INTERIM REPORT
for
THE FEASIBILITY SURVEY
of
THE STUNG CHINIT MULTI-PURPOSE PROJECT

(CAMBODIA)

December, 1968

Investigation Team
organized
by
Overseas Technical Cooperation Agency
Government of Japan

CONTENTS

I. Introduction

The first feasibility survey for the Stung Chinit multi-purpose project was carried out from February to May of 1968 in close cooperation with the Government of Cambodia and the Mekong Committee, and the first interim report was submitted to the Committee in July of 1968.

The second feasibility survey, the first in the rainy season, was conducted for one month from October to November of 1968 with the view of observing actual water and land use, farming and fishing.

The present second interim report has been written to report the additional studies on irrigation and power generation, analysis of the soil samples and the results of the rainy season survey in accordance with the plan of operation.

The third feasibility survey will start by the end of December of 1968, and the final report will be submitted to the Mekong Committee by the end of 1969.

II. General description of the project

The Stung Chinit is one of the major tributaries of the Lower Mekong Basin which flows down to the Tonle Sap. Its drainage area is about 4,130 km^2 at Kompong Thma with an annual rainfall of about 1,500 mm.

The reconnaissance report of the area of the Great Lake in 1967 pointed out that the Stung Chinit multi-purpose project was a most favorable project in the area. And it is also indicated that by constructing a 22 m high earth dam some 600 million cubic meters of stored water would be created at the water level of EL 36 m, and this reservoir could irrigate 40,000 ha and generate some 22 million KWH of power.

Out of the 40,000 ha the 23,000 ha of the existing paddy field could be stabilized for the rice production by a supplemental water supply during the rainy season and also could be introduced for the dry season cultivation by irrigation. The other 17,000 ha of presently non-cultivated area could be reclaimed. Some of experimental pilot farms to be established before or at the time of implementation of the project construction, will assist the farmers for the adequate agricultural techniques for farming.

The energy generated at the power station could be supplied to a big demand center: Kompong Cham which is about 60 km far from the damsite. Some of the energy would also be utilized for the nearby lift irrigation, town and villages of the power station.

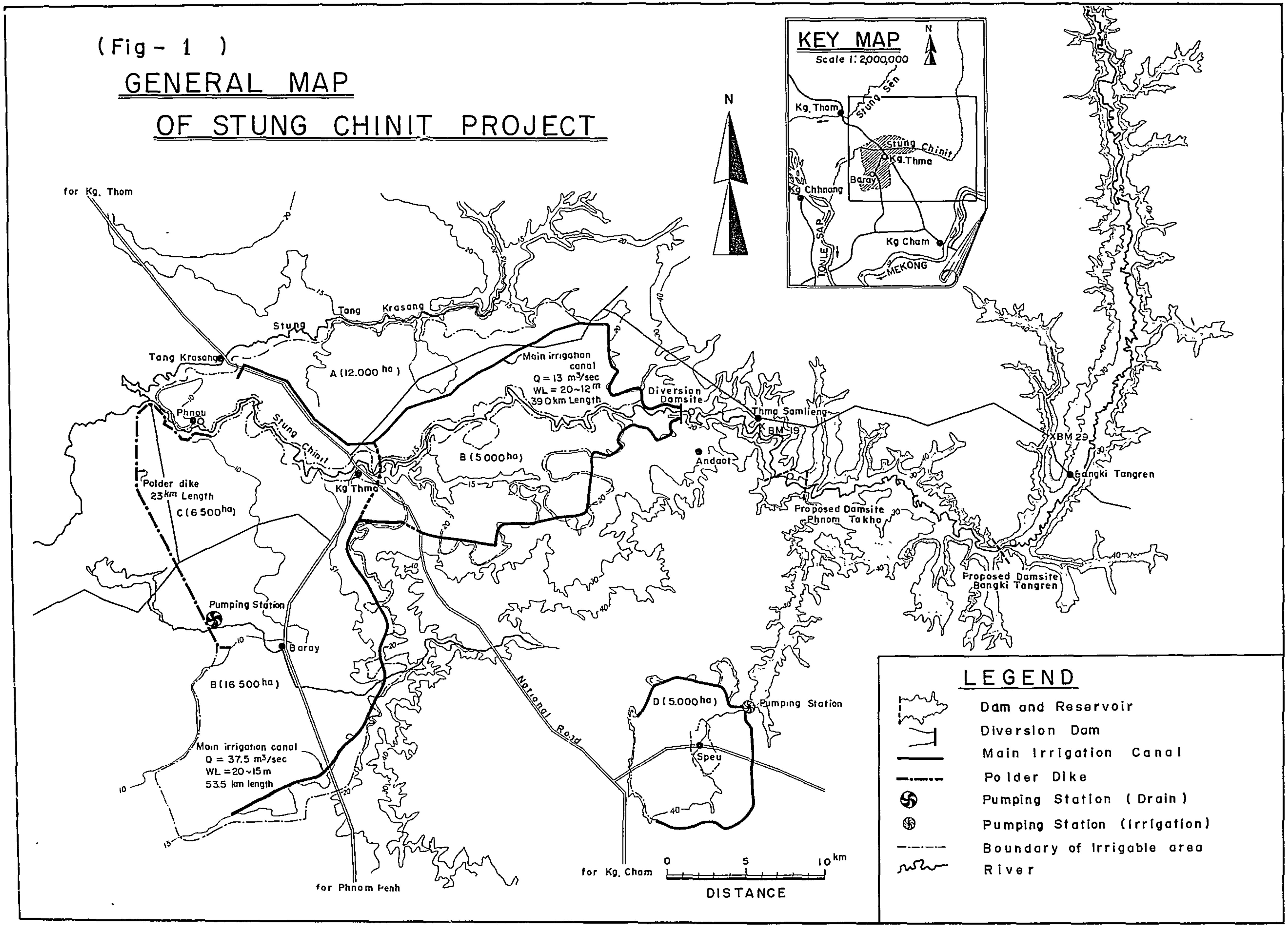
The floods of downstream of the damsite could be completely controlled and navigation, downstream and upstream of the project site, might be improved.

The reservoir would increase the fish output and create recreation facilities.

Many variations and stages of the project formulation have been studied. A result of the above is shown in the section III.

(Fig- 1)

GENERAL MAP OF STUNG CHINIT PROJECT



III. Formulation of the project plan

III-1. Irrigation

Irrigable area

The previous reconnaissance study of the area North of the Great Lake in 1967 suggested that an irrigation study for the area of 40,000 ha of the Stung Chinit should be made at the feasibility level. The 40,000 ha-area consists of a gravity irrigable area of 36,000 ha lying in the left bank and a lift irrigable area of 4,000 ha lying in the detached valley in the left bank.

As a result of the first feasibility investigation reported in June of 1968, the following area indicated in Table- 1 was selected tentatively as a proposed irrigable area. (refer to Fig- 1)

Table- 1 Irrigable Area

(unit in 1,000 ha)

Location	Project area	Irrigable area	Existing paddy field	Area to be reclaimed
(A) Right bank, Khet Kg. Thom EL 10 - 20 m	16,000	12,000	5,000	7,000
(B) Left bank, Khet Kg. Thom EL 10 - 20 m	27,000	21,500	17,000	4,500
(C) - ditto - EL 7 - 10 m	8,000	6,500	1,000	5,500
Total	51,000	40,000	23,000	17,000
(D) Valley of the left bank, Khet Kg. Cham EL 40 - 45 m	5,500	5,000	4,000	1,000

The sub-area (D) is adopted as an alternative area by reasons of its fertile soil, though pumping irrigation and drainage facilities are required. The sub-area (D) may alternate with the sub-area (C) according to the result of comparison of economic evaluation for each plan, because the (C) area also requires drainage pumping stations and polder dikes to introduce perennial farming.

In selecting the irrigable area, the project area is subdivided further into 6, that is, A_1, A_2, B_1, B_2, B_3, and C according to soil productivity mainly (see App. Table-11). The area A_1 of 3,400 ha is surrounded at the west of the national road No.6 by the Stung Taing Krasang, the Stung Chinit and the national road. The area A_2 of 8,600 ha spreads on the right bank side of the Stung Chnit, at the east of the national road, being surrounded with the Stung Taing Krasang and Stung Chinit. The area B_1 of 12,000 ha lying on the left bank side of the Stung Chinit consists of the Sandy Grayish Brown Soils and the B_2 of 4,800 ha of Verti Soils lies between the national road No.6 and No.7. The B_3 of 4,700 ha lies to the east of the national road No.6 on the left bank side of the Stung Chinit. The area C of 6,500 ha is an inundation area where is located between EL 7 m and 10 m.

This subdivision is made for the purpose of finding out alternatively a favolable combination of an irrigable area and a construction plan which will give a high benefit-cost ratio.

Isolated irrigation plan

The following 3 cases are considered as an alternative irrigation plan without power generation.

Case I;	40,000 ha	Sub-area (A), (B) and (C)
Case II;	21,000 ha	A_1, B_1 and Sub-area (C)
Case III;	11,500 ha	Sub-area (C) and a part of B_1

In this report no studies on sub-area (D) is made due to lack of information.

(Case I) This is a final stage of development of the Stung Chinit basin. The main dam has to be equiped with a storage capacity of 525 x $10^6 m^3$ in order to irrigate the project area of 40,000 ha throughout the year.

(Case II) In this case that 21,900 ha of the comparatively fertile area is selected among 40,000 ha, the main dam has to create a storage capacity of 265 x $10^6 m^3$.

(Case III) Out of 18,500 ha of Sub-area (B_1) and (C), 11,500 ha of the fertile area is selected as an irrigable area by constructing a diversion weir at 15 m-HWL without main dam.

The dam scale to be constructed for each case is as follows:

Table- 2 Dam scale for each case

Case	Net required capacity (10^6m^3)	Drawdown (m) Height	HWL	LWL	Crest EL (m)	Volume contents of dam (10^3m^3)
I	525	12.0	32.0 -	20.0	34.0	350
II	265	7.0	27.0 -	20.0	29.0	121
III	-	-	15.0	-	15.0	20

Note; As to net required capacity, refer to IV-3

The dam scale can be diminished in size by reducing the proposed arable area in the dry season. When the arable area in the dry season is reduced with the ratio of 80% and 60% to the whole irrigable area, dam scale in each case is shown in the following Table.

Table- 3 Dam scale for each case

Case	Net required capacity (10^6m^3)	Drawdown (m) Height	HWL	LWL	Crest EL (m)	Volume contents of dam (10^3m^3)
I-2	415	10.5	30.5	20.0	32.5	260
I-3	285	8.0	28.0	20.0	30.0	162
II-2	185	6.0	26.0	20.0	28.0	100
II-3	135	5.0	25.0	20.0	27.0	72

Note; Each case of I-2, II-2 indicates the dry season area, being equivalent to 80% of the total area, and I-3 and II-3 are equivalent to 60% of the total area

Among these alternative irrigation plans a favorable area shall be selected considering the benefit and cost corresponding to each area.

III-2. Project cost and benefit

1) Irrigation

The previous survey indicated that the area of 40,000 ha could be irrigated by constructing a dam equipped with a 600 x $10^6 m^3$ of the reservoir capacity. In this report subdivision of the area of 40,000 ha was made for the purpose of selecting an effective development plan.

The cost and benefit estimated below are tentative ones and are subject to revision. (As to the alternative irrigation plan, III-1 should be refered to)

Cost Project cost is estimated as described in the following Table-4 .

A terminal irrigation system is planned as to irrigate 20 ha at the end, and main canals are of earth lining. Land development works consist of reclamation and land consolidation works. Polder dike and pumping station are planned at the (C) area. One main dam and one diversion dam are to be constructed in case I and II, one diversion dam in case III. In miscellaneous cost engineering fee and contingency cost are included.

Table-4 Project cost

Item of works	Case I (40,000 ha)	Case II (21,900 ha)	Case III (11,500 ha)
1. Canal works	9,100	3,520	925
2. Land development	11,550	4,700	1,325
3. Polder, Pump station	2,840	2,840	2,840
4. Dam works	1,675	855	150
5. Miscellaneous	7,555	3,575	1,572
Total	32,720	15,490	6,812
6. Cost per ha ($/ha)	818	707	592

In 2 cases, I and II, the project is subdivided further into two alternative plans by changing the cropping intensity. (refer to III-1) Table-5 shows the cost of each plan.

Table-5 Cost

(in 10^3\$)

Item of works	Case I		Case II	
ci =	I-2 (180%)	I-3 (160%)	II-2 (180%)	II-3 (160%)
1. Canal works	8,240	7,290	3,240	2,940
2. Land development	11,550	11,550	4,700	4,700
3. Polder, Pump station	2,840	2,840	2,840	2,840
4. Dam works	1,315	935	625	485
5. Miscellaneous	7,185	6,785	3,425	3,295
Total	31,130	29,400	14,830	14,260
6. Cost per ha ($/ha)	778	735	677	651

Note; ci = cropping intensity

Benefit By introducing irrigation, fertilization, utilization of agricultural medicines, reclamation and so on, the following net benefit stated in Table-6 could be expected. (refer to IV-7 and App. Table-11)

Table-6 Benefit

	Case I			Case II			Case III
	I-1	I-2	I-3	II-1	II-2	II-3	
Area (10^3ha)	40	40	40	21.9	21.9	21.9	11.5
Total benefit (10^3\$)	3,651	3,142	2,632	2,149	1,859	1,570	892
Benefit per ha ($/ha)	91	79	66	98	85	72	78

Economic evaluation Economic analysis of the irrigation project is made tentatively by means of the benefit-cost ratio when an interest rate of 6% and 50 years of the period of analysis are considered.

Table-7 Benefit-cost ratio

Item		Case I	Case II	Case III
1. Project area	(ha)	40,000	21,000	11,500
2. Project cost				
Total cost	($10^3$$)	32,720	15,490	6,812
Unit cost	($/ha)	818	707	592
3. Project benefit				
Total benefit	($10^3$$)	3,651	2,149	892
Unit benefit	($/ha)	91	98	78
4. Benefit-cost ratio				
Annual cost*	($/ha)	72	63	55
Annual benefit**	($/ha)	78	84	66
Ratio		1.09	1.34	1.20

Note; * *Reduced to an equivalent annual amount by amortizing over the period of analysis.*

** *Reduced to an equivalent annual present worth assumed that full benefit increase uniformly for 5 years after completion of the project which may need 2 years.*

The order of priority is shown from case II, III to I from the standpoint of the benefit-cost ratio.

III-3. Power generation

A model study of hydropower generation was made up tentatively in the previous interim report of June 1968 according to the discharges proposed to be released for irrigation of 40,000 ha throughout the year from the reservoir, it was supposed that the minimum power production would be 1,000 kw and the maximum 5,000 kw. If the entire quantity of water released for irrigation (813 x $10^6 m^3$/year) is utilized for power generation, 22 million kwh would be generated. And the cost of power was assessed at 15 mills/kwh for 22 million kwh which was assumed to be consumed entirely.

For the above model the following question was risen by the Mekong Committee officials. That is, for nearly six months of rainy season in the year the power production is limited to 1,000 kw or 8.7 million kwh/year. Therefore, the entire 22 million kwh being consumed for general purposes does not seem to be in order. The secondary power available to the extent of about 13 million kwh cannot be utilized for any industry so far as the power is utilized for irrigation pumping from the month of December to April. Consequently, it might be recommendable to reduce the total cost of the power by reducing the capacity of installation and so on.

Then, the studies for many variation of project models in combination with power have been made to find out the formulation of the most economical project. The present study was based on the assumption stated below.

i) Power house is installed at immediatly downstream of the Phnom Takhor damsite proposed tentatively. Discharge water used for irrigation should be through the turbine and be regulated by the diversion dam. Power should be transmitted to Kompong Cham area, 60 km away to meet the growing demand for power in the area.

ii) It is aimed to regulate the annual river discharge as equal as possible in order to generate stable firm power to the greatest extent. To regulate completely some 330 million m^3 of the reservoir capacity with mean discharge of 25 cumecs is required in the droughty year which is selected as the duration of Dec. 1962 to Nov. 1963.

iii) Despite of the above item, the required discharge for irrigation, particularly in the dry season, should be prior to the regulation for power. These principles of the item ii) and iii) are considered in the Fig.-a and b which show the comprehensive discharge plan by means of differential mass curves in combination with six models of the irrigation plans.

iv) As a minimum water level of the reservoir an elevation of 20 m or dead capacity of about 80 million m^3 is considered. The elevation is similar to the water level of the diversion dam in the case I and equivalent to twice quantity of sediment* expected in 100 years. Subsequently, studies of the cases to raise minimum water level up more are also made in order to give a higher potential head for power generation.

v) Usable power delivered is estimated throughout the year basing upon the firm power or mean output, smaller one in the rainy season or dry season, without any secondary power. Installation power is designed as two times of annual mean output. For this the diversion dam is available to equalize the discharge water of average 12 hours by means of raising the water level up less than 50 cm. (The diversion dam of HWL 20 m has a reservoir area of 4.5 km^2 and another one of HWL 15 m has a 6.7 km^2)

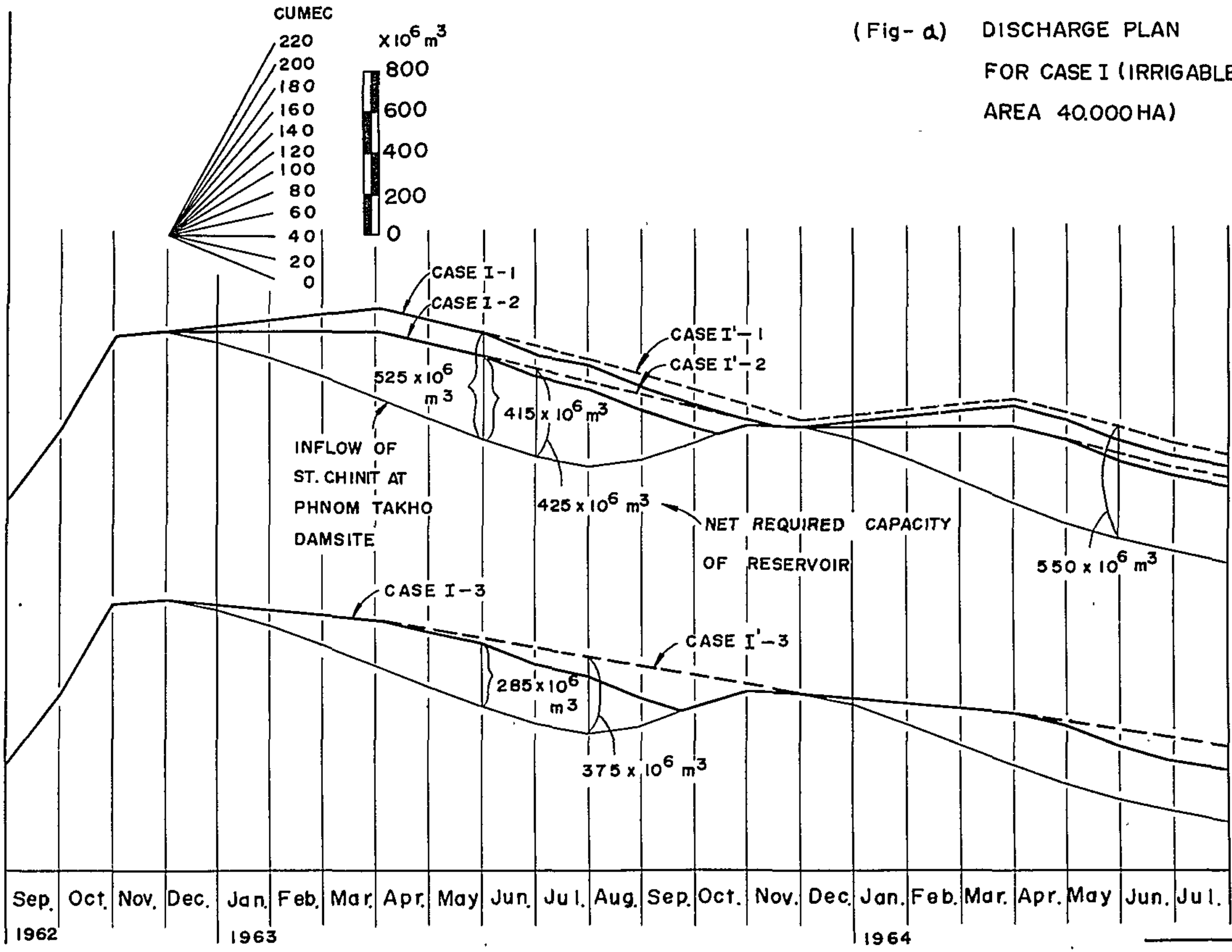
As a result of the studies shown in Fig.-c, d and Appendix I, annual mean outputs to be expected distribute widely at a range of 635 kw in case I'-1 to 2,590 kw in case II"-1. The lowest power cost is about 16 mill/kwh in case II'-1, II"-1, 2 and 19 mill/kwh in case I'-3 by providing some 500-600 million m^3 of the gross reservoir capacity for each case.

As to the benefit-cost ratio of power, the most high ratio of 1.7 can be seen in the case of power cost 16 mill/kwh, the ratio of 1.4 in the case of power cost 19 mill/kwh and the lowest 0.8 for the power cost 34 mill/kwh when the ratio is assessed by a ratio of the alternative power cost** (27 mill/kwh) to the computed cost.

* Assumed to have been made in accordance with sediment concentration of 300 p.p.m. for the St. Chinit in average.

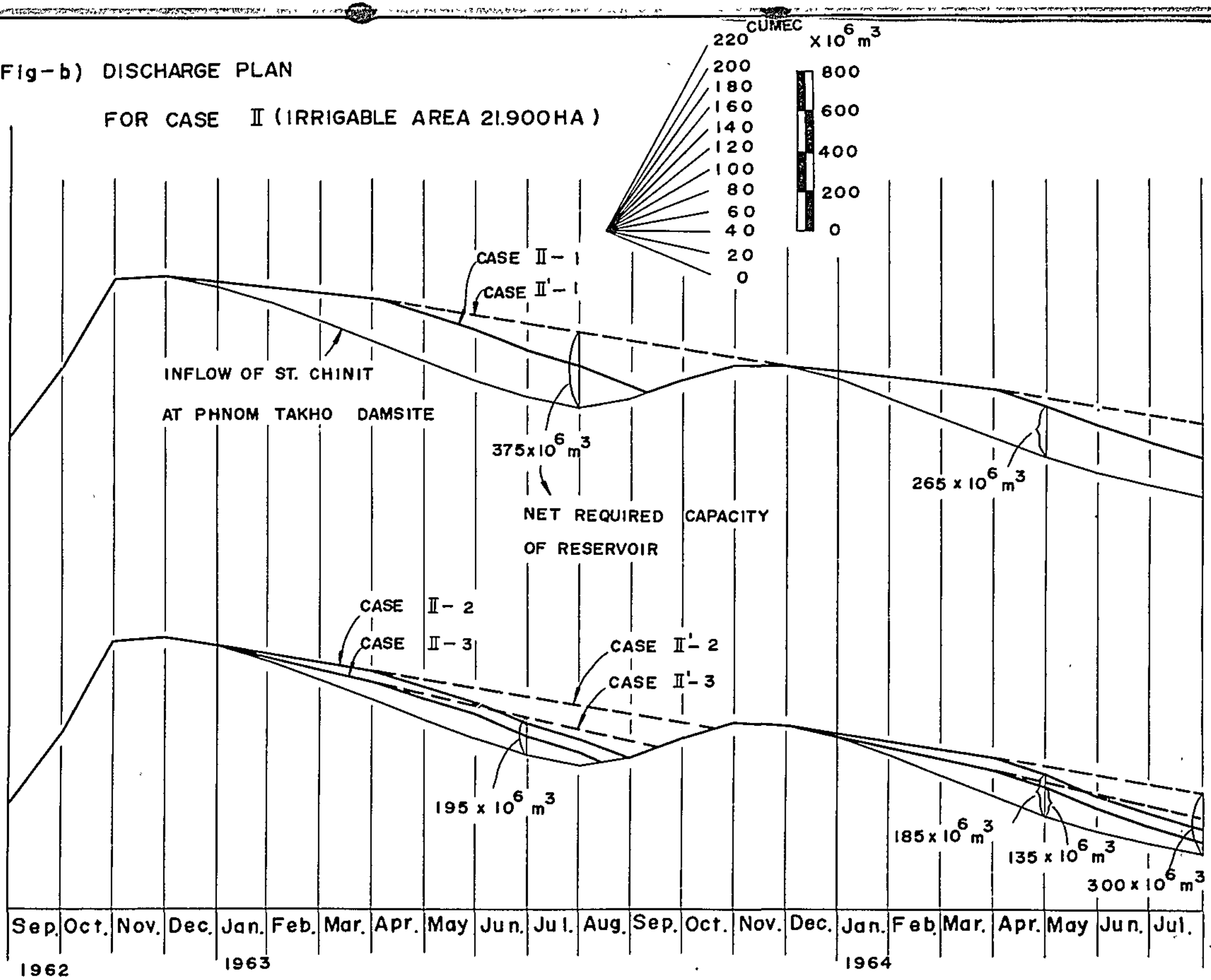
** Steam power cost in Phnom-Penh. Refer to previous interim report, June 1968, page 34.

(Fig- d) DISCHARGE PLAN FOR CASE I (IRRIGABLE AREA 40.000 HA)



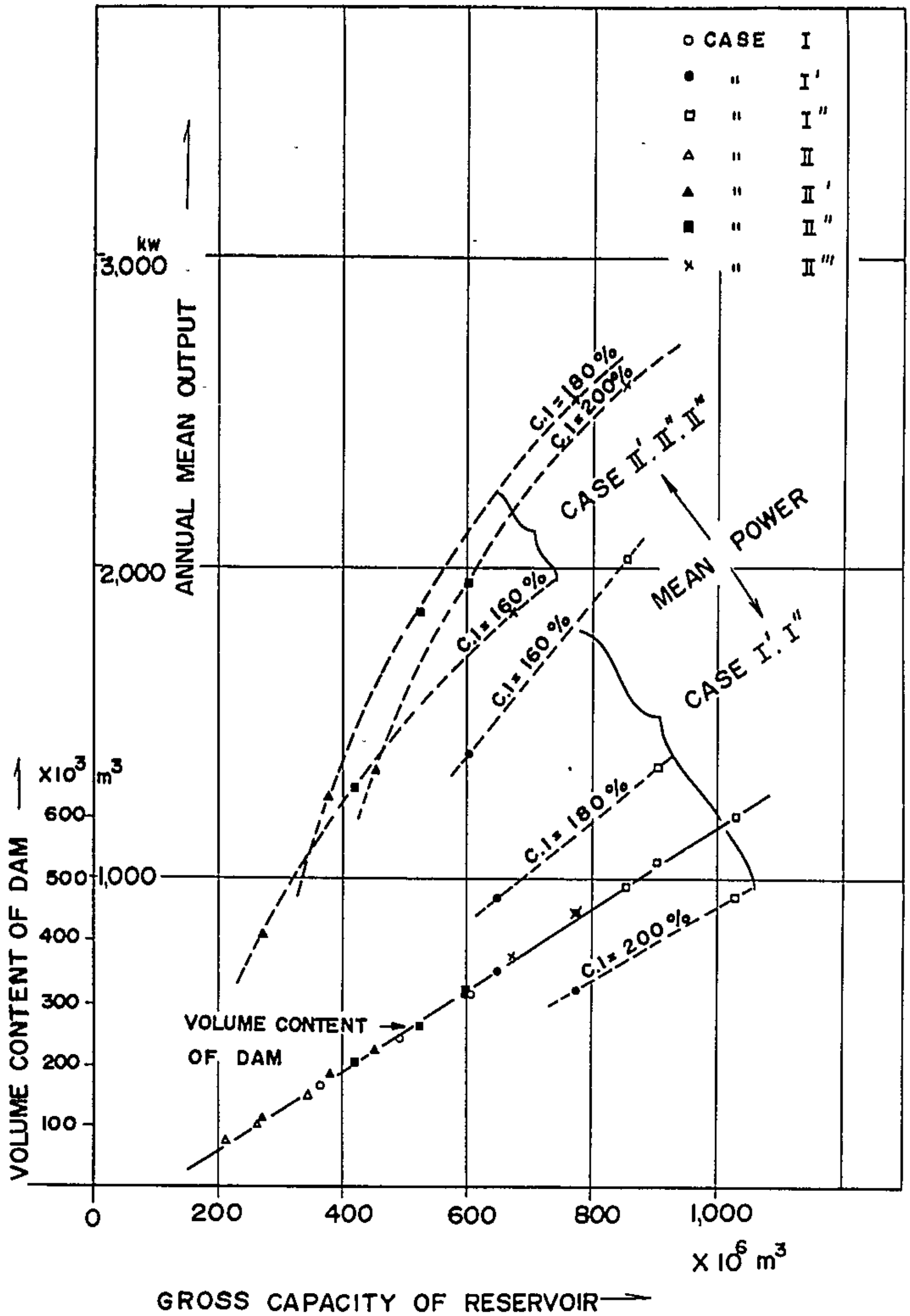
(Fig-b) DISCHARGE PLAN

FOR CASE II (IRRIGABLE AREA 21.900 HA)



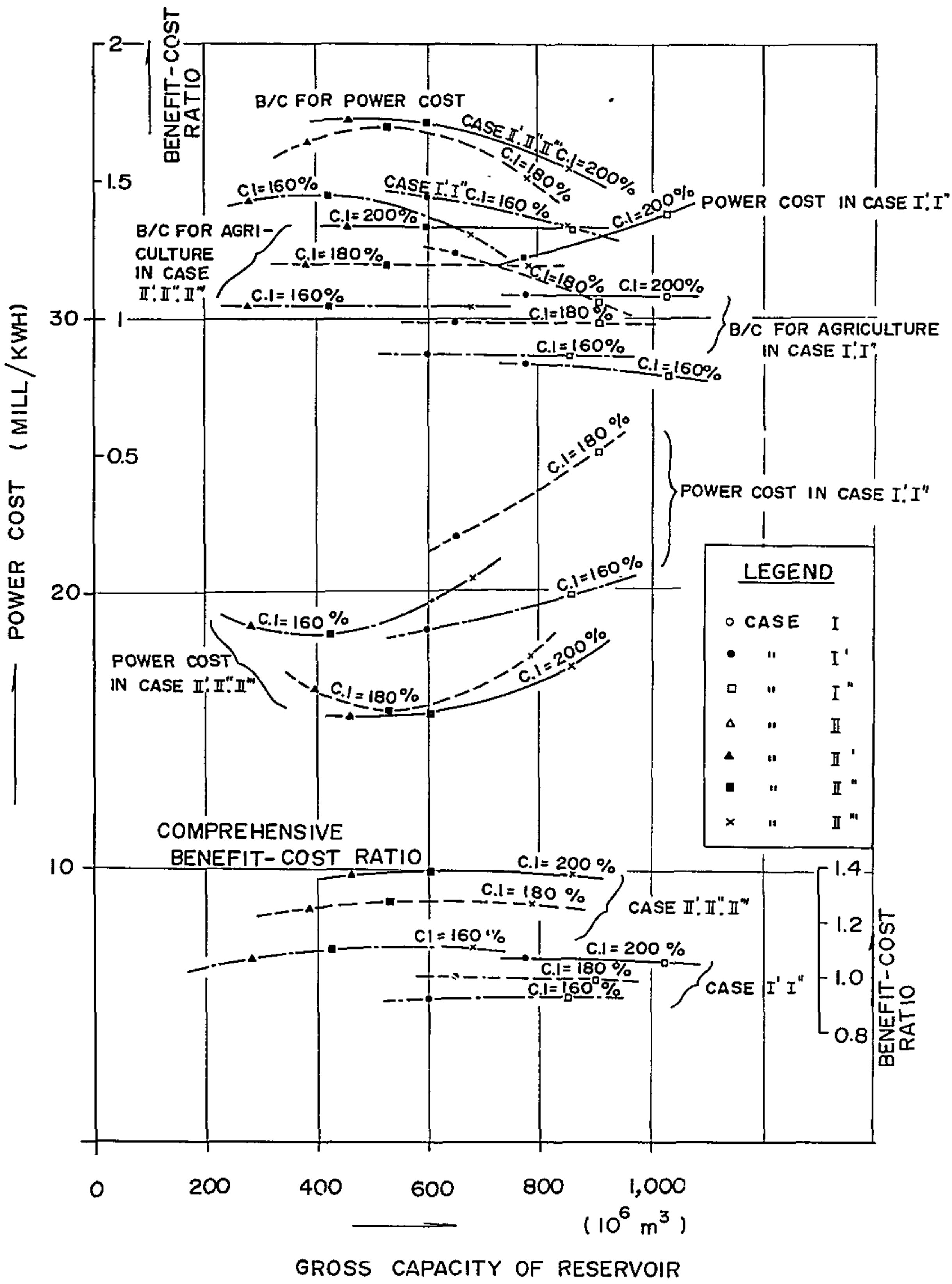
(Fig - C)

DAM CAPACITY AND MEAD OUTPUT OF POWER



(Fig— d)

POWER COST AND BENEFIT-COST RATIO



III-4. Tentative conclusion

1) The study on formulation of the project has been made in combination with irrigation and power as mentioned in this section III. As far as can be seen in the table-a, the cases of II'-1, 2 and II''-1, 2 seem to be most favourable, i.e. the combination of the irrigable area 21,900 ha in the rainy season and 100-80% of the area in the dry season by providing some 400-600 million m^3 of the reservoir with power plant bring the most high benefit-cost ratio synthetically and the lowest power cost. For the above the height of main dam is required to be only 17.5 m (EL. 14.0 m - El. 31.5 m) in maximum.

2) However, it may also be said that there are still many unknown or uncertain factors in regard of topography of the damsite, anticipated power demand, more reliable agricultural benefit in future, financial condition and so on. Furthermore, there is a paradox that if the area, which is being divided into the smaller sub-sections, were chosen according to the higher benefit-cost ratio, the bigger scale of the area could not be developed in final. In the above point of view, a standard like a comprehensive benefit-cost ratio of 1.0 would be necessarily considered to form the project. The case I' and others having irrigable area of 40,000 ha might also be promising.

One of difficulty from the view of development stages for irrigation and power is that it is possible to develop the area 21,900 ha by means of commencement of the case III, but it may be impossible to develop the 40,000 ha from the 21,900 ha without reducing the power generation. For which some other formulation like providing two diversion dams or direct intake from dam or pumping station and smaller installation of power would be studied.

3) The study in combination with irrigation and power was made with assumption of the main and diversion reservoirs for the isolated irrigation purpose. But the futher study of the case assuming the facilities for the isolated power generation should also be made in order to allocate the project cost by using the separable cost-remaining benefits method.

4) As for the formulation of the fishery and navigation development, the study is undergoing. However, they seem to be rather characterized as involving the compensatory schemes.

Table-a Comparison of Project Formulation with Various Cases

	Max. irri- gation area ha	Instal- lation power kw	Max. W.L. in main dam m	Total cost/ha $/ha	B/C ratio in agri- culture	B/C ratio in power	B/C ratio synthetic	Power cost mill/kwh
I-1	40,000	-	31.5	818	1.09	-	1.09	-
I-2	"	-	30.0	778	0.99	-	0.99	-
I-3	"	-	28.0	735	0.87	-	0.87	-
I'-1	"	1,270	33.5	870	1.09	0.84	1.07	32.2
I'-2	"	1,880	32.0	833	0.99	1.22	1.00	22.1
I'-3	"	2,800	31.5	803	0.87	1.44	0.92	18.7
I"-1	"	1,880	35.5	900	1.09	0.80	1.06	33.9
I"-2	"	2,720	34.5	868	0.99	1.07	0.99	25.2
I"-3	"	4,060	34.0	843	0.87	1.35	0.93	20.0
II-1	21,900	-	27.5	707	1.34	-	1.34	-
II-2	"	-	26.0	677	1.20	-	1.20	-
II-3	"	-	25.0	651	1.05	-	1.05	-
II'-1	"	2,700	29.5	808	1.34	1.73	1.38	15.6
II'-2	"	2,520	28.5	776	1.20	1.63	1.26	16.6
II'-3	"	1,630	26.5	726	1.05	1.43	1.08	18.9
II"-1	"	3,900	31.5	854	1.34	1.72	1.39	15.7
II"-2	"	3,720	30.5	817	1.20	1.70	1.28	15.8
II"-3	"	2,580	29.0	767	1.05	1.45	1.11	18.6
II‴-1	"	5,180	34.0	922	1.34	1.55	1.38	17.4
II‴-2	"	5,100	33.5	894	1.20	1.52	1.27	17.8
II‴-3	"	3,700	32.5	835	1.05	1.31	1.11	20.6

IV. Progress of the investigation

IV-1. Survey and mapping

Two kinds of maps, published by the Service Géographique Khmer, whose scale are 1:50,000 and 1:250,000, were available for the investigation.

Four possible damsites were selected and the cross section of the Stung Chinit at each damsite was surveyed. As a result of the leveling survey to connect each damsite with the existing bench marks, a little difference in ground elevation was in the map of 1:50,000.

A checking survey for the proposed reservoir basin will be started from January of 1969 in order to confirm the capacity of the reservoir. This checking survey will be carried out by means of photogrammetry, which needs a topographic control surveying in the basin.

A survey of one main damsite and diversion damsite will be done from January of 1969 to make maps of 1:2,000 with 1 m interval of contour line.

The ground control survey for mapping of the project area of about 800 km^2 is being undertaken by the Service Géographique Khmer and 90% of the field works, 302 km to 337 km to be surveyed, was finished as of October 1968. The rest of 35 km^2 is due to a flood of the Stung Taing Krasang, a tributary of the Stung Chinit, and shall be finished by the end of the dry season of 1968. Room work concerning the ground control survey is also being undertaken. The ground control work is expected to complete by the end of January of 1969, concequently the mapping work will be begun from February of 1969.

IV-2. Study on damsite

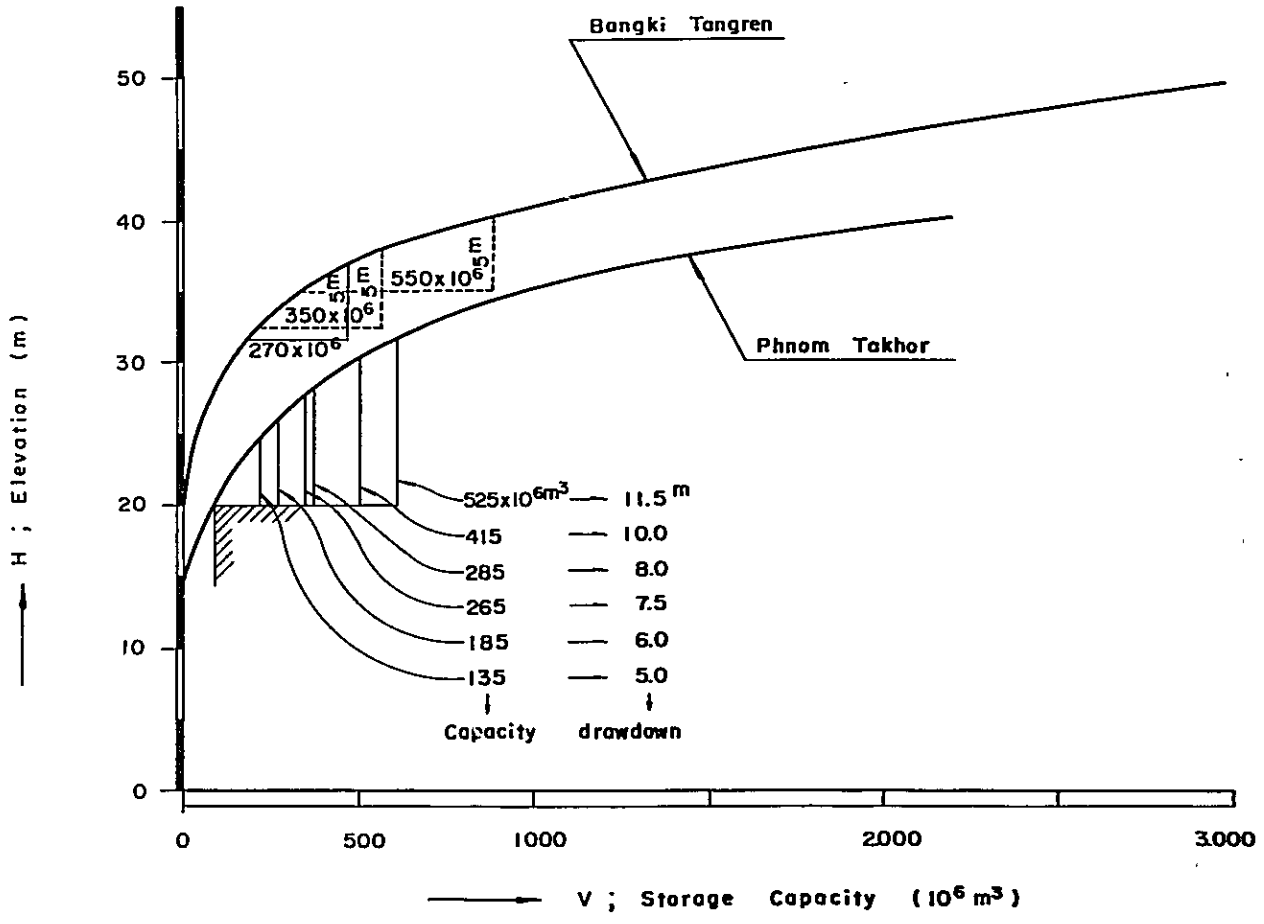
Four possible damsites, three main dams and one diversion dam, were chosen after a topographic study using a stereoscope and aerial photographs had been made.

Out of three possible main damsites two, Bangki Tangren and Phnom Takho, are selected requiring the proposed damsites which have an enough capacity to irrigate 40,000* ha, as 520 x $10^6 m^3$ of the irrigation water. (concerning the irrigation water, see IV-3).

* This area is the maximum one among alternative plans, but subject to change in a further study.

(Fig.- 2)

H-V RATING CURVE



One main damsite will be selected finally between the Bangki Tangren and Phnom Takho proposed damsite from the geologic and constructive points of view after a geologic survey to be carried out from January of 1969.

IV-3. Study on irrigation

Water requirement Observations of water consumption in the existing paddy field are being made from the end of September of 1968 at 8 stations, which are installed at such four typical soil grounds as gray, sandy, loamy and clayey. (see Fig. 8)

Each station consists of 3 drum cans, of which 1 with paddy rice plant, is bottomless 1 with paddy rice plant is bottomed and the rest with no paddy rice plant is also bottomless. By comparing the consumed value of each drum can, the water consuption use shall be separated into percolation, evaporation and evapotranspiration.

In this interim report the following unit water requirement* is assumed for irrigation study.

	Rainy	Dry
Paddy	(4.8 + 1.0)/(1 - 0.25) = 7.7 mm/day = 0.89 m/sec/1,000 ha	(6.7 + 2.0)/(1 - 0.25) = 11.6 mm/day = 1.34 m/sec/1,000 ha
Upland farm	3.0/(1 - 0.25) x 0.7 = 5.7 mm/day = 0.66 m^3/sec/1,000 ha	4.5/(1 - 0.25) x 0.7 = 8.6 mm/day = 0.99 m^3/sec/1,000 ha

Water balance Table-8 shows an operation plan of the Phnom Takho reservoir in case of 40,000 ha irrigation. Also Table-10 indicates the effective rainfall for irrigation as an example of a fairly drought year.

* 4.8 mm in the rainy season and 6.7 mm in the dry season are daily evapotranspiration computed with the Blaney-Criddle formula.
1.0 mm in the rainy season and 2.0 mm are assumed daily percoration.
(1 - 0.25) = irrigation efficiency

Table-8 Water balance sheet of the Phnom Takho reservoir (40,000 ha, Cropping intesity 200%)

Month	Year	Season	Net available runoff at damsite[1] (10^6m^3)	Discharge		Storage at the end of month[4] (10^6m^3)
				Irrigation[2] (10^6m^3)	Non-available[3] (10^6m^3)	
Sep.	1962	Wet	449.9	-		525
Oct.	"	"	566.6	55.6	511.0	525
Nov.	"	Dry	122.5	46.4	76.1	525
Dec.	"	"	56.5	131.6		449.9
Jan.	1963	"	28.9	131.6		347.2
Feb.	"	"	9.0	131.6		229.6
Mar.	"	"	3.7	131.6		96.7
Apr.	"	"	-4.2	46.4		46.1
May	"	Wet	8.0	49.6		4.5
Jun.	"	"	21.9	-		26.4
Jul.	"	"	56.2	50.0		32.6
Aug.	"	"	137.6	-		170.2
Sep.	"	"	187.1	17.2		340.1
Oct.	"	"	181.8	29.6		492.3
Nov.	"	Dry	94.5	16.0	45.8	525.0
Dec.	"	"	49.4	131.6		442.8
Jan.	1964	"	8.8	131.6		320.0
Feb.	"	"	1.0	131.6		189.4
Mar.	"	"	-4.6	131.6		53.2
Apr.	"	"	-1.1	46.4		5.7
May	"	Wet	29.7	1.6		33.8
Jun.	"	"	47.8	32.4		49.2
Jul.	"	"	50.9	52.0		48.1

Note. 1) *Calculated by the ratio of drainage area 3,600/4,130 basing on the discharge record at Kg. Thma. Evaporation from the water surface of the reservoir was also considered.*

2) *Refer to the computation sheet "Net irrigation water". (Table*

3) *Amount of the overflow at the dam.*

4) *Summation of (1) - 2))*
The storage capacity 525 x 10^6m^3 with a 12 m drawdown from EL 32 to 20 was assumed.

5) *The net capacity to be stored is about 520 x 10^6m^3 (=(600-55.7)x10^6)*

Table-9 Net irrigation water
(40,000 ha, cropping intensity 200%)

Month & season		Rainfall[1] (mm)	Available[2] rainfall (mm)	Water re-[3] qurement (mm)	Net irrigation water[4] (mm)	($10^6 m^3$)	(m^3/sec)
(1962)							
Sep.	W	436	327	231	-	-	-
Oct.	"	123	92	231	139	55.6	21.4
Nov.	"	47	-	116	116	46.4	17.9
Dec.	D	4	-	329	329	131.6	50.8
(1963)							
Jan.	D	-	-	329	329	131.6	50.8
Feb.	"	-	-	329	329	131.6	50.8
Mar.	"	50	-	329	329	131.6	50.8
Apr.	W	5	-	116	116	46.4	17.9
May	"	143	107	231	124	49.6	19.1
Jun.	"	325	244	231	-	-	-
Jul.	"	141	106	231	125	50.0	19.3
Aug.	"	323	242	231	-	-	-
Sep.	"	250	188	231	43	17.2	6.6
Oct.	"	209	157	231	74	29.6	11.4
Nov.	"	101	76	116	40	16.0	6.2
Dec.	D	-	-	329	329	131.6	50.8
(1964)							
Jan.	"	-	-	329	329	131.6	50.8
Feb.	"	-	-	329	329	131.6	50.8
Mar.	"	-	-	329	329	131.6	50.8
Apr.	W	40	-	116	116	46.4	17.9
May	"	303	227	231	4	1.6	0.6
Jun.	"	200	150	231	81	32.4	12.5
Jul.	"	134	101	231	130	52.0	20.1

Note. 1) Observed at Baray.

2) 75% of monthly rainfall is consumed as available and less than 50 mm per month is unabailable for irrigation

3) Computed with Blaney-Criddle formula, 1.34 m^3/sec/ha in the dry season, 0.99 m^3/sec/1,000 ha in the rainy season.

IV-4. Meteorologic and Hydrologic observation

Meteorology Eight rain gauges, i.e. three recording and five pot gauges, were used continuously from May to October of 1968 (refer to Fig. 5)

The rainfall observed during the rainy season of 1968 at each station is shown in Table-10

Table-10 Monthly rainfall in 1968

(in mm)

Name of Station	May	June.	Jul.	Aug.	Sep.	Oct.	Total
Krayea	126.5	129.5	119.0	207.5	207.0	190.5	980.0
Loak	126.5	194.0	57.0	164.5	162.5	140.0	844.5
Phnou	134.0	161.0	97.0	135.5	174.5	207.5	909.5
Krava	63.8	242.7	111.0	181.7	189.0	170.4	958.6
Baray	184.5	168.0	74.5	237.5	249.0	243.0	1,156.5
Speu	187.8	150.5	95.5	208.0	157.5	176.0	975.3
Mean	137.5	174.6	92.5	189.5	190.3	188.3	972.7
Bangki Tangren	135.0	348.0	133.0	237.0	228.0	276.0	1,357.0
Roneam	164.0	189.5	218.4	268.6	245.2	---	---

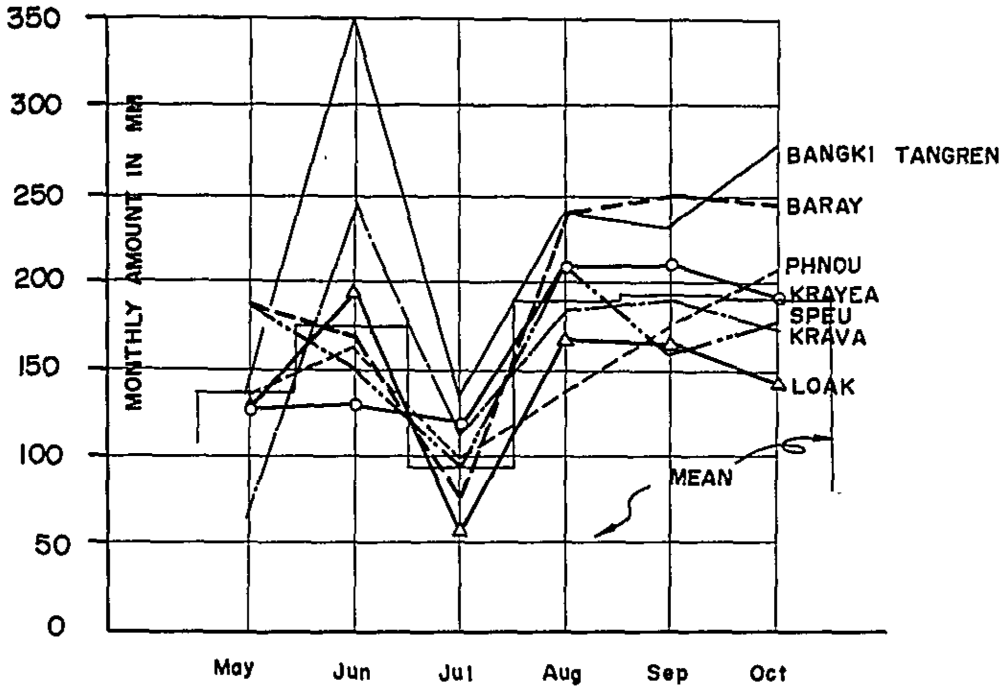
A mean value of 972.7 mm may stand for the annual rainfall of the project area in 1968. However, Bangki Tangren is located in a forest land and has a lot of rainfall, therefore this station is excluded from the mean value.

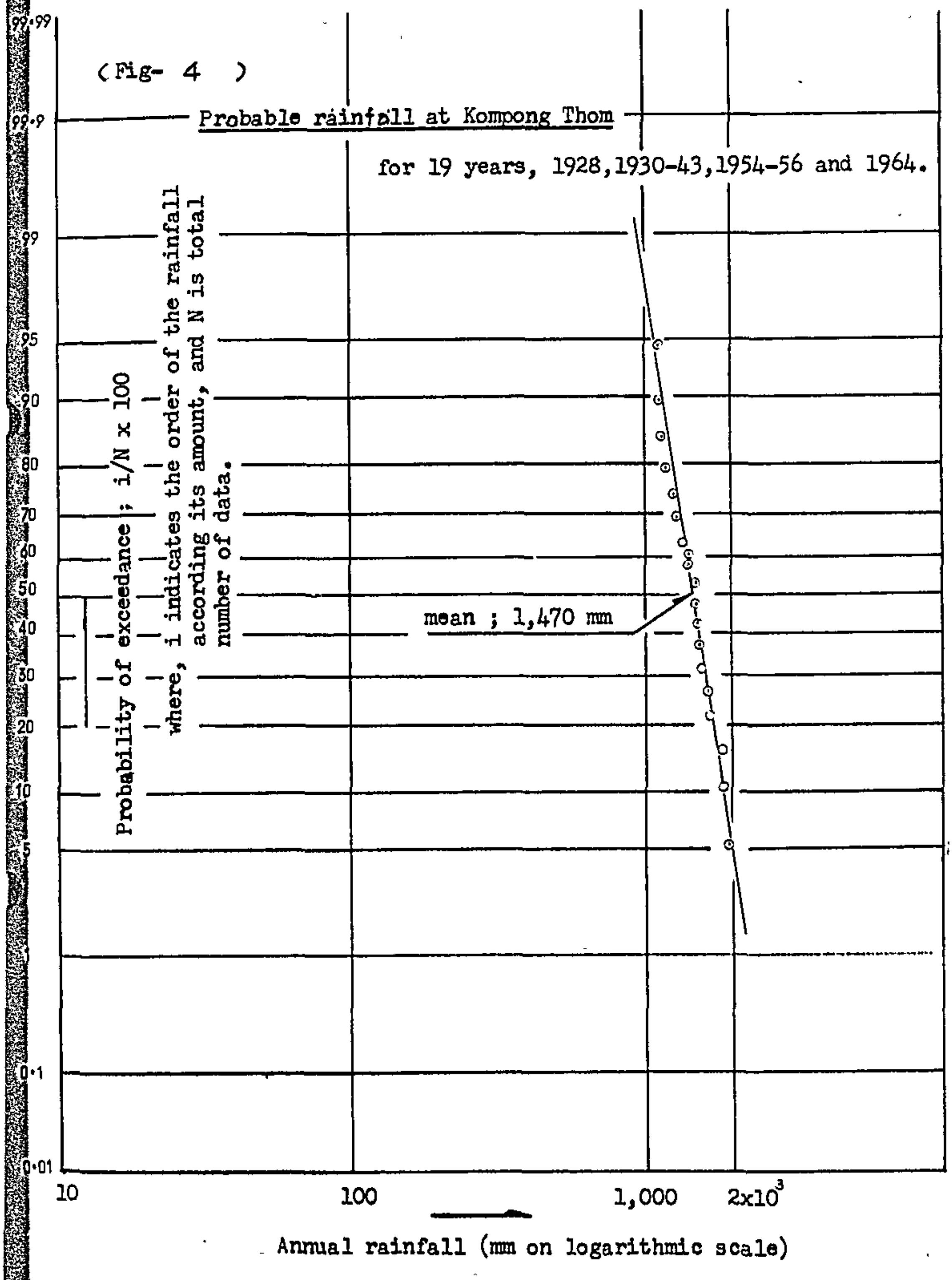
Comparing the rainfall of 972.7 mm with records at Kompong Thom, it is found possibly to regard this year as a considerable drought.

Such caracteristics of the rainfall as distribution, monthly concentration, the length of the rainy period and so on will affect the farming as well as the amount of rainfall. The rainfall of this year is little in total amount, and especially little in July. The monthly rainfall of each station is shown in Fig. 3.

(Fig- 3)

MONTHLY VARIATION OF RAINFALL (1968)

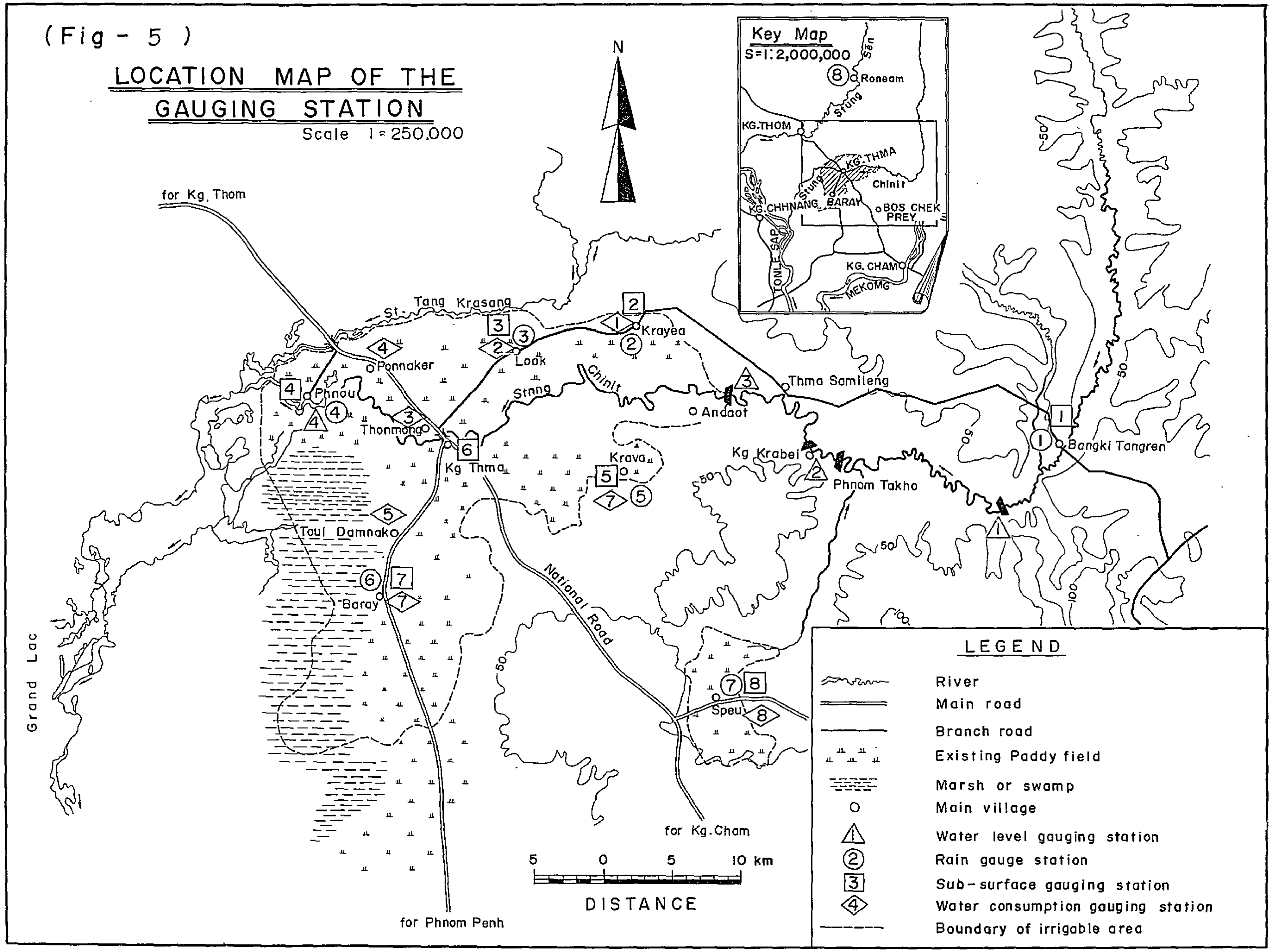



(Fig- 4)
Probable rainfall at Kompong Thom
for 19 years, 1928,1930-43,1954-56 and 1964.
Probability of exceedance ; i/N x 100
where, i indicates the order of the rainfall according its amount, and N is total number of data.
mean ; 1,470 mm
99.99
99.9
99
95
90
80
70
60
50
40
30
20
10
5
0.1
0.01
10
100
1,000
2x10³
Annual rainfall (mm on logarithmic scale)

(Fig - 5)

LOCATION MAP OF THE GAUGING STATION

Scale 1 = 250,000



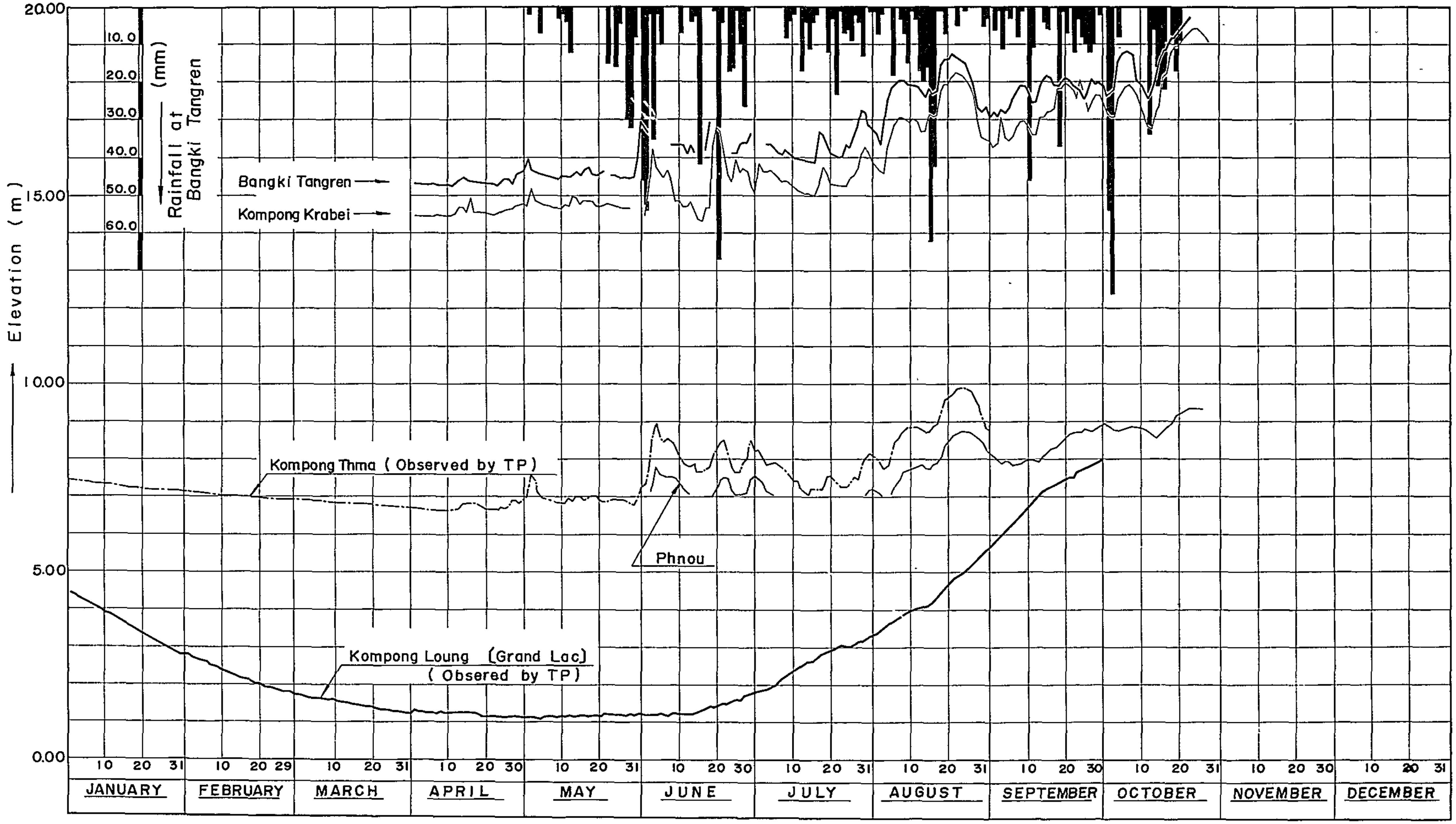
(Fig- 6)

Hydrograph of the Stung Chinit and Grand Lac

CAMBODIA

Station ____________ ____________ River, in the Basin of Tonle Sap

YEAR. 1968



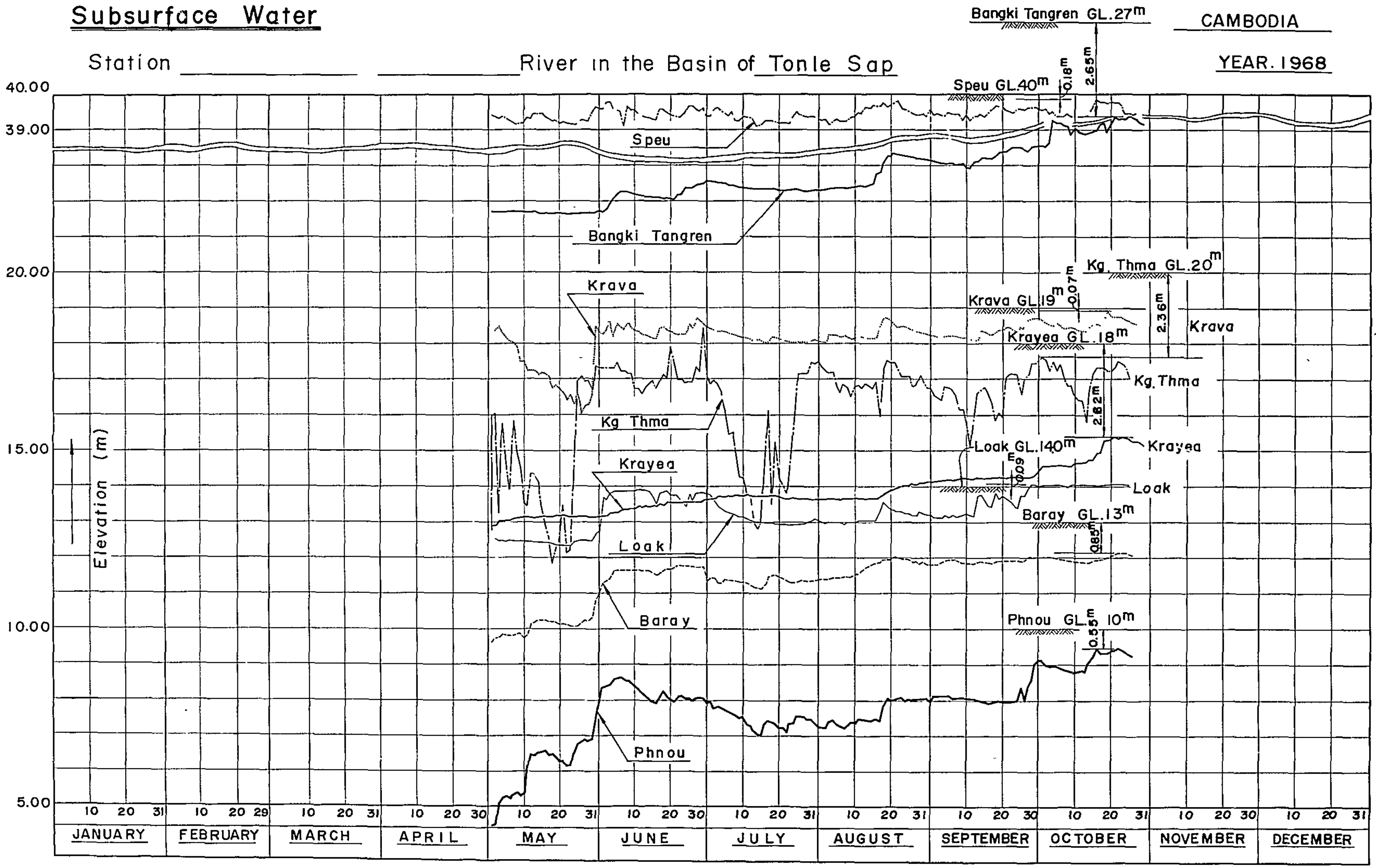
(Fig - 7)

Subsurface Water

Station ______________ ______________ River in the Basin of Tonle Sap

CAMBODIA

YEAR. 1968



Hydrology Four gauging stations for observing the water level of the Stung Chinit were installed, of which two water-level recorders were at the Bangki Tangren proposed damsite and the Kompong Krabei proposed damsite, the rest of two staff gauges were at the diversion damsite and Phnou. The observations are being continued from May of 1968 and the hydrograph recorded until October is described in Fig.6.

A maximum high-water level at Kompong Krabei was observed on 24th of October, which seemes to be about 2 m lower than that of the usual year because of shortage of the rainfall. No inundation from the Stung Chinit was observed over the project area located to the upstream of the national road.

Those observation are much useful for determing discharge and analyzing runoff.

Observation of the subsurface water is being carried out at eight stations using the existing wells. A variation of the subsurface water level during the rainy season is described in Fig.7.

IV-5. Geologic survey

As the result of the geologic and topographic survey conducted in April of 1968, two possible main damsites and one diversion damsite were proposed as suitable.

A further geologic survey for the proposed damsites has been planned to be undertaken from January of 1969 in order to reveal their geologic structures and distribution and also to analyze a property for base rock and construction materials.

This geologic survey is summarized as follows:

Table-11 Geologic survey plan for damsite

Works item \ Site	Bangki Tangren dam	Phnom Takho dam	Diversion dam	Total
Seismic survey	2,880	4,320	1,680	8,880 km
Drilling	110	190	60	360 m
Penetration test	50	80	60	190 times
Permeability test	11	26	11	48 "
Soil mechanic test	2	4	3	9 samples
Test pit	-	10	-	10 spots
Embankment materials	-	23	-	23 samples

Results of the seismic survey mentioned above shall be analyzed at the field and the final location of the main damsite shall be decided.

IV-6. Soil survey

The soil of this project area was classified into the following four soil types and nine soil series as the result of the previous report.

1. Alluvial soils
2. Gray soils
3. Graish brown soils (Sandy)
4. dittos (Loamy)
5. dittos (Clayey - fine)
6. dittos (Clayey - very fine)
7. Verti soils (Normal)
8. dittos (Shallow)
9. dittos (Hydromorphics)

After making an ensuing study, it was pointed out that one soil type and one soil series, i.e. Alluvial soils and Verti soils (Normal), may be excluded from the project area, for the land and soil conditions are not suitable for an agricultural practice by irrigation. Therefore, this report aims to consider the remaining seven soil series and three soil types by using analysis data.

A land condition and soil chemical properties were analyzed, but some parts are still undertaking, and there made an attempt to obtain a new interpretation on the soil productivity of the paddy field. However, these present conclusion and explanation are tentative, and consequently, a final conclusion is subject to a further study.

Land condition

Land condition should be taken into consideration in relation to many experimental data, such as the depth of plowing layer at present time, the depth of available plowing layer in soil profile, the character of water permeability, the gravel contents in plowing layer, the degree of soil reduction, the relative difficulty of plowing operation, the contents of ferric iron in surface layer, and so forth.

The actual values obtained in the soil survey are shown in Table 1. The soil productivity is introduced from these values and the tentative classification of land condition as shown in Table 2, in which the comprehensive standards of land condition are mentioned in the extreme right column. According to this standard, both soils of Grayish brown soils (Clayey - fine) and the same soil type (Clayey - very fine) are most suitable ones for paddy productions.

Soil chemical properties

The definition of soil productivity is based upon the chemical properties of each soil. Generally, these properties may be divided into two categories, i.e. natural fertility and quality of nutrient situation.

(1) Natural fertility

Natural fertility consists of three factors, such as an ability of holding cation among nutrient elements (base exchange capacity), a fixative power of nutrient element (absorbed coefficient of phosphoric acid), and a degree of base saturation (saturated degree of calcium for base exchange capacity).

The results, which were examined by two data of chemical analysis, are shown in App-Table-14.. This Table indicates that two soil series belonging Verti soils have better conditions than other soil series as the paddy field.

(2) Quality of Nutrient situation

According to a method of judgement of this problems in Japan, an analysis is undertaken as for the following items, i.e. exchangeable-CaO, exchangeable-K_2O, exchangeable-MgO, available-N, available-P_2O_5, soil acidity, and so on.

App-Table-14 shows that two soil series belonging Verti soils have better conditions as well as the natural fertility.

Summary of Land condition and Soil chemical properties

In this report, there have tried to classify the soil productivity, of which only a few problems, namely the land condition, the natural fertility and the quality of nutrient situation in the soil, are described. The results are summarized in Table-5.

From this table, it is possible to consider that Grayish brown soils (Clayey - fine), Grayish brown soils (Clayey - very fine), and Verti soils (Hydromorphics) are more fitable for paddy soil compared with other soil series.

It may be said that there is a considerable difficulty to improve a land condition, but on the contrary it is easier to improve a quality of nutrient situation by introducing suitable fertilization techniques. Consequently, it is understood that two soil series which belong to Grayish brown soil have been in a better property than Verti soils.

Future Problems

When soil survey and soil sampling have been made in the dry season of this area, there were no plant and water remained in the fields. It is suggested that the dry season is not necessarily proper to investigate a feature of rice production. Therefore, further investigations on soil survey and soil sampling in the rainy season should be desirable to carry out keeping pace with a rice plant investigation. Furthermore, it is desirable to establish an experimental model farm for the fertilization test in order to solve the relation between soil conditions and management of profitable fertilization for each soil type.

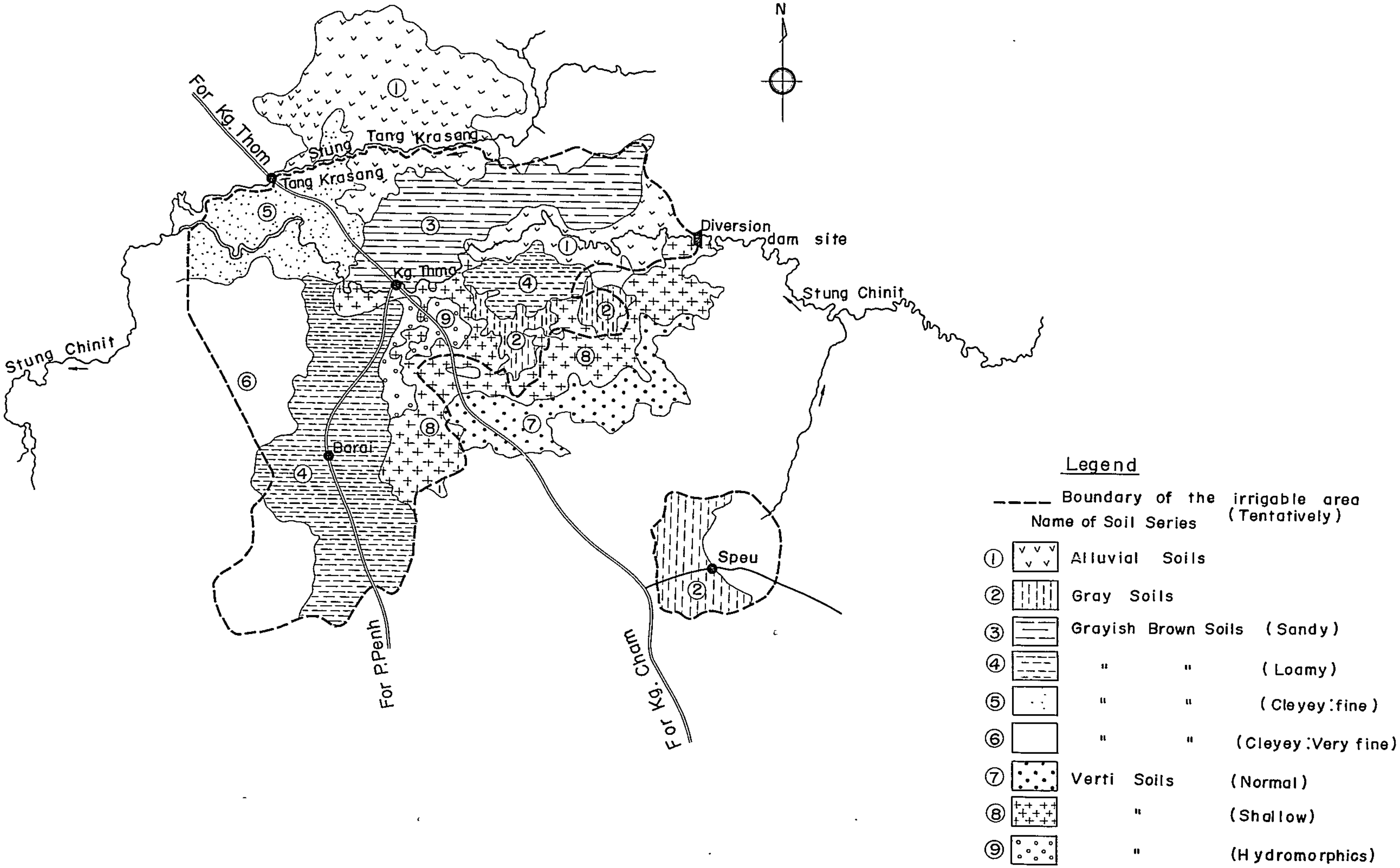
Table-12 Syntheitc Judgment

Soil types and soil series	Land condition	Natural fertility	Quality of nutrient situation	Synthetic judgment
1. Gray soils	II	II	II	II
2. Grayish brown soils (Sandy)	II	II	III	II - III
3. " " " (Loamy)	I - II	III	II	II
4. " " " (Clayey - fine)	I	II	II	I - II
5. " " " (Clayey - very fine)	I	II	II	I - II
6. Verti soils (Shallow)	III	I	I	II
7. Verti soils (Hydromorphics)	II	I	I	I - II

(Fig- 8)

Soil Map of The St. Chinit Basin

Scale 1 : 250.000



IV-7. Study on the present situation and development of agriculture

An outline of the present agriculture in this area was stated in the interim report published in June, 1968.

Observations on the actual use of water and land in the area were made in the rainy season, during October and in the beginning of November, 1968, and the fact that the land use is quite regulated by the rainfall or flood was made clear.

Water use The project area could be classified into 4 as far as water use, whose classifications are almost similar to the subdivision of irrigable area described in IV-III, i.e.

(1) the right bank area located to the east of the national road where only rainfall is available for paddy field and no inundation is seen in an ordinary year.

(2) the inundation area of the Stung Chinit located in the west of the national road without catchment area behind.

(3) the left bank area, with catchment area composed of rubber plantations, banana plantations and dense forest lands located above EL 7 m where no inundation water reaches.

(4) the inundation area from the Grand Lac between EL 7 and 10 m.

Scarce rainfall of this year brought the (1) area on a drought damage because of having no catchment area, and a bad harvest is presumed in the (1) area together with poor soil fertility. In the area (2) water is supplied from the Stung Chinit by means of natural overflow, consequently, it is affected completely by water level of the Stung Chinit. As to the (3) area, water to be necessary for the irrigation seems to be enough except some local points. The Prek Ta Prok originated from the dense forest land flows into the Grand Lac through a town of Baray and it does not dry up even in the dry season.

The flow of the Stung Chinit is hardly utilized for irrigation, though there can be seen an enough flow in quantity to irrigate the paddy field spread on both sides of the river, as irrigation facilities such as diversion works, intake works and canals have not been constructed. In other words, the paddy fields can be kept off from the drought damage in the rainy season by making small diversion works and canals even when any dam is not constructed.

Land use Almost the area is utilized as paddy fields in the rainy season except some families vegetable garden around the house. There seems to be some room for reclamation above approximately EL 15 m on the left bank of the Stung Chinit.

The Seasonal rice called 6-month rice is generally cultivated in the area and the floating rice is raised only in the inundation area of the Grand Lac.

A typical farming practice of the seasonal rice is as follows: the first plowing and puddling are made in May or June according to the rainy season. Transplantation is made in July and harvest time is November or December.

Agricultural products Agricultural products is tentatively estimated as shown in Table-13 on the basis of the data collected in the first survey. Unit yield per ha is distinguished into three according to the tentative land productivity classification. (refer to IV-6. Soil survey)

Table-13 Agricultural products

Land classification	Item		Present Paddy Rainy season	Present Paddy Floating	Future Paddy Rainy season	Future Paddy Dry season	Future Maize
I	yield	(t/ha)	1.2	1.0	3.0	3.3	
	sale price	(R/t)	2,270	2,270	2,270	2,270	
	product	(R/ha)	2,724	2,270	6,810	7,491	
	input	(R/ha)	1,915	1,660	4,850	4,850	
	net product	(R/ha)	809	610	1,960	2,641	
		($/ha)	26.5	17.4	56.0	75.5	
II	yield	(t/ha)	1.1		2.7	3.0	
	sale price	(R/t)	2,270		2,270	2,270	
	product	(R/ha)	2,497		6,129	6,810	
	input	(R/ha)	1,915		4,850	4,850	
	net product	(R/ha)	582		1,279	1,960	
		($/ha)	16.6		36.5	56.0	
III	yield	(t/ha)	1.0		2.3	2.6	3.8
	sale price	(R/t)	2,270		2,270	2,270	1,890
	product	(R/ha)	2,270		5,221	5,902	7,185
	input	(R/ha)	1,365		4,300	4,300	4,880
	net product	(R/ha)	905		921	1,602	2,305
		($/ha)	25.9		26.3	45.8	65.8

Note; R = Riel, 35 Riel = 1 US$

Samdech Euv project The Samdech Euv project undertaken by the Government of Cambodia in 1968 at Baray of Kompong Thom province should be here introduced. This aims at an improvement of drainage, a practice of dry season irrigation and a flood control. Two canals with 8 km length which were branched off from the Prek Ta Prok toward the Grand Lac at Baray town were constructed as of August of 1968. A land of 4,000 ha is drained by these canals, especially in the end of the rainy season, so that marshy lands can be converted into paddy fields, and also work be irrigated in the dry season. A polder dike of 6 km is planned in order to protect the area from the inundation from the Grand Lac so as to introduce a two-crops farming.

The scheme of the Samdech Euv project should be well cooperated with the Stung Chinit multi-purpose project.

These scheme and method of the Samdech Euv project correspond well with those of the Stung Chinit multi-purpose project, and a study to relate the Samdech Euv project with the Stung Chinit project will be made.

IV-8. Actual condition of the electric power supply in Cambodia

Concerning the above, the report published in June of 1968 should be refered to.

IV-9. Fishery survey

In the Stung Chinit, five sites were selected between the proposed reservoir site and the Stung Taing Krasang basin, of which fishery circumstances were investigated and made a comparison among them.

St. 1	Reservoir Area	Bangki Tangren
St. 2	Damsite	Kg. Krabei
St. 3	Diversion Damsite	Thma Samlieng
St. 4	Irrigation Area	Kg. Thma
St. 5	Inundation of the Great Lake	Kg. Thma - Taing Krasang

Result of the investigation

A) Fishery circumstances of the Stung Chinit

1) Eight species of fish were known through hearing and observed at Bangki Tangren in the upstream of the proposed reservoir site, and three species at Kg. Krabei. At Thma Samlieng twenty-six species and other eight unaffirmed species, then total thirty-four species inhabit there, in which eight species as important ones stated by the French Survey Mission were included. From Kg. Thma and its vicinity to the downstream of the river, it is supposed that more than several tens of species inhabit just the same as at Kg. Cham. These fishes are coming up from the Tonle Sap, and then propagate somewhere in marshy lands near the confluence of the Stung Chinit and the Stung Taing Krasang.

2) Fishing tools in the upstream from Kg. Thma, there can only see trol-lines and traps because of typical river types in which migratory fish lives. On the contrary, in the downstream from Kg. Thma cast nets, seines and drift nets are chiefly used as the current is slow and there is rich in non-migratory fish.

3) In the Stung Chinit basin, there exists one fisherman's house at Thma Samlieng, which is located in the upstream of Kg. Thma, and only a few to subsist by the fishery. However, a good many farmers can be found around here to capture fishes flowed down the stream temporarily during the middle of October to the middle of November. Generally speaking, there is a tendency that the fish fauna is scant in this basin compared with that of the other river basin.

Around downstream of Kg. Thma, some floating houses and net-drying facilities possessed by seines fishermen can be seen in spots, whose families are also engaged. And at the same time fishermen using cast nets and drift nets form a group each other and subsist by the fishery.

4) In the upstream of Thma Samlieng, inhabitants can not supply themselves with fresh fish, so they purchase fresh fish, Nuc Mum, and Prahoc transported from Kg. Thma, Kg. Thom and Son Ke located at the coast of the Mekong. In the downstream of Kg. Thma, it is carrying out to capture fish throughout a year, and fishing products are sent to Kg. Thma and Kg. Thom.

5) The following counterplans for fishery may be considered from the investigation mentioned above.

i) In the proposed reservoir site, water surface will be increased, and fish will propagate gradually. Accordingly it is advised to fell down trees around there in advance and transplant appropriate species whereas it could be good fishing ground.

ii) It will be not necessary to build fish passing facilities such as fish way, lock and so forth in the proposed damsite.

iii) It is desirable that an appropriate facility for fish breeding could be provided by intaking water from the irrigation canal into the natural ponds or depressions between the diversion dam and the irrigation area in order to increase useful fish species. The facility may also be available for irrigation by means of fertile returnflow from the ponds.

iv) As for the irrigation area and polder area, it will be decided how to cope with the situation after the result of a future investigation.

Future problems

1) It is required to study why there is few in fish species in this river compared with other rivers.

2) It is advised to provide in advance fish grounds in the flooding area of the upstream, suitable transplantation of fishes and development of fishing tools and methods. In order to carry out these things, it is urgent requirement to investigate the condition of fish multiplication in the existing dam.

3) As for the fish multiplication facilities of the irrigation canal between the diversion dam and the irrigation area, it is necessary to estimate a detailed program for profitable fish species, a structure and scale of facilities, and flow discharge.

4) Future investigation will be required for the irrigation and polder area.

IV-10. Study on navigation

The most important use of the Stung Chinit for navigation is timber transportation by means of raft. The timbers auctioned by merchants in the mountains are transported by raft to Thma Samlieng located at 15 km downstream along the river from the Phnom Takho proposed dam site. Quantity of the timbers produced in 1967 is shown as below:

Table-14 Timber quantity of the Stung Chinit basin in 1967

Name of branch river		Quantity in m^3
o Kbal	right bank of the St. Chinit	1,177.806
o Take	"	562.145
.....	"	472.503
o Kambor	"	3,577.899
o Bey Pvas	left bank of St. Chinit	1,686.164
Total		7,475.164 m^3

Source; Statistics offered by Division of Water and Forest, Kg. Thma.

About 90% of 7,475.164 m^3 timbers was transported by raft from Thma Samlieng to Phnom Penh and the rest was by truck. Transportation by raft is available for 3 months, from August to October, in the rainy season in which truck transportation is not utilized because of bad road condition.

A typical raft party operated by about 10 persons consists of 6 to 8 rafts, of which each party is about the size of 15 m by 10 m. It takes about three days for this party flowing down from Thma Samlieng to Kompong Thma, and two more weeks are required from Thma Samlieng to Phnom Penh through the Tonle Sap, but it takes only one week when a motorboat is used.

Transport capacity of a truck for one time is fairly small compared with that of a raft. 2 or 3 timbers, approximately 0.6 m diameter with 10 m length, can be transported. Owing to this reason, the transport cost per unit by truck will be more expensive than the cost by raft.

The proposed timberlands in the Stung Chinit basin have a tendency to move into year by year toward the interior forestland, in the direction of the Stung Sen basin or the Mekong.

The navigation study shall be made in connection with forest resources development plan.

V. Acknowledgement

The team would like to thank the officials listed below who have been concerned with the investigation for their willing cooperation.

Ministry of Public Works

Mr. Khy Taing Lim	Deputy Representative of Mekong Committee for Cambodia, and Director of Direction of Hydraulics and Energy
Mr. Mey Phath	Chief of Service Hydraulics and Navigation
Mr. S. A. Satharainsy	Chief of Service Climate
Mr. Songthara Om-Kar	Principal Engineer, Liaison Officer for the investigation team

Ministry of Agriculture

Mr. Te Sen Hoa	Chief of Division of Agricultural Statistics, Direction of Agriculture

Geographic Service of FARK

Mr. Keo Phath	Director, Geographic Service

The team also wishes to thank the offices and the experimental farm mentioned below.

Srok Office of Baray, Kompong Thom Province

Division of Water and Forest, Kompong Thma, Kompong Thom Province

Cambodian-Japanese Experimental Farm at Battambang

VI. Participants and short itinerary of the survey trip

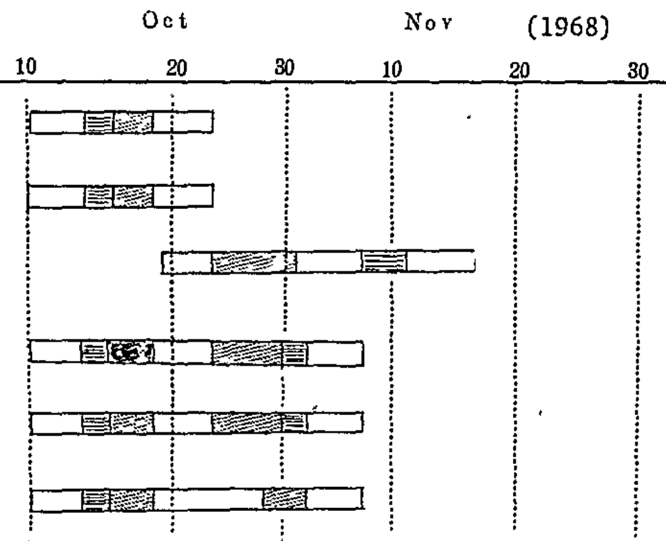
Member of the team

Dr. Hitoshi Fukuda	Leader of the team, Irrigation expert	Adviser to Sanyu Contultants International, Inc. and OTCA*
Mr. Susumu Takamine	Deputy leader Dam engineer	Sanyu Consultants International, Inc.
Dr. Yoshikazu Shiraishi	Fishery expert	Ministry of Agriculture and Forestry
Mr. Kunio Ohta	Irrigation engineer	Sanyu Consultants International, Inc.
Mr. Masahiro Isomura	Irrigation engineer	Sanyu Consultants International, Inc.
Mr. Hiroshi Yamamura	Coordinator	OTCA*

* Overseas Technical Cooperation Agency, Japan

Itinerary

Name of member	Speciality
H. Fukuda	Irrigation
S. Takamine	Dam
Y. Shiraishi	Fishery
K. Ohta	Irrigation
M. Isomura	Irrigation
H. Yamamura	Coordination



Note,

Field work for the survey of the St. Chinit project

Field work for the Area S-W of the Great Lake

Desk study and visit to the offices for the survey of the St. Chinit project and the Area S-W of the Great Lake

Appendix I

App-Table-1. Required capacity of the reservoir

1) Isolated irrigation purpose

Case	Irrigable area		Discharge flow		Net required capacity
	rainy season	dry season	max.	min.	
I-1	40,000 ha	40,000 ha	50.8 cumec	0 cumec	525 x $10^6 m^3$
I-2	"	32,000	40.7	"	415 "
I-3	"	24,000	30.5	"	285 "
II-1	21,900 ha	21,900 ha	29.4	"	265 "
II-2	"	17,500	23.5	"	185 "
II-3	"	13,100	17.6	"	135 "

2) Irrigation with hydropower purpose

Case	Irrigable area		Discharge flow		Net required capacity
	rainy season	dry season	max.	min.	
I'-1	40,000 ha	40,000 ha	50.8 cumec	10.0 cumec	550 x $10^6 m^3$
I'-2	"	32,000	40.7	15.0	425 "
I'-3	"	24,000	30.5	23.0	375 "
II'-1	21,900 ha	21,900 ha	29.4	23.5	375 "
II'-2	"	17,500	23.5	23.5	300 "
II'-3	"	13,100	17.6	17.6	195 "

Note: 1) Required capacity is computed with differential mass-curve (see App-Fig-1), which are available from Dec, 1962 to Jul, 1964 as a drought year.

2) The hydropower plan is made considering the following principle. To regulate the discharge flow as equally as possible throughout the year, meanwhile, to maintain the required irrigation discharge satisfactory in quantity.

App-Table-2. Required volume contents of dam

1) Isolated irrigation purpose

Case	High Water Level (EL:m)	Low Water Level (EL:m)	Depth of Water drawdown (m)	Capacity of dead-water ($10^6 m^3$)	Gross capacity of reservoir ($10^6 m^3$)	Volume content of dam ($10^3 m^3$) 1)
I-1	31.5	20.0	11.5	80	605	310
I-2	30.0	"	10.0	"	495	238
I-3	28.0	"	8.0	"	365	162
II-1	27.5	20.0	7.5	80	345	146
II-2	26.0	"	6.0	"	265	100
II-3	25.0	"	5.0	"	215	72

2) Irrigation with hydropower purpose

Case	Low Water Level (EL:m)	Capacity of dead water ($10^6 m^3$)	Net required capacity ($10^6 m^3$)	Gross capacity ($10^6 m^3$)	High Water Level (EL:m)	Depth of water drawdown (m)	Volume content of dam ($10^3 m^3$) 1)
I'-1	25.0	225	550	775	33.5	8.5	446
I'-2	"	"	425	650	32.0	7.0	350
I'-3	"	"	375	600	31.5	6.5	314
I"-1	30.0	480	550	1,030	35.5	5.5	600
I"-2	"	"	425	905	34.5	4.5	524
I"-3	"	"	375	855	34.0	4.0	484
II'-1	20.0	80	375	455	29.5	9.5	220
II'-2	"	"	300	380	28.5	8.5	182
II'-3	"	"	195	275	26.5	6.5	110
II"-1	25.0	225	375	600	31.5	6.5	314
II"-2	"	"	300	525	30.5	5.5	258
II"-3	"	"	195	420	29.0	4.0	200
II‴-1	30.0	480	375	855	34.0	4.0	484
II‴-2	"	"	300	780	33.5	3.5	446
II‴-3	"	"	195	675	32.5	2.5	372

Note: 1) A 2 m-freebord is taken above HWL.

App-Table-3. Dam cost and power generation scheme

Case	Cost of maindam Total[1] x10³$	Additional[2] x10³$	Potential energy head[3] Max.	Min.	Mean	Annual[4] Mean output(Pm)	Installed[5] Power(Pi)
I-1	2,015	-					
I-2	1,547	-					
I-3	1,053	-					
II-1	949	-					
II-2	650	-					
II-3	468	-					
I'-1	2,899	884	13.5 m	5.0 m	9.3 m	635 kw	1,270 kw
I'-2	2,275	728	12.0	"	8.5	940	1,880
I'-3	2,041	988	11.5	"	8.3	1,400	2,800
I"-1	3,900	1,885	15.5	10.0	12.8	940	1,880
I"-2	3,406	1,859	14.5	"	12.3	1,360	2,720
I"-3	3,146	2,093	14.0	"	12.0	2,030	4,060
II'-1	1,430	481	12.5	3.0	7.8	1,350	2,700
II'-2	1,183	533	11.5	"	7.3	1,260	2,520
II'-3	715	247	9.5	"	6.3	815	1,630
II"-1	2,041	1,092	14.5	8.0	11.3	1,950	3,900
II"-2	1,677	1,027	13.5	"	10.8	1,860	2,720
II"-3	1,300	832	12.0	"	10.0	1,290	2,580
II‴-1	3,146	2,197	17.0	13.0	15.0	2,590	5,180
II‴-2	2,899	2,249	16.5	"	14.8	2,550	5,100
II‴-3	2,418	1,950	15.5	"	14.3	1,850	3,700

Note: 1) *Unit cost of 6.5 $/m for dam construction including engineering service and contingency, 30% of net construction cost.*

2) *Additional cost to the main dam cost in the isolated irrigation case, i.e. equivalent to a difference between the cost in each case and the isolated irrigation cost.*

3) *In case of including hydropower, water level at the downstream of the power house is assumed that: i. EL 20 m for case I' and II", which is same as the water level of the Thma samlieng diversion dam . ii. average EL of 17 m for case II', II" and*

I", in which EL 15.5 m for the dry season and EL 18.5 m for the rainy season.

4) *Estimated as follows,*

Pm = 9.8 x Q min x.H mean x 0.75

where, Qmin = minimum discharge flow (refer to App-Table-1.)
Hmean = mean potential energy head

5) *Estimated as follows,*
Pi = Pm/50%

where, 50% of load factor for the annual mean output is considered.

The percentage is less than 50% for the firm power to the installation Pi.

App-Table-4 Investment cost of power

(in 10^3\$)

Case	Additional dam cost	Power house	Trans-mission line	Sub-station	Miscella-neous	Total	Total Installation $/KW
I'-1	884	250	450	200	290	2,142	1,690
I'-2	728	338	"	"	336	2,184	1,160
I'-3	988	488	"	"	405	2,743	980
I"-1	1,885	288	"	"	336	3,341	1,780
I"-2	1,859	400	"	"	399	3,588	1,320
I"-3	2,093	600	"	"	500	4,258	1,050
II'-1	481	550	"	"	398	2,204	820
II'-2	533	500	"	"	384	2,197	876
II'-3	247	313	"	"	317	1,622	995
II"-1	1,092	625	"	"	488	3,205	820
II"-2	1,027	588	"	"	474	3,081	830
II"-3	832	388	"	"	389	2,516	975
II‴-1	2,197	738	"	"	584	4,726	915
II‴-2	2,249	713	"	"	578	4,752	935
II‴-3	1,950	500	"	"	473	3,998	1,080

Note: The following unit construction cost are assumed.

1) Power house; 250 \$/KW

2) Transmission line: 7,500 \$/km x 60km
where, 30 KV of transmission wire and wooden pole are used.

3) Sub-station; 40% of the transmission line cost

4) Miscellaneous: {1) + 2) + 3) + 4)} x 30%

App-Table-5 Power cost and benefit-cost ratio

Case	Annual power[1] delivery MWH	Annual[2] cost x1,000$	Power[3] cost mill/KWH	Alternative[4] power cost mill/KWH	Benefit-cost[5] ratio
I'-1	5,560	179	32.2	27	0.84
I'-2	8,230	182	22.1	"	1.22
I'-3	12,260	229	18.7	"	1.44
I"-1	8,230	279	33.9	"	0.80
I"-2	11,910	300	25.2	"	1.07
I"-3	17,780	356	20.0	"	1.35
II'-1	11,830	184	15.6	"	1.73
II'-2	11,040	183	16.6	"	1.63
II'-3	7,140	135	18.9	"	1.43
II"-1	17,080	268	15.7	"	1.72
II"-2	16,290	258	15.8	"	1.70
II"-3	11,300	210	18.6	"	1.45
II‴-1	22,690	394	17.4	"	1.55
II‴-2	22,340	397	17.8	"	1.52
II‴-3	16,210	334	20.6	"	1.31

Note: 1) *Firm power* x *8,760 hours for usable power delivered*

2) *2% of total cost for maintenance and operation, 50 years of analysis period and 6% of interest rate for amortization*

3) *2)/3)*

4) *0.936 Riel/KWH for the steam power in Phnom Penh (refer to Interim Report, June, 1968)*

5) *Ratio of alternative power cost to power cost*

App-Table-6. Total benefit and total cost

Case	Irrigable Area	Cropping intensity	Power installation	Total cost (10^6US$) Agriculture	Power	total	Annual full benefit (10^6US$) Agriculture	Power	* total
I-1	40,000 ha	200 %	-	32.7	-	32.7	3.65	-	3.65
I-2	"	180	-	31.1	-	31.1	3.14	-	3.14
I-3	"	160	-	29.4	-	29.4	2.63	-	2.63
II-1	21,900 ha	200	-	15.5	-	15.5	2.15	-	2.15
II-2	"	180	-	14.8	-	14.8	1.86	-	1.86
II-3	"	160	-	14.3	-	14.3	1.57	-	1.57
I'-1	40,000 ha	200	1,270 kw	32.7	2.1	34.8	3.65	0.15	3.80
I'-2	"	180	1,880	31.1	2.2	33.3	3.14	0.22	3.36
I'-3	"	160	2,800	29.4	2.7	32.1	2.63	0.33	2.96
I"-1	"	200	1,880	32.7	3.3	36.0	3.65	0.22	3.87
I"-2	"	180	2,720	31.1	3.6	34.7	3.14	0.32	3.46
I"-3	"	160	4,060	29.4	4.3	33.7	2.63	0.48	3.11
II'-1	21,900 ha	200	2,700	15.5	2.2	17.7	2.15	0.32	2.47
II'-2	"	180	2,520	14.8	2.2	17.0	1.86	0.30	2.16
II'-3	"	160	1,630	14.3	1.6	15.9	1.57	0.19	1.76
II"-1	"	200	3,900	15.5	3.2	18.7	2.15	0.46	2.61
II"-2	"	180	3,720	14.8	3.1	17.9	1.86	0.44	2.30
II"-3	"	160	2,580	14.3	2.5	16.8	1.57	0.31	1.88
II‴-1	"	200	5,180	15.5	4.7	20.2	2.15	0.61	2.76
II‴-2	"	180	5,100	14.8	4.8	19.6	1.86	0.60	2.46
II‴-3	"	160	3,700	14.3	4.0	18.3	1.57	0.44	2.01

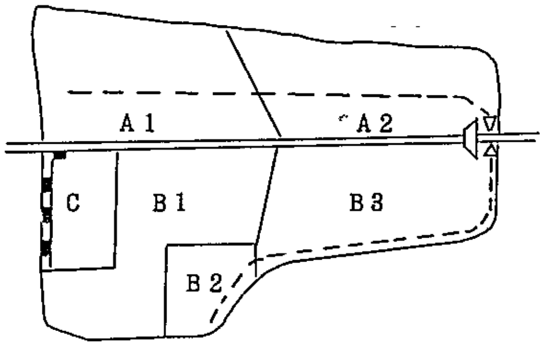
*Note: * At the alternative power cost (refer to App-Table-3, 5)*

App-Table-7 Benefit-cost ratio for the project

Case	Unit cost[1] of project	Annual cost[2] (10^6US$) Agri-culture	Power	Total	Annual benefit[3] ($10^6$$) Agri-culture	Power	Total	Benefit-cost ratio
	$/ha							
I-1	818	2.87	-	2.87	3.12	-	3.12	1.09
I-2	778	2.73	-	2.73	2.69	-	2.69	0.99
I-3	735	2.58	-	2.58	2.25	-	2.25	0.87
II-1	707	1.38	-	1.38	1.84	-	1.84	1.33
II-2	677	1.32	-	1.32	1.59	-	1.59	1.20
II-3	651	1.27	-	1.27	1.34	-	1.34	1.05
I'-1	870	2.87	0.18	3.05	3.12	0.15	3.27	1.07
I'-2	833	2.73	0.18	2.91	2.69	0.22	2.91	1.00
I'-3	803	2.58	0.23	2.81	2.25	0.33	2.58	0.92
I"-1	900	2.87	0.28	3.15	3.12	0.22	3.34	1.06
I"-2	868	2.73	0.30	3.03	2.69	0.32	3.01	0.99
I"-3	843	2.58	0.36	2.94	2.25	0.48	2.73	0.93
II'-1	808	1.38	0.18	1.56	1.84	0.32	2.16	1.38
II'-2	776	1.32	0.18	1.50	1.59	0.30	1.89	1.26
II'-3	726	1.27	0.14	1.41	1.34	0.19	1.53	1.08
II"-1	854	1.38	0.27	1.65	1.84	0.46	2.30	1.39
II"-2	817	1.32	0.26	1.58	1.59	0.44	2.03	1.28
II"-3	767	1.27	0.21	1.48	1.34	0.31	1.65	1.11
II‴-1	922	1.38	0.39	1.77	1.84	0.61	2.45	1.38
II‴-2	894	1.32	0.40	1.72	1.59	0.60	2.19	1.27
II‴-3	835	1.27	0.33	1.60	1.34	0.44	1.78	1.11

Note: 1) Total project cost (including power cost)/total irrigable area
2), 3) refer to III-2

App-Table-8 Project cost - Case I (40,000 ha) -

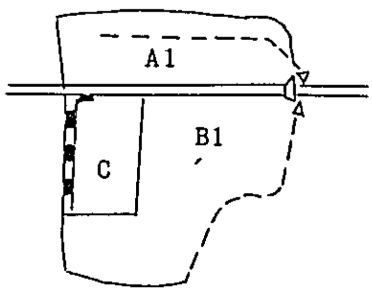


		Cost	
		\$/m	10^3\$
L = 39.0 km			
Q = 13.08 t/s	(ci=200%)	44.9	1,751
= 10.47	(ci=180%)	37.0	1,443
= 7.85	(ci=160%)	30.8	1,201
L = 53.5 km			
Q = 37.53 t/s	(ci=200%)	84.2	4,505
= 30.04	(ci=180%)	74.0	3,959
= 22.50	(ci=160%)	60.7	3,247

Item		Construction Cost (10^3US\$)			
		ci=200%	ci=180%	ci=160%	
1)	Main canal	6,260	5,400	4,450	
2)	Collateral works	1,560	1,560	1,560	17 x 10^3\$/km
3)	Lateral canal	1,280	1,280	1,280	32 \$/ha
4)	Land consolidation (including drainage)	3,600	3,600	3,600	90 "
5)	Reclamation	7,950	7,950	7,950	580 \$/ha
6)	Polder dike	2,300	2,300	2,300	100 x 10^3\$/km
7)	Drainage pump	540	540	540	
8)	Main dam	1,500	1,190	810	
9)	Diversion dam	125	125	125	
	Sub total	25,165	23,945	22,615	
10)	Engineering	2,520	2,395	2,260	
11)	Contingency	5,035	4,790	4,525	
	Sub total	7,555	7,185	6,785	
	Total	32,720	31,130	29,400	
12)	Unit development cost	818\$/ha	778\$/ha	735\$/ha	
13)	Annual cost[1]	71.7 "	68.3 "	64.6 "	
14)	Full benefit[2]	91.3 "	78.5 "	65.8 "	
15)	Annual benefit[3]	78.3 "	67.4 "	56.5 "	
16)	Ratio 15)/13)	1.09	0.99	0.87	

Note: 1) *Refer to the computation sheet "Annual Cost", App-Table-12*
2), 3) *Refer to the computation sheet "Project Benefit", App-Table-13*

App-Table-9 Project cost - Case II (21,900 ha) -



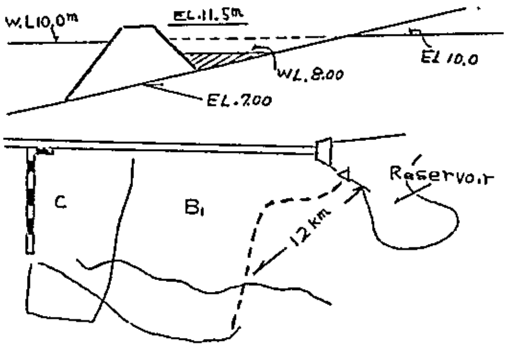
		Cost $/m	Cost 10^3\$
L = 11.8 km			
Q = 4.56t/s	(ci=200%)	21.8	257
= 3.65	(ci=180%)	18.9	223
= 2.74	(ci=160%)	15.8	186
L = 29.0 km			
Q = 24.80t/s	(ci=200%)	64.7	1,876
= 19.85	(ci=180%)	56.0	1,624
= 14.86	(ci=160%)	46.9	1,360

Item	Construction Cost (10^3US\$) ci=200%	ci=180%	ci=160%	Remarks
1) Main canal	2,130	1,850	1,550	
2) Collateral work	690	690	690	$17x10^3$\$/km
3) Lateral canal	700	700	700	32 \$/ha
4) Land consolidation	1,970	1,970	1,970	90 "
5) Reclamation	2,730	2,730	2,730	580 "
6) Polder dike	2,300	2,300	2,300	$100x10^3$\$/km
7) Drainage pump	540	540	540	
8) Main dam	730	500	360	
9) Diversion dam	125	125	125	
Sub-total	11,915	11,405	10,965	
10) Engineering	1,190	1,140	1,100	
11) Contingency	2,385	2,285	2,195	
Sub-total	3,575	3,425	3,295	
Total	15,490	14,830	14,260	
12) Unit development cost	707 \$/ha	677 \$/ha	651 \$/ha	
13) Annual cost 1)	62.9 "	60.4 "	58.2 "	
14) Full benefit 2)	98.1 "	84.9 "	71.7 "	
15) Annual benefit 3)	84.0 "	72.7 "	61.4 "	
16) Ratio 15)/13)	1.34	1.20	1.05	

Note: 1) Refer to the computation sheet "Annual Cost", App-Table-12

2), 3) Refer to the computation sheet "Project Benefit", App-Table-13

App-Table-10 Project cost - Case III (11,500 ha) -



$2,600^{ha} \times 0.5^{m} = 13 \times 10^6 m^3$
$= 150$ t/s-days
$= 2$ t/s-75 days

El. 15.00 m

A = 670 ha
v = 670 ha x 1.0 m
$= 6.7 \times 10^6 m^3 +$
= 77.5 t/s-days
≑ 1 t/s-78 days

	Item	Construction cost (10^3US$)	Remarks
1)	Main canal	353	12 km x 29.4 $/km
2)	Collateral works	204	17×10^3 $/km x 12 km
3)	Lateral canal	368	32 $/ha x 11,500 ha
4)	Land consolidation	1,035	90 $/ha x 11,500 ha
5)	Reclamation	290	580 $/ha x 500 ha
6)	Polder dike	2,300	100 $/km x 23 km
7)	Drainage pump	540	
8)	Main dam	- - - - - - - -	- - - - - - - -
9)	Diversion dam	150	$5\$/m^3 \times 30,000 m^3$
	Sub total	5,240	
10)	Engineering	524	
11)	Contingency	1,048	
	Sub total	1,572	
	Total	6,812	
12)	Unit development cost	592	
13)	Annual cost	55	
14)	Full benefit	78	
15)	Annual benefit	66	
16)	Ratio	1.20	

Note: In the dry season 60% of the total area (11,500 ha) is planned to be irrigated and 3 m^3/sec of water is expected to be utilized, i.e. 2 m^3/s in the polder area and 1 m^3/s in the diversion reservoir.

App-Table-11 Computation of benefit

Item	Name of area: A_1	"	A_2	"	total(A)	B_1	"	B_2	B_3	Total(B)	(C)
Land productivity	I	I	III	III		I	II	II	II		I
Cult. area: present (ha)	1,000	1,000	3,000		5,000	1,200	10,300	4,500	1,000	17,000	4,300
Cult. area: future (ha)	3,400	-	8,600	(8,600)	12,000	1,500	10,500	4,800	4,700	21,500	6,500
Present net product ($/ha)	26.5	*17.4	25.9	-		26.5	16.6	16.6	16.6		*17.4
Future net product ($/ha) : rainy	56.0	-	26.3	-		56.0	36.5	36.5	36.5		56.0
Future net product ($/ha) : dry	75.5	-	45.8	65.8**		75.5	56.0	56.0	56.0		75.5
(1) Present total product ($10^3$$)	26.5	*17.4	77.7	-	121.6	31.8	171.0	74.7	16.6	294.1	74.8
Future total product ($10^3$$)											
(2) rainy (ci=100%)	190.4	-	226.2	-	416.6	84.0	383.3	175.2	171.6	814.1	364.0
(3) dry (ci=100%)	256.7	-	-	565.9**	822.6	113.3	588.0	268.8	263.2	1,233.3	490.8
(4) " (ci= 80%)	205.4	-	-	452.7**	658.1	90.6	470.4	215.0	210.6	986.6	392.6
(5) " (ci= 60%)	154.0	-	-	339.5**	493.5	68.0	352.8	161.3	157.9	740.0	294.5
Total net benefit ($10^3$$) (A_1 + " and A_2 + " combined)											
(6) rainy (ci=100%)	146.5		148.5		295.0	52.2	212.3	100.5	155.0	520.0	289.2
(7) case-1(ci=200%)	403.2		714.5		1,117.6	165.5	800.3	369.3	418.2	1,753.3	780.0
(8) case-2(ci=180%)	351.9		601.2		953.1	142.8	682.7	315.5	365.6	1,506.6	681.8
(9) case-3(ci=160%)	300.5		488.0		788.5	120.2	565.1	261.8	312.9	1,260.0	583.7

Note: * *floating rice*, ** *Maize*, *ci=cropping intensity*

(6) = (2) - (1)
(7) = (6) + (3)
(8) = (6) + (4)
(9) = (6) + (5)

Case I = (A) + (B) + (C) = 3,650.9 x $10^3$$ I-2= 3,141.5x$10^3$$, I-3=2,632.2x$10^3$$
Case II = (A1)+(B1)+(C) = 2,149.0 x $10^3$$ II-2= 1,859.2x$10^3$$, II-3=1,569.5x$10^3$$
Case III = (B1 1st)+1/3(B1 2nd)+(C) = 892.2x$10^3$$

App-Table-12 Annual cost

Item	Case I	Case II	Case III
(1) Maintenance and operation of dam, canals, and structures 3% of construction cost	755 x10^3\$	357 x10^3\$	157 x10^3\$
(2) Amortization of Investment Cost 50 years @6% (0.06344)	2,074 "	981 "	432 "
(3) Replacement of pumps 25 years @6% (0.233x0.06344)	8 "	8 "	8 "
(4) Power cost of pumps	32 "	32 "	32 "
(5) Total Annual Costs (1) + (2) + (3) + (4)	2,869 "	1,378 "	629 "
(6) Annual Cost	71.7 \$/ha	62.9 \$/ha	54.6 \$/ha

App-Table-13 Project benefit

Item	Case I	Case II	Case III
1) Cultivated area (ha)			
Present	26,300	17,800	11,200
Future	40,000	21,900	11,500
2)*Production at present:			
Paddy (rainy season)	398.3 x $10^3$$	229.3 x $10^3$$	88.8 x $10^3$$
" (floating)	92.2 "	92.2 "	74.8 "
Total net present yield	490.5 "	321.5 "	163.6 "
3)*Estimated production after completion of project:			
Paddy (rainy season)	1,594.7 "	1,021.7 "	575.7 "
" (dry season)	2,546.7 "	1,448.8 "	480.1 "
Total net annual production	4,141.4 "	2,470.5 "	1,055.8 "
4) Gain in net annual production	3,650.9 "	2,149.0 "	892.2 "
5) Full benefit ($/ha)	91.3	98.1	77.6
6) Annual benefit ($/ha) 5) x 0.856	78.3	84.0	66.4

*Note: * Refer to the computation sheet, App-Table-11*

Appendix II

App-Table-14 The Values used for Judgement of Land Condition

Soil Types and Soil Series	Depth of Plowing Layer (Depth of A-Layer) in cm	Depth of Available Plowing Layer (Depth of B-Layer from surface) in cm	Character of Water Permeability (Subsoil about 50cm) Soil Texture	Soil Compaction
1. Gray Soils	7	35	SCL	35
2. Grayish Brown Soils (Sandy)	12	70	SL	22
3. Grayish Brown Soils (Loamy)	15	45	SCL	35
4. Grayish Brown Soils (Clayey: fine)	20	165	SC	28
5. Grayish Brown Soils (Clayey: very fine)	14	85	LiC	-
6. Verti Soils (Shallow)	10	10	SCL	-
7. Verti Soils (Hydromorphics)	7	35	HC	25

App-Table-15 Classification of Land Condition

Soil Types and Soil Series	Depth of Plowing Layer	Depth of Available Plowing Layer	Character of Water Permeability	Collective Judgement
1. Gray Soils	II	II	I - II	II
2. Grayish Brown Soils (Sandy)	II	I	II	II
3. Grayish Brown Soils (Loamy)	I	II	I - II	I - II
4. Grayish Brown Soils (Clayey: fine)	I	I	I	I
5. Grayish Brown Soils (Clayey: very fine)	II	I	I	I
6. Verti Soils (Shallow)	II	IV	II	III
7. Verti Soils (Hydromorphics)	II	II	I	II

App-Table- 16 Analysis Results, Strength of Factor and Collective Judgement on the Natural Fertility

Soil Types and Soil Series	Analysis Results		Strength of Factor		Collective Judgement
	Base Exchange Capacity m.e.	Saturated degree of Ca%	Base Exchange capacity	Saturated degree of Ca	
1. Gray Soils	9.2	30.3	2	2	II
2. Grayish Brown Soils (Sandy)	12.9	8.0	2	3	II
3. Grayish Brown Soils (Loamy)	3.2	39.8	3	2	III
4. Grayish Brown Soils (Clayey: fine)	14.9	21.5	2	3	II
5. Grayish Brown Soils (Clayey: very fine)	13.7	18.8	2	3	II
6. Verti Soils (Shallow)	30.9	40.9	1	2	I
7. Verti Soils (Hydromorphics)	33.0	44.3	1	2	I

App-Table- 17 Analysis Results, Strength of Factor and Collective Judgement on the Quality of Nutrient Situation

Soil Types and Soil Series	CaO (mg)	MgO (mg)	K_2O (mg)	P_2O_5 (mg)	Soil Acidity PH(H_2O)	Soil Acidity Exch. Acidity	Collective Judgement
1. Gray Soils	78(3)	112(1)	6(3)	4(2)	5.6	1.3(1)	II
2. Grayish Brown Soils (Sandy)	29(3)	13(2)	5(3)	4(2)	4.5	2.5(2)	III
3. Grayish Brown Soils (Loamy)	36(3)	13(2)	9(2)	7(2)	4.8	2.5(2)	II
4. Grayish Brown Soils (Clayey: fine)	90(3)	43(1)	16(1)	3(2)	4.7	16.0(2)	II
5. Grayish Brown Soils (Clayey: very fine)	72(3)	9(3)	33(1)	2(2)	5.1	5.0(1)	II
6. Verti Soils (Shallow)	353(1)	199(1)	32(1)	5(2)	5.2	7.5(1)	I
7. Verti Soils (Hydromorphics)	410(1)	257(1)	10(2)	3(2)	5.6	0.3(1)	I

Note: The values noted in a parenthesis indicate the strength of factor.