Tentative

R E P O R T

ON

THE RECONNAISSANCE SURVEY OF THE MULTIPURPOSE

DEVELOPMENT OF THE AREA S-W OF THE GREAT LAKE

IN

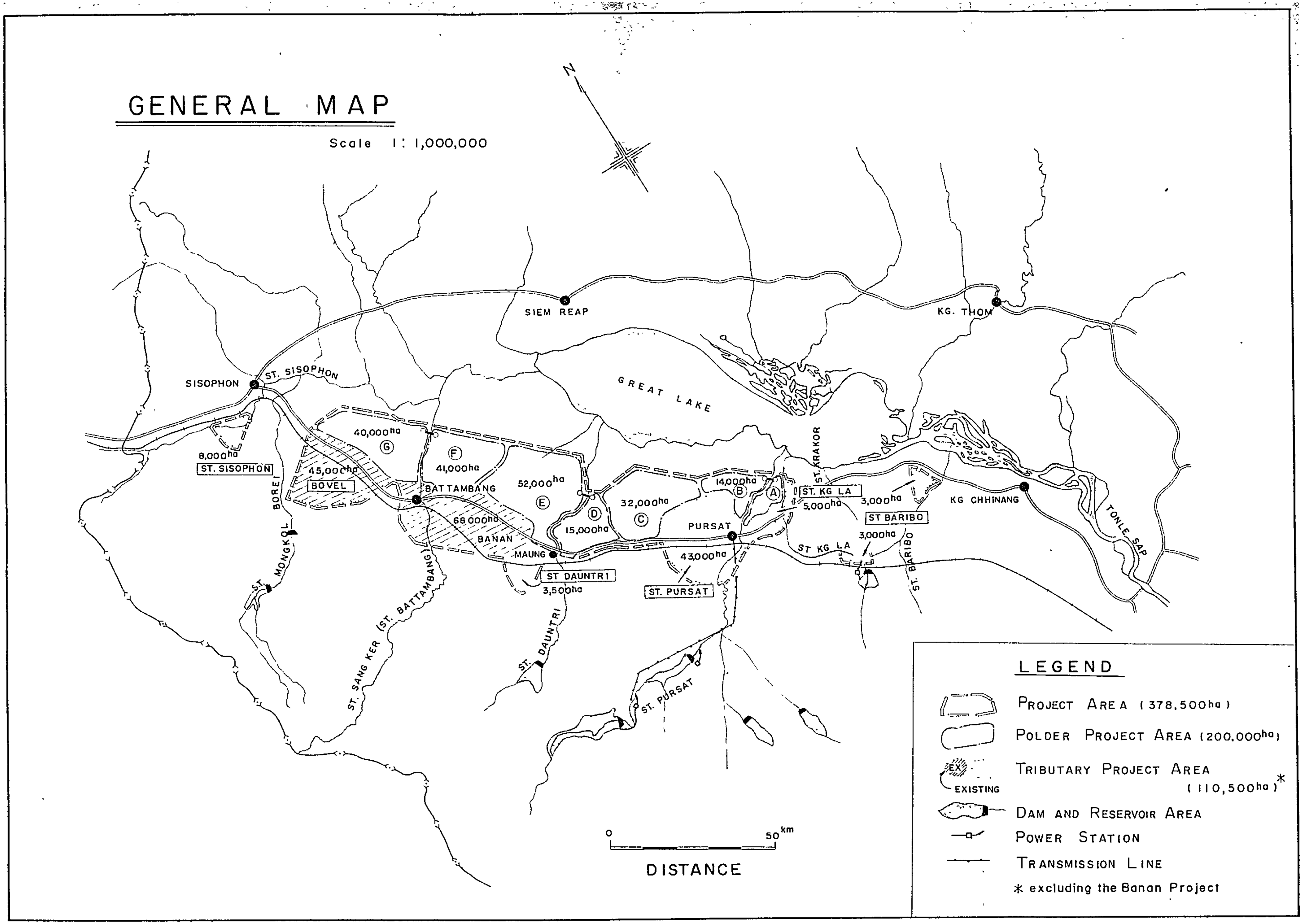
CAMBODIA

DECEMBER 1969

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

CONTENTS



GENERAL MAP
Scale 1: 1,000,000
N
SIEM REAP
KG. THOM
SISOPHON
ST. SISOPHON
GREAT LAKE
8,000ha
ST. SISOPHON
40,000ha G
F 41,000ha
45,000ha
BOVEL
BATTAMBANG
52,000ha E
14,000ha B A
ST. KRAKOR
ST. KG LA
3,000ha
KG CHHINANG
TONLE SAP
5,000ha
ST BARIBO
32,000ha C
D 15,000ha
68,000ha
BANAN
PURSAT
MAUNG
ST DAUNTRI
3,500ha
43,000ha
ST. PURSAT
ST KG LA
3,000ha
ST. BARIBO
BOREI
ST. MONGKOL
ST. SANG KER (ST. BATTAMBANG)
ST. DAUNTRI
ST. PURSAT
0 50km
DISTANCE
LEGEND
Project Area (378,500ha)
Polder Project Area (200,000ha)
Tributary Project Area (110,500ha)*
EX
EXISTING
Dam and Reservoir Area
Power Station
Transmission Line
* excluding the Banan Project

Introduction

Brief History of Survey

In November 1966, a reconnaissance survey of the Northern Area of the Great Lake was carried out by the team of the Mekong Committee Secretariat and OTCA, Japan. The team recommended a reconnaissance study in the Southern Area, because it might be more favorable than in the North.

In August 1967, the Government of Japan offered the Mekong Committee to undertake the reconnaissance survey of the multi-purpose development of the Area S-W of the Great Lake.

In August 1968, the reconnaissance survey was begun by the team organized by OTCA, Japan, under the Plan of Operation prepared by the Mekong Committee Secretariat and agreed by the riparian countries.

In September 1969, the survey was completed in the cooperation with the Government of Cambodia and the Mekong Committee.

Development Plan Undertaken for the Southern Area of the Great Lake

The Bovel Project which aimed at the development of the Stung Mogkol Borei was built more than 30 years ago. This project was reviewed a few years ago and is now supplying irrigation water for the 30,000 ha area out of a total irrigable 45,000 ha area.

The Banan Project was started since 1935, and a final report on the Battambang Plain Development (Banan project) was submitted by a French consulting farm, SOGREAH, in 1964. The project plan includes 2 reservoirs on the Stung Battambang to supply water for the 68,000 ha area out of a total irrigable area of 80,000 ha along the river and also to generate some hydroelectric power.

In 1961, a report entitled "Comprehensive Reconnaissance Report on the Major Tributaries of the Lower Mekong Basin" was presented by the Government of Japan. Regarding the area S-W of the Great Lake, this report suggested a possibility to irrigate some areas by constructing reservoirs on the major tributaries such as the Stung Mongkor Borei, the Stung Battambang, the Stung Daun Tri and the Stung Pursat. The Stung Pursat was especially recommended by the team since it was the most promising. The Stung Pursat development plan included an irrigable area of 35,000 ha and 21,000 kW of hydroelectric power generation by constructing dams and diversion weirs.

In 1964, a report entitled "Tonle Sap Barrage Project" was submitted by the Government of India. This project is a multi-purpose project to aim flood control and irrigation as major objectives.

In 1967, a report on Mathematical Model of Mekong River Delta was submitted to the Committee by SOGREAH.

As to the development of the Area S-W of the Great Lake, the reconnaissance survey was completed by OTCA in 1969 as mentioned in I-1.

Scope of Work

The scope of work by the Plan of Operation covered the following items.

PHASE I: The preliminary study of the area:

(1) Study of the previous reports[1/] and existing topographic maps of the project area.

(2) Study of the existing meteorological and hydrologic data of each tributary.

(3) Review of test of the sample of soils which was taken at the reconnaissance survey by the 4-man team.

(4) Collection and study of economic and other data, which are available in Japan in relation to the area around the Great Lake.

(5) Preparation of the field investigation to be carried in the Second Phase and submission of the Phase I report (progress report in English) to the Mekong Secretariat.

PHASE II: Field investigation and desk study for the preparation of appraisals of each project and of the whole area.

(1) Soil survey

(2) Overall reclamation study

(3) Collection and study of data related to meteorological and hydrological conditions and water requirement in the project area.

(4) Collection of economical and other data, especially on agriculture and power consumption related to the project planning.

(5) Study of topography and geology of dam sites, sites of irrigation and drainage facilities.

1/ "Design and Cost Estimates of the Tonle Sap Barrage"
"The final report on the Battambang Plain Development Project"
"Report on Mathematical Model of Mekong river delta"

(6) Planning and preliminary layout of each project.

(7) Influence of reclamation on fish production.

(8) Navigation at present and in the future.

(9) Flood problem at present and in the future.

(10) Power study at present and in the future.

(11) Collection of information on cost estimates and rough estimation and evaluation of costs and benefits of each project.

(12) Study on the most preferable scale and sequence of each development.

I. Conclusions and Recommendations

I-1. Conclusions

(i) The project area of 310,500 ha was divided into the following 2 parts from a viewpoint of development method.

a) The tributary projects area which can use the impounded water of the tributaries for irrigation and power generation (110,500 ha).

b) The area of the polder projects, located southeast of the national road, which is at present partly inundated every year for some time by the Great Lake (200,000 ha). This area can be reclaimed and cultivated by building dikes and installation of irrigation and drainage pumps.

(ii) Among the tributary projects, the Stung Pursat project of 43,000 ha and the Stung Mongkol Borei project of 45,000 ha turned out to be promising because of fertile soil and rather low construction costs ($871/ha and $531/ha respectively), of which the Stung Pursat project has an installed generating capacity of 20,500 kW.

The Stung Baribo project of 6,000 ha and 700 kW of generating capacity is favorable next to the above with rather high cost (1,195 $/ha) though it has fertile soil.

The other projects such as the Stung Kg. La of 5,000 ha, the Stung Dauntry of 3,500 ha and the Stung Sisophon of 8,000 ha, seem to be less favorable.

(iii) The polder projects turned out to be favorable though A diversion is less beneficial owing to rather sterile soil. The influence of the polder development on fishery will have to be carefully studied as well as the influence on the hydrology of the Great Lake.

(iv) The <u>remaining area</u>, where the conditions of soil or water resources are in general the least favorable, does not seem at present attractive for development.

(v) The anticipated costs of the projects and their expected net benefits and internal rate of returns are tentatively computed, and are summarized in Table 1.

Table 1 Costs, Benefits and Internal Rate of Returns

Name of Project	Area (ha)	Power (kW)	Costs: Agriculture (10^6\$)	Costs: Agriculture (\$/ha)	Costs: Power (10^6\$)	Costs: Total (10^6\$)	Target 1/ Benefits (\$/ha)	IRR 2/ (%)
St. Baribo	6,000	700	7.17	1,195	0.43	7.60	77	5-6
St. Kg. La	5,000	-	5.11	1,022	-	5.11	56	4-5
St. Pursat	43,000	20,500	37.43	871	9.48	46.91	77	7-8
St. Dauntri	3,500	-	4.63	1,323	-	4.63	68	4-5
St. Mongkol Borei	45,000	-	23.90	531	-	23.90	45	7-8
St. Sisophon	8,000	-	5.50	688	-	5.50	45	4-5
Total Tributaries	110,500	21,200	83.74	756 3/	9.91	93.65		
Polder A	6,000	-	8.58	1,430	-	8.58	93	4-5
" B	14,000	-	18.11	1,294	-	18.11	99	5-6
" C	32,000	-	43.89	1,371	-	43.89	101	5-6
" D	15,000	-	17.02	1,135	-	17.02	104	7-8
" E	52,000	-	60.14	1,156	-	60.14	102	6-7
" F	41,000	-	44.19	1,078	-	44.19	108	7-8
" G	40,000	-	49.81	1,245	-	49.81	106	6-7
Total Polders	200,000	-	241.74	1,209 3/	-	241.74	103 3/	
Grand Total	310,500	21,200	325.48		9.91	335.39		

1/ Five years after completion of the project

2/ Internal rate of return

3/ Weighted average

I-2. Recommendations

The following are recommended for the development of the area S-W of the Great Lake.

(i) To undertake a feasibility study of the St. Pursat project of 43,000 ha in the immediate future, due to having a favorable ratio of cost to benefit, by taking account of a staged development, that is, improvement of the present dry seasonal production with small diversion weirs only at the first stage, and introduction of double cropping and reclamation with storage dams and the diversion weirs at the second stage.

(ii) To undertake a feasibility study of the St. Mongkol Borei project of 45,000 ha in the near future for the purpose of covering the present poor water resources causing a drought sometimes even in the rainy season, because the area already has facilities and organizations of irrigation farming and experimental farms so that the target benefit seems to be easily realized.

(iii) To undertake a prefeasibility study, at the same time or shortly after the above studies, for 1 or 2 polder areas (D + E and/or F + G), because they are promising projects, and it is possible, by practicing 1 or 2 projects gradually, to study the influence of a polder project on fishery.

II. Present Status of the Area and View of Development

II-1. Problems and Needs

The area S-W of the Great Lake has a high potentiality of development as pointed out in the report of the reconnaissance survey of the area north of the Great Lake. In the area S-W of the Great Lake, there are four major tributaries, the Stung Sisophon, the Stung Mongkol Borei, the Stung Sangker and the Stung Pursat.

The Bovel irrigation project which takes water from the Stung Mongkol Borei is the only one, which utilizes water of the tributaries mentioned above. No hydroelectric generation is practiced in the area.

All the tributaries except the Stung Pursat, are not blessed with topographic conditions suitable for construction of a dam, but water use by constructing diversion weirs or small scale dams seems to be favorable for the development.

The area contains the Battambang plain at its central part, which is now a good granary zone of rice, so this existing granary zone should be expanded to the neighboring area.

In planning large scale irrigation, pumping from the Lake will be necessary since irrigable area with a gravity flow is limited by topography and water resources. Accordingly, for the development of the eastern area of the national road as far as the reserved area for fishery, a polder method will be suitable. It is a matter of course that the influence of polder projects on the water level of the Lake and fishery should be carefully considered.

The development of power has been required for the electrification of the area. On the other hand, when a main power supply system surrounding the area is realized with the Banan or other projects, the power development of the area will strengthen the main supply system by being connected with it, any may be also useful to supply polder project area with power.

The Great Lake, a vast treasurehouse of fishery, has been reported that its fish production is on the decrease in recent years. Though it might be possible to be covered enough by such counterplans as improvement of methods of fishing, reservation and propagation of fish and so on, the influence of the construction of polder dikes and dams or weirs on fishery should be further studied.

On the fishery in the tributaries, the construction works may be judged to bring rather favorable influence since the area of water surface will be increased by constructing dams or weirs.

From a viewpoint of navigation, rather profitable conditions will result from polder projects, because weirs to be built at the estuary of tributaries will raise water level and keep it high.

Navigation development plan to link the Great Lake and land on the tributaries will be required to meet the convenience of rice transportation.

II-2. Agriculture

II-2-1. Agriculture

The main crop of the area is rice. The province of Battambang is reckoned as one of the chief producing districts of rice, amounting to more than 20% of the total production of rice in Cambodia. And cooperation and collecting systems are well provided compared with other provinces. Having experience in farming for a long period of time, they have a comparatively high level of rice cropping, and introduction and extension of modern agricultural techniques will be effectively made.

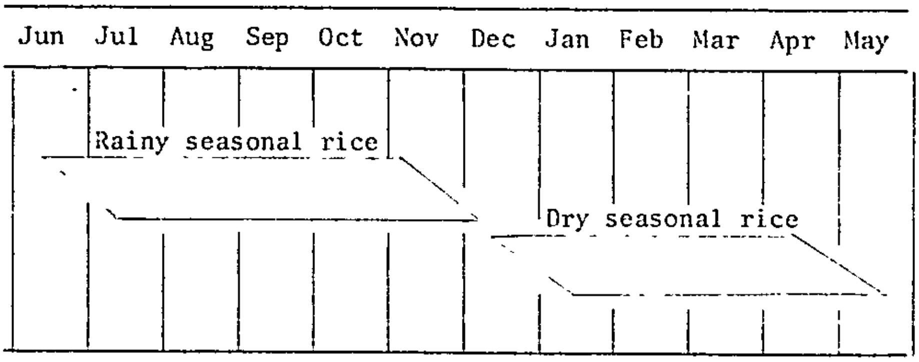
Irrigation facilities have been positively provided around Battambang. Small scale irrigation can be seen also at many places, the Bovel Project, as a large scale, covering 30,000 ha is under operation.

The soil of the area is classified into 4 groups, which productivity is comparatively high. Grayish brown soil with fine texture lying between the Stung Mongkol Borei and Stung Daun Tri is suitable for paddy fields. Grayish brown soil situated between the Stung Daun Tri and Kompong Chhnang will need such consideration on fertilization due to its coarse texture as to use a large quantity of organic fertilizer or manure, barnyard manure, for example, and so on.

For the land development under such soil conditions, irrigation and drainage facilities are necessary.

A proposed cropping schedule with irrigation is illustrated in Fig. 2.

Fig. 2 Cropping Schedule



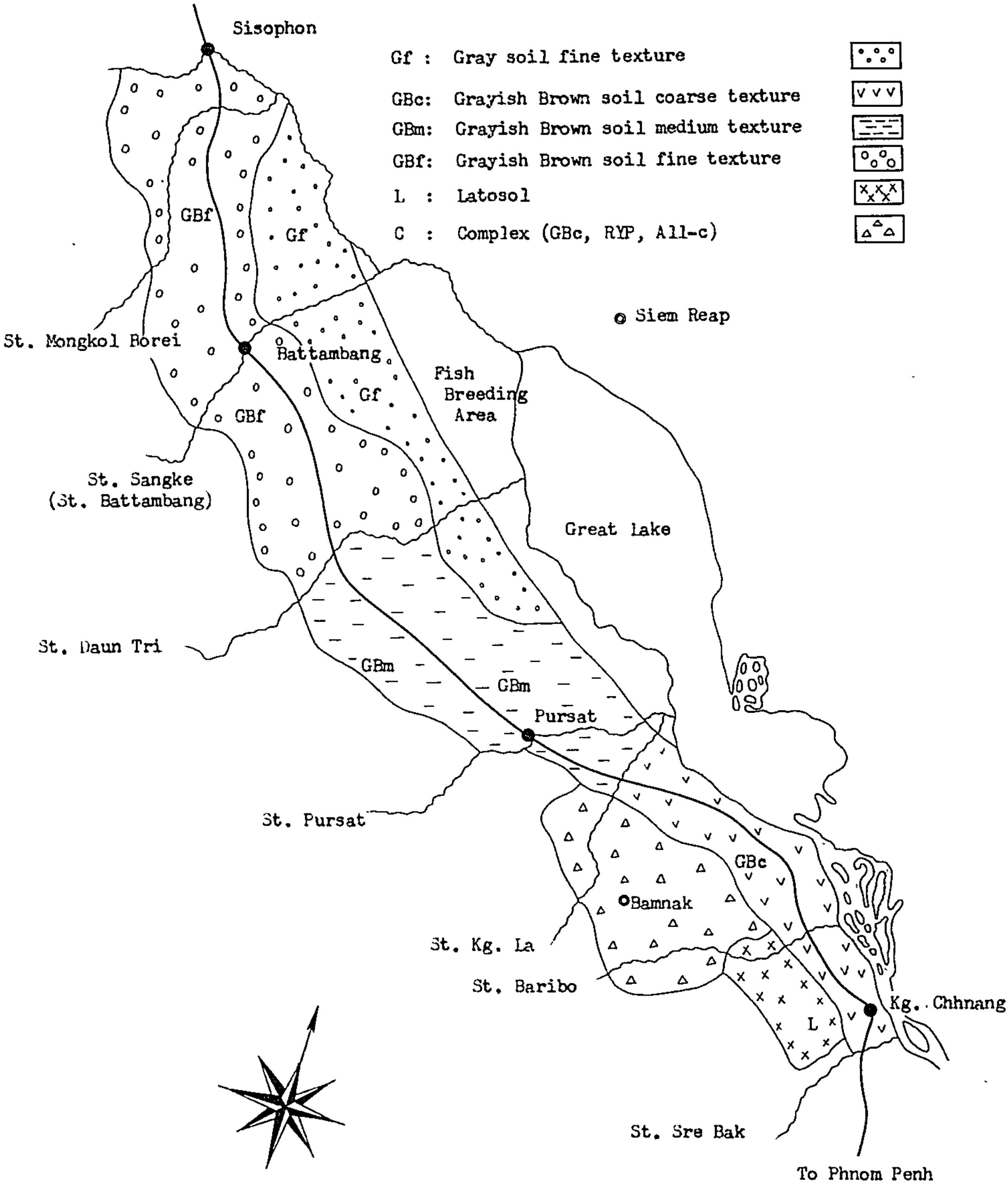
In this schedule IR 5 or Masuri shall be cultivated as rainy seasonal rice, and IR 8 as dry seasonal one.

II-2-2. Soil

Soils of plains and rolling hills in the south-west area of the Tonle Sap were classified into the following soil groups as shown in Fig.3. Gray Soils of fine texture, Grayish Brown Soils being subdivided into three families by texture, Latosols, Rendzina and Complex of some groups.

From a viewpoint of soils, as was connected to topography, water use, land use and so on collectively, agricultural development of this area is divided into two main types. First, in the area north-west from the basin of Stung Pursat, productivity of soils is higher than that south; especially, Gray Soils and Grayish Brown Soils of fine texture, being distributed on the wide plain close to the Tonle Sap, are highly productive. Therefore, general agricultural project, such as the Stung Pursat Project, including polder reclamation may be suitable and effective. Then, rice or upland crops could be cultivated even in dry season if water-supply is enough. Second, in the area between the basin of Stung Kompong La and of Stung Sre Bak, soil texture is very coarse, so that, it may be difficult to apply the same plan as the former. However, there are some fertile soils sporadically among hills, such as the area around Bamnak. It is expected, therefore, that a project with organization of cannals and roads would be carried out for the enlargement of paddy fields and the breeding of livestocks, such as cattle and duck.

Fig. 3 Soil Map of the Area S-W of the Great Lake



II-3. Hydroelectric Power

II-3-1. Supply Capacity

Generally, the main cities in Cambodia derive their electric supply independently from their own diesel plants. Among these cities, Phnom-Penh and its surroundings get a part of supply from a steam power station and a hydraulic power station as well.

At present, Cambodia has no transmission network covering the whole country, but only a 110 kV, 1-circuit transmission line (total running about 110 km) to Phnom-Penh from the foregoing hydraulic power station (Kirirom No.1).

That is mainly because the scale of diesel plant belonging to each city is so small and the distance between power plants is so far that the independent supply system in each city is much more economical.

II-3-2. Organization of Electric Power Industry

In Cambodia, the total electric supply except Battambang, is made by *Eléctricité de Cambodge* (EDC), and only in Battambang by *France Khmeré de Eléctricité de Battambang* (FKEB).

The control over those electric supply industries is secured by the department of *Service de Control des Eau et le Eléctricité* in *Ministre de Travaux Publics* (TP).

TP is taking charge of planning the electric supply, assuming the coming power demand and planning the development of the electric power equipments; and furthermore, the new construction of the large scale power station, and the power increase of the existing stations are executed by the department. TP controls the collection of charge and the maintenance of the instrument capacities by the electric companies. The foregoing power station Kirirom No.1, and the receiving station in Phnom-Penh and the transmission line (110 kV) between them are operated and maintained by TP.

The power output by the generation equipment in Cambodia as of the end of 1968 is shown in Table 2.

Table 2 Power Output by Generation Equipments

Classification	Hydraulic power	Steam power	Diesel	Total
TP	10,000			10,000
EDC		21,000	32,890	53,890
FKEB			2,175	2,175
Total	10,000	21,000	35,065	66,065

II-3-3. Trend of Power Demand

The annual increase rate of the power by ready-installed equipment is between 5 - 10 per cent, the annual power loss factor between 15 - 20 per cent and the annual load factor between 30 - 50 per cent.

The rather large rate in the loss factor comes from the poorly equipped distribution facilities and their sub-facilities. The daily load factor keeps its level at approximately 40 to 50 per cent. The specification of the loads is shown as the private domestic use, lighting of public way, public domestic use, and public and private use for the motor-power. The private domestic use accounts for approximately 60 per cent of total power use. What is important is that the power for main industries is managed to be obtained by their own power stations.

EDC is now making the effort to include the loads supplying by those private power stations. The total output by the private power stations in Cambodia is between 20 - 30 MW (Ref. The Sambor Feasibility Report by the Japanese OTCA Survey Team in 1967). According to the Appendix, the supply amount of the power by EDC has been decreased since 1963, and the fact tells that the motor load is switchovered from the supply by EDC to the supply by private power generation.

II-3-4. Power Cost

In the thermal power station, belonging to EDC, in Kandal Province, the suburbs of Phnom-Penh, the average original power cost form January to March, 1968, by the steam unit (6 MW x 3) was calculated as 1.53 Riel/kW, in which the cost equivalent to the fuel charge, 0.595 Riel/kWh is included.

Furthermore, the cost of power generation in the Kirirom No.1 hydraulic power station, operated by TP is 0.38 Riel/kWh at the generating stage, 0.5 Riel/kWh at the input to the Phnom-Penh receiving substation after running through the 110 kV transmission lines, and the selling price to EDC from TP at the receiving stage in the diesel plant of EDC is approximately 1.0 Riel/kWh. (The Kirirom No.1 hydraulic power station, the first construction of the hydraulic power plant in Cambodia, started in the operation in 1968 and the installed capacity is 10 MW, and average annual power generation is 49,700 MWh. The construction cost was needed at US Dollars 8,981,781).

On the other hand, the power cost at the generating side by the diesel plant at Kg. Cham, operated by EDC, (Installed capacity: 785 kW) is 2.7 Riel/kWh. The distributed power cost is 4.632 Riel/kWh.

II-3-5. Power Rate

The power rate by EDC is fixed as Table 3.

Table 3 Power Rate by EDC

(Riel/kWh)

Use	Phnom-Penh	Kandal province	Others
Private domestic use	3.064	3.171	6.337
Lighting of public way	2.873	2.953	5.470
Public building domestic use	3.046	3.136	6.153
Electro-motive force for private use; High voltage	1.778	1.778	4.370
Low voltage	2.251	2.261	5.003
Electro-motive force for public use; High voltage	1.778	1.778	3.933
Low voltage	2.301	2.311	4.786

Also FKEB fixes on the rate in Table 4.

Table 4 Power Rate by FKEB

(Riel/kWh)

Use		Battambang
Administration	Lighting	6.484
	Motor	5.119
Private	Lighting	6.714
	Motor	5.186

II-3-6. Location of Project Area in Cambodia

The area S-W of the Great Lake has been electrified by only a small scale diesel plant for each city.

Regarding the power equipment increase plan in Cambodia, Phnom-Penh and its surrounding area, and the looped supply system connecting Sihanouk-Ville, Kampot, Takeo are given top priority in their construction, the effort is also concentrated on the development of the power sources for those cities. As a result of them, the connection of the supply system of the project area with the main lines mentioned above cannot be taken into consideration for a while.

II-3-7. Power Development in the Future

According to the above-mentioned situation of the project area, the study of several hydraulic power sources along the man rivers in the S-W basin of the Great Lake have been carried out.

After the study it can be said that the development of the Stung Pursat will be most promising and suitable from the stand-point of using water resources and meeting power demand of the rural area including Pursat.

II-4. Fishery

Fishery is one of the essential industries for each Battambang, Pursat and Kg. Chhnang Province. Each province has a distribution center of the fish production respectively, that is, Bac Prea located at confluence of the Stung Mongkol Borey and the Stung Sangker, Krakor situated near the shore of the Great Lake and Kg. Chhnang faced toward the Tonle Sap.

The fish production for each province is shown in Table 5.

Table 5 Fish Production

(in ton)

Year	Battambang province	Pursat province	Kg. Chhnang province
1961	2,093	10,411	
1962	2,823	10,473	
1963	4,000	10,130	
1964	5,277	10,150	
1965	6,844	10,000	10,865
1966	7,635	11,000	17,175
1967	7,451	10,000	4,819

The production stated in Table 5 contains mostly raw fish, dried fish, smoked fish and "Prahoc" (salted small fish). Besides the above product, "Nac Mum" (fish source) is important in the region especially in Kg. Chhnang.

Regarding the monthly fishing product it is said that fishing is performed mainly in the duration from December to March and closed season from June to September as a spawning period, however the monthly product in statistics appears to have no correlation for the fact mentioned above. Then, further study may be required.

Fishing ground is chiefly at the Great Lake and its inundation including the reserved brush wood area for fish propagation.

Fishing in the tributaries is mainly conducted in the flood period of September and October.

By providing project facilities such as regulating dams, polder dikes, and so forth, the fishery in the region would be more or less affected. A practical way to solve the problem will be to develop polder projects gradually in order to examine the influence of the polder on fishery.

The Stung Pursat was selected as one of the typical big tributaries in the area and was surveyed on its fishery conditions.

As the riverbed of the Stung Pursat between the national road and the Great Lake is rather low and the paddy fields in the basin form a polder area surrounded by the natural levees, therefore fishery might not be affected by river flow regulation.

In the vicinity of Leach located at about 60 km upstream from Pursat city along the river, comparatively great variation of the water level is observed. But it will be converted into a suitable place for propagation of fish provided that a stable water basin could be created by constructing dams.

Some 30 fishing houses can be seen around the upstream of Leach and they capture a considerable amount of fishes during the most fishing season from October to November. Further investigation should be required whether it is able to maintain the fish production at the upstream area and to reserve fish to come up from the Great Lake.

II-5. Navigation

Navigation practice is mainly seen at the Stung Pursat. As for the other river in the area S-W of the Great Lake, navigation is quite few.

The logs produced at the broad forest in the upstream basin of the Stung Pursat, are transported to the town of Leach, which is a big transportation transit for production of the timber which is located at the mid-stream of the Stung Pursat, namely, 28 km upstream of Pursat town along the road. During November and June the transportation for timber production mostly depends on trucks. The navigation period is limited to September and October using logs with bamboo rafts in two boats through 80 km of the meandering river to the Great Lake.

The logs gathered to Kompong Chhnang from Pursat, are formed to big rafts and taken to Prek Kdam located near Phnom-Penh, the bigest timber market in Cambodia, via Tonle Sap. It takes about a week including the rafts preparation from Kg. Chhnang to Prek Kdam and the transportation cost of 45 Riels per one cubic meter of log.

The basins of St. Peam and St. Santre, tributaries of the St. Pursat, are being developed on timber production by means of providing new roads to carry logs. In the future, after completion of the dams proposed in this report, the timber transportation will be much improved by using new reservoirs to be created. Access roads, to be built, to the damsites from the existing road passing Leach, will also assist the transportation.

On the other hand, navigation between the highway and the Great Lake through the St. Pursat, St. Daun Tri and St. Sangher will be intensified by the polder projects, because those polder areas must provide diversion dams with a lock at the estury of the above mentioned rivers to secure irrigation water pumped from the rivers.

II-6. Overall Plan

II-6-1. Study on the Development Plans

One of the purposes of this reconnaissance survey was to review the ideas of the development plan ever reported for the area S-W of the Great Lake.

In the report entitled "Comprehensive Reconnaissance Report on the Major Tributaries of the Lower Mekong Basin", the followings were proposed.

(1) The St. Pursat: to build a dam of 63 m height, having 420 x $10^6 m^3$ of an effective capacity at HWL of 155 m, and a diversion dam at HWL of 40 m, in order to generate 21,000 kW of hydropower and to secure irrigation water for 35,000 ha throughout a year.

(ii) The St. Daun Tri: to examine a possibility of building a multipurpose dam at the upstream.

(iii) The St. Battambang: to exist a possibility to develop the basin by creating a dam, and expect the results of survey for the Banan project which was undertaking with the US fund.

(iv) The St. Mongkol Borei: to examine a possibility of constructing a multipurpose dam to extend the effect of the existing Bovel project.

All ideas but (iii) mentioned above were examined in this study. Being quite reasonable except detailed items, the ideas of (i), (ii) and (iv) are able to be utilized in formulating the project plan in this study. As 1 : 50,000 maps covering almost of the area S-W and river discharge data since 1962 are available, the development plan including the area other than 4 tributary basins stated above was possibly evaluated more exactly.

On the other hand, the report entitled "Report of the Reconnaissance Survey made in January 1967 to assess the Possibility of Irrigating the Area North of the Great Lake in Cambodia" suggested as following, dividing the area into 3 from the viewpoint of effective use of water resources and development of the area.

(i) The Area between the National Road and Fishery Reservation Area, a little to the Great Lake, which could be protected from inundation by building a polder dike, and be irrigated by pumping up.

(ii) Tributaries Development Areas located from the national road to the mountain side, where could be supplied with irrigation water from diversion dams and/or storage dams on the tributaries.

(iii) Remained Areas, located in the mountain side
There is no way to irrigate this area other than diverting water from the Mekong for instance, because the water sources of the tributaries have already been insufficient.

The scope of the above overall plan is concluded to be appropriate from viewpoints of utilization of the water resources and the project economy in the long run, therefore we have followed the policy of our predecessors. However, the method of (iii) is not feasible in the S-W Area of the Great Lake, consequently there is no other way to utilize more small-scaled streams, ground water and pumps, than to adopt the above (i) and (ii) proposals.

Thus, the South-West Area of the Great Lake is divided into the above two concepts, and considered that one unit area for irrigation plan is to be over 3,000 ha and power development to be about 1,000 kW and over. The overall plan of each project is described as the following paragraphs.

II-6-2. Main Features of the Overall Plan

a) Project Area

An arable land is situated at the elevation between 50 and 5 m, and its total area is about 10,000 km^2, of which 60 per cent of the area is the existing paddy fields. As for the project area this time excluding a 68,000 ha of the Banan Project, it sums up to be 310,500 ha. Breakdown of the area is shown as Table 6.

Table 6 Project Area

(Unit: ha)

Project Area	Irrigable Area		Area of existing paddy	Area to be re-claimed	Remark
	Rainy Season	Dry Season			
1) Tributary Project					
St. Baribo	6,000	2,250	6,000	-	
St. Kg. La	5,000	300	3,500	1,500	
St. Pursat	43,000	21,100	38,000	5,000	
St. Daun Tri	3,500	1,170	3,500	-	
St. Mongkol Borei (Bovel Project)	45,000	10,000	30,000	15,000	
St. Sisophon	8,000	-	6,000	2,000	
Sub-total	110,500	34,820	87,000	23,500	
2) Polder Project					
Polder A	6,000	5,100	4,000	2,000	
" B	14,000	11,300	7,000	7,000	
" C	32,000	26,600	9,000	23,000	
" D	15,000	12,300	9,000	6,000	
" E	52,000	36,600	15,000	37,000	
" F	41,000	37,000	25,000	16,000	
" G	40,000	30,000	16,000	24,000	
Sub-total	200,000	158,900	85,000	115,000	
Total	310,500	193,720	172,000	138,500	

b) Soil Conditions and Water Requirement for Irrigation

Soil conditions as described in II-3 can be divided into as Table 7, according to soil textures and their permeability.

Table 7 Soil Conditions

Soil textures	Quantity of permeability	Soil groups	Adopted area
Coarse Textured	5.0 mm/day	Grayish Brown coarse textured	
Medium Textured	3.0 mm/day	Grayish Brown medium textured Complex	St. Baribo St. Kg. La St. Sisophon
Fine Textured	2.0 mm/day	Grayish Brown fine textured Gray Soil fine textured	St. Daun Tri St. Mongkol Borei St. Sisophon Polder area

The unit water requirement for paddy fields and upland fields is decided as Table 8, considering consumptive water use and other water loss.

Table 8 Unit Water Requirement

Soil texture	Paddy field						Upland field in dry season	
	Coarse		Medium		Fine			
Season	Wet	Dry	Wet	Dry	Wet	Dry	Forage	Vegetable
Net water * requirement (mm/day)	10.1	11.3	8.1	9.3	7.1	8.3	4.7	3.8
Total water** requirement (m^3/sec/1,000ha)	1.05	1.74	0.85	1.44	0.76	1.28	1.04	0.84

* Percolation and evapotranspiration computed by Blaney-Criddle's formula.

** Losses of 25% for conveyance and operation, 70% of irrigation efficiency for upland field.
Besides, some available rainfall in monthly minimum considered.

c) Cropping Rotation and its Effect

Only rainy seasonal rice is cropped at present, and even after the project is completed, improved varieties of rice will be cropped in the rainy season, and grass will be introduced partially in the dry season for the purpose of improving sandy soils, though rice is then mostly raised. And vegetable cultivation is planned in the vicinity of city.

The present and target production for paddy are shown in Table 9.

Table 9 Soil Productivity and Paddy Yield

Projects	Soil productivity classification	Present paddy yield	Future paddy yield	
			rainy seasonal	dry seasonal
St. Baribo	II	1.0 t/ha	3.1 t/ha	3.4 t/ha
St. Kg. La	III	0.9	3.0	3.3
St. Pursat	III	1.0	3.1	3.4
St. Daun Tri	II - III	1.1	3.2	3.5
St. Mongkol Borei	II	1.8	3.4	3.6
St. Sisophon	II	1.1	3.2	-
Polder A	III	0.9	3.1	3.4
Polder B	III	1.0	3.2	3.5
Polder C	III	1.0	3.2	3.5
Polder D	II	1.1	3.3	3.6
Polder E	I - II	1.2	3.4	3.6
Polder F	I	1.3	3.5	3.7
Polder G	I	1.2	3.5	3.7

d) Plan of Storage Dam, Diversion Dam and Power Generation

Many storage dams and diversion dams are planned to supply the area with irrigation water. A list of them is as of Table 10. As a general rule, a storage dam is planned to have a capacity enough to regulate perfectly runoff water in a droughty year in order to keep a constant discharge throughout a year, and its site is selected so as to make costing less than it is worth.

As to power generation, all dams more or less have a possibility, but favorable generation can not be expected unless a canal or pressure pipe is constructed for a long distance, because generally dam height is too low to cause big fluctuation of water level. After all 2 of power stations on the St. Pursat, and 1 on the St. Baribo, as a test case of rural electrification, are favorably studied.

e) Project Costs and Internal Rate of Returns

The cost of each project is shown in Table 10, 11 and internal rate of return of each project is shown in Fig. 4 & 5.

Table 10 Contents of Dams in S-W Area, Great Lake

Name of River	Name of Dam & Location	Type of Dam	Catchment area km^2	Reservoir area km^2	Storage Capacity Total $x10^6m^3$	Storage Capacity Effective $x10^6m^3$	Water level m	Dam height m	Available water depth m
St. Baribo	Kbal Teahean	Earthfill	310	11.0	60	46	80.0	17.0	6.0
	Ta Ches	Diversion weir	600(290)*	0.3	-	-	30.0	5.5	
St. Kg. La	Dong Leak	Diversion weir	360	1.2	-	-	19.0	5.0	
(O Lead)	Chhuk Meas	Diversion weir	215	0.2	-	-	20.0	5.0	
St. Pursat	St. Pursat No.1 (Saom)	Concrete gravity	1,000	28.3	240	130	180.0	28.0	6.0
	St. Pursat No.2 (Tang Luoch)	Earthfill	2,080(1,080)	23.0	145	123	40.0	15.0	7.0
	St. Arai (Arai)	Concrete gravity	240	6.6	35	27	100.0	12.0	5.0
	St. Peam (Phnom Don Sdong)	Combined	490	5.5	72	57	74.0	19.0	12.0
	St. Santre (Phnom Banteay)	Earthfill	490	20.0	75	60	80.0	12.0	4.0
	St. Pursat (Samrong Yea)	Diversion weir	4,320(1,020)	18.0	25	18	20.0	6.5	1.0
St. Daun Tri	St. Daun Tri (Phnom Momung)	Combined	380	5.0	22	11	112.0	12.0	3.5
	St. Daun Tri (Chrak Poplea)	Diversion weir	690(310)	0.3	-	-	40.0	5.0	
St. Mongkol Borei	Ta Hen	Combined	2,700(500)	47.0	143	106	30.0	11.5	4.5
	Tuol Tel	Combined	2,200	9.0	36	36	44.0	12.0	5.0
St. Sisophon	Samrong	Diversion weir	1,600	-	-	-	18.0	11.5	

* Own catchment area, i.e., area upstream damsite is omitted.

Table 11 Construction Cost of Tributary Project

(Unit: US$ 10^3)

Name of Project	St. Baribo	St. Kg. La	St. Pursat	St. Daun Tri	St. Mongkol Borei	St. Sisophon	Total
Area (ha)	6,000	5,000	43,000	3,500	45,000	8,000	110,500(ha)
Land Reclamation	-	700	2,350	-	-	940	3,990
Land Consolidation	600	500	4,300	350	3,370	800	9,920
Irrigation Canal	840	700	6,020	490	2,100	1,120	11,270
Drainage Canal	480	400	3,440	280	3,600	640	8,840
Diversion Dam	870	1,930	2,100	1,180	-	1,050	7,130
Main Dam	3,140*	-	12,620*	1,530	10,680	-	27,970
Engineering (10%)	590	420	3,080	380	1,980	450	6,900
Sub-total	6,520	4,650	33,910	4,210	21,730	5,000	76,020
Contingency (10%)	650	460	3,390	420	2,170	500	7,590
Total	7,170	5,110	37,300	4,630	23,900	5,500	83,610
Cost per ha. ($/ha)	1,195	1,022	867	1,323	531	688	757
Cost of hydro-power development	430	-	9,840	-	-	-	10,270
Total Project Cost	7,600	5,110	47,140	4,630	23,900	5,500	93,880

* Multi-purpose dam cost allocated to irrigation.

Table 12 Construction Cost of Polder Area

(Unit: $\$10^3$)

Name of Project	A	B	C	D	E	F	G	Total
Area (ha)	6,000	14,000	32,000	15,000	52,000	41,000	40,000	200,000
1) Land Reclamation	940	3,290	10,810	2,820	17,390	7,520	11,280	54,050
Land Consolidation	600	1,400	3,200	1,500	5,200	4,100	4,000	20,000
2) Irrigation Canal	840	1,960	4,480	2,100	7,280	5,740	5,600	28,000
3) Drainage Canal	480	1,120	2,560	1,200	4,160	3,280	3,200	16,000
4) Polder Dike	2,540	4,770	6,670	3,450	7,060	7,010	7,930	39,430
5) Pumping Station	1,190	880	5,810	2,620	7,070	4,970	4,410	26,950
6) Gate	500	1,540	2,740	370	1,540	3,900	4,740	15,330
7) Engineering (10%)	710	1,500	3,630	1,410	4,970	3,650	4,120	19,990
Sub-total	7,800	16,460	39,900	15,470	54,670	40,170	45,280	219,750
8) Contingency (10%)	780	1,650	3,990	1,550	5,470	4,020	4,530	21,990
Total	8,580	18,110	43,890	17,020	60,140	44,190	49,810	241,740
($/ha)	1,430	1,294	1,371	1,135	1,156	1,078	1,245	1,209

Fig. 4 Internal Rate of Return

(Tributary Project)

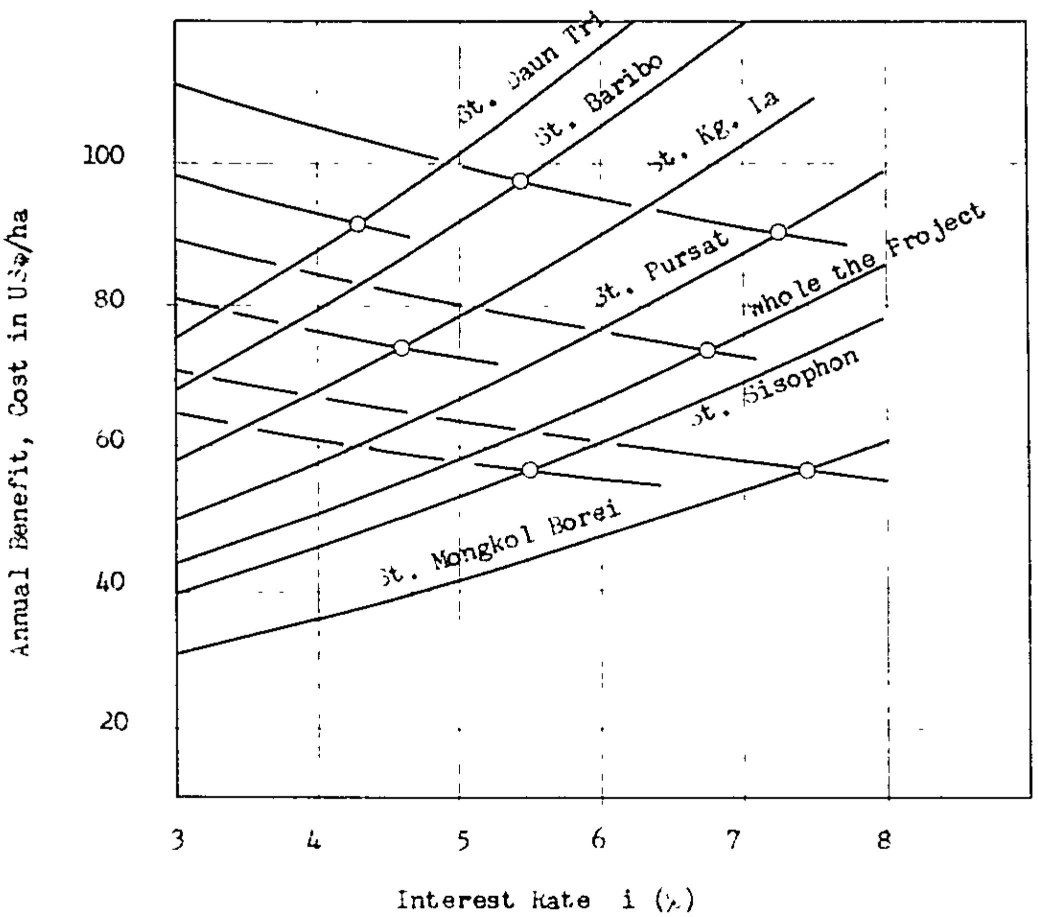
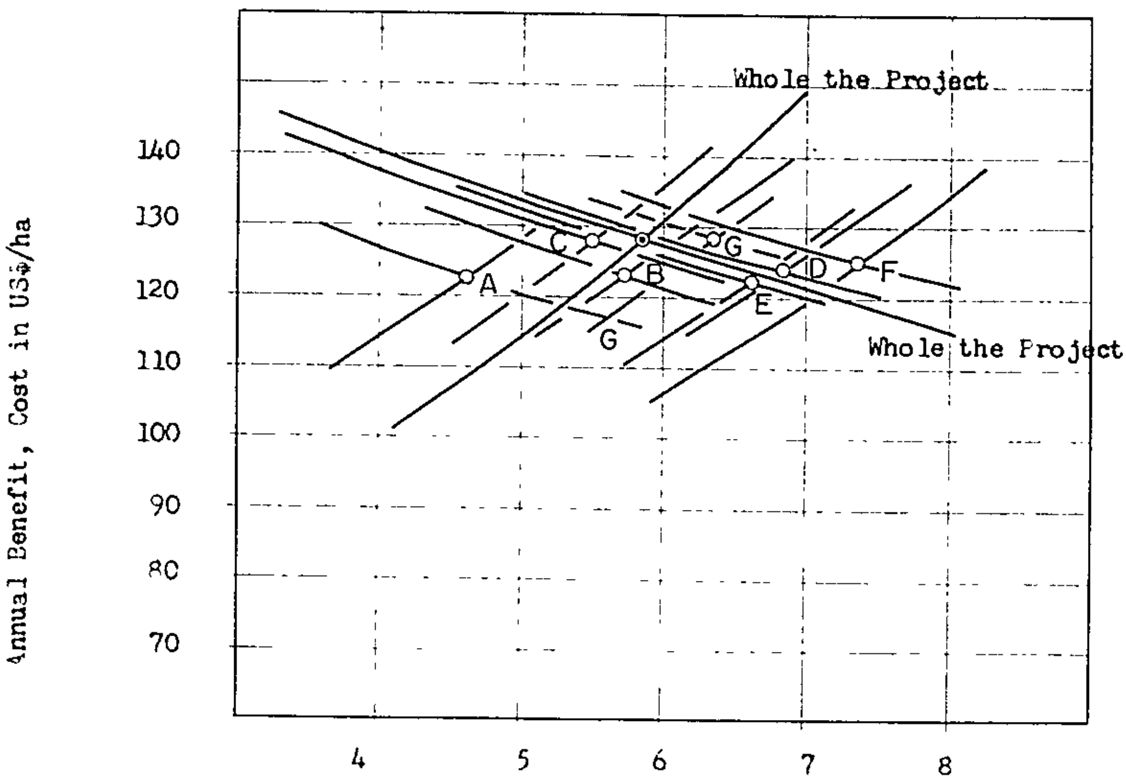


Fig. 5 Internal Rate of Return

(Polder Project)



Division	IRR(%)	Division	IRR(%)
A	4.6	E	6.6
B	5.7	F	7.9
C	5.5	G	6.4
D	6.9	Mean	5.9

III. Tributary Projects

III-1. St. Baribo Project

The Stung Baribo has a catchment area of about 870 km^2 at Babaur and an annual runoff of 280 x $10^6 m^3$ in a rather dry year. According to a 1 : 50,000 map, a storage dam could be built at a location Ph. Kbal Teahean, 5 km upstream of Bamnak (see General Map). The low dam, which might be of the earthfill type, could create a reservoir with H.W.L. at EL 80 m, having a net storage capacity of about 46 x $10^6 m^3$ with a 6 m drawdown. The storage would be sufficient to regulate the annual run-off completely in a dry year from the St. Baribo at the damsite (catchment area at the damsite about 310 km^2), so that a discharge 3.13 m^3/sec could be utilized throughout a year for 3,500 ha irrigation and 700 kW hydropower generation.

Further, a diversion dam would also be provided at Ph. Taches (half-way between the railroad and the national road) in the downstream, which will be able to take water from the river flows in a remained catchment area of 290 km^2 and further to irrigate a 2,500 ha in the rainy season.

An irrigable area of 6,000 ha is roughly divided into 2 areas, i.e. 3,000 ha each. On one hand, the area is located at the northern part of Bamnak in Pursat Province, and is a valley between the railroad and the mountains, such as Phnom Kbal Khla and so on. The soil of the area is of fairly fertile, Complex Soil. As there are some small scale of existing diversion dams and irrigation canals, a new irrigation system will be established, repairing and utilizing the existing facilities, in order to take water discharge from the dam. The another irrigable area is located at the area downstream of the weir at Ta Ches in Kg. Chhnang Province, among the St. Baribo and O Sanlung on the left bank of the St. Baribo, which forms a triangular-shaped and extends to Ponley along the national road. The soil composed of mostly sandy Grayish Brown Soil, included a part of Complex and Latosol, and its fertility is inferior to the soil of the northern area of Bamnak.

The land utilization could be in the rainy season 6,000 ha of paddy. In the dry season, under the limitations of water for the secondary cropping, it will be some 2,250 ha and mostly concentrated on the northern area of Bamnak. As for the secondary cropping, paddy cultivation in 1,50- ha, forage cultivation in 650 ha for promotion of livestock in the valley and hilly land, and vegetable cultivation in 100 ha for consumption at Kompong Chhnang might be provided.

The hydropower plant is possible to generate 700 kW by a dam type, having a 14 km maximum water head and a 6.26 m^3/sec maximum discharge. An annual generating energy taking 50% of the load factor will be 2,360 MWh, which will be consumed in the project district, transmitted to Bamnak by a 5 km of transmission line. Power cost at the load center is about ¢1.65/kWh.

Total project cost is $7.60 million, included $7.17 million for the irrigation sector ($1,195/ha). The target benefit is assumed at $77/ha at the 5th year after completion of the project, and is increasing at 2% per annum for sums of investment and production. The I.R.R. of the irrigation could be between 5 and 6%.

Cost allocation of the dam for irrigation and power, and assumption of power cost are seen in Appendix B.

III-2. St. Kompong La Project

The Stung Kompong La has a catchment area of 420 km^2 (the whole area in Pursat Province) at Thnot Chum and annual runoff of about 130 x $10^6 m^3$* in a droughty year. It is no suitable site to build a storage dam and reserve runoff water, consequently there is no other way to utilize a natural river flow than by a diversion dam for the water re-

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* Note: The observation of discharge in this river is only available until March 1967. Accordingly, the discharge in 1968 of a droughty year is computed from the specific discharge in the Stung Baribo. The data between 1962 and 1966 indicate similality of the discharge of both rivers. The discharge of this river seems rather much in the south-west of the Great Lake. A diversion dam in the Stung Kbal Siem (in the upstream of the Stung Kompong La) is under programmed by Srok Krakor.

sources development. A diversion dam could be built at Phum Dong Leak, about 5 km north of the railroad in the upstream of the Stung Kompong La, having about 700 m length of crest and a 19 m of high water level. Moreover, to introduce river flow from the other river system of the O Leak located at about 2 km west of this proposed site, one more diversion dam with H.W.L. at EL 20 m could be built at around Vatt Chhuk Mess in the upstream of the O Leak. The total catchment area at the sites of the proposed diversion dam amounts to 575 km^2, of which 360 km^2 at the Stung Kompong La and 215 km^2 at the O Leak, therefore it is possible to get water of 4.6 m^3/sec in the rainy season and 0.3 m^3/sec in the dry season of a droughty year.

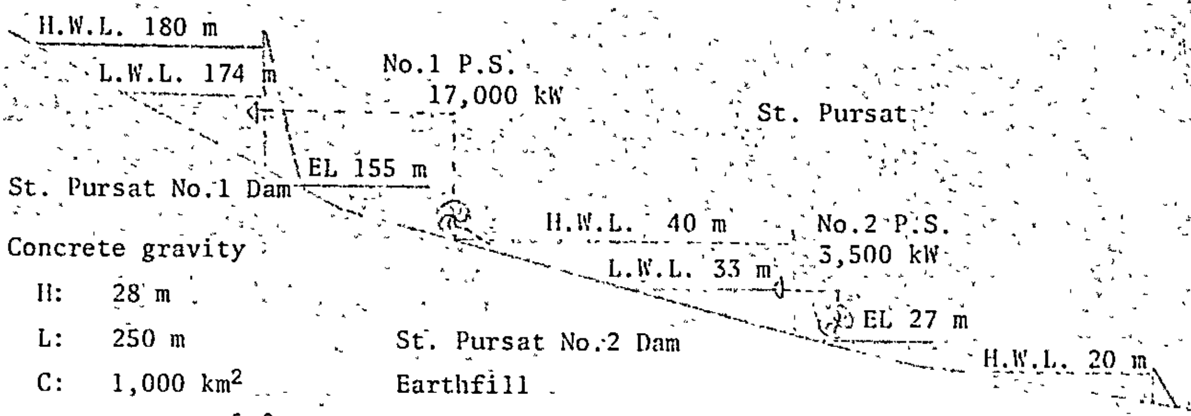
Irrigation will be practiced in 5,000 ha paddy fields at around EL 15 m in the rainy season at the right bank of the Stung Kompong La (Thnot Chum will be a center along the national road), and will be introduced forage and vegetable cultivation in the dry season in 300 ha. A promotion of livestock is possible to improve land fertility in the area by putting organic fertilizer into the poor fertility sandy Grayish Brown Soil. The production of vegetable could be consumed at Pursat easily.

The project cost is $5.11 million, target benefit of irrigation is $56/ha (at the 5th year after completion of the project, after that year 2% rate of growth per annum), and its I.R.R. is between 4 and 5%.

III-3. Stung Pursat Project

The Stung Pursat has a catchment area of 4,480 km^2 at Pursat ville, which is the largest one of the whole rivers in the S-W Area of the Great Lake, and annual runoff of 1,210 x $10^6 m^3$ in a droughty year. The river has some tributaries, such as St. Santre, St. Peam, St. Arai and so on, at nearby of Leach in a 26 km upstream of Pursat, and the catchment areas of the main stream and its tributaries are about 2,000 km^2 respectively. According to a 1 : 50,000 map, it is possible to make water resources development by construction of 5 reservoirs and 1 diversion dam, as shown in the undermentioned illustrations.

Profile of Dam Scheme on the Stung Pursat



St. Pursat No.1 Dam

Concrete gravity

H:	28 m
L:	250 m
C:	1,000 km^2
S:	240 x $10^6 m^3$
Se:	130 x $10^6 m^3$
Qm:	8.7 m^3/sec
$:	6.8 x 10^6

St. Pursat No.2 Dam

Earthfill

H:	15 m
L:	200 m
C:	2,080 km^2
C':	1,080 km^2
S:	145 x $10^6 m^3$
Se:	123 x $10^6 m^3$
Qm:	8.7 + 9.4 = 18.1 m^3/sec
$:	2.64 x 10^6

Diversion Dam

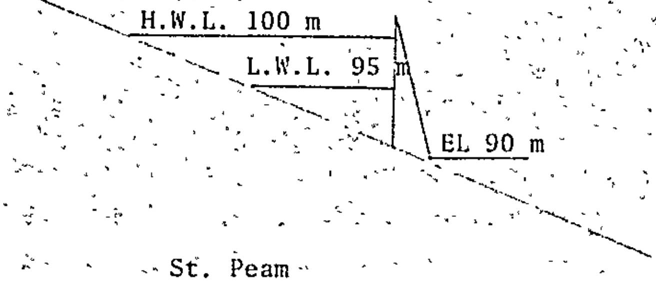
Concrete

H:	6.5 m
L:	400 m
C:	4,320 km^2
C':	1,020 km^2
Se:	18 x $10^6 m^3$
Qm:	28.7 + 10.2 = 38.9 m^3/sec (rainy season)
	28.7 + 3.1 = 31.8 m^3/sec (dry season)
$:	2.10 x 10^6

Remarks:

H:	Height of dam
L:	Length of dam
C:	Catchment area at dam site
C':	Net catchment area at damsite excluding the area of upper damsite
S:	Gross storage capacity
Se:	Effective storage capacity
Qm:	Available discharge throughout a dry year
$:	Cost of dam excluding the engineering cost and contingency

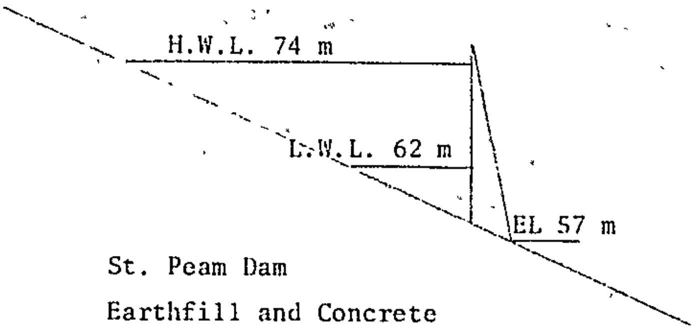
St. Arai



St. Arai Dam
Concrete gravity

H: 12 m
L: 180 m
C: 240 km^2
S: 35 x $10^6 m^3$
Se: 27 x $10^6 m^3$
Qm: 2.1 m^3/sec
$: 1.48 x 10^6

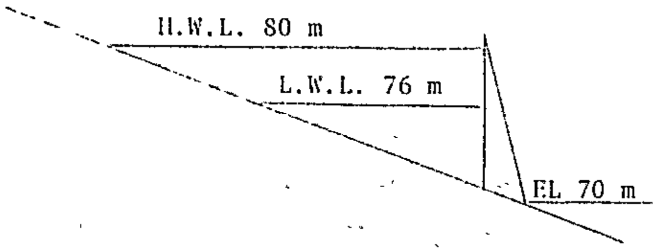
St. Peam



St. Peam Dam
Earthfill and Concrete

H: 19 m
L: 150 m
C: 490 km^2
S: 72 x $10^6 m^3$
Se: 57 x $10^6 m^3$
Qm: 4.3 m^3/sec
$: 2.04 x 10^6

St. Santre



St. Santre Dam
Earthfill

H: 12 m
L: 350 m
C: 490 km^2
S: 75 x $10^6 m^3$
Se: 60 x $10^6 m^3$
Qm: 4.3 m^3/sec
$: 2.60 x 10^6

5 dams, 2 at the main stream and 3 at the tributaries, could have a total effective storage capacity of 397 x $10^6 m^3$, and control annual runoff completely from the catchment areas of the dams, totaled 3,300 km^2, in a droughty year, so that average 28.7 m^3/sec discharge could be released. The diversion dam to be built at Samrong Yea in the downstream, has 1,080 km^2 of its own catchment area, together with 4,320 km^2 including the other dams' catchment areas, and a 18 x $10^6 m^3$ of storage with 1 m drawdown, so that 38.9 m^3/sec discharge in the rainy season and a 31.8 m^3/sec in the dry season, summing up the discharge from the upstream dams, could be utilized in a droughty year.

III-3-1. The Plan of Irrigation

Water utilized for irrigation will be taken from the diversion dam. 36.9 m^3/sec in the rainy season and 29.8 m^3/sec in the dry season, deducting about 2 m^3/sec of other necessary water from the aforementioned available discharge, could be utilized. An irrigable area will be about 43,000 ha, located at both sides of the St. Pursat (mostly left of the river) at EL 20 - 10 m. Pursat ville is included in the area, and the national road is passing through about the center of the area. The majority of soils in the area are Grayish Brown Soil of medium textured and are not always fertile. However, among 21,100 ha of irrigable area in the dry season, 3,000 ha could be cultivated for forage, so that soil fertility would be improved by promotion of livestock together with putting more organic fertilizer. Furthermore in about 300 ha in the dry season, vegetable cultivation could be introduced to supply it for Pursat, and in the other area of 17,800 ha paddy for double cropping could be introduced. 43,000 ha of the whole benefited area (including 5,000 ha reclamation of sparce forests) will be introduced paddy cultivation in the rainy season.

Then, the target benefit of irrigation is computed to be $77/ha at the 5th year after completion of the project, and after that it is expected to be a 2% increase per annum for sums of production and investment to the farms.

On the other hand, the project cost, after making cost allocation for irrigation and power, is computed to be \$37.30 x 10^3 or \$867/ha for irrigation. Based on the figure, the I.R.R. is to be between 7 and 8%, considering annual cost and annual benefit.

III-3-2. The Plan of Power Generation

a) The Project Area

The purpose of the power development plan is to electrify the S-W Area of the Great Lake, such as Pursat and its surroundings. In this project, two hydropower plants will be constructed in utilizing dams built on the St. Pursat for agricultural use, and the power generated will be supplied to Pursat and its surroundings for their general demand. The development plan also aims at securing the hydropower sources in establishment of the main power net work throughout the country in the future.

In the project area, power is supplied on the spots by the diesel generating plants of EDC at Pursat (generating capacity being 600 kW, peak output 230 kW) and other places, and by some parts of private power plant. Most of villages where power will be supplied by this project, can be mostly considered as areas of un-electrification.

Around the Great Lake areas including the project area, a main power supply system will be settled starting from Phnom-Penh, and this system will be connected with the main cities, such as Kg. Chhnang, Pursat, Battambang and so on in future, but the timing is not fixed under present conditions. In this project plan, the area of Pursat and its surroundings are to electrify local areas with a suitable scale at first, and at the next stage, to connect the main power supply system in a big scale throughout the whole country, then it is expected that power supply will be operated economically.

b) The Plan of Power Sources

The location of the hydropower plants to be constructed in the project plan are shown in Fig. 1, and the main features are indicated in Table 13.

Table 13 Contents of Power Stations in S-W Area of the Great Lake

Name of Power Station	Plant output		Annual generating energy (MWh)	Turbine					Generator				No. of Units	Construction Cost for electrical equipment (US$ 1,000)
	Maximun (kW)	Firm (kW)		Type	Max. output (kW)	Max. net head (m)	Max. discharge (m^3/s)	Speed (rpm)	Type	Rated output (kVA)	Voltage (kV)	Fre-quency (Hz)		
St. Pursat No.1	17,000	8,400	71,500	Vertical Deriaz	9,000	120	8.7	600	Vertical synchro-nous	11,000	11	50	2	1,280
St. Pursat No.2	3,500	1,300	9,000	Horizontal Kaplan (Tublar)	1,850	12	18.1	300	Tublar (synchro-nous)	2,200	6.6	50	2	665
Subtotal	20,500	9,700	80,500										4	1,945
St. Baribo	700	250	2,350	Horizontal Kaplan (Tublar)	730	14	6.26	600	Tublar (synchro-nous)	860	6.6	50	1	165
Total	21,200	9,950	82,850										5	2,110

Note: Speed of generator is same as that of each turbine.

Two power plants of St. Pursat No.1 and St. Pursat No.2 will be constructed at the upper river basin of the main stream passing through Pursat. Further, three more power plants of some 1,000 kW capacity each will be able to build on the tributaries of the St. Pursat, namely at St. Arai, St. Peam and St. Santre, but these plans are not included in the project study. Since they are uneconomical in the power cost compared with the cost of the St. Pursat No.1 and No.2 plants. And also, the demand to meet additional power from the tributaries is uncertain.

The maximum output of the two power plants will amount to 20,500 kW, the total firm output to 9,700 kW and the annual output energy to 80,500 MWh. Besides, each dam has an enough regulation ability of run-off, so that the peak discharge is decided to be divided in annual average discharge by 50% of the load factor.

c) The Plan of Transmission, Distribution Lines and Substations

Two hydropower plants in the river system of the St. Pursat will be connected with 66 kV transmission line each other, and will join on to Leach and Pursat. For this purpose, two receiving substations of 66/15 kW will be constructed at Leach and Pursat. Power supply for each load is principally conducted by the 15 kV distribution lines. These distribution lines will be equipped with from the hydropower plants, both substations at Leach and Pursat, and from some small substations for their local distribution purposes to be built complied with demand along the distribution lines.

Besides, the connection with the main power supply system in the coastal area of the Great Lake will be conducted at Pursat Substation.

d) The Plan of Power Consumption

The power generated at two power plants will be chiefly supplied with to the general power load at Pursat and other farm villages, and also to power demand for agricultural purpose including irrigation and drainage pumps.

e) The Power Cost

The cost of power generated at the St. Pursat No.1 and No.2 plants will be about ¢1.1/kWh at load center, after the cost allocation of dams. It will be enough usable from viewpoint of economy.

As for the breakdown of power cost including the share of dam cost allocated to power, refer to Appendix B.

III-4. Stung Daun Tri Project

The Stung Daun Tri has a catchment area of 835 km^2 at Maung and an annual runoff of 76 x $10^6 m^3$ in a droughty year. This river is most inferior to other rivers of the S-W coast of the Great Lake in its specific discharge. In the upstream there are some favorable sites to build dams, but it is not effective to construct a large dam, because of small quantity of runoff water. A dam, which might be of the earth fill and concrete type, could be created between Phnom Momung and Phnom Bek Peng with its high water level 100 m and 11 x $10^6 m^3$ of storage capacity at 3.5 m of water drawdown, so that it is possible to control runoff completely in a droughty year. Then the discharge from the dam will be 1.14 m^3/sec throughout a year. Further, provided that an diversion dam with H.W.L. 40 m, 690 km of catchment area is to be built at Phum Chrak Poplea, located between the hilly land and the plain in the downstream of the main dam, then it is possible to get 2.69 m^3/sec in the rainy season and 1.44 m^3/sec in the dry season from the diversion dam together with the discharge of the main storage dam.

Irrigation of 3,500 ha, in the south-western parts in which Maung is situated at the center, in the rainy season and of 1,170 ha in the dry season might be possible. The soil is comparatively fertile of Grayish Brown Soil - fine textured - so that it is possible to cultivate the rainy seasonal paddy in the rainy season and the dry seasonal paddy (950 ha) in the dry season, and forage (170 ha) and vegetable (50 ha) in the area. The cropping pattern is also considered to promote livestock farming and supply vegetable to Maung.

The target benefit of irrigation is computed to be $68/ha after completion of the project, and after that it is expected to be a 2% of annual increase of benefit. The project cost is \$4.63 x 10^3 or \$1,323/ha. The I.R.R. is computed to be between 4 and 5%.

As for hydropower generation, it is concluded that diesel power generation is superior to hydropower, only due to output around 500 kW.

III-5. Stung Mongkol Borei Project

The Stung Mongkol Borei is one of the biggest rivers in the south-western coast of the Great Lake, and has 4,170 km^2 of the catchment area at Mongkol Borei and a 440 x 10^6m^3 of annual runoff in a droughty year. At present 30,000 ha of paddy fields is being irrigated by the famous Bovel diversion dam (about 2,850 km^2 of its catchment area) from the river. Its tributary, the Stung Pailin, provides its discharge for irrigating coffee plantation near Pailin.

The catchment area of the river extends to Thailand, however it is mainly situated at the plainly area and there is no suitable site to build a storage dam. According to a 1 : 50,000 map, a reservoir could be created at the place of depression of about 40 km^2 in 5 m depth, left bank of the Stung Mongkol Borei in scattered clump of trees, and water to introduced from the Stung Mongkol Borei. That is by building a closing dam at Phum Ta Hen, 10.5 km in a straight beeline from the Bovel diversion dam in the upstream of the river, and another dike closing the Stung Dang, which are connected with the depression, a storage capacity of 106 x 10^6m^3, having H.W.L. at 30 m with a 4.5 m drawdown, could be created, taking evaporation loss into consideration. The Bovel diversion dam is of W.L. 24.5 m, maximum W.L. 25.5 m and 22.5 m of crest level.

In addition, a closing dam, having a 36 x 10^6m^3 of storage capacity with H.W.L. 44 m and 5 m drawdown, could be built at Phum Tuol, 16 km upstream in a straight beeline from the Phum Ta Hen dam.

Thus getting 142 x 10^6m^3 water, supplemental purpose for the extension plan of the Bovel irrigation project can be achieved. The original Bovel project is insufficient to irrigating 30,000 ha sometimes in summer of droughty periods, and in 1969 there were many paddy fields unplanted even in August. According to the computation of water requirement and supply in the Bovel project area, it is proved that 45,000 ha of paddy fields from June to October can be irrigated by the 2 proposed dams and be made a flood control between August and October, and 10,000 ha can be introduced double croppings of paddy in the dry season from December to March.

The project cost is computed to be \$23.9 x 10^6or \$531/ha, including costs for dam, main and branch canals in the proposed area of 15,000 ha (most of them is existing rain-fed paddy fields), and terminal irrigation systems and drainage canals for the whole area.

The target benefit is expected to be about \$45/ha, which is only considered to be available for paddy cultivation, and the I.R.R. is to be between 7 and 8%, assuming to be a 2% of increase benefit per annum.

As for hydropower generation, it will not be expected to develop hydropower generation, due to low head of both dams and big fluctuation of discharge.

III-6. Stung Sisophon Project

Stung Sisophon is a big stream, having 4,310 km^2 of its catchment area of Sisophon, and extends to Thailand about half of its catchment area. At present there is irrigation system including some of diversion dams in the main stream, which are utilized for the rainy seasonal paddy fields in some thousands hectares.

It is difficult to find out a suitable dam site to reserve the river flow in the territory of Cambodia. However, it is possible to make irrigation for about 8,000 ha of the existing paddy fields by creating a diversion dam at Phum Samrong located about 20 km downstream of Sisophon. The catchment area, where the proposed diversion dam is to be created, is limited within the area of St. Samrong (the name of the upstream of the St. Sisophon), and it amounts to 1,600 km^2 and is able to get river runoff about 8 m^3/sec in June and July of a droughty year. The river has a high flooding stage, but its discharge is scarce in the dry season, therefore irrigation in the dry season is impossible.

The soil is Grayish Brown Soil of fine textured, and is suitable for paddy cultivation. The target benefit of irrigation is expected to be $45/ha and the I.R.R. is computed to be between 4 and 5%, computing to be a 2% of annual increase benefit. The total project cost is computed to be $55 x 10^6 or $688/ha.

IV. Polder Project

IV-1. Area

An area of 249,000 ha is selected as a survey area for agricultural development by means of a polder system. This area extended on 2 provinces, Battambang and Pursat, is divided into 7 divisions for making the development plans. The area is habitually inundated with flood water of the Great Lake (below EL 10 m), from where the reserved areas for fish propagation (approximately below EL 5 m area in elevation) are excluded, and also unfavorable areas in topography and deep swamps, together with the areas too small to make a plan economically, are excluded. (Fig. 1)

Total net beneficial area will be 200,000 ha exclusive of lots for roads, canals and so on.

IV-2. Topography, Soils and Hydrology

Topography The polder area is composed of the flood plain of the Great Lake and of the tributaries pouring approximately perpendicular into the Lake. The drainage systems of the area, therefore show a dendritic pattern and the rivers are exceedingly meandered. The area descends slowly toward the Great Lake, from the southwest to northeast, at a slope of about 1 : 5,000.

Soils The area is composed of alluvial soils originated by the tributaries and lacustrine soils by the Lake, which textures belong to gray and grayish brown soil groups. Their productivity is high and the area is one of the most fertile farm lands in Cambodia.

Hydrology There are 5 major tributaries flowing down through the area, the Stung Mongkol Borei, the Stung Sanke, the Stung Daun Tri, the Stung Svay Donke and the Stung Pursat from the north. The hydrological conditions on the tributaries are described on III.

The Great Lake is wellknown as a lake to regulate the annual flood of the Mekong. The variation of the lake water level usually ranges from EL 1 m to 10 m, and the maximum lake level ever recorded is recognized as aground EL 11 m. The Lake capacity at EL 11 m is measured to be 72 x 10^3 x $10^6 m^3$ 1/, and the median Lake level is EL 9 m corresponding to 48 x 10^3 x $10^6 m^3$ 2/

IV-3. Land Use and Cropping Plan

Land Use A 85,000 ha area out of the total 200,000 ha is existing cultivated lands, of which most are paddy fields but few upland fields are seen around farm houses and along the tributaries. 70% of the existing paddy fields are for seasonal rice fed by rainfall only, the rest are for floating rice.

An increase of cropping intensity is planned together with enlargement of farm land, and dry season cropping will be introduced at the cropping intensity of 75%. This value of 75% is reasonablly decided considering the followings; low dry season cropping intensity at present, limitation of the pump capacity designed for rainy season cropping due to higher water requirement in the dry season than the rainy season.

A plan of land use is described in Table 14.

Table 14 Plan of Land Use

Name of Division	Present		Total	Project	
	Non-cultivated	cultivated		Rainy season	Dry season
A	2,000	4,000	6,000	6,000	5,100
B	7,000	7,000	14,000	14,000	11,000
C	23,000	9,000	32,000	32,000	26,600
D	6,000	9,000	15,000	15,000	12,300
E	37,000	15,000	52,000	52,000	36,600
F	16,000	25,000	41,000	41,000	37,000
G	24,000	16,000	40,000	40,000	30,000
Total	115,000	85,000	200,000	200,000	158,900

1/, 2/ "Mathematical Model of Mekong River Delta" Report I

<u>Cropping Plan</u> Paddy rice will be cropped over the whole area in the rainy season, fodder crops, besides paddy rice, such as sudan grass, tropical grass and so on will be introduced partially in the dry season.

A plan of dry season cropping by the division is as follows:

Division A: Paddy rice cropping mainly, fodder cropping for 300 ha, soil fertilizing required.

Division B: Paddy rice cropping mainly, fodder cropping for 900 ha, soil fertilizing required.

Division C: Paddy rice cropping mainly, fodder cropping for 1,800 ha, soil fertilizing required.

Division D: Paddy rice cropping mainly, fodder cropping for 900 ha, soil fertilizing required.

Division E: Paddy rice cropping mainly, fodder cropping for 1,700 ha, vegetable cropping for 100 ha.

Division F: Double-cropping of paddy rice, fertile soil.

Division G: Double-cropping of paddy rice, fertile soil.

IV-4. Irrigation and Drainage Plan

<u>Irrigation Plan</u> Evapotranspiration is calculated by the Blaney-Criddle formula, the designed unit water requirement per 1,000 ha is;

Paddy fields (clayey texture, percolation of 2 mm/day)

Dry season; $8.3 \times 10^4/86{,}400 \times 0.75 = 1.28\ m^3/sec$

Rainy season; $7.1 \times 10^4/86{,}400 \times 0.75 = 1.10\ m^3/sec$

Upland fields (dry season)

Grass; $4.7 \times 10^4/86{,}400 \times 0.75 \times 0.70 = 1.04\ m^3/sec$

Vegetables; $3.8 \times 10^4/86{,}400 \times 0.75 \times 0.70 = 0.84\ m^3/sec$

75% of the monthly rainfall more than 50 mm are taken into account as effective rainfall for irrigation.

As irrigation water resources for the polder project area are tributary waters and the Lake waters in addition to the rainfall mentioned above. The tributary waters will be taken by constructing a diversion dam at the upstream site of the area. The rest water to be supplied will be lifted up from the Lake.

Drainage Plan As to drainage of rainfall in the rainy season, an unit discharge equivalent to 12 mm/day is decided considering a runoff control effect of the paddy fields. Intercepting drainage canals will be constructed along the mountain side boundary of each division to catch rainfall water from mountains and reduce the construction cost of drainage facilities. Drainage pumping stations are necessary to drain out rainfall water.

Polder Dike In order to prevent the area from flooding of the Great Lake, polder dikes with a crest of 5 m width will be constructed at EL 12 m in crest height, and the polder dikes along the tributaries running through the area are also planned.

Duel-purpose Pumping Plan All pumping stations to be installed at the downstream of the area have the duel functions of irrigation and drainage. The operation of the duel-purpose pump is manageable, as the pump will be mainly used for drainage in the rainy season.

Movable weirs will be constructed at the estuary of the tributaries with the pumping station to keep the water level at EL 10 m. In the dry season, irrigation water lifted from the Great Lake, being adversely discharged up through the tributary, will be taken into the field at the diversion dam.

In the rainy season, a part of waters of the tributary will be divided for irrigation at the diversion dam, and the rest will be drained off to the Lake by operating the movable weirs. The pumping station will function for drainage from the field.

The cost of the duel-purpose pumping station is cheaper than the total of 2 single purpose stations. A total installed capacity is 48,120 kW and maximum required energy is 34,760 kW.

IV-5. Costs and Benefits

Construction Costs Total required costs for the polder project is $241,740 x 10^3 corresponding to $1,209 per ha on an average.

Construction costs for each division are indicated in Table 15.

Table 15 Construction Costs by Division

($)

Division	A	B	C	D	E	F	G	
Total(10^6)	8.58	18.11	43.89	17.02	60.14	44.19	49.81	241.740(total)
Per ha	1,430	1,294	1,371	1,135	1,156	1,078	1,245	1,209 (Average)

Annual Costs Annual costs are estimated on the basis of the following assumption.

Analysis period: ----------- 50 years
Economic life: Pump -------- 25 years
Others ------ 50 years
O & M cost: Power tariff ------- 1% of total cost
Others ------------1.5% of total cost
Total 2.5% of total cost

Present worth values of annual cost discounted over 50 years of the analysis period is illustrated in Fig. 5 at 3 - 8% interest rate.

Benefits A target benefit will be realized in the 5th year after completion of the project. Furthermore, by such effects as development and extension of agricultural techniques, and improvement of product in quality and market conditions, the target benefit will be increased at an annual rate of 2%, in which the increase of agricultural input is considered. Namely, the target benefit will be 2.438 times in the 50th years after completion of the project. The target benefit is described in Table 16.

Table 16 Costs and Target Benefits

Division	Area (ha)	Costs in $		Target benefits in $	
		Total (10^3)	per ha	Total (10^3)	per ha
A	6,000	8,580	1,430	557	93
B	14,000	18,110	1,294	1,388	99
C	32,000	43,890	1,371	3,236	101
D	15,000	17,020	1,135	1,553	104
E	52,000	60,140	1,156	5,386	102
F	41,000	44,190	1,078	4,437	108
G	40,000	49,810	1,245	4,229	106
Total	200,000	241,740	(1,209)	20,786	(103)

Parentheses show average value.

The present worth values of annual benefit with a 2% of annual increasing rate, being discounted over 50 years, are plotted in Fig. 5 with the annual cost.

Internal Rate of Return (IRR) The IRR of the whole polder project area is 5.9% as shown in Fig. 5. The IRR of each division ranges from 4.6% of A division at the lowest to 7.9% of F division at the highest.

[illegible]