of the area from the ground and by air and our preliminary investigation of the problems definitely reveal the importance and need for basin-wide planning. This is required to better insure the formulation of plans that will result in better utilization of the available water resources for the benefit of the people of the area. The basin plan will permit more economic scheduling of the various features for construction and will result in an integrated project at least cost.

We also believe that the various needs of the area, resulting from water resource development, should be investigated and those needs combined in multi-purpose project developments wherever possible. Such a plan of development will reduce the individual unit costs and will usually improve the feasibility of a project.

ACKNOWLEDGMENT

We would like to express our thanks and appreciation for the fine assistance and cooperation extended to us by representatives of the Bureau of Public Works and National Power Corporation of the Republic of the Philippines and by representatives of the Agency for International Development and to the Philippine Air Force in providing facilities for our inspection of the area from the air.

INTRODUCTION

The progressive physical and economic development of the numerous potentially rich river valleys in the Philippines is handicapped by a lack of unified river basin development. Water control and utilization projects have been limited to single purpose undertakings designed and treated as isolated problems to meet the immediate demands of particular localities or regions within limitations of budgetary appropriations or under strong political influence. Water properly controlled and utilized is the most valuable natural resource of the country. Social and economic growth is directly dependent on an adequate and controlled water supply for domestic and industrial requirements, irrigation, hydro-power production, fishery management, navigation improvement, and abatement of pollution. In the Central Luzon Basin, storage of water will be required during dry cycles for salt water repulsion upon completion of any channel to the bay that could

permit ocean water to reach the area. With increased development and expansion of population, there is a growing demand for additional flood control measures. The conservation of flood flows in multipurpose reservoirs can provide irrigation water for more efficient use on the land to meet the increasing demands for food. Efficient control and economic utilization of water resources are possible only through adequate planning based on reliable data and investigations. To accomplish this objective, the Agency for International Development and the Bureau of Public Works initiated the Water Resources Survey Project.

Through an agreement between the Agency for International Development and the U.S. Bureau of Reclamation, arrangements have been made for the Bureau to furnish a team of engineers and technicians to work with representatives of the Government of the Philippines to assist in the surveys, investigations and studies necessary in formulation of comprehensive plans for river basin multi-purpose developments on seven of the major river basins. The Bureau of Reclamation is now recruiting a team of engineers and technicians to carry out the provisions of this agreement. Because of the urgency for immediate consideration of the plans for flood control in the Central Luzon basin, together with very preliminary considerations of potential multi-purpose projects, the Manila Office of the Agency for International Development requested the Bureau of Reclamation to detail to Manila as soon as possible two engineers qualified to review and comment on the Bureau of Public Works plans for flood control and reclamation of

the Candaba and San Antonio swamp areas in the Central Luzon Basin and a geologist qualified to make a reconnaissance examination of sites for potential dams including recommendations for an initial exploratory program. Accordingly, arrangements were made for Engineers Vaud Larson and Phil Gibbs and Geologist Dr. William Gardner to report at Manila for this assignment beginning late in November 1962.

This report covers the review and recommendations by Messrs. Larson, Gibbs and Gardner of the plans for flood control and reclamation and other reconnaissance examination in the Central Luzon Basin. Dr. Gardner is also preparing a separate report covering his geological examination of potential damsites and suggested initial drilling program.

GENERAL DESCRIPTION

The Central Plain of the Island of Luzon is drained by two major river systems, namely, the Pampanga River traversing the eastern and southern portions to Manila Bay and the Agno River which drains the northwestern areas, and empties into Lingayen Gulf. Our review is limited at this time to the area drained by the Pampanga River and its tributaries shown on the enclosed Drawing No. USBR-I.

The Pampanga River has a total length from its source, in the Caraballo Range on the North to its mouth at Manila Bay in the South, of 260 km. (160 mi.). The elevation of the highest peak at the head water is 1,700 meters (5,570 ft.). The total Pampanga watershed area is 8,912

sq. km. (3,400 sq. mi.) but at the point of control, near Calumpit is 8,550 sq. km. (3,300 sq. mi.), divided as follows:

1. Rio Chico Watershed ---- 2,848 sq. km. (1,100 sq. mi.)
2. Upper Pampanga Watershed ---------- 3,278 sq. km. (1,265 sq. mi.)
3. Angat Watershed -------- 939 sq. km. (362 sq. mi.)
4. Candaba Swamp Watershed ---------- 1,485 sq. km. (573 sq. mi.)

8,550 sq. km. (3,300 sq. mi.)

The elevation of the river bed at the junction of the Pampanga River and the Rio Chico, which is its largest tributary, is 1.7 meters (5.6 ft.) above sea level. This junction is approximately 80 km. (50 mi.) upstream from its mouth, or a slope of .02 m./km. (0.1 ft./mi.). Upstream from this junction, along Rio Chico there is a low area known as the San Antonio Swamp. Downstream from the junction along and east of the Pampanga River is an area designated as the Candaba Swamp. Although they are referred to as Swamp Areas, the nomenclature is somewhat misleading. Each year, during the rainy season, these areas are inundated in various degrees depending upon the magnitude of the flood. Probably a more accurate reference to these areas would be "temporary detention basins" on the flood-plain of the river. Large volumes of any major flood is held temporarily and greatly reduces the magnitude of the potential peak flow. Seasonally, however, as water drains or evaporates from these areas, the land is cultivated and planted to crops. During an annual cycle, substantially all of the area produces at least one crop. With flood prevention

or a hastening of the drainage, much of the area could produce more than one crop each year. To begin a practice of double or triple cropping would require that plans be made to provide additional surface water supplies and distribution systems for irrigation as well as alleviation of the flood problem.

Approximately 21.5 km. (13.4 mi.) downstream from the junction of the Pampanga and Rio Chico Rivers is the lowest part of the Candaba Swamp area, which is a large depression having a low point at mean sea level. This low area is about 35 km. (22 mi.) from Manila Bay. The Swamp area is often referred to as about 30,200 hectares (75,000 acres), although the ponded area is much less or much greater at various times of the year. On December 2, 1962, we visited the area and found that the land was being cultivated and planted as the water receded. We were told by local farmers that based on present indications, the remaining water would be gone and the balance of the land will be planted by the latter part of December, Immediately upstream from its junction with the Pampanga River, the Rio Chico meanders through an area known as the San Antonio Swamp. This area is usually referred to as about 12,000 hectares (30,000 acres).

The Angat River, which is the other major tributary, joins the Pampanga River at Calumpit, about 23.5 km. (14.6 mi.) upstream from Manila Bay. Downstream from Calumpit, the main channel divides into two major streams and these in turn branch and re-branch into a network of tidal streams before discharging into the Bay.

FLOODS AND FLOOD DAMAGE

In the 26-year period from 1935 to 1960, eight major floods occurred in the basin, namely, the floods of 1935, 1936, 1937, 1943, 1948, 1950, 1952 and 1960. The flood of August, 1960, caused damages estimated by the Flood Control and Drainage Division of the Bureau of Public Works at ₱18,000,000. The average annual flood damage was calculated by BPW to ₱8,435,000

The mean annual rainfall on the watershed is shown on Plate USBR-1 and ranges from about 2,000 mm. (80 in.) to 3,500 mm. (140 in.) Extremes of precipitation at representative stations are shown in Table IV. On the basis of statistical studies on rainfall records over the watershed, the 100-year rainstorm and project design flood characteristics are shown in the following table:

Day	Average Rainfall Over Watershed 7-day 100-year storm		Project Design Flood Runoff Including Base Flow		
	MM	Inches	CM/S	Million M^3	Million A.F.
1	54	2.1	2041	176	.14
2	111	4.4	5152	445	.36
3	207	8.1	10456	903	.73
4	64	2.5	12182	1053	.85
5	53	2.1	9066	783	.63
6	29	1.2	6807	588	.48
7	28	1.1	4923	425	.34
8			2895	250	.20
9			1643	142	.11
10			1005	87	.07
11			758	66	.05
12			657	57	.05
13			628	54	.05
14			625	54	.04
TOTALS	546	21.5	-	5083	4.10

Table IV

Extremes Of Rainfall In Central Luzon

Station Period	Malolos, Bulacan		Cabanatuan City, Nueva Ecija 1947-55 (Inches)			San Isidro, Nueva Ecija 1922-33 (Inches)			San Fernando, Pampanga 1920-32 (Inches)	
	Wettest	Driest	Wettest	Driest	Max.1-Day	Wettest	Driest	Max.1-Day	Wettest	Driest
January	3.56	0	0.88	0.04	.60	1.69	0	1.28	2.94	0.03
February	1.78	0	0.67	0	.67	1.53	0	1.21	1.49	0
March	1.66	0	3.03	0	2.83	2.79	0	1.91	2.55	0
April	2.09	0.14	7.48	T.	2.40	5.77	0	3.22	4.19	0.05
May	20.20	1.46	10.07	3.05	3.56	20.41	1.50	4.78	20.39	2.79
June	27.74	4.83	14.00	3.70	5.32	23.56	0.89	7.46	22.64	4.64
July	40.57	11.60	22.56	5.61	5.97	30.72	6.07	5.49	46.94	5.48
August	51.30	5.47	25.49	10.23	4.72	36.32	4.93	6.75	39.26	5.09
September	27.42	4.89	17.31	7.41	4.03	20.31	3.22	6.67	17.11	3.60
October	22.42	2.49	13.34	1.79	5.25	16.23	0.53	9.00	12.84	1.50
November	43.04	1.33	9.80	0.53	4.53	14.71	0	6.99	23.28	1.29
December	5.12	0.03	8.38	0.01	4.80	22.80	0.04	2.22	2.64	0.11
Annual	160.07	64.32	100.78	52.70	5.97	104.24	54.52	9.00	135.21	60.32

In reviewing the potential plans for flood control and reclamation of the swamp areas, it was noted that a 100-year flood frequency had been adopted. This seemed to be a rather severe design condition for levees; therefore, we made a study of the relationship or deviation for shorter frequency periods. An analysis of the available records indicates that the 100-year frequency is a reasonable condition to adopt. Design storm and flood discharge frequencies are tabulated below.

Frequency in Years	Design Storm Rainfall Probability	Peñaranda River Flood Discharge
	Percent of design	Percent of design
100	100	100
50	96	91
25	88	81
10	77	68
5	65	59
2	50	47

PROPOSAL TO RECLAIM THE CANDABA AND SAN ANTONIO SWAMPS

A report on the "Proposed Reclamation of the Candaba and San Antonio Swamps - prepared by the Flood Control and Drainage Division of the Bureau of Public Works - April, 1962" presents the plans and analysis of two potential plans of reclamation of the Candaba and San Antonio Swamps including flood control under each plan. The report also includes data for a plan covering flood control features in the Central Luzon area but with reclamation to a lesser extent. In the report, the two reclamation plans are referred to as Schemes I and II. The same designations will be used in this report. The plan for flood control and

a limited amount of reclamation will be referred to in this report as Scheme III. A brief description of each potential plan follows:

Scheme I. - Details of the plan are shown on plate 32, a copy of which is included in this report. In general, the plan consists of the following:

a. Labañgan Floodway extending from Calumpit to the Manila Bay for a distance of 17 km. (10.5 mi.). The floodway is 2 km. (1.2 mi.). The pilot channel is 150 m. (490 ft.), with an average depth of excavation of 4.5 m. (15 ft.). The floodway will carry a large part of the discharge from the Pampanga and Angat Rivers.

b. Parallel levees along the banks of the Angat River to confine increased backwater heights extending from Calumpit to Baliwag, a distance of about 20.5 km. (13 mi.).

c. The Candaba Floodway extending from the San Antonio swamp to Calumpit, a distance of 47 km. (29 mi.). This floodway will be 1 km. (0.6 mi.) wide, with a pilot channel 150 m. (490 ft.) wide and an average depth of excavation of 3.5 m. (11.5 ft.).

d. Parallel levees along the banks of the tributary stream draining the hillside slopes east of the Candaba swamp. These streams are the Malimba, Bulu, San Miguel and Maasim Rivers.

e. Parallel levees along the banks of the upper Pampanga River to confine increased backwater heights.

f. Parallel levees along the banks of the Parua and Rio Chico rivers to confine increased backwater heights.

g. Pumping systems in the Candaba and San Antonio swamps to pump out local run-off into the Candaba floodway.

An alternative of the plan outlined above includes appropriate modifications by providing for flood control storage capacity in the reservoirs of three potential multi-purpose dams; namely, the Angat, the Pantabangan and Talavera. This alternative is referred to in this report as Scheme I-B.

Schemes I and I-B are designed to pass a 100-year flood through the San Antonio and Candaba Swamp areas without inundation except for the local rains which would have to be pumped into the floodway channel.

Scheme II. - Details for this plan are shown on plate 33, a copy of which is also included with this report. The major difference between Scheme I and Scheme II is that in the latter a hillbase intercepting channel is substituted for the parallel levee along the banks of tributary streams draining the hillside slopes east of Candaba swamp.

Scheme II includes an alternative designated as Scheme II-B which also provides for appropriate modifications, allowing for flood control storage capacity in upstream reservoirs behind dams now under consideration; the Angat, Pantabangan and Talavera.

Scheme III. - This scheme includes features required for flood control as well as features which will aid in reducing the time required for draining water from the Candaba and San Antonio Swamps. Location of the features is shown on Drawing No. USBR-1. Some of the features incorporated in this plan have been under construction for more than 15 years, some are now under construction and others are proposed for further construction. The basic plan has, in general, been formulated from studies and experience by the Bureau of Public Works as well as from studies and recommendations of experienced consultants, some of whom are former employees of the Corps of Engineers and the Bureau of Reclamation.

In connection with these studies, the Flood Control and Drainage Division of the Bureau of Public Works constructed a fixed-bed hydraulic model of the flood plain of the Pampanga River extending from San Antonio Swamp to Manila. Bay. The model has horizontal and vertical scales of 1:1000 and 1:100, respectively. The model was verified by using observed data in the prototype during the major flood of August 1960. The discharge ratio adapted for the model following careful verification tests is 1:500,000. Velocity ratio is 1:5, time ratio 1:200. This model was used to determine flood stages and profiles under Scheme III. The model was also used to determine flood stages and profiles that would result from Scheme I and II. Water surface elevations for a 100-year design flood and for alternative conditions under Scheme III, of the Labangan Floodway channel as

well as different spans for the Bagbag, Calumpit and Sulipan Bridges is shown in Table II. The same data is shown in Table III for actual conditions of the 1960 flood. Drawing No. USBR-III is enclosed to show the location of the gaging stations shown in the above tables.

The features of Scheme III as well as the location of four of the potential multi-purpose dams are shown on Drawing No. USBR-I. Table I of this report, was prepared to show the features, estimated construction cost, total cost to date, and remaining cost to complete each feature.

REVIEW OF THE THREE ALTERNATIVE SCHEMES

Each of the three alternative plans provided for flood control and reclamation of land, although to different degrees. The plans were reviewed from the standpoint of engineering practicability and economic feasibility.

The proposed channel and levees for schemes I and II were located and designed to protect and avoid interference with the maximum number of barrios and towns. Also the location incorporated alignment to provide desirable hydraulic properties. The conveyance channel would employ levees on either side, constructed to a height required to pass a flow resulting from a 100-year flood and with allowance for freeboard of one meter which appears satisfactory to us. The carrying capacity of the floodway channels of course, is based upon the assumption that adequate management will be followed to keep the channels free of growth which

TABLE - I

Features & Estimated Construction Cost-Scheme III

Item No.	Feature	Total Estimated Cost	Expenditure to 6-30-62	Balance to Complete
1	San Antonio Flood Channel	₱6,251,000	₱ -	₱6,251,000
2	Cabiao-Candaba Floodway	14,629,000	516,200	14,112,800
3	Cabiao-San Isidro (Dike only)	1,490,000	195,000	1,295,000
4	Arayat-Cabiao Ring Levee	2,868,000	721,000	2,147,000
5	Arayat-Apalit-Masantol Setback Levee	9,529,000	4,467,700	5,061,300
6	Sulipan-San Miguel Cut-off channel	2,567,000	1,539,100	1,027,900
7	Bebe-San Esteban Diversion channel	4,626,000	2,864,300	1,761,700
8	Calumpit-Plaridel Dike	699,000	-	699,000
9	Labangan Flood Channel	9,592,000	-	9,592,000
10	Calumpit Pocket Dike	1,716,000	481,000	1,235,000
11	Tabagan Cut-off Channel	118,000		
12	Nigui Cut-off Channel	125,000	60,000	,000
13	Budbud Cut-off Channel	157,000		
14	Raising & Improving of Existing Bridge	5,000,000	-	5,000,000
15	San Antonio-Cabanatuan Levee	1,383,000	-	1,383,000
16	Rio Chico Dike System	32,080,000	525,000	31,555,000
	Total - - - - - - - - - -	₱93,030,000	₱11,369,300	₱81,660,700

TABLE II

MAXIMUM FLOOD LEVELS AT DIFFERENT POINTS IN THE PAMPANGA RIVER FLOOD PLAIN FOR VARIOUS CONDITIONS OF LABANGAN OUTLET (100-YEAR DESIGNED FLOOD)

Point	Existing outlet conditions without Labañgan flood channel	With 500-meter span Bagbag Bridge Existing spans for Calumpit and Sulipan Bridges: Without Labañgan flood channel	With 150-meter wide Labañgan flood channel	BPW Scheme with 80-meter wide Labañgan flood channel	With 1000-meter span Bagbag Bridge existing spans for Calumpit & Sulipan Bridges: Without Labañgan flood channel	With 150-meter wide Labañgan flood channel	With 80-meter wide Labañgan flood channel
San Antonio Swamp (Bamban-Rio Chico Junction)	El. 13.46	El. 13.52	El. 13.47	El. 13.50	El. 13.47	El. 13.42	El. 13.45
Candaba Bridge	8.79	8.94	8.83	8.90	8.84	8.73	8.80
San Simon	7.94	8.14	7.98	8.10	7.92	7.78	7.88
Sulipan, Apalit	6.97	7.20	6.96	7.15	6.93	6.70	6.88
Bagbag Bridge	6.30	6.50	5.80	6.42	5.25	5.32	5.87
Hagonoy	2.85	2.76	2.70	2.48	2.88	2.82	2.62
Pulilan Poblacion	9.75	9.83	9.70	9.81	9.75	9.61	9.72

NOTE:

1. Elevation in meters based on Mean Sea Level datum
2. Flood heights obtained by hydraulic model tests
3. Flood magnitude used -100-Yr. Design Flood (Without flood control storage in mountain reservoirs)
4. Levee and floodway system as per B.F.W. Flood Control Scheme

TABLE III

MAXIMUM FLOOD LEVELS AT DIFFERENT POINTS IN THE PAMPANGA RIVER FLOOD PLAIN FOR VARIOUS CONDITIONS OF LABANGAN OUTLET

– August 1960 Flood

Points	Existing outlet conditions: without Labangan flood channel	With 500-meter span Bagbag Bridge existing spans for Calumpit and Sulipan bridges: Without Labangan flood channel	With 150-meter wide Labangan flood channel	BPW Scheme with 80-meter wide Labangan flood channel	With 1000-meter span Bagbag Bridge existing spans for Calumpit & Sulipan Bridges: Without Labangan flood channel	With 150-meter wide Labangan flood channel	With 80-meter wide Labangan flood channel
San Antonio Swamp (Pambansang Chico Junction)	El. 12.07	El. 12.11	El. 12.08	El. 12.10	El. 12.07	El. 12.04	El. 12.06
Calumpit Bridge	8.11	8.24	8.14	8.21	8.15	8.07	8.13
Sta. Simon	6.79	6.96	6.83	6.93	6.75	6.64	6.73
Sulipan, Apalit	6.26	6.46	6.24	6.42	6.21	6.02	6.18
Bagbag Bridge	5.83	5.99	5.43	5.93	5.50	4.97	5.45
Bonoy	2.01	1.90	1.88	1.70	1.72	1.7	1.56
Malolos, Poblacion	8.82	8.89	8.77	8.87	8.79	8.70	8.78

NOTE:-

1. Elevation in meters based on Mean Level datum.
2. Flood heights obtained by hydraulic model tests.
3. Flood magnitude used - August 1960 Flood.
4. Levee and floodway system as per B.P.W. Flood Control Scheme.

could greatly reduce the carrying capacity of the channel and cause overtopping of the levees.

There are several modifications that could be considered for some of the features of these schemes, such as to retain most sections of the present levee constructed along the river and utilize that portion as part of the west levee for the proposed channel. Such an alternative might result in a slight reduction of the total construction cost, but the alignment would have less desirable hydraulic properties. Also existing barrios and towns would be afforded considerably less flood protection under such as alternative.

Time did not permit a detailed review of the cost estimates. Our limited review, however, indicated that they appear to be reasonable for comparative purposes of the alternative schemes, except that in our opinion, the allowance of 5% for engineering, overhead and supervision; and 5% for contingencies appear to be low. This was discussed with Bureau of Public Works engineers and they indicated that past experience showed these factors to be adequate. The same factors were used in all of the alternatives; therefore, a comparison of construction cost should be adequately reliable except that if the factors should be higher, the span between high and low cost alternatives would be greater than indicated in the report.

The total estimated construction cost of the three schemes are as follows:

Scheme I	₱530,400,000
Scheme II	545,420,000
Scheme III	93,030,000

Based upon the estimated benefits and the construction and operation costs which would result from Schemes I and II, as estimated by the Flood Control and Drainage Division of the Bureau of Public Works, the benefit-cost ratio would be about 0.44 under present conditions. Further refinement of the estimated costs and benefits, as well as potential revisions of the plans might result in a change of the benefit-cost ratio but major modifications would be required for the ratio to reach 1:1 or better.

Another important element which must be considered in connection with Schemes I and II is that unless proper operation and management of the facilities were maintained, the plan could not serve its purpose; for example, keeping the floodways free of vegetal growth would periodically involve a major operation that would require very large expenditures. If necessary funds were not made available, the channel could become choked with growth that would reduce the carrying capacity of the floodway to the extent that floods could overtop the levees and result in flooding of adjacent areas. This would defeat the purpose of the scheme and nullify the contemplated benefits. Another feature of Scheme I and II that would be expensive and difficult to maintain in a dependable manner would be the many pumping plants required. To insure against occasional inundation

of the adjacent areas during heavy rain and floods, the pumping plants would have to be maintained to operate at all times over a wide load range, from very low to maximum capacity.

Schemes I and II do not lend themselves to an orderly construction program which could proceed over a period of years as funds became available for work in the Central Luzon Area. Unless the features could be constructed and placed in operation within a relatively short period of years, the maintenance cost of completed but unused portions would be just as much and possible more, in some cases, than if the features were actually in service.

The plan designated as Scheme III in this report is divided into 16 features. Some of the features of this plan were recommended for initial construction in 1936. Actual construction was started shortly thereafter and has been continued as funds were made available. The total expenditure to date is ₱11,369,300. Features constructed, under construction, or planned for construction, follow the general scheme but have been modified and expanded as additional information became available and as changing conditions arose.

This scheme lends itself to an orderly program of construction as funds can be made available. Also, the features of this plan are such that reasonable modifications can be made as changing conditions dictate without nullifying major parts of the completed works. With additional data that will become available, and with changing conditions that may be

experienced, further modifications of the plan might become desirable.

Under plans for scheme III, the Candaba Swamp area will still be subject to flooding in varying degrees during the high streamflow season. This is a natural condition that has taken place throughout the history of the area. To abruptly change this process as would occur in schemes I and II, not only presents a very costly solution but one that introduces many complex operation and maintenance problems. Furthermore, under schemes I and II, additional expenditures would be required to control sanitary conditions which are now corrected to some extent each year by floods.

The velocity of the water in the flooded areas is relatively low even during large floods because of the very flat gradient of the lower Pampanga River. It is reported that flood waters in the inundated areas do not carry a large amount of floating debris; nevertheless, unrestricted construction of homes in the flood plains is causing greater depths of water for similar recurring flows. In some areas, the squatter problem is creating a condition which is aggravating the flood control problem. Unless restricted and controlled, corrective measures will become more complex and difficult to impose as time passes.

The matter of providing large storage capacities for flood control in upstream multi-purpose reservoir is one of the potentialities which is considered in a very tentative manner at this time and one that will be considered in detail by the team of USBR representatives to be assigned

to work with representatives of the Philippine Government. It is entirely possible, however, that if unrestricted developments are permitted to continue in the existing floodways and channels, the increased inundation which will result may be sufficient to neutralize the flood reductions provided by other flood control measures such as the flood control capacity in upstream reservoirs.

NEED FOR MULTI-PURPOSE AND BASIN-WIDE CONSIDERATION

In our review of the available data and the various plans for potential developments, our observations from field inspection by ground and air, and from our discussions with people familiar with the problems and conditions, we find that many of the problems are very similar to those confronting us in the Bureau of Reclamation. It is true that many are different in varying degrees but many have close similarity. As an example, the rainfall, flood volumes per unit of area, and cropping patterns are different than most areas in the 19 Reclamation States which, in general, includes the western half of the United States. We find, however, that progressively the need for water for irrigation, domestic and industrial uses and other requirements is increasing in the Philippines as in our reclamation states. Also there is a need for large storage capacity in reservoirs here to provide for needed flood control and conservation. We were informed by the General Manager of the National Power Corporation that the demand for electrical energy is now averaging 14% increase per year which amounts to the load

doubling about every seven years. This rate of growth exceeds the average for the United States which is doubling every 10 years, and considered to be a rapid rate.

Another important similarity of potential projects in the Philippines and in the Reclamation States is in the showing of need, economic feasibility and in many cases repayment ability. It is because of the latter element that plans for multi-purpose development of projects or project features is becoming even more essential. In many cases the cost of constructing a project for a single-purpose development could not be economically justified but by combining all needs into a joint or multi-purpose project, feasibility requirements are often met. Assuming the geological condition of a damsite is satisfactory, the cost per unit of reservoir storage capacity usually decreases with height of dam and volume of reservoir capacity. Therefore, it is always advisable to combine where ever practicable the various needs into a multi-purpose development.

Experience in developing projects by the Bureau of Reclamation has definitely shown that basin-wide planning provides for a more logical program of proceeding with the development, and a much better plan for the utilization of the available water and land resources. Also a basin plan provides assurance of better serving the needs of an area. Piece-meal development of projects could not possibly realize maximum potential possibilities that is accomplished through basin-wide planning. Under basin-wide consideration of development, each project designed and

constructed will better fit into a pattern of ultimate accomplishment of serving the needs and realizing maximum utilization. Our tentative consideration of the needs for upstream storage are discussed in the following sections.

Irrigation Requirements. - Storage required to provide for additional irrigation in the Pampanga River Basin will eventually be needed if full development is to take place. The extent of present irrigation above Arayat appears to be about as follows:

BPW Projects	50,700 hectares	(125,000 acres)
Pumping Units	6,020 hectares	(15,000 ")
Water rights (private)	125,280 hectares	(310,000 ")
Total - - - - - - -	182,000 hectares	(450,000 ")

In dry seasons there is insufficient water for all the irrigated lands and it is reported that only about 25 percent of the lands can be supplied water during such low flow months. Nevertheless, the BPW has plans for bringing irrigation to another 26,200 hectares (65,000 acres) in the near future. It will also need 75 percent of a supply if it is to be irrigated during the dry season.

Storage water supplies may be used to irrigate either the existing lands or the new lands during the dry streamflow months. It is apparent that if full irrigation service is to be provided for all existing and potentially irrigable lands, the storage requirement to carry out these plans will be considerable. Allowing for reuse and rediversions of return flows after

full irrigation development, it is roughly estimated that irrigation storage requirements would be more than 130,000-hectare meters (in excess of one million acre-feet).

There appears to be several good potential groundwater developments around the perimeter of the central plain. Any dependable groundwater resources can be developed in lieu of storage in reservoirs if suitably located.

Storage Requirements to Protect Against Salinity. - Upon construction of the Labangan Floodway, the probability of salt-water intrusion will arise. This problem can be solved in various ways, but a fresh water supply flowing to the bay is probably the most satisfactory solution although it may not be the most economical. This is a problem which will require study by the Bureau of Public Works and the Bureau of Reclamation representatives. As a first approximation of the magnitude of the storage required for this purpose, the following rough analysis has been made.

The gaging station near Arayat on the Pampanga River is located below the major irrigated areas of the Central Luzon Plain. The water recorded at the Arayat gaging station must therefore satisfy the requirements of irrigation diversions and pumping between Arayat and Manila Bay. In the wet season there is a surplus of water, but in the dry season the flows are very low. The Angat River is a principal tributary which enters the Pampanga in the vicinity of Calumpit but it also supports considerable irrigation and cannot be relied upon to supply water for the needs of the lower Pampanga River in dry seasons unless storage for that purpose is provided. To gain some

knowledge of the amount of water required in the dry seasons at Arayat to meet the needs downstream, we have made an estimate of needs below Arayat.

Assuming that irrigation below Arayat is practiced on 8,413 hectares under pump units and that the 15,727 hectare-liters of granted water rights represents 10,500 hectares at 1.5 liters per hectare per second, then there is an area of 24,140 hectares which would or could make use of dry season streamflow. It is understood that the fish ponds derive most of their water from the bay so would not require fresh water supplies normally. On the above basis, a dry period of five months would require about 32,000-hectare meters of fresh water supply, or about 260,000 acre-feet. Some of the requirement could be met from streamflow in the Pampanga River. The gaging station at Arayat shows that the dry period January through May 1946 was the driest of record, but followed closely by other 5-month periods in 1947 and 1955. In such periods, the flow is as little as 33,000 hectare meters, or 265,000 acre feet. Assuming present development in the Basin below Arayat, it appears that the dependable flow of 33,000 hectare meters will just satisfy the requirement of 32,000 hectare meters if the distribution is good, but any difference would need be provided by storage at some upstream point. This would be the estimated minimum storage needed to use up all the streamflow if present users take the water they could use in dry seasons. If further development of land in the upper Pampanga River Basin occurs, then it may become necessary to rely on less of the minimum historic flow of 33,000 hectare meters, and some amount of upstream storage will become necessary to meet existing requirements.

It is concluded from this very rough estimate that the agencies of the Republic of the Philippines will some day need to provide upstream storage of at least some small amounts for existing demands below Arayat plus the requirements to protect against salt water intrusion if the Labangan Floodway is constructed. This requirement is presently unknown and will need to be determined, but it is estimated from limited knowledge that it may require as much as 50 CMS continuously, which would indicate the need for an additional 65,000 hectare meters of storage. We therefore believe that it would be desirable for the long-time benefit of the Central Luzon area to plan upstream storage, for use in dry seasons in conjunction with present flood control plans, of as much as 70,000 hectare meters, or 570,000 acre feet. It can be located in any combination of the four upstream reservoir sites being considered, or in new sites which may yet be discovered.

HYDROELECTRIC POWER PRODUCTION

The amount of hydroelectric power production at potential reservoir sites will have to be determined during formulation of the plan for multipurpose development. It is readily apparent, however, that the runoff is substantial and, except for uncontrollable reservoir spills, can be converted to kilowatt-hours in substantial quantities. The optimum reservoir and power plant capacity will have to be determined by detailed studies.

In favor of power generation, in addition to the heavy runoff, are the factors of probable high heads and the consideration that all irrigation releases and some flood control releases can be used for power production,

thus probably reducing the specific reservoir space for power except that small amount required for minimum power operating level. The joint uses of irrigation waters for power production, flood control releases for power production, and minimum power pool for sediment retention and fish propagation, sets up a reasonably good potential for multi-purpose dam construction. Any water which is released for salt water repulsion is also available for power generation as well as for navigation and pollution abatement.

Hydroelectric power generated under such conditions may have one undesirable aspect, however, the generating pattern will conform more to the irrigation requirements than the power load curves, and thus will mean that only a portion of the energy will be saleable as firm energy, and the remainder as non-firm energy at a lesser value. There is the possibility, however, that with the high available head it may be possible to develop peaking capacity at the potential reservoirs and thus increase the energy value providing that necessary downstream regulatory storage capacity is provided. Such determination will need be made to fully explore the desirability but it is obvious already that any power which can be produced will find a market in the fast growing power demands of Luzon.

FLOOD CONTROL STORAGE

Potential reservoir sites have thus far been limited to some of the mountain valleys. Only about 20 percent of the drainage area could be controlled or partly controlled by storage works now being considered.

While it is obvious that the large uncontrollable area will be able to always cause floods, it is nevertheless important to include flood control space in each future reservoir to the maximum practical extent. It may also be possible to find large amounts of offstream storage in certain areas which may be used as storage reservoirs and which may be filled by the diversion of surplus waters to further effect the flood control plan.

Floods on the Pampanga watershed are caused primarily from repeated rainfall associated with cyclonic storms in the summer and autumn months. Any plans for controlling floods, therefore, must be incorporated into a system of levees, and should be based on a plan of frequent evacuation of impounded flood waters as rapidly as safe channel capacity at downstream points will allow.

Even if flood control space can be justified in all tributary reservoirs, and upon completion of many of the levees and floodways as planned in Scheme III, some degree of flooding in Candaba Swamp will still prevail in the advent of large floods. The flood control measures to be provided in Scheme III will, however, limit the flooding to a much smaller area, and will be of particularly value in passing the smaller and more frequent floods which now overflow the area.

GEOLOGY

Preliminary to a further study of multi-purpose possibilities at the potential dam sites, an inspection review of a reservoir site on the Pampanga River and one on the Talavera River was made for an early evaluation of

water control and development for the Central Luzon Plain. The two proposed sites for further study are Pantabangan on the Pampanga River and in the vicinity of Puncan Mt. on the Talavera River. They will be discussed in detail in the accompanying Engineering Geology Report, but the main findings for early consideration in the general planning are given below.

Pantabangan dam site is on the Pampanga River about three kilometers (1.9 mi.) (air line) downstream from the junction of the Carranglan and Pantabangan Rivers. A dam about 48 m. (158 ft.) high had been considered to store some 36,600 ha. ms. (293,000 a.f.). A rapid inspection of the river indicates favorable possibilities for a site where a high dam may be built, if future studies find a large reservoir to be warranted. There is a good reservoir site; an area capacity curve using topography from the 1:50,000 scale military maps shows that a reservoir with a capacity of 125,000 ha. ms. (1 million a.f.) can be obtained by a dam about 90 m. (300 ft.) high. The military map indicates that the ridges forming the abutments and confining the reservoir site are high enough for an even larger capacity if the proposed geologic explorations and the engineering studies find a larger capacity desirable. The mean annual runoff at the Bongabon gage is given as 84,100 ha. ms. (680,000 a.f.) and hence the above considered reservoir capacity of 125,000 ha. ms. is not excessive but may be small for a multi-purpose feature that would supply conservation storage for irrigation use and power and provide flood control space. In fact, if the geologic studies find favorable conditions, a larger reservoir would probably be desirable to allow additional space for a minimum pool and the deposition of sediment.

A dam site on the Talavera River had been considered in the vicinity of Lumboy where a dam 91.5 m. high (300 ft.) would store about 21,500 ha. ms. (175,000 a.f.). A rapid inspection of the general area and some study of the aerial mosaic indicates that the river in that locality is probably following a major geologic fault. Further study suggests a more favorable location for the dam is in the Puncan Mountains about 4.5 kms. (2.8 mi.) (air line) upstream from Lumboy. An area capacity curve for the Lumboy site was used to obtain a rough estimate of storage at the Puncan Mountains site and this indicates that a dam of the same height as that considered for Lumboy (91.5 m.) would give about 125,000 ha. ms. of storage at the Puncan Mountains site. The mean annual runoff of the Talavera River at Kitakita gage is given to be 60,500 ha. ms. (490,000 a.f.) and the runoff at the Puncan Mountains site would be slightly less.

The military topographic sheet suggests that the river drops about 60 m. (200 ft.) in the short distance from Puncan Mountains to Lumboy. It may be feasible to develop some of this head for power production.

RECOMMENDATIONS

1. Of the three Schemes outlined in the Bureau of Public Works Report on the proposed reclamation of the Candaba and San Antonio Swamps - April 1962, it is our opinion that the general plan outlined under Scheme III should be followed, except for certain modifications which may be found desirable as conditions change and as additional data and studies become available.

2. As funds are made available, work should progress on features which will carry out the intent of Scheme III and for which investigations have been completed, such as closing the gaps in the Arayat-Masantol levee. Also urgently needed cut-off channel work could proceed immediately. Those features for which data are incomplete should be deferred until studies have been completed to insure reliable conclusions. Features which fall in this category are, as an example, the parallel levees along the river channels included under Item 16 of Table I for the Rio Chico Dike System, although some of the needed cut-off channel work included in this item could proceed. Features, such as the Labangan Flood Channel could proceed, but it might be advisable to leave a partially excavated restriction or reduced channel opening which could be closed to the extent required to prevent salt water intrusion during any low flow period. Such a restriction should remain in place until upstream stored water or other measures are provided to prevent ocean water from moving inland.

3. The water surface profile for the 100-year flood under the routing study, and the actual profile for the 1960 flood seems to show a pronounced restriction in the vicinity of Calumpit. This is apparently caused by the ring-levee protecting Calumpit, and the Bagbag, Calumpit and Sulipan Bridges. We recommend that further studies and investigations be made to determine the maximum width of spans that can be justified for the Bagbag Bridge. Also, we recommend that design of the bridge incorporate provisions for additional span openings which might be justifiable in the future.

4. To promote sound planning and the development of potential multi-purpose projects for maximum utilization of the available water and land resources, it is highly desirable that the Republic of the Philippines initiate studies as soon as practicable for the purpose of providing data needed to formulate legislation which will establish priorities for the appropriation and utilization of available water supplies.

5. Unrestricted development of homes, buildings, etc., within the flood channels and flood plains are, in many cases, aggravating the flood problem. If permitted to continue uncontrolled it is entirely possible that benefits from potential flood control improvements could be nullified as fast as projects could be constructed to provide the desired benefits. Therefore, we recommend that the Philippine Government initiate studies by appropriate agencies to develop zoning controls which would aid in preventing undesirable conditions from spreading which add to the annual flood problem.

6. As an aid to the Bureau of Public Works, and to the Bureau of Reclamation team in connection with further investigations of the problems considered in this report and the basin-wide investigations of the other six river basins included in the agreement, it is recommended that the Bureau of Public Works begin the preparation of an inventory of data available for each of the seven river basins which will be required in the comprehensive investigation, such as, but not limited to the following:

a. Water supply records of stations available.

b. Maps; type, coverage, highways, trails, etc.

c. Survey control; horizontal and vertical.

d. Records of construction and operation and maintenance costs for single purpose or multi-purpose type projects.

e. Records of exploration and tests of construction materials required for multi-purpose type projects.

f. Statistical records:

Population and trends

Electrical power consumption and trends

Cultivated acreages and production

g. Aerial mosaics of the basins.

Vaud Larson

Vaud Larson, Team Leader
(Detail Assignment)

Phil Q. Gibbs

Phil Gibbs, Engineer

William L. Gardner

Dr. William Gardner, Geologist

December 19, 1962

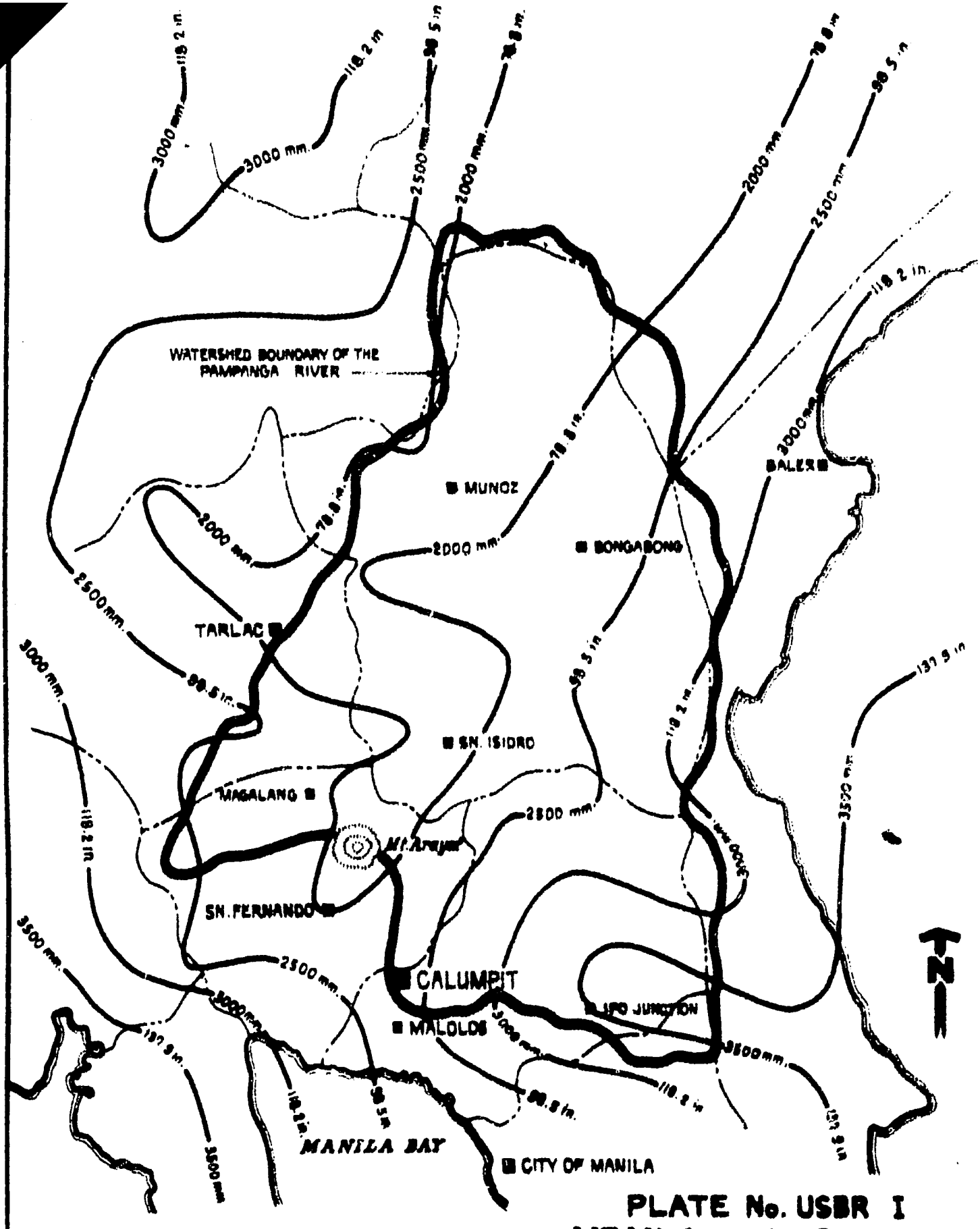
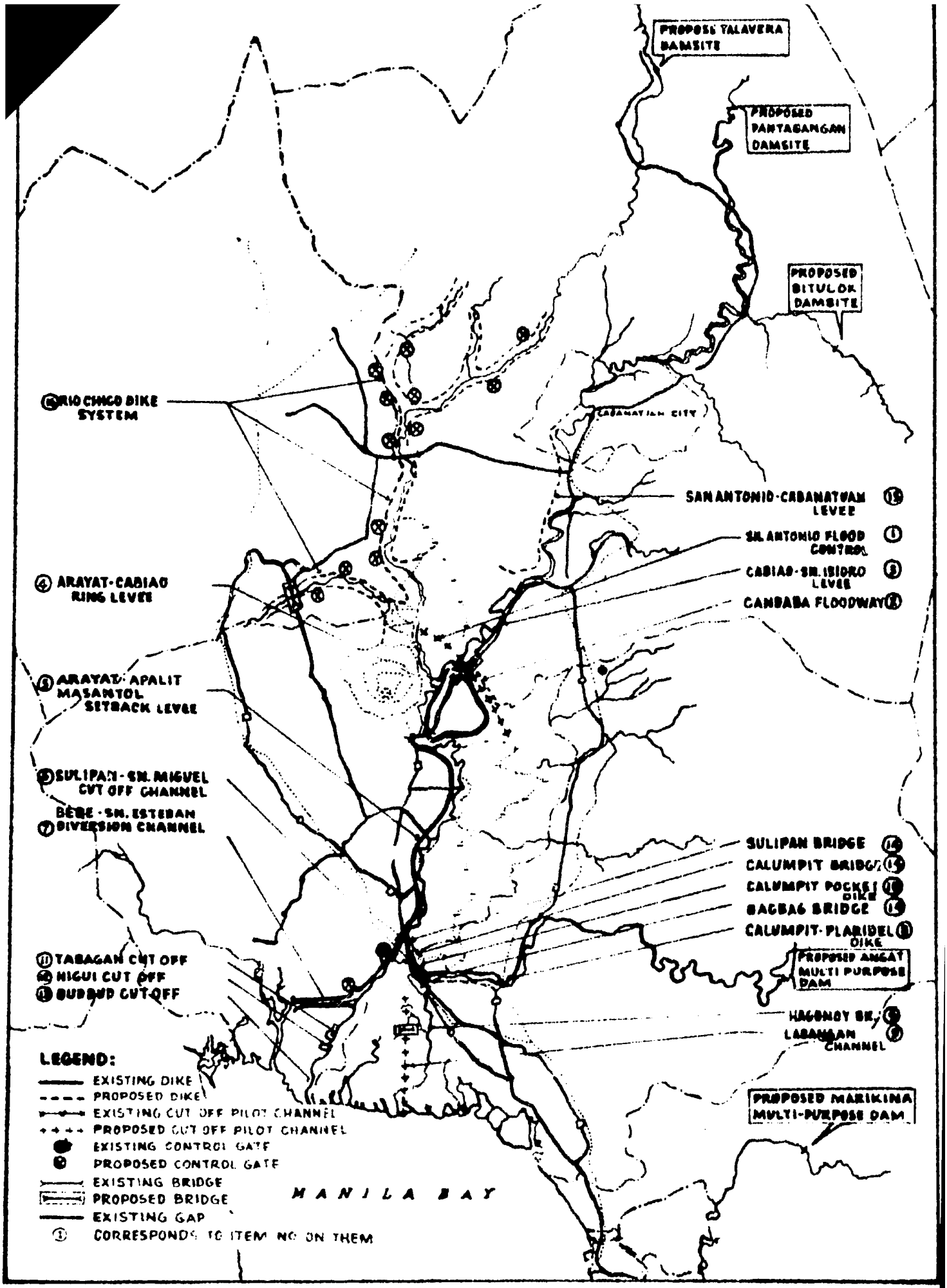


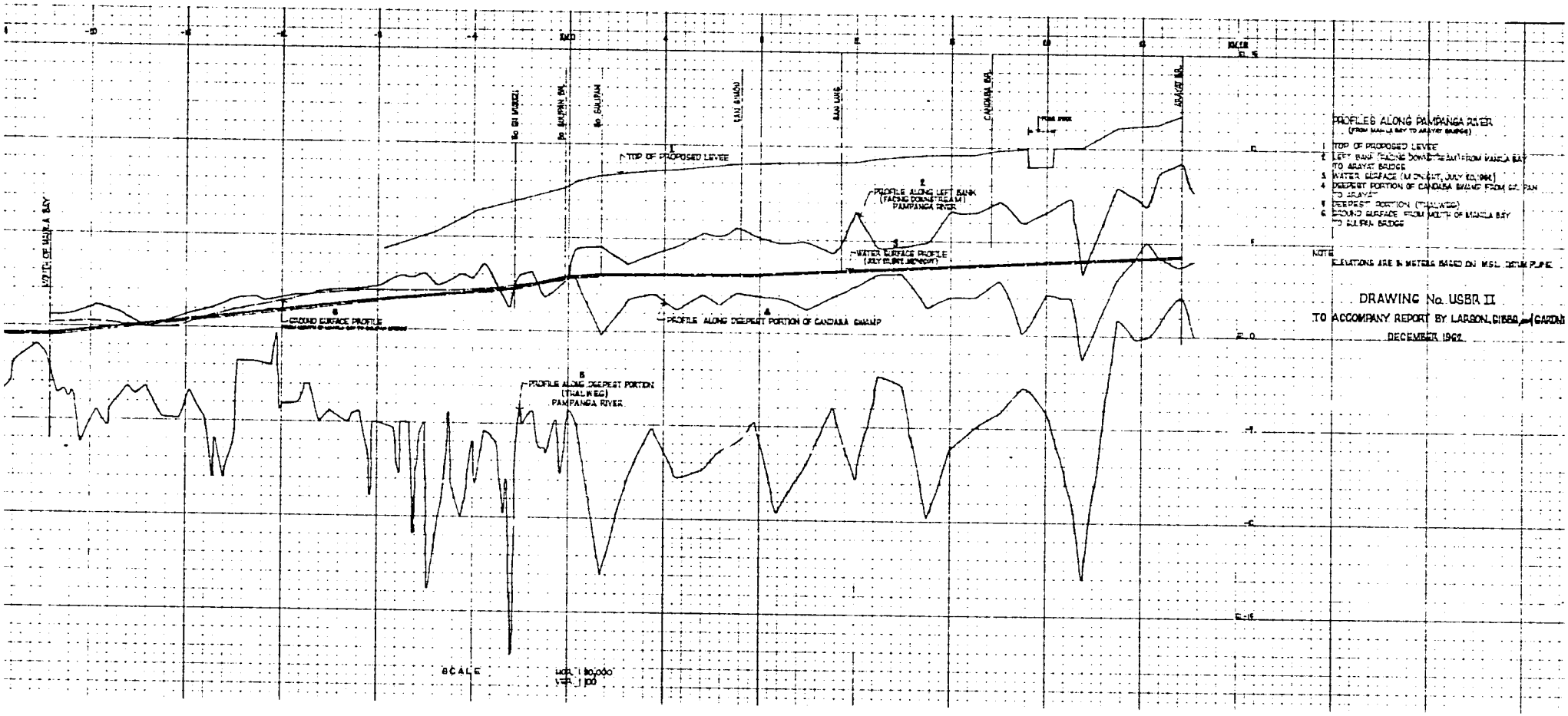
PLATE No. USBR I
MEAN ANNUAL RAINFALL

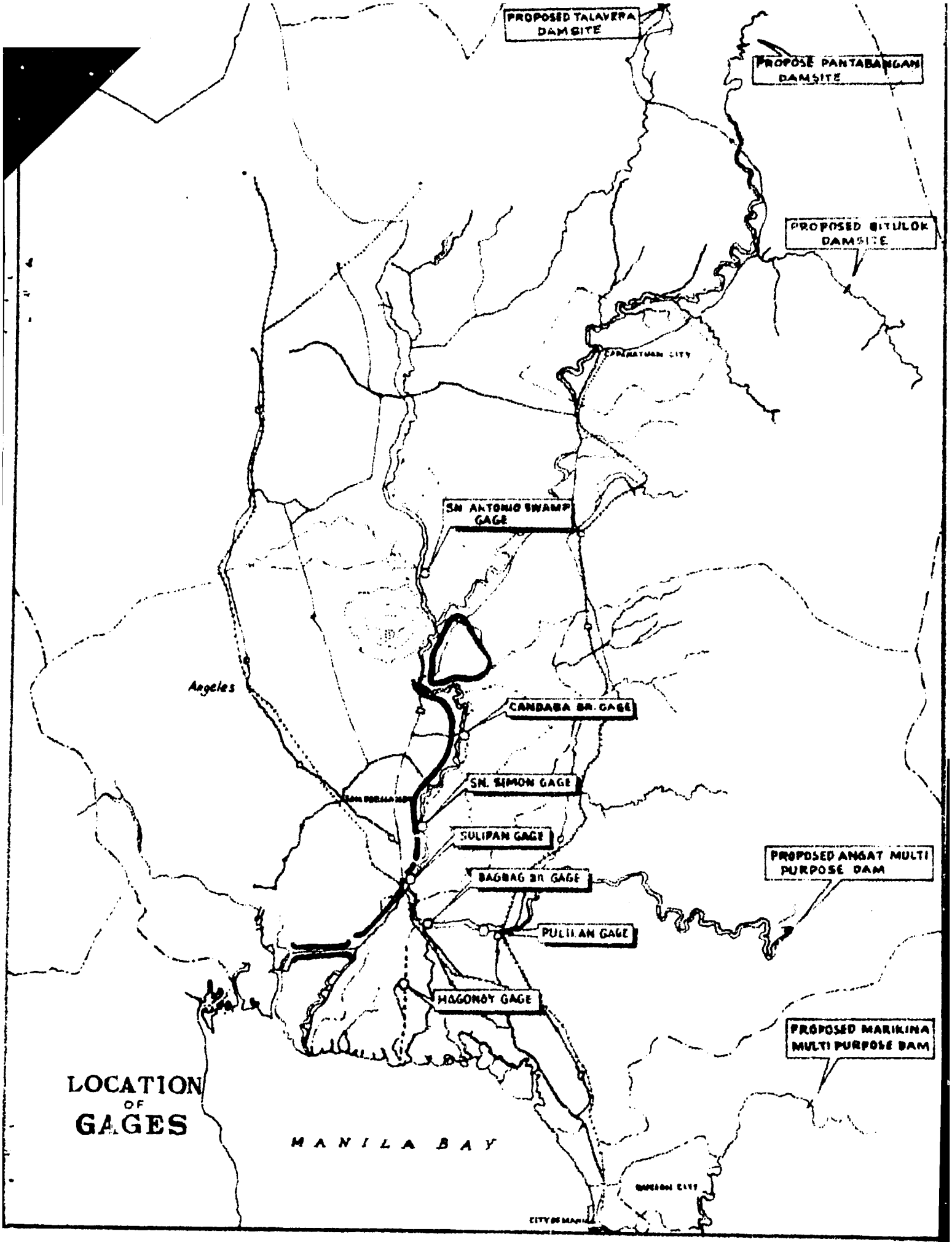
TRACED : E A SAMSON

B.P.W. APRIL, 196



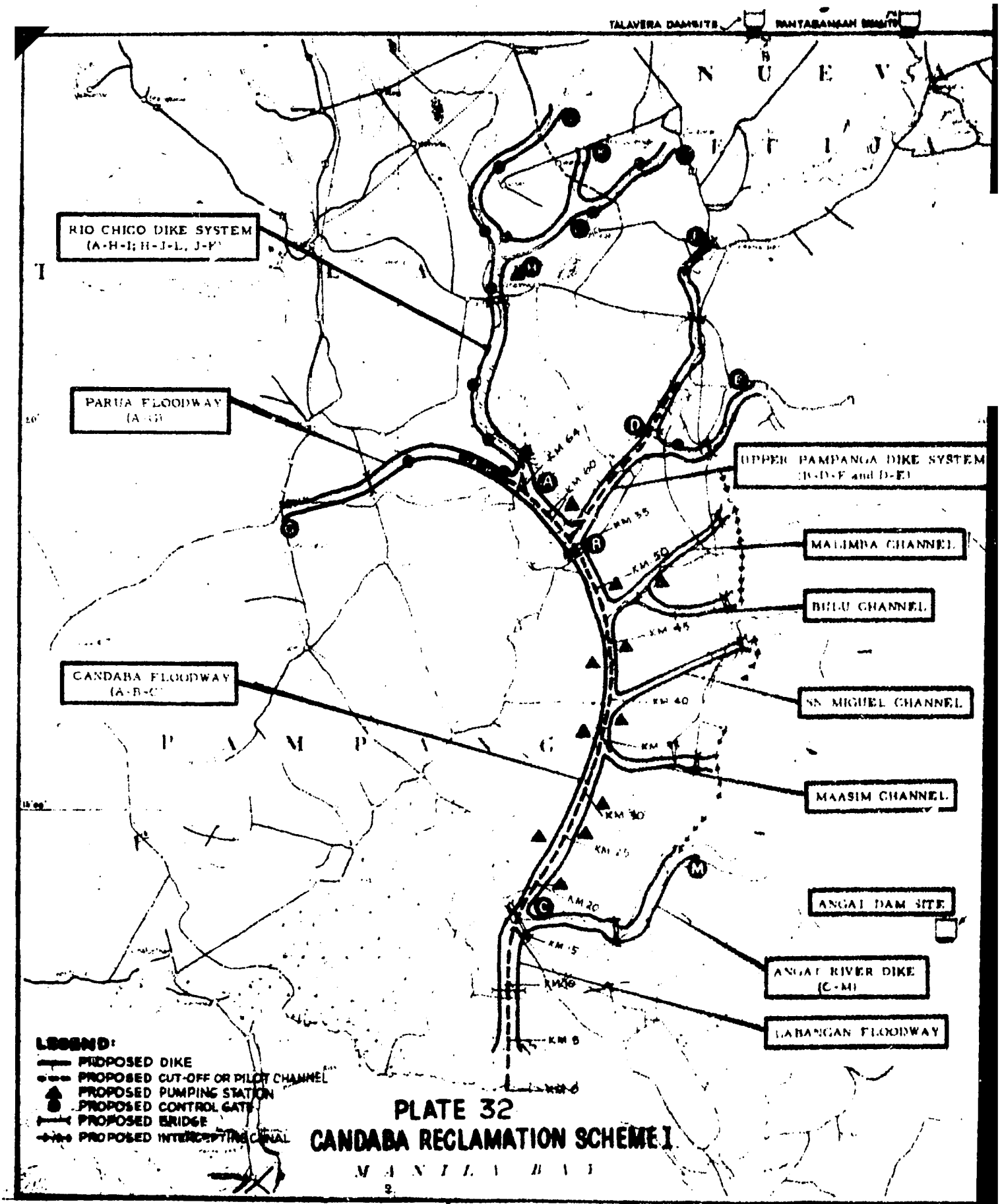
DRAWING No. USBR I
TO ACCOMPANY REPORT BY LARSON, GIBBS & GARDNER
DECEMBER 1962


PROFILES ALONG PAMPANGA RIVER
(FROM MANILA BAY TO ARAYAT BRIDGE)
1 TOP OF PROPOSED LEVEE
2 LEFT BANK FACING DOWNSTREAM FROM MANILA BAY TO ARAYAT BRIDGE
3 WATER SURFACE (MIDNIGHT, JULY 6)(1962)
4 DEEPEST PORTION OF CANDABA SWAMP FROM SAN FAN TO ARAYAT
5 DEEPEST PORTION (THALWEG)
6 GROUND SURFACE FROM MOUTH OF MANILA BAY TO SULIPAN BRIDGE
NOTE
ELEVATIONS ARE IN METERS BASED ON MSL DATUM PLANE
DRAWING No. USBR II
TO ACCOMPANY REPORT BY LARSON, DIBBLE AND GARDNER
DECEMBER 1962
TOP OF PROPOSED LEVEE
PROFILE ALONG LEFT BANK (FACING DOWNSTREAM) PAMPANGA RIVER
WATER SURFACE PROFILE (JULY 6,1962 MIDNIGHT)
PROFILE ALONG DEEPEST PORTION OF CANDABA SWAMP
PROFILE ALONG DEEPEST PORTION (THALWEG) PAMPANGA RIVER
GROUND SURFACE PROFILE
MOUTH OF MANILA BAY
SCALE
HOR. 1 to 50,000
VER. 1 to 100



DRAWING No. USBR III

TO ACCOMPANY REPORT BY LARSON, GIBBS & GARDNER


TALAVERA DAMSITE
RANTABANGAN DAMSITE
N U E V A
E C I J A
RIO CHICO DIKE SYSTEM
(A-H-I; H-J-L, J-P)
PARUA FLOODWAY
(A-G)
UPPER PAMPANGA DIKE SYSTEM
(D-D-F and D-E)
MALIMBA CHANNEL
BIELU CHANNEL
CANDABA FLOODWAY
(A-B-C)
SN. MIGUEL CHANNEL
MAASIM CHANNEL
ANGAT DAM SITE
ANGAT RIVER DIKE
(C-M)
LABANGAN FLOODWAY
P A M P A N G A
KM 64
KM 60
KM 55
KM 50
KM 45
KM 40
KM 30
KM 20
KM 15
KM 10
KM 5
KM 0
LEGEND:
PROPOSED DIKE
PROPOSED CUT-OFF OR PILOT CHANNEL
PROPOSED PUMPING STATION
PROPOSED CONTROL GATE
PROPOSED BRIDGE
PROPOSED INTERCEPTING CANAL
PLATE 32
CANDABA RECLAMATION SCHEME I
M A N I L A B A Y
SCALE 1:200,000
BUREAU OF PUBLIC WORKS

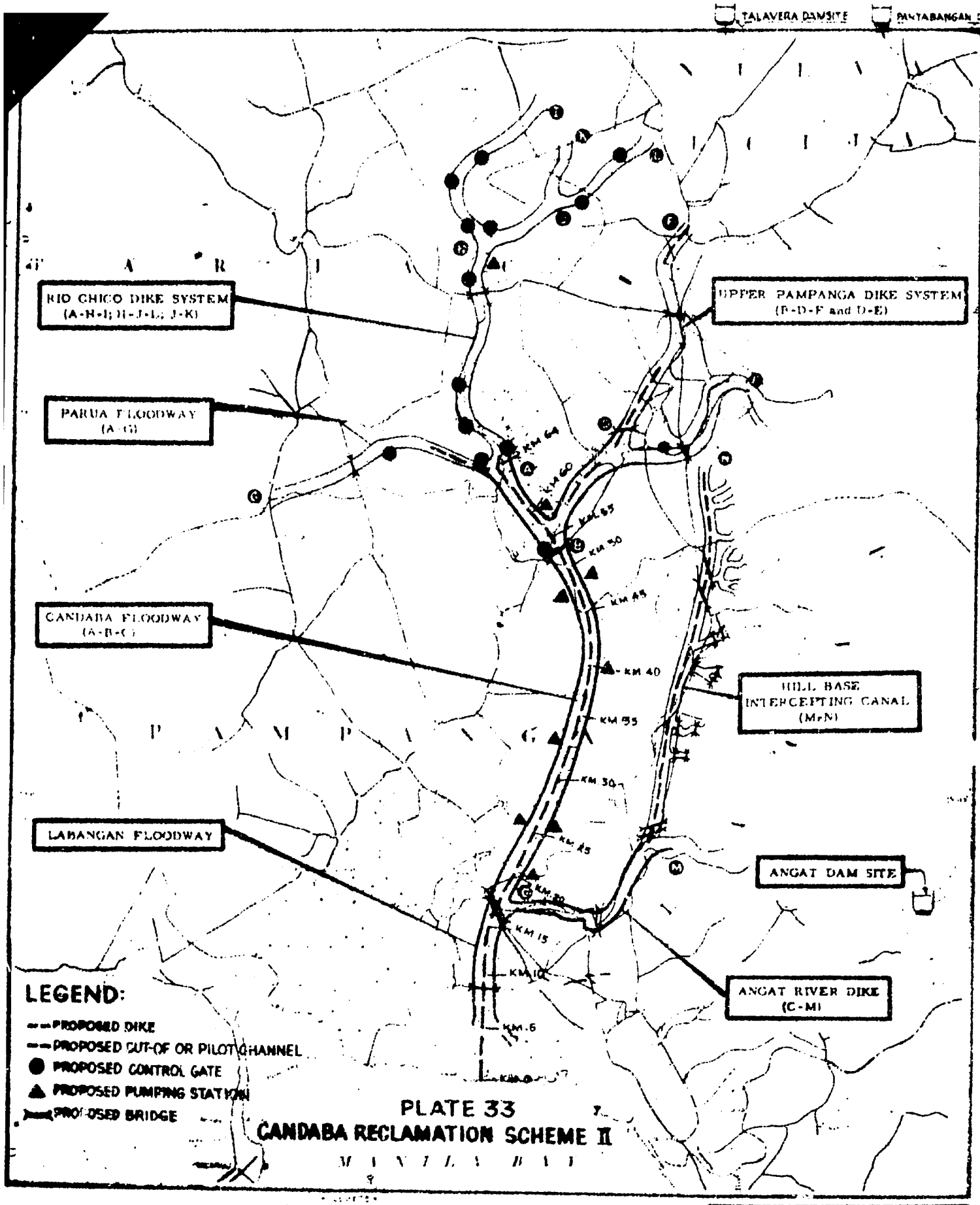


PLATE 33
CANDABA RECLAMATION SCHEME II

SCALE 1:200,000

BUREAU OF PUBLIC WORKS

FLOOD PLAIN OF THE PAMPANGA RIVER SYSTEM