DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK

PHASE I

EXECUTIVE SUMMARY

PREPARED FOR

THE MEKONG SECRETARIAT

BY

ORSTOM IN ASSOCIATION WITH BCEOM

ORSTOM

OCTOBER 1993

BCEOM

DEVELOPMENT PLAN

FOR TONLE SAP AND CHAKDOMUK

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October 1993

SCOPE OF THE STUDY

The Great Lake of Cambodia is the largest permanent freshwater lake in Southeast Asia, covering areas between 2 500 km² during the dry season and more than 13 000 km² at the end of the rainy season. The Great Lake is connected to the Mekong by the Tonlé Sap River. The confluence is at Chakdomuk in Phnom Penh city, some 120 km to the south-west of the outlet of the lake.

The study area (comprising the Great Lake, the Tonlé Sap River and their surrounding wetlands and agricultural fields) constitutes a highly productive ecosystem for the country. However, several reports have indicated that environmental conditions have changed during the last years. The siltation of the Tonlé Sap, especially at the confluence with the Mekong and at the entrance of the lake (near Snoc Trou) was reported as being an obstacle to the flow in the Tonlé Sap River. It was also alleged that sedimentation has significantly reduced the depth of the lake. Serious reduction in fish catches have also been reported. Sedimentation and uncontrolled fishing practices are thought to be major causes for this reduction.

The Interim Committee for Coordination of Investigations of the Lower Mekong Basin resolved to address these problems, including inland navigation aspects and river morphology problems in the confluence area of Chakdomuk, through a comprehensive integrated development plan of the area. The ultimate objective of the project is to develop the Tonlé Sap's resources in a sustainable and environmentally sound way, the immediate objectives being :

(i) to identify and examine the environmental changes, the present use of the natural resources and the development possibilities ; and
(ii) to propose specific actions for preserving the environment and to select and implement priority projects for short and long-term development of the area.

BCEOM, in association with ORSTOM (the French Institute for Scientific Research and Cooperation for Development) was entrusted with the study. The project was financed by the Government of France and by ORSTOM, which granted 3 man-months of international expertise to the project.

Phase I of the project was an identification and fact-finding phase. The objectives were the following :

(i) to review available reports and data related to the Great Lake, Tonlé Sap, and surrounding areas ;
(ii) to undertake an inception mission in Cambodia, including field reconnaissance and collection of all information available in Cambodia and meetings with the development agencies, including the technical departments of the ministries of Agriculture and Transport & Communication, the Cambodian National Mekong Committee, the United Nations Development Programme (UNDP) and several UN executing agencies (FAO, UNESCO), the United Nations Transitional Authority in Cambodia (UNTAC), the French Embassy in Cambodia, several NGOs (GRET, SAWA, PADEK, etc.) ;
(iii) to conduct relevant data interpretation and studies, and to select priority projects for management and development of the resources of the project area, including a programme of data collection and investigation.

Eight experts, including two national/regional staff were assigned by BCEOM and ORSTOM to provide expertise in the various fields of hydrology, river morphology and sedimentology, environment, aquatic biology, fishery, agriculture, socio-economy and navigation. All staff carried out a joint inception mission in Cambodia from 10 to 23 March 1993. An inception report of the mission was drafted and submitted to the Mekong Committee on 26 March 1993. The draft final report was presented and discussed with the national authorities and the international and regional organisations concerned during a workshop held in Phnom Penh on 24 August 1993. The final version of this report was submitted in October 1993.

The Consultants wish to express their thanks to the Mekong Secretariat's officials, to the Cambodia National Mekong Committee who ensured coordination of the project and generally to all authorities who kindly extended their assistance to the team of experts and made the implementation of this study possible.

GENERAL CONCLUSIONS AND JUSTIFICATION OF AN INTEGRATED DEVELOPMENT PLAN

Phase I of the Development Plan for Tonlé Sap and Chakdomuk provided the forum for a preliminary assessment of existing conditions which has been carried out mainly on the basis of a review of existing available data. "*The lack of quantitative and reliable data, especially during the past 15 years, is the more general finding of each sectoral assessment*" (Inception Report p.22). This situation has severely restricted the certainty of the conclusions given in the sectoral assessments of the Report. As an example, two crucial issues could not be solved :

- Does the sedimentation rate occur with its natural and normal magnitude or is there any recent and on-going significant increase of this rate which could threaten the sustainability of the physical and biological environment in the wetland area, and hamper its economic exploitation (fish, navigation, etc.) ? This question applies especially to the Great Lake, and to some extent to the Tonlé Sap river, where it appears that Mekong sediment deposit at both end of the stream (Snoc Trou and Chakdomuk) has been a natural and long lasting process.
- Is the current pressure of the fisheries sustainable for the bio-ecological environment ? As discussed in the technical section on fisheries, a definite answer would require accurate information on the actual level of the catches and the composition of the catches by size and specie. The socio-economical conditions in Cambodia are changing at an unusual high rate which will undoubtedly urge the fishermen on higher fish production. Thus, recent data on catches and on fish marketing conditions are absolutely necessary, but as it has been shown in the analyses of fisheries and fish production (Section C), the available data are patchy and most of them have been collected several decades ago.

It is a long term objective for any country to access accurately the situation of its renewable resources (water, fish, forests, etc.,) and the conditions of their exploitation. This implies the set up of efficient technical departments, having strong scientific back-up. Institutional building, training of staff, availability of field equipment and data processing facilities are the required components to achieve such objectives. High priority should be given by the National Authorities to such

programmes, even if the Nation's priorities have to be focused on more urgent and day-to-day issues. Regional institutions such as the Mekong Committee can play a key role in promoting such long term investigations and data collection.

Therefore, additional data collection, surveys and investigations are clearly one of the objectives of the coming phase II and should be undertaken as soon as possible.

- But as the indicative duration of phase II is 2 years only, it is clear that most results and analysis of long term "strategic" data collection will not be available before the end of phase II. Therefore during this phase, priority should be given to small scale surveys and data collection programmes, aiming at the verification of the tentative conclusions presented during phase I of the project.
- On the other hand, the implementation of a development plan of the area, which is a long term and a permanent process, will require long term data bases, permanently updated, to take into account the natural fluctuations and the socio-economic trends. As such, the project must stress the needs for long term data collection programmes in different sectors (water, fish, wild-life, land use, transport infrastructure, etc.), even if these activities are not carried out within the institutional and financial framework of the project.

It would however be unrealistic as well as unacceptable for the Country to delay the formulation of a development plan of the area until all above mentioned data and information have been collected and analysed. Currently a dynamic and mostly informal development process is taking place in the whole country, and especially in the project area. The fringes of the Great Lake and of Tonlé Sap River are target areas for the returning refugees and displaced persons. Most of them are believed to be farmers and therefore pressure on agricultural land and possibly on forests will increase. Some of the newcomers may as well undertake activities providing higher and more immediate income than agriculture such as fishing, fish processing, wood processing (charcoal, construction wood), wildlife poaching, etc. Under such specific conditions, even without all desirable information on environmental characterisation, the basics of an environmentally sound development plan can be formulated and implemented, on the basis of the few available data, general expertise and common sense. It is expected also that aside from the required data collection programmes previously mentioned, large quantities of information will be available in the very near future, as several sectoral reviews are currently in progress, such as the review of the fishery sector by FAO; the review of the irrigation sector by UNDP, the review of the agricultural sector by FAO, etc. Information on population has already been collected for the purpose of the May general elections.

The immediate tasks of the proposed Integrated Development Plan project will include :

- to centralise and analyse all relevant information on the area ;
- to advise the Government in the decisions concerning the development of the area ;
- *to* set up an institutional framework which will be able to formulate a plan for an integrated and sustainable development of the area. This will include the definition of rules and of working procedures between the identified stakeholders (national, regional, international, bilateral). It has been proved in every country that inter-

ministry collaboration can be a delicate process, which would require a specific institutional forum to share the information and to come to a consensus when any decision has to be made. The building of this *ad-hoc* institution is clearly an objective on which the project should be focused in its initial step. The National Mekong Committee could play a key role in the implementation of such coordinating process.

SECTORAL CONCLUSIONS AND RECOMMANDATIONS

Hydrology and sedimentology

The major recommendations of the hydrological and sedimentological assessment were the following :

(i) As a preliminary estimate, the catchment of Great Lake would contributes about 1/3 of the total water flow volume entering the Great Lake. The sedimentation of the Great Lake and of the upstream and downstream sections of Tonlé Sap River (at Snoc Trou and Chakdomuk) are major concerns reflected in the terms of reference of this study. There are no data currently available to support the assumption that the sedimentation rate of the lake is higher now than it was 30 years ago. However; very significant changes in land use of the Great Lake drainage basin have been reported (mining activities, logging, etc.). The importance of these issues and the different interpretations of the few available information warrant the priority projects addressing the bathymetric survey and sedimentation assessment of the Great Lake. Hydrological stations shall be installed and an operational monitoring of liquid and solid discharge carried out on the major tributaries of the lake and/or at the outlets of the most disturbed watersheds, at least for one or two monsoon seasons.

A minimum network of six hydrological and sediment monitoring stations is proposed. Core samples of the bottom of the lake shall be taken and analysed using the more up-to-date techniques, to assess the long term siltation rate over several centuries (considered as being the "natural" process). This figure shall be compared with the rate of the last decade(s), given by the analysis of the upper part of the cores and by the sediment delivery figures, given by the solid discharge monitoring of the lake tributaries.

(ii) At the mean time, as the contribution of Mekong river would be around 2/3 of the total water supply of the lake the Mekong flows in Phnom Penh and the upstream and downstream flows (water and sediment) of the Tonlé Sap River shall be monitored. The Mekong control station in Phnom Penh should be backed-up by an upstream station; the best option being the rehabilitation of the station of Kratié.

(iii) Interpretation of the water levels of Tonlé Sap River in Kompong Chhnang has shown that the differences in the annual maximum levels of the lake range from 1 to 2 m, which result in changes of several thousands of km^2 for flooded area and of more than 10×10^9 m^3 for water storage. If several years with low flows follow each other, which has happened several times in the recent past, the ecological conditions are temporarily modified, with subsequent effects on fish development and fishery catches. Therefore it is recommended to monitor the

water level of the Great Lake and to determine accurate curves relating flooded area and water storage, which implies to undertake :

- a bathymetric and topographic survey of the lake, to be conducted on the overall area, including the remaining water body at the end of the dry season and the flooded area in its largest possible extension, and,
- the continuous recording of the lake water level, possibly at two different sites.

(iv) The expertise did not identify any impact of existing dams or hydraulic control structures on the Great Lake water balance. This conclusion should however be considered as an initial and tentative estimation, to be improved through comprehensive and careful analysis of all hydrological data collected on the Mekong main stream and its main tributaries.

Fish and fisheries

(i) Any modification in the Mekong flows and floods have consequences on the environment and resources of the study area. Similarly, all modifications of the environment and resources in the Great Lake can have consequences in Mekong river - mainly downstream of Phnom Penh -, but also upstream in the case of migratory fish. The role and importance of the inundated forests in relation to reproduction of fish have inspired many assumptions. These forests have been used since ancient times by fishermen as sources of wood for cooking, construction, fish traps. In addition, the land clearing for agriculture has probably been particularly destructive during the last decades. Based on the available evidence, this ecosystem deserves protection, appropriate management and detailed study to determine its capacity for renewal and its role in relation to fish reproduction.

(ii) Assessment of the living resources is particularly difficult because of the scarcity and unreliability of the available data. A generally held viewpoint, supported by several expert opinions, is that there is currently an over-exploitation of the fish and a "*general decline in yields*". Our conclusion is much more moderate, firstly because there are no data to support such a viewpoint and secondly because the data which do exist show a situation of relative stability, and the variations in yield can be attributed as much to natural causes as to the harmful effects of man's activities. If the pressure on the living resources of the Great Lake has probably been relatively low during the last twenty years, because of stagnation of development, this situation is changing rapidly. Population growth, attraction of new markets and short term prospects are putting an increasing pressure on fish and other natural resources. The existing legislation aiming at the protection of the renewable resources has to be improved, both in its relevance to the changing conditions and to its application.

An overall project, which would integrate the research and development aspects, concerning the sustainable management of Great Lake/Tonlé Sap living resources is recommended. The implementation of such a project, will require a more longer period than two years, and would therefore go beyond the scope of Phase II. As such, the two proposed priority projects, identified in this study as *Bio-ecological Basis for Fish Production* and *Response of Fishermen to Environmental and Socio-*

Economic Changes, shall be considered as first contributions to the overall project, aiming at the verification of the different hypotheses presented in the final main report.

Navigation

(i) The rehabilitation and extension of the port of Phnom Penh will be completed by the end of 1995. Ships up to 4 000 DWT will then be able to access the port located on the bank of Tonlé Sap river, but continuous dredging of the access channel at Chakdomuk will be required. In the long term, with the proposed new port at Chrui Changvar on the Mekong river mainstream, the Chakdomuk pass dredging may not be necessary. Therefore, there is a risk that the existing entrance channel of Tonlé Sap river may be blocked by sediment.

(ii) Tonlé Sap river is navigable from Phnom Penh to Kompong Chhnang all year round by boats up to 150 T, but navigation beyond Kompong Chhnang to the Great Lake is hampered by the shallow pass at Snoc Trou. Important agricultural and forestry resources, as well as fish, could be transported more economically by waterways along the naturally favourable system provided by Tonlé Sap. This is particularly relevant to the poor road conditions during the rainy season, when waterborne transport becomes the only link for certain areas with the rest of the country. Navigation requires less maintenance and investment than highways and is a low-energy mode of transport, consuming from 50 to 75 % energy less than road transport, and therefore providing better protection of the environment. Boats for Tonlé Sap could be built locally with limited amounts of imported equipment and material.

In-depth investigations and study of navigation development in Tonlé Sap are therefore strongly recommended to determine optimum use of its natural resources in this respect.

Agriculture

(i) Based on available climatic, rainfall and crop production data, irrigation is required for the development of agriculture even in the wet season, but the most suitable type of irrigation scheme for each specific area needs to be determined. Therefore, it is recommended to prepare a comprehensive development plan for irrigation in the study area, giving careful attention to any possible environmental impact. Agriculture development projects located outside the riparian areas of the lake and Tonlé Sap River, but in the same catchment area, needs to be taken into consideration as well, since they may have strong impact on the environment of the project area.

(ii) The studies for agricultural improvement of several irrigation projects in Tonlé Sap basin, such as Battambang Multi-purpose Project and Stung Mongkol Borey Irrigation Scheme, are presently on-going. In addition, the inventory of existing irrigation projects is included in the on-going Irrigation Rehabilitation Study of Mekong Secretariat. The results of these studies will be extremely relevant for the planning of irrigation and agricultural development in the Tonlé Sap - Great Lake project area.

(iii) A small scale irrigation pilot project (area of 100-400 ha) should be implemented, aiming at the development of participatory management and capacity strengthening of governmental technical staff and farmers. It is expected that the present government policy of developing private ownership of agricultural land will encourage the farmers to actively participate in such projects.

Environmental aspects

No evidence was found that the Great Lake is on the fringe of an environmental disaster. Existing speculations of high siltation rates, prevention of fish migration and fish reproduction as well as over exploitation of the aquatic resources are not based on hard data. Figures of current deforestation rates of the inundated forest could not be found, but the process is taking place in some areas. The major environmental impacts are currently expected to be :

- sedimentation and pollution of the Battambang River and of the Great Lake due to gem mining in the upper parts of the watershed ;
- possible impact of deforestation of the inundated forest on wildlife, fish and fisheries yields ;
- Possible impact - especially on aquatic life and fisheries - of domestic waste water released from the urban areas (Phnom Penh, Siem Reap, Battambang, etc.).

To assess environmental impacts in the Great Lake, data has to be collected during base-line surveys and consecutive interpretation studies have to be carried out, especially in the fields of hydrology, sediment transport, water quality, fisheries, land-use and socio-economy. Environmental impact studies will be a worthwhile exercise for the purpose of a regional development plan only when this base line data will be available.

PROPOSED PRIORITY PROJECTS

In line with the conclusions given above, recommendations for further activities consist of several coordinated actions to be undertaken as part of Phase II of the Development Plan for Tonlé Sap and Chakdomuk. The actions recommended to be carried out during Phase II are presented in the form of lone-standing priority projects. For the sake of consistency and coordination of the proposed actions with other actions being implemented, the setting-up of an institutional structure able to formulate the integrated and environmentally sound development plan is recommended as a major priority project, thereby making a total number of six recommended priority projects as follows :

PROJECT No.1 : INTEGRATED DEVELOPMENT PLAN FOR THE GREAT LAKE, TONLE SAP AND CHAKDOMUK

This project is expected to ensure coordination and consistency to the whole Phase II Development Plan.

Development planning has to be considered as a dynamic process, with periodical assessment of the results and updating of the objectives. The first step could therefore be based on existing information and on data supplemented by limited additional investigations and survey to be undertaken during the formulation of the Plan. Institutional strengthening and national capacity building should be initiated at the same time as the formulation of the Plan.

The functions of the new institutional set up should include the following :

(i) to coordinate and to synchronise the sectoral planning ;

(ii) to advise the decision making in screening projects in order to avoid duplication and to ensure that the projects will not pre-empt the long-term development ;

(iii) to build up a comprehensive data base on the project area and make the information accessible to line agencies and donor countries/organisations.

The main activities of the project will include :

(i) During the first year
- additional investigations, survey and data collection,
- collection and review of new information and data from on-going and planned projects in the Tonlé Sap - Great Lake area ;
- sectoral reassessments based on updated information and identification of the potential and constraints of each sector (fishery, agriculture, navigation, tourism...) ;
- establishment of the new institution and training of core staff, especially on integrated regional development planning ;
- analysis of the government policy, strategy and priorities.

(ii) During the second year
- preparation of scenarios of long-term development ;
- formulation of a short-medium term development plan.

Duration : 2 years

Cost : US$ 700 000

PROJECT No.2 : BATHYMETRY AND SEDIMENTOLOGY OF THE GREAT LAKE

The need for a bathymetric and topographic survey of the flooded area of the Great Lake and the Tonlé Sap was discussed and justified to address issues regarding water management, environmental aspects and navigation purposes. Due to its foreseeable high cost, this has to be considered as a major technical support project for the country. The expected outputs are :
- bathymetry of the "dead storage" area of the Great Lake (dry season conditions).

- topography and/or bathymetry of the zone flooded during the monsoon season (up to the highest water levels - around 10 m asl).

The sedimentological study component comprises core sampling and suspended sediment study. It has to be undertaken in close coordination with the hydrological monitoring of the main tributaries of the lake and of the Tonlé Sap River.

Duration : 8 months

Costs
- Topographic and bathymetric survey : US$ 1 000 000 (estimate)
- Sedimentological study : US$ 170 000

PROJECT No.3 : HYDROLOGICAL MONITORING OF TONLE SAP BASIN

Since 1963 no comprehensive assessment has been carried out simultaneously on water and sediment dynamics of the overall hydrological system of the Great Lake watershed, Tonlé Sap River and Mekong. According to many findings, the characteristics of the lake have changed since, but with the lack of any recent data, it is quite impossible to find any solid element to support such findings, and an hydrological and sedimentological network has to be implemented in the area, as is usually the case in the monitoring of wide water bodies such as the Great Lake.

Duration : 3 years

Costs :
- US$ 500 000, according to the specifications of the country-wide hydrological rehabilitation project
- US$ 400 000, for a scaled-down project

PROJECT No.4 : BIO-ECOLOGICAL BASIS FOR FISH PRODUCTION

The proposed approach of fish bioecology in the framework of Phase II focuses on fish movements between the Mekong basin and the Great Lake with special attention to the Chakdomuk area. This preliminary study of migrations will pave the way for other ecological aspects : reproduction and growth.

Species to be observed and surveyed should be focused on the current catches in different sites, such as selected *days* in Tonlé Sap River, fishing barriers at Snoc Trou, fishing lots in the lake and around the confluence zone of Chakdomuk.

Duration : one year

Cost : US$ 200 000

PROJECT No.5 : RESPONSE OF FISHERMEN TO ENVIRONMENTAL AND SOCIO-ECONOMIC CHANGES

Fishery in the studied area is a major activity with important socio-economic and environmental impacts. There are some indications of strong changes in fisheries management and marketing due to changes in the socio-economic context.

The main objectives of the project are :

- to appraise the effects of the current regulation of fisheries ;
- to estimate of the impact of fisheries on the living aquatic resources, in particular regarding the sustainable management of the fishery sector ;
- to identify catching and processing techniques which could endanger the resource or the environment ;
- to review the present conditions of fish processing and marketing and its recent evolution ;
- to estimate the prospective of cage culture development as an alternative to the fishery effort.

Duration : one year

Cost : US$ 150 000

PROJECT No.6 NAVIGATION DEVELOPMENT IN TONLE SAP

The proposed approach under Phase II comprises an economic and technical assessment of inland navigation development from Phnom Penh to the Great Lake and its tributaries. The main objectives of the project are :

- to identify the actual resources of Tonlé Sap system in respect of navigation ;
- to estimate investment and operating costs of navigation improvement in Tonlé Sap system ;
- to work out the potential transport demand in terms of passengers and freight and to assess technically and economically the viability of navigation development on Tonlé Sap system ;
- to evaluate navigation development relating to the development of touristic activities in the area ;
- to review the dredging needs governed by international navigation in the Chakdomuk area at various time scales and for various options of national port development plans.

Project activities and expected output will include :

- hydrographical survey of Tonlé Sap River by cross section soundings to produce navigation charts, especially for the difficult sections at Chakdomuk and Snoc Trou ;
- the study of dredging and other works required to open navigation channels in the lake (estimation of capital and maintenance dredging quantities, dredging methods and costs) ;
- the technical and economical assessment of inland navigation conditions ;
- a tourism development study related to boat cruises on Tonlé Sap River ;
- a review of alternative plans of port development country-wide.

Duration : 6 months, not including time for surveys and mapping.

Cost : US$ 135 000, not including surveys and mapping works.

Workshop on Development Plan for Tonlé Sap and Chakdomuk (Phnom Penh, 24-25 August 1993)

Formal address by H.E. Mr. Kon Som Ol, Chairman of Cambodian National Mekong Committee, Ministry of Agriculture, Forests and Fisheries

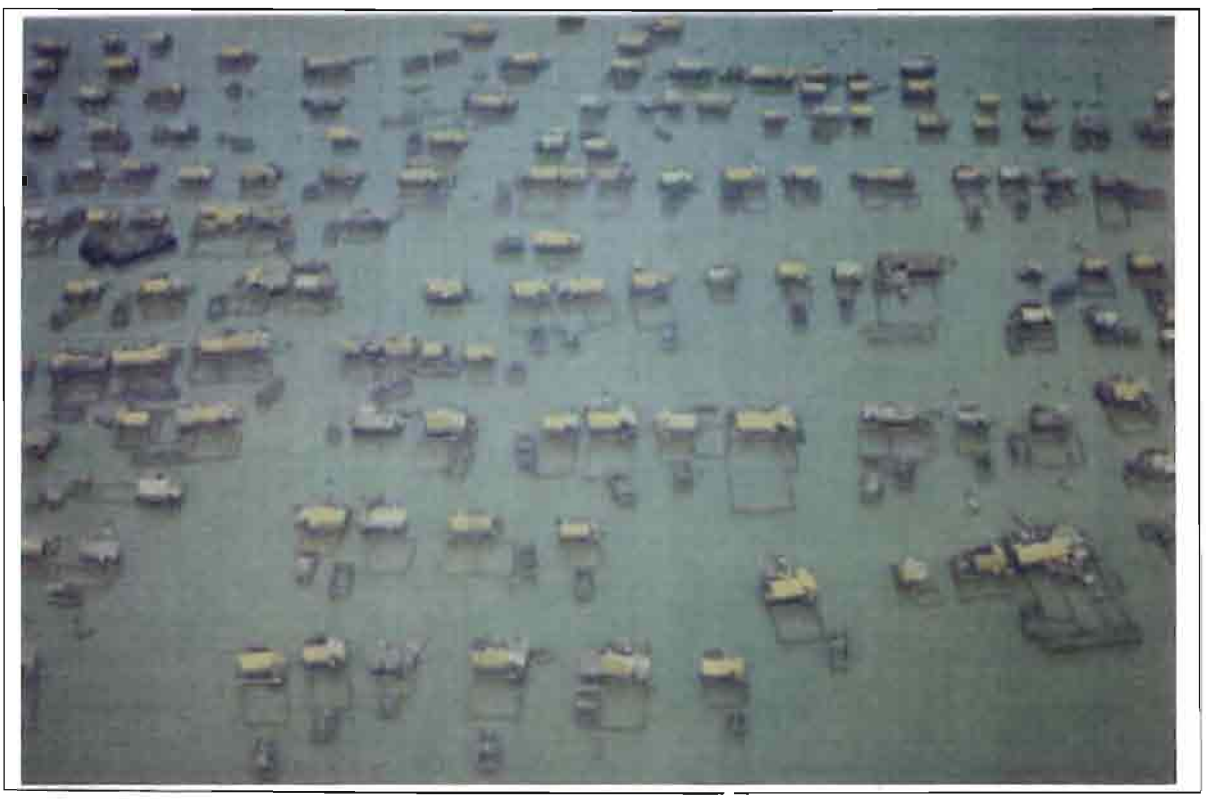
Formal Address by Mrs Do H. Phan, Mekong Secretariat

Workshop on Development Plan for Tonlé Sap and Chakdomuk (Phnom Penh, 24-25 August 1993)

Presentation of the report by the consultant

DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK

PHASE I



FINAL REPORT

PREPARED FOR

THE MEKONG SECRETARIAT

BY

ORSTOM IN ASSOCIATION WITH BCEOM

ORSTOM

OCTOBER 1993

BCEOM

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ORSTOM

OCTOBER 1993

BCEOM

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ANNEXES

A. INTRODUCTION

A.1 SCOPE

The Great Lake is the largest permanent freshwater lake in Southeast Asia. The lake covers an area varying between 2 500 km² during the dry season with an average depth of less than 2 metres, and more than 13 000 km² at the end of the rainy season with a maximum depth of 8 to 10 metres. The Great Lake is connected to the Mekong by the Tonle Sap River. The confluence is at Chakdomuk in Phnom Penh city, some 120 km to the southwest of the outlet of the Lake.

The study area (comprising the Great Lake and its surrounding wetlands and agricultural fields, and the Tonle Sap River) constitutes a highly productive ecosystem. It has always been the most important inland fishery resource, not only for the population living in the area but for the whole country. **Figure A.1** shows the location of the principal features of the study area in relation to the provinces and international boundaries of Cambodia.

Several reports in the 1960's indicated that physical conditions have rapidly changed. The siltation of the Tonlé Sap, especially at the confluence with the Mekong and at the entrance of the lake (near Snoc Trou) was reported as being an obstacle to the flow in the Tonle Sap River. It was also alleged that sedimentation has significantly reduced the depth of the lake.

Serious reduction in fish catches have been reported. Sedimentation and uncontrolled fishing practices are thought to be major causes for this reduction ; this decline in catches led to a technical feasibility study of a barrage on the Tonlé Sap river in 1967. The location of the proposed dam is near the entrance of the Great Lake, about 3 km north of Kompong Chhnang (Figure A.1).

The Interim Committee for Co-ordination of Investigations of the Lower Mekong Basin (The Interim Mekong Committee or IMC) resolved to address these problems, including inland navigation aspects and river morphology problems in the confluence area of Chakdomuk, through a comprehensive integrated development plan of the area.

The project was launched with the invitation to bid N° CAM/167/TSAP "Consultancy Services for the Development Plan for the Tonlé Sap and Chakdomuk, Phase I". The deadline for the proposals was 25 February 1993.

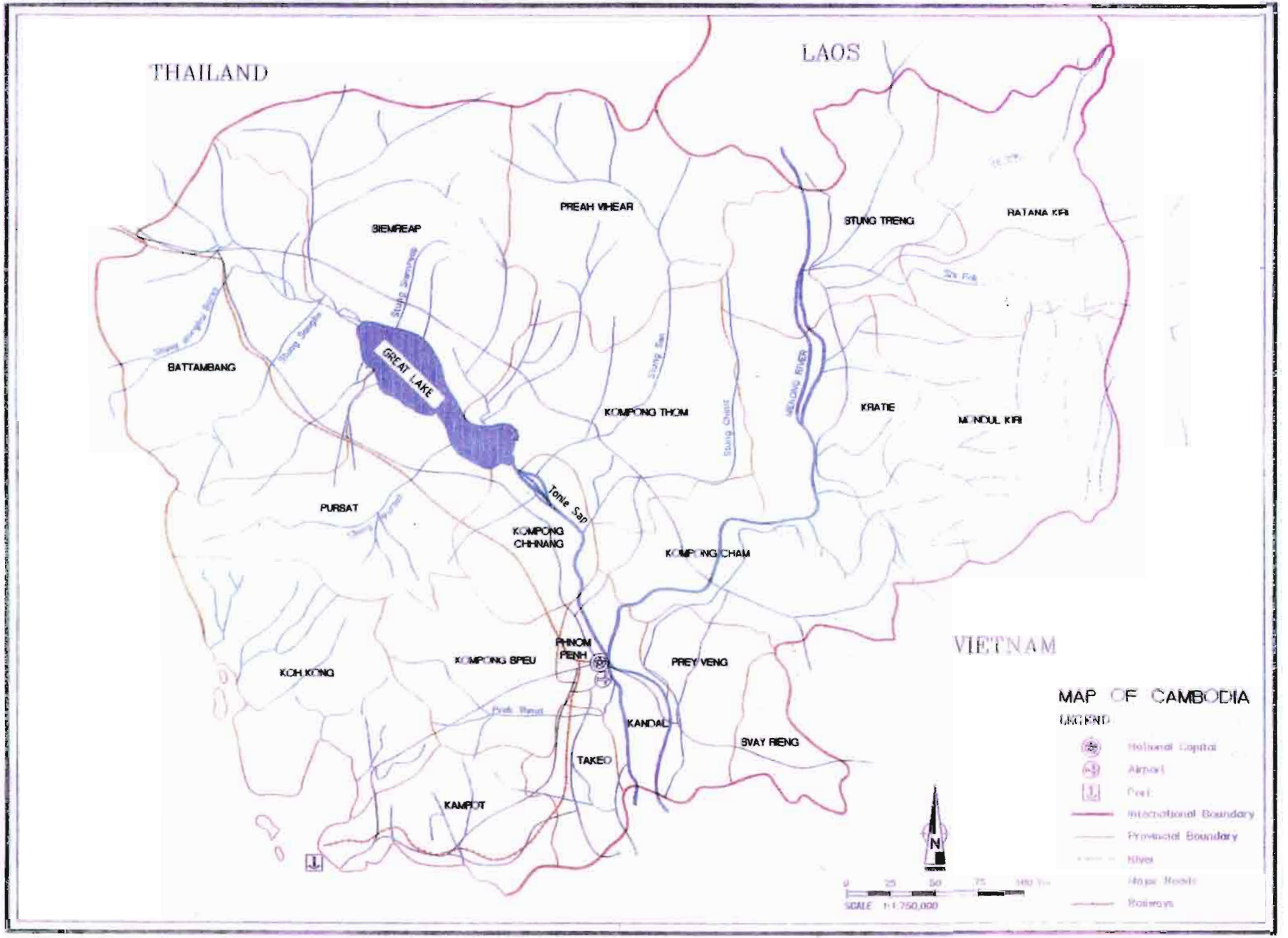
THAILAND
LAOS
VIETNAM
PREAH VIHEAR
STUNG TRENG
RATANA KIRI
SIEMREAP
BATTAMBANG
GREAT LAKE
KOMPONG THOM
KRATIE
MONDUL KIRI
MEKONG RIVER
Tonle Sap
PURSAT
KOMPONG CHHNANG
KOMPONG CHAM
PHNOM PENH
KOMPONG SPEU
PREY VENG
KOH KONG
KANDAL
SVAY RIENG
TAKEO
KAMPOT
MAP OF CAMBODIA
LEGEND
National Capital
Airport
Port
International Boundary
Provincial Boundary
Rivers
Major Roads
Railways
N
SCALE 1:1,750,000

Figure A.1

A.2 OBJECTIVES

According to the Mekong Secretariats' Project summary sheet, and Terms of Reference, the ultimate objective of the project is to develop the Tonlé Sap's resources in a sustainable and environmentally sound way. The immediate objectives are :

1) To identify and examine the morphology changes, the present use of the natural resources and the development possibilities ; and
2) To propose specific actions for preserving the environment and to select priority projects for short and long-term development of the area and to select and implement priority projects.

A.3 PROJECT AREA

The Project Area is specified in the Mekong Secretariat's Project summary sheet and terms of reference as follows :

> "The project area covers the Great Lake, its surrounding area, the Tonlé Sap river including the confluence with the Mekong at Chakdomuk".

However, a more accurate and detailed definition deserves to be discussed and finalized in view of further implementation of the Development Plan for Tonlé Sap and Chakdomuk.

In scientific terms, as the study addresses such matters as hydrology, sedimentation, irrigation and navigation, the project area does spread over the entire catchment area of the Great Lake and Tonlé Sap river. This means that all liquid and solid discharges to the Great Lake should be taken into consideration, as far as it affects the project (see Figure C.1).

However it is understood that the actual area where proposed Phase II projects would be implemented is restricted to lands likely to be flooded by the Great Lake, in addition to the Tonlé Sap river and the zone of confluence of Chakdomuk.

In this connection, the proposed definition of the project area is the strip of territory stretching from Sisophon to Phnom Penh of which the boundaries are the layout of RN6 to the north and east and, the layout of RN5 to the west and south.

A.4 IMPLEMENTATION

BCEOM, in association with ORSTOM (the French Institute for Scientific Research and Cooperation for Development) was entrusted with the study. The project was financed by the Government of France and by ORSTOM, which granted 3 man-months of international expertise to the project. Experts were mobilised on 10 March 1993.

Phase I of the project was an identification and fact-finding phase. The objectives were the following :

(i) to review available reports and data related to the Great Lake, Tonle Sap, and surrounding areas;

(ii) to undertake an inception mission in Cambodia covering :

- field reconnaissance for observation of the natural conditions and collection of all relevant data and information available in Cambodia ;

- meetings with the development agencies in Cambodia, including :

  . technical departments of the Ministries of Agriculture, Transport Communication, and Post ;
  . the Cambodian National Mekong Committee ;
  . the United Nations Development Programme (UNDP), and certain UN executing agencies (FAO, UNESCO) ;
  . the United Nations Transitional Authority in Cambodia (UNTAC) ;
  . the French Embassy in Cambodia ;
  . NGO's (GRET, SAWA, PADEK, etc.).

(iii) to conduct relevant data interpretation and studies, and to draft an assessment report, and

(iv) to select priority projects for management and development of the resources of the project area, including a programme of data collection and investigation.

Eight experts, including two national/regional staff were assigned by BCEOM and ORSTOM to provide expertise in the various fields of hydrology, river morphology and sedimentology, environment, aquatic biology, fishery, agriculture, socioeconomy and navigation.

For BCEOM :
- Mr. J. Bouloc, river morphology
- Mr. X. Dubosc, navigation
- Mr. Kovit Thuamsangim, agriculture and irrigation, regional expert, (PRO-EN Consultant and Management Co.)
- Mr. R. Schouten, environmental aspects, (PRO-EN Consultant and Management Co.)

For ORSTOM :
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- Dr. Srinn Kim You, aquatic biology, regional expert
- Dr. J.Y. Weigel, socioeconomy

All staff carried out a joint inception mission in Cambodia from 10 March to 23 March 1993. An inception report of the mission was drafted and submitted to the Mekong Committee on 26 March 1993.

The present draft final report (July 1993) will be discussed with the authorities and organizations concerned in Cambodia in August 1993. The final version of this report shall take into account their comments and shall be submitted in October 1993.

A.5 ACKNOWLEDGEMENTS

The Consultants wish to express their thanks to the Mekong Secretariat's officials, especially the Chief of the Water Resources and Hydropower Unit, to the Cambodia National Mekong Committee who ensured co-ordination of the project and generally to all authorities who kindly extended their assistance to the team of experts and made the implementation of this study possible.

B. BACKGROUND

B.1 GENERAL FEATURES OF THE PROJECT AREA

B.1.1 Mekong River Basin

Mekong River is among the ten largest rivers in the world in terms of annual volume of flow. On average it discharges more than 500 billion m^3/year to South China Sea ($500 \times 10^9 m^3$), where the total drainage area is nearly 795 000 km^2. The riparian countries are China, Burma, Thailand, Vietnam, Lao PDR and Cambodia, of which the latter two are almost entirely in the Mekong watershed.

The project area comprises Tonlé Sap River, the Great Lake and its surrounding flood plain areas. A wide alluvial plain, mostly occupied by open water during the flooding periods, stretches upstream from Phnom Penh to the vicinity of Siem Reap and Battambang in the northwest.

In the central part of the plain, comprising the areas surrounding the Great Lake during the dry season and the riparian zones along the Tonlé Sap River, the altitudes vary from 1.5 m to less than 10 m *asl* (the sea level reference in the region being the mean sea level in Ha Tien). Because the variations of water level of Mekong river between low and flood flows are in the same range (1-10 m *asl*), the whole region is flooded and is under the hydraulic influence of Mekong river during several months each year.

B.1.2 Geological Aspects

The Great Lake plain is surrounded in the south by the Cardamom mountains (Phnom Kravanh) and the Elephant mountains. The highest points vary from 1 500 m in the eastern part of the range to 1 800 m in the western part, where the highest point of Cambodia is located (Phnom Aoral 1 813 m).

To the north of the plain, the Dangkrek mountains are limited by a steep escarpment extending more than 300 km in a WSW-ENE direction, with altitudes between 500 and 700 m. South of the Phnom Dangkrek range down to the Great Lake, the landscape is composed of numerous hills with altitudes decreasing from 200 m near the range to 40 m around the plain. In this area the valley bottoms are flat and swampy and are occupied by the Stung Sen and the Stung Tren rivers and their tributaries.

The original geological layers of the Cardamom mountains are shales and sandstones which have locally undergone intense metamorphic and tectonic activity. Intrusive rocks (granite, ryolite) are particularly widespread in the region of Païlin, where intensive gem mining takes place. The Dangkrek mountains are of sedimentary origin and composed of siliceous sandstones.

B.1.3 Vegetative Cover

The vegetation has been described by Schmid (1956) who identified the following vegetal associations :

a) Dense and semi-dense forests

These are most notably developed on the upper parts of the Great Lake watershed. According to Schmid, this forest had already been degraded into a secondary forest fallow in the northern part of the Lake along Highway RN6 at the time of his study.

b) Open forest

This one-storey tree cover is typical of South Indochina. The trees are small and widely spaced. Though this forest has certainly been exploited by man for centuries, the open forest should not be considered as a degraded dense forest but as a vegetation related to poor soil conditions in the lowlands. The open forest is widespread in the southern part of the plain, stretching from the lake margins up to the hills making the transition to the Cardamon range.

c) Inundated forest

The inundated forest covers a ring which is nearly 40 km wide in the western part of the lake and 32 km in the eastern part (when the lake is at its lowest water level). The nature of the forest varies from a continuous cover of big trees to an open cover of shrubs. It is alleged that the impact of man's activities has been quite strong in these areas. Carbonnel and Guiscafré (1963) pointed out that "*everywhere, this forest has been degraded by logging*".

d) "*Veals*"

These large bare areas, locally called "*veal*", are low herbaceous covers with local concentrations of reeds, rushes and small bamboos. The surface area of the veals was estimated to be as much as 5,000 km² (Carbonnel and Guiscafré, 1963). The ecological zone of the veals extends between the inundated forests and the terra firma forests. The water depth over the veals during the flooding is generally less than 50 cm. Occurrence of veals coincides with heavy clay soils, having very compact underlayers at depths of 20 to 50 cm beneath the surface.

Several assessments of the vegetative cover have been made since Schmid, the latest one being the *Reconnaissance Land Use Map* produced by the Remote Sensing and Mapping Unit of the Mekong Secretariat in 1991.

The ecology of the vegetation in the area is very complex due to the combination of different soil conditions and flooding dynamics, and as a result of long lasting impacts of man's activities. It cannot therefore be assumed that all open forests, shrub areas or low herbaceous zones result from the degradation of a natural and pre-existent closed and dense vegetal cover.

B.1.4 Climate

Because the project area is located between latitudes 12° N and 15° N, the major climatic feature of the area is the seasonal fluctuation of the Inter-Tropical Convergence Zone (ITCZ) associated with alternate seasonal changes in the direction of the trade winds (from SE and from NE). However, in South and South-East Asia this global phenomenon is modified by the massive continental areas of the northern parts of the Asian continent, into a specific large-scale meteorological process know as the monsoon.

- The so-called "*winter monsoon*" generally occurs during the period end November to end April. The general direction of the wind is from NE or N up to January. From February to April the wing speed usually decreases and wind direction may be from E or even from SE. Because the origin of the air mass is the dry and cold Asian continent, the winter monsoon period corresponds to the dry season.

  In Potchentong (Phnom Penh airport) the long-term average rainfalls in January and February are 5 and 6 mm respectively. December, March and April can be considered as dry months with averages of 39, 28 and 70 mm.

- The "*summer monsoon*", referred to generally as "the monsoon", commences in May and continues through to November. The air masses coming from the Indian Ocean are humid and highly unstable. Any vertical movements in the air mass, which may be caused by orographic effects, thermal ascending currents or frontal contacts with another air mass, bring the vapour pressure to the saturation point and heavy rains take place. The average monthly rainfalls in Potchentong are 255 mm in October and 230 mm in September. From May to November the rainfall exceeds 140 mm every month, the long term annual rainfall for this station being around 1,340 mm.

The rainfall is highly influenced by the relief. The seaward slopes of the Elephant and the Cardamon mountains, whose alignments are perpendicular to the south-western monsoon, receive more than 5 000 mm per year. Carbonnel and Guiscafré (1963) have quoted the figure of 6 360 mm as the maximum annual rainfall observed at Bokor (altitude 1 050 m) in Elephant mountain. The rainfall decreases sharply to around 1000-1200 mm on the northern side of the mountain. Rainfall then increases again with values of 1 200-1 400 mm over the central area of the Great Lake and another strong increase takes place when the air masses reach the Phnom Dangkrek range, where the rainfall is estimated as being around 1 600 to 2 000 mm per year. As a consequence of this rainfall heterogeneity, the hydrological regimes of the lake tributaries are very different according to the location of their respective headwater areas.

The range of seasonal temperature variation is very narrow, a typical characteristic of tropical regions. Whereas the annual average in Phnom Penh is 27.5°C, the average temperatures of the hottest month (April) and of the coldest month (December) are respectively 29.3°C and 25.6°C.

The maximum and minimum instantaneous temperatures observed in Phnom Penh were slightly over 40°C (in April) and over 13°C (in January). The diurnal variation is usually less than 10°C.

B.2 DEMOGRAPHIC ASPECTS

During the last thirty years, two population census were held in Cambodia, the first in 1962 and the second in 1980. The most recent demographic study was undertaken by J. Migozzi (1972).

Estimations of the population of Cambodia and of the Great Lake and Tonlé Sap areas must therefore be made from projections based on the 1980 census figures and may be different according to the method of estimation. An example of the fluctuations which can be found is clearly shown by the estimations of the population of Phnom Penh. The Ministry of Planning (1992) gave a figure of 491 000 and the World Bank (1992) a figure between 700 000 and 1 000 000 inhabitants.

Table B.1

Population by Province
(Source : Ministry of Planning)

	1986	1987	1988	1989	1990	1991
Kandal	776,000	798,000	820,000	844,000	867,000	892,000
Siem Reap	548,000	563,000	563,000	579,000	595,000	612,000
Kompong Chhnang	254,000	261,000	268,000	275,000	283,000	291,000
Pursat	201,000	207,000	212,000	218,000	225,000	231,000
Battambang [1]	825,000	844,000	888.000	913,000	939,000	965,000
Kompong Thom	435,000	447,000	460,000	473,000	486,000	499,000
Phnom Penh City	428,000	440,000	452,000	465,000	478,000	491,000

[1] In 1988 five districts were removed from Battambang and three from Siem Reap to form the province of Banteay Meanchey. For convenience the statistics given for Battambang province include those of the new province.

Based on the Ministry of Planning's appraisal, the population of the provinces around the Great Lake and Tonlé Sap river down to Phnom Penh would be around 4 100 000 (see Table B.1), half of the total population of Cambodia estimated at 9 000 000 by the Ministry of Planning. From the same source the growth rate would be 2.8%.

Within this area, the population is very irregularly distributed and the densities vary depending on the subdivisions of the provinces. (Provinces are called *khet* which are

divided into *srok* and further subdivided into *khum*). According to the Ministry of Planning, the most populated *srok* around the Great Lake or the Tonlé Sap River, are those of Bakan (Pursat Province), Maung Russei and Songke (Battambang Province), and Kompong Tralach (Kompong Chhnang Province). Densities vary from 30/km² (Sampuoch *khum* in Kompong Thom Province) up to 1 500/km² (Rokakong *khum* in Kandal Province).

The importance of this irregularity of population density would need to be taken into account in any future studies and planning. Seasonal migrations and the isolation of some communities (especially the fishermen floating villages) are also important.

UNICEF in 1989 provided the following estimates :

- life expectancy at birth : 50 years,
- unadjusted birth rate : 40/1000 (one of the highest in Asia), and
- unadjusted death rate : 16/1000 (two times more than the Asian average).

The infant mortality rate is one of the highest in the world. The population is very young and women form 63% of the whole population, 35% of heads of households, and 70% of the whole rural labour force.

Certain social indicators, not yet available with any precision at regional level, show worrying nutritional and sanitary conditions (World Bank, 1992). Only 12% of the whole population have access to drinking water in rural areas, the rate of tuberculosis incidence is considered to be the highest in the world, malnutrition affects 20% of the population in the provinces, the overall school enrollment rate is assessed at 30% in the rural areas. Despite the lack of field studies in this area, and in view of the isolation of the fishing and rural populations around the Great Lake or the Tonlé Sap river (Kompong Chhnang and Kandal Provinces), it can be assumed that the sanitary and schooling situations of the project area are probably the worst in the country.

As far back as 1925. Gruvel drew attention to the migrations of fishermen during the north-east monsoon, shown by the convergence of boats from the rivers leading to the Great Lake. At that time the migrations concerned Vietnamese, Chinese and Cambodian fishermen. The result of this migration was a growth in activities linked to fisheries such as the building of floating villages and of fish traps. Apart from the period 1975-1979 those migrations did not stop, but the Regional Office of the Department of Fisheries in Siem Reap has indicated that the present tendency is a change towards a more sedentary lifestyle.

Migrations presently occur from October to May (with a peak in March and April). During this period the fishermen and their families settle in the area (fishery masters, unskilled workers). These migrants contribute to the spread of fishery or aquaculture know-how.

There are, however, no data concerning the movements and the origins of these migrants in the project area. Some figures provided by the Regional Offices of the Department of Fisheries are given below in Table B.2, although the unreliability of the figures has been emphasised by this office.

Table B.2

Number of Fishermen and Families for Siem Reap Province
(Source : Department of Fisheries)

	1985	1990	1992
Fishermen	4,260	3,670	3,900
Fishermen families	1,405	1,190	1,300
Total	5,605	4,760	5,200

Based on the fishing permits which are issued, it is possible to estimate the numbers of industrial or artisanal fishermen, but not the numbers involved in family fishery (for which a permit is not required). Estimates of numbers involved in family fishing are therefore much less reliable. For Siem Reap Province the industrial, artisanal and family fishermen have been estimated to be 420, 880 and 2600 (an average during the period October 1992-May 1993). On a regional scale the number of industrial fishermen has not changed in recent years, but the numbers of artisanal and family fishermen are increasing.

B.3 REGIONAL PRODUCTION AND ECONOMICS

The seven provinces considered during this study provided almost half of the national rice production : 950 000 out of 2 400 000 tons. Thus the role of these regions in the national rice production economy is very important. Rice production represented 15% of Gross Domestic Product in 1991 (Table B.3) and as much as 47% of GDP of the agricultural sector.

The role of other cultures (essentially corn and vegetables) is marginal compared with rice because they represented less than 10% of total cultivated area in 1991 (Statistics Office, Ministry of Agriculture).

Fishery production represented 5% of GDP in 1991 and is very important at the regional level where the production of 61 000 tons represents half of the national capture.

Even though it was not possible to establish the contribution of every region to GDP, it can be assumed that these two products , rice and fish, play a major role in the creation of the wealth of region, especially since almost all industries and services (53% of GDP) are concentrated in Phnom Penh.

Table B.3

Gross Domestic Product at Constant Prices (10^9 Riel)
(Source : World Bank, 1992)

	1987	1988	1989	1990	1991
Agriculture	107	106	113	112	131
rice	37	43	47	44	49
other crops and rubber	20	25	24	21	33
livestock	35	25	29	31	31
fishing	9	10	9	12	14
forestry	4	4	3	3	4
Industry	32	41	41	40	44
Services	69	95	93	95	105
Gross Domestic Product	208	242	247	247	280
Real GDP Growth Rate (%)		16.2	2.4	-0.1	13.5
Average official exchange rate (Riel/US$)	100	142	194	407	711

By the end of the seventies only 750 000 hectares were cultivated, equivalent to 30% of the total area cultivated in the sixties. After a further ten years the total area planted for rice was estimated by IRRI at more than 1 600 000 hectares, which shows both the rapidity of recovery which is possible and the high potential of unexploited cultivable areas (in 1967 the total cultivated area was of 2.5 million ha). The introduction of some improved (IRRI) rice varieties has resulted in higher average yields, but these varieties were grown on only 150 000 ha during the dry season and 30 000 ha during the rainy season. The average yields of traditional varieties are low (1.3 t/ha). According to the same source, a large increase in fertiliser application for the cultivation of traditional varieties would not be profitable.

Table B.4 shows the importance, in terms of planted area, of rice cultivation compared with other cash crops.

Table B.4

Cash crops in Cambodia
(Source : Ministry of Agriculture)

Crops	1989 (ha)	1990 (ha)
Rice (both seasons)	1 615 530	1 890 000
Maize	47 485	44 500
Cassava	9 336	11 260
Sweat Potatoes	14 667	7 670
Vegetables	25 189	28 640
Soy beans	13 101	14 690
Mung beans	27 176	25 150
Peanuts	5 035	6 450
Sesame	12 147	9 410
Sugar Cane	6 544	6 330
Jute	2 132	1 540
Cotton	473	930
Tobacco	23 598	13 630
Black pepper	111	260

The study area provides almost half of the total rice production, and has recovered to a level of production close to that which pertained at the end of the sixties (Table B.5). Also, because these provinces provide the major part of the national production of the deepwater/floating rice whose yields have, according to IRRI, the highest capability for increase, an important potential exists for increased regional production, mainly in the areas bordering the Great Lake in the provinces of Siem Reap, Kompong Thom, Battambang and Pursat.

With regard to improvements of rainfed lowland rice and dry season rice, the approach should focus firstly on varieties and secondly on the improvement of irrigation.

As the fishery sector has not received the same level of international assistance as rice cultivation during the last decade, there has not been a large effort with regard to research and development. Therefore, the estimates of the present and future capture and fisheries production are even more uncertain than those for rice production. a similar situation is found for estimating the profitability of the fishery units, the organization of the different segments of the chain of production and marketing, and the process of formation of fish prices.

Table B.5

Area Planted for Rice and Rice Production[1] (1981-1991)
(Source : Statistics Office, Ministry of Agriculture)

Province	Phnom Penh	Kandal	Kompong Thom	Siem Reap	Battam-bang	Pursat	Kompong Chhnang	Total
Area (10^3 ha)								
1981	2	86	94	150	260	57	49	698
1982	2	86	117	162	288	65	52	772
1983	3	81	118	168	295	75	52	792
1984	3	74	97	160	182	51	34	601
1985	3	79	105	157	190	63	44	641
1986	10	77	99	156	203	60	62	667
1987	10	63	99	128	203	46	39	588
1988	13	73	137	180	129	75	64	671
1989	13	93	138	163	152	78	63	700
1990	13	94	142	169	148	79	66	711
1991	12	92	130	143	162	86	72	697
Production (10^3 t)								
1981	3	125	71	141	246	43	54	683
1982	4	163	112	168	342	80	61	930
1983	6	154	126	162	276	97	63	884
1984	6	108	73	156	144	35	41	563
1985	4	142	91	159	231	74	57	758
1986	13	140	109	159	270	69	74	834
1987	16	142	116	131	264	53	47	769
1988	19	124	166	220	181	96	85	891
1989	21	178	161	212	209	101	88	970
1990	21	190	162	194	197	93	89	946
1991	20	177	155	172	228	100	95	947

[1] Variation in time of area and production within a single province may not be significant, because of changes of the boundaries of some provinces, such as Phnom Penh and Battambang.

The following figures given by the Department of Fisheries give the estimates of fishery production for the study area. In 1991, production in the study area represented 75% of the production from national freshwater catches and cultures (Table B.6).

Table B.6

Annual Commercial Fish Catches by Province (1981-1991)
(Source : Department of Fisheries)

Province	Phnom Penh M	Kandal	Kompong Thom	Siem Reap	Battam-bang	Pursat	Kompong Chhnang	Total
Production (tons)								
1981	5500	7050	2000	9000	5200	7400	11500	47650
1982	6200	11000	4800	8300	6700	8700	11600	57300
1983	4100	4600	6200	8200	6700	8300	10700	48800
1984	4700	7700	4600	7900	4900	5900	12300	48000
1985	5700	10400	2500	8500	3700	5400	10200	46400
1986	7500	15200	2600	9000	3800	6000	9700	53800
1987	4200	10800	5200	9600	3500	7000	12100	52400
1988	5600	11800	4500	9000	3800	4200	11000	49900
1989	3250	7200	4100	8200	3900	5700	9900	42250
1990	4600	12500	4100	9000	4300	7200	12000	53700
1991	5800	14000	4800	9000	4500	8700	14000	60800

If the above captures are combined with the prices of each type of fish, it appears that the value of fish yield is satisfactory. On a regional level in 1991, the value of the fishery yield was estimated at 14×10^9 Riel, that is 75% of the value of the rice production as shown in Table B.7.

Table B.7

Value of Fish Catches and Rice Production in 1991
(Source : Department of Fisheries)

Province	Phnom Penh M	Kandal	Kompong Thom	Siem Reap	Battam-bang	Pursat	Kompong Chhnang	Total
Value (10^9 Riel)								
rice	0,4	3,6	3,2	3,5	4,7	2,0	2,0	19,4
fish	1,3	3,2	1,1	2,1	1,0	2,0	3,2	13,9

The above table shows that the relative importance of these two products varies from one province to another. For example, Battambang is the major rice producer but the value of its fisheries production is relatively low. A similar situation occurs in the province of Kompong Thom. The value of fish production is the highest in the provinces of Kompong Chhnang and Kandal. Fish captures for the municipality of Phnom Penh are estimated at more than 10^9 Riel. It can be concluded that efficient and effective management of the fisherv sector at regional level would result in important economic and socio-cultural benefits. This sector is especially important in relation to the revenues raised for public services through taxation and auctioning of fishery plots. Revenues for the freshwater fisheries alone were estimated to be 52×10^6 Riel in 1988 (Curtis, 1988).

C HYDROLOGY, SEDIMENTOLOGY AND RIVER MORPHOLOGY

C.1 HYDROLOGICAL ASPECTS

C.1.1 Hydrological Dynamics of the Great Lake

The Great Lake of Cambodia can be considered as a common water body, fed by the rivers of its own drainage basin and by direct rainfall on its water mirror. The overflow of the lake runs through the Tonlé Sap River downstream to its confluence with Mekong River in Phnom Penh. However, the most specific hydrological feature occurs during the Mekong flooding period when its waters flow back into the Tonlé Sap. The current of the Tonlé Sap then changes direction and the Mekong inundates the Great Lake. With the ebbing of this flood, the water which was stored in the lake flows again to the sea, through the Tonlé Sap, and then through the delta complex, where the Mekong itself and the Bassac are the major channels.

The watershed of the Great Lake and its connections with Mekong River and Bassac River are shown in **Figure C.1**.

Because of the very flat topography, any variation of the volume stored in the lake results in very large variations of the flooded surface. According to Carbonnel and Guiscafré (1963), the surface of the flooded area during the 1962-63 hydrological year ranged from 2 700 km² during the dry season, to nearly 16 000 km² at the maximum level of the flooding. The alignment of the two highways surrounding the lake (RN5 in the SW and RN6 in the NE) corresponds to the limits of the open water of the lake at its highest level. At this stage, the area of the drainage basin of the Great Lake is 67 600 km².

Water levels are around 1 m *asl* or less during the dry season, and over 9 m *asl* when the lake is full, the storage capacity then being $72*10^9$ m^3. This figure, which was given by Carbonnel and Guiscafré (1963), corresponds to a level of 9.36 m asl reached from 11 to 14 October 1962. This storage figure was established using the water balance method (which is not very accurate), as no bathymetric and topographic surveys have ever been carried out in the area. The remaining capacity of the lake during its low periods is unknown. The same authors gave an estimated capacity of $1.3*10^9$ m^3 for the lake at the end of the dry season (all *asl* water levels are referenced to Ha Tien sea level).

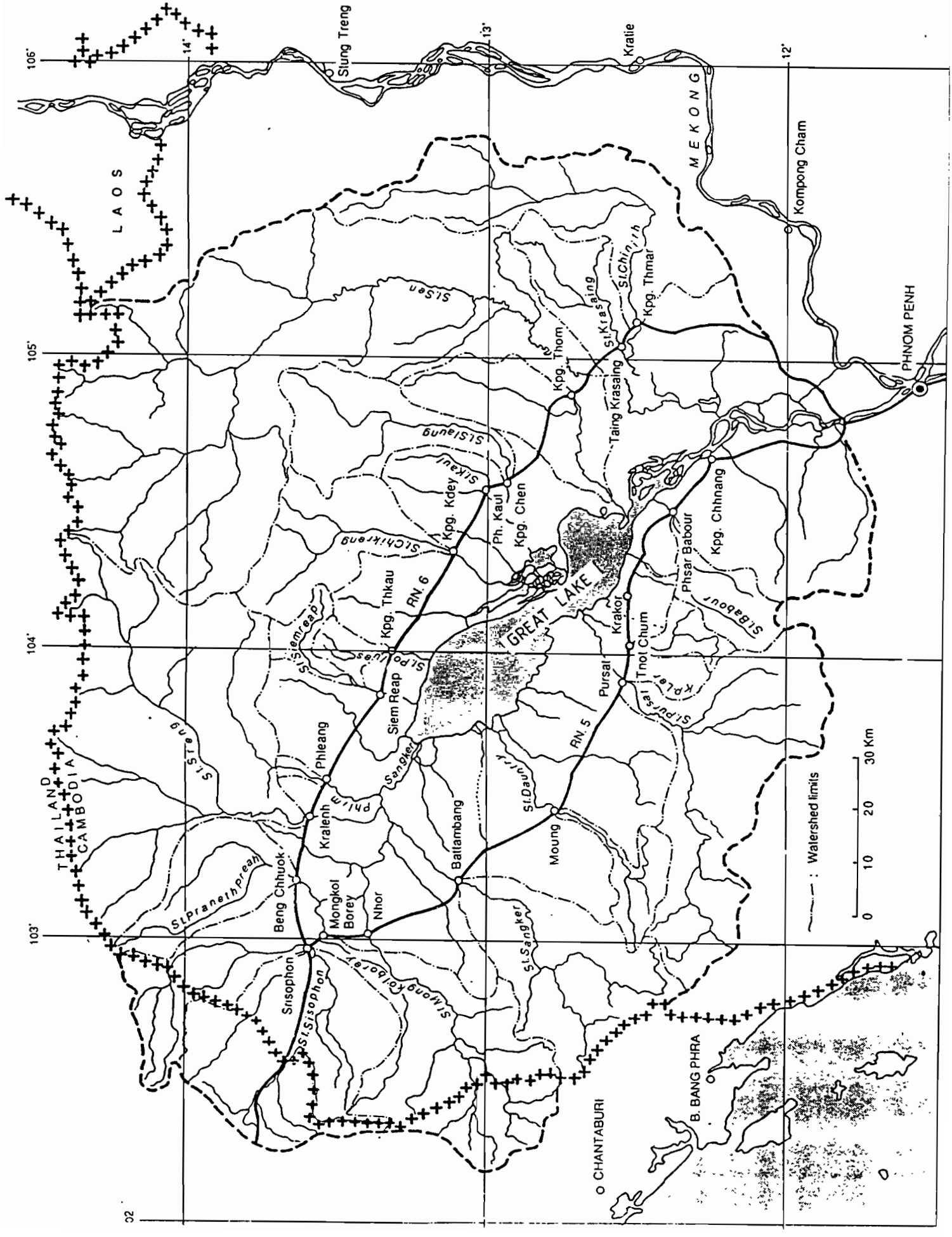
C.1.2 Available hydrological data

The Mekong Committee operates an extensive electronic data bank where most of the hydroclimatological existing information is stored. In conjunction with this historical series, some other processed data can be found in technical reports or studies. All the data of the recent past years are not yet stored in the electronic data bank.

A comprehensive assessment of the available numerical data available for this study is presented in **Annex 3**.

Figure C.1

WATERSHED OF THE GREAT LAKE AND TONLE SAP RIVER



C.1.3 Hydrological analysis of the system

a) Background and objectives of the present analysis

As described in section C.1, the Great Lake and its watershed area, the alternate drainage and supply channel of the Tonlé Sap and the Mekong form a complex hydrological organization which will be designated further with the generic term "system".

According to many technicians' findings and experts' advice, there has been a prolonged degradation of the physical characteristics of the lake. In summary, an alarming trend in the decrease of the water depth due to the siltation of the lake has been observed in the last few decades, and this process would have accelerated recently. Decreases in fisheries' yields and problems of navigation during the dry season are seen as impacts of this reduction of the lake's depth.

If these findings are confirmed, some modification or continuous trend in the hydrological and/or sedimentological behaviour of the system should exist. The sedimentological expertise will be developed in the next chapter. The aim of the current hydrological report is to find out any modification or trend in hydrological behaviour which could sustain these alarming findings.

b) Water balance

The objective of the calculation of the system's water balance is to assess the respective contributions of the Mekong and of the Great Lake drainage basin in the filling of the lake.

The hydrological data of the lake watershed, the Tonlé Sap River, and of the Mekong are simultaneously available for one single hydrological year, that of 1962-63. Carbonnel and Guiscafré derived the following water balance for that period (all figures in 10^9 m^3) :

(i) Inputs from the drainage basin of the lake

- Inflow from the rivers	24.3	*(1)*
- Net balance "rainfall on the lake" (+13.9) minus "evaporation" (-10.4)	3.7	*(2)*
Total inputs from the lake drainage basin	28.0	*(3)*

(ii) Inputs from the Mekong through the Tonlé Sap

- inflow to the Tonlé Sap at Prek Kdam (going to the lake)	**45.0**	*(4)*
- Outflow from the Tonlé Sap at Prek Kdam (going to the sea)	**72.9**	*(5)*
Net balance at Prek Kdam = *(5)-(4)*	**27.9**	*(6)*

(iii) Contribution of the Mekong overflow and of the part of the basin between the outlet of the lake and Phnom Penh

References *(3)* and *(6)* which were obtained by two separated methods, are nearly the same. However, the inflow-outflow balance in Prek Kdam cannot be taken as being the contribution of the Great Lake drainage basin, as reference *(6)* does not take into account some water entering the system which had not been monitored during the increasing flow at Prek Kdam. There are two main sources for such inputs :

(1) Water coming from the overflow of the Mekong upstream of Phnom Penh :

When the water level passes 8 m in Phnom Penh and 10 m in Kompong Cham, the Mekong overflows its right bank upstream of Phnom Penh and inflow may enter the lake by-passing the Tonlé Sap at Prek Kdam (however it is controlled at this point during the ebbing period). According to Carbonnel and Guiscafré study, the most important channel for collection of this overflow is *Prek* Spean Tras. The *prek* starts from the Mekong at Roka Kaong in a sharp curve of the Mekong between Kompong Cham and Phnom Penh (point X=501, Y=1310 on the 1/50 000 map of Cambodia). The greater part of the overflow is routed to the lake under a bridge located at Kilometre 54 of highway RN6. At this location, the embanked road which crosses the flooded plain in a S-N direction has an opening of 132 m width, which allows the water to flow westward (bridge coordinates X=494, Y=1319 on the 1/50 000 map). Discharges were monitored at this site during the 1962-63 hydrological year. The water crossing the road at this point flows to the Tonlé Sap, somewhere in the South-East of Kompong Chhnang, much further upstream of Prek Kdam. It has to be mentioned that the bridge at Km 54, as well as several waterways from the Mekong to the Tonlé Sap have been located on the maps. However, the name "Spean Tras" could not be found on the different maps available for the study (1/50 000 and 1/250 000).

During the 1962-63 period, the volume of the Mekong overflow which crossed the bridge control section was.....$4.0*10^9$ m^3 *(7)*

Thus, when compared with the $45*10^9$ m^3 which flowed to the lake at Prek Kdam site, the overflow gave an additional input of around 10%.

However modest, this contribution has very specific dynamics and as such is worth consideration : at the end of the Mekong flood, the water in Prek Spean Tras was still flowing in the direction of the lake for a two-week period, while the stream direction had already changed in Prek Kdam, where the current was oriented to the sea.

RN6 highway was constructed in 1927 and Carbonnel and Guiscafré stated that "*before the road construction, the volume of the overflows going to the lake was probably larger*".

The impact of the road construction is most probably minor, but this fact has to be pointed out in a study aiming to compile every likely natural or man-made change in the system. Moreover, it is not impossible that some changes are attributable to hydraulic works which were extensively carried out in the country during the 70's. In any case, the current importance and the role played by the Mekong overflow will have to be assessed.

(2) Water coming from the part of the watershed between the outlet of the lake and Prek Kdam.

- This area of 2 500 to 3 000 km² could bring an addition of.....$1*10^9$ m^3 *(8)*

The estimation of the water supply to the lake area using the water balance method would be *(5)-(4)-(7)-(8)*, or $23*10^9$ m^3, which can be compared to the $28*10^9$ m^3 given by the monitoring of the flow entering and leaving Prek Kdam. The monitoring in Prek Kdam overestimated the supplies from the lake drainage basin. Moreover, as the final result comes from a difference, the method is not very accurate : if the inflow and the outflow had been monitored with an accuracy of 10% to 15% (which would not have been bad, according the difficult hydraulics conditions of the site), then the accuracy of the difference (contribution of the lake watershed area) would be estimated with an accuracy not better than 20% to 30%.

In summary, for the year considered, the share of the water between the Mekong and the Great Lake watershed area was as follows :

-Mekong	**49 x 10^9 m^3**	**or 62% of the total supply**
-Great Lake watershed area	**28 x 10^9 m^3**	**or 38% of the total supply**

c) Hydrological variability of the system in time

The information of daily flow of the electronic data bank, also published in the hydrological year-books for the period 1963-70 have been used to estimate the hydrological variability of the system in time (**Table C.1**)

According to these figures :

- Either, there is a very strong variation of the hydrological yield on the Great Lake watershed area from year to year, shown by differences in runoff as great as 450 mm in 1963-64 and 75 mm only in 1967-68 (respectively 32.2 and $4.5*10^9$ m^3). However, the low values seem to be aberrant, and a careful study of the rainfall on all stations of the watershed may reveal these values as being outlying or inconsistent
- Or, some changes have occurred in the calibration at Prek Kdam and starting from 1967-68, discharges were not measured with the required accuracy.

From the available information, it is not possible to determine which hypothesis is the correct one.

Table C.1

Water Balance of the Tonlé Sap at Prek Kdam - Unit = 10^9 m^3
Source : Mekong Secretariat Year-books

Year	Flow going to the lake (a)	Flow going to the Mekong (b)	Balance (b)-(a)
1962-63 (1)	45.0	72.9	27.9
1963-64	43.4	75.6	32.2
1964-65	49.1	66.1	17.0
1965-66	48.3	67.8	19.5
1967-68	56.5	61.0	4.5
1968-69	42.9	53.8	10.9
1969-70	61.3	65.6	4.3

(1) data taken from Carbonnel and Guiscafré 's study

The historical records of the water levels in Kompong Chhnang are another valuable source of information to assess the hydrological variability of the lake. This station has been observed since 1924. The water level in Kompong Chhnang can be taken as being the level of lake with an acceptable approximation (around 10 to 20 cm). The quality of the data is extremely poor. In some years there are more gaps than readings and some readings are obviously aberrant. Moreover, we did not find the altitude of the datum of the gauge in any document. Therefore, a first interpretation was made of the range of the variations of water levels, rather than the true altitudes related with the level of the sea in Ha Tien. For each year, maximum and minimum water levels were extracted from the data base, the difference was calculated and the values were plotted as shown in **Figure C.2.**

To minimize the effects of odd readings, the maximum was defined as the average level of the five highest days and the minimum as the average level of the ten lowest days of the year.

Considering the variations of the lowest annual values, three different periods can clearly be identified :

- 1925-56, with minimum levels close to 3 m.
- 1957-61, with minimum levels close to 2 m.
- from 1962, with minimum around 1 m.

Knowing that the water level in the lake at the end of the dry season is around 1.3 m *asl*, we conclude that the situation of the gauge was probably in accordance with

sea level topography during the last period. We assume that this was not the previously the case and put forward the following hypothesis :

(i) The shifting of the gauge was exactly 1 m during the 1957-61 period and 2 m during the former 1925-56 period.

(ii) The shifting was the same for all gauge staffs, from lowest to highest levels.

Thus we have corrected the data, subtracting 2 m from the readings during the 1925-56 period and 1 m during the 1957 -61 period. The graph with the corrected data is shown on **Figure C.3.**

According to this data, the maximum level of the lake would usually have been between 9 and 10 m *asl*, but sometimes the maximum was no more than 8 m and could reach nearly 11 m.

The distribution of the annual maximum levels for the 50 years with available data was the following :

Over 10.00m : 8% of time (max 10.73)
Over 9.50 m : 32% of time
Over 9.00 m : 52% of time
Over 8.50 m : 76% of time
Over 8.00 m : 100% of time (min 8.01)

If the validity of these data is confirmed, it is clear that the high water of the lake must be very different from one year to the another. There have never been any bathymetric or topographic surveys carried out on the lake area and no accurate relations between depths, volumes, and surfaces have been made available. However, using the monthly water balance, Carbonnel and Guiscafré published a graph establishing an approximate relationship between water depth, flooded area and stored capacity, which can be extrapolated up to 10 m asl. The flooded areas and stored volumes are as follow (**Table C.2**) :

Table C.2

Flooded area and storage capacity of the Great Lake in relation with water level
(Source : Carbonnel and Guiscafré, 1963)

Water level (m *asl*)	Flooded area (10^4 km²)	Storage (10^9 m ^{3})
8	13.5	51
9	15.2	65
10	17.0	80

Taking 10 m *asl* water level as a reference, a drop in the level of filling of the lake equal to 1 m (9 m *asl*) leads to a reduction of nearly 2 000 km² in the flooded area and of $15*10^9$ m³ in storage. If the reduction is 2 m, these values are as high as 3 500 km² and $29*10^9$ m³, respectively. Such situations, which according to the historical data are not unusual, will probably have very significant impacts on the ecology of the flooded area (especially on the "inundated forest") and therefore on fish and fishery yields.

With data of such poor quality, attempts at identification of trends in water levels are very risky :

(i) In correcting the data, we assumed that the 1 m level in Kompong Chhnang was a steady feature and thus no trend may appear on the graph for the low water levels.

(ii) For the high water levels, the situation is less clear. However two periods of recession can be identified (see Figure C.3):

- 1924-33, during which the lake shrank continuously (except for two years 1929 and 1930) and finally reached its lowest known high level (8.03 m in 1933).
- 1947-56 (except 1952)

There is no runoff data available for the Great Lake watershed during these periods, the only reference being the Mekong flow. During these two periods, the flow was generally less than average (see Figure C.7), the phenomenon being especially visible between 1924 and 1933. The impact of the Mekong floods on the inflow of the lake will be discussed in section (e).

d) Variability of the Mekong flow in time

The discharge of the Mekong in Phnom Penh (drainage area 663 000 km²) has been monitored for too short a period to carry out any trend analysis. The nearest station with several decades of reliable data is Paksé, where the watershed area is only 545 000 km². A double-mass curve analysis, as well as correlations between flow in Phnom Penh and Paksé during the joined observation period, showed that despite the difference in drainage area, the regime was the same for the two stations and that there was a fairly good correlation between the discharge in Paksé and in Phnom Penh (see Annex 3).

Figure C.4 shows the variations of the annual discharge of the Mekong in Paksé for the period 1923-1989, as well as the 5-year moving average and the long-term average for the overall period (10 122 $m^3 s^{-1}$). The Mekong annual discharges show significant variations and these variations determine periods with stronger flow than the average, such as 1937-54, and other periods with reduced flow (1955-61), and most recently, 1985-89.

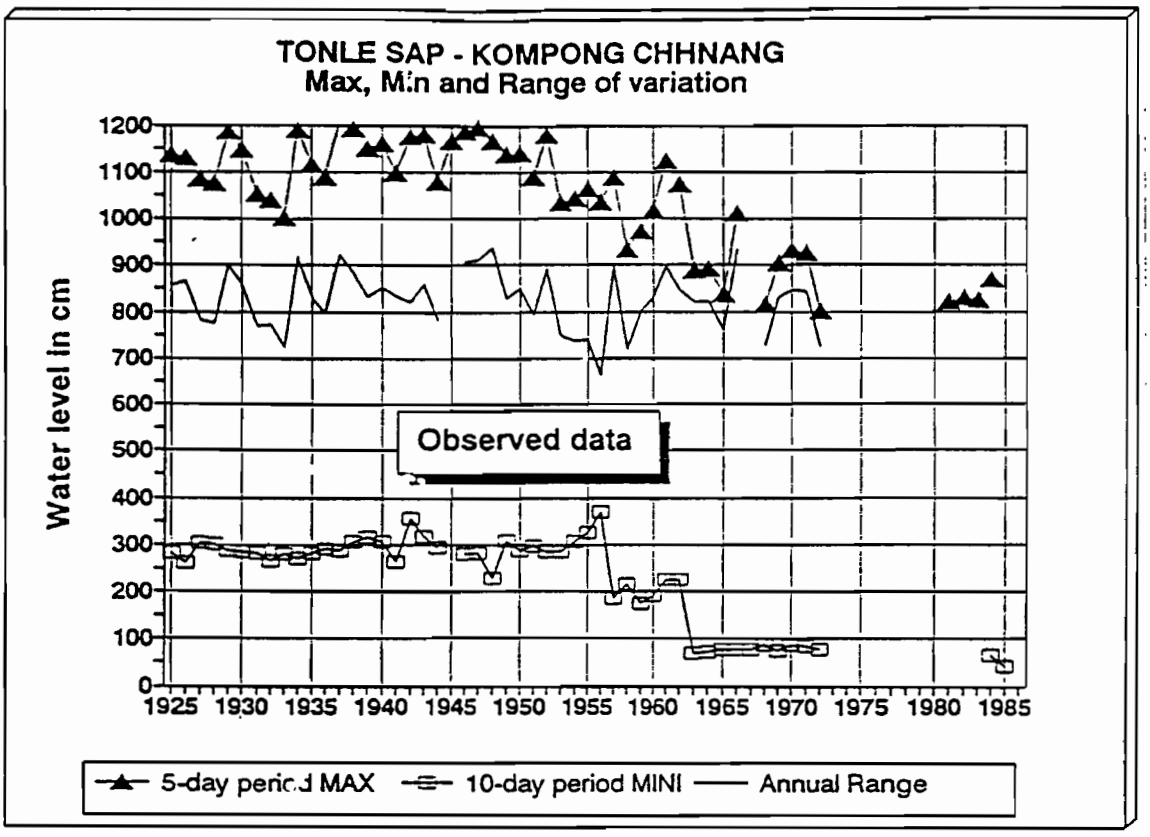


Figure C.2

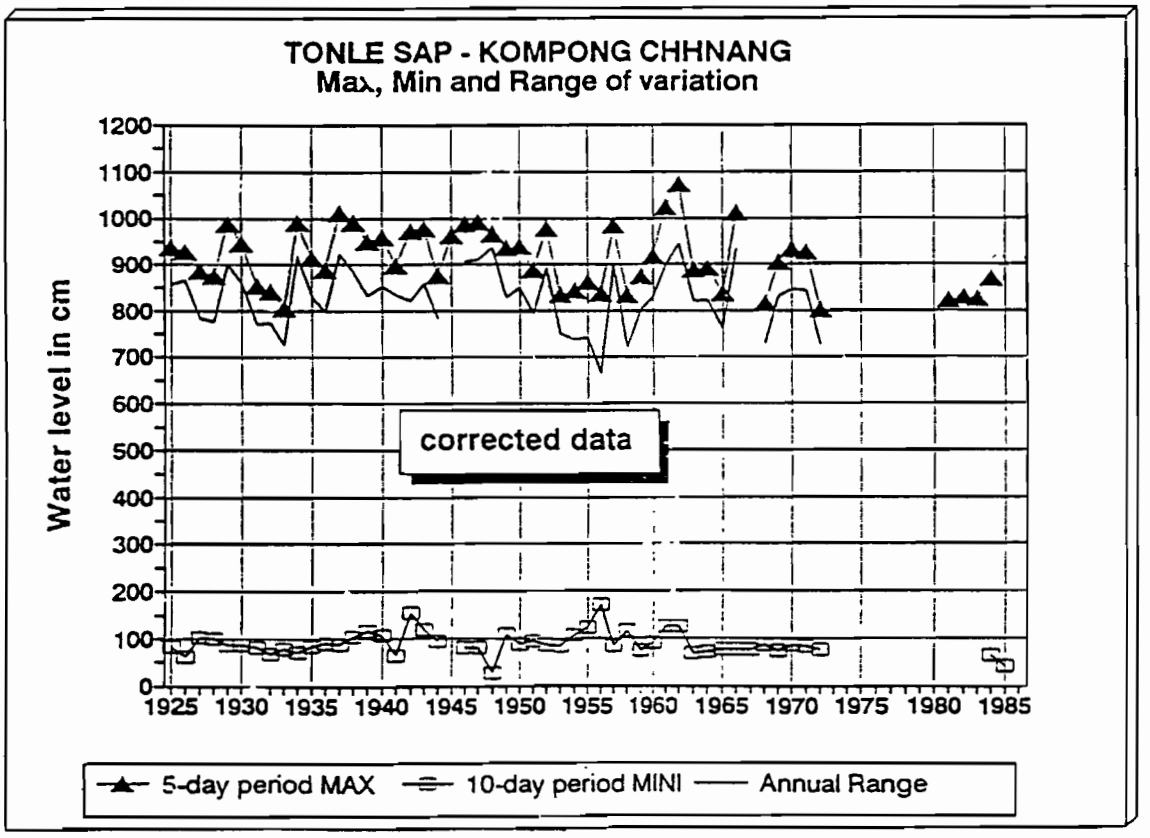


Figure C.3

The question is to know if the reduction of flow during the most recent period can be related with the construction of the dams which started during the late sixties. A list of existing reservoirs and of their capacities is given in Annex 3. According to this information, the overall storage capacity upstream of Phnom Penh is $8.8*10^9$ m^3. This value is less than 2% of the average annual flow of the Mekong in Phnom Penh ($410*10^9$ m^3, for an annual discharge of 13 000 $m^3\ s^{-1}$).

However, the effects of the barrages might be detectable during very dry years when the water demand is high and the Mekong flow is reduced. If one considers the variations of the flow in Vientiane, upstream of the reservoirs (**Figure C.5**), the departures from the mean have the same magnitude and occurred at the same periods than in Paksé. Moreover, such reductions in flow already occurred in the past, prior to any dam construction. The conclusion is that the ecosystem has a strong natural variability, a feature which has to be taken into account when addressing the problem of hydrological changes in the area.

e) Relationship between the Mekong floods and the filling of the lake

The discharges of the Mekong in Phnom Penh and of the Tonlé Sap in Prek Kdam are simultaneously available during a period of 7 years during the sixties. This allows examination of an existing relationship between the flow of the Mekong and the flow entering the Tonlé Sap.

For each year where data was available, we selected the months during which Tonlé Sap was flowing upstream on all days. On an annual basis, a regression was drawn between the volume discharged by the Mekong River in Phnom Penh during these months and the volume which entered the Tonlé Sap[1]. Results are shown on **Figure C.6**).

(i) Despite an increasing dispersion, as floods become larger, it is clear that the volume of water entering the Tonlé Sap and thereby the Great Lake shows a strong correlation with the magnitude of the Mekong floods.

(ii) Regulation of the Mekong floods will lead to a reduction of the supply of the lake. This would happen even if the regulation did not reduce the annual flow but only causes a redistribution throughout the year, such as an increase of flow during dry periods and a reduction of flood peaks.

(iii) The Tonlé Sap - Great Lake system is small compared to the Mekong : whereas the annual flow of the Mekong during the selected months varies between 150 and $300*10^9$ m^3, the volume "lent" to the Tonlé Sap in the same period is of the order of 35 to $65*10^9$ m^3, or a little over 20% of the Mekong flood waters.

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(1) : These volumes are an underestimation of the entering volumes for the considered year, as the flows of the months during which the direction of the stream changed are not included in the total.

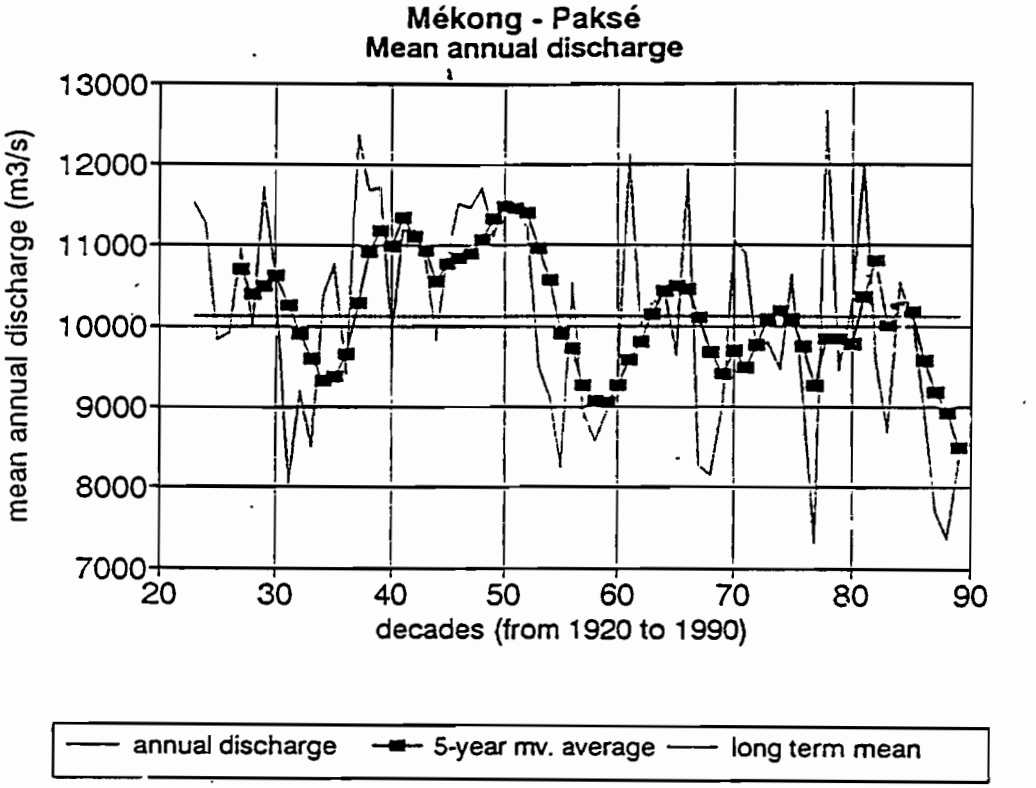


Figure C.4

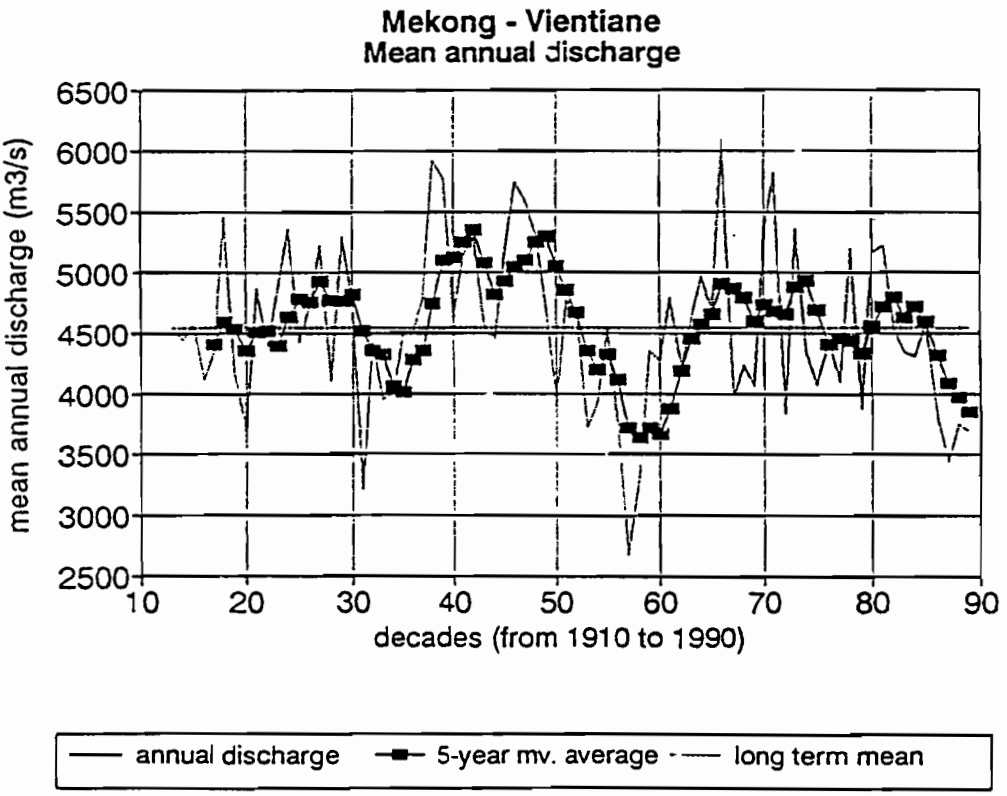


Figure C.5

Because of the crucial role of the floods, the analysis previously carried out on annual discharge of the Mekong in Paksé (see section C.1.3 (d) and Figures C.4 and C.5), was repeated for the flooding period. The flooding period was identified as extending from 1 June to 30 September, i.e. the period having most frequent inflows to Tonlé Sap. Results are shown in **Figure C.7** (for each year, average discharge during the 4-month period, moving average over a 5-year period, and long-term average over the overall period). The following conclusions can be drawn from the results :

(i) The floods have variations in their hydrological regimes similar to those of the annual flow.

(ii) The volume of the Mekong floods during 1962, which corresponds to the period of the study carried out on the lake by Carbonnel and Guiscafré, is close to the average. As far as the Mekong contribution is concerned, it can be assumed that the findings of this study apply to a normal situation. A comprehensive analysis of the rainfall on the lake basin might give some information about the rank of the contribution from the lake watershed.

(iii) The period 1947-56 which has been identified in Kompong Chhnang as having a decreasing trend in the filling of the lake, corresponds on Figure C.7 to a similar situation for the Mekong floods.

(iv) The recent period (1985-89) already identified as having a deficit in annual discharge is also clearly marked on flood discharge.

C.2 SEDIMENTOLOGY AND RIVER MORPHOLOGY

Assessments were made of sediment transport and river morphology in the drainage channels which constitute the river system known as Quatre-Bras (Chakdomuk). The objective of this assessment was to determine the likely evolution of channel forming processes in the Quatre-Bras zone. Of major concern, therefore, were transport and deposition of sediment emanating from flood flows.

C.2.1 Sediment Transport and Deposition

a) Importance of the phenomenon

As with all major rivers in humid tropial regions of Asia, the Mekong river has a very high rate of sediment transport, principally suspended sediment (more than 90% of total solid transport) in its lower reaches. An understanding of the characteristics of these sediments and their transport mechanisms (entrainment, deposition, re-entrainment) in the complex Mekong-Tonlé Sap-Great Lake system is of vital importance, because these phenomena have a direct impact on the biological environment of this system, and in particular on fish.

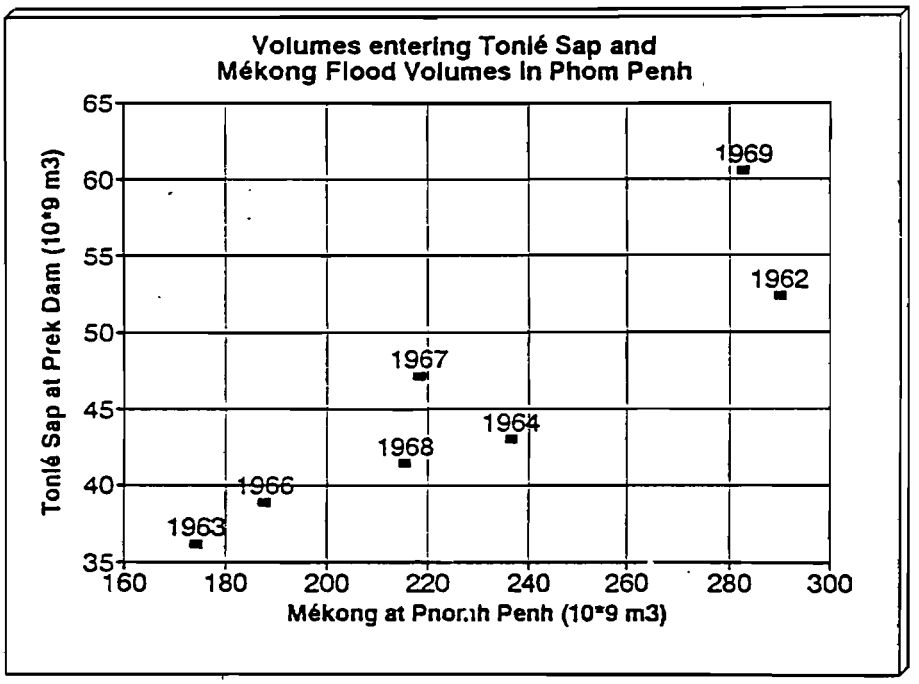


Figure C.6

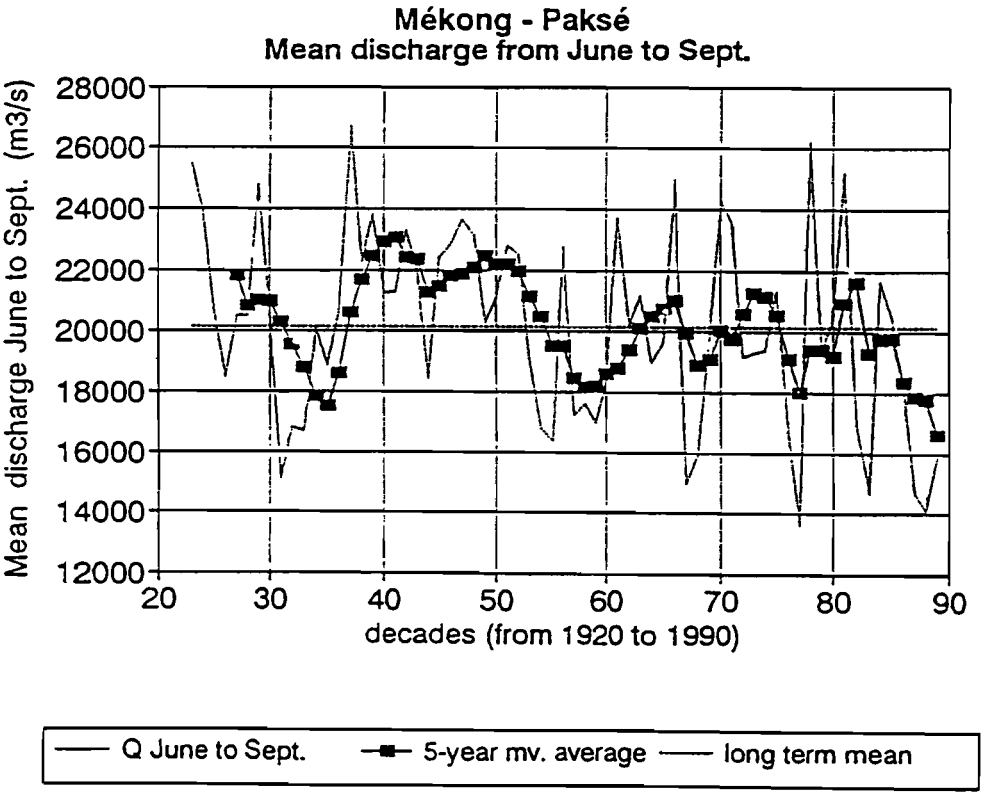


Figure C.7

b) Previous Studies and Investigations

Prior to 1960, very little information was available on these phenomena in this area. However, J. Bardach's "Fishing on the Great Lake" (1959), described the increase in lake sedimentation and endeavoured to define causes for this growth.

The most relevant studies carried out during the last thirty years are :

i) Publications by J.P. Carbonnel and his team (1962 to 1964), including :

- J.P. Carbonnel and J. Guiscafre, "Cambodia's Great Lake : Sedimentology and Hydrology" (1962, 63).
- J.P. Carbonnel, "Mixing of the waters at the Snoc Trou bar in flood periods" (1963).
- J.P. Carbonnel, "Report of the French sedimentation mission" (1964).

ii) During a four year period, detailed studies and research were carried out (topographical surveys, sediment analyses, measurement of sediment transport by radioactive tracers, etc.) to evaluate quantitatively certain hydrological and sedimentological characteristics. The documentation includes :

- a very clear description of the hydraulic functioning of the Mekong-Tonlé Sap-Lake system.
- Tonlé Sap flow velocities at Phnom Penh :

- Mekong river towards the lake	1.7 m/s max
- Tonlé Sap towards Mekong river	2.0 m/s max
- average velocities (including floods)	1 to 2 m/s.

- a suspended sediment assessment in the lake in 1962-63 :

- contribution by the lake affluents	1.9×10^6 t/year
- contribution from Tonlé Sap (Prek Kdam)	2.7×10^6 t/year
Total deposition in the lake	4.6×10^6 t/year
(including bedload transport)	4.7×10^6 t/year

According to the authors, this rate of sediment transport to the Great Lake would produce an aggradation of around 0.3 to 0.5 mm/year in the bed.

However, in 1964 Carbonnel expressed an apparently different opinion : "*The material brought by the Mekong in high water periods is negligible in the Great Lake proper and consequently does in no way modify the accumulation rate in the Great Lake. All alluvial matters transported by the Mekong as it flows up towards the Great Lake settle in the region between Kompong Chhnang and Snoc Trou*".

This would mean that the contribution of Mekong river flood flows to lake sedimentation is negligible and that sedimentation is due only to material emanating from the lake's own affluents. If this is the case, deposition in the Kompong Chhnang - Snoc Trou zone must be very high.

iii) "*The Lower Mekong Basin - Suspended sediment transport and sedimentation problems*", P.O. Harden and A. Sundborg, 1992. This is the most recent report on the subject and it is based on thorough bibliographical research, sedimentological measures and statistical studies. It provides the following useful information :

- A summary of rare data collected during the period 1960-91.
- Some suspended sediment concentrations at Phnom Penh (less than 2 g/litre), which is low compared with such rivers as Yellow River (44 g/l).
- An estimation of sediment transport and its evolution at several points, from which the following figures are quoted (**Table C.3**) :

TABLE C.3

Transport Rates (10^6 t/year)

Location	1961	1961-65	1986-90
Paksé	115	126	178
Stung Tren	146	-	-
Kratié	-	-	250
rivermouth	-	-	200 to 300

These figures imply a degradation of the catchment area of the order of 300 t/km²/year. The authors believe that the sediment charge of the lower Mekong is increasing, but this remains to be confirmed.

- Recommendations to continue studies in this field.

iv) On the subject of lake sedimentation, M. Imre Csavas, FAO Fish Expert, expressed the following opinion during an FAO mission in Phnom Penh in November 1990 :

- The intensive deforestation around the Lake is the essential cause of sedimentation.
- Deposition in the bed of Great Lake is presently occurring at a rate of 4 cm/year and, as the lake has an average depth of 40 cm in the dry season, it could cease to exist as a lake in the dry season in 10 years' time.

Some caution is necessary, however, in this regard. Considering that the average surface area of the lake is about 5 000 km², then the available storage volume is about 2×10^9 m^3. For a deposited sediment density of 1.4 t/m^3, this would require some 1 500 years of sedimentation at the rate proposed by Carbonnel (1.9×10^6 t/year). At the more pessimistic rate of 4.7×10^6 t/year the period would be 600 years, which is very different from the 10 years suggested by M. Imre Csavas.

c) Present knowledge of sediment phenomena

After an analysis of available existing documentation, several reconnaissance visits in the zone and various interviews, we can state that :

i) There are some indications, based on very few, and insufficient, data, that suspended sediment transport rates in the lower Mekong river are increasing slightly.

ii) Except at its two extremities (Chakdomuk and Snoc Trou) it would appear that Tonlé Sap river is not experiencing any marked change in sediment transport and deposition rates.

- At Chakdomuk (Quatre Bras) heavy deposition of sediment occurs, as proven by the annual dredging which is carried out, not only to maintain access to the port, but also (according to the authorities) to assist fish migration. At this location some 40 to 80,000 m^3/year is dredged. The morphological evolution of this zone is described in the following chapter.

- Several cross sections were measured in the lower Tonlé Sap river in March 1993 at distances of 2, 7, 8, 10 and 30 km from Phnom Penh, corresponding to some of the same sites measured in 1969. These sites comprise typical reaches of the river (straight and winding). A comparison of these two series of cross sections leads to the following remarks :

  . A small amount of aggradation has occurred at the P10 and P30 setions (about 2 m in 24 years).

  . Sections P7 and P8 have barely changed.

  . Aggradation at section P2 has been about 3.5 m in the period 1969 to 1993.

  Because of the dynamic nature of elevation changes in alluvial riverbeds it is hard to draw any firm conclusions from these measurements apart from the fact that bed aggradation at section P2 is significant. The large bed rise in this section, near Quatre Bras, confirms that heavy sedimentation is occurring in this zone.

- At Snoc Trou there has been aggradation of the bed, and the causes appear to be twofold :

  . The discharge of flood water coming from Mekong river creates a delta due to the sharp reduction in velocity and turbulence.

  . The Stung Sen affluent, one of the most important contributing rivers in the catchment of the Great Lake, discharges also at this location. Because Stung Sen transports coarser sediments (sands) than those of the flood flows in Tonlé Sap, the corresponding deposits are not easily eroded by Tonlé Sap flood flows. It can clearly be seen from the maps and aerial photos that the inflow of Stung Sen causes a diversion in the flow of Tonlé Sap towards the west. This can be clearly seen in **Figure C.8.**

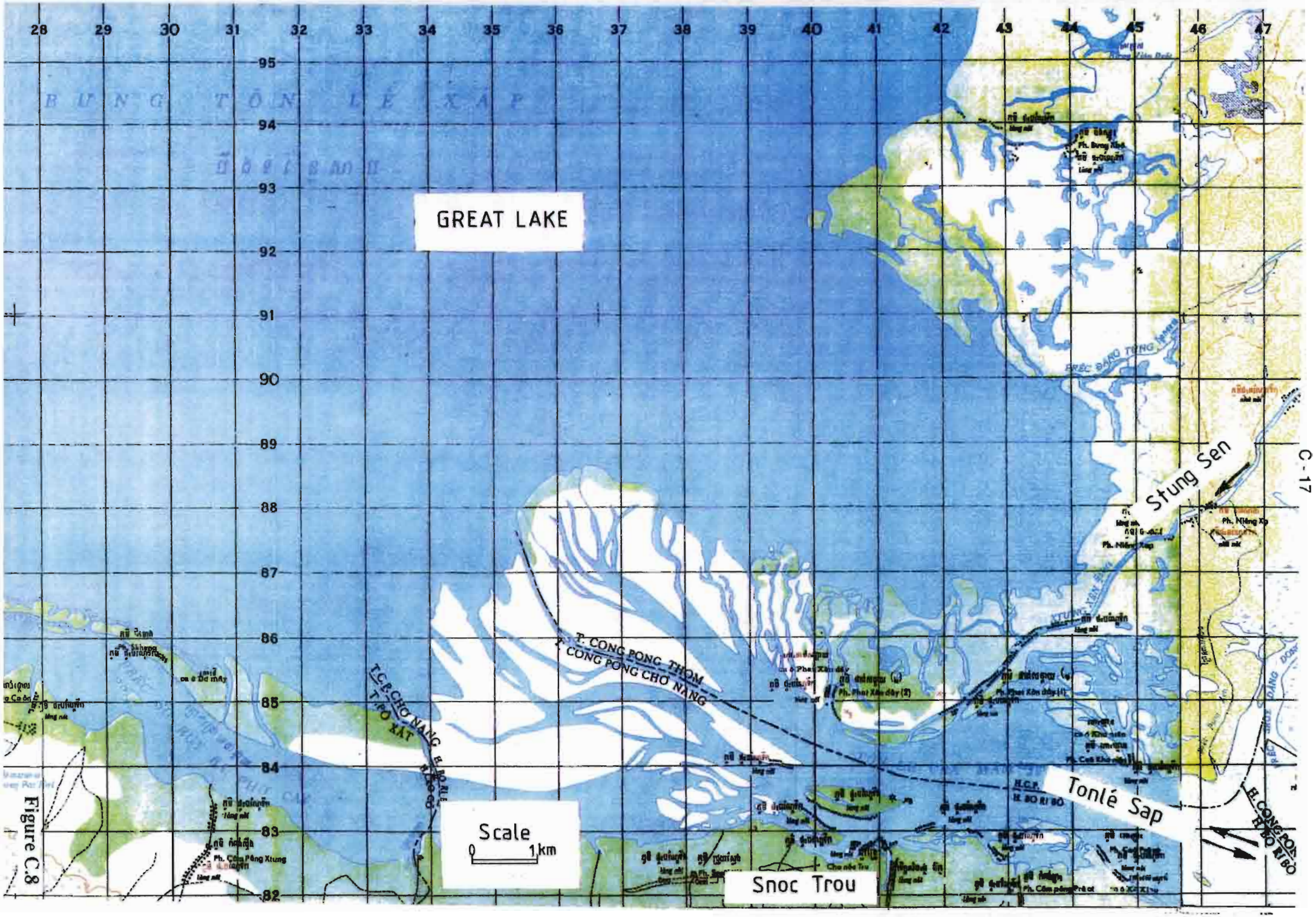


Figure C.8

C - 17

An in-depth study based on radioactive tracers was carried out on the Stung Sen by J.P. Carbonnel and is described in his 1962-63 report (see bibliography).

Investigations should be continued at these two sites (Chakdomuk and Snoc Trou) to determine the causes and rate of the sedimentation which can be observed.

iii) Any lake which receives heavily sediment-charged waters will undergo an aggradation in its bed level, even if there are periods of outflow. The important considerations are the rate of accumulation of sediments and the distribution of the sites of deposition.

It is the belief of this consultant that the deposition of sediments over the whole bed of the lake is relatively minor because there are very few changes which can be observed between the 1965 maps of the dry season lake boundary and corresponding aerial photographs taken in 1992.

The contributions to lake sedimentation due to the rivers in the catchment of the lake and due to flood flows in Tonlé Sap are not known, neither in absolute nor relative terms. The contribution from Mekong river would appear to be the most important, especially since some of the Mekong flood waters enter via overland flow (see discussion in Section C.1.3.

Local deforestation is generally given as the main cause of the increased sedimentation rates. Whereas deforestation of the Mekong basin upstream from Phnom Penh has increased the sediment concentration of the flood flows of this river, it has not yet been shown that deforestation within the direct catchment of the Great Lake has had a marked effect on sediment transport rates in the rivers discharging to the lake. The deforested zones are often only gently sloped, and the erosive action of rainfall would not be very significant.

There is no evidence that the situation has rapidly deteriorated in recent years.

In conclusion, it should be noted that available data relating to sedimentary phenomena are insufficient and that complementary investigations are absolutely necessary to determine the actual situation.

C.2.2 Evolution of the Zone of Confluence of Chakdomuk (Quatre-Bras)

a) Basic Principles

This zone near the capital has been undergoing slow but constant morphological changes for many decades. During floods, strong currents erode the not very resistant river banks on the outside of bends and, as the floods recede, sediments are deposited to form point bars on the opposite sides of the channel. The confluence of Mekong, Tonlé Sap and Bassac rivers is slowly moving downstream as a result of the erosion and deposition phenomena which are characteristic of alluvial rivers.

Figure C.9 shows the changes which have been observed in the last thirty years.

b) Consequences

The following points are made :

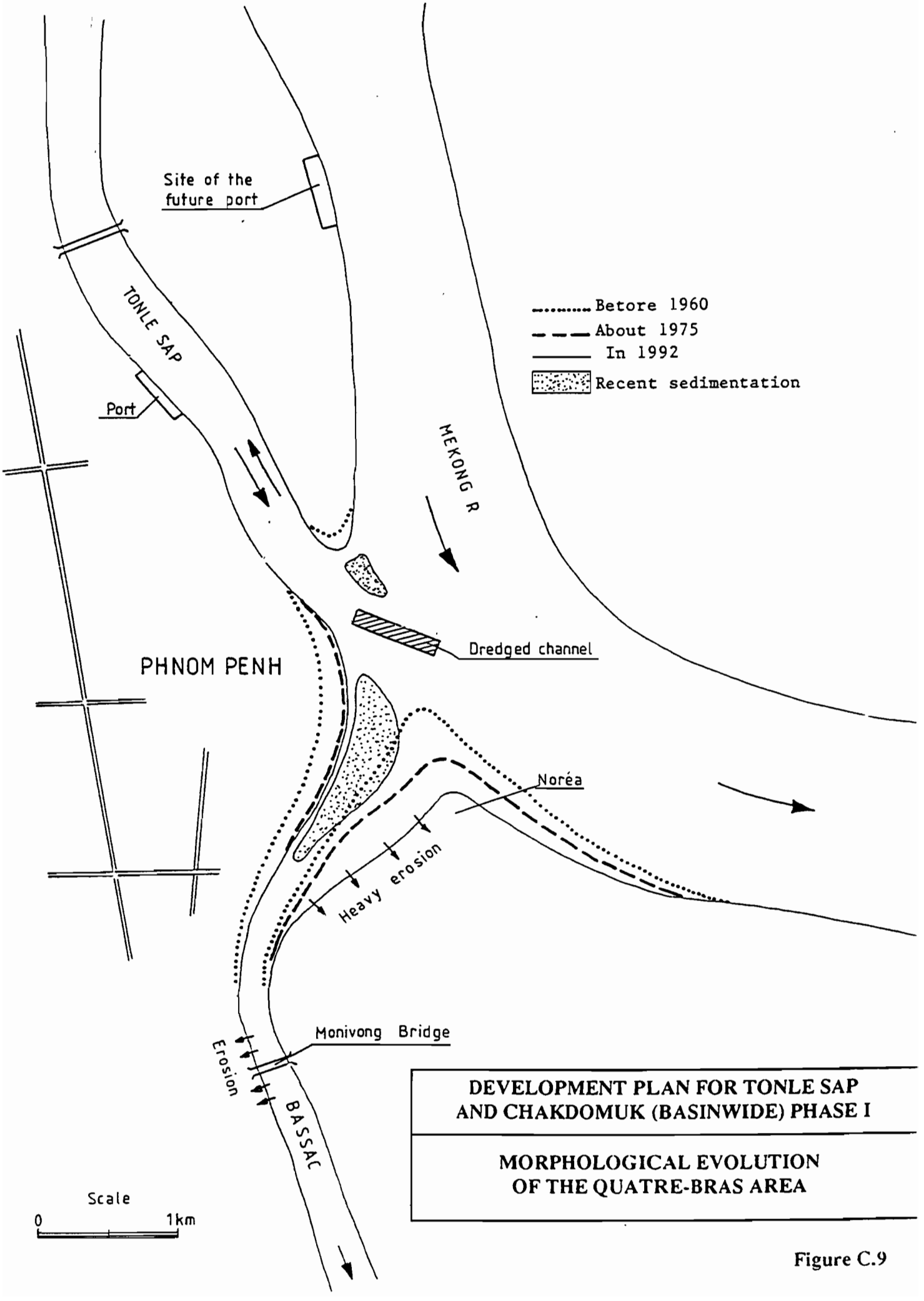
- The Noréa point and the whole of the northern bank of the zone situated between Mekong and Bassac rivers are eroding rapidly. For the last thirty years this bank has been receding at a rate of 10 to 15 m per year (see photograph).
- Concurrently a point bar is progressively building on the opposite bank of Bassac river. In this regard the backfilling of the bank for construction of the Cambodiana Hotel has certainly contributed to increasing the erosion.
- As a result of the two preceding phenomena flows to Bassac river are being diminished.
- This deformation of the entry to Bassac river increases the risks of erosion on the right bank near Monivong bridge.
- The rivermouth of Tonlé Sap is moving simultaneously downstream. The small sediment island which appeared 8 to 10 years ago will shortly be linked to the river bank. However, because the growth of the point bar separating Tonlé Sap and Mekong rivers is occurring at a slower rate than the erosion on the Noréa point, the surface area of Quatre-Bras is increasing and, as a consequence, sediment deposition will be facilitated. Dredging of the access channel to the port (Chakdomuk zone) will therefore need to be increased as a consequence.

It can be concluded that the natural evolution of this zone is unfavourable and that current problems related to erosion and sedimentation will increase.

C.2.3 Expected influence of proposed dams

All dams along a river modify the hydrological regime and sediment transport of the river to a greater or lesser extent. Several dams have already been proposed in the Mekong river basin, either in the upper Mekong basin or on Tonlé Sap river.

Several major dam projects for harnessing the main stream the Mekong were proposed during the 70's. Because of the very heavy impact on populations and environment, such projects are currently not likely to be achieved at short or medium term. As far as we have been able to determine, the dams proposed in the upper reaches would be built on tributaries and would therefore only intercept relatively small subcatchments of Mekong river. Their influence on solid discharges of the river would barely be noticeable at Phnom Penh.



DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK (BASINWIDE) PHASE I

MORPHOLOGICAL EVOLUTION OF THE QUATRE-BRAS AREA

Figure C.9

A dam on Tonlé Sap, as proposed in 1964 by the Central Water and Power Commission (New Delhi), would have a very strong influence on this watercourse. The site recommended by CWPC is located about 3 km upstream from Kampong Chhnang, and the following advantages have been claimed :

For Cambodia :

- increase in fish production, as a result of raising the lake level,
- irrigation of the zones bordering Great Lake and of downstream areas,
- reduced downstream flooding,
- possibility of installing hydro-electric generators,
- improved drainage of the zones bordering Great Lake during the wet season, and
- improved navigation on Tonlé Sap during the dry season.

For Vietnam :

- reduced flooding in the delta,
- reduced salt water intrusion,
- improved drainage,
- increased water availability for irrigation during the dry season, and
- increased draught during the dry season giving improved navigation.

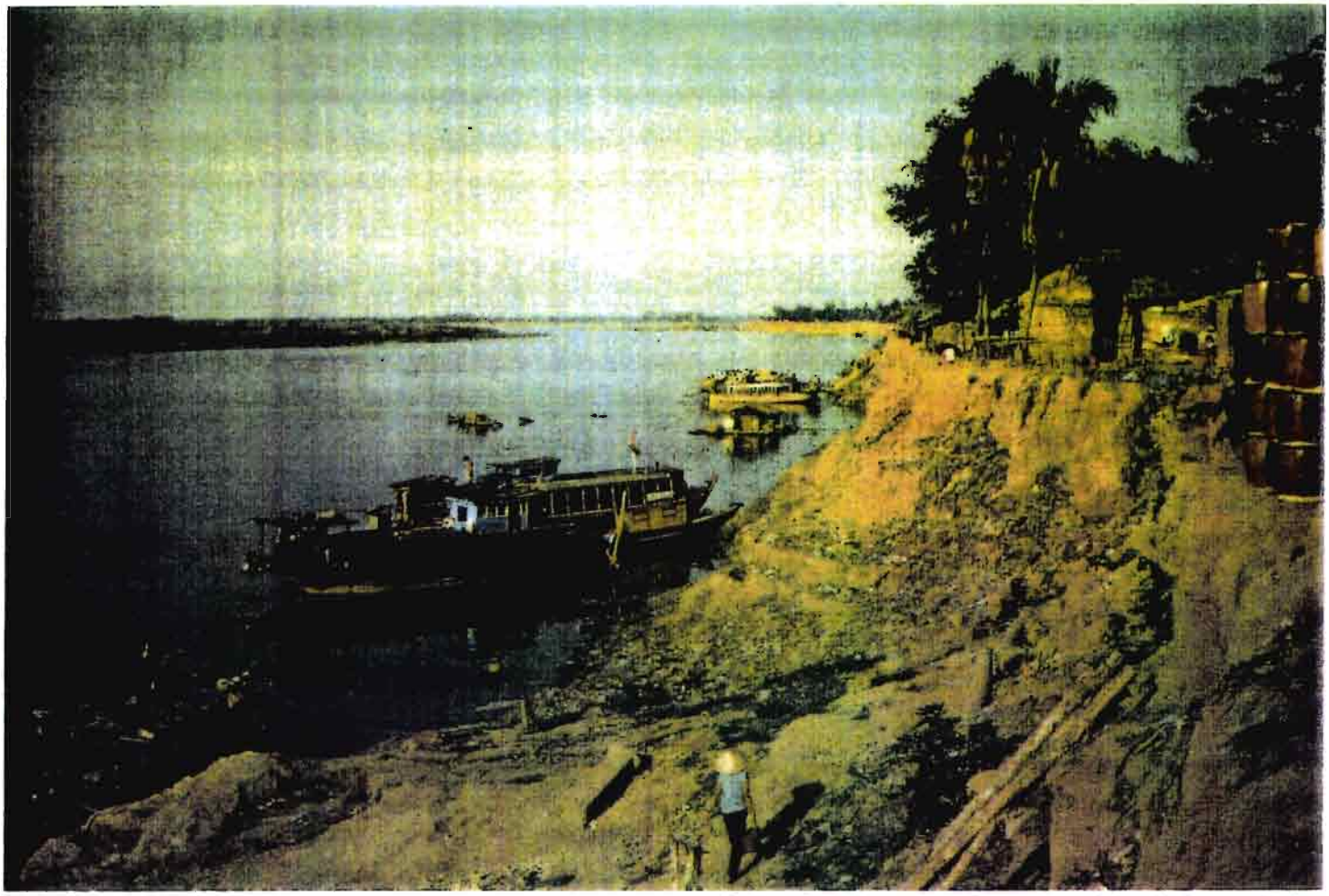
However, the proposed scheme does not address two important problems :

- influence of the dam on fish life (particularly migration), and
- influence of the dam on sediment transport (deposits in Great Lake, evolution of Tonlé Sap).

Furthermore, this project was conceived in 1964 and should now be completely reviewed to take account of recent data, and to benefit from recent progress in mobile barrage design.

C.2.4 Future Port Site for Phnom Penh

In the opinion of the author the site proposed for the new port of Phnom Penh on the right bank of Mekong river, as shown in Figure C.9, is better than the present site in Tonlé Sap with regards to sediment deposition. Channel dredging should not be required to maintain boat access, but according to the results of the survey on fish ecology and fish migrations, dredging of the Chakdomuk zone may still be necessary.



Bank erosion at the entrance to Bassac river at the location known as Noréa.

Delta formed by Tonlé Sap where it discharges into the Great Lake

D FISH AND FISHERIES

D.1 BACKGROUND AND AVAILABLE DATA

D.1.1 Preliminary Remarks

Literature on Cambodia's aquatic resources makes frequent reference to the abundance of its fish, to the inundated areas that cover up to a quarter of its territory and to the knowledge of fishermen involved in the exploitation of these riches. Recently, attention has also been drawn to endangered species, degradation of the environment, deforestation and the adverse effects of fishing on wild life stocks.

These concerns were kept foremost in the assessments that were made of the current situation during the brief site visits in March 1993, and in the literature review based on publications provided by the Mekong Committee and documents held by the National Museum of Natural History in Paris.

The present study has been mainly concerned with the Great Lake, its connecting channel (Tonlé Sap) leading to Mekong river, and the zone of low land surrounding the lake to the limit of inundation during the flooding periods. The Great Lake, however, is inseparable from the Mekong river basin system, and any consideration of physical conditions (sediment flows, hydrological variability) or biological aspects (fish migrations) should address the entire system and not just the Great Lake subsystem.

In support of the statement that the whole Mekong river basin/Great Lake drainage basin should be considered in any analyses of the fish resources, it is worth noting that, when the lake is filled to its highest levels, it accounts for less than half of the 50 000 km² total flooded areas of Cambodia. A comparison of fish resources and their exploitation in the lake with those in the remaining flooded areas should therefore also be made. It is particularly necessary to take into account the links with the waters of the Mekong upstream and downstream of Phnom Penh to verify the hypothesis of its bioecological processes.

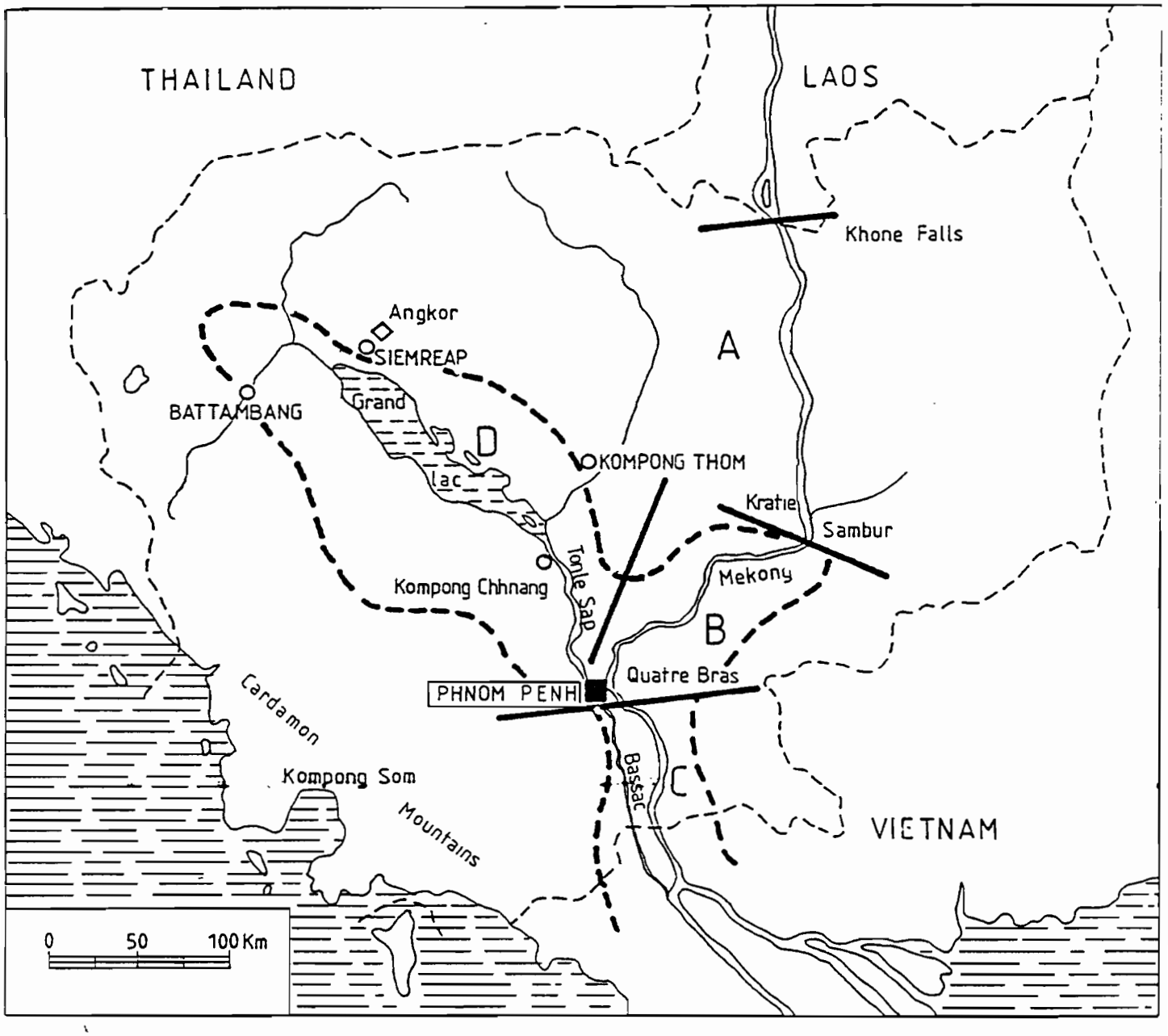
The hydro-climatic system comprising the Great Lake and its connections with Mekong river has already been described in Section C. Some features of the Mekong river basin are described below with reference to the four zones shown in **Figure D.1** :

A : To the North, from Kratié to the Khone Falls, Mekong river is interrupted by numerous rapids with noticeable deep holes (up to 40 m deep according to Blanc, 1960) and absence of inundation.

B : South of Kratié the profile of the river changes as it meets the plain. Inundations periodically affect this area which links the Phnom Penh junction to the upstream.

DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK (BASINWIDE) PHASE I

MAP OF CAMBODIA SHOWING THE MAIN AQUATIC ECOSYSTEMS : A,B,C,D



Legend ___ approximate limit of inundation during floods

_____ separation of zones

Figure D.1

C : From the south of Phnom Penh to the Vietnam border : a complex system where the upper Mekong river merges with Tonlé Sap river and with the estuarial zone downstream in Vietnam.

D : Great Lake which is related via Tonlé Sap to both the upper and lower waters of the Mekong (B and C) at Chakdomuk (Quatre Bras confluence)[1] .

The present study has considered the living resources in two parts :

- ecosystems and biology, and
- exploitation of fish resources.

D.1.2 AVAILABLE REPORTS AND DATA SOURCES

Basic data concerning fish populations, their environment and their exploitation is patchy and mostly very old. **Table D.1** shows some of the more relevant works known to be available and which were consulted. This does not represent an exhaustive survey. The outstanding works in terms of soundness and relevance are : Chevey and Le Poulain (1940), Smith (1945), Fily and d'Aubenton (1965), Kottelat (1985), Department of Fisheries (1990), and Mekong Committee (1992).

It is important to distinguish between original research publications and some expert reports which have simply quoted from older works. Both should be taken into account, but with appropriate care depending on the sources of data.

The first publications on the fisheries and fishes of Cambodia date back to the second half of the 19th century. One can quote in particular Buchard (1880) among the first interesting descriptions and the works of Pavie (1904) for observations carried out from 1882 to 1885. It should be noted that it was Pavie who described "*Pangasius (ex Pangasianodon) gigas*" and forewarned its likely extinction.

At the beginning of the 20th century numerous taxonomic descriptions appeared, and they are practically the only scientific works in the ichthyological field. Two interesting works are those of Petillot (1911) and Gruvel (1925).

The Oceanographic Institute of Nha Trang was the first permanent scientific institution for research. This period was marked by the pioneering works of Krempf (1925-1927) and above all of Chevey (1925-1948) who made observations on growth marks, inundated forest, the first fish population descriptions as well as numerous biological and systematics notes. Chevey and Le Poulain's book is the reference on bioecological studies of the Great Lake of Cambodia.

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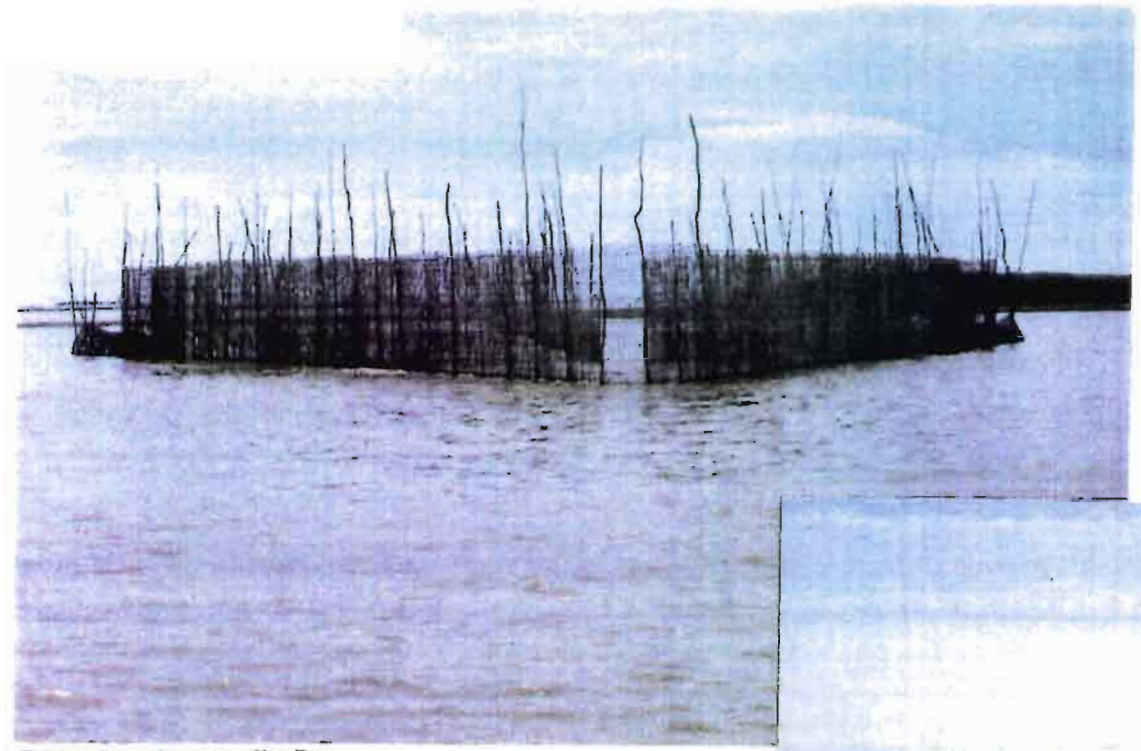
[1] The Chakdomuk area is of the utmost importance to the river/lake system and should be given special consideration in any analysis. It is the hydraulic junction, influenced by erosion and siltation, and it is the passage for upstream and downstream migrating adult fish and for juveniles as flood waters recede.

Table D.1. **Acquisition of knowledge concerning aquatic ecosystems in Cambodia**

Legend : ( ) : expert opinion based on secondary data only

1850	Explorers and naturalists	Buchard, 1880
		Pavie, 1904
1860	Recognition of economic importance	Petillot, 1911 Gruvel, 1925
1930	First attempts at biological, fisheries and socio-economic analyses	Chevey, 1933
1940 --------->	**CHEVEY, LE POULAIN**	First description of the Great Lake and its resources
	SMITH, 1945	
	Blache et Goossens, 1954	
	Expert opinions	Blanc (1950), Bardach (1959)
1960 -------->	Study of the Great Lake and Tonlé Sap	(SOULIER, 1963)* Bibliography **CARBONNEL / GUISCAFRE, 1963** **FILY / d'AUBENTON, 1965**
1970	Second series of expert opinions : Barrage proposed on Tonlé Sap	(Schmid, 1964) (d'Aubenton, 1963) (Mékong Committee, 1962)
1975 -------->	(Lagler / University of Michigan, 1976)	
1985 -------->	**KOTTELAT** (taxonomy)	
1986-88 ----->	Vietnamese works	**NGUYEN XUAN THAN et NGUYEN VAN HAO, 1991**
1991-92 ----->	Third series of expert opinions	(Edwards), (Grünewald), (FAO)... **(MEKONG COMMITTEE, 1992)**
1993 :	(Phase I, Mekong committee)	



Fish breeding enclosure near Siem Reap.

Aerial review of fish traps in the Great Lake.

Typical fishing village in the Great Lake. The houses and fish enclosures are clearly visible.

Smith's book on the fishes of Siam was published in 1945. This book gave the first comprehensive view of fish fauna at a regional level, including the Mekong species. The next notable works are those of Blache and Goossens (1954), Bardach (1959), and Blanc (1960). Blanc drew attention to the natural barrier to migration formed by the Khone Falls (see Figure D.1, Zone A).

These works can be separated into those concerned mainly with the physical environment (hydrology and sedimentation) and those treating mainly biological production (fish and fisheries) : Carbonnel and Guiscafré (1963), Fily and d'Aubenton (1965). Apart from recent Vietnamese works (see below), they constitute the latest scientific contributions to a broad view of the Great Lake.

At that time the Mekong Committee carried out studies on the consequences of construction of a barrage on Tonlé Sap : Schmid (1964), d'Aubenton (1963), and Mekong Committee (1962).

Due to political disturbances during the last twenty years, there has been little further publication in this field. The publications of the University of Michigan (Lagler, 1976) are an example : the basin-wide programmes initiated by the Mekong Committee were only partially implemented in Vietnam and had to be cancelled in Cambodia. The Department of Fisheries relaunched a research programme on limnology and fisheries and carried out an ambitious programme from 1986 to 1988, whose first results have recently been published in Vietnamese (Nguyen Xan Tan and Nguyen Van Hao, 1991).

Recent works on taxonomy, such as those of Kottelat (1988) and Roberts and Vidthayanon (1992), are important. There have been no updated scientific field studies on Cambodia and the Great Lake for the last thirty years (Table D.1). There are, however, some useful national records (Fisheries Statistics, 1980-1991; Regulation, 1990) and some recent studies related to an expected new economic boom : Grunewald (1990), FAO (1991), Edwards (1990), Nandeesha (1992), Durand (1992).

Finally mention is made of a study carried out in 1992 for the Mekong Committee and financed by Denmark (Mekong Committee, 1992). This work reviews all of the available literature on the subject, and is often referred to in this report.

D.2 BIO-ECOLOGICAL CONTEXT

The productivity of the fresh waters of Cambodia is acknowledged to be among the highest in the world. High temperatures (the Great Lake lies at 13°N) and periodical flooding are responsible for the high productivity. The role of the inundated forest should also be noted. It contributes to the process in different ways : enhancement of the overall productivity of the system, rapid development of micro-organism, phyto and zooplankton, shelters to juveniles and/or specific adult fish species, reproduction zones for some fish species.

However, the bio-ecological importance of the inundated forest is difficult to demonstrate and there is a need to clarify the process of this very specific ecosystem. It is essential that, at some time, research studies be performed to quantify the role of the inundated forest.

The identification of the characteristic fish species of Mekong river and of Cambodia, in particular, was made as early as the 19th century (Sauvage, Tirant, Boulenger), and in the early descriptions by Cuvier and Valenciennes. More recently Kottelat (1985) listed 215 species belonging to 127 different genus and 47 families. According to Kottelat, 400 nominal species have been described since Sauvage.

After Smith (1945), a large collection was implemented by d'Aubenton between 1960 and 1964 which paved the way to the evaluation of genus or groups of a relatively limited size (d'Aubenton, 1965b; d'Aubenton and Blanc, 1965, 1966, 1967; Blanc and Fourmanoir, 1965; Stauch, 1966; Stauch and d'Aubenton, 1965; de Soutter, 1975, 1977).

Meanwhile Kottelat completed the identification of fish in this collection, enabling the inventory of 215 fish species in the Cambodian fish fauna and the establishment of a comprehensive list of 131 khmer terms. Kottelat gives particulars on the overwhelming abundance of "Cyprinidae", with 42 genus and 81 species and the "Siluriformes" which include 23 genus and 41 species for 8 families. In his taxonomic review Kottelat remarked the lack of systematics on "*Pangasius*", so much as to write that of the 16 nominal species in the Cambodian waters only "*P. larnaudi*" could be identified. Since then, the family of "*Pangasiidae*" has been reviewed by Roberts and Vidthayanon, (1992).

The distribution of species does not prove any particular endemism and the great majority of the species appear elsewhere in the Mekong, in south of Vietnam, Laos and in Thailand. There does not, therefore, seem to be a geographical barrier at the Khone Falls as far as we know.

It is possible to classify the major species into three groups with a view to their biological and ecological features (Mekong Committee, 1992) :

a) A group of species which are mainly associated with the larger streams/main river, but undertake spawning migrations between these and the flooded areas in the wet season. This group is commonly classified as "white fish". They are mainly cyprinids (*Cirrhinus aurautus, Hampala macrolepidota, Puntius altus, Leptobarbus hoevenii, Osterchilus melanopleura, Labeo [Morulius] chrysophekaidon),* Schilbeidae *(Notopterus chitala and N.notopterus*) ;

b) Species which are able to survive under more adverse and varied environmental conditions (low oxygen levels, some acidity, some salinity) and which can remain in the swamps and plains year round, commonly classified as "black fish". This group includes members of the families Clariidae (*Clarias batrachus*),

Ophicephalidae (*Channa micropeltes, C. striata*), Bagridae (*Mystus [Macrones] nemurus*) and Anabantidae (*Anabas testudineus, Trichogaster trichopterus*);

c) Smaller, fast growing and prolific species (opportunists), which are able to utilize the flood period for prolific reproduction and growth. The group consists mainly of cyprinids (*Thynnichthys thynnoides, Dangila siamensis, Cirrhinus jullieni*). Due to their biology they can exhibit very high abundance in a distinct seasonal pattern. The opportunists and small specimen of several species are collectively called "*trey changvar*".

The reproduction cycle functions predominantly by migrations, which are themselves regulated by the hydrological cycle. Referring to the consequences of a barrage on Tonlé Sap, d'Aubenton (1963) gave particulars of the main biotopes in Cambodia and on the related migrations.

Two main migration types are commonly distinguished : the genetic migrations, related to the reproduction of species, and the trophic migrations, related to the search for food. Another typology makes a distinction between longitudinal and lateral migrations. The first ones cover larger distances : the species involved are able to cover very large distances (group a). The lateral migrations are concerned with relatively sedentary species which pass from the river to flooded areas with no specific displacement at low water : they can be trophic as well as genetic (group b). The lateral migrations are generally catadromous : the fish follow the flood while the longitudinal migrations can be either anadromous or catadromous.

At lowest water level, the total volume of residual waters of the Great Lake is about 2 to 3×10^9 m^3 compared with a maximum volume at high water level about 20 to 30 times higher. The shelter provided by Tonlé Sap is only about 10% of the volume of low waters in the Great Lake. It is probable that the main shelter is provided by Mekong river. considering the overcrowding which occurs in the residual waters of the lake. This is substantiated by d'Aubenton (1965a) : "*at high waters the fish try to find their way to the inundated zones. They travel in the direction of the rising waters, that is to say with the stream. At receding waters the fish leave the inundated zones and shelter from the stream in still waters (Great Lake, Beng, Tonlé Sap). They then descend as the waters recede in accordance with the lunar cycles until they reach permanent waters (rivers, tributaries, stung) where they move upstream*" [2].

In conclusion it can be said that the migration patterns in the Great Lake and Tonlé Sap system are well documented, but that the quantitative and qualitative evolution to the present time, particularly in recent years, is not known. The situation upstream and downstream of Phnom Penh in Mekong river is less well understood (Zones B and C in

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[2] The opportunists species (see group c above) migrates collectively as the waters of the Great Lake recede in Tonlé Sap, and provide the major part of the day catches. Their behaviour in Mekong river is not yet fully understood.

Figure D.1). It is important that the exchanges between Mekong river and Tonlé Sap at Quatre Bras be studied in the near future.

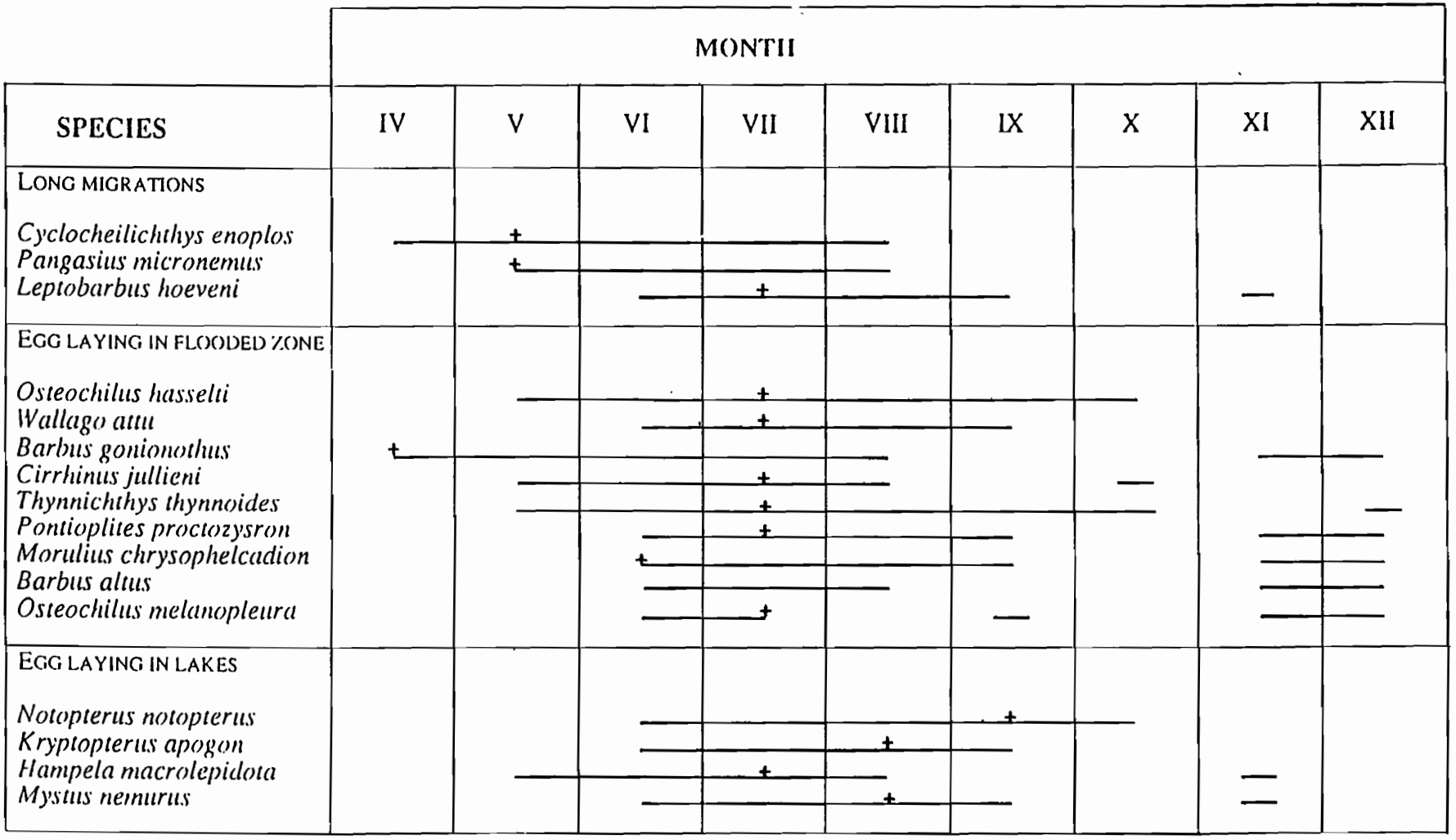
There are 3 basic domains in bio-ecology : reproduction, feeding and growth.

- Fish reproduction, which is heavily dependent on the hydrological cycle and on migrations, is the best understood of these fields (Chevey, 1939). There are some fragmentary data in old publications as well as in Roberts (1992) on the Pangasiidae, or in recent Vietnamese works[3] . These works have adequately confirmed the peak egg laying period which, in the lower Mekong, corresponds to the flooding periods (see **Figure D.2**).
- Feeding patterns and behaviour provide useful information essential for the analysis of fish populations and dynamics. The diet composition has only partiallty been assessed. The same reference as for those cited for reproduction apply. The interrelations between the various species, competition for food and role of the biotopes cannot be understood without a comprehension of sources and utilisation of food. The evaluation of existing data would be a preliminary step.
- The growth of the main species is only approximately known. Chevey's works revealed the existence of distinct growth marks on various fish species in the Great Lake, but the large differences he quoted between the growth of fishes in the inundated forests and in the lakes, and between lakes and Tonlé Sap for many Cyprinids species remains unconfirmed. Being able to determine the age of a fish is essential for the management of stocks, and should be given high priority. More precisely, the determination of age at first reproduction for the principal species should be undertaken as soon as new biology research programmes are commenced.

[3] These works devoted to the diet composition and fish growth were not taken into consideration because the translation was not available in time.

Figure D.2. Egg laying periods for 16 species of economically important + freshwater fish in Cambodia (NGUYEN XUAN TAN and NGUYEN VAN HAO, 1991)

+ : maximum



D.3 EXPLOITATION OF RESOURCES

D.3.1 Introduction

In the 19th century leases for fisheries were awarded by the drawing of lots, giving rise to many conflicts (Petillot, 1911). The present system with its complicated rules and centralised administration results from the 1884 Convention between France and Cambodia and from the Royal Decree of 1908. This organization is described below, followed by a review of the available data and an analysis of the present level of exploitation.

D.3.2 System of Exploitation

A large diversity exists in fishing gear and methods, each adapted to the environmental conditions and to the species being sought according to the stages of the annual flooding cycle. A recent work by the Department of Fisheries describes more than 70 different techniques and gears taken into account in the regulations. The range extends from lines, dipping nets and harpoons used by families to the falling-stage traps and large fixed trawls including all the gill nets, cast nets and draw nets. An interesting description can be found in Fily and d'Aubenton (1966).

The Department of Fisheries defines three main fishery types : family (subsistence), small-scale (artisanal) and industrial, each one being characterized by fishing techniques and gears.

- For **subsistence fishery**, different gears are authorized all year round, including fish traps, bamboos, baskets, gill nets having less than 10 m in length, square-dipping nets less than 2 m wide. The artisanal or small-scale fishery includes larger fishing gears which are privately owned. Industrial fishery corresponds to collective gear, generally large-sized and of greater efficiency such as large draw nets, falling-stage traps or *days* (working as large fixed trawls). Family fishery is private subsistence fishery, whereas the two other types are professional and often include some kind of commercialisation of fish products, the distinction being mainly in the private or individual as opposed to the collective nature of ownership. While family fishery may be practised all year round with certain pre-defined gear and territorial limitations, artisanal and industrial fisheries are heavily regulated.
- **Artisanal and industrial fisheries** are prohibited during four months (from 1 June to 30 September north of Quatre Bras and from 1 July to 30 October downstream of the confluence area). The whole of the territory which can be exploited for fishing (banks of Mekong and Bassac river, areas surrounding the Great Lake, inundated zones, etc.) is strictly divided into zones where fishing is prohibited and zones divided into lots (**Figure D.3**).

DEVELOPMENT PLAN FOR TONLE SAP
AND CHAKDOMUK (BASINWIDE) PHASE I

FISHING PERMITS IN THE GREAT LAKE
WITH THE LOW WATER SURFACE
OF THE LAKE SHOWN SHADED

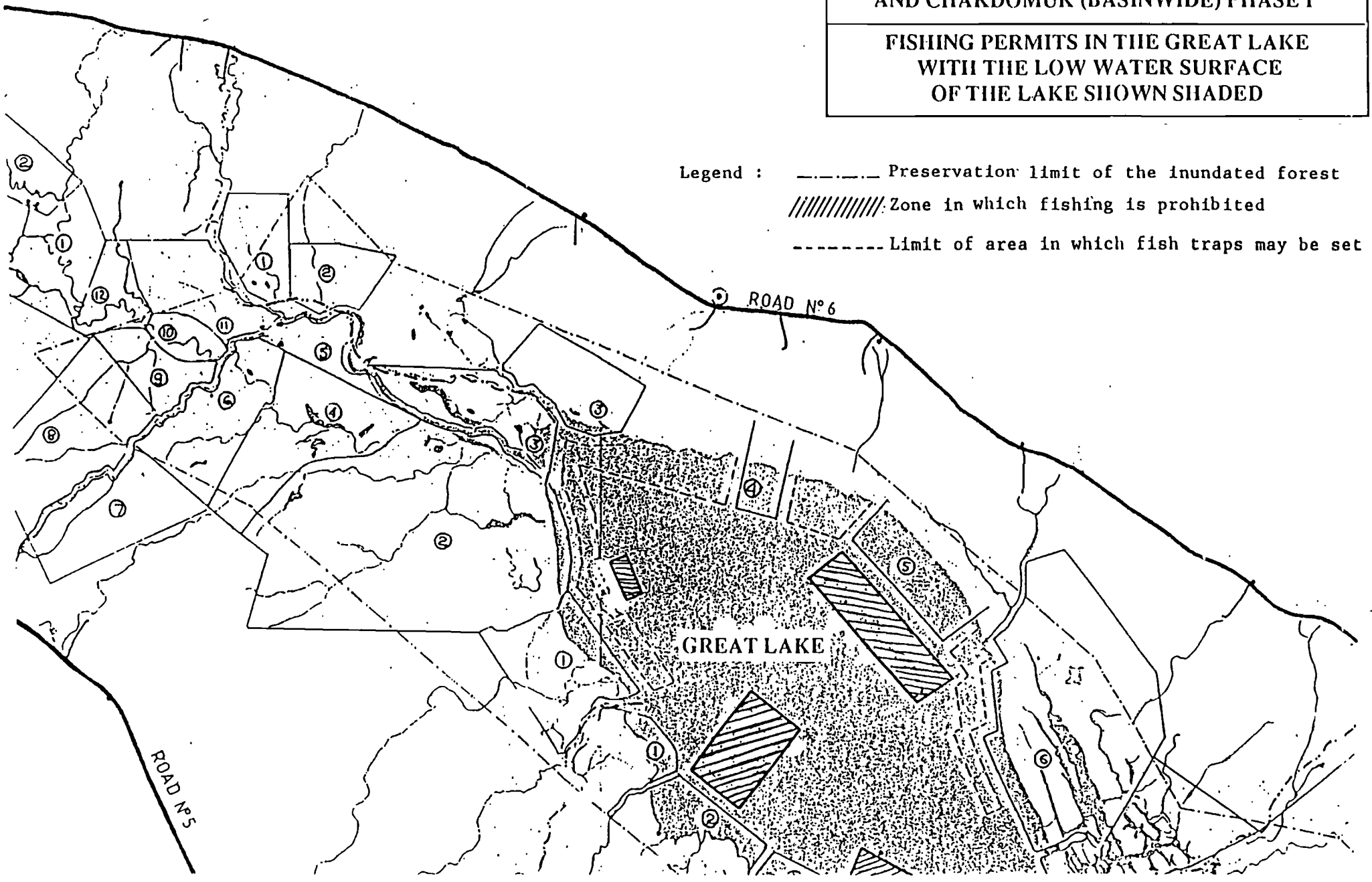


Figure D.3

Each lot corresponds to a territory and is put up for auction every two years, the minimal value of the lot being fixed by the Department of Fisheries according to the fishing potential and to the catches of the previous year. Inside the lot the use of fishing gears is regulated by the Department of Fisheries which restricts also the type of gear and their number, location and period of operation.

For each lot there is a record book in which the catches are recorded for each day of exploitation and for each type of gear according to the major categories of fish. These official statistics are compiled and published each year by the Department of Fisheries. The Department of Fisheries also operates several lots as state fisheries, from which it would be hoped that some useful statistics relating to commercial fishing could be obtained.

Figure D.3 shows the complexity of the regulation of exploitation, particularly in the Great Lake which includes fishing lots, zones strictly limited to lobster pots and zones where fishing is prohibited. In theory at least the organization is very elaborate, but adherence to its restrictions should be checked in the field, as should the accuracy of the records of catches. Possibly as a result of political unrest, there are some lots which are not being operated at present (along Battambang and Stung Sangker rivers, for example). Quite apart from any considerations of differences between regulation and common practice, it may be worthwhile to overhaul the whole regulatory system to improve its effectiveness.

Fishing and related activities in the Great Lake and Tonlé Sap are determined by the hydrological cycle of rising and receding flood waters and the corresponding fish migrations. Fily and d'Aubenton (1965) described the fishing calendar in the Great Lake and Tonlé Sap as it relates to the water level (**Figure D.4**). It is worth noting that in 1993 the overall organisation is the same as it was 30 years ago, and there is quite a strong similarity with the scheme described by Chevey and Le Poulain in the thirties. This is very marked for industrial fisheries : the same distribution of lots and traps, comparable size of *days* in Tonlé Sap, existence of low water draw nets and the disappearance of the unprofitable high water draw nets. A closer examination would be required to establish the situation with regard to the individual fishing gear.

The apparent stability of the organisation of fisheries does not mean that there have been no significant changes in the level of activity and in the relative importance held by each type of fishing. In particular, there have been important technological innovations.

Aquaculture has not been studied in great depth to the present, but some general observations can be found (Lafont et Savoeun, 1951; Tin, 1976, Mok, 1991). More recent reports include those of Edwards, 1991; Nandeesha, 1991; Lazard et Legendre, 1993).

DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK (BASINWIDE) PHASE I

TIMING OF FISHING ACTIVITIES IN RELATION TO FLOOD LEVELS

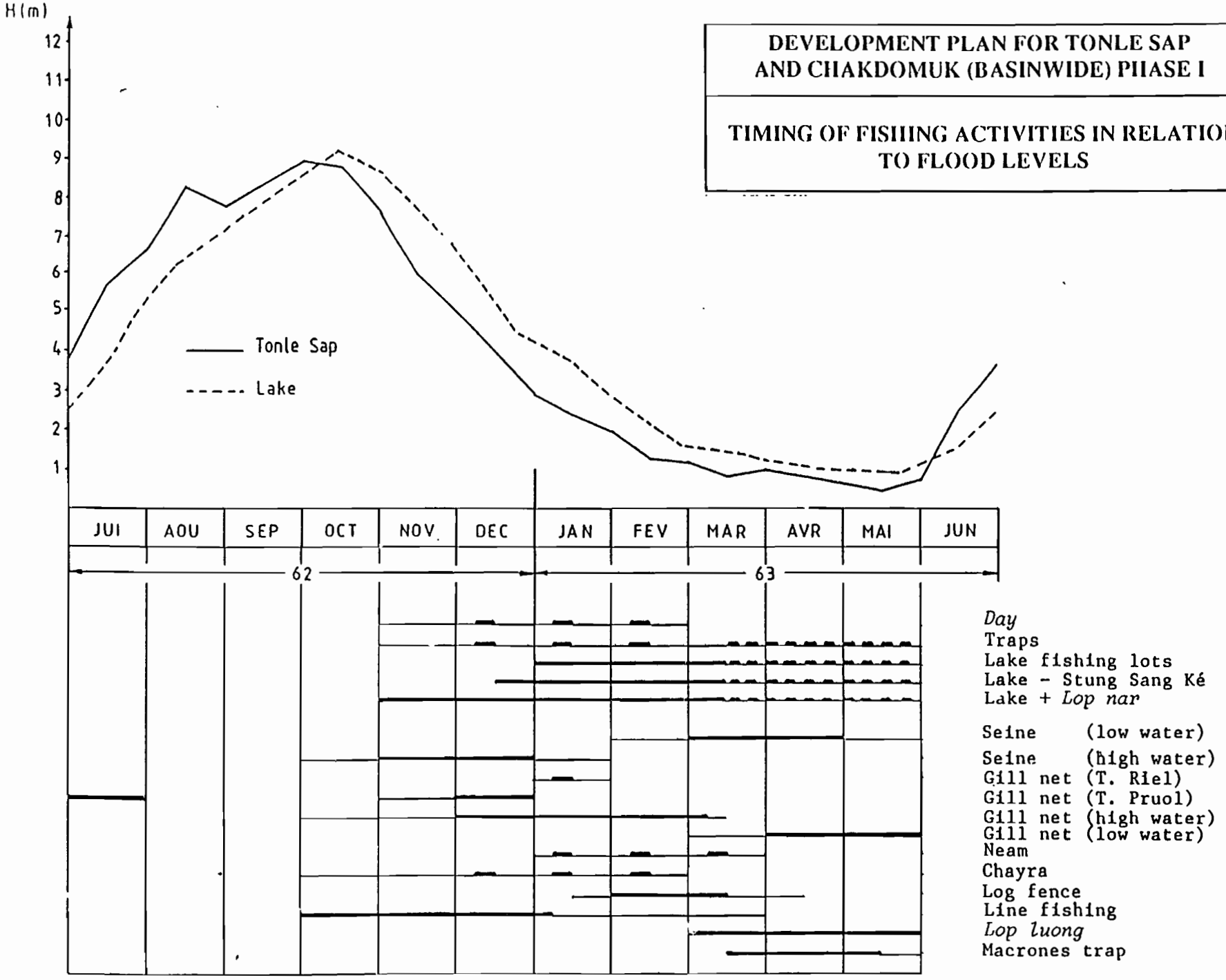


Figure D.1

Aquaculture has been practised in Cambodia for a long time without ever being developed to any large extent. This is essentially due to the prevalence of inland fisheries which provide some 150 000 to 200 000 tons/year.

Though the aquaculture yields were negligible at the end of the seventies and in the early eighties, official statistics show a continuous growth in total production in recent years : from 1 600 tons in 1984 to 6-7 000 tons in 1990-1991. The Department of Fisheries aims to increase aquaculture production to 10 000 tons by 1995.

Fish culture in cages and pens accounts for 85% of the 12 000 tons produced during the two years 1989 and 1990, of which about two-thirds were from cages. The breeding and raising of fish in ponds, introduced by fishermen from Vietnam, also exists. Integrated rice production with fish culture and the use of fish ponds and temporary water bodies for fish raising are also prevalent. In the beginning cages were only used to keep fish alive prior to delivery to markets. Progressively the period of retention was increased, corresponding to the inclusion of younger fish which are fed until they are large enough to be sold. This phase may last up to one year and is now widely practised in the Tonlé Sap and in the Great Lake.

There are from 10 to 15 species cultured in Cambodia. The list includes numerous Cyprinidae, of which Cambodians seem to be very fond, as well as Pangasiidae and such species as *Clarias batrachus* or *Channa* (ex *Ophiocephalus micropeltes*). Imported species such as carps and tilapias are also raised in cages.

Aquaculture in Cambodia remains largely dependent on capture fisheries. Breeding in hatcheries, despite recent improvements, is still far from meeting the needs and it may be assumed that 90 to 95% of larvae and juveniles are captured directly from natural water bodies. Hatching techniques therefore need to be developed. Feed is partially provided by using small fish captured in artisanal fisheries, which means that there is less available for traditional processed fish products (dried fish, prahoc,...). Consequently the development of aquaculture will depend on finding other feed sources.

There is a general lack of facilities to carry out any aquaculture research. The Chhrang Cham Res research station near Phnom Penh could be a suitable venue, as some production of indigenous species is already on-going there. It could also play a role in training because of the existing facilities : laboratories, classrooms, hatcheries. However, the station is currently inoperative because of the lack of water, electricity supply and skilled staff.

In conclusion, aquaculture will continue to expand, but should be the subject of a strategic analysis. Its potential for meeting the needs of subsistence, national markets and exportation should be developed, and it would be wise to concentrate on indigenous species because of established taste preferences.

Various NGO's have recently shown interest and have tentatively implemented some field projects : such efforts should also be directed in a manner likely to provide the greatest national benefit.

The implementation of a national aquaculture development scheme necessitates taking all the various factors into consideration, with a comprehensive approach and multi-disciplinary point of view.

D.3.3 Relevant Data

There exist reasonably extensive and detailed descriptions of the different fishing techniques employed, and these could be used to help modify the regulations concerning permissible types of gear, prohibited zones and fishing seasons. These descriptions, including the outstanding descriptions of gears and techniques by Chevey and Le Poulain (1940), Fily and d'Aubenton (1965) are still valid in relation to industrial and artisanal fishing. However, they do not provide sufficient accurate data relating to production, neither at the national level, nor at the regional or local levels. Therefore, it is necessary to consider different methods and approaches to estimate fish production.

An initial estimate can be made from the number, the locations and the main characteristics of the various fishing gears used. Such information is relatively easy to obtain for collectively-owned gear (*days*, draw nets, traps) but is much harder to gather information for individual fishing gear. It would be worthwhile to examine the information collected by Regional Fisheries Offices and examine if it would be possible to make indirect estimates from the available data. The first level of estimate therefore defines the fishing potential, that is the capacity of a particular type of fishing gear in a given zone.

A second estimate can be done by measuring the yields of each type of fishing gear, during fixed periods of time (for instance, a month) and for different locations. There are comprehensive figures for industrial fisheries, but sampling and extrapolation would be required for all individual fishing gears of any size. If, at the same time, the main species are identified as well, then it would be possible to obtain total and spatial-temporal estimates for the major locations : the Great Lake, the Tonlé Sap and the whole water resources of Cambodia.

The fishing effort would represent a third quantitative estimation. The definition of a unit of effort (for instance a given surface of gill net during a given period of time) would enable definition of the fishing gear yield, would improve the accuracy of extrapolations and would enable drawing up of comparisons and preparation of fisheries yield models. Such data have never been collected on the fresh waters of Cambodia.

Fishing village and fish raising enclosures

Return from a fishing trip near the entrance to the Great Lake in the dry season

A final and more elaborate quantitative estimation is given by analysis of the fish population structure. This requires a knowledge of size according to age and of the yield of the various fishing gears for any particular effort. From such an analysis it would be possible to formulate analytical models which would be valuable for sectorial planning[4] .

It would appear that quantitative data are lacking with respect to the production of inland fisheries in Cambodia. There are no data on yields, fishing effort and fish population structures. The only exceptions are the studies on *days* by Chevey and Le Poulain (1940), Fily and d'Aubenton (1966), Nguyen Van Hao and Nguyen Xuan Tan (1991). A tentative analysis is given below.

D.3.4 Evaluation of Statistics

Estimates of total annual catches enable comparisons to be made from one year to another for any given ecosystem. The total yield, expressed as t/km², provides a convenient basis for comparison with other similar systems, thereby indicating the relative level of exploitation. These comparisons are of limited value in the absence of reliable and accurate quantitative data.

In Cambodia official statistics given by the Department of Fisheries date back to 1980 (**Figure D.5**), although 1980 itself was a year of transition and re-installation and should not be used in analyses. For the period for which data are available (1981 to 1991) the total catches range from 50 000 to 74 000 t/year. One must be cautious in interpreting these figures, as :

- family fisheries are not taken into account, though they probably contribute for an important amount of fish ;
- it is unknown whether all the small-scale fishing is considered or not ; and
- there must be some undeclared catches (for example, poaching) which would not be insignificant.

Assuming that these factors are uniformly present from one year to another, the quoted yields which greatly underestimate the total catches would still be useful indices of total catches. It is interesting to note that no trend is apparent in the 11 years considered, the recent increases (1989 - 1991) being not necessarily significant. Taking the average of 60 400 t/year (Figure D.5) as a reference value, and considering that family fisheries (essentially subsistence) contribute with an additional average of 50 000 t/year (FAO, 1991), **total fish production would be around 120 to 140 000 t/year**, after allowing a reasonable amount for under-estimation of catches. About 2/3 of this total is sold in markets.

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(4) No reference is intended here to techniques using artificial intelligence or to interactive simulations. These, however, should not be rejected as possible tools, as recent studies, such as Morand and Bousquet (1993) have been particularly promising.

DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK (BASINWIDE) PHASE I

TOTAL FRESH FISH PRODUCTION
(Department of fisheries , 1992)

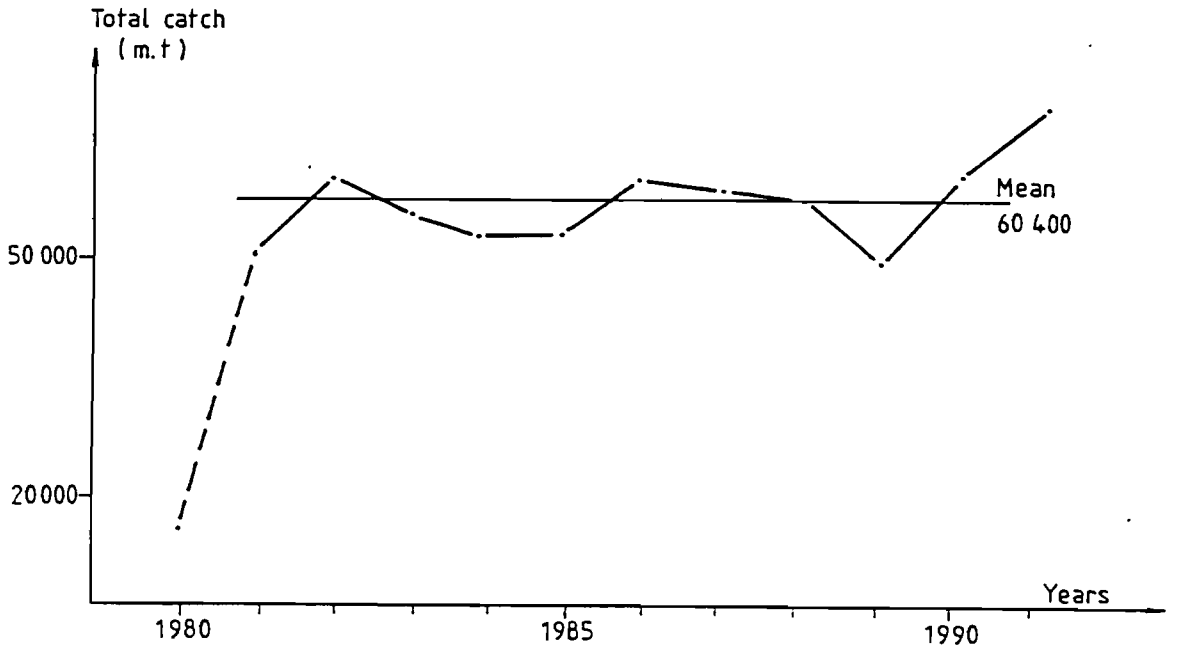

Figure D.5

To provide a basis for comparison it is interesting to compare the above figures with those given in published works of which those of Chevey and Le Poulain (1940) seem to be the most reliable. They state that (p. 41) : "*the total annual fishery yield of Cambodia is estimated to be 120 000 t*"...."*The Great Lake in Cambodia [...] yields an estimated 50 000 t of fresh fish*". The methods used for these estimations are not given by the authors.

Another estimate (more precise and well documented) was given by Fily and d'Aubenton for the 1962-1963 fishing season (p. 339) : they estimate total catches for the Great Lake and Tonlé Sap at 54 000 t/year (of which 55% were produced by family and small-scale fisheries). As did Chevey and Le Poulain, they assume a larger contribution from the Mekong and the related inundation zones than from the Great Lake, which would therefore means a total production of 120 000 to 130 000 tons for the year 1962-1963.

Bardach (1969) considers that Chevey and Le Poulain underestimated the fish catch and gives a total catch of 147 000 t for 1939. While admitting that the statistics of the 1950's are "*even less reliable [...] than in the past*", he estimates the production as being 130 000 t for the year 1957.

Lastly, the University of Michigan (1975) made indirect evaluations based on average fish yields per ha for the overall inundated area and on the fish consumption *per capita* during year 1970. Their estimates range from 125 000 to 160 000 t/year for the total fresh waters of Cambodia, of which 50 000 to 80,000 t come from the Great Lake.

The various figures are presented in **Table D.2**. It would not be possible from these figures to draw any conclusions regarding trends, the only tentative conclusion which can be made is that the yields in the 1980's are of the same order as those 40 years earlier. We therefore disagree with Dennis and Woodsworth (1992) who claim that "*Inland fish production was more than 30% below annual production in the 1960's*".

The *day* net fishing in Tonlé Sap provides a noticeable exception to the general lack of quantitative and reliable data on fish yields. The sources include the works by Chevey et al. (1939), revised by Chevey and Le Poulain (1940), those of Fily and d'Aubenton (1965), and the recent field observations by Nguyen Van Hao and Nguyen Xuan Tan (1991).

The *day* fishing method is unique to Cambodia. Some of its characteristics include the following :

- The *day* is a stationary trapping device set in the river with bamboo rafts and anchors so that the flow passes through it;
- Its cross-sectional shape is about 20 to 25 m in width and about 10 m in depth, the net being up to 100 m in length. The mesh size decreases from 10 to 15 cm near the entrance of the net, to 10 mm at the end of it, where an open bamboo or

Table D.2. Assessment of Total Freshwater Fish Catches

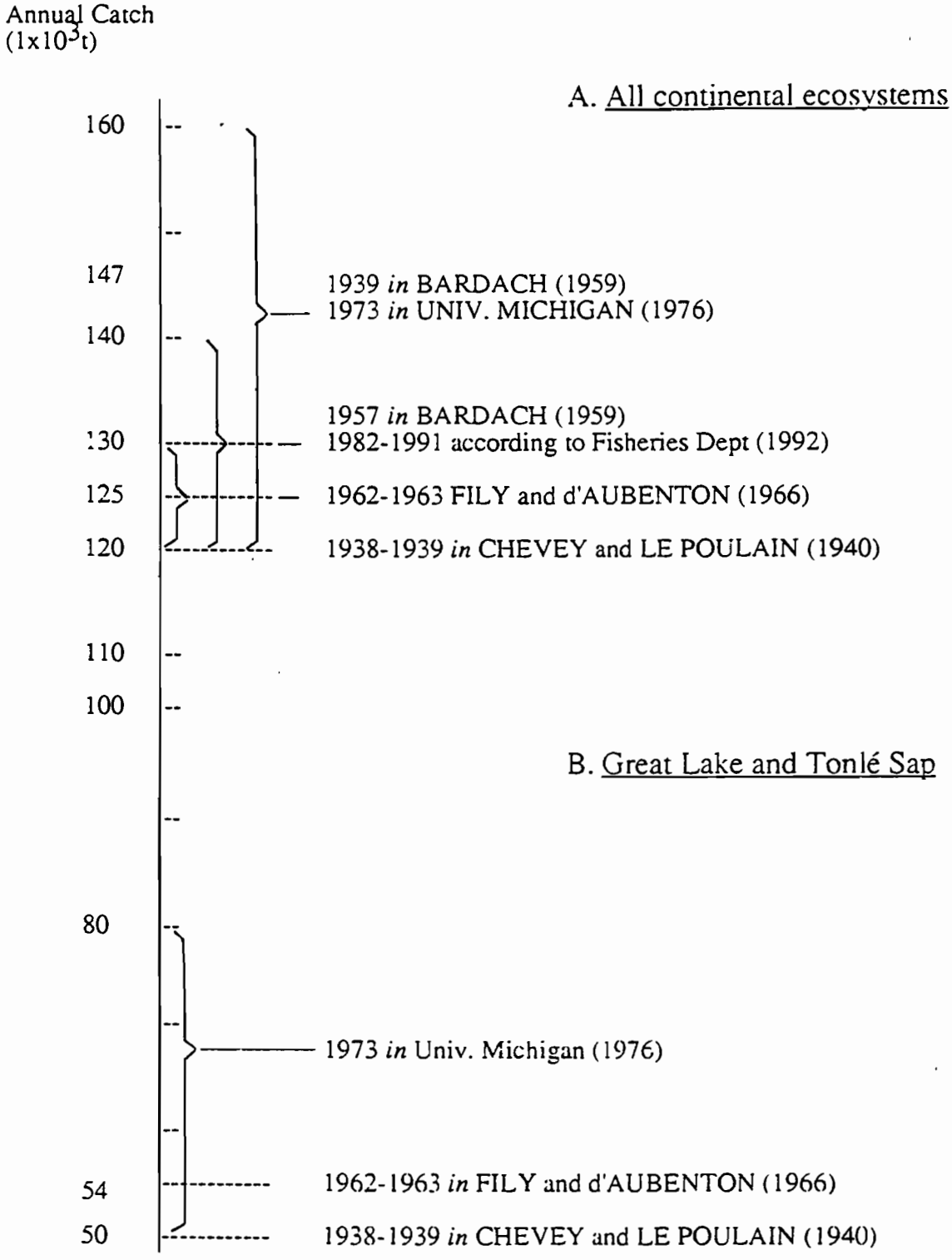

TABLE D.3 : Yields of DAY in TONLE SAP averaged over four fishing seasons.
(according to NGUYEN XUAN TAN and NGUYEN VAN HAO, 1991)

The sites 1 to 22 are shown on Figure D.6.

Site	1	2	3	4	5	6	7	8	9	10	11/12	13	14	15	17	18	19	22	$\overline{m}$	Total Catch/yr
1983-84	157	257	205	210	233	63	79	81	59	105	59	68	214	38	60	88	304	59	117	10 090
1985-86	250	345	352	344	390	122	157	157	116	206	110	133	420	74	118	176	600	114	209	18 026
1986-87	71	101	99	98	109	62	78	79	56	104	55	68	213	38	59	83	299	57	86	7 413
1987-88	187	240	270	261	296	98	124	127	86	171	90	110	350	63	96	128	488	94	164	14 142
Nb. DAY	4	4	4	4	6	7	7	8	5	7	7	5	1	1	7	1	3	5	86	/
Av.Yield/DAY	166	236	232	228	257	86	110	111	79	147	78	95	299	53	83	118	423	81	144	12 419
Total Av.Yield	665	943	927	912	1544	602	769	890	396	1027	544	473	299	53	583	118	1269	404		

rattan basket is placed. On each site, they are generally several *days* set perpendicular to the flow, a maximum number of 10 days operating together on a same line (**Figure D.6**).

- There are only 2 to 3 periods each year during which the *day* operates (in Tonlé Sap). Each period comprises about 10 days during the falling stage of the water (from December to February), and corresponds to the waxing moon. For the available data sample covering the 1983-1988 period, 80% of the *day* catch was made during the single month of January (Table **D.3**).

These characteristics would tend to indicate that capture of fish migrating on the falling stage from the Great Lake is very efficient. There are a number of reasons for this : selectivity is low (even the smallest fish are harvested), the volume of water passing through each *day* is large because of the area presented to the flow (about 200 m²), there is a large number of *day* in Tonlé Sap (108 of them in 1939 according to Chevey and Le Poulain, 61 in 1962-63 according to Fily and d'Aubenton, 86 between 1983 and 1988 according to Nguyen Van Hao and Nguyen Xuan Tan).

Chevey and Le Poulain explicitly conclude : "*the day is not such a detrimental fishing gear during the passage of Trey Changvar*[5] *from November to February but becomes so from March to November in all the rivers where there is a strong current*". As a direct result of the findings of this report the number of *day*s was strictly limited and the use of the fishing gear was limited to the Tonlé Sap. Bardach (1959) admits that the limitation of the use of *day* to Tonlé Sap is a progress, but states that they should be made more selective or that they should be withdrawn completely. One finds, however, the same number of *day*s on Tonlé Sap in 1993 as in 1939, with the same characteristics and the same distribution pattern (Figure D.6). Any new regulations should be supported by more comprehensive knowledge of fish ecology and fish production, as well as by analyses of the *day* catches to know which juvenile fish of particular economic importance are trapped in these devices.

The *day* yield and the level of exploitation give an indication of changes in fish stocks. In 1938-1939 Chevey and Le Poulain stated : "*A typical day yield is 100 to 130 tons for the fishing season*". During the 1962-1963 fishing season, Fily and d'Aubenton recorded much lower figures for 11 *days* for which the yields varied from 16 to 69 tons. For the years 1983 to 1988, comprehensive data on four fishing seasons are available (Nguyen Van Hao and Nguyen Xuan Tan, 1991). A rapid analysis provides some interesting findings (**Figure D.7** and Table D.3) :

- for a given season the average yield varies extensively from one row of *day* to another, the ratio being has high as 1 to 8 between sites 15 and 19, but the results are consistent through the period considered;

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(5) *Trey Changvar* is a generic term describing all small fish (used for the making of prahoc) whether they be adults of small species or young fish of large species.

- interannual variability for a given site is very high : 100 tons for sites 2 to 5 for 1986-87 and more than 350 tons in 1985-86;
- total annual catches are high : from 7 400 t in 1986-87 to 18 000 t in 1985-86, with an average of 12 419 t harvested in a very short time;
- average day yield also reflects interannual variability : a maximum of 209 t in 1985-86, a minimum of 86 t in 1986-87, the average being 144 t.

This average of 144 t is of the same order of magnitude as the yield given by Chevey and Le Poulain 40 to 50 years ago. Comparisons of this nature, however, should be made with caution because of the many unknowns regarding the conditions of collection of figures, the interannual variability of the small opportunist fish (see above) and so on.

In any case there is no evidence of any diminution of stocks, even though the figures do not distinguish between different forms of exploitation of fresh water fish, nor between adults of small species and juveniles of others. Nevertheless the broad findings of this study do not substantiate any biological over-exploitation.

D.3.5 Socio-Economic Aspects

a) Methodology of Fishery Management

The content of any fish management system depends on its objectives. These could be, for instance, highest profitability for all fish production units or for only a few of them, highest employment rate in the sector, exclusion of certain classes of fishermen, highest taxation returns to the government, etc. No matter which objectives are set, a knowledge of the existing socio-economic context is a prerequisite.

To assess the socio-economic context, a suitable analytical frame is the chain of production and marketing followed by bio-economic modelling as the appropriate decision-making tool. Study of the chain of production and marketing provides knowledge of the fishery activities, and particularly of modifications of the interrelations between the various segments of the chain of production and marketing (from the fisherman to the consumer), or new relations of dependency.

Before any biological or socio-economic analysis may be performed, the compilation of data must be carried out. Existing data are, however, relevant to particular segments only, and no complete data set exists covering all of the fishery production units as well as processing and marketing units. Firstly there is a large gap between data collection at any point in time and the dynamic nature of fishery activities. There are also differences caused by such external agents as formal or informal taxations by the public service, which inspire fishermen to declare much lower catches than they achieve.

DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK (BASINWIDE) PHASE I

LOCATION OF *DAY* ALONG TONLE SAP (Chevey and Le Poulain)

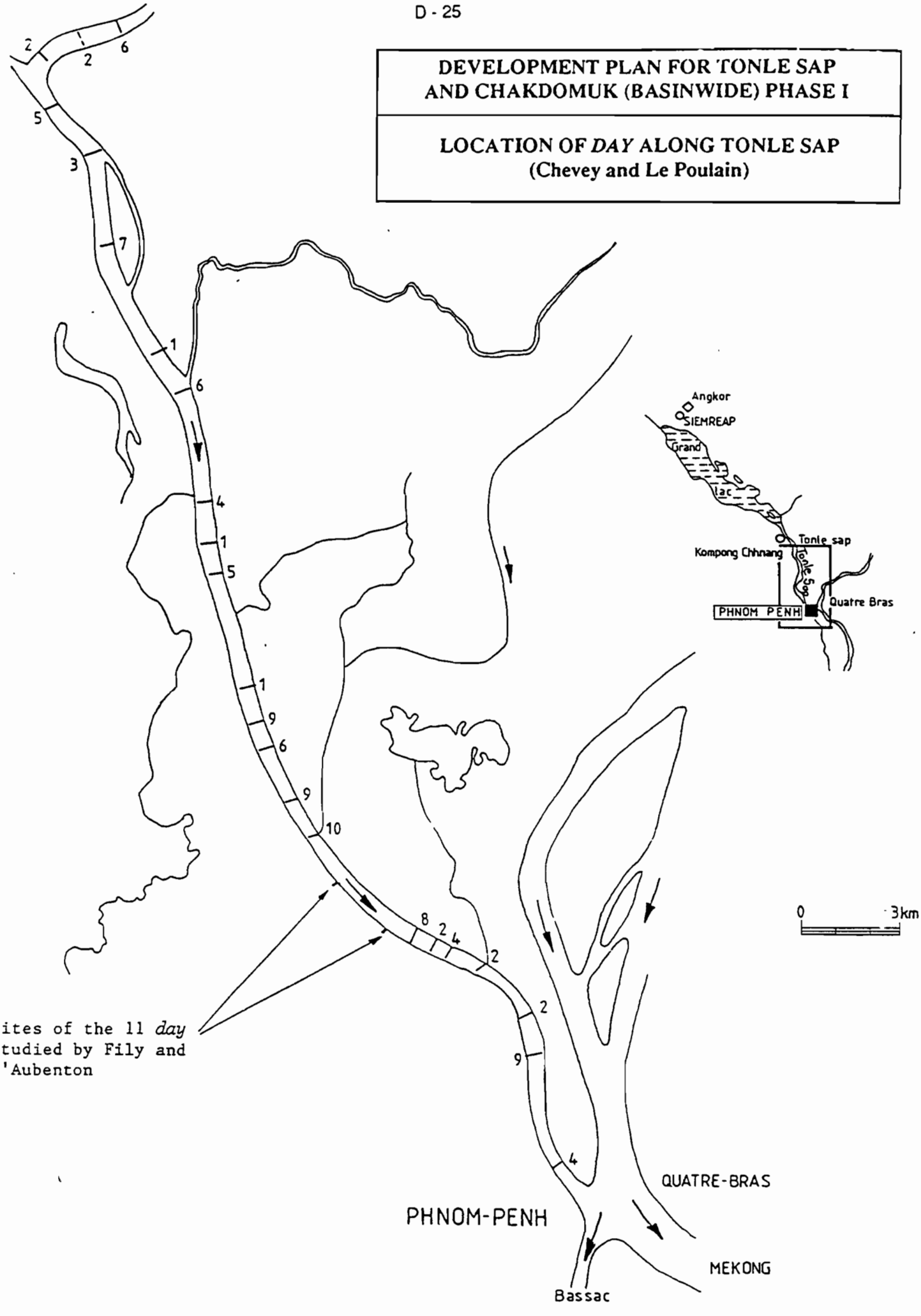

Figure D.6

DEVELOPMENT PLAN FOR TONLE SAP
AND CHAKDOMUK (BASINWIDE) PHASE I

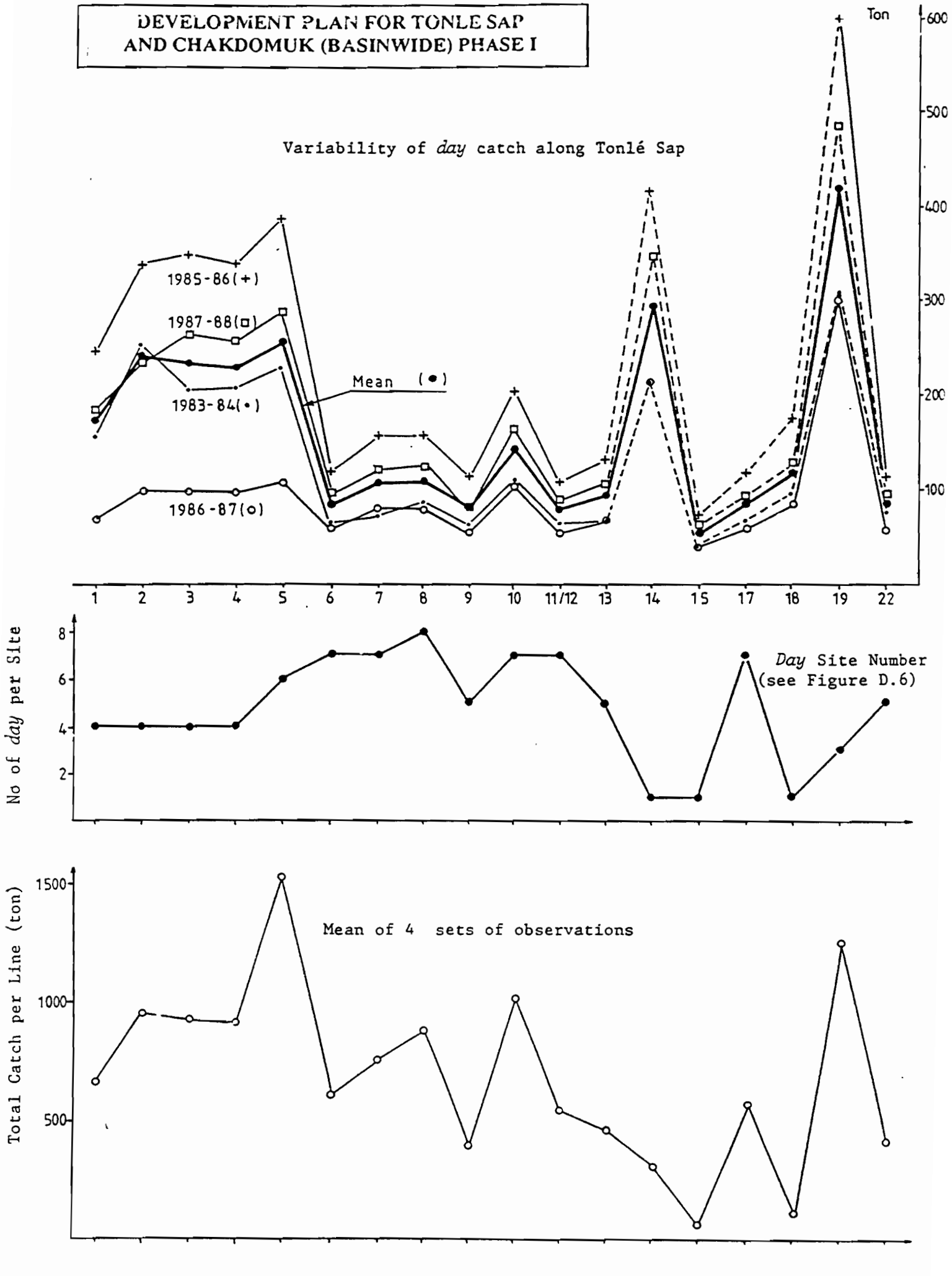

Figure D.7

To analyse the modifications or the restructuring concerning the various production or marketing systems, after identification of these systems, we have to compare their productivity and the share of each system in the value added creation. Then the description of the formal or informal relationships between the various operators might allow commanding positions all along the chain of production and marketing to be confirmed.

In particular, the recent transformation of these production systems is linked to the new conditions regarding a significant accumulation of capital which allow larger investments involving in some cases a technical change and dramatic changes in the labour relations : it is the history of this capital accumulation which would allow the appraisal of this process of accumulation.

It should be kept in mind that the fishery sector is characterized by specific technological process regarding the catches as well as the fish processing or marketing. Depending on these processes, the operators will choose, for instance, the labour organizations and financing modalities to reduce the risk and the uncertainty linked to the characteristics of the aquatic living resources.

Bio-economic modelling is a tool for decision-making. These models might to be considered as a complement of biological models. Evolving such a model means, first of all, describing the various types of fishery units, their production system and the level and distribution of the catches; if they are working on several stocks, pluri-specific models have to be used. Secondly, costs and price functions might be introduced after the appraisal of the interrelations between the fishery efforts, the state of the stocks and the fish landings. Finally, an appraisal of the profitability of each type of fishery unit on the catches and the stocks must be carried out.

In the case of the Great Lake and Tonlé Sap fisheries, such a model could be used for direct control (fishing permits) or indirectly (investment policy) to manage production factors; or to control the production itself directly (individual quotas) or indirectly (market).

b) Vitality of the Informal Financing System

Excluding a financing operation implemented by the State Bank of Cambodia between 1980 and 1987 for a total amount of 200×10^6 Riel, the financing of fishery activities is done following the traditional channels. This informal financing system is mainly done by merchants. The merchants involve the fishermen in continuous indebtedness (the governmental financing operation during the 1980's was an attempt to liberate the fishermen from their creditors). This traditional system is distinguished by the toughness of financing conditions : high interest rates, obligatory selling (fish) or buying (nets, food etc.).

Nevertheless, this is this type of financing system which allows the preservation or the development of the fishery sector. In granting loans at short notice, requiring few warranties, this system gives a high degree of flexibility in money use according to needs and seasonal variations. These traditional financing channels facilitated, for example, technological innovations such as the introduction of monofilament nets.

On the other hand, this system allows the merchants downstream in the marketing chain to develop a commanding position, which explains the high margins. For instance , in March 1993 for the same species and size, the price of a fresh fish doubled between the fishermen's village and the urban market (Siem Reap) and doubled again between this market and the nearest Thai market.

c) Alternative Sources of Financing

There are insufficient data regarding commercial activities to enable the drawing of any conclusion regarding the current marketing of fish from the Great Lake and Tonlé Sap river. Nevertheless some factors point to the efficiency of commercialisation procedures and to signs of new sources of financing.

The marketing of fish caught in the Great Lake and Tonlé Sap is an old practice, as witnessed by studies from the beginning of the century (Petillot, 1911; Gruvel, 1925). Fresh fish as well as processed fish have been commercialized from early times on local, inter-regional and international bases (Vietnam and Thailand mainly).

There have been no radical changes in the techniques of commercialisation; but because of the development of road networks and the increase in demand due to population growth and the attraction of the Thai market, some modifications of the marketing conditions have occurred. In particular the increase in demand is presumed to have led to increases in fishing effort and aquaculture. The share of commercialized processed fish has fallen for the benefit of fresh fish and the share of each processing method has changed.

According to Chevey and Le Poulain (1940), fish commercializing methods were completely different depending on whether they came from the Great Lake or Tonlé Sap. From the Great Lake dried fish predominated because of remoteness of urban markets and the navigational barrier for boats presented by the shallow pass of Snoc Trou during the low water stage. Unmotorized junks were used to bring the dried fish to Phnom Penh because they were able to cross the pass (15 days only were necessary to cross the Great Lake and to reach Phnom Penh). The junks drew no more than 60 cm at full load and were able to cross the pass even if it entailed dragging the boats through the mud.

Fish harvested in the Mekong and Tonlé Sap rivers were traded mainly as fresh fish in Phnom Penh and Vietnam. Chevey and Le Poulain wrote that "the provinces of Kompong Chhnang, Kompong Cham, Prey Veng, Takeo and Kandal export the major part of their production of fresh fish to the huge markets of Saigon, Phnom Penh and Tanchau, and

to the secondary markets located along the Bassac or Mekong rivers such as Chau-Doc or Can Tho".

According to the people we interviewed in March 1993, most of the fish catches of the Great Lake as well as the fish harvested and traded upstream the Tonlé Sap river (Kompong Chhnang Province), is cleared via Siem Reap or Battambang to be marketed in Thailand. The Thai demand has thus modified the orientation of commercial flows and given impetus to the marketing of fresh fish. According to the Office of the Department of Fisheries in Siem Reap, the mean price for first grade fish from the Lake is 2 500 Riel/kg in the main Phnom Penh market compared with 5 000 Riel/kg in Chonburi market (Thailand). According to the same source, the quantity of fish marketed in Siem Reap and traded in Phnom Penh is less than the quantity traded in Thailand, although it is presently impossible to get precise figures for this trade.

The exports of Cambodian fish to Thailand have a long history (Petillot, 1911), but were essentially concerned with processed fish, *khlan-trey* (oil) and *prahoc* (paste). In response to the Sino-Thai investments in transport, there are changes in the traditional composition and orientation of the flows : generally speaking, and with a view to the difference of prices, traders are now able to obtain better prices for fish products. This new orientation of flows is detrimental to traditional flows (which used to be destined for Indonesia, according to Chevey and Le Poulain, 1940) and to Hong Kong, Singapore and Vietnam which receive smaller shares of the market.

d) Diversity of Fish Processing

During the last fifty years there have been significant changes in the processing methods. In spite of internal diversity and adaptation to natural constraints (fish characteristics, use of heat source and of locally available materials), these processes remain characterized by a low efficiency and a misuse of raw material (losses from processing), even though the development of cage aquaculture consumes some share of the processing wastes that were previously lost.

Department of Fisheries data on fish processing describe the main processing types, although the compilers of the data point out the inaccuracy of the statistics. The processes include making of fish oil and fish sauce, drying and the making of fish paste which together use the largest quantities of fresh fish, and the smoking of fish which is minor compared with the other processing techniques.

It is worth mentioning that the processing coefficient of fresh fish into oil is assumed to be 0.15 (Marcelet, 1940), that the making of oil is predominantly located along the banks of Tonlé Sap river (the most appropriate fish are the *Cyprinidae* harvested in day), and that the species providing the highest potential for the oil making are *Amblyrhynchichthys truncatus, Albulichtys albuloides, Cirrhinus jullieni*, but that *Pangasius spp.* and *Channa micropeltes* are also used. The process is distinguished by the amount of unrecovered wastes and by a large loss of fats : up to half of the fats

contained in the raw material (Krempf, 1928). An improvement would be to process the fish into paste and then into flour and oil.

The *prahoc* is a paste made from *Pangasius spp., Channa striata, Clarias batrachus* after fermentation, salting and pounding (specially aimed at the Thai market). During the fermentation process a juice is obtained which is used as a sauce (*tûk trey*) which is equivalent to the Vietnamese *nuoc mâm*; this preparation may be obtained directly with no intermediate stage by fermentation of *Cirrhinus microlepis*, etc. No particular locality is favoured for making *prahoc* and *tûk trey*. The processing coefficient from fresh fish into *prahoc* is known to be 0.33 (Chevey and Le Poulain, 1940). As in the preparation of fish oil, a large quantity of the residue is spoiled.

Drying of fish is extensive and requires large fish tray areas which are periodically insufficient for the demand, bearing in mind the low efficiency of this drying technique. The "white' fish (essentially *Pangasius spp*) and "black" fish (mainly *Channa micropeltes* and *Channa striata*) are mostly used. As the drying is a relatively swift technique (less than two days after fermentation and salting), a transformation coefficient of 0.3 is assumed. Better use is made of the wastes in large fisheries than in smaller ones, generally as feed for aquaculture or oil making (heads and viscus). As for other processing methods some waste products could be used as fertilizer. Undercapacity of drying areas could be overcome by the introduction of new drying techniques which are more intensive and better adapted to local environmental and traditional socio-economic conditions. This would relieve some of the pressure on forestry and vegetal products for the building of fences or enclosures.

Smoking of fish represents about 1/3 of the dried fish, in equivalent fresh fish. *Pangasius spp, Clarias batrachus* and *Notopterus notopterus* are mainly used. Smoking of fish is still a small-scale, family activity. Because the head of the fish is not removed, the waste is less important than for the making of prahoc and of dried fish. However, the very poor efficiency of the traditional ovens is responsible for a large loss of fuel, as for oil making. Some technical improvements would have positive results with regard to reducing pressure on the use of forestry and vegetal products as fuel.

D.3.6 Exploitation and Overexploitation

Exploitation of a renewable resource enables a reasonable consumption of limited stocks without detrimental effects to the renewal of species and to the harvesting of the natural resource in coming years.

The process of production of a natural resource is intricate and diverse. Aquatic ecosystems transform incidental solar energy through various trophic chains. Even without any human intervention such complex systems have an intrinsic variability, more or less linked to climatic variability. Hydrological changes from one year to another : rainfall, flooding, inundation. In addition there is variability in the ecosystems associated with changes in fish populations and in their capacity to adapt. This means that the

production of living resources is naturally variable. Experience shows that, beyond a certain level of complexity of ecosystem and population level, there are compensatory effects and that overall production is closely linked to changes in climate. In other words, biological production of reproducing stocks may be characterized by a definable level in any given environment.

The issue with regards to the fish resources of the Great Lake lies therefore in the identification of any human interventions which could have produced a degradation of this complex environment.

Firstly it should be noted that any modification, whether qualitative or quantitative, of the water supply of Mekong river via Tonlé Sap may have repercussions on the biological production in the Great Lake. This would be the case, for example, if large hydroelectric works were to modify the regime of the river. For the time being, it seems that the main problem is deforestation of the upper Mekong river basin and the resultant increase in sediment transport. Until a more detailed study is carried out the observations made above in Section C indicate that this is not yet a serious problem.

The situation is quite different for the overall degradation of the environmental conditions in the Great Lake due to human interference. Two main types of alteration may be identified : those which act directly on the physical environment and those which modify the biological production.

The changes in the physical environment are essentially erosion and increased sediment generation in the subcatchments of the lake as a result of deforestation. Increased exploitation of forest products and clearing of land for agriculture are the main detrimental activities. Another harmful activity is the mining in the region of Païlin, which is the cause of large sediment deposition at the mouth of Stung Sangker. With reference to the earlier discussions of sediment generation and transport in Section C, it would seem that sedimentation of the Great Lake has been low and stable for the past 30 years. It would therefore be unlikely that increased sedimentation could have altered the productivity of the system.

It is more likely that any degradation in productivity is due to direct attacks on the ecosystem. In this regard the inundated forest surrounding the Great Lake would appear to be the most vulnerable link in the production system. Clearing of the inundated forests was mentioned as early as 1940 by Chevey and Le Poulain. This is a particularly urgent issue and the recommendations made at that time to conserve the remaining forest are equally pertinent now. It should be noted firstly that there is no link between accelerated sedimentation (which in any case has not been demonstrated to be occurring) and clearing of the inundated forest. These forests have been exploited by fishermen for ages to supply wood (which is still the case) and previously also to build samras (large brush wood traps).

Although the lack of reliable records makes it impossible to analyse with any precision the actual link between changes in the inundated forest and the (as yet unproven) decline in fish yields, this aspect merits a concentrated research effort.

It may be concluded that variability in fish yields is essentially due to changes in the level of flooding which are responsible for interannual variations in the inundated areas and in the duration of inundation. For the last few years the floods in Mekong river have been relatively low and this is certainly the main cause of the decreased catches of freshwater fish.

With regard to the fishery sector it is important to define what is meant by overexploitation. In 1940, Petillot stated "*the disappearanc of fish from the rivers, lakes and bengs in Cambodia will not happen before a great many years...*". Chevey and Le Poulain (1940), under the heading "*Diminution of fish in the lakes*" mentioned that "*As early as 1907, fishermen [...] were complaining about the diminishing amount of fish [...]. Even at that time they accused the inhabitants of destroying the spawning grounds. ...*". Chevey and Le Poulain deduced that the possible fall in catches was due to increasing intensity of exploitation, and stated that the average sizes being caught were smaller, using as an example the *Pangasius (*ex *Pangasianodon) gigas*. One of the causes postulated was the sedimentation of the lake (in the 1930's), there having been at least 3 m depth at low water level at the beginning of the century and an average of only 0.70 m in 1940 [6].

In addition Chevey and Le Poulain stated that there were hardly any fish left in the lake : ... "*everything has been fished relentlessly*"... "*the fact that one finds no fish of any significant size is a direct result of over-fishing*". According to Blache and Goossens (1954), between 1949 and 1951 it was observed that some species may reach big sizes but are "*currently fished at much lower sizes and it seems that this is a typical example of over fishing*"..."*Species of economical and biological value are threatened with disappearanc*e"..."*The depletion of fish is taken for granted*".

Opinions opposed to these are those of Fily and d'Aubenton (1965), Bardach (1959), Lagler (1976), and the Mekong Committee (1992). The statement of Dennis and Woodwortn (1992) is therefore surprising : "*Over fishing is endemic and spawning grounds are progressively destroyed by the cutting of wetland forests*".

There seems to be some confusion, which is logical in so far as there is a need to define over fishing and its scope.

A general definition of over fishing could be : ***excessive catches, which do not allow recovery of the optimal production level that the ecosystem is capable of providing from one annual fishing cycle to another - all things being equal.***.

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[6] The figure of 3 m seems to be highly doubtful bearing in mind the findings of Carbonnel and Guiscafré (1963) and the discussions presented in the present report. Nevertheless, the shallow depths noted in 1940 at low water level support the findings of this study.

This definition, either economically or biologically, may be interpreted in as many ways as the meaning of "optimal". Emphasis could be given to overall production (quantity of protein), the economic value of the production (some species having a higher value and/or larger size than others). Alternatively it could be interpreted in terms of minimum revenue for fishermen. Whatever it may be, these are political alternatives which should guide management choices and whose objectives may be conflicting.

It should also be stressed that biological over fishing of some highly vulnerable species may occur even though the level of exploitation is average or low. This is the case for large sized migrating fishes, predators and generally the biggest most active fish. Conversely, relatively stationary species which are less vulnerable may be under fished in a system which is actually over fished. This emphasises the choices which need to be made in fisheries management.

From the limited available data and after considering what has been contributed by various researchers in the fishery sector, we conclude that there is not as yet any evidence of over-exploitation of fish in Cambodia. Attention is drawn, however, to the need to instigate a consistent nation-wide data collection and processing effort, both in relation to fish catches and to fish reproductive dynamics with the aim of determining the relative importance of flood levels, inundated forest, migrations and other factors or components of the reproductive process.

Checking the contents of a net near the entrance to the Great Lake

Cast net fishing on Mekong river

E NAVIGATION, AGRICULTURE, IRRIGATION AND ENVIRONMENTAL ASPECTS

E.1 NAVIGATION

E.1.1 Existing Situation of Navigation

a) General

Water transport plays an important role in domestic distribution of goods in Cambodia. During most of the rainy season, when part of the territory is flooded, waterways are almost the only means of communication. The Tonlé Sap river and Great Lake rank among the most important waterways of Cambodia. Although the shallow pass of Snoc Trou makes navigation unpracticable during the dry season, the share of Tonlé Sap is about 15 % of the total waterborne traffic of the country. The Tonlé Sap lake and river, with its tributaries, provide natural transport routes from Phnom Penh to Battambang, Siem Reap, Kompong Thom, Pursat and Kompong Chhnang.

The project area encompasses various levels of navigation as follows :

(i) International navigation from the South China Sea and Southern Vietnam, ending up across the Chakdomuk area at Phnom Penh port in the mouth of the Tonlé Sap river.

(ii) Industrial riverborne transport on the Tonlé Sap river up to Kompong Chhnang.

(iii) Semi-industrial to craft-industrial navigation on the Great Lake and its tributaries.

b) Navigation Conditions

Sea-going vessels can steam all the way from the South China sea in Vietnam along the Mekong river and call at Phnom Penh using the entrance channel of the Tonlé Sap river located in the Chakdomuk area. Maintenance dredging is required and periodically performed in this area to maintain the minimum water depth required for the passage of sea-faring vessels.

In the old days, the maximum available depth of water at Phnom Penh during the dry season used to be 5.50 m. Ships with maximum draft of 5.10 m or about 3 000 DWT could call at Phnom Penh the year round. Towards the end of the low water period, the maximum draft at Phnom Penh was reduced to about 4.60 m due to siltation in the channel.

Nowadays, the water depth in the dry season is 4.90 m. Navigation is restricted to ships of 2 000 DWT of capacity or which draft does not exceed 4.50 m. The Cambodian government has recently acquired new cutter suction dredgers of ample capacity to reinstate the past situation.

During the high water stage (from May to November) ships of 4 000 DWT usually call at Phnom Penh, entering the Tonlé Sap. Larger ships, up to 6 000 DWT can sail up to Phnom Penh but have to moor at midstream buoys as the present structure of the wharves could not bear the impact of this size of ships. The project of future port at Chrui Changvar is designed for ships up to 5 000 DWT.

In any case, international navigation in Phnom Penh is restricted by sand-bars building up at the entrance of the Mekong river in Vietnam and by sharp bends reducing the allowable ship overall length on the Mekong in Cambodia downstream of Phnom Penh (see Figure E.1).

The maximum size of sea-faring vessels expected to ever call at Phnom Penh is in the range of 6 000-7 000 DWT depending on ship categories. However, the water depth of 5.50 m in the channel of the Tonlé Sap is deemed sufficient in any case to meet international navigation requirements.

Upstream of Phnom Penh, the Tonlé Sap river is navigable the year round to Kompong Chhnang. Channel width is not less than 150 m and minimum depth is 2.80 m. The distance is 102 km. Barges of up to 150 DWT can operate the year round.

Navigation upstream of Kompong Chhnang to the Great Lake is hampered by the shallow pass of Snoc Trou near the inlet of the river into the lake. The available depth at Snoc Trou is limited to 0.80 m during low water stage thereby hampering navigation to the Great Lake. Channel is 100 m wide and depth at high water stage is not less than 2.00 m. Distance from Kompong Chhnang to the Great Lake mouth is 53 km.

Navigation across and around the Great Lake is practicable. During the low water period, when the water depth is reduced to some 0.80 m, natural peripheral channels are known by old pilots with sufficient water to be used by wooden launches the year round. Distance from the mouth of the Tonlé Sap river to the northern tip of the lake is 130 km. From the lake, navigation can be extended up along lake's tributaries, in particular up the Stung Sen connecting with the Tonlé Sap right in the Snoc Trou pass, up to Kompong Thom where channel is 85 m wide and depth is more than 2.0 m at high water stage. Distance to Kompong Thom is 47 km.

The depth in the Bassac river downstream of Chakdomuk is too shallow for any vessels apart from small wooden boats catering to local traffic. No development is envisaged on this arm as the Mekong mainstream provides a better alternative route to Vietnam and the sea. There is no need to imorove the channel of the Bassac river at this point.

c) Types of Rivercraft

Very little information on the composition of the Inland waterways fleet operating on the Tonlé Sap could be obtained. From observations made during the field trips, most of the rivercraft are small mixed cargo-passenger wooden launches hardly exceeding 20 T in capacity.

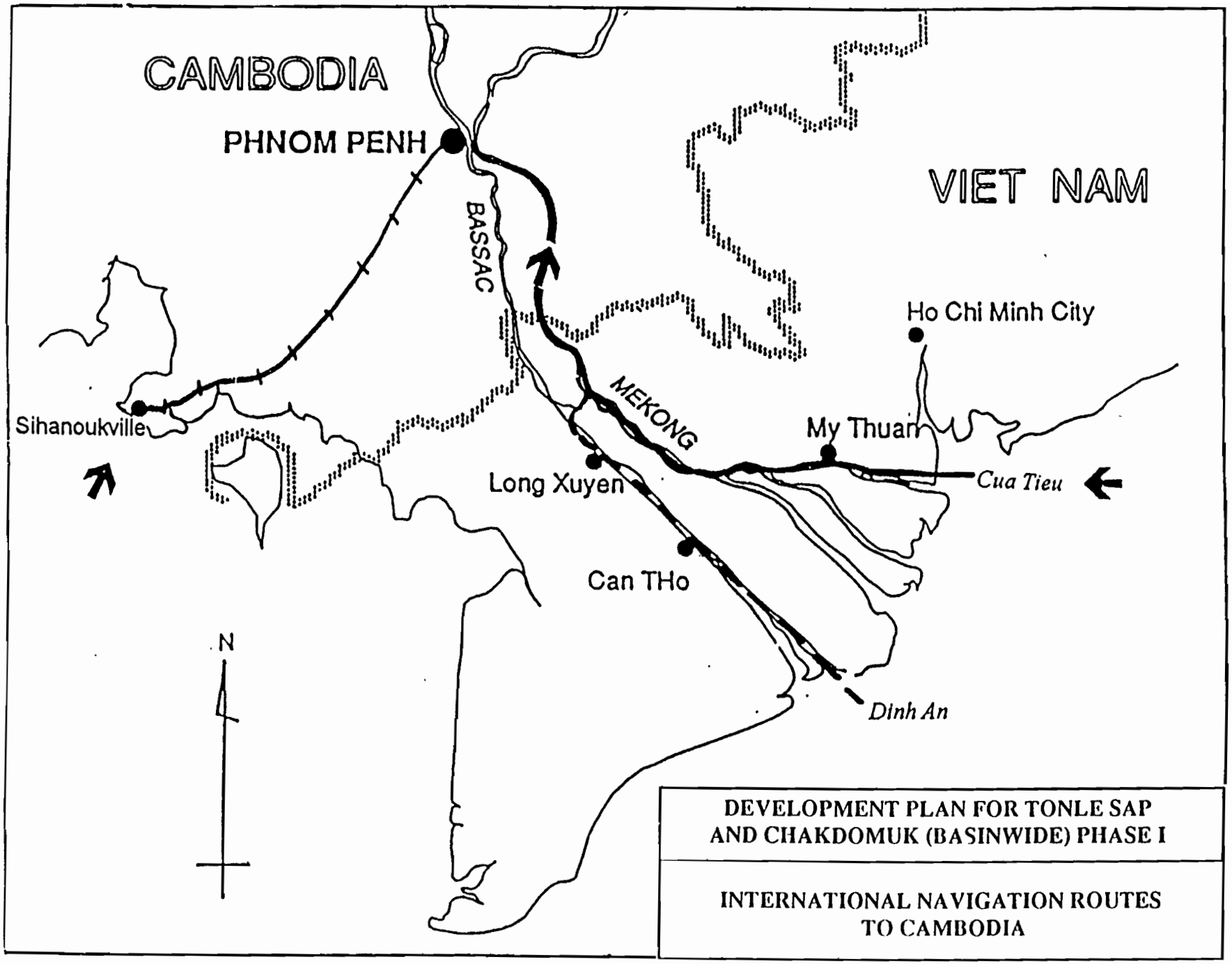

CAMBODIA
PHNOM PENH
VIET NAM
BASSAC
Ho Chi Minh City
MEKONG
Sihanoukville
My Thuan
Long Xuyen
Cua Tieu
Can THo
N
Dinh An
DEVELOPMENT PLAN FOR TONLE SAP
AND CHAKDOMUK (BASINWIDE) PHASE I
INTERNATIONAL NAVIGATION ROUTES
TO CAMBODIA

Figure E.1

Larger wooden junks of 100 to 200 T would operate during high water stage and on the lower Tonlé Sap section, i.e. downstream of Kompong Chhnang. Modernization of the fleet operating on inland waterways seems to be another preliminary requirement to sound development of waterborne transport in the area. Construction and operating costs of wooden boats are relatively high. Their efficiency needs improvement.

d) Aids to Navigation

Day and night navigation safety used to be ensured by a system of aids to navigation on the main channel of the Mekong river and in the entrance channel of the Tonlé Sap. Pilotage is compulsory for all sea-faring vessels. In 1965, lighted beacons, leading lights, steel lighted buoys and steel dumb buoys were installed by the local hydrographic department with the help of the Mekong Committee and donor countries. Most of these aids to navigation have now disappeared. The Mekong Committee has already specified the navigation aids needs in the area of Chakdomuk, which can be found in "Aids to Navigation study" conducted in 1976. This study would probably need some up-dating to take into account the morphological change of the area and the perspectives of development of the port of Phnom Penh and Chrui Changvar.

As regards the Tonlé Sap lake and river upstream of Phnom Penh, very little information is readily available on the status of existing aids to navigation. There are likely none on this large natural reservoir which in high water stage expands to double its normal area with depths of about 10 m, whereas its average depth in dry season is only 1 m.

In normal time day and night navigation take place on the Great Lake and the Tonlé Sap river. A hydrographic survey will be needed to detect the deepest channels which could be beaconed. Navigation in the low water stage could be greatly improved by lighted shore marks and lighted buoys meant to guide navigators across and around the waters of the Great Lake. Depending on conclusions of detailed navigation study, channel marking could be required to ensure good navigation condition and consequently lower transport costs.

e) Navigation Charts

Basic hydrographic surveys of the Mekong river and tributaries have been achieved in the early 1960's providing maps at a scale of 1/20 000. This was part of the action programme under the Colombo Plan. Although a reliable survey carried out in 1969 on the Tonlé Sap river was made available to the Consultants during the field trip, up-dating surveys have seldom been undertaken on the Tonlé Sap.

The Mekong Secretariat is now undergoing a programme called "Up-dating of the Mekong Hydrographic Atlas" funded by the Government of Finland. To date, Cambodia has not been covered under this programme. Moreover, the programme covers the Mekong mainstream channel. It is not clear whether additional surveys could be included in this programme to cover the Tonlé Sap waters. Furthermore, aerial photographic survey of the country has been completed recently with the assistance of Finland.

A complete bathymetric survey of the Great Lake and Tonlé Sap river will be needed under Phase II of the Development Plan for Tonlé Sap and Chakdomuk as dealt with in connection with Hydrological matters herein. This bathymetric survey will serve as a basis for a navigation study and aids to the navigation study to be carried out during Phase II of the project.

f) Ports and Landing Facilities

The port of Phnom Penh, the Tonlé Sap river, lake and tributaries are lack port facilities. The major port in terms of traffic is Kompong Chhnang which has no facilities. Cargo has to be handled by ship's gear or gang-and-plank methods. Prek Kdam is to be mentioned as the Tonlé Sap ferry crossing point.

Phnom Penh is located on the right bank of the Tonlé Sap river at short distance from its mouth in the Chakdomuk area. Designed for ships of 4 000 DWT and 5 m draft, the port has a present capacity of 450 000 T per year. Ships calling at Phnom Penh port have to steam upstream the Mekong river for 332 km from its mouth of Cua Tieu into the South China Sea in Vietnam. Wharves and berthing facilities are laid along the bank of the Tonlé Sap river. The main facilities are the following :

- Berths No 1 and No 2 : Two floating pontoons for ships of 2 000 DWT at high water stage.
- Berth No 4 : One concrete wharf 83 m x 12 m for ships of 2 000 DWT,
- Berth No 5 : One concrete wharf 100 m x 12 m for ships up to 4 000 DWT

Due to the present state of disrepair of the wharves, the port of Phnom Penh cannot operate at its nominal capacity. The Government of Japan has provided a grant for a project of rehabilitation and extension of the port, expected to be completed by the end of 1995. The port of Phnom Penh will then provide ample facilities to accommodate ships up to 4 000 DWT.

At a short distance downstream of the floating port can be found some passenger terminals for river launch services and public port for domestic traffic by mixed cargo-passenger wooden boats. Proceeding further upstream along the Tonlé Sap, landing places can be found for log barges waiting to be loaded on sea-faring vessels for export, oil terminals where tankers up to 2 300 DWT can be accommodated and other facilities associated with industries situated along the river, notably rice mills.

At Km 6 along the Tonlé Sap, upstream of Phnom Penh, some port facilities belonging to the Ministry of Commerce include 200 m pier which used to bear railway extension for direct transhipment from barge to rail. The port designed for river barges and small ships less than 500 DWT is dedicated to rice and cereals. The port is provided with 21 sheds of total capacity 50 000 T. Cereals from up-country are barged down to Km 6 port

facilities where they are sorted and conditioned for export. In the old days ships over 1 000 DWT could berth also at Km 6, for the handling of heavy loads.

g) Traffic and Commodities

Due to long periods of serious political disturbances and war, no reliable sources of traffic data can be found. No figures of traffic volume on the Tonlé Sap could be obtained. From information gathered during field trip, large quantities of dried fish are carried on small boats from villages of the lake area to Kompong Chhnang where they are transferred to larger wooden junks and carried to Phnom Penh or to Vietnam.

The main commodities transported by waterways in the Tonlé Sap area are southbound : dried or salted fish, maize, rice/paddy, timber and firewood/charcoal, rottan, beans, fruits and vegetables and, northbound : consumer goods, construction materials and petroleum products.

Phnom Penh is the major centre of the country's economic activities. Most domestic freight transits through Phnom Penh. As a result, Phnom Penh is the breakpoint for most of import and export commodities.

Cargo traffic through Phnom Penh port reached its maximum in 1963, with 963 000 T. Subsequently, its traffic decreased gradually in favour of the new port of Sihanoukville opened in 1968. In recent years, traffic through the port of Phnom Penh recovered positive growth rates from 260 000 T in 1988 to around 400 000 T in 1991. In terms of ship traffic there are currently about 300 calls of sea-faring vessels of not more than 2 000 DWT of capacity per year in Phnom Penh. All vessels use the channel across Chakdomuk area. Forecast traffic is dealt with hereafter.

E.1.2 Perspectives of Navigation Development

Navigation conditions in the channels of Tonlé Sap and Chakdomuk are deemed favourable. However navigation development will depend on magnitude of waterborne transport demand. Sound assessment of transport demand and modal split in the project area is essential. During Phase I of this study only limited information on prospective development of fisheries, forestry and agriculture in the project area could be found. Forecasts of production, consumption and export would have to be worked out as part of Phase II. As regards Chakdomuk, the navigation channel will have to meet characteristics required by navigation of sea-faring vessels calling at Phnom Penh Port.

a) Hinterland of the Great Lake and Tonlé Sap River

The Tonlé Sap waterways system provides ideal communication routes between Phnom Penh and each of the six following provinces : Battambang, Siem Reap, Kompong Thom, Odong Meanchey, Kompong Chhnang and Pouthisat.

However, the road belt outlining the perimeter of the wet area of the lake competes with the waterways system. Made of Road No 5 to the western part of the basin and Road No 6 to the eastern part, the road belt links up with Phnom Penh. The railway line from Battambang to Phnom Penh provides an additional competitive route.

Therefore, the hinterland of the Tonlé Sap system is outlined by the road/rail network surrounding the area and clearly does not extend beyond this belt. Modal competition within this perimeter further reduces demand for water-borne transport to a short range from the lake's shore and its tributaries (see **Figure E.2**).

Detailed modal split should be carefully studied for each main commodity, as well as its seasonal variations as part of the second phase of the project in order to assess with sufficient accuracy the share of cargoes and passengers which would be conveyed by boat against those to be conveyed by road and railways.

b) Tonlé Sap : Commodities, Passengers, Tourism

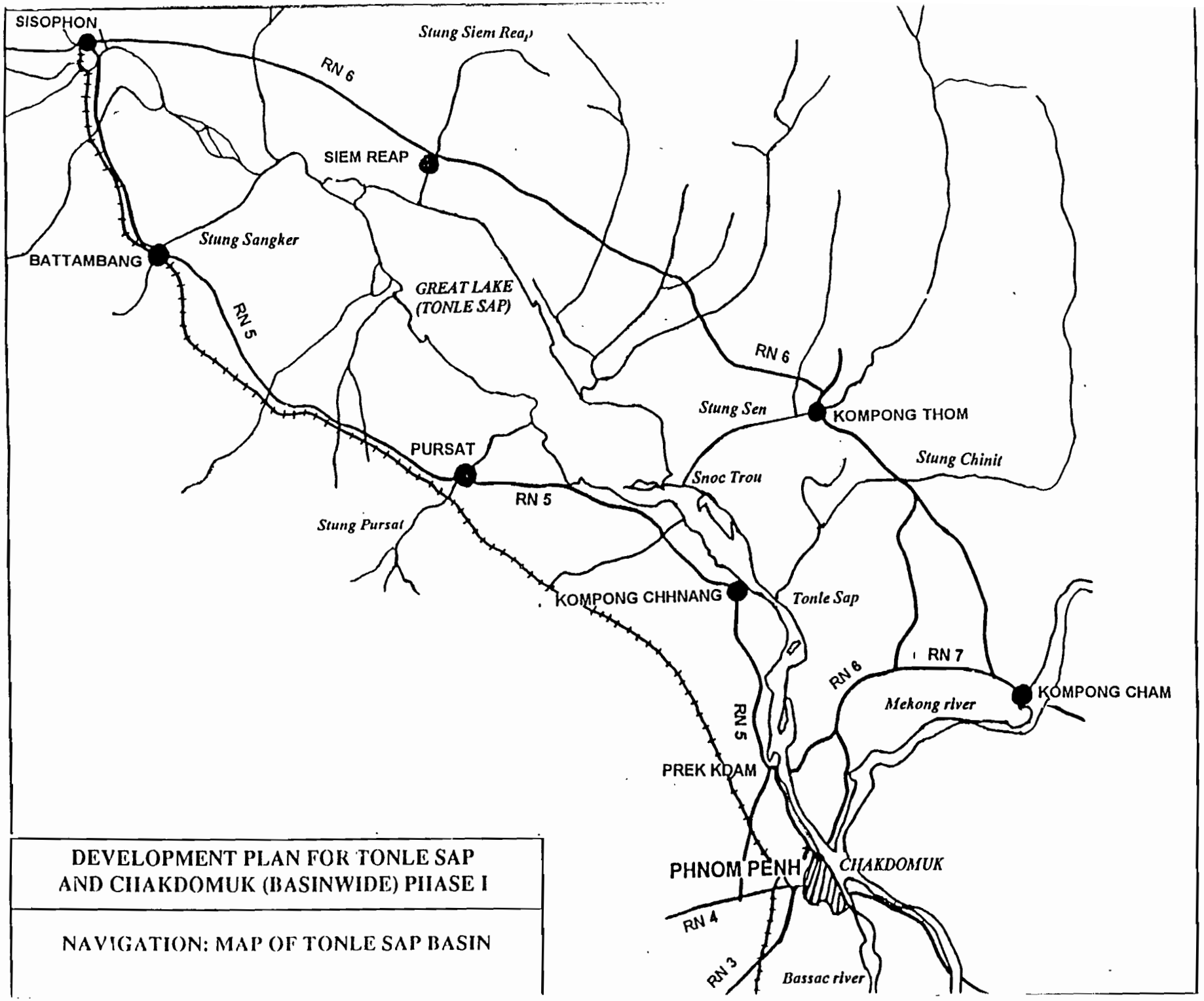
The major commodities and categories of traffic expected to develop in the future along the waterways system of the Tonlé Sap are the following :

Timber : Forestry resources is one of the most important natural resources of Cambodia. Large quantities of timber are extracted from the Tonlé Sap area, part of it being transported along the tributaries of the Great Lake and further down the Tonlé Sap river to Phnom Penh.

Fish : The Tonlé Sap is well known for being one of the richest fishing grounds in the world. For many years, the annual catch from the Tonlé Sap has been in the range of 50-60 000 tons of fish. Large quantities of dried fish are transported to Phnom Penh by boat. Thailand and Vietnam count among final destination of fish export.

Rice : Battambang and Siem Reap are two top rice-producing provinces, sharing respectively 13.9 % and 7.1 % (as of 1986) of the total domestic production of the country. Cambodia used to be net exporter of rice in the old days until the late 1960's. Added to the consumption of Phnom Penh, large quantities of paddy and rice are traditionally to be carried from the north to Phnom Penh, but rail and road are usually favoured over waterways for transportation of these commodities.

Tourism : Tourism is one of the government's aims in developing navigation on the Tonlé Sap. The Tonlé Sap river and Great Lake will eventually provide attractive cruises to Siem Reap and the ruins of the famous Angkor Wat complex. In this regard, future development of the port of Phnom Krom located at the mouth of the Siem Reap river and dredging of the river mouth are to be considered.



DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK (BASINWIDE) PHASE I

NAVIGATION: MAP OF TONLE SAP BASIN

Figure E.2

Passengers : Transport of passengers on the Great Lake and tributaries caters mostly to local inter-village traffic by small wooden launches. This traffic is combined with individual cargoes. Demand for line passenger transportation requires specific enquiries.

A balance in the distribution of transportation in this area, which is particularly rich in export products, is still difficult to establish. A detailed economic survey could determine the nature, origin and destination of merchandise, as well as the most promising routes and means of transport within the Tonlé Sap basin.

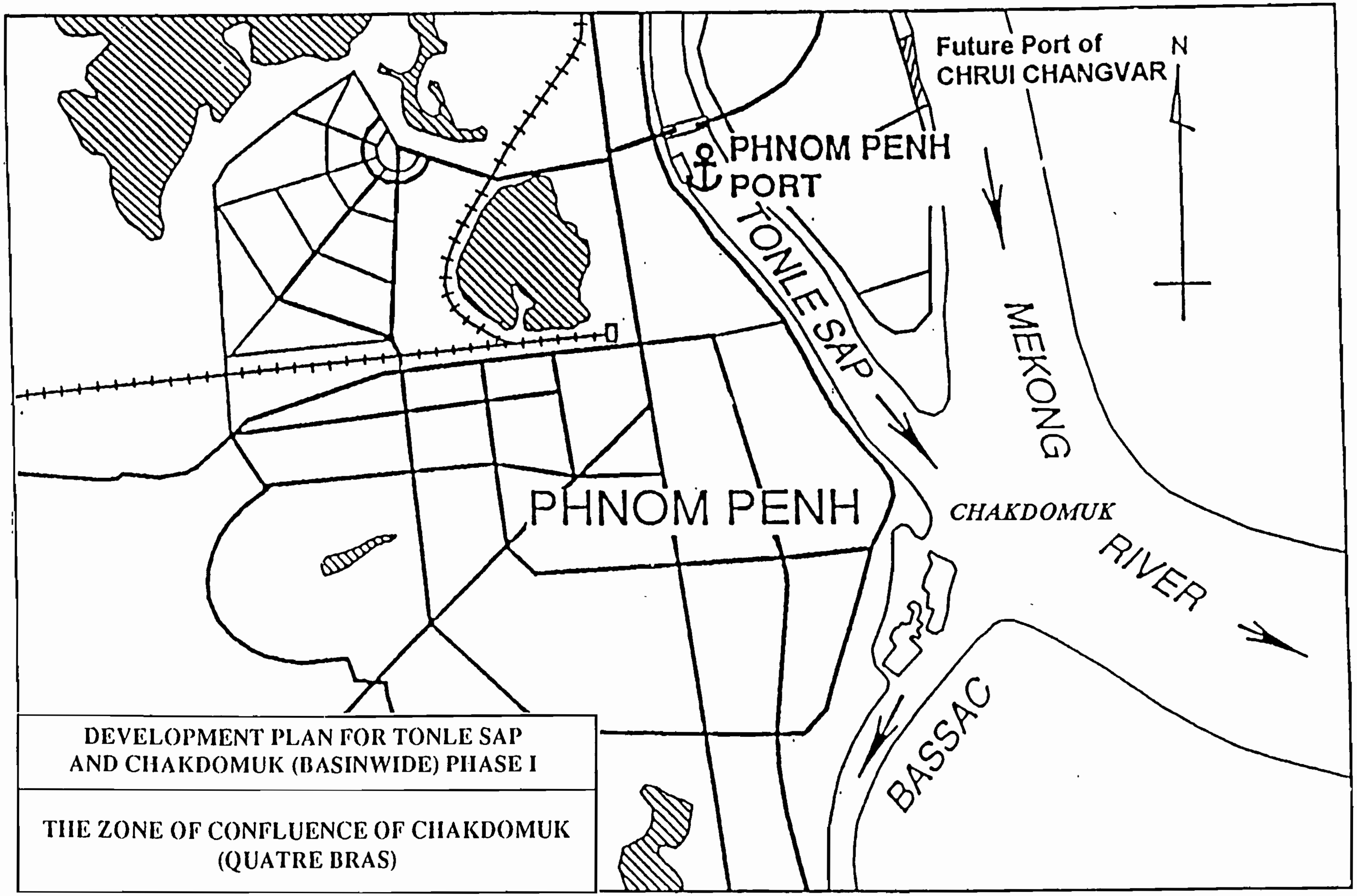
c) Phnom Penh Port : Chakdomuk

Traffic through the port of Phnom Penh will govern the traffic of sea-faring vessels in the navigation channel of the zone of Chakdomuk. In this respect, the traffic growth will heavily depend on future development options for the ports of Cambodia as follows :

(i) Respective roles of the ports of Phnom Penh and Sihanoukville in the handling of import/export of Cambodia. The recent economic appraisal carried out by the Mekong Committee on the rehabilitation and extension of the port of Phnom Penh gives forecast share of traffic between the two ports. This study led to the conclusion that each port would share a steady 50% of the traffic in the future. According to the same study, the traffic through the port of Phnom Penh would reach some 600 000 T in the year 2000 and remain almost steady beyond that. Owing to the expected improvement of the port of Phnom Penh and its access channel, the ships calling at Phnom Penh will become larger, up to 4 000 DWT. As a result, the total number of ship calls is expected to remain in the range of 300 to 400 calls per year.

(ii) Project of relocation of the port of Phnom Penh on the Chrui Changvar Peninsula along the Mekong mainstream. Another project of port extension is envisaged on the Mekong river in Chrui Changvar to replace the existing port facilities squeezed between the Tonlé Sap river and the urban area of Phnom Penh (see **Figure E.3**). The project port has 675 m of waterfront and six wharves. It can accommodate ships up to 5 000 DWT. Its capacity will exceed 1 million tons per year. It is at short distance from Phnom Penh across the Chrui Changvar bridge which first has to be re-constructed.

If built, the port of Chrui Changvar will ultimately replace the port of Phnom Penh, diverting the traffic of sea-faring vessels from the Tonlé Sap to the Mekong mainstream. There would possibly be no more requirements in terms of navigation in the Tonlé Sap entrance, but for rivercraft with limited draft.



DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK (BASINWIDE) PHASE I

THE ZONE OF CONFLUENCE OF CHAKDOMUK (QUATRE BRAS)

Figure E.3

E.2 AGRICULTURE AND IRRIGATION

E.2.1 General

Agriculture is the dominant sector in the Cambodian economy; it accounts for nearly 45% of the Gross Domestic Product and employs 85% of the labour force. Production generally meets only subsistence requirements and the cultivated land areas, as well as overall crop production, are still well below the levels of the 1960's.

Rice accounts for more than 80% of the overall agricultural tonnage production, is the main employer of people in Cambodia and it occupies most of the land area. However, the yield is very low by international standards. The total rice production is insufficient for consumption requirement. Estimated deficit in 1992 is about 150 000 tons.

The control and use of water to irrigate rice and field crops has traditionally played an important role in cultivation. Water control and usage for agriculture in Cambodia includes:

- the simple movement of water from one paddy field to another,

  the retaining of receding flood waters in the lowlands (wetlands) for dry season irrigation, and

- the construction of dikes, reservoirs, diversion weirs and canal systems for the distribution of stored or diverted irrigation waters.

Due to the complex ways in which water is utilized and the various developments of irrigation systems, many of which do not function effectively, the current status of irrigation is not known.

Major studies and projects are currently being implemented in Cambodia, dealing with irrigation and agricultural development which, in fact, overlap the Tonlé Sap Area.

The specifics of the study area, composed of the Tonlé Sap, the Great Lake and its surrounding swamp forest and agricultural fields are described hereafter.

E.2.2 Land Classification

From the field observation, the agricultural lands, excluding the inundated forest, may be classified as followed :

1) Island area : this area is a high land in the lake which may be cultivated during December to June, from July to November the area is flooded.

2) Seasonal flood area : the area is situated near and surrounding the lake. Deep water (floating) rice is grown in this area.

3) Rainfed lowland area : the area is located next to the seasonal flood area and wet season rice is planted.

E.2.3 Present Agricultural Practice

From the observation, interviews and related reports, and based on the earlier classified areas, the present agricultural practice may be concluded as followed :

1) Some island areas are cultivated by dry season crops, i.e. rice, corn, mung bean and vegetables. The cultivation period is between December and June.

2) Seasonal flood areas around the Great Lake are the major floating rice areas of Cambodia. Most deepwater rice crops are dry seeded in April-May with seeds germinating with the onset of the opening rains. The depth and duration of flooding depends on local rainfall as well as the height of the Mekong River resulting from rainfall upstream. The areas remain flooded for between 3 and 6 months up to October when the river height begins to recede. It is also reported that dry season rice is planted in some areas with supplementary irrigation.

3) For the rainfed lowland area, wet season rice is a major crop planted in the area. The water regimes in which the rice grows is variable. Rice varieties are matched to the expected maximum water depth. In shallow rainfed lowland environments, early varieties are grown; in middle rainfed, medium duration varieties; and lower rainfed, later maturing rices are planted. Other crops (vegetables, jutes and fruits) are also grown on some limited areas.

E.2.4 Government Policy and Preliminary Findings

According to relevant literature some existing irrigation systems/structures can be found in the study area. The locations and functions of these systems/structures are not sufficiently known. The required inventory, surveys and diagnosis exceed by far the preliminary study of this Phase I of the Development Plan for Tonlé Sap and Chakdomuk.

The present land policy, released by the government in 1989, intends dividinge all agricultural and residential land holdings among private individuals and providinge permanent titles. It is intended to provide farmers with land tenure for parcels of land which were, in the past administered and allocated through the farmers' organization groups termed Kram Samaki. According to the policy, each farmer will be allowed to have, on a permanent basis, a maximum of 5 hectares of agricultural land.

These changes to land ownership and owner management of that land have major implications on the direction of research in Cambodia. Farmers tend to take a pride in their own land and are more likely to accept long-term programs for crop production improvement.

For rural development purposes, small scale irrigation projects may provide immediate agricultural improvement. It is suggested that an appropriate model for viable and sustainable small scale irrigation development be formulated through pilot studies. The concept of the model is mainly aimed at participatory planning and management as well as capability strengthening of local staff and farmers.

E.3 ENVIRONMENTAL ASPECTS

E.3.1 General

The Great Lake together with the Tonlé Sap River functions as an important water reservoir and buffer to the Mekong and Bassac Rivers. It therefore plays a role in diminishing the effects of flooding and salt water infiltration in the Mekong Delta.

As shown in **Figure E.4** the flood plain of the Great Lake consists mainly of secondary forest dominated by thickets (the so called inundated forest) and grassland brushwood. Paddy fields, where receding rice culture is practiced, are located at the fringes of the flood plain.

The Great Lake area is probably a spawning and nursery ground for migrating fish species, which may be of importance to Mekong basinwide fish production.

Fisheries yields and aquaculture production at the Great Lake and the Tonlé Sap River contribute to the Cambodian economy as hard currency earners and form an important animal protein source to the Cambodian population.

The Great Lake and its surroundings are considered to be of global importance for designation as a protected natural area and is one of the sites of highest priority for conservation in the Indo-Malayan Realm (McKinnon and McKinnon, 1986).

15% of the total Cambodian wet season rice is estimated to be produced within the project area, including the surroundings of the Tonlé Sap River.

The secondary forest (dominated by thickets), which is annually flooded, probably plays a significant role in the Great Lake's function as a nursery for fish.

a) Land Use

Land Use around the Great Lake and part of the Tonlé Sap river is shown on the map overleaf (Figure E.4) and detailed in the following table in hectares.

Tonle Sap Landuse

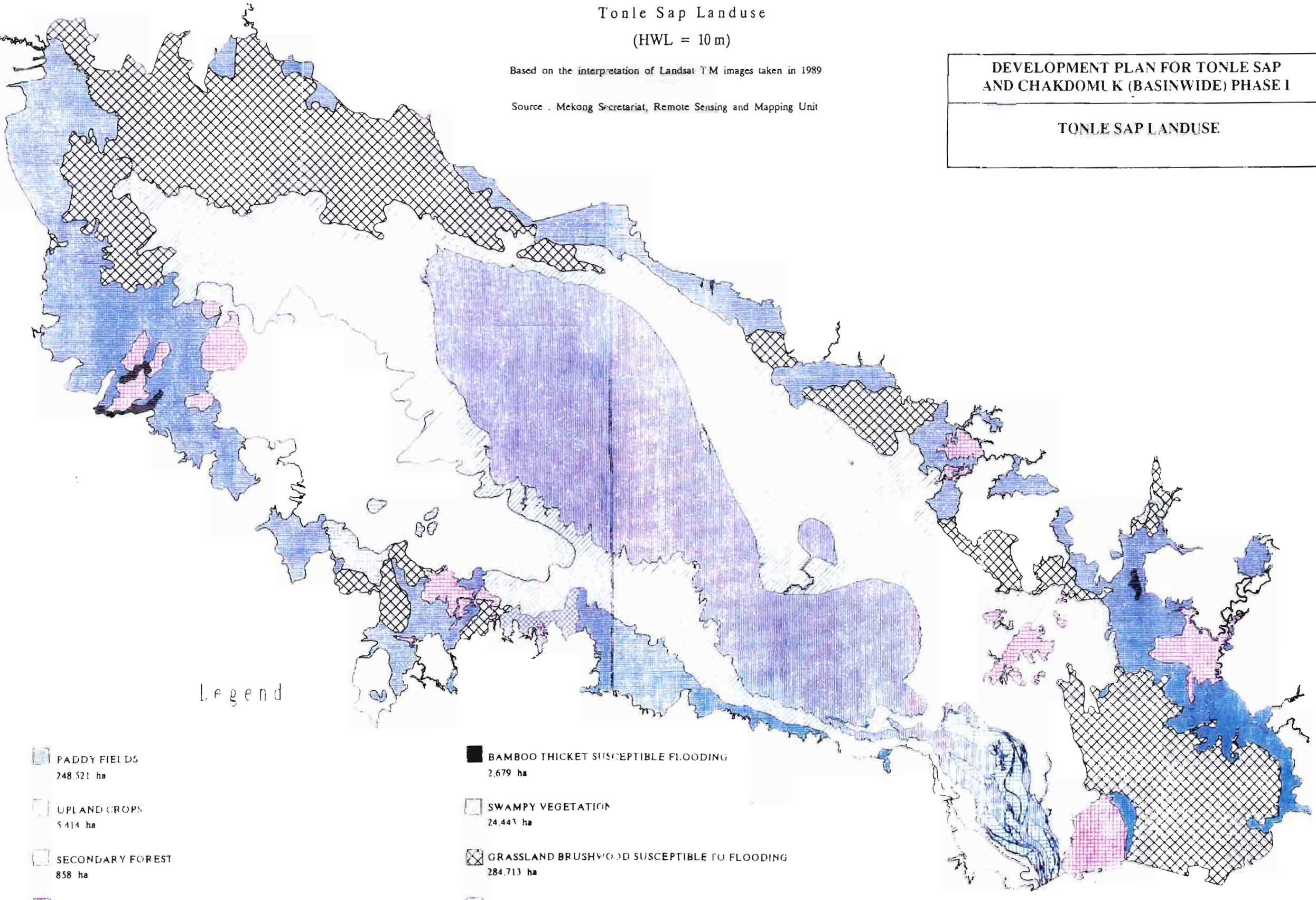
(HWL = 10 m)

Based on the interpretation of Landsat TM images taken in 1989

Source . Mekong Secretariat, Remote Sensing and Mapping Unit

DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK (BASINWIDE) PHASE I

TONLE SAP LANDUSE



Legend

- PADDY FIELDS 248,521 ha
- UPLAND CROPS 5,414 ha
- SECONDARY FOREST 858 ha
- UNAFFECTED AREAS 46,298 ha
- SECONDARY FOREST DOMINATED BY THICKETS ANNUALLY FLOODED 549,922 ha
- BAMBOO THICKET SUSCEPTIBLE FLOODING 2,679 ha
- SWAMPY VEGETATION 24,443 ha
- GRASSLAND BRUSHWOOD SUSCEPTIBLE TO FLOODING 284,713 ha
- WATER 270,607 ha

Figure E. 4

Table E.1

Land Use around the Great Lake and the Tonlé Sap River
(Source : Mekong Secretariat/Landsat imagery interpretation 1989)

Vegetation	hectares
open water	270 607
secondary forest dominated by thickets, annually flooded	549 922
grassland brushwood, susceptible to flooding	284 713
swampy vegetation	24 443
bamboo thickets, susceptible to flooding	2 679
paddy fields	248 521
unaffected areas	46 298
upland crops	5 414
secondary forest	858

b) Available Information

Little environmental information is available for the project area in the form of hard data. Recent documents speculate on:

(i) The rate of siltation of the lake, which is believed to result in a rapid change of the lake into a swamp area during the dry seasons.

The World Bank (1992) mentions a sedimentation rate of 4 cm a year, which would shorten the life of the lake to a few decades. However it is not clear where this high sedimentation rate is derived from.

A record from Chou Ta-Kuan dating back to the 14th Century stated that the average depth of the lake in the year 1312 was 1.2 meters during the dry season. However, recent measurements indicate an average depth of the lake during the dry season of .8 meters. This may indicate that the Great Lake has still some centuries to go, as can be expected of life cycles of natural lakes.

(ii) The supposed prevention of fish migration by sediment deposits at the mouth of the Tonlé Sap River and at the confluence of the Mekong and the Tonlé Sap Rivers (World Bank, 1992).

This theory is not based on any studies undertaken on migrating behaviour of fish in Cambodia.

(iii) The rate of on-going deforestation of the swamp forest around the Great Lake due to anticipated encroachment, logging, firewood use, charcoal production and wood use in fisheries and fish culture.

The Department of Forestry (1991) states that during the period 1965 - 1989 a 24 % decrease of the inundated forest area took place in Cambodia, largely in the vicinity of the Great Lake. It is doubtful if the 1965 study can be compared with the land use classification of 1989 based on satellite images.

Based on little information, unreliable data and worst case scenarios, as mentioned above, proposals have been made for dredging projects at Chakdomuk and the entrance of the Great Lake. Also a moratorium on export of all natural resources, including fish is proposed, while the Great Lake is said to be silted up within a few decades.

E.3.2 Integrated Water Management and Development Plan

Any management and development plan of the Great Lake and the Tonlé Sap River area will be greatly dependant not only on the water quantity and the water quality of its tributaries, but even more on the water quantity and the water quality of the Mekong River at Chakdomuk.

The tributaries of the Great Lake and the Tonlé Sap River continuously influence the water quality in the project area to some degree, but the water quality of the Great Lake may be mostly determined by the Mekong River, during the 4-5 months inflow period each year.

The water level of the Great Lake is also dependent on the water flow from its tributaries and on the water level of the Mekong River for the whole year round.

A management and development plan for the Great Lake and the Tonlé Sap area should include not only the use of water and related resources in the project area, but also the use of water and related resources in the watershed of the Mekong River and the watershed of the Great Lake.

Developments in the project area will not be sustainable, without anticipating future developments in the Great Lake watershed and in the Mekong River watershed.

Developments in the Great Lake area can also have impacts on the use of water resources in the Mekong River watershed. Therefore an integrated water management plan is proposed which should address the following environmental concerns.

E.3.3 Expected Environmental Impacts

a) Impacts of the whole Mekong Basin Development on the Project Area

(i) Barrages and dams

Dams and barrages, especially mainstream dams, will have an influence on the flow of the Mekong River. Both hydropower dams and irrigation schemes will result in reduced flooding. However only large reservoirs or great numbers of medium-size dams may significantly affect the flood magnitude in the Great Lake. In the case of hydropower dams, the release of water during dry season is more than in natural conditions. This would have a positive impact on water level of the lake where the recession of the water in the dry season is governed by the water level at Phnom Penh. On the contrary, irrigation dams which divert water during the dry season would worsen the natural flowing condition. Impacts on fisheries production and impacts on the swamp forest and floodplain around the lake are expected. Any flow intervention or flow diversion at the Mekong River upstream of Chakdomuk should be evaluated carefully for possible impacts on the project area.

(ii) Domestic and industrial waste water disposal

Disposal of untreated domestic waste water from urban centres add to health risks, increase of biological oxygen demand and increase of suspended solids. Especially the disposal of raw sewage at Phnom Penh forms a threat to the Mekong and Tonlé Sap River.

With the expected industrial activities near Phnom Penh in the near future, a legal frame work should be put in place to regulate industrial waste water treatment and disposal.

(iii) Forestry and deforestation

Deforestation is linked with increased sediment load and increase of seasonal flow fluctuations. Water depth and water exchange of the Great Lake can be dependant of forestry management in the Mekong watershed.

(iv) Flood protection

Flood protection in the Mekong delta may result in a rise of the level of the Mekong River (Mekong Secretariat, 1992). Effects of flood protection downstream of Chakdomuk on the water level and the water exchange in the project area should be evaluated.

(v) Fisheries

Fisheries management in the Mekong watershed will influence the fish production of migrating species in the Great Lake.

(vi) Port development and navigation

With the construction of a new port in Phnom Penh and the expected increase of water transport, the risks of accidental pollution, such as oil spills, can be anticipated to increase.

b) Impacts of the Tonlé Sap Basin Development onto the Project Area

(i) Barrages and dams

Several irrigation schemes are planned at the tributaries of the Great Lake and the Tonlé Sap River. Possible conflicts in use of the water may arise (water supply to the main towns in the watershed, waste water disposal, fisheries, aquaculture and irrigation). Also irrigation will result in intensification of agriculture with probable use of fertilizers, herbicides and pesticides, which may end up in the lake.

Dams may block the movement of migratory fish.

(ii) Domestic and industrial waste water disposal

Disposal of untreated domestic waste water into the tributaries should be avoided. Treatment and disposal of waste water from food and fish processing as well as jute manufacturing needs to be evaluated.

(iii) Forestry and deforestation

As deforestation can lead to high sediment load and increased flow fluctuations in the tributaries, hopefully the enforced export ban on timber will diminish deforestation and resulting negative effects to the project area.

(iv) Gem mining

Gem mining upstream of the Battambang River leads to a high sediment load in the river, with possible effects to water supply, fisheries, aquaculture and wildlife.

(v) Fisheries

Fisheries management in the tributaries and fisheries management in the Great Lake and Tonlé Sap River are probably interdependent.

c) Impacts within the Project Area

(i) Aquaculture

Existing fish culture is completely dependent on fisheries, no hatcheries and/or nurseries are producing fingerlings and the fish feed consist of small catch fish, fish processing waste or cooked rice bran. With the establishment of hatcheries

and nurseries and with the development of a semi-moist fish feed pellet, fish culture in the project area is expected to boom.

When no regional management plan exists aquaculture booms generally result in temporary problems with fish diseases, oxygen depletion and organic pollution, together with bankruptcies of the smaller fish culture enterprises.

(ii) Agriculture and irrigation

Plans for irrigation and intensification of agriculture need evaluation to determine possible conflicts in use of the water and effects on water resources.

(iii) Forestry and deforestation

Deforestation of the swamp forest is said to be considerable, but estimations of the deforested area are not based on hard data.

Forestry management probably influences fisheries production and determines wild life conservation.

(iv) Wild life reserves

Cambodia has under consideration the establishment of a protected area of 100 000 hectares of swamp forest in Siem Reap, Battambang and Pursat Provinces to support both resident and migratory birds and lessen threats to endangered species such as the giant ibis and the Siamese crocodile (Mok Mareth, 1993). Conflicts of interest may arise between the protection of fish eating species and existing fisheries and aquaculture practices. Socio-economic as well as environmental impacts of tourism may be expected, when the wild life reserves are established.

(v) Water transport

The low water level of the Great Lake during the dry season has lead to dredging proposals, to enable water transport during all seasons. Boat design should be considered as an option to enable water transport during all seasons, to avoid impacts and costs of dredging.

(vi) Gas and oil exploration

A number of concession blocks for oil and gas exploration cover portions of the wet season lake area. Provisions for protection of the wetlands ecosystems should be incorporated in both explanatory and development proposals to ensure that adequate protection is provided. (Dennis and Woodsworth, 1992).

(vii) Tourism

When security can be guaranteed for tourists in the Siem Reap area, many visitors to Anchor Wat are expected, resulting in an extra demand in water supply and in an increase of the quantity of domestic waste water. Domestic waste water treatment may be necessary.

An environmental zoning and management plan will soon be proposed for the Siem Reap area by UNESCO.

(viii) Barrage or dam

As long as no fundamental understanding of the hydrological and biological processes in the Great Lake has been reached, the idea of constructing a barrage or dam in the Tonlé Sap River to raise the water level of the Great Lake in the dry season should not be supported.

(ix) Infrastructure

Road building to improve transport in the project area and to improve access to the lake should not reduce the flood plain area or reduce fish breeding and/or feeding grounds (Mekong Secretariat, 1992).

(x) Life cycle of the Great Lake

If the lake will turn into a swamp area due to siltation, fisheries yield and aquaculture production will be restricted to seasonal activities.

d) Impacts of the Tonlé Sap Development Projects on the Mekong Basin

(i) Fisheries

Fisheries management at the project area will influence fisheries of migratory species downstream as well as upstream of Chakdomuk.

(ii) Aquaculture

Uncontrolled fish culture may lead to introduction of foreign species and fish diseases as well as degradation of the water quality.

(iii) Siltation of the Great Lake

If the current high siltation rate is confirmed, the storage capacity of the lake will be reduced, which can affect flood protection and salt water intrusion in the Mekong delta. Also fish migration to the Mekong basin may be restricted.

(iv) Barrage or dam

A barrage or dam planned to increase the water level in the lake during the dry season may also affect salt water intrusion in the Mekong delta and restrict fish migration to the Mekong basin.

(v) Wild life protection

The wetlands within the project area can play a regional role as a refuge area for migratory birds.

F INSTITUTIONAL ASPECTS

F.1 NATIONAL CAMBODIAN INSTITUTIONS

The following sections (F.1.1 and F.1.2) describe the institutional framework in Cambodia as it was at the time of the visit of the consultant team in March 1993. With the occurrence of the elections and the constitution of the *Provisional National Government of Cambodia*, the situation has been extensively modified. Some information on the current governmental temporary structure are given in section F.1.3.

The governmental ministries which will be directly involved in carrying out the Tonlé Sap Project or which will be concerned by its coordination or planning stages are Ministry of Agriculture and Ministry of Transport, Communications and Post.

F.1.1 Ministry of Agriculture

The areas of involvement for the Ministry of Agriculture (MOA) are very wide. It is responsible for every state controlled development action, including civil works, in the domains of water, land, crops and livestock management. The MOA is also responsible for the survey and monitoring of the overall physical and biological environment and the management planning and protection of all renewable resources (water, fish, forests, wildlife. It is for this reason that the MOA is the interlocutor as far as the environmental issues in general, and the dynamics and use of the aquatic or forest resources in particular, are concerned.

The present organization chart comprises five Vice-Ministries two of which concern the Project directly : the Vice-Ministry in charge of training and general coordination of research and the Vice-Ministry of Fishery and Forestry.

Thus, the MOA exercises authority over the whole range of activities concerning research and training. Training is carried out by the Institute of Agricultural Techniques of Chamcar Daung (which should become the University of Agronomic Sciences) for the education of engineers, teachers and research staff, and by the Secondary School of Prek Leap for medium-level technicians. The current situation is quite critical because the Soviet teachers responsible for training in Cambodia left the country in December 1990. As a consequence there is a need to assess the level of people who were trained prior to 1990 (essentially in Russian language), and to make up for the extreme deficit of teachers in the four agronomic faculties, including fishery.

The MOA includes an Environmental Steering Committee (ESC) which is chaired by the Vice-Minister and which has representatives of all departments of this ministry. The ESC is presently preparing a national environmental institutional framework.

a) Department of Hydrology

This department within the MOA has a large complement of staff (725 persons in total), of whom 59 are engineers and 131 are medium-level technicians. The Department of Hydrology comprises eight sections or offices, of which five can be considered as technical sections. There are large discrepancies in the sizes of the sections and their respective staff quotas. For instance, the section of hydrometeorology has three engineers only, which is not sufficient to operate the surveys required on a country-wide basis.

Only three of the engineers have been trained outside the country (in Vietnam, Soviet Union and Laos). The remainder obtained their training from the Soviet-Khmer Technical University or in Chamkar Daung Agricultural University. For the medium-level staff, the range of technical skills is expected to be broad, some having benefited from on-the-job training while being involved in assistance projects; others have a general college or high school background with little hydrology-oriented technical knowledge. The Department of Hydrology is giving high priority to the training of its staff, including language training.

Some support in terms of expert assistance, equipment and training is expected to be given soon to the Department of Hydrology through a Mekong Committee Project (see below).

b) The Department of Fishery and Forestry

This department is in the process of being reorganized. With regard to fisheries it is in charge of all activities linked to exploitation (definition of plots and sale by auction, establishment and supervision of the implementation of regulations, collecting and processing fishery statistics); it trains directly four groups of state fisheries distributed among Kompong Thom, Kompong Chhnang, Kandal and South Mekong; and it is in charge of fishery and fish culture research.

The research laboratories are presently inoperable because the hydro-biological research station in Phnom Penh and the oceanographic research station in Kompong Som were completely destroyed in the 1970's. There remains only the fish culture station of Chan Cham Res, but it is almost inactive. The Cambodian government wants to rebuild a research institute near Phnom Penh. If this project is realised the institute could be conceived to regroup all the aquatic environments and all the aquatic resources. The establishment and functioning of this station should be given the highest priority.

The Department of Fisheries manages the inundated forest around the Great Lake, including the aspects of law and enforcement. The department is developing proposals relating to the wetland and inundated forests conservation within the frame of a Wildlife Protection Office created in 1992.

F.1.2 Ministry of Transport, Communication, and Post

The existing institutional framework of navigation and river transport is under the Ministry of Transport, Communication and Post. It includes the River Transport Company for operational aspects and the River and Construction Enterprises which undertakes river works : dredging, navigation aids and port facilities. Ports other than Phnom Penh are administered by provincial administrations.

F.1.3 The Provisional National Government

The Provisional Government includes 27 different ministries, of which the following may have strong links with the development of the Tonlé Sap and Great Lake area.

- Ministry of Planning
- Minister of Agriculture, Forestry and Fishery
- Ministry of Rural Development
- Ministry of Environment
- Ministry of Transport
- Ministry of Energy and Mines
- Ministry of Public Works
- Ministry of Industry
- Ministry of Tourism
- Ministry of Commerce
- Ministry of Education
  Ministry of Higher and Technical Education
- Ministry of Social Welfare and Labour

It is highly foreseeable that this institutional structure will not be exactly renewed in the definitive National Government. Particularly, the number of Ministries should be less than now (around 20), which should make the coordination for technical matter within each sector easier.

However, it is expected that there will be more ministries and departments in the final National Government than in March 1993 and that a new assessment of the institutional situation will be required in a few months. As an example of the consequence of the re-organization, the tasks carried out by a single department of a former Ministry would be split into 7 different ministries. This is the case of the water sector, which was totally in charge of the Department of Hydrology and whose future structure is given in Table F.1 [1] :

Whatever the future governmental structure will be, the formulation and the implementation of an integrated development plan will require the direct participation of several line ministries and the involvement of most of them at information, discussion and advisory levels. Therefore the institutional framework for a project aiming at the

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(1) Information provided by Mr. Nick Mandeville, ODA, Hydrology Programme Adviser, during the discussion of the Draft Report.

formulation of a Development Plan for the Tonlé Sap region, the links and the working procedures of the project staff with the technical departments of the different ministries remains major and preliminary objectives for achieving such a project. These aspects will be adressed in chapters G and H.

Table F.1

Future Structure of the Water Sector
(as envisaged 13-08-1993)

MINISTRY IN CHARGE	Task
AGRICULTURE, FORESTRY AND FISHERY	Irrigation
ENVIRONMENT	Water Management Water pollution
PUBLIC WORKS	Hydroclimatological data Climatology Large dams Flood control Dredging
RURAL DEVELOPMENT	Drinking Water Rural sanitation Water reservoirs Irrigation systems Micro-hydropower systems
TRANSPORT	Meteorology forecasting Navigation
INDUSTRY	Urban water supply
ENERGY AND MINES	Large hydropower schemes

F.2 INTERNATIONAL AND REGIONAL ORGANIZATIONS

F.2.1 Interim Mekong Committee

The Interim Mekong Committee (IMC) is the abbreviation for the Interim Committee for Coordination of Investigation of the Lower Mekong Basin, the only regional body addressing water-related development issues with regard to the four riparian countries of the Lower Mekong Basin. The IMC plays an important role in the planning, coordination,

implementation and monitoring of bilateral assistance in the region. It also acts as the central repository of data and information concerning water-related resources of the whole area.

Every year the IMC publishes a work-plan giving a summary of on-going and future projects. A list of projects relevant to the integrated development of the Great Lake, Tonlé Sap and Chakdomuk areas is given in Annex 4.

a) Assistance in Hydrology

As far as hydrology is concerned the most important project is undoubtedly MKG/R.91038/Rev.1, *Rehabilitation and Development of the Hydro-Meteorological Network in Cambodia*. This is a 3-year project with a total cost of US$ 757 000, of which US$ 289 000 is for measurement and monitoring equipment and transport facilities. The project will provide a full-time field hydrologist assigned to the Department of Hydrology to ensure the effective implementation of the programme. Among other activities the programme will install 15 staff gauges and 8 float recorders for stream gauging measurements, and collect sediment and water quality samples with a frequency allowing the assessment of sediment transport in Tonlé Sap and in the tributaries of the Great Lake.

The Tonlé Sap Development Project area will benefit from 8 hydrological/sedimentological stations on the Great Lake tributaries, two recording stations for lake water level changes, the rehabilitation of the gauge in Kompong Chhnang and an intensive monitoring programme in Prek Kdam.

If carried out according to the specifications of the project document, this project would require only minor modifications to fit the needs of the current Tonlé Sap project. Some points which will have a bearing on the implementation of future phases of the present project are discussed below :

(i) The 3-year period for installation of all stations may be too long for the purpose of the Tonlé Sap Project. Thus the *Hydro-Meteorological Rehabilitation and Development Project* should be either strengthened to enable installation of the monitoring equipment in a shorter time, or the Tonlé Sap and Great Lake monitoring sites should be given first priority for installation.

(ii) The project is designed as a comprehensive operational hydrology programme, emphasizing infrastructure rehabilitation, data collection, and field hydrologists' training. This is clearly the first priority for the country. However, there is little provision in the project for data interpretation and studies specifically targeting the Tonlé-Sap, Great Lake and Mekong dynamics. It is foreseeable that the day-to-day implementation of this ambitious project will require the full-time involvement of the hydrologist, who would not be available for carrying out studies specific to Tonlé Sap, Great Lake and Mekong river interactions.

The Tonlé Sap Project should therefore include a data interpretation and analysis component to be carried out in close collaboration with the country-wide hydrological project.

(iii) The timing of commencement of the Project is doubtful. Because this is the key project for hydrology and monitoring of sediment transport, a more definitive schedule should be drawn up.

Another important project being prepared by the Interim Mekong Committee is the proposed MKG/R.91039/Rev.2 *Mekong Geographic Information System - Cambodian Component*. This project will provide useful data for the future monitoring of land use changes associated with a study of watershed condition and sediment generation. The monitoring of changes in land use with time (deforestation in the upper watershed, extension of mining areas, land use changes in the agricultural zones surrounding the Great Lake, changes of vegetation features and type of vegetation cover in the inundated areas) should be undertaken with updating on a regular yearly basis. Associated with this is the need to measure and monitor the sediment transport into the lake by its tributaries.

The issue of topographical levelling and bathymetric surveys of the Great Lake area is not included in any project of the Mekong Committee. This aspect should be specifically addressed within the current Tonlé Sap project as soon as possible.

b) Assistance in Fishery Management

Several IMC projects are planned in the fishery sector. These are :

- *Assessment and Management of the Freshwater Fisheries of Cambodia* (MKG/R.91050) to be funded by Denmark for an amount of US$ 1 888 000 and to be implemented over a period of 36 months,
- *Management of Regional Fisheries Resources* (MKG/R.92063) with a projected budget of US$ 270 000 and an implementation schedule of 24 months, and
- *Investigation of Commercially Important Fish Species* with a projected budget of US$ 400 000 and an implementation period of 30 months.

All of these projects emphasize training of staff and the strengthening of the concerned agencies.

c) Assistance in Navigation Aspects

- IMC has a proposed project titled *Long-term Development of Inland Navigation in Cambodia* (MKG/R.92057) but it does not yet have funding.

Other on-going studies which are not directly carried out under the umbrella of the IMC also address navigation in a general way, but not in sufficient detail for the needs identified in the present study. On-going projects include :

- The jointly funded UNDP-ADB *Transport Rehabilitation Study*, and another implementation project in the transport sector funded by ADB.
- *The Phnom Penh Port Rehabilitation and Extension Project* funded by JICA.

The navigation aspects of Tonlé Sap should be addressed by a specific study because none of the on-going projects consider these in detail.

F.2.2 United Nations

The contribution of the United Nations to Cambodia has been especially outstanding with the deployment of UNTAC and all connected activities.

The **United Nations Development Programme** (UNDP) implements numerous development projects focused on the enhancement of institutional capacity in the country with special regard to environmental and renewable resources management. To achieve this objective, several initiatives have been started (Dennis and Woodsworth, 1992), including :

(i) *The Cambodian Environmental Advisory Team* (CEAT) is a team of advisers working with UNTAC, UNDP, the SNC Secretariat, the Ministries of Planning, Agriculture, Industry and Finance, and with a National Investment and Environment Board yet to be created. The brief of CEAT is to screen all major investments and development aid proposals for potentially adverse environmental impacts and for development sustainability.

(ii) *The Cambodian Environment Fund* which could be used for environmental rehabilitation projects including reforestation, erosion control and water management works. The CEF will also be used to provide long-term support for environmental protection and management of protected areas. In the first two years CEF will emphasize training and employment of returned refugees, demobilised soldiers and local inhabitants in labour-intensive environmental restoration and surveys. Such projects would be designated by the CEAT and proposed for funding through the UN coordination process.

If this process is implemented, it will be an unprecedented effort in the coordination of development projects in the country, and the current Development Plan for Tonlé Sap and Chakdomuk will benefit from being carried out in such a context.

UNESCO is currently carrying out the *Zoning and Environmental Management Plan for Angkor* which can be considered as a pilot project for further integrated studies of the Great Lake surrounding areas. Even though the site conditions are very particular, it is expected that some findings and experience gained from this project will be of help for a project addressing the overall riparian areas of the Great Lake.

FAO has current projects in Cambodia, including :

- *Improvement of Floodplain Fishery Resources in the Mekong and Bassac Rivers*, with a projected budget of US$ 1 670 000 and an implementation schedule of 5 years,

- *Multi-Sectoral Development Plan for the Great Lake (fisheries component)*, with a projected budget of US$ 100 000 and an implementation schedule of 20 months, and
- *Rehabilitation of the Inundated Forests of the Great Lake for a Multi-Purpose Use (fisheries component)*, with a projected budget of US$ 825 000 and an implementation schedule of 5 years.

Generally speaking the value of these projects lies in the integration of fishery aspects into other sociological and developmental activities, including agriculture and utilisation of vegetal cover. Unfortunately the FAO projects have been conceived in the light of catastrophic predictions relating to fish resources and the environment. The present project has not found evidence within the body of available data to support such negative assessments of the current situation, although the need for extreme vigilance has been highlighted.

F.2.3 Non-Governmental Organizations

The NGOs play a key role in Cambodia because, for many years, they have been the only channel for providing international assistance to the country. Currently the inputs of the non-governmental sector are widespread in every domain related to the environment, development and day-to-day life of the people. Some of the staff of NGOs have gained an in-depth knowledge of the country (in the environmental, sociological, economical and institutional sectors). Their contributions to the project will be helpful in its design stage as well as in the implementation phase.

The importance of the assistance provided by NGOs is illustrated by the hydrology and water resources sectors. The contribution from the NGO donors is US$ 15 to 20 million since 1979, the current annual inputs being between US$ 2.5 and 3 million during recent years. In 1990 direct assistance from the NGOs to the Central Hydrology Department in Phnom Penh was provided by :

- AFFHC (Australian Freedom for Hunger Campaign)
- CIDSE (Coopération Internationale pour la Solidarité et le Développement)
- OSB (Overseas Service Bureau)
- OXFAM UK and Ireland

At the same time assistance has been provided at the provincial level for site-specific actions by :

- ACR (Australian Catholic Relief)
- ADRA (Adventist Development and Relief Agency)
- CIDSE (Coopération Internationale pour la Solidarité et le Développement)
- MCC (Mennonite Central Committee)
- WCC (World Council of Churches)

Currently PADEK (Partnership for Development in Kampuchea), GRET (Groupe de Recherche et d'Echanges Technologiques) and SAWA (Stichting Adviesgroep Waterbeheer) are involved in small-scale development projects in the water sector.

Generally the NGO staff are highly committed to their duties, but the organisations have long-term funding problems. The assistance, which has to be given on an "ad-hoc" basis, should be included in long-term projects aiming at enhancement of the Department of Hydrology, including institutional strengthening, supply of equipment and staff training. CEAT might bring such coordination and long-term perspective for the NGO work programmes.

G. CONCLUSIONS

G.1 GENERAL CONCLUSIONS

Phase I of the Development Plan for Tonlé Sap and Chakdomuk provided the forum for a preliminary assessment of existing conditions which has been carried out mainly on the basis of a review of existing available data. "*The lack of quantitative and reliable data, especially during the past 15 years, is the more general finding of each sectoral assessment*" (Inception Report p.22). This situation has severely restricted the certainty of the conclusions given in the sectoral assessments of the Report. As an example, two crucial issues could not be solved

- Does the sedimentation rate occur with its natural and normal magnitude or is there any recent and on-going significant increase of this rate which could threaten the sustainability of the physical and biological environment in the wetland area, and hamper its economic exploitation (fish, navigation, etc.) ? This question applies especially to the Great Lake, and to some extent to the Tonlé Sap river, where it appears that Mekong sediment deposit at both end of the stream (Snoc Trou and Chakdomuk) is a natural process.
- Is the current pressure of the fisheries sustainable for the bio-ecological environment ? As discussed in the technical section on fisheries, a definite answer would require accurate information on the actual level of the catches (partially known), composition of the catches by size and specie (unknown). The socio-economical conditions in Cambodia are changing at an unusual rate which will undoubtedly urge the fishermen on higher fish production. Thus, recent data on catches and on fish marketing conditions are absolutely necessary, but as it has been shown in the analyses of fisheries and fish production (Section C), the available data are patchy and most of them have been collected several decades ago. Almost without exception, experts who have prepared reports and expressed opinions on the bio-ecological environment in the last 30 years have done so on the basis of very few field observations, using instead second or third hand information sources.

Inadequacy of data is especially constraining when the system to be analysed is dynamic, has strong variability with time (at annual, interannual and pluriannual levels) and its components are interactive. The links between the annual magnitude of the Mekong flood and the variations of the catch of fish are an example of such variability in time. The effects can be highly significant if an under average (or an over average) flood pattern is observed during several consecutive years. In a similar way, human activities can have short term influences (on migrations, for example) and long term influences (such as changes in the demand for fish due to regional development and population growth). To manage such an ecosystem in an environmentally sound way, it is therefore necessary to have long series of data concerning environmental changes, resources, their exploitation and the communities involved in the exploitation. It is a long term objective

for any country to access accurately the situation of its renewable resources (water, fish, forests, etc,) and the conditions of their exploitation. This implies the set up of efficient technical departments, naving strong scientific back-up. Institutional building, training of staff, availability of field equipment and data processing facilities are the required components to achieve such objectives. High priority should be given by the National Authorities to such programmes, even if the Nations's priorities have to be focused on more urgent and day-to-day issues. Regional institutions such as the Mekong Committee can play a key role in promoting such long term investigations and data collection.

It must be stressed that usually, the collection of data without clear objectives (identification of the problem to be addressed and of the questions to be answered) is usually not a very effective process. Such multi-purpose data collection programmes led to patchy data bases which remained untouched without any analysise for too long a period. As it is only when data interpretation starts that the lacks in data collection will be discovered, any data collection programme should include studies and analyses of the data carried out at the time of the collection. So, an appropriate feed-back can be provided to the data collection activities.

G.2 SCOPE OF A DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK

Therefore, **additional data collection, surveys and investigations** should be undertaken as soon as possible and **are clearly one of the objectives of the coming phase II**.

However, as the indicative duration of phase II is 2 years only, it is clear that the results and interpretation of long term "strategic" data collection will not be available before the end of Phase II. Therefore during this phase priority should be given to data collection and surveys of additional and representative data aiming at the verification of the tentative conclusions presented during phase I of the project.

On the other hand, the implementation of a development plan of the area, which is a long term and a permanent process, will require long term data bases, permanently updated to take into account the natural fluctuations and the socio-economic trends. As such, the project must stress the needs for long term data collection programmes in different sectors (water, fish, wild-life, land use, transport infrastructure, etc.), even if these activities are not carried out in the institutional framework of the project.

However it would be unrealistic as well as unacceptable for the Country to delay the process of the formulation of a development plan of the area until all above mentioned data and information have been collected and analysed. The justification of such a statement includes the following reasons :

(i) A dynamic and mostly informal development takes place in the whole country, and especially in the project area. The fringes of the Great Lake and of Tonlé Sap River are target areas for the returning refugees and displaced persons. Most of

them are believed to be farmers and therefore pressure on agricultural land and possibly on forests will increase. Some of the newcomers may as well undertake activities providing immediate and higher income than agriculture such as fishing, fish processing, wood processing (charcoal, construction wood), wild life poaching, etc. Under such specific conditions, even without all desirable information on environmental characterization, the basics of an environmentally sound development plan can be formulated and implemented, based on available data and common sense.

(ii) Aside from the required data previously mentioned, (collection of which are activities of some of the priority projects recommended by this study), a large quantity of information will be available in the near future, as several sectoral reviews are currently in progress, such as :

- Review of the fishery sector by FAO (the draft report is already available)
- Review of the irrigation sector by UNDP (will be available during the course of 1994)
- Review of the agricultural sector by FAO ((will be available during the course of 1994)
- information on population has already been collected for the purpose of the May general elections

Compared with the present situation (September 1993), the initial step of the development plan of the area (which is the formulation of the plan) which should start in the first months of 1994, will therefore benefit from a significant amount of new information in the fields of rural development, if not in those directly related with the environment.

(iii) The concept of an integrated development plan implies the participation, at various degrees of involvement, of a great number of national and non-national institutions.

In the present case, the first line of national stakeholders will comprises the following ministries :

- Planning
- Finance
- Agriculture (water sector, crops, fish, forest)
- Environment
- Transport
- Energy and Mines,
- Public Works
- Tourism

To a lesser extent, some others ministries will be concerned for the formulation as well as for the implementation of the plan, such as Commerce, Education, Industry, Health, Social Welfare and Labour, Veterans, etc.

Others regional and international organisations will be concerned as well, with the Mekong Committee having a key role to play. As discussed in the different technical sections of the report, the environmental conditions of Great Lake and Tonlé Sap river and therefore the development of their riparian areas depends largely on the conditions prevailing in the upstream parts of the Mekong watershed. The development of the area may also have some downstream effects. The implication of the only existing regional and basinwide organisation is therefore essential, at least to provide the project with the required data and information.

The immediate tasks of the project will include :

- To centralize and analyse all relevant information on the area. This will allow the Project to advise all institutions acting in the area (national and non-national), for a better coordination and synchronization of their activities, avoiding duplication of efforts and implementation of development projects which could threaten the environment and the long term sustainable development. The data base of the project will be a useful tool for national ministries, international and bilateral developing agencies, national and international research community, donor community.
- to advise the Government in the day-to-day decisions concerning the development of the area
- *to* set up an institutional framework which will be able to formulate a plan for an integrated and sustainable development of the area. This will include the definition of rules and of working procedures between the above identified stakeholders. It has been proved in every country that inter-ministry collaborations may be a delicate process, which would require a specific institutional forum to share the information and to come to a consensus when any decision has to be made. The building of *ad-hoc* institution is clearly an objective on which the project should be focussed in its initial step.

The scouring near the abutment of Monivong bridge has been identified as an urgent issue. However, the studies and works required for solving the problem were not considered as being a component of the Development Plan of Tonlé Sap and Chakdomuk. The protection works to the Monivong bridge remains therefore as a lone-standing project, already in the pipe-line of Mekong Work Programme, which will benefit from high priority from this institution.

G.3 HYDROLOGICAL AND MORPHOLOGICAL ASPECTS

The hydrological and sedimentological assessment led to the following comments, questions and recommendations.

(i) Relative contribution of Great Lake catchment to the lake water supply

Measurements and analyses have been carried out for only one complete year (1962-63). During this period, the contribution of the lake watershed was found to be 38% of total supply. As a preliminary estimate, the catchment of Great Lake would contributes about 1/3 of the total flow volume entering the Great Lake.

Although quantitative assessments cannot be given in the absence of stream gauging measurements in the various rivers entering the lake from its own catchment, a general observation is that there has been more mining and land clearing activity in recent times than at any other time in the past. This will certainly have had an effect on the hydrological regime of the rivers within the lake catchment area, tending to give sharper peak flows following rainfall events and more extended periods of low flows. There would also have been an strong increase in sediment transport rate to the lake, as a result of both mining and deforestation. This phenomena has widely been observed and reported, but no quantitative information are available.

Suggested action 1 :

To assess the siltation of the lake in the vicinity of the mouths of these rivers, hydrological stations shall be installed and an operational monitoring of liquid and solid discharge carried out, at least for one or two monsoon seasons. The selection of the stations will be made according to two criteria :

(1) Stations controlling the watersheds of the biggest tributaries of the lake

(2) Stations on heavily disturbed watersheds, where erosion and sediment transport is taking place.

The minimum design of this network would include the six following stations :

River	Station	Drainage area (km²)	Selection criteria
Stung Sen	Kompong Thom RN5	13 700	(1)
Stung Sreng	Kralanh RN6	8 175	(1)
Stung Pursat	Pursat RN5	4 480	(1)
Stung Sisophon	Sisophon RN6	4 310	(1)
Stung Mongkol Borey	Mongkol Borey RN5	4 170	(2)
Stung Sangker	Battambang	3 220	(2)

(ii) Contribution of Mekong river to the lake water balance

The share of Mekong river was a little over 2/3 of the total water supply during the single year for which data were available, corresponding to an entry of 45×10^9 m^3. According to the short historical series of daily discharge of Tonlé Sap in Prek Kdam, the inflow ranged from 43×10^9 m^3 to 61×10^9 m^3 according to the magnitude and the duration of the Mekong flood for each respective year.

Suggested action 2 :

The dominating influence of the Mekong to the supply of the lake implies that the flow moving upstream and downstream of the Tonlé Sap shall be monitored in an operational way, i.e. with the best accuracy and continuously for a long period. The control station shall be re-calibrated with frequent and accurate gauging measurements (several measurements per week) carried out using modern gauging techniques and equipment, during at least one hydrological cycle. The objectives of this new hydrological calibration of the section will be :

- To evaluate the volume flowing in and out of Prek Kdam.
- In addition, to verify indirectly if some sedimentation has actually taken place in the Tonlé Sap River between the outlet of the lake and Prek Kdam. The new calibration will be compared with that used during the sixties. Any significant departure from the former curves will be an indication that some change occurred in the hydraulic conditions of the Tonlé Sap River.

Since 1992 a new gauge has been installed for the monitoring of the Mekong water level in Phnom Penh at Chrui Chanvgar island. The corresponding cross-section of the Mekong has to be calibrated. This control station of the Mekong discharge in Phnom Penh should be backed up by an upstream station in Cambodia, the best option being to rehabilitate the station of Kratié.

The activities suggested in this recommendation are related to the hydrological basin wide monitoring of the Mekong and is closely linked with action 5.

(iii) Water supply to the Lake by overflowing of the Mekong

Part of the Mekong floodwaters flows directly to the lake due to overtopping of its right bank between Kompong Cham and Phnom Penh. The volume of this overflow was measured during one year only (1962) and its contribution was found to represent 10% of the total supply of Mekong river to the lake. However modest, this contribution may have a significant effect as it takes place late in the season when Tonlé Sap at Prek Kdam is already flowing downstream to Mekong river. This part of the lake supply is very sensitive to civil works and may have been modified by the construction of roads and hydraulic works undertaken during the 70's.

Suggested action 3 :

The contribution of the water supplied by overflowing has to be checked. Hydrological monitoring of the flow crossing the bridge at Kilometre 54 of

highway RN6 has to be carried out during at least one rainy season to make sure that this supply still exists and to evaluate its volume.

(iv) Variability in water level and supply to the Great Lake

Interpretation of the available recorded water levels in Kompong Chhnang show that the differences in the annual maximum levels of the lake at its final filling stage range from 1 to 2 m. Because of the very flat topographical conditions of the area, such variations result in changes in lake surface area of several thousands of km^2 and storage variations of more than $10x10^9$ m^3. If several years with low flows follow each other, which has happened several times in the recent past, the ecological conditions are temporarily modified with the anticipated effects on fish development and fishery catches. Such climatic variations will continue to occur, either in the lake catchment or in the Mekong river basin.

Suggested action 4 :

The water level of the Great Lake must be monitored and accurate curves relating flooded area and stored water with water levels must be determined, which implies :

A bathymetric and topographic survey of the lake,

to be conducted on the overall area, including the remaining water body at the end of the dry season and the flooded area in its largest possible extension.

The survey shall be carried out using modern positioning systems. The topography and bathymetry must be linked up with a large number of topographic benchmarks all around the lake. The grid of the bathymetric survey will have to be very dense in the sites where sedimentation is supposed to be active (at the outlet of the lake near Snoc Trou and in the northwestern part where rivers carrying silt flow into the lake). This document will be a basic reference, which has never been established up to now, for the assessment of the sedimentation of the lake in the future. It will be crucial for the establishment of the water balance, for ecological characterization, and for planning of any navigation development. This geodesic document will be the reference of the situation at the end of this century to be given to future generations.

The continuous recording of the lake water level

As breakdown of chart recorders and data loggers are routine events, the levels should be measured at two different sites, one near the inlet of the lake (somewhere between Snoc Trou and Krakor) and the other at the northern end, possibly near Siem Reap. The recorders will be installed on scaffolding towers sunk into the lake bottom. As far as possible, the sites should remain in sight of a topographical benchmark located on firm land, to easily ensure checking of the datum level of the gauges during the dry season, as the towers may sink into

the muddy bottom of the lake. With the availability of the depth-volume curve, it will be possible to monitor the water balance of the lake.

Suggested action 4 is urgent and crucial. Without this information, the definition of any development plan of the area will indefinitly remain a topic for controversy and unproductive discussion.

(v) Impact of existing dams and hydraulic control structures

The expertise did not identify any impact of existing dams or hydraulic control structures on the Great Lake water balance. The 1985-1989 period was actually one of generally low flows at Phnom Penh (on an annual discharge basis as well as on a flood season basis). However, this feature was also observed in the upper part of Mekong river, upstream of any known large-scale water-harnessing structures or recently constructed hydraulic controls.

This conclusion should however be considered as an initial and tentative estimation which should be improved through comprehensive and careful analysis of all hydrological data collected on the Mekong and its tributaries.

Suggested action 5 :

All operational activities in the hydrological monitoring of the Mekong and its tributaries carried out under the coordination of the Mekong Committee, especially the project MKG/R.91038 "*Rehabilitation and Development of the Hydro-Meteorological network in Cambodia*" shall be supported and strengthened as all information gathered in this context is of definite interest for the understanding of the Tonlé Sap hydrological behaviour. The recurrent activities of electronic data encoding, processing, and control shall be supported with the same level of priority. In addition, hydrological interpretation and synthesis of this information must be developed. Special interest shall be given to Project MKG/R.900029 "*Water Balance of the Lower Mekong Basin*", which outputs on a basin-wide scale will be of great help to understand the comparatively local phenomena of the Great Lake and to access, as much as possible, the range of its expected hydrological variability.

The monitoring and the assessment of the low-flow levels and discharges of the Mekong in Phnom Penh shall be carried out carefully, as there are actually two possible processes for the Mekong to modify the water balance of the lake :

- a reduction of the floods, already discussed, and
- a reduction of low flows or an occurrence of low flow earlier in the season, which would hasten the start of the draining of the lake, with all the foreseeable consequences on ecology, fisheries and navigation. In this range, hydropower dams are of less concern as they usually release higher discharge than the natural one during low-flow periods. Contrarily, irrigation schemes provide genuine uptake of water which is returned to the atmosphere in the form of evaporation, essentially during the dry season, and thus their impact can be very significant.

(vi) Capability of the Department of Hydrology to monitor the situation

Several reviews of the Department of Hydrology have been conducted recently, the most comprehensive being the "*Appraisal of Management Systems and Resources. Department of Hydrology - Cambodia*" supervised by AFFHC/CIDSE, Phnom Penh, December 1990. It was concluded that in its present stage, the Department needs equipment to carry out the surveys, to store, process and analyze the data, and qualified and trained staff to use the equipment. A comprehensive assistance programme providing equipment and training is required to make the Department fully operational. A country-wide project for the rehabilitation of the hydrological network (MKG/R.91038) is included in the 1993 Mekong Work Programme and will be initiated as soon as funding is provided. Some local rehabilitation work has already been undertaken near Phnom Penh under the co-ordination of the Mekong Secretariat

It must be pointed out that the re-organisation of the department will be a long lasting process, with huge training needs as the department has 725 skilled workers, including 59 engineers and 139 staff with a medium-level background. However, the activities specifically targeted on the development of the Tonlé Sap and Great Lake area, are well identified and of a smaller scale. Thus it seems that to subordinate all the recommended hydrological activities to a previous and comprehensive rehabilitation of the overall Department of Hydrology might be a ambitious, costly and prolonged programme. Especially, if the nation-wide project is not going to start very soon, it might be more realistic to set up inside the Department a specific team for the Tonlé Sap area. This unit will have a limited number of staff, who will be responsible for the surveys and the studies, and will benefit of every needed assistance, including the supply of equipment and training. This design would allow a more efficient mobilization of the staff, better control of the funding, and more efficiency in the accomplishment of their duties. The "Tonlé Sap Team" should include the field and office technicians working in the other domains of the environment (fishery, forestry, etc.). The team could share the measuring devices, the transportation facilities (cars, boats, motorbikes, etc.) and the data processing equipment.

G.4 FISH AND FISHERIES

(i) The Great Lake/Tonlé Sap river is dependent on the floods of the Mekong river. Any modifications in the floods have repercussions on the environment and resources of the study area, and three major influences were identified :

- flood volumes which are essentially a function of climate;
- water quality (sediment content, in particular) which is a function of climate and also of environmental degradation due to human activities (for example, deforestation in the upper catchments); and
- the level of exploitation of fish resources in Mekong river upstream and downstream of Phnom Penh (zones B and C in Figure D.1). Determination

of the changes and interrelationships affecting the water, sediment content and fish stocks is of the highest priority.

Similarly, all modifications of the environment and resources in the Great Lake can have consequences in Mekong river, mainly downstream of Phnom Penh but also upstream in the case of migratory fish.

(ii) Although the project area for Phase I was not the whole catchment area of the Great Lake and Mekong river, the Great Lake/Tonlé Sap system is strongly dependent on outputs from the whole drainage basin : liquid and solid discharge which evolve as a function of erosion and human activities (deforestation, mining); chemical and organic pollution (mining, agriculture). In this respect attention needs to be given to quantitative and qualitative surveillance of runoff.

(iii) The role and importance of the inundated forests in relation to reproduction of fish and generation of sediment, neither of which are currently well understood, have nevertheless inspired many affirmations. These forests have been used since ancient times by fishermen as sources of wood for cooking, construction, fish traps, and *samras*. The land clearing for agriculture in the 1970-80s has probably been particularly destructive. However, due to the flat topography of the area, the clearing of the inundated forests cannot be blamed for any increase of sediment supply to the Great Lake

Based on the available evidence, this ecosystem deserves protection, appropriate management and detailed study to determine its capacity for renewal and its role in relation to fish reproduction. These objectives will be partially covered by the FAO project "*Rehabilitation of inundated forests of the Great Lake for a multi-purpose use*" (fisheries component).

(iv) Sedimentation of the Great Lake and of the upstream and downstream limits of Tonlé Sap (Snoc Trou and Chakdomuk) were major concerns reflected in the Terms of Reference for this study. The building-up of an island of sediment in the vicinity of Quatre Bras and interference with navigation caused by reduction in the draft of the lake compared with the situation of 20 or 50 years ago, led to hypotheses of accelerated erosion in the catchments affecting the Great Lake. Some writers have even expressed the opinion that the lake will soon cease to exist in the dry season.

An assessment of this pessimistic scenario was presented (Section C), which led to more reasonable hypotheses. There are no data available at present to support the assumption that the rate of sedimentation of the lake is higher now than it was 30 years ago. However, even though the condition of the lake at low water is not appreciably different from the descriptions given in that period, there are signs that changes are occurring, in the Great Lake watershed as well as in the Mekong drainage basin.

Our tentative conclusions are somewhat different from those given recently by other authors. However, the importance of these issues and the different interpretations of the few available information warrant the priority projects adressing the bathymetric survey and and sedimentation assessment of the Great Lake.

(v) Assessment of the living resources is particularly difficult because of the scarcity and unreliability of the available data. A generally held viewpoint, supported by several expert opinions made by FAO, is that there is over-exploitation of the fish and a "*general decline in yields*". Our conclusion is much more moderate, firstly because there are no data to support such a viewpoint and secondly because the data which do exist show a situation of relative stability. It is necessary to recall two important elements in relation to living resources :

- It is actually possible that the potential production has decreased during the last 10 or 20 years. This could be due to two major series of factors : (i) lower flood volumes and levels in Mekong river giving correspondingly lower reproductive rates in the aquatic ecosystem, and/or (ii) environmental degradation caused by man's activities (deforestation, erosion, construction of embankments and other agricultural development works). The present level of exploitation should be assessed in terms of the present reproductive potential of the aquatic ecosystem.

- Given that there has been an increased intensification of fishing effort, linked to technological innovations in fishing gear, the composition of the catch has probably changed as a function of the vulnerability of the species. It is probable that less large fish and less species of high economic value are caught, while at the same time the proportion of fish of less value has increased. Depending on the priorities and a definition of value, the present situation could be considered acceptable in terms of total yield even though there may or may not be a real decline in the value of the catch. This does not necessarily mean over-fishing.

(vi) Although there was no specific mention in the Terms of Reference, we considered the effects of the barrage proposed on Tonlé Sap (1964) by the *"Central Water and Power Commission"* (New Delhi). According to the CWPC the preferred site is 3 km upstream from Kompong Chhnang and the barrage would offer many advantages, among which the most probable are :

- For Cambodia : increased fish production due to increased lake levels, possibility of irrigation in the zone surrounding the lake and downstream of the lake, reduction of flooding downstream, improved navigation in Tonlé Sap in the dry season;
- For Vietnam : If well managed, reduced salt-water intrusion during dry season, improved drainage, increased water availability for irrigation in the dry season, greater draft and improved navigation in the dry season.

This whole argument should be reworked in the light of more recent data and up-to-date methods for analysing the benefits and constraints of such complex multi-purpose dams.

In relation to the production of fish in the lake, Schmid (1963) and d'Aubenton (1964) analysed the consequences of such a dam on the inundated forest and the migration of fish. The conclusions are ambiguous : there would probably be a diminution of the area of inundated forest and consequent disturbance of fish migration, even if the best technical solutions are envisaged. Increased production of fish is not certain if the lake is permanently maintained at a higher level, there being the negative effects of interference in the seasonal flooding.

Although we were not explicitly asked to consider this aspect we feel that its consequences could be important. At the very least, the proposed dam merits a new study, possibly to be undertaken in the form of a workshop specifically dedicated to the Tonlé Sap dam project.

Our overall conclusions, arrived at in the most objective manner possible, tend towards a less pessimistic view than those which have been expressed in recent reports. The present condition of the environment and the fish resources is not (subject to verification by more complete data) seriously degraded, and the apparent variations in yield can be attributed as much to natural causes as to the harmful effects of man's activities. It would appear also that the pressure on the Great Lake and its ecosystem has not been too heavy in terms of sustainable use of resources during recent years because of the unusual political and socio-economic situation of Cambodia.

This situation is changing rapidly. Population growth, attraction of new markets and short term prospects are putting an increasing pressure on the natural resources. The existing legislation aiming at the protection of the natural resources has to be improved, both in its relevance to the changing conditions and to its application.

An overall project which would integrate the research and development aspects concerning the Great Lake/Tonlé Sap system is recommended. Such a multi-sector and multi-disciplinary project would be beyond the scope of Phase II of the study because it would need to be implemented over a longest period. The identified priority projects could be considered as first contributions towards the overall project, especially in relation to the collection of new data and the verification of the various hypotheses described in this report. The overall project should include a programme of monitoring and the training of professional local staff.

This overall project should take into account the various on-going and planned projects in the study area, implemented by a number of developing agencies (Interim Mekong Committee, FAO, UNESCO, other United Nations agencies, NGOs and bilateral assistance programmes) to avoid as much as possible any duplication of activities. Overlapping appears as being already a problem, and there is also the risk that some high

priority actions will be adressed by any project. A national development master plan is necessary to ensure that priorities will be kept and that national objectives are clearly defined. This comment is particularly relevant to the management of the living aquatic resources which is currently not coordinated in the most efficient way.

The first priority for Phase II is therefore defined as being the setting-up of a institutional structure to oversee further research programmes and development actions for the Great Lake/Tonlé Sap system.

G.5 NAVIGATION ASPECTS

(i) The project of rehabilitation and extension of the port of Phnom Penh funded by the Government of Japan will be completed by the end of 1995. Ships up to 4 000 DWT will then be able to access the port located in the Tonlé Sap river, but dredging of the access channel, across Chakdomuk will be required at a minimum water depth of 5.50 m LLW.

In the long term the proposed new port at Chrui Changvar in Mekong river mainstream will serve sea-faring vessels, thereby allowing the existing entrance channel to Tonlé Sap river to become blocked by sediment in the absence of frequent dredging. If the project is implemented, an approximate completion time for this new port project is 7 to 9 years from now.

(ii) Tonlé Sap river is navigable from Phnom Penh to Kompong Chhnang all year round by boats up to 150 T, but navigation beyond Kompong Chhnang to the Great Lake is hampered by the shallow pass at Snoc Trou. At present only small craft carrying dried fish can continue beyond Tonlé Sap river during the low water period. Further downstream, fish is collected by larger junks and forwarded to Phnom Penh. The traffic of timber coming from Tonlé Sap tributaries is also interrupted during the dry season because of shallow draft at Snoc Trou.

Important agricultural and forestry resources as well as fish could be transported more economically by waterways along the naturally favourable system provided by Tonlé Sap. Dredging in the pass of Snoc Trou would be required to ensure continuous navigation by barges up to 200 T and over from the provinces to Phnom Penh, which requires further investigation.

Waterborne transport is cheap and efficient, and contributes to the economic development of local populations. Navigation routes in Tonlé Sap could readily provide accessibility, without heavy investment, to most of the economically important areas, especially those areas which are inaccessible because of poor road conditions. During the rainy season waterborne transport is presently the only link for certain areas with the rest of the country.

Navigation requires less maintenance and investment than highways and, during the flood season, navigation on Tonlé Sap would relieve road infrastructure from further degradation. Inland waterborne transport, like railways, is a low-energy

mode of transport consuming from 50 to 75 % energy less than road transport, and therefore providing better protection of the environment.

Both the capital and operating costs of waterborne transport are relatively inexpensive in terms of foreign currency. Boats for Tonlé Sap could be built locally with limited amounts of imported equipment and material, whereas road transport requires import of trucks and spare parts. Operating costs of rivercraft per t.km are also lower.

In-depth investigations and study of navigation development in Tonlé Sap are therefore strongly recommended to determine optimum use of its natural resources in this respect.

G.6 AGRICULTURE

(i) Based on available climatic, rainfall and cropping data, irrigation is needed for the development of agriculture even in the wet season. The command area of the irrigation project and amount of irrigation water required depends on the variable parameters concerned. Also, the most suitable type of irrigation scheme for each specific area needs to be determined. Therefore, it is recommended that a development plan for irrigation in the study area be prepared with careful consideration of environmental impacts. Development in areas outside the study area but located in the same catchment area needs to be taken into consideration as well, since it may have a major impact on development in the study area.

(ii) The studies for agricultural improvement of several irrigation projects in Tonlé Sap basin, such as Battambang Multi-purpose Project and Stung Mongkol Borey Irrigation Scheme, are presently on-going . In addition an inventory of existing irrigation projects is included in the on-going Irrigation Rehabilitation Study of Mekong Secretariat. The results of these studies will be useful for planning of the irrigation and agricultural development in the Tonlé Sap - Great Lake project area.

(iii) If rural development and subsistence farming are considered as high priorities, the development programme should be country-wide and be started as soon as possible. In the study area, a small scale irrigation pilot project (area of 100-400 ha) should be developed and appropriate development models should be formulated through the study of this project. The concept of this pilot development project should be aimed at participatory planning and management as well as capability strengthening of governmental technical staff and farmers. It is expected that the present policy of the government of private ownership of agricultural land will encourage the farmers to actively participate in the project.

G.7 ENVIRONMENTAL ASPECTS

No evidence was found that the Great Lake is on the fringe of an environmental disaster. Existing speculations of high siltation rates, prevention of fish migration

and fish reproduction as well as over exploitation of the aquatic resources are not based on hard data.

Current deforestation of the inundated forest could not be proved, but takes probably place in some areas.

To assess environmental impacts in the Great Lake, data has to be collected during base-line surveys and consecutive interpretation studies have to be carried out, especially in the fields of hydrology, water quality, fisheries, land-use and socio-economy. Environmental impact studies will be a worthwhile exercise for the purpose of a regional development plan only when this base line data will be available.

The major environmental impacts are expected to be :

- Sedimentation and pollution in the Battambang River and the Great lake due to gem mining in the upper parts of the watershed
- Possible impact - especially on aquatic life and fisheries - of domestic waste water released from the urban areas (Phnom Penh, Siem Reap, Battambang, etc.)
- Possible impact of deforestation of the inundated forest on wild life and fish (and fisheries)

A project to establish baseline measurements relating to water quality, sediment transport rates and hydro-climatological parameters is recommended to provide the basis for monitoring of environmental degradation. These baseline data will also be essential to the definition of a national master plan for the study area.

H. RECOMMENDATIONS

In line with the conclusions given above, recommendations for further activities consist of several coordinated actions to be undertaken as part of Phase II of the Development Plan for Tonlé Sap and Chakdomuk.

The actions recommended to be carried out during Phase II are presented in the form of lone-standing priority projects. For the sake of consistency and coordination of the proposed actions with other actions being implemented, the setting-up of an institutional structure able to formulate the integrated and environmentally sound development plan is recommended as a major priority project, thereby making a total number of six recommended priority projects as follows :

H.1 INTEGRATED DEVELOPMENT PLAN FOR THE GREAT LAKE, TONLE SAP AND CHAKDOMUK

As stated above and discussed in section G.2, this proposed sub-project is expected to ensure co-ordination and consistency to the whole Phase II Development Plan. For any major development proposals, environmental impact assessments are recommended to be made in prefeasibility, feasibility and implementation stages.

H.2 BATHYMETRY AND SEDIMENTOLOGY

The need for a bathymetric and topographic survey of the flooded area of the Great Lake and the Tonlé Sap was discussed and justified to address issues regarding water management, environmental aspects and navigation purposes (see G.3, suggested action 4 and G.5). Due to its foreseeable high cost, this has to be considered as a major technical support project for the country.

The sedimentological sub-project comprises core sampling and suspended sediment study. It has to be undertaken in close coordination with the hydrological monitoring of the main tributaries of the lake and of the Tonlé Sap itself.

H.3 HYDROLOGICAL MONITORING OF TONLE SAP BASIN

The needs for hydrological monitoring have been presented, amongst others, in sections G.3 (water management and siltation assessment), G.5 (agriculture) and G.7 (environment). When phase I began, an MS project for a country-wide hydrological monitoring (MKG/R.91038) should have started shortly afterwards. Thus, the design of the proposed hydrological project was identified as a component of the country-wide project limited to the watershed of the Lake and Tonlé Sap.

H.4 BIO-ECOLOGICAL BASIS FOR FISH PRODUCTION

The proposed approach of fish bioecology in the framework of Phase II focuses on exchanges between the Mekong basin and the Great Lake. This preliminary study of migrations will pave the way for other ecological aspects : reproduction and growth.

H.5 RESPONSE OF FISHERMEN TO ENVIRONMENTAL AND SOCIO-ECONOMIC CHANGES

The justification of the project is to assess the behaviour of the fishermen communities in relation to institutional regulations, technical innovations, and economic return, the objective being the planning of a sustainable fishing effort.

H.6 NAVIGATION DEVELOPMENT IN TONLE SAP

The proposed approach under Phase II comprises an economic and technical assessment of inland navigation development from Phnom Penh to the Great Lake and its tributaries.

The critical issue in this connection is year-round navigability of the pass of Snoc Trou which is closely linked to the general issues to be addressed under the integrated study on environment and resources proposed herein. Another focal point of the proposed study is the navigation channel at the entrance of Tonlé Sap river at Chakdomuk.

H.7 MISCELLANEOUS RECOMMENDATIONS

H.7.1 Agriculture

In terms of agricultural development, it is recommended that appropriate small scale irrigation development be implemented as a pilot project. The result of such study would be adopted in other areas of Cambodia as well as in the study area. The main objective would be to assist in the improvement of living standards amongst smallholder farmers in the areas surrounding the Great Lake by increasing agricultural production through a viable and sustainable development of irrigation techniques. The terms of reference of the study would include the following requirements:

- to make a reconnaissance survey for site selection and conduct a Rapid Rural Appraisal in the proposed areas,
- to select the target areas and formulate an appropriate development model based on the participatory planning and management of local staff and farmers,
- to prepare an implementation programme,
- to draw up a recommended approach for viable and sustainable irrigation agricultural development in the area surrounding the Great Lake.

Since other on-going projects launched recently by the Interim Mekong Committee and by the Asian Development Bank overlap with this sub-project, no specific agriculture/irrigation priority project is proposed in the framework of the Phase II of the Development Plan for Tonlé Sap and Chakdomuk.

H.7.2 Land Use

There are various land use data, aerial photographs, satellite images and GIS maps held by the Mekong Secretariat but, due to a lack of manpower, no thorough compilation of these data has been carried out. Other relevant data are available in the Asian Institute of Technology (AIT) in Bangkok, and at the Land Use Mapping Office (LUMO) in Phnom Penh.

A priority project to provide institutional support to Mekong Secretariat for the compilation of all available land use data would be a worthwhile exercise, the implications of such a compilation being vast in terms of development in Cambodia. However, such a project has not been included here, because it is considered as being be of a general purpose nature and not specifically targeted to the needs of the Great Lake and Tonlé Sap area.

H.7.3 Water Quality Monitoring

The setting-up of a water quality monitoring network is recommended to ensure that relevant and up-to-date data are collected, processed and compiled for management and planning decisions. Sampling points should be located downstream of the main urban centres, such as Phnom Penh, Siem Reap, Battambang, near the food and fish processing facilities, and downstream of the jute manufacture in Battambang, to monitor the impacts of waste water disposal. The water quality monitoring may indicate immediate needs for waste water treatment.

H.7.4 Aquaculture

Fish culture in the Great Lake depends on capture fisheries for fingerlings (stocking) and feeding. The development of a price competitive fish feed and the construction of fish hatcheries and nurseries are previous conditions for an increase in the aquaculture production. Aquaculture would not be restricted to a seasonal activity and dependant only on capture fisheries.

H.7.5 Environmental Impact

For any major development action, environmental impact assessments are recommended to be undertaken in prefeasibility, feasibility and implementation stages.

PRIORITY PROJECT SHEETS

PRIORITY PROJECT NO. 1

INTEGRATED DEVELOPMENT PLAN FOR THE GREAT LAKE, TONLE SAP AND CHAKDOMUK (PHASE II)

OBJECTIVES

To assist the Government of Cambodia in :

1) Formulating sustainable integrated development and management plans for Tonlé Sap and Chakdomuk areas.
2) Strengthening the institution and capacity building for the planning, development and management of the project area.

JUSTIFICATION

1) With the increasing population pressure, the expected rapid economic upturn, enhancement of food production from all available land and water resources is becoming an economic and social imperative.
2) Natural resources exploitation will occur at a much faster pace and on a large scale, and some development options are antagonistic to each other.
3) Attention must also be given to the management, conservation and protection of the environment for the sustainable exploitation of land and aquatic resources.
4) Without an integrated development and management plan, the natural beneficial and productive function of the Great-Lake-Tonle Sap area could be endangered.
5) There are several on-going and planned activities in the project area which need to be coordinated in order to avoid duplication and waste of resources and time.
6) There is still a lack of institution framework/body for coordination of several projects and for integrated regional development planning.

APPROACH

1) Development planning should be considered as a dynamic process which requires the setting-up of an institution responsible for periodic updating.
2) The first plan should therefore be based on existing information and data supplemented only by limited additional investigations and survey to be undertaken during the formulation of the plan.
3) The institution strengthening and capacity building should be initiated at the same time thas the plan formulation and should be a step-wise approach.
4) The basic function of a new set up should include :
    i) Coordination and synchronisation of sectoral planning.

ii) Advisory role to the decision making in screening projects in order to avoid duplication and to ensure that the projects will not pre-empt the long-term development.

iii) Comprehensive data base center accessible to line agencies and doner countries/organisations.

5) The new set-up should not be another bureaucratic layer but should be under the jurisdiction of existing government organisation (Ministry of Planning ?, National Mekong Committee ?).

6) The new set-up should not be under a line ministry to ensure efficient coordination. It should not take away functions and tasks of existing agencies in order to be accepted.

MAIN ACTIVITIES

First year

1) Additional investigations, survey and data collection (see annex).

2) Collection of information on on-going and planned projects in the project area.

3) Establishment of new institution and training of core staff mainly on integrated regional development planning.

4) Review and assessment of new information and data.

5) Sectoral reassessment based on updated information and identification of the potential and constraints of each sector (Fishery, agriculture, navigation, tourism...).

6) Analysis of the governement policy, strategy and priority.

Second year

7) Preparation of scenarios of long-term development perspective.

8) Formulation of short-medium development plan.

TIME FRAME : 2 years

FUNDS TO BE SECURED : US$ 700 000

PRIORITY PROJECT No.1 - ANNEX

Main Additional Investigation, Surveys and Data Collection

Those activities, stated on page H6, section 1, may include the following tasks :

1) Topographic survey of inundated area
2) Monitoring of water level in the Great Lake.
3) Monitoring of water quality, sedimentation of the major tributaries as well as tributaries exposed to serious degradation (could be handled by the on-going project of Mekong Secretariat)
4) Socio economic survey at provincial level
5) Fish species sampling of current catches in selected locations
6) Survey of the type and volume of goods transports through the Tonle Sap river
7) Identify major obstruction on navigation channel
8) Land use and land suitability mapping (in cooperation with the on-going project of the Mekong Secretariat)

These activities should be promoted and coordinated by the "*Integrated Development Plan for the Great Lake, Tonlé Sap and Chakdomuk*" Project rather than direcly carried out and supported by it. However, certain urgent, preliminary and limited investigations and surveys could be directly undertaken by the project.

PRIORITY PROJECT No. 2

BATHYMETRY, TOPOGRAPHY AND SEDIMENTOLOGICAL STUDY OF THE GREAT LAKE AREA

OBJECTIVES AND OUTPUTS

(1) To establish a bathymetrical and topographical map of the Great Lake, i.e

- Bathymetry of the "dead storage" area of the Great Lake (dry season conditions).
- Topography and/or bathymetry of the zone flooded during the monsoon season (up to the highest water levels - around 10 m asl).

(2) To locate the areas of the lake where "recent" and "current" siltation is taking place, and to access the rate of sedimentation over time.

This is a sedimentological expertise based on the interpretation of core samples of the Lake bottom, taken in several typical sites (Snoc Trou, Battambang area, middle of the "small" Great Lake, middle of the "big" Great Lake, Stung Sen mouth, etc...

JUSTIFICATION

The bathymetrical and topographical map of the Great Lake and the sedimentological study are essential to achieve the following four objectives :

(1) To monitor the water balance of the Great Lake

Any water management project or environmental assessment requires knowledge of the quantity of water stored in the lake and in the Tonle Sap River, and the variations of these quantities with time. Such data is crucial, for instance, to detect possible modifications of the Mekong supply flow (due to climatic change or to the activity of Man). The hydrological feasibility of a possible artificial regulation of the Great Lake with a barrage will require water balance data of the system in different conditions ("normal" year, dry year, wet year). The easier and more accurate method to estimate the water balance of a lake is the utilization of a water level/storage relationship, which can only be derived from bathymetrical and topographical surveys.

(2) To provide an environmental characterisation of the flooded area

In the analysis carried out in the part C "Hydrology", it appeared that the maximum extension of the flooded area could be significantly different from one year to another, and that the occurrence of several years with low or high levels following each other are common phenomena. These situations will have direct

impact on the vegetation of the flooded area (including the "flooded forest") and on fish ecology and fishery productivity.

The combination of a permanent monitoring of the lake level and the use of a relationship between the water level and extension of the flooded area will enable the extension and the location of the flooded areas and the duration of flooding to be assessed. This will be concrete information for environmental and ecological characterization. Protected areas may be identified as areas which are flooded for an extended duration, and quite regularly every year, while potential areas for development could be identified as zones where flooding occurs only during exceptional hydrological conditions or for a short duration. A bathymetrical and topographical survey of the lake is required to establish such a relationship linking water level and flooded area extension.

(3) To access the siltation process in a definite manner

An indisputable way to access the siltation of the lake during a certain period of time is to compare changes of the lake bottom from a former survey. Such a basic and irreplaceable document is still not available and is urgently required for any long-term environmental monitoring of the area. Moreover, a general bathymetrical/topographical map fitting the needs of objectives (1), (2) and (4), this component will require some additional and specific small-scale and more accurate surveys in the sensitive areas (Snoc Trou, Northwest of the lake, Stung Sen mouth, some cross-sections of the Tonle Sap River). For the monitoring of the sedimentation in the central areas of the lake, very accurate bathymetry has to be carried out along several cross-sections. The position of these cross-sections must be precisely known (using electronic positioning systems) in such a way that future surveys can be carried out following exactly the same route.

This topographical information will be cross-checked with the "recent" and "current" siltation rates determined by the core sample analysis. The "recent" time-scale refers to the natural sedimentation rate which has occurred during the last hundred years (and which is the bottom line of the sedimentation rate of the Lake) ; the "current" time-scale refers to the past few years (i.e. the last decade). The comparison of the sedimentation rate over the two periods will give an estimation of the environmental degradation and of the importance of Man activity in the current siltation process. The current siltation rate assessed through sedimentological studies will be cross-checked with the sediment flow of the lake tributaries which will be obtained from the hydrological and water quality monitoring of the major streams of the Great Lake watershed area (see "Operational hydrology programme : hydrological and sedimentological survey of the Great Lake Watershed and of the Tonlé Sap River".

(4) To help navigation and to set up a navigation extension plan

A bathymetrical map and the recording of the lake level will the maximum draught for a specified route on a day-to-day basis. In the context of a navigation

development plan, such documents will identify on the relevancy of carrying out dredging in specific areas, will help to define ad hoc specifications for ship construction, and to carry out other navigation-related work in the area (building of wharves, etc...).

OUTPUTS AND ACTIVITIES

The realization of the topographical and bathymetrical map is highly dependent on the latest technological developments. Electronic positioning system, digital recording and processing of the information, and automatic mapping are techniques which not only may reduce the cost of the survey but also make it more precise. As such, the task should be considered as a sub-contract rather than a conventional assistance project. However the national technical departments could be entrusted with some of the small-scale and site-specific surveys, such as bathymetry of cross-sections of the Tonle Sap River, or survey of some riparian areas of the lake where positioning can be achieved with optical means.

Depending on the technology, the objectives can be achieved by a bathymetric survey of the lake at its highest level or to combine a bathymetric survey during the dry season (when water level is around 1 m asl) with a topographical survey of the remaining area (between 1 and 10 m asl). The topographical survey would probably include cross-checking field survey information with remote sensing data (aerial photographs, satellite information, microwaves, etc...). Currently, the 1/50 000 topo map presents the situation of the lake at the end of the dry season, the position of the 10 m contour line, and the altitude of a number of specific points between 1 and 10 m asl, which are not sufficient for the definition of the water-level/storage/flooded area relationships.

The activities required for the sedimentological expertise will include :

- Shallow drillings and core sampling of the bottom of the lake. The sampling methodology and the drilling locations should be as possible the same as those carried out by Carbonnel in 1962. However, some techniques in core analysis and interpretation have been improved since.

- To access the "recent" and "current" sedimentation rates, laboratory analysis of the core samples will be carried out in the following fields :

  - Sediment mechanics and physics
    Variation with depth of the core density and of water contents of the silts, etc
  - Isotopic analysis
    Carbon C14 and others
  - Mineralogical analysis
    To determine the watershed area where the sediment came from. As the geology in the northern part of the Great Lake (the Phnom Dangkrek) is quite different to the southern part (especially if we consider the intrusive rocks in

the region of Païlin), it should be possible to determine the area of origin of the sediment using the mineralogical patterns of the cores. To optimise this "natural tracers" study, the same mineralogical characterisation shall be carried out on some of the suspended sediment samples taken from the major tributaries of the lake, including the Mekong and the Tonlé Sap Rivers, during the "Hydrological and sedimentological survey of the Great Lake watershed and of the Tonle Sap river"

DURATION : 8 months

COSTS

(1) Topographic and bathymetric survey

To be executed by an organisation specialized in these fields, on the basis of a tender. Several different technological options are currently available to achieve the objective (airborne laser scanning, airborne micro-waves altimetry, water-borne bathymetry using electronic positioning systems, etc.). In any case, the cost estimate would not be less than US$ 1 000 000.

COST ESTIMATE : US$ 1 000 000

(2) Sedimentological study

Field work :

2 man-months of sedimentologist
field equipment
air ticket, local transport (vehicles and boats),
per diem, allowances for local staff (8 man-months)
shipping of the core samples

Laboratory analysis and data interpretation :

3 man-months of sedimentologist
laboratory analysis (soil physics, mineralogy, isotopic analysis)
reporting costs

COST : US$ 170 000

PRIORITY PROJECT No. 3

HYDROLOGICAL MONITORING OF TONLE SAP BASIN

JUSTIFICATION

The hydrological expertise in this report shows that the quantitative information on water and sediment dynamics of the complex system of the Great Lake watershed, the Tonlé Sap River, and the Mekong were measured once in 1962-63. Since this period no comprehensive assessment has been carried out. However, according to many findings and much advice, the characteristics of the lake have since changed. With the lack of any data collection network in the area, it is quite impossible to find any solid element to support such findings. An hydrological and sedimentological network has to be implemented in the area, as is usually the case in the monitoring of wide water bodies such as the Great Lake.

ACTIVITIES

Within the hydrological section of this report, a list is given with a minimum number of sites to be monitored. This breaks down as follows :

Water level, discharge and sediment flow measurements

- 6 stations on the lake tributaries (see recommendation 1) ;
- 1 station on the Tonlé Sap (Pre Kdam) ;
- 1 station on the Mekong (Phnom Penh), with an upstream station providing back-up, such as Kompong Cham or Kratié.

Water level and discharge measurements

- 1 station for the assessment of the Mekong overflow (at RN6 PK 54)

Water level measurements only

- 2 stations for the recording of the lake level ;
- 1 station on the Tonlé Sap River (rehabilitation of the gauge of Kompong Chhnang) ;
- the gauges of the Tonlé Bassac and the Tonlé Sap in Phnom Penh, already rehabilitated, will be part of this design.

Hydrological activities on this network will be the following :

(1) Field activities :

- rehabilitation or installation of gauges, levelling of the gauges datum, installation of water level recorders ;
- training of observers for gauge reading and maintenance, water level recorder maintenance and operation ;

- gauging measurements with appropriate frequencies ;
- water sampling in the cross-sections for sediment concentration assessment with appropriate frequencies. The analysis of the samples could either be directly carried out by the project, or the samples could be forwarded to the laboratory of the water quality project in Phnom Penh.

(2) Office-based activities :

- determination of the calibrations of the stations ;
- calculation of water and sediment flow ;
- encoding of all data with appropriate software and merging with the existing data base of the Mekong Committee.

(3) Training activities :

- training of the technicians and professionals in field work and desk activities (electronic data processing), study tours in hydrological organisations in the region.

INPUTS

(1) Equipment

- Hydrological measuring equipment such as water level recorders, current meters, sediment samplers, echo-sounder, winches, topographical and optical equipment, etc. ;
- transport facilities (pick-up cars and boat for the measurements) ;
- data processing and encoding equipment (PC computers).

(2) Operating costs

- Fuel, field allowances, car and boat maintenance, spares and expendables for the measuring equipment and data processing equipment.

(3) Training costs

- On-the-job training sessions, local group training, regional and international training for selected technicians and engineers.

(4) Staffing

- As discussed in the report (see part F "Institutional aspects" chapter, "International and Regional organizations" section), a project document for a country-wide programme on operational hydrology was drafted in 1991. (Ref. MKG/R.91038/rev.1, Rehabilitation and Development of the Hydro-Meteorological Network in Cambodia). In the project design and budget, special emphasis was given to the supply of equipment, running costs, and training costs, according to the local conditions. International expert contribution was reduced to 1 man-month per year and the project was under the responsibility of a full-time riparian hydrologist.

Thus, the design of the project led to relatively low costs when compared with the project objectives. For an overall period of 3 years, the provisional budget was US$ 757 000. Being a country-wide project, part of the proposed network extends outside of the current Great-Lake - Tonlé Sap project area. The number of monitoring stations concerning each project breaks up as follows :

	Country-wide project	Tonlé Sap project
Mekong main stream	6	4
Tonlé Sap River	3	3
Others (Great Lake tributaries, others "Prek")	22	12
Total	31	19

DURATION

As for the country project, it is doubtful that all stations may be installed during a single dry season (low water levels are required for the installation). As such, a two-year period would be a realistic schedule for the installation of all equipment. Therefore, to obtain a minimum of two years of data on each site, the project will last for 3 years, with high equipment and installation inputs during the first two years. The budget split would be 50% for year 1, 35% for year 2 and 15% for year 3.

COSTS

Following the same specifications for the Tonlé Sap network as those given for the country-wide project (type of equipment, frequency of flow gauging measurements and sediment sampling, training activities, etc.), an estimation of the cost of a hydrological project limited to the needs of the "*Integrated Development Plan of Great Lake and Tonlé Sap*" would be around US$ 500 000 (according to a 19/31 ratio of the number of stations monitored in each project).

If the country-wide project is not likely to start soon and to give some of the required information within the next two years (i.e. during phase II), a more modest hydrological monitoring programme could be envisaged. Such a programme would concentrate only on the 6 selected stations on the lake tributaries, on 2 stations on the Mekong (Phnom Penh and Kratié as a back-up), and 3 level recording stations on the Great Lake and the Tonlé Sap. The number of stations would therefore be reduced to 11 instead of 19. However the cost will not be reduced in the same proportion, as some of the equipment (pick-up vehicles, boats and heavy measuring equipment for working on the Mekong and Tonlé Sap streams, etc.) will have to be supplied for both situations. The only significant way to scale down the cost would be to concentrate the measurements on the lake tributaries only, and on the recording of the water level of the Great Lake (no action on

Tonlé Sap and Mekong). However, it must be pointed out that to collect hydrological data in the lake area without simultaneously having the corresponding information (i.e. water levels, discharges, and suspended sediment concentration) of the Mekong and Tonlé Sap River would be a waste of effort and means, and such an alternative cannot be recommended. In both cases, the training effort and the allowances for international, regional and national staff will have to be provided. According to a first estimation the cost reduction for the scaled down hydrological project will not be more than 20%, the cost estimate of such project would then be around US$ 400 000 for a 3-year period.

PRIORITY PROJECT No. 4

BIO-ECOLOGICAL BASIS FOR FISH PRODUCTION

OBJECTIVES

The ichtyological production is tightly governed by the functioning process of the system (flooding, inundated forests...) and by the bio-ecological characteristics of species.

The objective of the study is to identify the conditions of exchanges between the Great Lake and Mekong river via the Tonlé Sap as a basis for determining reproduction and growth mechanisms and the role of Tonlé Sap river in these mechanisms.

JUSTIFICATIONS

The available information and knowledge about bio-ecology of fish in the Mekong and Great Lake system is outdated. There is a need for up-dating and further in depth studying of the phenomenon, with special attention to the Chakdomuk area where basic data are believed to be available. Such data as the age at first reproduction for the species of major economic importance are particularly needed.

OUTPUTS AND ACTIVITIES

Investigations to be conducted are the following :

(i) Study of main species found in the catches. Characteristics of migrations and enquiries of fisherman.

(ii) Study of reproduction process, observation on one-year cycle basis.

(iii) Demographic structures : repeated comprehensive measurements throughout a one-year cycle, size and age survey.

The study area should be the Great Lake and Tonlé Sap river. Species to be observed and surveyed should be focused on the current catches. In this connection, there will be a fourfold observation :

- selected *days* in Tonlé Sap river,
- fishing barrier at Snoc Trou (Government lot),
- fishing lot no13 : dams, hoops and nets,
- confluence zone of Chakdomuk : gill nets, cast nets and square nets

TIME FRAME

The study schedule will focus on the fishing period (from October to March). Two months will be required for preliminary preparation (training of local technicians, interviews, selection of samples) the total duration of the study will be 12 months.

INPUTS

The study will require 8 man-months of international experts in addition to 5 man-year of national engineer/technician staff.

COSTS

Estimated cost including international and national staff allowances, transportation costs, field allowances and procurement of equipment is US$ 200 000

PRIORITY PROJECT No. 5

RESPONSE OF FISHERMEN TO ENVIRONMENTAL AND SOCIO-ECONOMIC CHANGES

JUSTIFICATION

Fishery in the studied area is a major activity with important socio-economic and cultural implications. The present exploitation seems to be stable, even though there are some indications of internal modifications in the chain of production and marketing due to changes in the socio-economic context. The fishermen's adaptability study should point out the capabilities and the constraints of the fishermen's societies regarding possible changes in fisheries management.

OBJECTIVES

After the identification of the traditional and institutional regulations, the first objective would be to estimate their effects on the living aquatic resources exploitation. In particular to appraise the influence of this regulation system regarding a sustainable fishery development.

After the description of the recent technological innovations, the second objective might be to point out their consequences on the effort, and catch per effort unit. Particularly to identify the techniques which endanger the resources or the environment (fish catches and fish processing) or the traditional social organization.

After the review of the present fish valorization (processing and marketing) and of its recent evolution, the third objective should be to grasp the consequences on the short and medium term fishery units profitability, in comparison with a sustainable fishing effort.

After having analysed the multi-functionality of the cage culture, the fourth objective will be to estimate the development prospects as an alternative to the fishery effort increase.

OUTPUTS AND ACTIVITIES

After choosing a representative sample of fishery units, this sample would be monitored during a yearly fishery cycle. The inquiry will concern :

- the effort and catch per effort unit of the main fishery techniques (day, gill nets, fishery lots). In particular a typology of gill nets should be developed.
- the various technical process of cage culture including the calculation of the transformation coefficient. The profitability, the conditions of employment, of financing, of revenue distribution of cage culture.

- the profitability, the conditions of employment, of financing, of revenue distribution of the fishery units. The distribution of the production factors and the multi-activity of the fishery units.
- the profitability, the conditions of employment, of financing, of revenue distribution according each fish processing.
- the cost and benefit analysis of the first stage of marketing, the relations between the fishermen and the fish traders.
- the effects on the fishery effort of the traditional and institutional regulations.

These indicators would allow the formulation of a fishery unit typology, and to point out the various strategies regarding the fishermen's adaptability.

TIME FRAME, INPUTS AND COST ESTIMATE

The duration of this Project is one year :

- 10 months for preparing up the methodology, sampling the fishery units, computerizing the results, training of Cambodian counterparts and field inquiries (questionnaires and interviews).
- 2 months for writing the report including recommendations for the following studies with the aim of evolving a sustainable fishery development plan.

The project will need 8 man-months of international experts : 4 man-months of a fishery biologist expert and 4 man-months of a fishery socio-economist expert.

Total cost, including international and national staff salaries and allowances, field expenses (inquirers, transportation), data encoding and processing, miscellaneous is estimated to be US$ 150 000.

PRIORITY PROJECT No. 6

NAVIGATION DEVELOPMENT IN TONLE SAP RIVER, THE GREAT LAKE AND TRIBUTARIES

OBJECTIVES

Waterborne transport is a relatively low-cost, non-pollutant mode of transport. It can contribute efficiently to the reconstruction efforts of the country especially during the period in which damaged road and railways infrastructures are being re-installed. Navigation development in Tonlé Sap system is needed to make optimum use of its naturally favourable natural condition.

JUSTIFICATION

(1) To identify the actual resources of Tonlé Sap system in respect of navigation.

(2) To estimate investment and operating costs of navigation improvement in Tonlé Sap system.

(3) To work out the potential transport demand in terms of passengers and freight and to assess technically and economically the viability of navigation development on Tonlé Sap system.

(4) To evaluate navigation development relating to the development of touristic activities in the area.

(5) To review the dredging needs governed by international navigation in the Chakdomuk area at various time scales and for various options of national port development plans.

OUTPUTS AND ACTIVITIES

(1) Remap by aerial photography the contours of Tonlé Sap river and the Great Lake. Using the new aerial maps, survey hydrographically Tonlé Sap river by cross section soundings every 250 to 500 m to locate the navigable channel, to draw a plan of aids to navigation, to lay down buoys and beacons and to produce navigation charts. Conduct detailed hydrographic survey of the difficult passages (1:25,000) especially at Chakdomuk and Snoc Trou (in conjunction with hydrology-related activities).

(2) Study of dredging and other training works required to open navigation channels in the lake, its tributaries, the shallow passes of Tonlé Sap river (Snoc Trou), in Phnom Penh berthing areas dedicated to inland navigation, at Km 6 berthing facilities, and Chakdomuk area. Estimate capital and maintenance dredging

quantities, dredging methods and costs (in close relation with the main study on sedimentation and fisheries).

(3) Technical-economic assessment of inland navigation including (i) Transport demand forecast in the hinterland of Tonlé Sap system (ii) Identification of navigation routes, distribution of the traffic of goods and passengers (iii) Specifications of rivercraft adapted to navigation condition, commodities and magnitude of cargo volumes to be transported. (iv) Boat construction method, use of local shipbuilding facilities, investment and operation cost estimates. (v) Anticipated transport costs. (vi) Modal split between roads, railways and inland waterways at various time-scales and forecast traffic on the Tonlé Sap waterways (vii) Investment programme, cost-benefit analysis and rate of return.

(4) Tourism development study related to boat cruises on Tonlé Sap river including (i) Survey of existing tourism orientated infrastructure (ii) Marketing study (iii) Investment and operation cost estimates for specific rivercraft (iv) Economic and financial evaluation.

(5) To review alternative plans of port development country-wide, with their respective time scales and compile relevant requirements with regards to navigation, dredging and minimum available depth, across the Chakdomuk area and in the Tonlé Sap river in Phnom Penh. The future role of Phnom Penh port as compared to that of Sihanoukville and its possible relocation on the Chrui Changvar Peninsula should not be part of the study. Such issues are being dealt with under separate studies already initiated by the Mekong Committee.

TIME FRAME, INPUTS AND COST ESTIMATE

The total time-frame for the study is 6 months, not including surveying and mapping works. The study itself will require 6 man-months of international experts (Transport Economist, Navigation Expert, River Engineer, and Tourism Development Specialist) in addition to local input of riparian engineers and specialists to undertake the necessary surveys and data collection. The total cost of this component, not including survey and mapping works would be US$ 135 000.

ANNEX 1

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ANNEXE 2

PROJECT SHEET : MKG/R.92050

DEVELOPMENT PLAN FOR TONLE SAP AND CHAKDOMUK (BASINWIDE) **W.P.code: 3.1.39/93**

MKG/R.92050

Objectives: The ultimate objective is to develop the Tonle Sap's resources in a sustainable and environmentally sound way. The immediate objectives are:

1. To identify and examine the morphology changes, the present use of the natural resources and the development possibilities; and

2. To propose specific actions for preserving the environment and to select priority projects for short and long-term development of the area and to select and implement priority projects.

Justification: The project area covers the Great Lake, its surrounding area, the Tonle Sap river including the confluence with the Mekong at Chakdomuk. The project area has high potential for development, especially fisheries, agriculture and navigation. The system also functions as a natural regulator of Mekong flow which benefits downstream areas.

With the increasing population pressure, enhancement of food production from available land and water resources is becoming an economic and social imperative. The natural functions and productivity of the system will be further endangered if its specific ecology and constraints are not taken into account.

The development of the area has to consider two main issues:

(a) Most of the previous reports indicate that the Great Lake and the Tonle Sap, particularly at Chakdomuk, and the entrance of the Great Lake are exposed to serious siltation. This is partly due to natural phenomena and probably further aggravated by human activities. If no action is taken, the Great Lake would probably be reduced in volume considerably and its bottom shape might be transformed into a number of separate small lakes during the dry season within a few decades.

(b) The socioeconomic conditions which have been prevailing for the last 20 years (low population pressure and limited funding capacity for economic development) are changing rapidly. Natural resources exploitation will occur at a much quicker rate and on a larger scale, and some of the development options may be antagonistic to each other.

There is a need to assess the present trend of the Tonle Sap/Great Lake system in order to prepare appropriate actions for management and development of its resources. The proposed project will gather all elements required for formulating appropriate development actions. It will also draw up an action plan for short and long-term development and management for the GreatLake-Tonle Sap resources as well as a study of selected high priority projects.

Outputs and Activities:

The outputs will be: (1) Phase I: a report assessing the natural conditions and recommending priority alternatives in various sectors including a programme of investigations/studies; and (ii) Phase II: a report showing priority projects and an action plan for the ecologically-sound management and development of the Tonle Sap/Great Lake resources. Another output is two trained riparian engineers in water resources planning.

The main activities for Phase I will include: (i) collection and analysis of all available study reports, data and information; (ii) carrying out a field reconnaissance mission including a preliminary survey to collect relevant data and information, and to observe natural phenomena/conditions; (iii) preparation of an assessment report; and (iv) recommendations on priority projects to be studied further, including a programme of data collection and investigations.

Activities for Phase II will be dependent on the findings of Phase I and include the following: (i) collection of additional data, preparation of topographic maps from available aerial photographs and surveys of the areas of first priority; (ii) prefeasibility study on the priority projects; (iii) preparation of an action plan for development and management of the Tonle Sap/Great Lake resources; and (iv) two workshops for discussion of the study's findings and the draft final reports of Phase I and Phase II.

Time frame: Phase I: 7 months; Phase II: 13 months.

Inputs: Phase I: 5 man-months of international and 3 man-months of national/regional experts, together with the Mekong Secretariat staff will be required. Contribution (in-kind) by the Government of Cambodia is estimated at US$10,000; Phase II: The actual cost of Phase II will be finalized after the completion of the first phase. Tentatively estimated at 12 man-months of international and 30 man-months of regional experts. Contribution (in-kind) by the Government of Cambodia is estimated at US$ 40,000.

Costs: US$

		Phase I US$	Phase II US$	Total US$
Total cost:		**176,000**	**645,000**	**821,000**
National input (in-kind):		10,000	40,000	50,000
External funds required:		166,000	605,000	771,000
Funds being secured from:	France	**166,000**	-	-
Funds being sought:		-	**605,000**	**605,000**

ANNEX III

HYDROLOGICAL DATA AND INFORMATION

1 AVAILABLE HYDROLOGICAL DATA

1.1 Discharges

1.1.1 Electronic data base of the Mekong Secretariat in Bangkok (see Table 1)

Mekong (upstream of the confluence with the Tonlé Sap)

The upstream station having the longest period of observation is Vientiane (77 years of continuous observations from 1913 to 1989). This allows for a trend analysis of the hydrological regime, but the drainage area in Vientiane is only 299 000 km² compared with 663 000 km² in Phnom Penh. The station of Paksé can be used as well for such purpose (65 complete years of data from 1925 to 1989). The watershed area in Paksé is 545 000 km²

Tonlé Sap - Great Lake

On the watershed area of the Great Lake, three stations with short observation periods were operated between 1961 and 1973, namely : Stung Sen (7 years), Stung Pursat (4 years), and Stung Sangker (8 years).

The discharges of the Tonlé Sap have been measured in à Prek Dam. The data base includes 11 years, from 1960 to 1973

Mekong (downstream of the confluence with the Tonlé Sap)

No discharges are available for the Mekong main stream. For the Bassac River, the data base includes 11 years with many gaps in Phnom Penh (from 1964 to 1974), and 2 years with complete data among 6 observed at Chau Doc (1960-65).

1.1.2 Published documents

Tonlé Sap - Great Lake

The study carried out by Carbonnel and Guiscafré (1965) includes an hydrological and sedimentological monitoring of 17 tributaries of the Great Lake (see annex H2). The total drainage area of these tributaries is 58 000 km² compared to the 67 600 km² of the overall watershed area (77%). A major part of the flow and of the sediment discharges was measured during a single hydrological cycle (from April 1962 to March 1963). Liquid and solid discharges of the Tonlé Sap in Prek Dam were monitored on this occasion as well as the part of Mekong overflow channelled by Prek Spean Tras. This hydrological year (1962-63) is the only one available with a coherent and comprehensive data set for the Mekong, Tonlé Sap and Great Lake system.

1.2 Water levels

Here we considered only those water levels which have not been converted into discharges (these have already been cited in section 1.1

1.2.1 Electronic data base of the Mekong Secretariat in Bangkok (see annex H3)

Mekong (upstream of the confluence with the Tonlé Sap)

Mekong in Phnom Penh : 5 complete years from 1983 to 1988

Tonlé Sap - Great Lake

Tonlé Sap in Kompong Chhnang. This station is located on the Tonlé Sap 40 Km before the inlet (Snoc Trou). As there are no historical records of the lake level, the data of Kompong Chhnang is the best (and the only one) available approximation of the lake level. This approximation will overestimate the water level of the lake during the Mekong filling phase and underestimate it during the draining situation. The approximation should around or less than 20 cm for each situation. The data applies to the period a 1924-1971 period (i.e. 48 years, but only 33 are complete) and to the period from 1981 to 1988 (all years having substantial gaps and 1987 is missing).

Tonlé Sap in Prek Dam : data with gaps in 1987-88, data complete in 1989.

Mékong (downstream of the confluence with the Tonlé Sap)

Bassac in Phnom Penh : 9 complete years over 10, from 1980 to 1989

Bassac in Chau Doc : 8 complete years over 11, from 1979 to 1989

The field hydrologists who are aware of the local conditions of the data collection in the area have advised using extreme care and suspicion in the analysis of the water levels of the last decade, as the readings were restarted on gauges which have not been operated since the mid 70's and the appropriate topographical verification of the gauge levels with the datum has not necessarily been carried out.

1.2.2 Non-edited documents

Such documents have been collected in Phnom Penh during the inception visit of the expert.

Mekong.

Stung Treng (1991, 1992)

Kratié (1991 and 1992 up to September, 18)

Kompong Cham (1992)

Chrui Changvar (1992, since May). New gauge installed at the pumping station site).

Stung Sen at Kompong Thom (1981-92)

Tonlé Sap - Great Lake

Tonlé Sap in Prek Dam (1992)

Phnom Penh Port (1992, starting July)

Bassac
Chakdomuk (1992)

This gives evidence of a modest restart of the hydrological activities during the two past years. However, the information is still incomplete (i.e. no discharges are available).

1.3 Hydrological stations used for the calculation of the inflow to the Great Lake during year 1962-63 (Carbonnel and Guiscafré's study)

River	Station	Watershed area (km²)
Stung Babaur	Babaur RN5	869
Stung Krakor	Krakor RN5	138
Stung Kompong Lar	Thuot-Chum RN5	420
Stung Pursat	Pursat RN5	4 480
Stung Dauntry	Maung RN5	835
Stung Sangker	Battambang	3 220
O-Nhor	O-Nhor RN5	51
Stung Mongkol Borey	Mongkol Borey RN5	4 170
Stung Sisophon	Sisophon RN6	4 310
O-Phranet Preah	Beng Chhouk RN6	1 670
Stung Sreng	Kralanh RN6	8 175
Stung Phleang	Phleang RN6	96
Stung Roluos	Kompong Thkau RN6	281
Stung Chikreng	Kompong Kdey RN6	1 920
Stung Staung	Kompong Chen RN6	1 895
Stung Sen	Kompong Thom RN6	13 670
Stung Chinit	Kompong Thmar RN6	4 130
Tonlé Sap	Prek Dam	85 000
Spean Tras	PK54 RN6	n.s.

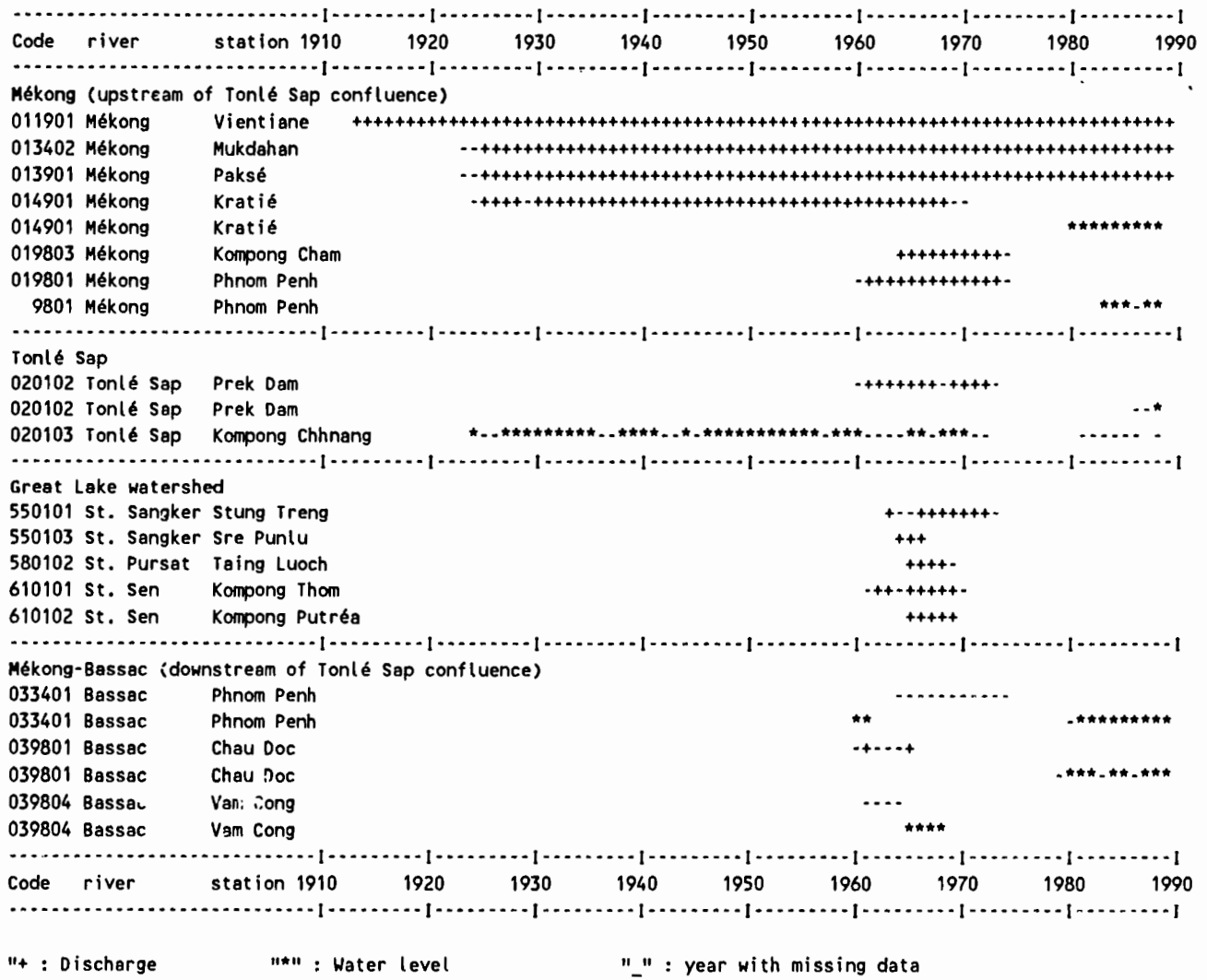
1.4 Rainfall

At this stage of the study, the rainfall information can be used to verify changes or trends in the climate. The electronic data base of the Mekong Secretariat includes rainfall data. Unfortunately the data for Cambodia refers only to the 1960-74 period. There is also a paper file with data collected before 1965. The oldest rainfall station is Pochentong airport, which has been operational since 1911. 48 years of data are available between 1911 and 1964 while 8 years are missing.

The monthly rainfall of Potchentong has been re-published by IRRI for the last years (1989-91) and collected during the inception mission in Phnom Penh.

Table I : Daily discharges and water levels in the Mékong Committee data base

Selected stations for the Tonlé Sap / Great Lake study



"+ : Discharge "*" : Water level "_" : year with missing data

2. CORRELATION OF THE MEKONG DISCHARGES IN PHNOM PENH AND PAKSE

Correlation between mean annuals discharges in Phnom Penh and Paksé

YEAR	PHNOM PENH $m^3.s^{-1}$	PAKSE $m^3.s^{-1}$
1960	11804	9358
1961	15988	12123
1962	13766	10009
1963	12928	10272
1964	12897	10412
1965	12606	9642
1966	13816	11938
1967	11438	8269
1968	10302	8148
1969	12853	9029
1970	13749	11077
1971	13864	10888
1972	13478	9673
1973.	13293	9807
Average	13056	10007

Correlation : Q(P. Penh) = Q(Paksé)*0.971517 + 3296 n=14 Df=12 r=0.87
Recalculation of discharges in P. Penh : accuray better than 6% 12 over 14
better than 8% 14 over 14

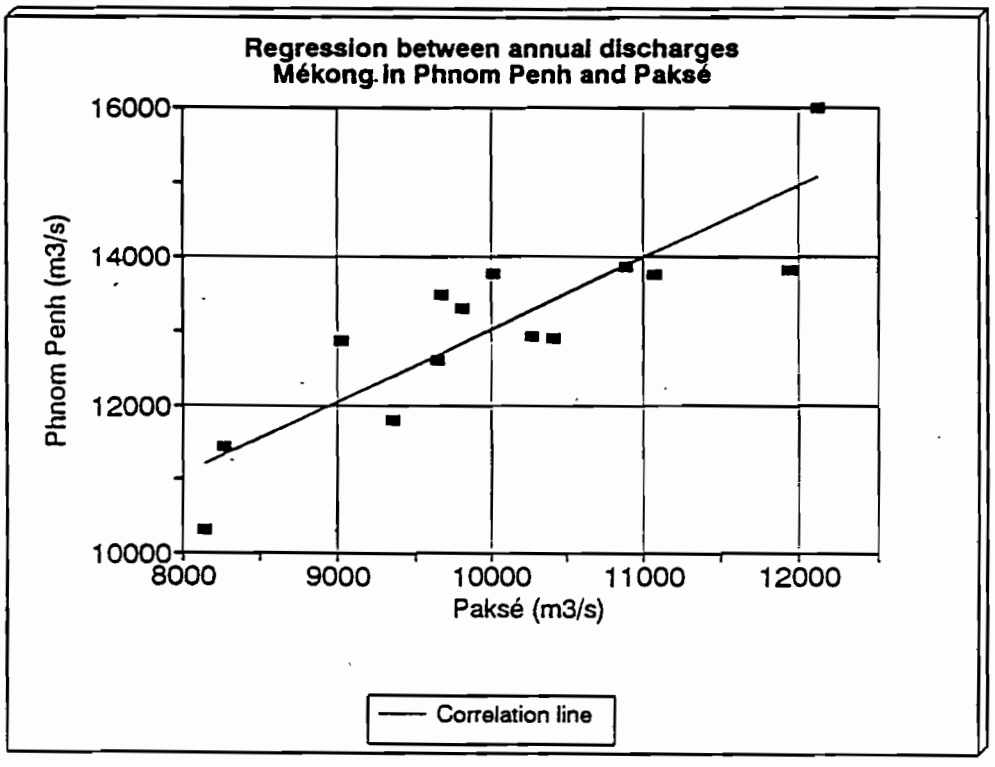


Figure 2.1

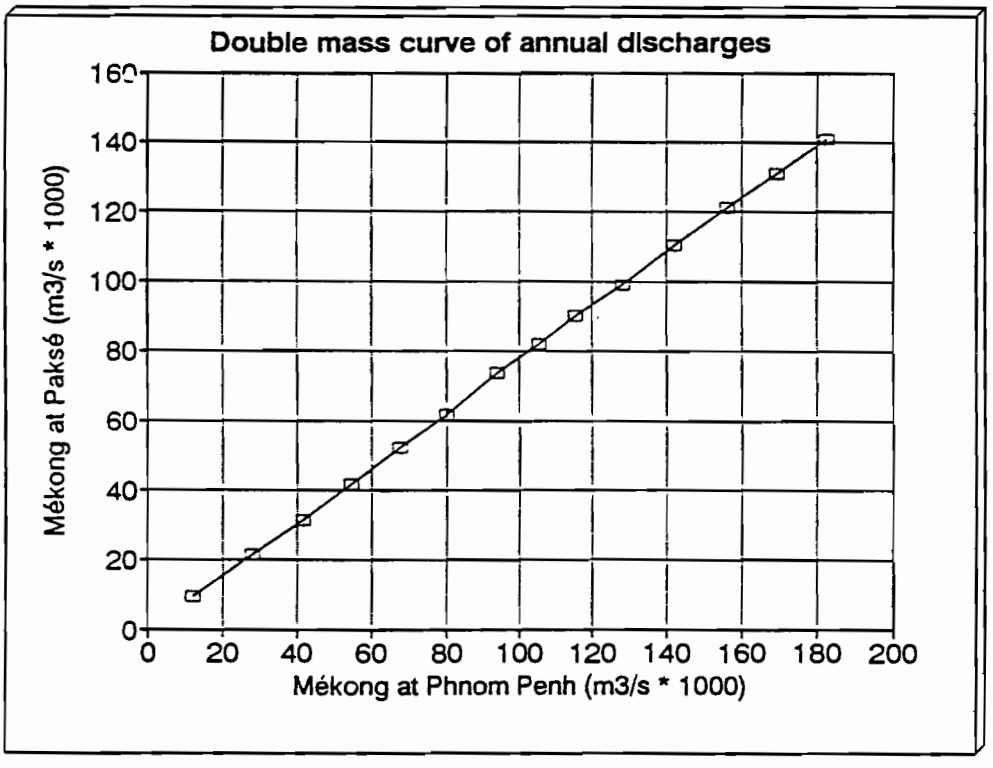
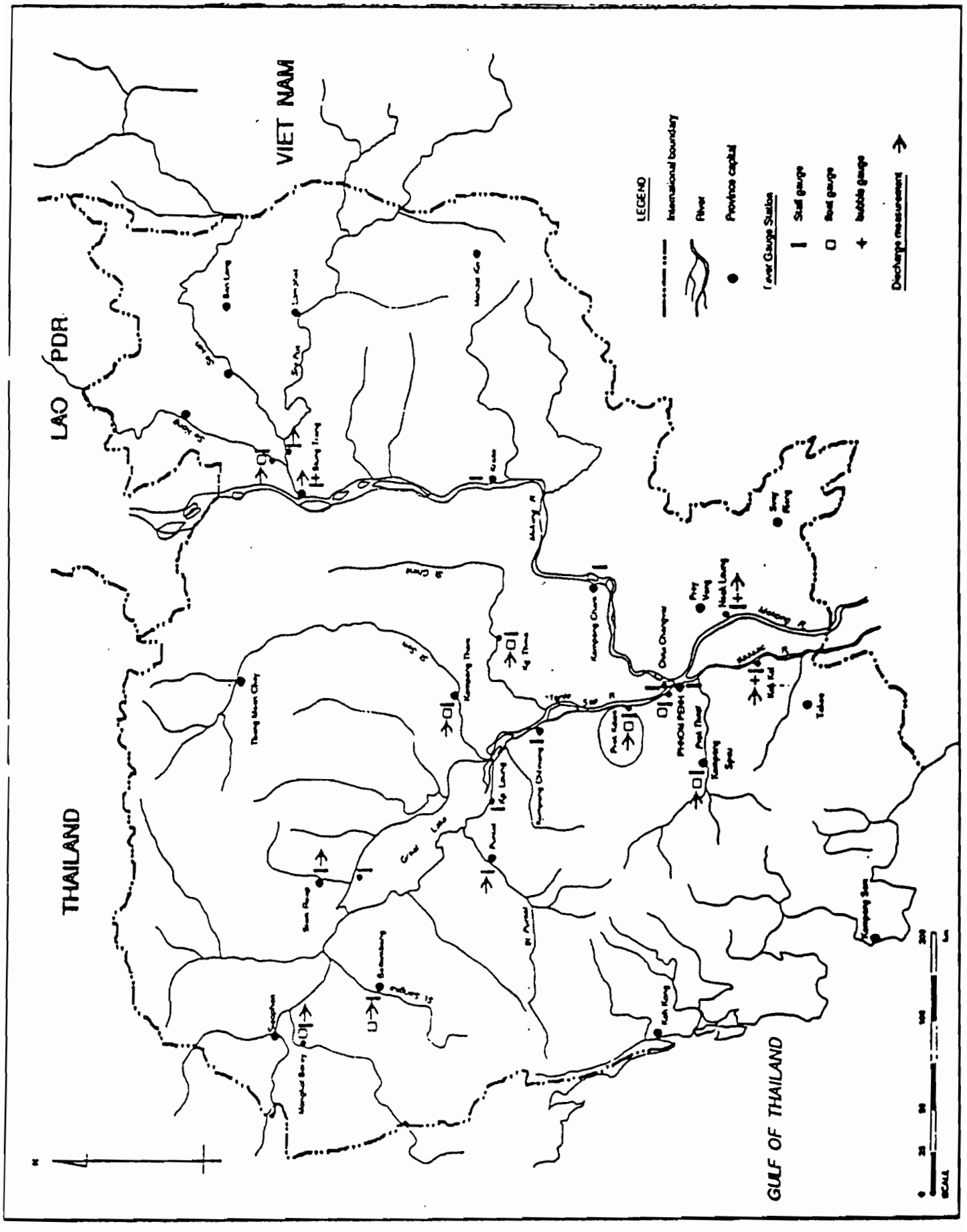


Figure 2.2

3. MAJOR DEVELOPMENT SCHEMES IN OPERATION ON THE LOWER MEKONG BASIN

Country	Project Name	Year of Completion	Installed Capacity KW	Irrigation ha	Active Storage 10^6 m^3
Lao PDR	Lower Se Done	1970	2 500	-	run-off
Lao PDR	Nam Dong	1971	1 250	-	negligible
Lao PDR	Nam Ngum I	1971	30 000	-	
Lao PDR	Nam Ngum II & III	1978 & 1987	120 000	-	run-off
Thailand	Nam Pung	1967	6 300	-	1.55
Thailand	Nam Pong	1966	25 000	53 000	1 695
Thailand	Lam Phra Plerng	1967	-	10 500	145
Thailand	Lam Pao	1968	-	54 000	1 260
Thailand	Lam Takong	1970	-	38 000	290
Thailand	Lam Dom Noi	1971	24 000	24 000	1 135
Thailand	Nam Phrom	1972	40 000	-	
Thailand	Nam Oon	1973	-	32 500	145
Thailand	Huai Luang	1979	-	12 800	113
Thailand	Huai Mong	1986	-	8 700	26
Thailand	Huai Pa Thao	1992	4 800	2 400	
Vietnam	Huong My	1987	-	3 800	pumping
Vietnam	Drayling	1987 & 1993	12 000	-	run-off
Vietnam	Tam Phuong	1989	-	5 900	pumping

4. LOCATION OF HYDROLOGICAL STATIONS TO BE OPERATIONAL AFTER ACHIEVEMENT OF MKG/R. 91038 PROJECT (1997)



5. THE FULLY REHABILITATED' AND EXPANDED HYDROLOGICAL NETWORK IN CAMBODIA. SITUATION AFTER ACHIEVEMENT OF MKG/R. 91038 PROJECT (1997)

Expected to be completed/operational by 1997

(Stations to be rehabilitated)	Water Level	Discharge measuring	Sediment sampling	Water quality
Mainstream	Station	Station	Station	Station
Mekong at Stung Treng	*	*	*	*
Mekong at Kratie	*	*		
Mekong at Kampong Cham	*		*	
Mekong at Phnom Penh (Chrui Changvar)	*	*	*	*
Mekong at Neak Leung	*	*	*	*
Chatamouk at Phnom Penh (formerly 'Bassac')	*			
Tonle Sap at Phnom Penh Port	*	*		*
Tonle Sap at Prek Kdam	*	*	*	*
Tonle Sap at Kampong Chnnang	*		*	*
Tributaries				
Stung Sangke at Battambang	*	*	*	*
Stung Sangke at Treng	*	*	*	*
Stung Sen at Putrea	*	*	*	
Stung Sen at Kampong Thom	*	*	*	*
Stung Pursat at Pursat	*	*	*	*
St. Pursat, Taing Luoch	*	*	*	
Stung Mongkol Borey at Mongkol Borey	*	*	*	*
Prek Thnot at Kompong Speu	*	*	*	*
Stung Siemreap at Siemreap	*	*	*	
Se Kong at Ban Khmuon	*	*	*	*
Se San at Ban Komphun	*	*	*	*
(New Stations)				
Mainstream				
Bassac at Kok Khel	*	*	*	*
Great Lake at Kompong Luong	*		*	
Great Lake at Siem Reap	*		*	
Tributaries				
Stung Chinit, Kompong Thma	*	*	*	*
Stung Chickreng at Kampong Kdey	*	*	*	*
Stung Staung at Kompong Chen	*	*	*	*
Stung Sreng at Kraulauh	*	*	*	*
Prek Te at Anlung Kha	*	*	*	*
Prek Chhong at Samrong	*	*	*	*
Prek Krieng at Prek Krieng	*	*	*	*
Se Pok at Lomphat	*	*	*	

ANNEX 4 :

ON GOING AND PROPOSED PROJECTS OF THE MEKONG COMMITTEE RELATED WITH THE DEVELOPMENT OF TONLE-SAP - CHAKDOMUK AREA

A FUNDED

A.1 Having significant part of the activities to be carried out on the Tonlé Sap Project area

MKG/R.91040	Aerial Photography for Resource Mapping (Cambodia)
MKG/R.91057/Rev.1	Review and Assessment of Water Resources for Hydropower and Identification of Priority Projects (Cambodia)
MKG/R.91072/Rev.2	Irrigation Rehabilitation Study in Cambodia
MKG/R.91050	Assessment and Management of the Freshwater Capture Fisheries of Cambodia (phase I)
MKG/R.90016/Rev.2	Water Resources Training Programme :Cambodian Component. (partly funded)

A.2 Projects with strong links with the Tonlé Sap Project, but major part of the activities and results outside the project area. Nevertheless shall take into account the Tonlé Sap Project findings and constraints

MKG/R.90042	Salinity Forecasting in the Mekong Delta
MKG/R.88011	Water Quality Monitoring Network In the Lower Mekong Basin, Phase II (Basinwide).
MKG/R.86045/Rev.1	Control of Soil Erosion, Sedimentation, and Flash Flood Hazards (Basinwide)
MKG/R.90011	Integration of Environmental Components in Projects (Basinwide)
MKG/R.87053/Rev.2	Master Plan for the Integrated Development of the Mekong Delta (Viet Nam)
MKG/R.89056	Integrated Development of the Lower Mekong Basin (Basinwide)
MKG/R.89017 MKG/R.91048 MKG/R.91066	Low Pa Mong Multipurpose Project (Basinwide)
MKG/R.89019	Assessment and Monitoring of the Mekong Basin Forest Cover (Basinwide)
MKG/R.88009	Mekong Watershed Assessment and Management (Basinwide)
MKG/R.89021	Environmental Training Fund (Basinwide)

ANNEX 4 (continued) :

ON GOING AND PROPOSED PROJECTS OF THE MEKONG COMMITTEE RELATED WITH THE DEVELOPMENT OF TONLE-SAP - CHAKDOMUK AREA

B SEEKING FUNDS

B.1 Having significant part of the activities to be carried out on the Tonlé Sap Project area

MKG/R.91038/Rev.1	Rehabilitation and Development of the Hydro-Meteorological Network in Cambodia
MKG/R.91039/Rev.2	Mekong Geographic Information System. Cambodian Component
MKG/R.91068	Inventory and Management of the Cambodian Wetlands
MKG/R.91074	Feasibility Study to update the Stung Mongkol Borey Irrigation Scheme, Phase 1 (Cambodia)
MKG/R.92072	Protection Works to the Monivong Bridge (Cambodia)

B.2 Projects with strong links with the Tonlé Sap Project, but major part of the activities and results outside the project area. Nevertheless shall take into account the Tonlé Sap Project findings and constraints

MKG/R.90029/Rev.1	Water Balance of the Lower Mekong Basin
MKG/R.91037	Improvement of the Hydro-meteorological Network (Basinwide)
MKG/R.92044	Assessment of the Impact of Deforestation on Runoff (Basinwide)
MKG/R.92063	Management of Regional Fisheries Resources (Basinwide)
MKG/R.88001	Assessment of Impacts of Water Management on Fishery Resources.