[illegible] (JICA)
[illegible]
[illegible]

THE STUDY
FOR
[illegible]
IN
[illegible]

[illegible]

[illegible]

AUGUST 1989

[illegible]
[illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF AGRICULTURE AND ANIMAL RESOURCES
GOVERNMENT OF THE REPUBLIC OF CÔTE D'IVOIRE

THE STUDY
FOR
THE INTEGRATED RURAL DEVELOPMENT PROJECT
IN
THE SAN-PÉDRO PLAIN

FINAL REPORT
SUPPORTING REPORT

AUGUST 1999

PACIFIC CONSULTANTS INTERNATIONAL
PASCO INTERNATIONAL INC.

THE STUDY ON THE INTEGRATED RURAL DEVELOPMENT IN THE SAN-PÉDRO PLAIN

FINAL REPORT

SUPPORTING REPORT

TABLE OF CONTENTS

ABBREVIATIONS

ANADER	Agence Nationale d'Appui au Développement Rural *Supporting National Agency for Rural Development*
ADRAO (WARDA)	Association pour le Développement de la Riziculture en Afrique de l'Ouest *West Africa Rice Development Association (WARDA)*
AGRIVOIR	*Ivoirean Agriculture (Rice milling Company)*
AISA	Association Ivoireenne des Sciencces Agronomiques *Association Ivorian for Agronomy Science*
ANAM	Agence Nationale des Aérodromes et de la Météorologie (- 1997) *National Meteorology Agency(-1997, presently SODEXAM)*
ANDE	Agence National de l'Environnement National Agency of Environment
ARSO	Autorité pour l'Aménagement de la Région du Sud-Ouest (1968-1980) *Southwestern Region Development Authority(1968-1980)*
BAD (AfDB)	Banque Africaine de Développement *African Development Bank*
B/C	Rapport de Bénéfice par Coût Benefit-Cost Ratio
BEIE	Bureau d'Etude d'Impact sur l'Environnement Beureau of Environmental Impact Assessment of ANDE
BIRD (IBRD)	Banque Internationale pour la Reconstruction et le Développement *International Bank for Reconstruction and Development -- World Bank*
BNDA	Banque Nationale pour le Développement Agricole *National Bank for Agricultural Development*
BNETD	Bureau National d'Etude Technique et de Développement National Office for Technique and Development Studies
BOAD	Banque Ouest Africaine de Développement *West African Development Bank*
CA	Conseiller Agricole Extension Worker
CAISTAB Or CSSPPA	Caisse de Stabilisation et de Soutien des Prix des Productions Agricoles (1955-1992-) *House for Stabilization and Support of Agricultural Products Prices*
CFA	Communauté Financière Africaine *African Financial Community*
CFMAG	Centre de Formation à la Méchanisation Agricole *Mechanized Agriculture training Center, Grand Lhou*
CIAPOL	Centre Ivoirien d'Anti-Pollution *Anti-Pollution Center of Côte d'Ivoire*
CIDA	*Canadian International Development Agency*
CIDT	Compagnie Ivoirenne pour le Développement des Textiles *Ivorian Company for Textile Development*
CIDV	Compagnie Ivoirienne pour le Développement du Vivrières *Ivorian Company for Food Crop Development*

CIE	Compagnie Ivoirienne d'Electricité *Ivorian Electric Company*
CIRES	Centre Ivoirien de Recherches Economiques et Sociales *Ivorian Social and Economic Researches Center*
CIRT	Centre Ivoirienne Recherches et Technologique *Ivorian Center for Technological Resarch*
CITES	*Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973)*
CNRA	Centre National de Recherche Agricole *National Center for Agricultural Research*
COOP	Coopérative *Cooperative*
COOPEC	Coopérative d'Epargne et de Crédit *Saving and Credit Cooperatives*
CREP	Caisse Rurale d'Epargne et de Prêts *Rural Saving and Loan Office*
CTFT	Centre Technique Forestier Tropical *Tropical Forest Technical Center*
DCGTx (BNETD)	Direction et Contrôle des Grands Travaux (BNETD) *Office for Management and Control of Detailed Design and Works (presently BNETD)*
DD	Direction Départmentale, MINAGRA *Department Directory, MINAGRA*
DE	Direction de l'Environnement Direction of Environment
DGA	Direction Générale de l'Agriculture, MINAGRA *Direction General of Agriculture, MINAGRA*
DMC	Direction de la Mutualité et de la Coopération, MINAGRA *Direction of Mutual Aid and Cooperation, MINAGRA*
DP	Direction de la Programmation, MINAGRA *Direction of Planning, MINAGRA*
DPN	Direction de la Protection de la Nature *Direction of Natural Protection*
DR	Direction Régionale, MINAGRA *Regional Directory, MINAGRA*
EECI	Energie Electrique de Côte d'Ivoire *Electrical Energy of Côte d'Ivoire*
EIA	Evaluation de l'Impact sur l'Environnement *Environmental Impact Assessment*
El.	Elevation *Elévation*
ENSEA	Ecole Nationale de Statistique et d'Economie Appliquée *National School for Statistic and Applied Economy*
EU	Union Européenne *Europian Union*

FAC	Fonds d'Aide à la Coopération *Aid Funds for Cooperation*
FAO	Fonds des Nations Unies pour l'agriculture et l'alimentation *Food and Agriculture Organization, United Nation*
FAD	Fonds Africaine de Développement *African Development Fund*
F CFA	Franc CFA *CFA Franc (FCFA 1.0 = FF 0.01)*
FF	Franc Français *French Franc*
FMI (IMF)	Fonds Monétaire International *International Monetary Funds*
FOB	Freight on Board *(Prix à Bord)*
FRAR	Fonds Régionaux d'Aménagement Rural *Regional Fund for Rural Développement*
FRAU	Fonds Régionaux d'Aménagement Urban *Regional Fund for Urban Développement*
GI	Groupement Informel *Informal Group*
GOCI	Gouvermente de la République de Côte d'Ivoire *Government of the Republic of Côte d'Ivoire*
GOJ	Gouvermente du Japon *Government of Japan*
GVC	Groupement á Vocation Coopérative *Cooperative Group*
HCH	Haut Commissaire à l'Hydraulique *High Commissioner of Hydraulic*
I2T	Institut de Technologie Tropicale *Institute for Toropical Technology*
IDESSA	Institut des Savanes *Savanna Institute*
IDEFOR	Institut des Forêts *Institute for Forest*
IEE (EIE)	Examen Initial de l'Environnement *Initial Environmental Examination*
INS	Institut National des Statistiques *National Institute of Statistics*
IRAT	Institut de Recherche en Agronomie Tropicale *Tropical Agriculture Research Institute*
JICA	Agence Japonaise de Coopération Internationale *Japan International Cooperation Agency*
KR-II	Kennedy Round n° II *The Second Kennedy Round (Increased Food Production Aid)*

LANADA	Laboratoire National d'Appui au Developpement Agricole *National Laboratory for Agricultural Development Support*
LANEMA	Laboratoire National d'Essais de Qualité, de Métrologie et d'Analyses *National laboratory of Quality Tests, Metrology and Analyses*
METT	Ministère de lEquipement des Transports et des Télecommunications *Ministry of Telecommunication, Transportation and Equipment*
MFPF	Ministère de la Famille et de la Promotion de la Femme *Ministry of Women Promotion and Family*
MLCVE	Ministère du Logement, du Cadre de Vie et de l'Environnement (-1998) Ministry of Habitation, Life Quality and Environment (-1998)
MINAGRA	Ministère de l'Agriculture et des Ressources Animales *Ministry of Agriculture and Animal Resources*
OCPV	Office d'Aide à la Commercialisation des Produits Vivriers *Office for Support to Commercialization of Food Crops*
O.M. (O&M)	Opération et Maintenance *Operation and Maintenance*
OMS (WHO)	Organisation Mondiale de la Santé *World Health Organization*
ONG (NGO)	Organisation Non-Gouvernementale *Non-Government Organization*
OPA	Organisation Professionelle Agricole *Agricultural Professional Organization*
ORSTOM	Office de la Recherche Scientifique et Technique d'Outer-Mer *Office for Overseas Technical and Scientific Research*
PASA	Programme d'Adjustement Structurel Agricole *Structural Adjustment Programme in Agriculture*
PNAE	Plan d'Action National de l'Environnement *National Action Plan for Environment*
PNASA	Programme National d'Appui au Service Agricole *National Program for Agricultural Supporting Services*
PNB (GNP)	Produit National Brut *Gross National Product*
PNGERNAT	Projet National de la Gestion des Ressources Naturelles et de l'Environnement *National Project for Management of Natiral Resources and Environment*
PRB (GRP)	Produit Régional Brut *Gross Regional Product*
PNR	Projet Nationale Riz, MINAGRA *Rice National Project, MINAGRA*
RYMV	Rice Yellow Mottle Virus *Virus Causant de Taches Jaunes sur Paddy*
SAPH	Société Africaine de Plantation d'Hévéa *African Rubber Plantation Company*
SATMACI	Société d'Assistance Technique pour la Modernisation de l'Agriculture en Côte d'Ivoire (1958-1994) *Public Corporation of Technical Assistance for Agriculture Modernization in Côte d'Ivoire (especially Coffee and Cacao) (1958-1994)*

SODECI	Société de Distribution d'Eau en Côte d'Ivoire, *Water Distribution Public Corporation*
SODEFOR	Société de Développement des Forêts, MINAGRA *Forese Developmet Public Corporation, MINAGRA*
SODEPALM	Société pour la Développement des Palmerais *Palm Tree Farming Development Public Corporation*
SODEPRA	Société de Développement de la Production Animale *Animal Production Development Public Corporation*
SODERIZ	Société pour le Développement de la Rizculture, MINAGRA (1977-1984) *Rice Farming Development Public Corporation, MINAGRA(1977-1984)*
SODEXAM	Société de Développement d'Exploitation Aéroportuaire, Aéronautique et Météorologigue *Development of Airport, Aeronautic and Meteorology Public Coperation*
SOGB	Société des Caoutchoucs de Grand Béréby *Grand Béréby Natural Rubber Public Corporation*
SOPRORIZ	Structure d'Organisation et de Promotion de la Riziculture (Projet National Riz), MINAGRA *Public Corporation for Promotion of Rice Farming (PNR), MINAGRA*
SORIZCI	Société des Rizeries de Côte d'Ivoire *Rice Mills Public Corporation*
TIR(E) *EIRR*	Taux Interne de Rendabilité Economique *Economic Internal Rate of Return*
TIR(F) FIRR	Taux Interne de Rendabilité Financière *Financial Internal Rate of Return*
TS	Technicien Spécialisé *Technician on Speciality*
UNEP (PNUE)	Programme des Nations Unies pour l'Environnement *United Nations Enviornmental Program*
UNESCO	Organisation d'Education, de Science et de Culture *United Nations Educational Scientific and Cultural Organization*
UNFPA (FNAP)	Fonds des Nations Unies pour la population *United Nations Population Fund*
USA	Etats Unis d'Amérique *United States of America*
VAN (NPV)	Valeur Actualisée Nette Net Present Value
WFP (PAM)	Programme Alimentaire Mondial *World Food Program*
WHO (OMS)	*Organisation Mondiale de la Santé* *World Health Organization*
MCM	*Million de mètres cubes* *Million Cubic Meters (X 1,000,000 m^3)*

A : METEOROLOGY AND HYDROLOGY

Table of Contents

LIST OF FIGURES

LIST OF TABLES

A.1 General

The objectives of the meteorological and hydrological study are to clarify the meteorological and hydrological conditions in the Study Area, and to provide various values and parameters necessary for the Study.

During the field survey, the available data and information on the meteorology and hydrology in the Study Area as well as the San-Pédro river basin were collected, and field reconnaissance surveys were also carried out to grasp the actual situation of the river basin. This study includes:

- the analyses of basic meteorological parameters such as rainfall and temperature;
- the flood and drought flow analyses of the rivers in the Study Area as well as the San-Pédro river;
- the water balance study to confirm the proper water allocation among the water users including the estimates of future water demands;
- the preliminary study on the hydrogeological aspect including groundwater availability; and
- the assistance in holding the meetings of the Technical consulting Committee on Water Use of San-Pédro Dam.

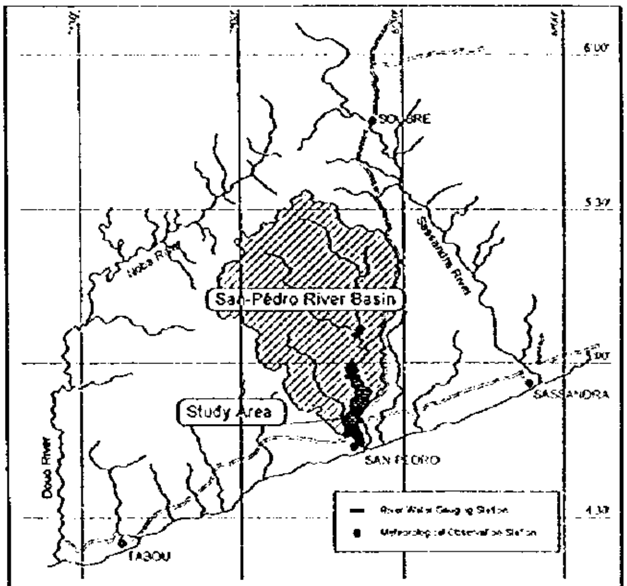
The details of these studies and analyses are presented below.

A.2 Collection of Available Data

A.2.1 Meteorological Data

(1) Meteorological Stations
Generally the meteorological observation had been carried out by the ORSTOM including processing and compilation of the observed records, and recently these services were handed over to the SODEXAM.

There are following six (6) meteorological stations in and around the San-Pédro river basin.



AVAILABLE METEOROLOGICAL AND HYDROLOGICAL STATIONS

Available Meteorological Stations in and around the San-Pédro River Basin

Name	Latitude	Longitude	Altitude	Establishment
1. San-Pédro	N4°45'00"	W6°39'00"	31 m	1976
2. Soubre	N5°47'00"	W6°36'00"	134 m	1940
3. Sassandra	N4°57'00"	W6°05'00"	62 m	1922
4. Tabou	N4°25'00"	W7°22'00"	20 m	1919
5. IDEFOR (San-Pédro)	-	-	-	1972
6. San-Pédro Dam	-	-	-	1983

The locations of these stations are indicated in the figure. The San-Pédro, the Soubre, the Sassandra and the Tabou stations are located at the airport of the respective cities, and the recorded data are processed and compiled by the SODEXAM. The Soubre, the Sassandra and the Tabou stations were established in the beginning or the middle of 1900s and various long-term meteorological data are available. The IDEFOR (San-Pédro) station is located just in the Study Area, and is considered suitable for representing the meteorology of the whole Study Area. At the San-Pédro dam site, a rainfall gauging station is installed by the CIE.


METEOROLOGICAL STATION IN SAN-PÉDRO AIRPORT

(2) Collected Data
The daily rainfall records are collected over 60 years mainly in the stations of the SODEXAM. The other parameter such as temperature, relativve humidity, sunshine hours, evaporation and wind are also collected on monthly or 10-day basis. The periods and stations of the collected meteorological data are illustrated in Fig. A.2.1.

A.2.2 Hydrological Data

(1) Hydrological Stations
There are following three (3) hydrological stations in the San-Pédro river basin as shown in the figure in the previous page.

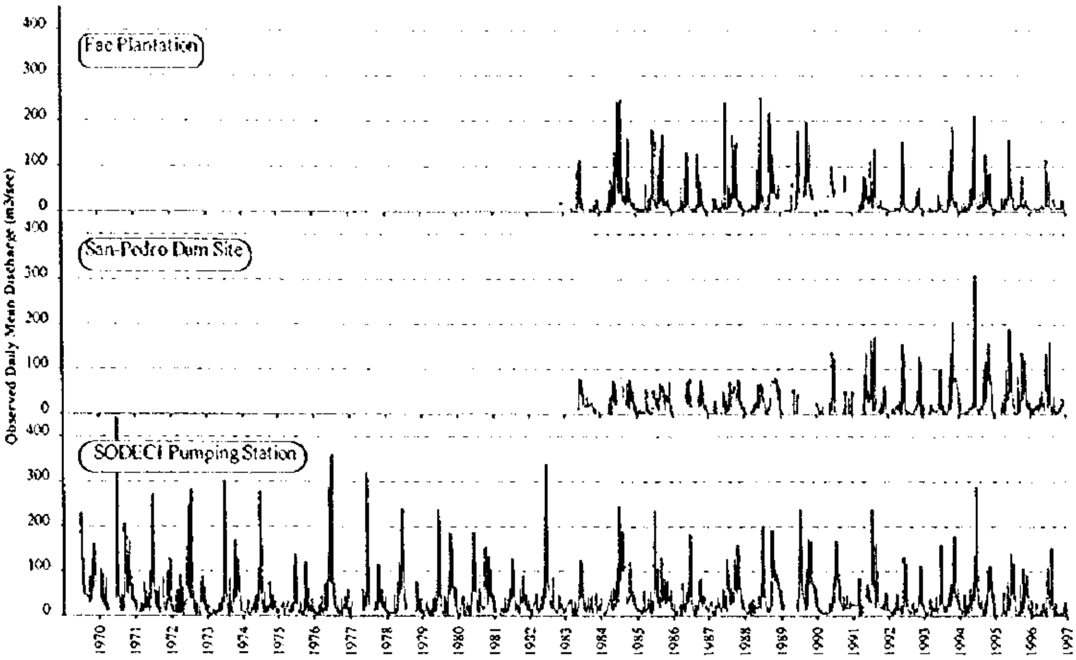
Available Hydrological Stations in the San-Pédro River Basin

	Catchment Area	Establishment
1. Fahé Plantation (downstream of the conjunction)	2,127 km^2	1983
2. San-Pédro Dam (downstream of spillway)	2,427 km^2	1981
3. SODECI Pumping Station	3,300 km^2	1969

The observed data are processed and compiled by the Hydrological Direction of the Ministry of Economic Infrastructure.

(2) Collected Data
The daily mean discharge of the above stations are collected for the period from their establishment. As seen in the figure, many lacking of data are found especially in the data of the San-Pédro dam, while those of the SODECI Pumping Station well continues.


HYDROLOGICAL STATION IN FAHÉ PLANTATION



VARIATION OF DAILY MEAN DISCHARGE OF SAN-PEDRO RIVER

A.2.3 Other Data

(1) Dam Operation Records
In order to grasp the actual situation of the reservoir and hydropower generation in the San-Pédro dam, the following records are collected on daily basis as illustrated in Fig. A.2.1.

- Reservoir water level of the San-Pédro dam reservoir from 1983 to 1998
- Operation hours of Hydropower generators from 1983 to 1998

(2) Tide Records of San-Pédro Port
Since the downstream of the San-Pédro river is affected by the tide, it is necessary to grasp the tidal variation of the sea in order to facilitate the hydraulic analyses of the river. The tide records observed in the San-Pédro port are collected over ten (10) years as shown in Fig. A.2.1.

A.3 Meteorology

A.3.1 Climate of the Study Area

The climate of Côte d'Ivoire depends generally on the north-south shift of the intertropical convergence zone (ITCZ), which is created between the tropical continental air mass and the equatorial maritime air mass. The country's climate is divided into three (3) zones depending on the volume of rainfall; north, central and south climatic zones.

The Study Area is located in the south climatic zone, which is characterized by rather long wet period throughout a year. A year is divided generally into the following four (4) seasons depending on the rainfall pattern.

- 1st.dry season from December to February
- 1st. rainy season form March to the middle of July
- 2nd. dry season from the middle of July to the middle of September
- 2nd. rainy season from the middle of September to November

CLIMATIC ZONES IN COTE D'IVOIRE

A.3.2 Rainfall

The following table shows the monthly variation of the rainfall observed in the respective meteorological stations in and around the Study Area.

Mean Monthly Rainfall of the Meteorological Stations in and around the Study Area

(Unit: mm)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
IDEFOR (San-Pédro)	17.5	48.3	82.9	108.0	239.7	366.0	91.4	66.5	76.2	128.4	90.3	38.8	1,354.1
San-Pédro	19.0	24.8	60.2	94.1	273.3	383.2	107.4	63.5	56.5	114.0	128.5	54.7	1,379.1
Sassandra	21.9	29.2	62.8	108.1	271.8	474.3	144.6	29.2	43.8	99.2	137.0	82.1	1,503.8
Tabou	49.2	48.0	87.1	136.8	421.9	522.6	174.4	122.4	229.1	194.2	180.7	139.4	2,306.0
Soubré	26.5	62.9	128.7	145.9	166.0	214.4	106.7	114.6	193.2	173.8	105.0	46.2	1,483.8

Generally, there are two (2) peaks found in the variation of monthly rainfall; the first peak in June and the second in October or November. The minimum rainfalls occur in January. In the IDEFOR (San-Pédro) station which is located at the center of the Study Area, the values of the first and the second peaks reach 366.0 mm and 128.4 mm, and the minimum is 17.5 mm.

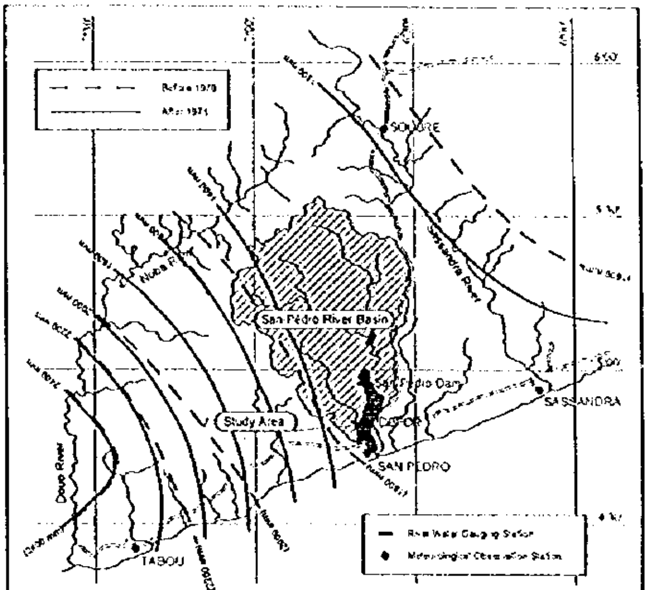
As shown in the following table, about 60 % of rainfall is occur during the first rainy season, and about 75 % during both rainy seasons.

Share of Rainfall in Rainy Seasons

(Unit: mm)

Stations	Rainfall in First Rainy Season (Apr - Jul)		Rainfall in Second Rainy Season (Oct & Nov)		Rainfall in Rainy Seasons		Annual Rainfall
IDEFOR (San-Pédro)	805.1	(59.5 %)	218.7	(16.2 %)	1,023.8	(75.6 %)	1,354.1
San-Pédro	858.0	(62.2 %)	242.5	(17.6 %)	1,100.5	(79.8 %)	1,379.1
Sassandra	998.8	(66.4 %)	236.2	(15.7 %)	1,235.0	(82.1 %)	1,503.8
Tabou	1,255.7	(54.4 %)	374.9	(16.3 %)	1,630.6	(70.7 %)	2,306.0
Soubré	633.0	(42.7 %)	278.8	(18.8 %)	911.8	(61.5 %)	1,483.8

The isohyetal map is prepared for the areas in and around the Study Area as shown in the figure based on the annual average rainfalls calculated periods before and after 1970. The calculated average rainfalls are tabulated below.



ISOHYETAL MAP OF THE SAN-PEDRO RIVER BASIN

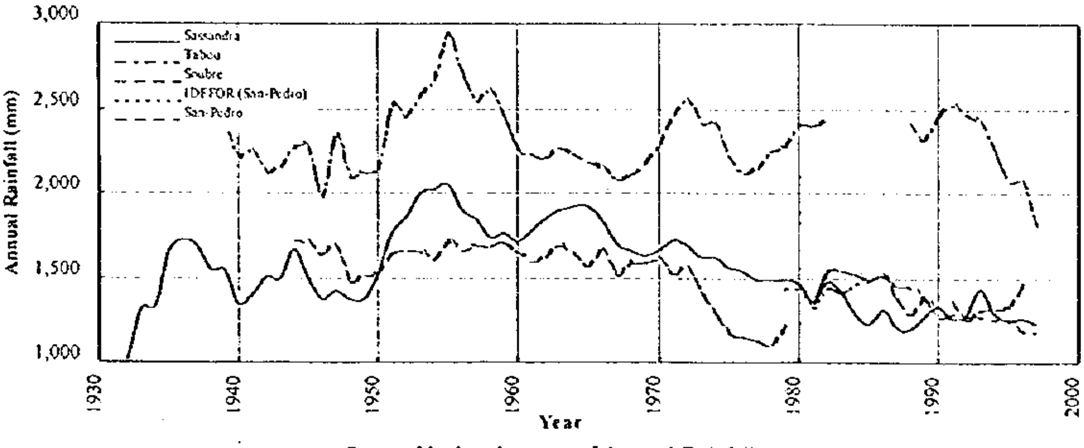
Average Annual Rainfall

(Unit: mm)

Stations	Before 1970	After 1970	Average
IDEFOR (San-Pédro)	-	1,354.1	1,354.1
San-Pédro	-	1,363.3	1,363.3
Sassandra	1,636.1	1,351.9	1,527.4
Tabou	2,359.5	2,256.6	2,307.8
Soubré	1,626.7	1,325.6	1,495.3

Generally, the rainfall gradually increases westward, and it reaches over 2,000 mm in Tabou, which is located near the country's border. It is found that the annual averages of the Sassandra, the Tabou and the Soubré stations decrease with a few hundred mm. Based on the average rainfall after 1970, the Study Area is situated in the zone of 1,300 - 1,400 mm.

The following figure shows the variation of 5-year moving averages calculated for the annual rainfall.



5-year Moving Average of Annual Rainfall

In the Sassandra and the Soubré stations, average values gradually decrease after the middle of 1950's, while that in the Tabou station seems to be constant though its variation is considered wide. The moving averages of the IDEFOR (San-Pédro) and the San-Pédro stations seem to vary in the same tendency. Therefore, the rainfall in the Study Area might have also decreased in these decades. The collected annual rainfalls are summarized in Table A.3.1.

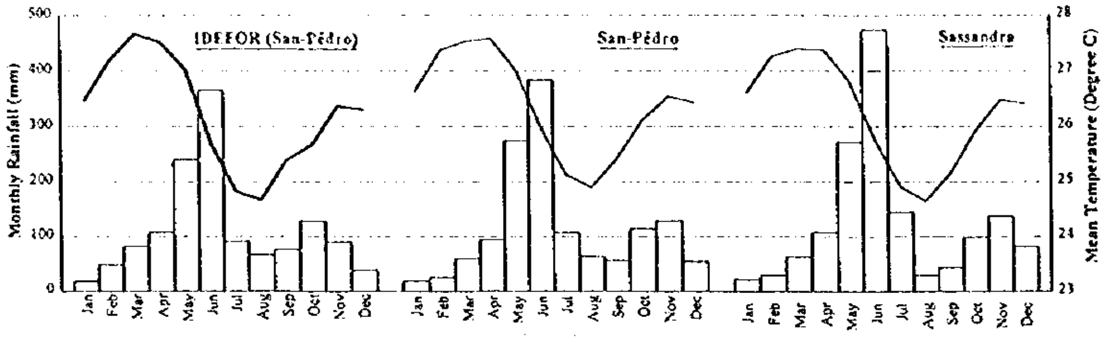
A.3.3 Temperature

The following table shows the variation of monthly mean temperatures observed in the IDEFOR (San-Pédro), the San-Pédro and the Sassandra stations.

Monthly Mean Temperature of the Meteorological Stations in and around the Study Area

(Unit: °C)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
IDEFOR (San-Pédro)	26.5	27.2	27.7	27.5	27.0	25.7	24.8	24.7	25.4	25.7	26.4	26.3	26.2
San-Pédro	26.6	27.4	27.5	27.6	27.0	26.0	25.1	24.9	25.4	26.1	26.5	26.4	26.4
Sassandra	26.6	27.3	27.4	27.4	26.8	25.8	24.9	24.6	25.1	25.9	26.5	26.4	26.2



VARIATION OF MEAN TEMPERATURE AND MONTHLY RAINFALL

The mean temperatures vary from about 24.7 °C to 27.5 °C in these stations, and any significant difference is not found among the stations. The temperature reaches to the peak in March or April, the intermediate period from the dry season to the rainy season, and the lowest occurs in August, after the rainy season. The annual average temperature is calculated to be 26.3 °C.

A.3.4 Other Parameters

The records of the following meteorological parameters are collected for the San-Pédro and the Sassandra stations on a 10-day basis other than those of rainfall and temperature.

- Relative humidity (%)
- Sunshine hours (hr/day)
- Wind velocity (m/sec)

As shown in the table summarizing the monthly mean values of the above parameters, the relative humidity reaches to the peak in August or September, while the temperature decreases to minimum in the same month. The sunshine hours become the shortest in June when the maximum rainfall occur, and the longest in November when the second peak of rainfall occurs. Wind velocity seems to be constant with the narrow variation from two (2) m/sec to three (3) m/sec in average.

The record of evaporation is also collected on a 10-day basis, but any series of a year is able to be completed because of frequent data interruption, through it is considered to be essential for estimating irrigation water requirements.

Monthly Mean Values of Relative Humidity, Sunshine Hours and Wind Velocity Observed in the San-Pédro and the Sassandra Stations

San-Pédro

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Relative Humidity (%)	81.0	81.9	81.8	83.1	85.3	87.2	85.6	87.7	87.6	86.4	85.7	83.4	84.7
Sunshine Hours (hr/day)	4.9	5.6	5.3	6.1	5.2	3.3	3.5	3.1	3.7	5.9	6.3	4.9	4.8
Wind Velocity (m/sec)	2.6	2.8	2.9	2.8	2.5	2.7	2.9	2.9	3.0	2.8	2.6	2.2	2.7

Sassandra

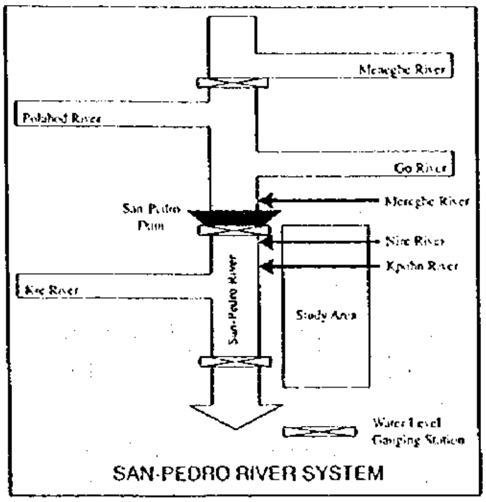
Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Relative Humidity (%)	84.7	85.3	85.0	85.1	87.1	88.0	87.7	89.6	89.8	88.4	87.1	85.6	87.0
Sunshine Hours (hr/day)	6.5	7.1	6.8	7.1	6.3	4.2	4.6	3.9	5.1	6.9	7.5	6.6	6.0
Wind Velocity (m/sec)	2.1	2.2	2.3	2.4	2.3	2.2	2.4	2.3	2.3	2.3	2.2	1.8	2.2

A.4 Hydrology

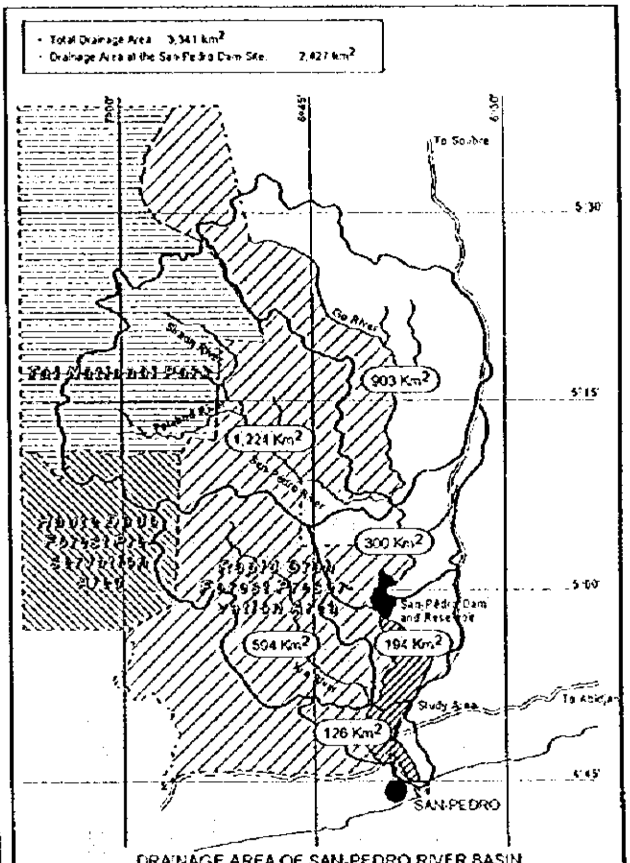
A.4.1 San-Pédro River Basin

(1) San-Pédro River System

The San-Pédro river, of which total length is measured to be about 150 km, originates in the west of the Tai National Park, and flows in the Rapide Grah Forest Preservation Area toward southeastern direction. At about 78 km point from the river mouth, the Go river joins the San-Pédro. The Go river is considered as the largest tributary of the San-Pédro river basin with the catchment area of about 903 km². The San-Pédro river runs southward and flows into the San-Pédro dam reservoir, which is located about 50 km from the river mouth. The river further flows



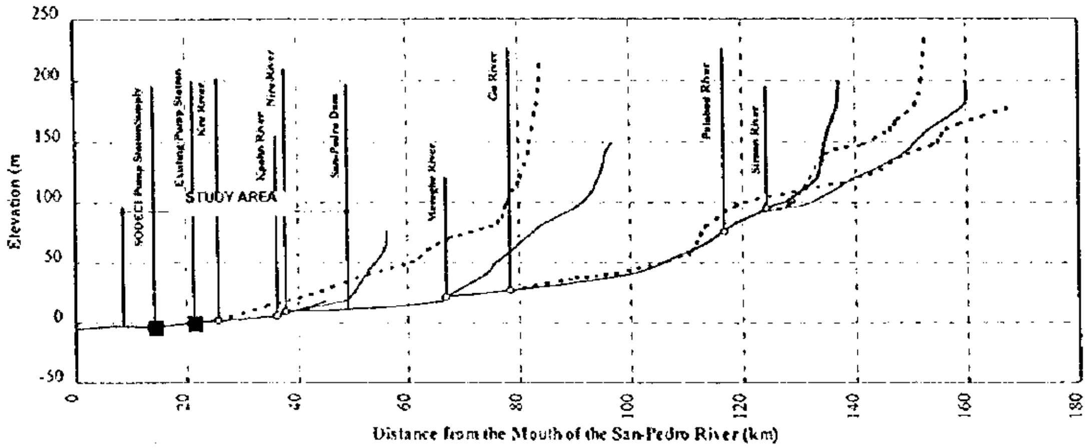
SAN-PEDRO RIVER SYSTEM



DRAINAGE AREA OF SAN-PEDRO RIVER BASIN

southward along the western edge of the Rapide Grah Forest Preservation Area to the point near the intake of the San-Pédro municipal water supply system (SODECI Pump Station). The Kre river with the catchment area of about 594 km^2 join the San-Pédro river on this reach. The San-Pédro river turns its direction to southeast near the intake, and flows along the northern and eastern side of the San-Pédro city area flowing into the Gulf of Guinea about 2.5 km west to the city. The total catchment area of the San-Pédro river basin is measured to be about 3,341 km^2.

As shown in the following longitudinal profile, the gradient of the San-Pédro river varies from 1:500 at the most upstream of the river to 1:5,000 near the river mouth.



LONGITUDINAL PROFILE OF THE SAN-PEDRO RIVER AND TRIBUTARIES

The approximate river gradients are measured to be 1:5,000 from the river mouth to the SODECI pumping station and 1:2,500 from the SODECI pumping station to the San-Pédro dam. The river bed elevation at the mouth is measured to be -5.5 m, and at the SODECI pumping station it is measured as still low as -2.8 m. It is, therefore, considered that the tidal compartment of the river extends to the west end of the reach running eastward along the south side of the Study Area.

(2) San-Pédro Dam and Hydropower Station

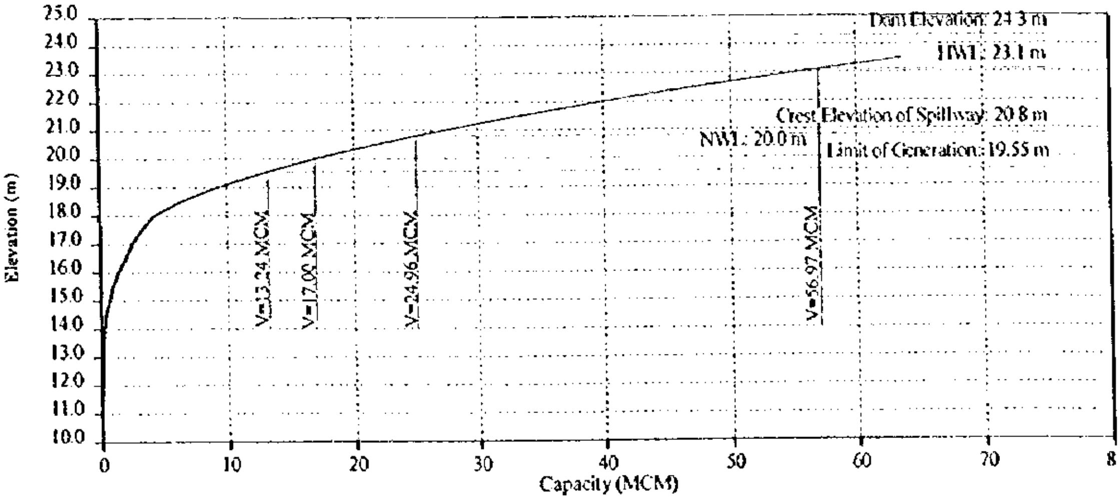
The San-Pédro Dam located near the Fahé village was constructed in 1983 to utilize the San-Pédro river water for:

- the irrigation of the farm land extending downstream of the river (0.37 - 1.54 m^3/s),
- the municipal water supply of San-Pédro (0.5 m^3/s), and
- the industrial water supply for the pulp factory (4.5 m^3/s) and the ironworks (0.4 m^3/s) to be promoted near the dam site.

However, since the planned industrial development was not realized, the hydropower station was additionally constructed in 1983, and the operation was started in November 1983.

The capacity of the dam reservoir is 56.97 MCM at the high water level (HWL: 23.10

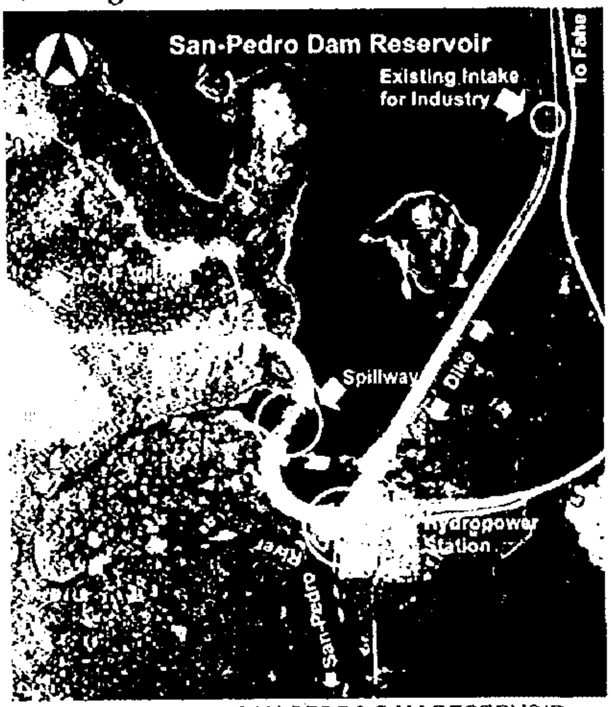
m) and 24.96 MCM at the top of the spillway crest (FWL: 20.80 m) as shown in the figure.



H - V CURVE FOR SAN-PEDRO DAM RESERVOIR

The dam consists of the embankment and the concrete spillway. The embankment extends from both sides of the spillway located on the original river course, and maximum height of the coffer is about nine (9) m. The crest elevation of concrete spillway was heighten for 0.8 m to utilize the reservoir water efficiently when the hydropower station was constructed. The present crest elevation is 20.80 m according to the construction drawing. An outlet hole of circular section is provided in the center pillar of the spillway bridge to release the irrigation water to the river. A blow-off (square section of 1.1 m x 1.1 m) is provided beneath the outlet for irrigation water. The design capacity of this blow-off is 12 m^3/s and the bottom elevation is set at 11.0 m. An intake structure was installed for the industrial water supply, but it has never used since the construction of the dam.

The intake structure of the hydropower station is constructed at the south end of the dam. Two (2) turbine generators are installed in the station and each has the capacity to generate the 2,500 kW requiring 30 m^3/s of discharge in maximum. The station is defined as the supplemental station in the national electricity supply network.



AERIAL VIEW OF SAN-PEDRO DAM RESERVOIR

A.4.2 Drainage Conditions of the Study Area

(1) Sub-basins in the Study Area
Many small tributaries flow into the San-Pédro river in the Study Area. Three (3) rivers are identified clearly in the Study Area. The largest tributary is the Nire river, of which drainage area of 70.0 km^2 is located at the northern end of the Study area. The Kpohn river flows south of the Nire river basin and its drainage area is measured to be 28.5 km^2. The Geranova river basin is situated at the southern end of the Study Area. Its drainage area is measured to be 23.4 km^2 including the drainage area of the Gonu river (14.9 km^2) the tributary of the Geranova river. As shown in Fig. A.4.1, the Study Area is divided into nine (9) sub-basins including these three (3) basins.

The gradients of these tributaries are found to be quite mild and there exist large depressions on their drainage routes. They consequently take a role as a retarding basin especially during the wet season resulting in small flood but poor drainage conditions in some low laying lands. The river courses are not considered clear in most of the tributaries, and the flood frequently changes its flow course.

Since most of the tributaries flow westward into the San-Pédro river, the Grand Canal, which is proposed to be constructed running southward, is considered to cross such tributaries at many places. It is, therefore, necessary to pay a careful attention to such crossings in planning and designing the canal so as to avoid unexpected inundation along the canal due to shortage of flow capacity in the crossing structures.

(2) Present Drainage Conditions in the Priority Project Area
The topography of the Priority Project Area is flat with gentle undulation, and gradually sloped southward. The area is surrounded by low hilly areas on the north and east sides, and in the west and south sides it faces to the San-Pédro river. The run-off from the back hills of the northern and the eastern sides of the area flows southward and catched by the Gonou river running along the northern side of the area toward the Geranova river flowing southward in the low laying area extending wast of the area. However, in the flood time, the run-off of the hilly area flows into the Project Area due to poor flow capacity of the Gonou river. This poor drainage capacity is considered to be caused mainly by the rather high floor level of the drainage culverts on the San-Pédro - Soubré national road and the insufficient flow gradient of the stretch from the Gonou river to the junction of San-Pédro river.

The small valley extending from the left bank of the San-Pédro river to the north of Grand Gabo sometimes introduce the flood water of the San-Pédro to the low lands extending near Grand Gabo as shown in Fig. A.4.2, because the ground elevation the valley is so low and flat that the flood water flows toward the village during the flood in the San-Pédro river. It often results in severe inundation problem in the area.

There are many small streams in the area, and they are connected each other forming the networks being connected to the lower stretch of the San-Pédro river running north of the San-Pédro city area. The run-off water in the area is gradually drained to the San-Pédro river through these networks of the streams, which are considered to function as drainage canals of the existing paddy field at present.

There extend low flood lands along the San-Pédro river, and the flood water is sometimes introduced into the Project Area along low depressions and valleys during flood. In order to prevent such intrusion of flood water into paddy fields, flood dikes are provided along the edges of the area.

A.4.3 Tide

(1) High Tide Analysis

Since the downstream reach of the San-Pédro river is tidal, the records on the tidal variation in the San-Pédro port are collected over 10 years. Although data series is frequently interrupted be lacking, the spring high tide and the maximum high tide are calculated for seven (7) years as tabulated below.

Mean High Spring Tide and Recorded Maximum High Tide in San-Pedro Port

(Unit: IGN m)

1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Ave./Highest
Spring High Tide											
-	0.91	0.98	1.03	-	-	0.96	0.91	0.97	0.99	-	0.96
Maximum High Tide											
-	1.08	1.19	1.18	-	-	1.22	1.10	1.12	1.16	-	1.22

The mean spring high tide and the maximum high tide are calculated to be 0.96 m and 1.22 m, respectively, and the monthly summary of the calculated data are presented in Table A.4.1.

(2) Saline Water Intrusion

Although the saline water may intrude into the river usually in the dry season, the effect of such intrusion has not been confirmed at site. It is found that the effect of tide variation reaches up to the point of the SODECI Pump Station according to the hearing survey results. The results of the survey, conducted in 1960s by ORSTOM indicate that the saline water intrudes to the point near the bridge of San-Pédro - Soubre national road.

The intrusion of saline water was confirmed at the bridge of San-Pédro - Soubré national road by the water quality analyses carried out in the Study. The following table shows the values of the parameters relating to saline content in the river water observed at the bridge and the SODECI pump station site, and they indicate that the saline water exists on the river bed at the bridge site.

Results of Water Quality Analyses on Parameters Relating to Saline Water Intrusion

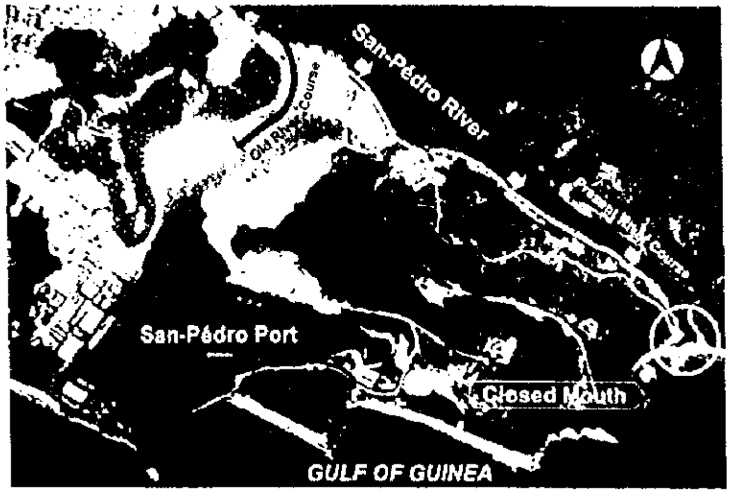
Parameters	SODECI Pump Station			San-Pédro Bridge			Parameters	SODECI Pump Station			San-Pédro Bridge		
	0 m*	1 m*	2 m*	0 m*	1 m*	2 m*		0 m*	1 m*	2 m*	0 m*	1 m*	2 m*
Conductivity (μS/cm)	124.3	108	109	129.9	140.9	3,710	Potassium (K)	4.5	5.1	4.9	4.2	4.5	36.1
Total Disolved Solid	124	108	109	130	141	3,700	Calcium (Ca)	6.1	3.4	3.5	5.2	4.8	24.6
Hardness (Total $CaCO_3$)	26.1	19.4	19.2	24.5	24.9	286.5	Chloride (Cl^-)	13.5	7.1	10.65	17.75	17.75	1,192
Sodium (Na)	10.6	8.8	9.1	11.3	11.45	410	Sulfate (SO_4^-)	67	55.7	56.5	62.1	62.5	115.7
Magnesium (Mg)	2.6	2.6	2.5	2.8	3.1	54							

Note: *: Depth from the river water surface.

Such intrusion is not considered to be occurred during the wet season when the river discharges are so large that the saline water can not intrude in the river toward upstream.

(3) Clogging of River Mouth and Sediments Load

As shown in the photograph, the mouth of the San-Pédro river is closed by the sand sediments from the sea during the dry season when the river discharge becomes small. This phenomenon results in severe flood problems even during the dry season in the downstream stretch of the river. Especially in the upland field along the river near Polo village, the effects of the flood are obvious and the farmers of such lands have to remove the sand sediments at the river mouth by themselves.



AERIAL VIEW OF THE PRESENT AND THE OLD RIVER COURSES

The San-Pédro river originally flows into the small bay where the San-Pédro port is located at present. Its river course was changed when the port was constructed, and the present river course was dredged in the estuary extending near the river mouth, resulting in the present longer river stretch and the effect of the tidal current in the Gulf of Guinea.

As for the sediment load in the San-Pédro river, there is no record observed on this aspect in the country, but the San-Pédro dam was designed considering about $27m^3/km^2/year$ of sediments according to its feasibility report in 1977. Since the storage capacity of the dam is considered quite important in the planning and more than 15 years have passed since its construction, it is necessary to confirm the actual capacity of the reservoir.

A.4.4 Rainfall Analysis

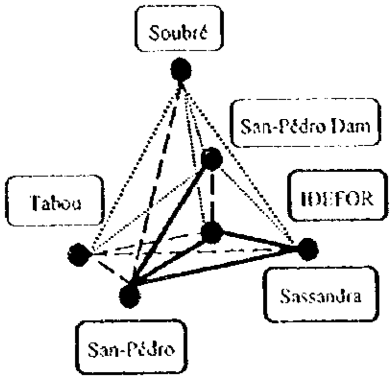
(1) Correlation among the Rainfall Stations

In order to grasp the characteristics of rainfall patterns in the San-Pédro river basin as well as the Study Area, the correlation is examined among the rainfall stations in and around the river basin. Since the distribution of rainfall is considered different from place to place and from time to time in the tropical forest area, the correlation examination is conducted on the monthly basis.

Correlation of Monthly Rainfall between Different Stations

Rainfall Stations	San-Pédro	Sassandra	Tabou	Soubré	IDEFOR (San-Pédro)	San-Pédro Dam
San-Pédro		***	**	**	***	***
Sassandra	0.89		**	*	***	*
Tabou	0.69	0.69		*	**	*
Soubré	0.69	0.42	0.53		*	*
IDEFOR (San-Pédro)	0.93	0.81	0.68	0.52		**
San-Pédro Dam	0.91	0.52	0.53	0.47	0.66	

Note: *: Poor correlation (r<=0.6)
**: Medium correlation (0.6<=r<0.8)
***: Good correlation (0.8<=r)



As shown in the above table, the good correlation is indicated among the San-Pédro, the Sassandra and the IDEFOR (San-Pédro) stations, and between the San-Pédro and the San-Pédro Dam stations.

The IDEFOR (San-Pédro) is considered to well represent the rainfall of the Study Area because of its location, but only 10-day period records are provided. Therefore, the records of the San-Pédro and the Sassandra stations are also considered to be applied for the further hydrological calculations and analyses. The records of the San-Pédro Dam also indicate good correlation with those of the San-Pédro, but they are not considered the Study because the applicable data period is too short for the Study. As for the northern parts of the San-Pédro river basin, the rainfall pattern thereof is considered to be more similar to the Soubré station, since the northern end of the basin reaches near the Soubré station.

(2) Probability Analysis
Probability Analyses are conducted on the followings items for the Soubré, the Sassandra, the San-Pédro, Tabou and the IDEFOR (San-Pédro) stations.

- Annual rainfall
- Maximum daily (24 hr) rainfall
- Maximum three (3) day rainfall

The results of analyses are summarized in the following table.

Results of Probability Analyses

(Unit: mm)

Return Period	Soubré	Sassandra	San-Pédro	Tabou	IDEFOR (San-Pédro)
1. Annual Rainfall					
1/100	2,985	2,755	2,259	3,620	1,952
1/50	2,739	2,567	2,120	3,442	1,867
1/20	2,418	2,306	1,930	3,186	1,747
1/10	2,173	2,091	1,775	2,969	1,647
1/5	1,919	1,862	1,606	2,719	1,533

Results of Probability Analyses

(Unit: mm)

Return Period	Soubré	Sassandra	San-Pédro	Tabou	IDETOR (San-Pédro)
2. Maximum Daily Rainfall					
1/100	183.3	303.2	257.4	332.3	-
1/50	163.0	275.5	240.7	303.4	-
1/20	137.6	238.0	217.0	264.5	-
1/10	119.4	208.4	197.1	233.9	-
1/5	101.6	176.7	174.4	201.2	-
3. Maximum 3-day Rainfall					
1/100	204.1	499.4	410.0	458.1	-
1/50	189.1	445.6	373.6	423.7	-
1/20	168.7	375.1	324.9	376.8	-
1/10	152.6	321.3	286.8	339.4	-
1/5	135.3	265.5	246.4	298.9	-
Data Period	1940 - 1996	1928 - 1997	1976 - 1996	1922 - 1992	1973 - 1997

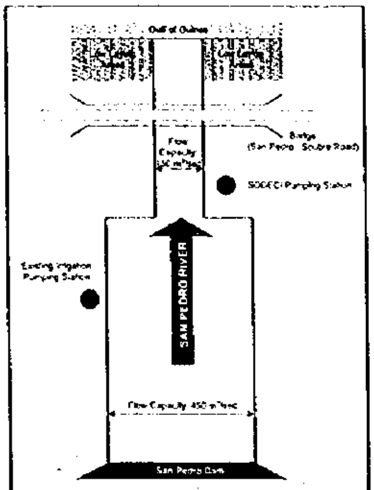
A.4.5 Runoff Analysis

(1) Flood Discharge Analysis

1) Present Flow Capacity of the San-Pédro River

The flow capacity of the present river course is examined for the San-Pédro river. The cross-sectional survey was carried out along the river with an interval of 1.0 km from the river mouth to the San-Pédro dam site about 50 km away from the mouth. The non-uniform flow calculations are conducted for these surveyed sections, and water surface elevations are calculated with various discharges as shown in Table A.4.2.

The water level at the river mouth is set as high as 0.96 m for the non-uniform flow calculation taking into account the mean spring high tide of the San-Pédro Port. Since most downstream stretch of the San-Pédro river runs in the low laying land and the tidal estuaries, of which ground elevations are considered lower than the mean spring high tide resulting in the inundation of such low lands. As seen in the table, the stretch from the bridge of the San-Pédro - Soubré national road to the upstream of the SODECI pumping station is considered to have a flow capacity of about 150 m^3/sec. The upstream stretches are generally considered to have a capacity of about 450 m^3/sec through there are some stretches of which the flow capacities are smaller.



FLOW CAPACITY OF THE SAN PEDRO RIVER

2) Probable Flood Discharge

The probable flood discharges are calculated for the Fahé and the SODECI pumping station sites based on the daily mean values recorded for these stations. The Iwai method is employed for this calculation. Applying the specific discharges for these stations the probable discharges for the other sites such as San-Pédro dam, the mouth of the San-Pédro river, the junction of the Kre river are calculated.

The calculated probable discharges in the respective sites are tablated below.

Probable Peak Discharge

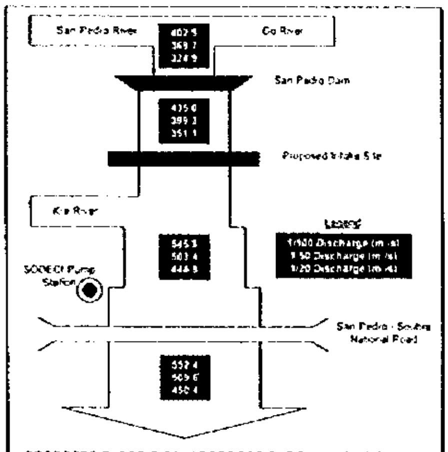
(Unit: m³/s)

Return Period	Fahe Station* (A=2,127 km2)	SODECI Pump Station** (A=3,300 km2)	San-Pédro Dam*** (A=2,427 km2)	River Mouth**** (A=3,341 km2)	Junction of the Kre River***** (A=2,621 km2)
1/500	420.3	639.5	479.6	647.4	517.1
1/200	382.1	586.6	436.0	593.9	470.4
1/100	353.1	545.6	402.9	552.4	435.0
1/50	324.0	503.4	369.7	509.6	399.3
1/40	314.6	489.5	358.9	495.6	387.7
1/30	302.3	471.3	344.9	477.1	372.6
1/25	291.5	459.6	336.0	465.3	363.0
1/20	284.8	444.9	324.9	450.4	351.1
1/10	253.9	397.3	289.7	402.3	313.1
1/5	221.0	344.8	252.2	349.1	272.4
1/4	209.7	326.2	239.2	330.2	258.4
1/3	194.1	300.3	221.5	301.0	239.2
1/2	169.5	257.9	193.4	261.1	208.5

Note
*. Probable discharges worked out by the annual maximum discharges ovserved at the SODECI pump station
**. Probable discharges worked out by the annual maximum discharges ovserved at the Fahe station.
***. Discharges calculated based on the specific discharges of the Fahe station
****. Discharges calculated based on the specific discharges of the SODECI pump station
*****. Discharges calculated based on the specific discharges of the SODECI pump station and the Fahe station

The records of the San-Pédro dam site is not used because they seem to include many lacking of the data. The records observed before the construction of the San-Pédro dam are used for the calculation of probable discharges for the SODECI pumping station because the observed values may be affected by the dam operation after completion of the dam, and it is considered quite difficult to segregate such affects.

Based on the above results, it is proposed to apply the probable values for the flood analyses as illustrated in the figure.



PROPOSED FLOOD DISCHARGES FOR THE SAN PEDRO RIVER

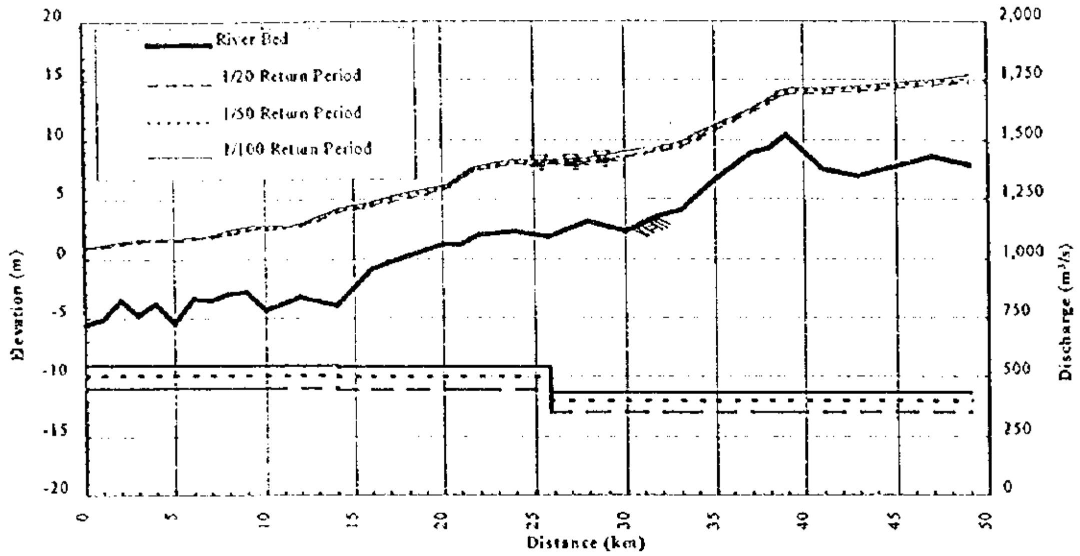
The longitudinal profile presented in the next page shows the flood water levels calculated for the proposed probable flood discharges applying the non-uniform flow calculation method.

3) Inundated Areas along the San-Pédro River

Most of the areas situated along the San-Pédro river is considered to be flood prone because of their low ground elevations. The inundation areas are studied and the areas getting flooded by the high water level of the San-Pédro river are delineated on the 1:10,000 topographic maps based on the flood water levels calculated as aforesaid. The results of such study are illustrated in Fig. A.4.1.

(2) Drought Discharge Analysis

Drought discharge analyses are carried out in order to examine the water balance of the San-Pédro river basin. The analyses are conducted considering the relation between the rainfall recorded at any station in or around the Study Area and the actual run-off observed at any station in the river. The tank model simulation method is applied for the

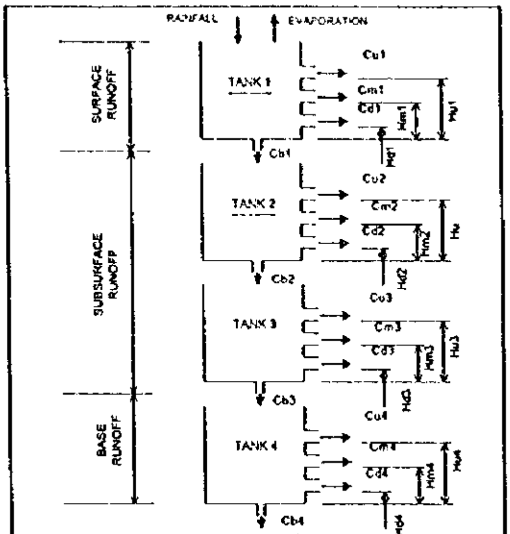


FLOOD WATER LEVELS BY THE PROBABLE FLOOD DISCHARGES

analyses of which details are discussed in the following sections.

1) Simulation by Tank Model Method

The simulation is conducted on the observed monthly rainfall and the monthly mean discharge for two (2) selected river water gauging sites; the Fahé and the SODECI pumping station sites. The monthly rainfall of the Soubré station is applied for the discharges observed at Fahé, and that of the IDEFOR (San-Pédro) station for the discharges at the SODECI pumping station. As for the records of the SODECI pumping station, since they might be affected by the operation of the San-Pédro Dam after the completion of its construction, the recorded values before such construction are applied for the simulation analyses.



LAYOUT OF TANK MODEL

The model consisting of four (4) tanks is designed for the simulation analyses as shown in the figure. The first highest tank represents surface run-off, and the lowest one represents base run-off. The remaining two (2) tanks on middle position represent sub-surface run-off. Each tank has four (4) holes; one on the bottom of the tank and the other three (3) on the side wall with different hights. The parameters such as diameters and hights of holes are determined by trial calculation so as to obtain the run-off patterns same as the actual records.

The parameters obtained through the trial simulations as explained above are tabulated below.

Parameters Obtained by Tank Model Simulation

Discharge at Fae referring to rainfall of Soubre

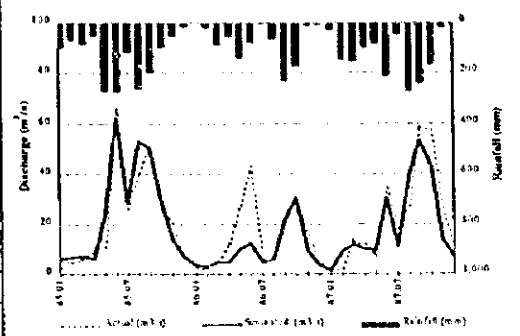
Catchment Area: 2,127 km^2

Tanks	Coefficient of Tank Hole				Coefficient of Tank Height		
	Cu	Cm	Cd	Cb	Hu	Hm	Hd
1	0.15	0.07	0.1	0.38	300	100	0
2	0.1	0.1	0.2	0.6	30	25	0
3	0.2	0.03	0.3	0.6	20	10	0
4	0.02	0.1	0.01	0.01	150	140	100

Rainfall Coefficient: 0.61

Evaporation Coefficient: 1.0

Correlation Coefficient between Simulated and Actual: 82.00 %



Discharge at SODECI pumping station referring to rainfall of IDEFOR (San-Pédro)

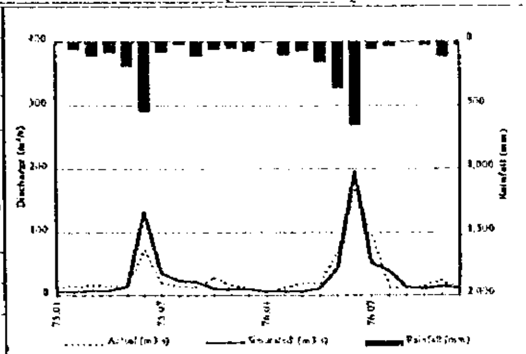
Catchment Area: 3,300 km^2

Tanks	Coefficient of Tank Hole				Coefficient of Tank Height		
	Cu	Cm	Cd	Cb	Hu	Hm	Hd
1	0.001	0.01	0.05	0.33	200	50	10
2	0.2	0.2	0.35	0.5	10	5	3
3	0.2	0.4	0.6	0.3	10	5	0
4	0.02	0.1	0.01	0.005	15	10	5

Rainfall Coefficient: 0.45

Evaporation Coefficient: 1.0

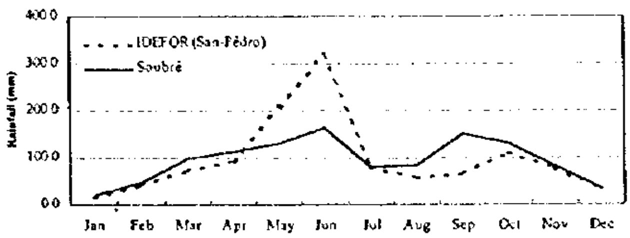
Correlation Coefficient between Simulated and Actual: 87.68 %



As shown in the above table, it is found that the generated run-off values vary with acceptable correlation with those observed in both cases; 82.00 % and 87.68 % for Fahé and the SODECI pumping station, respectively.

2) Rainfall for Drought Run-off Analyses

To facilitate the drought run-off analyses, the 5-year return period (20 % probability) rainfalls are worked out for the Soubré and the IDEFOR (San-Pédro) stations. The probable annual rainfalls and the monthly rainfall patterns for these stations calculated by the Iwai method are presented below.



Monthly Variation of Probable Rainfall
(Drought Rainfall of 5-year Return Period)

(Unit: mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
IDEFOR (San-Pédro)	15.1	41.7	71.6	93.3	207.1	316.3	79.0	57.5	65.8	110.9	78.1	33.5	1,170.0
Soubré	20.7	47.0	96.6	111.7	130.5	163.6	81.2	81.8	149.8	129.7	81.9	35.5	1,130.0

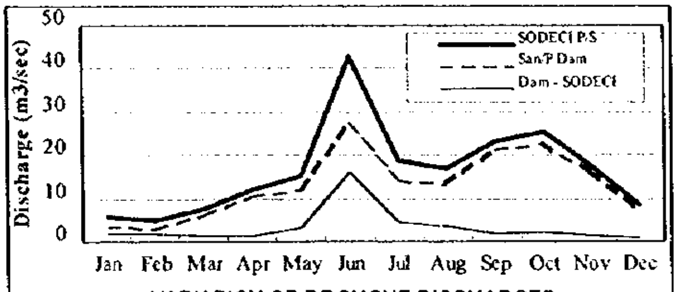
3) Drought Discharge

Based on the probable rainfall patterns worked out for the Soubré and the IDEFOR (San-Pédro) stations, and the simulation models of which parameters are determined as aforesaid sections, the variations of drought discharge are generated for the Fahé and the SODECI pumping station sites. The results of the calculations are summarized below.

Calculated Drought Discharge

Sites	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Fahé													
Drought Discharge (m^3/sec)	3.3	2.9	5.4	9.2	10.6	23.5	12.6	11.6	18.7	20.0	14.1	6.4	11.5
Specific Discharge ($m^3/sec/km^2$)	0.0015	0.0013	0.0025	0.0043	0.0050	0.0110	0.0059	0.0055	0.0088	0.0094	0.0066	0.0030	0.0054
SODECI Pumping Station													
Drought Discharge (m^3/sec)	7.6	7.1	4.8	5.3	11.8	61.1	16.1	14.0	7.4	9.3	5.6	4.2	12.9
Specific Discharge ($m^3/sec/km^2$)	0.0023	0.0021	0.0015	0.0016	0.0036	0.0185	0.0049	0.0042	0.0023	0.0028	0.0017	0.0013	0.0039

The drought discharges at the respective sites of the river course of the San-Pédro river are calculated applying the specific discharges and the drainage areas at each sites, and the figure illustrates the calculated monthly variation of the drought discharges, and the calculated discharge values are tabulated below.



VARIATION OF DROUGHT DISCHARGES

Calculated Drought Discharges at Respective Sites on San-Pédro River

(Unit: m^3/sec)

Sites	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
San-Pédro Dam	3.7	3.3	6.2	10.5	12.0	26.8	14.4	13.3	21.3	22.8	16.1	7.3	13.1
Dam – SODECI	2.0	1.9	1.3	1.4	3.1	16.2	4.3	3.7	2.0	2.5	1.5	1.1	3.4
SODECI Pump. Sta.	5.7	5.1	7.5	11.9	15.2	43.0	18.7	16.9	23.3	25.3	17.6	8.4	16.5

A.4.6 Effect of Weir Construction

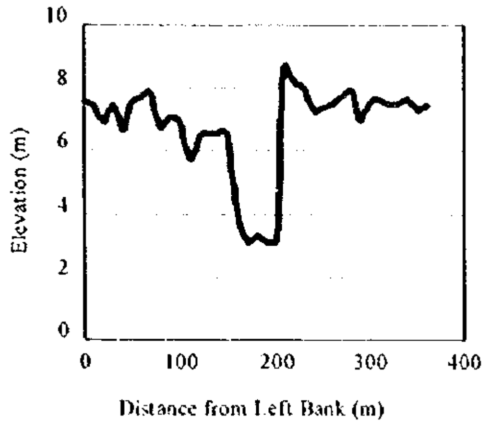
In order to confirm the possibility to take the irrigation water from the San-Pédro river, the following two (2) alternative sites are considered in the Study.

- Upstream of the junction with the Kre river (No. 26 section on the San-Pédro river)
- About 1.5 km downstream of Cpt. Colonel (No. 33 section on the San-Pédro river)

The hydrological study is carried out on the above two (2) alternatives focussing on the effects to the conservation forests on the right bank of the river as stated below.

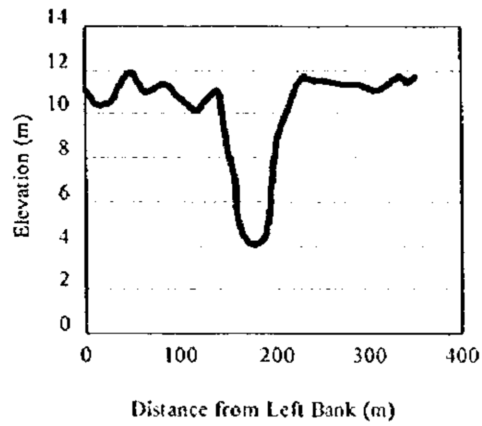
(1) Upstream of the Junction with Kre River

This location is originally proposed by PNR for constructing the weir to take the irrigation water. According the study on irrigation, the diversion water level at the intake site is calculated to be WL 8.1 m considering the necessary gradient to convey the water to the irrigation area by gravity flow. The inundation area in case that the river water surface is risen up to this elevation is examined on the topographic map as shown in Fig. A.4.3. The upsurge of river water level is considered to affect to wide areas especially along the Kre river, and it is necessary to construct the long protection dikes along the Kre river as well as the San-Pédro river even in the normal time. In addition, it is also necessary to provide some drainage sluices on the dikes in order to facilitate the drainage effect of the forest area surrounded by the dikes. If the flood water level is considered, much higher dikes have to be provided along both of the rivers.



Section 26

(2) About 1.5 km Downstream of Cpt. Colonel
This alternative site is selected after due site reconnaissance because the above original site is considered impossible for proposing as an intake site. According to the irrigation study, it is required to rise the river water level to WL 9.5 m for conveying the water to the irrigation area by gravity flow. The flood area by this level of upsurge is considered small, but in case that the flood water level tentatively set at WL 10.5 m is concerned some areas are found to be flooded as shown in Fig. A.4.3. It is, therefore, necessary to provide the flood dikes along the river to prevent the conserved forest area from such flood effects.



Section 33

A.5 Water Resources

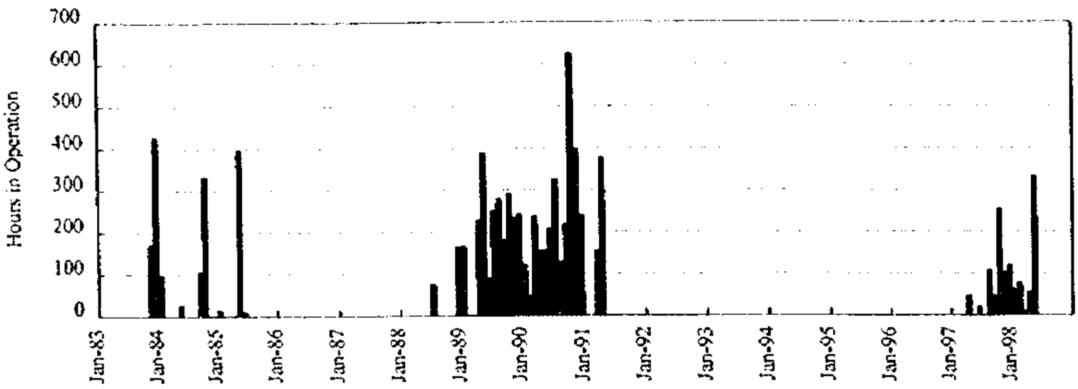
A.5.1 Water Users

The surface water of the San-Pédro river basin is at present used for the municipal water supply and the electric power generation, and the irrigation water had been taken until 1994 as described below.

(1) Hydropower Generation
At the beginning when the San-Pédro dam was constructed, the component of hydropower generation was not considered according to the feasibility report for the dam prepared in 1977. It is, therefore, considered that the hydropower generation seems to be taken up suddenly after the dam construction was completed at the beginning of

1980s.

The power generation was commenced in November 1983 and stopped in June 1985 due to the mechanical trouble. No power generation was made except for the period from 1988 to 1991, and in 1997 when its operation was re-started. The following figure indicates the operation hours of hydropower generation from 1983 to date, which are calculated based on the operation records kept in the operation office at the dam site.

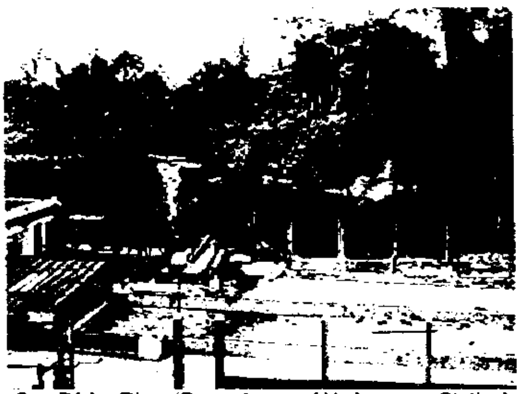


Year	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Operation Hr.	599	564	421	-	-	239	2,349	2,861	532	-	-	-	-	-	690	536
															Total Operation Hours:	8,789

OPERATION HOURS OF HYDROPOWER GENERATION

The table in the above figure shows that the total of 8,789 hr of power generation has been made, and that the annual operation hours reaches over 2,800hr in maximum in 1990 but never exceeded 2,900 hr.

Two (2) turbine generators are installed in the station, and the discharge of 30m^3/s/unit is required for their operation in maximum. The generator operation is stopped when the reservoir water level becomes below 19.55m. It is rare to operate both turbines at once though they have two (2) units of generators. The hydropower station is operated and managed by CIE, national electricity company, together with the San-Pédro dam according to the demand of electricity.



San-Pédro River (Downstream of Hydropower Station)

(2) Irrigation

The irrigation pumping station was constructed in 1976 to supply the water to the irrigation area of the Cité Agricole Paddy Project Area (450ha from 1973 to 1977 and 650ha from 1977 to 1979) extending in the southern part of the San-Pédro plain. The pumping station has three (3) units of diesel-engine-driven pump with a total lifting capacity of 0.7 m^3/s. This pumping station functioned until the beginning of 1994. Apart from this pumping station, there were four (4) small pumping stations along the San-Pédro river to supply the irrigation water to those small flat lands. All of them were abandoned and have been left unused to date. In the feasibility study of the San-Pédro dam, the discharge rate of 0.37 to 1.54 m^3/s was allocated for irrigation water supply. The details of the irrigation water supply are discussed in Appendix - F attached hereto.

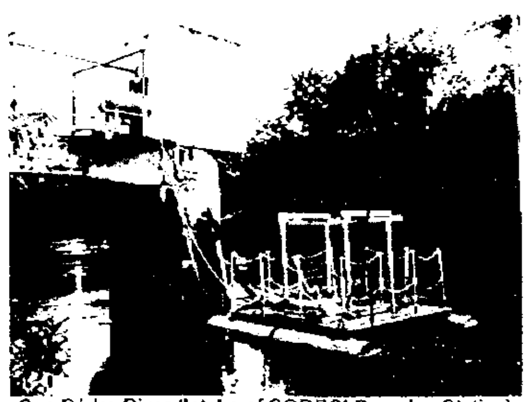

San-Pédro River (Intake of Irrigation Pumping Station)

(3) Municipal Water for the San-Pédro Municipality

During 1970s, the pumping station was constructed on the right bank of the San-Pédro river for the municipal water supply of San-Pédro as shown in Fig. A.5.1. Two (2) sets of submersible pumps are installed and the lifted raw water is conveyed with the steel pipeline to the water treatment plant. The water treatment plant with a production capacity of $6,000m^3$/day is located near the pumping station.

There are three (3) regulation tanks in the supply system, and one (1) booster pump station to convey the treated water to the southern part of the area. The water distribution network covers most of the municipality area, but since in some areas lateral supply lines have not yet been placed, such construction for placing lateral pipelines is being under way at present.

The water supply system of the San-Pédro municipality area is managed and controled by the SODECI, the national water supply company, including maintenance and repaire of their supply facilities. According to the SODECI's operation record of the treatment plant, the plant produces 4,500 - 5,000 m^3/day (about $0.06m^3/s$) of water at present. The discharge rate of 0.5 m^3/s was allocated for municipal water supply in the feasibility study of the San-Pédro dam prepared in 1977.


San-Pédro River (Intake of SODECI Pumping Station)

(4) Industry

When the San-Pédro dam was constructed, the water of 4.9 m^3/s was planned to be allocated for the industrial purpose such as pulp and ironworks factories. An industrial development area is indicated in the feasibility report for the San-Pédro dam construction. No industrial development was, however, realized since then. Any promotion of new industry in the San-Pédro city area has not been informed so far, and there may be no necessity to consider the industrial water allocation in the Study.

A.5.2 Available Surface Water Resources and Water Balance

(1) Present Water Balance

1) Available Surface Water Resources and Water Allocation

The present water allocation at the SODECI pump station is presented in the following table on the monthly average basis.

Present Water Allocation at SODECI Pump Station

(Unit: MCM)

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Run-off Volume	35.56	41.34	41.50	49.97	97.10	243.09	155.03	72.69	101.10	138.25	115.51	51.63	1,143
Municipal Water	0.16	0.14	0.16	0.15	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.16	2
Irrigation	1.75	0.93	1.79	1.52	1.26	0.55	0.86	0.38	2.13	1.25	1.23	1.23	15
Balance	31.90	39.34	37.76	46.77	94.42	241.81	153.15	71.77	96.69	135.59	112.90	49.01	1,126

In the above table, the municipal water supply volume of two (2) MCM is estimated based on the present daily production of 5,000m^3, and the irrigation water supply volume of 15 MCM is estimated based on the operation records (1981) of the existing irrigation pumping station kept by ANADER.

The annual runoff of 1,143 MCM seems to be enough to fulfill the demands of the municipal and the irrigation water supplies on the monthly average basis. Since the hydropower generation has been made intermittently, it is not included in the above table. Most of the balance volume is used for the power generation, when the water is available in the dam. However, quite small discharges are recorded during the dry season from December to March, and consequently it is considered necessary to use the reservoir water in the San-Pédro dam effectively considering such daily variation of the river discharge.

As for the dam reservoir capacity, it is 24.96 MCM at the crest elevation (20.80m) of the dam spillway, and this volume of water is considered enough to provide the supplemental water for the irrigation and the municipal water demand even during the dry season.

(2) Future Water Balance

1) Future Water Demand

The future demand in the year of 2015 has been estimated to confirm the water balance in the San-Pédro river basin. The proposed demand of each sector is worked out as described below.

Irrigation

The diversion water requirement for the whole proposed irrigation areas (950ha in net) is calculated as tabulated below.

Estimated Future Irrigation Water Demand

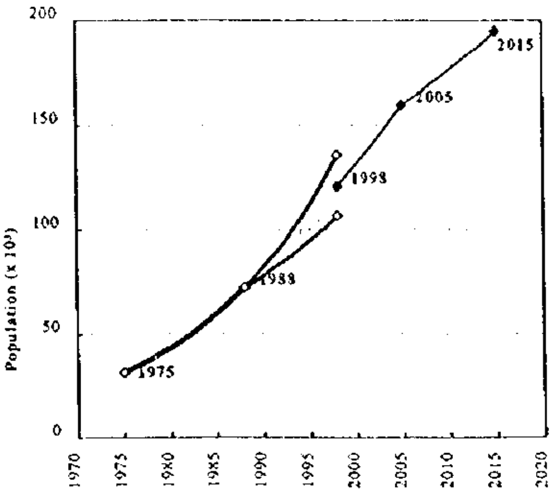
(Unit: MCM)

Irrigation Area	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
Upstream Area (950 ha)	3.3	0.0	2.2	3.8	2.1	1.7	1.6	0.3	3.2	3.5	4.2	3	28.7

The irrigation water for all the proposed are is to be taken from the San-Pédro dam in 2015. The details of the calculation of irrigation water demand are presented and explained in Appendix - F attached hereto.

Municipal Water Supply

The future demand of municipal water supply for the San-Pédro city is estimated considering the population increase, the extension of service area and the increase of consumption per capita. The population census is taken place every ten (10) years in the country. The latest census was carried out in 1998, but the results have not yet been announced so far. Therefore, the future population is estimated based on the growth rates of the actual value from 1975 to 1988 and those suggested by the National Institute of Statistics as tabulated below.



POPULATION FRAME FOR FUTURE WATER DEMAND

Population Settings in the San-Pédro City Area

(Unit: 1,000 persons)

Items	1975	1988	1998		2000	2005	2010	2015
Population in City Area	31.6	72.0	135.8	106.6	131.1	159.5	176.1	194.4
(Growth Rate)	(6.5 %)	(6.5 %)	(6.5 %)	(4.0 %)	(4.0 %)	(4.0 %)	(2.0 %)	(2.0 %)
Remarks	Based on the Census Data for 1975 and 1988		Estimated present population 6.5 %: Actual growth rate from 1975 to 1988, 4.0 %: growth rate of National Institute of Statistics		Estimated future population in the San-Pédro City Area			

In the above table, the population in 1998 is set taking the average of those calculated by the growth rates of 6.5 % (actual rate from 1975 to 1988) and 4.0 % (National Institute of Statistics). The annual growth rates are assumed at 4.0 % till 2005 and at 2.0 % from 2005 to 2015. The population growth is shown the figure. The served population considered to be about 70 % at present is assumed to reach 100 % in 2015, and the consumption per capita considered to be about 55 l/day/capita at present is assumed to be 150 l/day/capita in 2015.

As a result, it is found that the production and distribution capacity of the water supply system has to be increased to 30,000 m^3/day, and the annual demand becomes to be 11.0 MCM in 2015. Thus, the monthly diversion volume for municipal water is calculated as tabulated below.

Estimated Municipal Water Supply Demand

(Unit: MCM)

Item	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
Municipal Water Supply Demand	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.9	11.0

It is proposed that, in the future also, the raw water for the municipal water supply will be taken from the same location as the present SODECI pump station.

Industrial Water

Since no realistic industrial development plan exists, the water allocation for the industrial sector is not considered.

2) Water Balance and Allocation

Considering the above increase of water demands, the water balance of the San-Pédro river basin has been examined. The monthly run-off volume calculated for the drought rainfall of 5-year return period is applied for the balance calculation. The water balance for the hydrological year staring in April and ending in March is presented in Fig. A.5.2, and its annual balance is summarized below:

- Total run-off volume:	527.2 MCM	(100.0%)
- Evaporation from the San-Pédro dam:	4.5 MCM	(0.9%)
- Irrigation water demand:	28.7 MCM	(5.4%)
- Municipal water supply demand:	11.0 MCM	(2.1%)
- Annual balance:	483.0 MCM	(91.6%)

The annual run-off in the San-Pédro river basin is estimated at 527.2 MCM for the drought year of 5-year return period, and the balance after deducting the various consumption is as large as 483.0 MCM, equivalent to 91.6% of the total run-off.

The monthly variation of the run-off volume at the tail of dam is also calculated. As a result, it is found that the hydropower generation is possible throughout a year even in the drought years, and the possible hour of operation becomes over 2,900 hr. in condition that about 70% of the run-off at the tail of dam are used for hydropower generation. This value is considered to be almost the same as the total operation hour of the record for 1990.

Although the balance of run-off volume is confirmed on the monthly basis, extremely low discharge may occur in the daily variation. It is, therefore, important to prepare proper rules of water allocation among the water users in order to provide for such urgent cases.

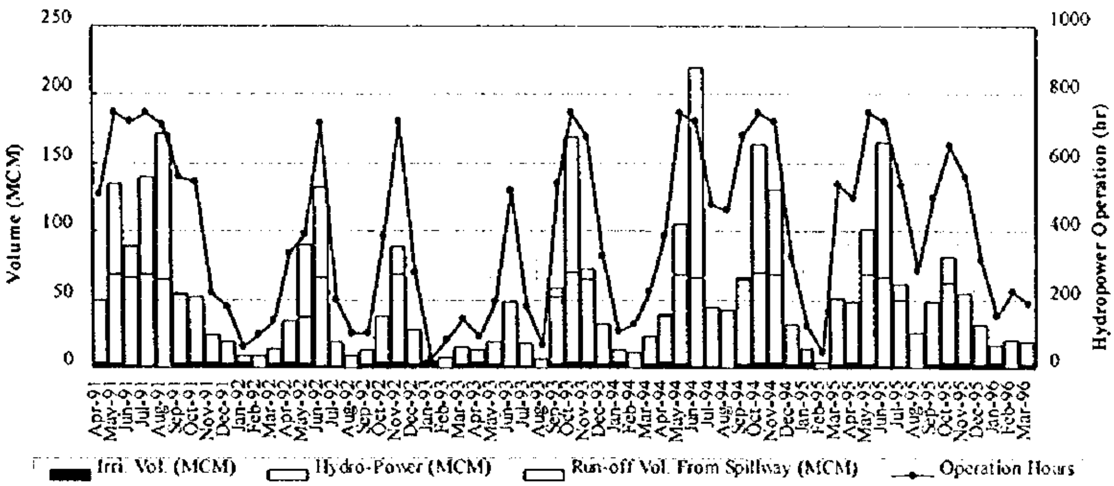
(3) Water Balance on Actual River Flow

To confirm the allocation of surface water resources, the water balance is examined on daily basis. The daily mean discharges observed in the Fahé gauging station from April 1, 1992 to March 31, 1996 is applied for the simulation. The annual summary of the calculation is tabulated below.

Summary of Water Balance Simulation on Actual River Flow

Hydrological Year	Flow-in Dis. (m^3/s)	Flow-in Vol. (MCM)	Irri. Vol. (MCM)	Hydro-Power (MCM)	Operation Hours	Run-off Vol. From Spillway (MCM)	Min. Dis. At Tail of Dam (m^3/s)
1991 – 1992	24.05	764.70	28.72	468.72	5,208	267.23	1.98
1992 – 1993	14.74	465.20	28.72	312.21	3,469	138.60	0.81
1993 – 1994	15.21	481.60	28.72	341.55	3,795	111.33	2.22
1994 – 1995	29.03	917.18	28.72	536.40	5,960	347.93	1.79
1995 – 1996	21.25	670.10	28.72	482.85	5,365	162.82	5.14

As shown in the table, the inflow volume to reservoir varies from 465 MCM to 917 MCM, and the surface water resource is generally considered enough to provide irrigation water to the proposed command areas, and about 3,469 hours of hydropower generation is considered possible. The minimum discharge at the tail of dam reaches to a minimum of 0.84 m^3/s. This discharge is considered enough to fulfill the municipal water supply demand which is estimated at about 350 lit./s for 2015. The details of the simulation results are presented in Table A.5.1, and the variations of discharges are illustrated below.



RESULTS OF SIMULATION ANALYSIS

A.6 Groundwater

A.6.1 Geology

The geology of Western Africa is characterized by a completely leveled Ante-Cambrian platform made of metamorphic and granitic materials, then later reshaped by the tectonics of the primary period.

The San Pedro river basin area is representative of this basic structure. It belongs to the so-called Sasca domain, which is separated from the Man domain by a major fault lying on the west of San Pedro. The domain of Man is slightly affected by the Eburneen orogeny of Precambrian and is then mainly constituted of materials present before such movements, classified as the Liberian materials. The domain of Sasca, to which the San Pedro area belongs, has been largely reshaped by the Eburneen orogeny, characterized by violent tectonics with formation of geosynclines. The belonging to the Sasca domain explains the presence of 2 major groups of materials in the area, namely those of the Liberian megacycle, made of granite and granodiorit, and those of the Eburneen megacycle, made of micashist, schist, and quartzite (flysh formation, which belongs to the so-called Birrimien formation).

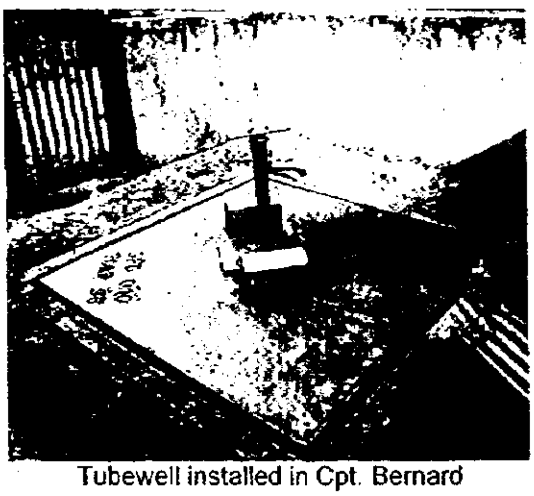
The river basin area of San Pedro mainly lies on the old Ante-Cambrian substratum of the Liberian orogenic stage, which has then remained stable, and partly on the substratum of the Eburneen orogenic stage, which has followed the latter, on its extreme south part. The Liberian substratum presents some oriented intrusion, like the NW-SE oriented dykes of magmatic materials (dolerite), apparently organized according to the distortions of the Liberian substratum, and due to the existing rock joints that are contemporary of the Hercynien tectonics. It is possible that these intrusions have determined some morphological features, specially the NW-SE orientation of the San Pedro River, downstream.

The overall geological structure is however covered with more recent materials, especially those of lateritic nature, due to the climatic effects of the quaternary period. This laterite cover is thick, between 20 and 50m in the southeast region. Cover materials also include the tertiary deposits (pieces of these sediments can be found in the extreme south of the river basin), and the quaternary fluvial deposits that can be found along the main riverbeds downstream, in the San Pedro plain.

The present morphology of the study area seems to be largely determined by the tectonics of the Eburneen period (geosynclines and faults of SW-NE direction). Magmatic intrusions could also have determined morphological directions in some places. More significantly, the landscape has been reshaped by the interactive actions of the climate and continental raising during the quaternary period, through river erosion on the one hand, and through laterite formation on the other hand. The geological map in and around the Study Area is shown in Fig. A.6.1.

A.6.2 Groundwater

There exist 31 tubewells constructed in 23 villages scattered in and around the Study Area under the rural water supply schemes of the Ministry of Economic Infrastructure as shown in Fig. A.6.2. These wells are constructed to utilize the fissure water in the granite zone extending widely in the area, and their target fractures are suited from 20 to 40m deep. The depths of these wells vary from 36 to 88m with an average depth of about 59m.


Tubewell installed in Cpt. Bernard

The results of pumping tests conducted during the construction of tubewells show that the optimum yields are within the range from 0.5 to 11.0m^3/hr and an average is calculated as 3m^3/hr. It is considered hardly possible to utilize the groundwater for irrigation development of the area, but is available for the rural water supply. As for the water quality, the iron content is considered high exceeding the allowable range in most of the tubewells in the area. As shown in Table A.6.1, the iron content is considered to exceed the allowable value.

There are a lot of open wells, used by private farms and communities in the villages. The depths of wells are less than 10m in most of the wells, and seasonal variation of the well water is so large that no well water is frequently available during the dry season according to the villagers. The number such wells that found in Grand Gabo, Campus I and Campus II located in the Priority Project Area are 7, 2 and 14, respectively.

A.7 Technical Consulting Committee on Water Use of San-Pédro Dam

A.7.1 Objectives of Technical Consulting Committee

There is no system for collection of water charges in the country. In the San-Pédro river basin also, no water charge has been collected so far, and the operation of dam is carried out by CIE depending only on the electricity demand, since the irrigation water supply was stopped in 1994. In 1996, the Office of High Commissioner for Hydraulics (HCH) was established in order to realize the appropriate and fair water resources management in river basins of the country. The establishment of the appropriate water allocation system (water right) and the proper collection system of water charge is considered to be one of the most important HCH's functions. Under these situation the Water Code Regulation, which consists of 134 articles under six (6) titles, was authorized in December 1998 in order to provide the rules for regulating the usage of water resources in the country.

The Technical Consulting Committee on Water Use of San-Pédro Dam (herein after referred to as the Water Committee) was established in order to facilitate the utilization and allocation of water resources in the river basin with the mutual understanding among the relating agencies such as PNR for irrigation water, CIE for hydropower generation, SODECI for municipal water supply, SODEFOR for environmental conservation, and other government agencies relating the utilization of such water resources. Since no such effort has been taken among the water users in the country so far, this approach is considered as the first trial and example toward the ruled basin water management in the country.

A.7.2 Results of the Committee Meeting

The first meeting of the Water Committee was held in San-Pédro on July 29, the second one on December 14, 1998 and the third one on June 28, 1999. The organizations concerned to the water resources utilization of the San-Pédro river basin were invited to the Committee's meetings, and the discussions on various aspects were made among the attendants. As a result, the following three (3) issues were confirmed.

- the importance of municipal water supply and the environmental protection of the Rapide Grah Classified Forest Area
- the Water Committee acts as the government body on determine the optimum use of the dam water
- the priority order should be municipal water supply, irrigation and power generation from the top

At the last meeting, the High Commissioner, chairman of the Committee, expressed that the San-Pédro dam operation regulation shall be formulated based on the suggestion by the JICA Study Team, referring the Bandama basin water management regulation, by the member of the committee as soon as possible

The relating documents are presented in Data Book of this Report.

A.8 Recommendations

(1) The rainfall in and around the Study Area is generally decreasing these decades as mentioned the previous section. This tendency may continue in the future, too, and the drought discharge of the San-Pédro river may become small beyond the levels considered in the Study. It is, therefore, to prepare some rules which stipulates the manners and importance of water use among the users providing against such emergency cases, although the water balance during the draught is confirmed in the Study.

(2) The San-Pédro dam has been operated and managed exclusively by CIE for their hydropower generation so far. In the future, however, the irrigation and the municipal water supply sections increase their water demand, and the industrial section which is not considered in the Study may require its demand on river water. It is indispensable to coordinate among the water users such as CIE, PNR, SODECI, and the City Municipality, etc. relating to the allocation of water resources in order to facilitate the communication among them, and to prepare water allocation rules with their due understandings as well as to provide against emargency.

(3) A series of discussions and meetings of the Technical Consulting Committee on Water Use of San-Pédro Dam has been held among the various government and private agencies relating to water use and watershed management of the San-Pédro river basin during the Study. In these committee meeting, the results of the Study were reported and explained for the attendants' understandings as well as for receiving their comments. It was consequently agreed as a basic understanding among them that the sector-wise priority of water allocation is put with the order of the municipal water supply, the irrigation water supply and the hydropower generation.

It is necessary to prepare the rules and regulations of the water allocation and use based on the quantified conditions to enable realistic operation and management for the fair water resources allocation. It is recommended to continue to hold the discussions and meetings of the committee after the Study in order to realize the proper water allocation under the fair rules and regulations.

(4) In the study on the effect by constructing intake weir on the San-Pédro river, it is concluded that the construction of such river structures would cause flood damage especially in the conserved forests areas on right bank of the river. It may require long and high flood protection dikes and drainage sluices on the dikes to prevent the conserved area from such damages. It is, therefore, not recommended to take the irrigation water from the San-Pédro river by gravity.

(5) The effect of tide is also one of the important issues. The saline water is confirmed to intrude into the river up to the bridge of the San-Pédro - Soubré national road in the Study. On the other hand, no water is often released at the tail of San-Pédro dam, which may result in water contamination and shortage of raw water for municipal water supply in the downstream stretch as well as intrusion of saline water from the river mouth. It is then recommended to keep the minimum flow at least flow in the river to mitigate these effects.

Furthermore, the river mouth is frequently closed by sand sediments mainly by the tide current, and it causes serious flood damages in the low lands along the downstream of the San-Pédro river. The sand sediments are at present removed by the farmers getting troubles by the flood. It is necessary to take substantial measures to prevent such clogging at the river mouth as soon as possible.

Table A.3.1 Summary of Annual Rainfall

Year	San-Pedro	Sassandra	Tabou	Soubre	San-Pedro Dam	IDEFOR (San-Pedro)
1922			1,676.1			
1923			1,643.0			
1924			2,551.2			
1925						
1926						
1927						
1928			3,217.1			
1929		834.0	2,523.0			
1930		1,115.0				
1931		1,028.5				
1932		1,093.5	2,221.2			
1933		2,528.8				
1934		901.0				
1935		2,760.5	2,939.8			
1936		1,338.3	2,576.5			
1937		904.2	2,188.5			
1938		1,803.4	2,620.4			
1939		900.5	1,745.1			
1940		1,761.3	1,936.8	1,535.5		
1941		1,639.9	2,763.0	1,662.8		
1942		1,420.8	1,570.2	1,331.1		
1943		1,730.6	2,759.5	2,419.1		
1944		1,788.7	2,289.4	1,643.0		
1945		894.6	1,956.8	1,516.7		
1946		1,006.3	1,322.4	1,284.6		
1947		1,686.8	3,374.2	1,547.8		
1948		1,502.9	1,583.8	1,439.8		
1949		1,756.6	2,373.1	1,789.9		
1950		1,616.2	2,043.6	1,543.9		
1951		2,229.5	3,207.8	1,883.1		
1952		2,198.5	3,044.8	1,625.3		
1953		2,194.9	2,219.3	1,455.6		
1954		1,867.7	2,844.1	1,537.4		
1955		1,790.0	3,400.3	2,050.4		
1956		1,453.4	2,022.0	1,609.7		
1957		1,912.2	2,235.4	1,785.0		
1958		1,645.7	2,515.3	1,394.0		
1959		2,035.0	2,081.4	1,714.7		
1960		1,516.4	2,444.7	1,790.5		
1961		1,760.7	1,916.7	1,328.7		
1962		2,249.3	2,092.7	1,851.6		
1963		1,921.6	2,824.8	1,769.7		
1964		2,156.8	1,883.7	1,469.5		
1965		1,476.6	2,191.0	1,418.0		
1966		1,394.7	1,770.2	1,797.4		
1967		1,550.0	1,742.9	1,102.1		
1968		1,735.8	2,944.9	2,143.6		
1969		1,967.7	2,224.4	1,499.7		
1970		1,646.3	2,778.9	1,486.1		
1971		1,726.5	2,629.0	1,390.4		
1972		1,360.2	2,137.8	1,289.0		
1973		1,391.6	2,350.9	1,368.2		1,533.3
1974		1,949.0	2,147.0	840.7		
1975		1,343.7	1,779.4	1,012.8		1,414.4
1976		1,631.6	2,213.8	1,256.4		1,671.9
1977	1,163.1	1,106.5	2,219.9	1,177.5		1,090.4
1978	1,358.3	1,375.0	2,892.0	1,232.4		1,389.9
1979	1,627.3	1,950.4	2,268.2	1,352.2		1,595.6
1980	1,406.6	1,272.8	2,417.5			1,409.1
1981	1,202.0	1,081.8	2,221.3	1,269.8		1,166.3
1982	2,066.9	1,667.0	2,382.5	1,228.0		1,636.5
1983	1,404.2	1,083.1		1,253.1		1,257.0
1984	1,557.9	1,279.0	3,351.0	1,532.4		1,828.8
1985	1,170.1	1,025.1	1,815.5	1,580.3		1,534.6
1986	1,401.1	1,499.1	1,673.4			1,298.2
1987	1,321.5	1,140.0	2,846.4	1,463.0		1,354.7
1988	975.7	1,040.1	2,347.6	1,213.9	1,349.9	1,267.2
1989	2,024.7	1,657.0	2,916.0	1,448.0	936.0	1,466.4
1990	818.1		2,499.9	1,395.7		972.2
1991		1,182.9	1,994.4	1,220.1		1,361.2
1992	1,041.2	1,233.8	2,608.1	1,031.3	1,114.6	1,317.8
1993	1,449.6	1,645.1	2,073.4	1,452.1	1,497.0	1,285.2
1994	1,261.1	1,085.1	2,042.0	1,487.9	1,511.5	1,337.7
1995	1,296.5	1,102.3	1,630.5	1,450.8	1,507.5	995.2
1996	1,356.8	1,204.0	1,996.0	1,868.8		1,017.8
1997		1,117.3	1,219.3			1,297.4
Ave.	1,363.3	1,527.4	2,307.8	1,495.3	1,319.4	1,354.1
After 1971	1,363.3	1,351.9	2,256.6	1,325.6	1,319.4	1,354.1
Before 1970	-	1,636.1	2,339.5	1,626.7	-	-

Table A.4.1 Mean High Spring Tide and Recorded Maximum High Tide in San-Pedro Port

High Spring Tide (Unit: IGN m)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Jan	0.81	0.81	1.02	1.02	0.92	-	1.22	0.96	0.98	0.95	-
Feb	0.80	0.84	1.16	1.11	1.09	-	1.03	0.81	1.12	0.91	-
Mar	1.09	1.00	1.11	1.13	1.12	-	1.09	1.02	1.00	1.12	-
Apr	0.60	0.96	1.06	0.93	1.03	-	1.04	-	0.99	1.16	-
May	-	1.04	0.90	1.14	0.97	-	0.80	0.78	1.00	1.07	-
Jun	0.72	0.68	0.75	0.93	-	-	0.78	0.82	0.86	0.93	-
Jul	0.86	0.87	0.93	0.80	0.58	-	1.00	0.82	0.74	0.92	-
Aug	0.84	-	1.01	0.97	-	-	0.94	0.87	0.86	0.97	0.99
Sep	-	0.98	1.05	1.08	-	-	1.01	1.00	0.96	0.92	1.01
Oct	-	1.04	1.14	1.08	-	-	0.95	1.07	1.04	1.07	0.97
Nov	-	1.02	0.81	1.18	-	-	0.87	1.04	1.08	1.13	-
Dec	0.96	0.86	0.84	-	-	-	0.90	0.89	1.02	0.82	0.89
Average	-	0.91	0.98	1.03	-	-	0.96	0.91	0.97	0.99	-
										Mean:	0.96

Maximum High Tide (Unit: IGN m)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Jan	0.93	0.89	1.02	1.02	0.92	-	1.22	0.96	0.98	0.97	-
Feb	0.84	0.96	1.19	1.11	1.12	-	1.05	0.87	1.12	1.14	-
Mar	1.09	1.08	1.12	1.13	1.12	-	1.09	1.03	1.04	1.12	-
Apr	0.83	1.04	1.07	0.93	1.03	-	1.04	-	1.00	1.16	-
May	-	1.07	1.11	1.16	1.00	-	0.94	0.90	1.00	1.08	-
Jun	0.79	0.76	0.82	0.93	-	-	0.78	0.89	0.86	1.00	-
Jul	0.86	0.90	0.93	0.84	0.58	-	1.00	0.82	0.77	1.04	-
Aug	0.84	-	1.04	1.00	-	-	0.96	0.89	0.86	1.00	1.02
Sep	-	1.00	1.05	1.08	-	-	1.01	1.00	0.96	1.01	1.01
Oct	-	1.04	1.15	1.08	-	-	0.98	1.07	1.04	1.07	0.98
Nov	-	1.03	0.94	1.18	-	-	0.91	1.10	1.09	1.13	-
Dec	0.96	0.91	0.86	-	-	-	0.93	0.94	1.04	0.86	0.91
Highest	-	1.08	1.19	1.18	-	-	1.22	1.10	1.12	1.16	-
										Recorded Highest:	1.22

Table A.4.2 Non-uniform Flow Calculation Results for the Present Course of the San-Pédro River

(Unit: m)

Distance (m)	River Bed	Discharges (m^3/sec) 5	10	20	50	100	150	200	250	300	350	400	450	Approximate Location of Major Facilities along the River Course
0	-5.54	0.96	0.96	0.96	0.96	0.96	[illegible]	0.96	0.96	0.96	0.96	0.96	0.96	River Mouth
1,000	-5.20	0.96	0.96	0.96	0.96	0.97	[illegible]	0.99	1.01	1.03	1.05	1.07	1.10	
2,000	-3.47	0.96	0.96	0.96	0.97	0.98	[illegible]	1.05	1.09	1.11	1.19	1.24	1.30	Near the San-Pédro Port
3,000	-4.75	0.96	0.96	0.96	0.97	1.00	[illegible]	[illegible]	1.18	[illegible]	1.29	1.36	1.43	
4,000	-3.85	0.96	0.96	0.96	0.97	1.01	[illegible]	[illegible]	1.26	1.28	1.36	1.44	1.53	
5,000	-5.47	0.96	0.96	0.96	0.97	1.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.48	1.57	Low Laying Tidal Compartment (0 – 5,000)
6,000	-3.43	0.96	0.96	0.96	0.98	1.03	1.1	1.19	1.28	1.38	1.48	1.58	1.68	
7,000	-3.56	0.96	0.96	0.97	0.99	1.08	1.2	[illegible]	1.36	1.47	1.58	1.69	1.79	Bridge of San-Pédro – Soubré National Road
8,000	-2.89	0.96	0.96	0.97	1.01	1.15	1.3	1.45	1.58	[illegible]	1.88	2.01	2.14	
9,000	-2.82	0.96	0.96	0.97	1.03	1.22	1.4	1.63	1.79	1.97	2.14	2.30	2.44	
10,000	-4.27	0.96	0.96	0.97	1.04	1.25	1.5	1.70	1.87	2.07	[illegible]	2.39	2.51	
12,000	-3.25	0.96	0.97	0.98	1.10	1.38	1.6	1.89	2.09	2.29	2.45	2.61	2.75	
14,000	-3.87	0.96	0.97	0.99	1.15	1.53	1.9	2.20	2.47	2.73	2.96	3.17	3.35	SODECI Pumping Station
16,000	-0.93	0.98	1.04	1.19	1.63	2.24	2.7	3.09	3.41	3.50	3.71	3.90	4.07	
18,000	0.22	1.40	1.65	1.97	2.55	3.21	3.4	3.58	3.89	3.98	4.19	4.38	4.55	
20,000	1.15	1.94	2.21	2.58	3.26	3.97	4.26	4.26	4.48	4.65	4.87	5.07	5.2	
21,000	1.21	2.24	2.54	2.92	3.64	4.39	4.74	4.93	5.20	5.36	5.54	5.71	5.8	
22,000	1.97	2.91	3.19	3.57	4.27	4.96	5.38	5.67	5.97	6.16	6.36	6.54	6.7	
24,000	2.22	3.17	3.46	3.87	4.64	5.40	5.89	6.26	6.60	6.87	7.11	7.31	7.5	
25,800	1.81	3.27	3.62	4.08	4.92	5.74	6.27	6.68	7.04	7.34	7.60	7.83	8.0	Existing Irrigation Pumping Station
28,000	3.07	3.79	4.03	4.42	5.22	6.07	6.64	7.09	7.47	7.72	7.98	8.20	8.3	
30,000	2.32	3.85	4.14	4.57	5.44	6.34	6.97	7.45	7.87	8.15	8.43	8.67	8.8	
32,000	3.58	4.32	4.62	5.05	5.89	6.80	7.46	7.97	8.39	8.70	8.98	9.21	9.4	
33,000	4.06	4.69	4.95	5.33	6.15	7.07	7.75	8.29	8.72	9.06	9.36	9.61	9.8	
35,000	6.70	7.05	7.20	7.44	7.95	8.60	9.14	9.61	10.02	10.38	10.70	11.00	11.2	
37,000	8.82	9.69	9.92	10.17	10.63	11.12	11.41	11.72	11.90	12.11	12.32	12.51	12.6	Junction with the Kpohn River
38,000	9.33	10.09	10.33	10.63	11.20	11.75	12.14	12.47	12.69	12.92	13.14	13.34	13.5	Junction with the Nire River
39,000	10.43	10.92	11.08	11.32	11.82	12.38	12.79	13.15	13.42	13.68	13.92	14.14	14.3	
41,000	7.54	10.94	11.11	11.36	11.89	12.51	12.97	13.38	13.70	14.01	14.30	14.56	14.8	
43,000	6.96	10.94	11.11	11.36	11.91	12.55	13.04	13.46	13.81	14.13	14.43	14.71	14.9	
45,000	7.82	10.94	11.11	11.37	11.95	12.64	13.17	13.62	14.00	14.35	14.66	14.95	15.2	
47,000	8.59	10.94	11.12	11.39	11.99	12.71	13.27	13.76	14.15	14.52	14.86	15.16	15.4	
49,000	7.89	10.95	11.13	11.41	12.05	12.84	13.44	13.95	14.38	14.77	15.12	15.44	15.7	
Flow Capacity		← 150 m^3/sec →						← 450 m^3/sec →						

Note: Shaded figures are considered to exceed the flow capacity of river.

Table A.4.2 [illegible] Course of the San Pedro River

Distance (m)	River Bed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	[illegible]	0.96	0.96	0.96	0.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	River Mouth
1,000	-5.26	0.96	0.96	0.96	0.96	0.97	[illegible]	[illegible]	1.01	1.02	1.05	1.07	[illegible]	
2,000	-3.47	0.96	0.96	0.96	0.97	0.98	1.0	1.05	1.09	1.14	1.19	1.25	1.30	Near the San Pedro Port
3,000	-4.75	0.96	0.96	0.96	0.97	1.00	1.0	1.09	1.19	1.22	1.29	1.36	[illegible]	
4,000	-3.85	0.96	0.96	0.96	0.97	1.01	1.0	1.22	1.20	1.28	1.36	1.44	[illegible]	
5,000	-5.47	0.96	0.96	0.96	0.97	[illegible]	1.0	1.34	1.22	1.31	1.40	1.48	[illegible]	
6,000	-3.33	0.96	0.96	0.96	0.98	[illegible]	[illegible]	[illegible]	1.28	1.38	1.48	1.58	[illegible]	
7,000	-3.56	0.96	0.96	[illegible]	[illegible]	[illegible]	[illegible]	1.30	1.36	1.47	1.58	1.69	[illegible]	Bridge [illegible]
8,000	-2.89	0.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.58	1.73	1.88	2.01	[illegible]	
9,000	-2.82	0.96	0.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.79	1.97	2.14	2.30	[illegible]	
10,000	[illegible]	0.96	0.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
12,000	-3.25	0.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.29	[illegible]	[illegible]	[illegible]	
14,000	-3.87	0.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.96	[illegible]	3.33	[illegible] Station
16,000	-0.93	0.98	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
18,000	0.22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
20,000	1.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
21,000	1.21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
22,000	1.97	2.91	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
24,000	2.22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
25,800	1.83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Station
28,000	3.07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
30,000	2.32	3.88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
32,000	3.58	4.32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
33,000	4.06	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
35,000	6.70	7.05	7.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
37,000	8.82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Junction with the [illegible] River
38,000	9.33	10.09	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Junction with the [illegible] River
39,000	10.43	10.92	11.08	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
41,000	7.54	10.94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
43,000	6.96	10.94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
45,000	7.82	10.94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
47,000	[illegible]	10.94	11.12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
49,000	7.89	10.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Flow			← [illegible] →											
Capacity						← [illegible] →								[illegible]

Table A.5.1 Summary of Water Balance Simulation at San-Pédro Dam (1/2)

Monthly Summary
(1991 - 1992)

Item	Flow-in Dis. (m3/s)	Flow-in Vol. (MCM)	Irri. Vol. (MCM)	Hydro-Power (MCM)	Operation Hours	Run-off Vol. From Spillway (MCM)	WL in Reservoir (m)	Dis. At Tail of Dam (m3/s)
April	24.04	62.30	3.81	45.63	507	0.05	20.91	17.62
May	51.38	137.61	2.11	66.96	744	65.76	21.16	49.55
June	35.19	91.20	1.70	64.80	720	22.92	21.31	33.84
July	47.08	126.11	1.55	66.96	744	70.73	20.06	51.41
August	67.30	180.25	0.31	64.17	713	106.44	20.98	63.70
September	15.89	41.19	3.16	50.22	558	1.34	19.56	19.89
October	19.47	52.16	3.45	48.69	541	0.00	19.56	18.18
November	9.09	23.55	4.17	19.44	216	0.00	19.55	7.50
December	7.08	18.96	2.98	15.93	177	0.00	19.56	5.95
January	3.20	8.58	3.30	5.31	59	0.00	19.56	1.98
February	3.50	8.46	0.00	8.46	94	0.00	19.56	3.50
March	5.34	14.31	2.19	12.15	135	0.00	19.55	4.54
Annual	24.05	764.70	28.72	468.72	5208	267.23	-	1.98

Monthly Summary
(1992 - 1993)

Item	Flow-in Dis. (m3/s)	Flow-in Vol. (MCM)	Irri. Vol. (MCM)	Hydro-Power (MCM)	Operation Hours	Run-off Vol. From Spillway (MCM)	WL in Reservoir (m)	Dis. At Tail of Dam (m3/s)
April	7.83	20.31	3.81	30.15	335	0.66	19.56	11.89
May	40.33	108.01	2.11	35.10	390	52.66	21.37	32.77
June	43.76	113.43	1.70	64.44	716	65.35	19.56	50.07
July	7.16	19.18	1.55	17.64	196	0.00	19.56	6.59
August	3.45	9.24	0.31	8.91	99	0.00	19.56	3.33
September	4.67	12.10	3.16	9.00	100	0.00	19.55	3.47
October	16.26	43.56	3.45	34.74	386	0.00	20.19	12.97
November	35.24	91.35	4.17	64.80	720	19.92	20.44	32.69
December	7.56	20.24	2.98	25.11	279	0.00	19.55	9.38
January	2.08	5.57	3.30	2.25	25	0.00	19.56	0.84
February	2.94	7.11	0.00	7.11	79	0.00	19.56	2.94
March	5.64	15.10	2.19	12.96	144	0.00	19.56	4.84
Annual	14.74	465.20	28.72	312.21	3469	138.60	-	0.84

Monthly Summary
(1993 - 1994)

Item	Flow-in Dis. (m3/s)	Flow-in Vol. (MCM)	Irri. Vol. (MCM)	Hydro-Power (MCM)	Operation Hours	Run-off Vol. From Spillway (MCM)	WL in Reservoir (m)	Dis. At Tail of Dam (m3/s)
April	4.67	12.11	3.81	8.37	93	0.00	19.55	3.23
May	7.71	20.66	2.11	17.55	195	0.00	19.69	6.55
June	18.30	47.42	1.70	46.71	519	0.00	19.55	18.02
July	6.59	17.64	1.55	16.11	179	0.00	19.55	6.01
August	2.36	6.33	0.31	5.94	66	0.00	19.56	2.22
September	25.19	65.29	3.16	48.51	539	6.31	20.40	21.15
October	66.00	176.77	3.45	66.96	744	97.86	21.18	61.54
November	21.74	56.36	4.17	60.93	677	7.16	19.56	26.27
December	12.08	32.36	2.98	29.34	326	0.00	19.56	10.95
January	4.79	12.82	3.30	9.54	106	0.00	19.55	3.56
February	4.74	11.46	0.00	11.43	127	0.00	19.56	4.72
March	8.36	22.38	2.19	20.16	224	0.00	19.56	7.53
Annual	15.21	481.60	28.72	341.55	3795	111.33	-	2.22

Table A.5.1 Summary of Water Balance Simulation at San-Pédro Dam (2/2)

Monthly Summary
(1994 - 1995)

Item	Flow-in Dis. (m3/s)	Flow-in Vol. (MCM)	Irri. Vol. (MCM)	Hydro-Power (MCM)	Operation Hours	Run-off Vol. From Spillway (MCM)	WL in Reservoir (m)	Dis. At Tail of Dam (m3/s)
April	20.44	52.99	3.81	34.56	384	0.71	21.01	13.61
May	39.70	106.34	2.11	66.96	744	36.19	21.11	38.51
June	82.96	215.04	1.70	64.80	720	152.83	20.72	83.96
July	12.53	33.56	1.55	42.75	475	0.00	19.56	15.96
August	15.72	42.10	0.31	41.76	464	0.00	19.56	15.59
September	25.96	67.29	3.16	61.02	678	2.19	19.69	24.39
October	67.45	180.65	3.45	66.96	744	93.66	21.33	59.97
November	47.98	124.38	4.17	64.80	720	62.34	20.71	49.05
December	8.02	21.49	2.98	29.07	323	0.00	19.56	10.85
January	5.23	14.02	3.30	10.80	120	0.00	19.56	4.03
February	1.82	4.40	0.00	4.32	48	0.00	19.56	1.79
March	20.51	54.93	2.19	48.60	540	0.00	20.06	18.15
Annual	29.03	917.18	28.72	536.40	5960	347.93	-	1.79

Monthly Summary
(1995 - 1996)

Item	Flow-in Dis. (m3/s)	Flow-in Vol. (MCM)	Irri. Vol. (MCM)	Hydro-Power (MCM)	Operation Hours	Run-off Vol. From Spillway (MCM)	WL in Reservoir (m)	Dis. At Tail of Dam (m3/s)
April	20.55	53.26	3.81	44.73	497	0.00	20.56	17.26
May	43.12	115.50	2.11	66.96	744	32.66	21.76	37.19
June	60.37	156.47	1.70	64.80	720	99.03	20.99	63.21
July	17.73	47.50	1.55	48.06	534	11.61	19.55	22.28
August	9.65	25.85	0.31	25.56	284	0.00	19.56	9.54
September	21.58	55.92	3.16	44.73	497	0.00	20.46	17.26
October	27.48	73.60	3.45	58.59	651	19.52	19.56	29.16
November	20.93	54.25	4.17	50.13	557	0.00	19.56	19.34
December	11.73	31.41	2.98	28.44	316	0.00	19.56	10.62
January	6.40	17.13	3.30	13.77	153	0.00	19.56	5.14
February	8.31	20.11	0.00	20.16	224	0.00	19.55	8.33
March	7.13	19.11	2.19	16.92	188	0.00	19.55	6.32
Annual	21.25	670.10	28.72	482.85	5365	162.82	-	5.14

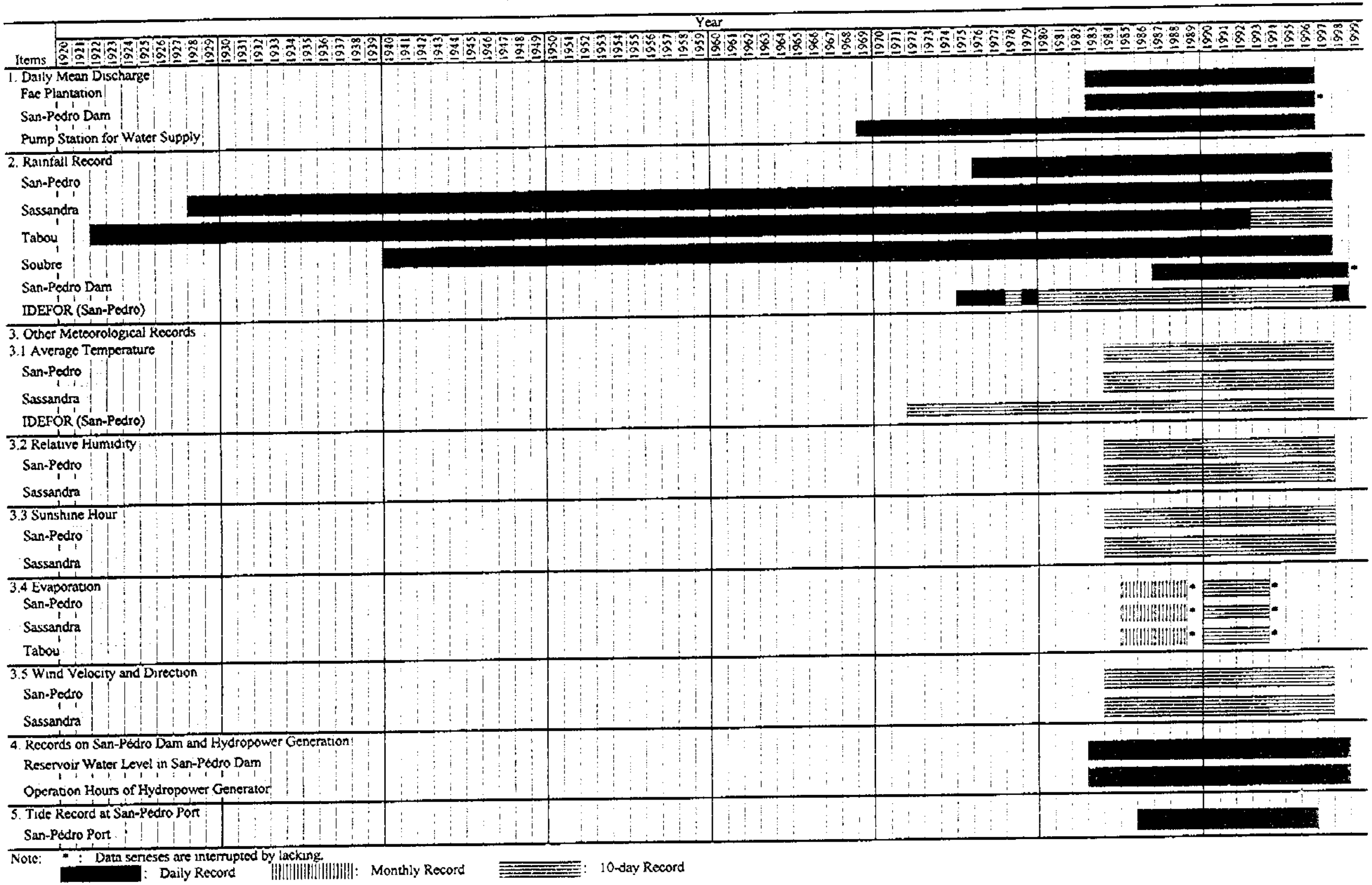
Table A.6.1 Water Quality of Tubewells in and around the Study Area

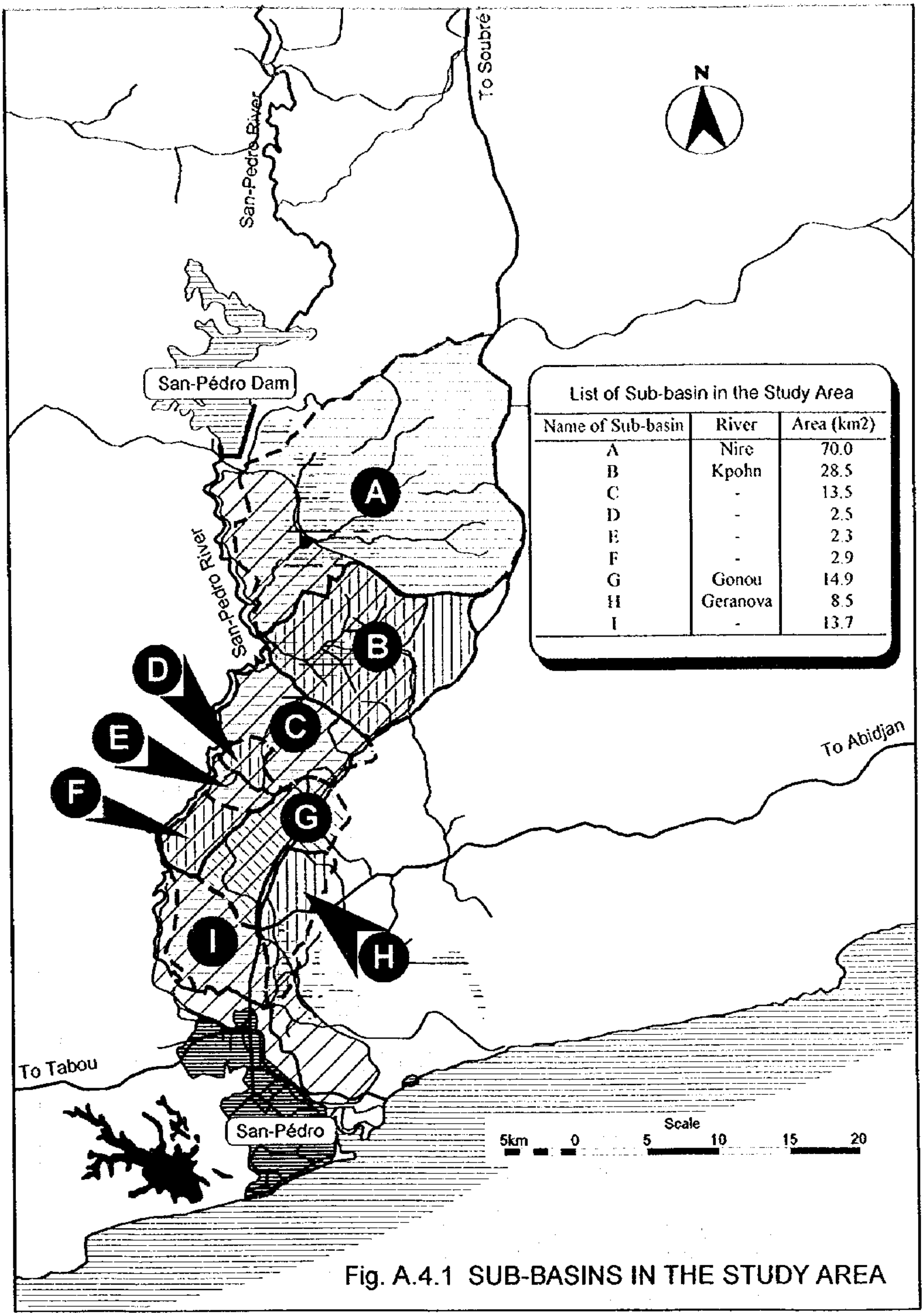
Tubewells	Allowable Values*	Lamene	Bidakro	Blaou	Cpt. Gilbert	Pt.Pedro (1)	Pt.Pedro (2)	Konankro	Dimoule	Kremouye	Enennekro	Cpt. Bernard (1)	Cpt. Bernard (2)	Koffikro	Kablake 1	Kablake 2
Physical Property																
Temperature (°C)	*30.0*	31.0	28.5	-	-	28.5	28.5	28.5	-	30.8	29.5	28.0	28.5	28.5	27.5	27.5
pH	*8.5*	6.1	6.8	-	-	6.6	7.1	6.4	-	5.9	6.5	6.3	6.4	6.3	6.6	6.6
Turbidity (NTU)	*1.0*	0.7	1.1	-	-	1.1	1.0	0.9	-	0.8	0.9	1.1	1.0	1.1	1.1	1.1
Color (mg/l Co/Pt)	*15.0*	2.5	10.0	-	-	15.0	15.0	5.0	-	10.0	10.0	15.0	15.0	15.0	5.0	5.0
Chemical Property																
Alkalinity (10 mg/l $CaCO_3$)	*0.0*	0.0	0.0	-	-	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alkalinity (bicarbonate) (10 mg/l CaCo3)	-	12.0	15.0	-	-	13.5	22.5	12.0	-	12.5	18.5	11.0	11.0	11.0	9.5	9.5
HCO_3^-(bicarbonate) (mg/l)	-	146.4	183.0	-	-	164.7	274.5	146.4	-	152.5	225.7	134.2	134.2	134.2	115.9	115.9
Hardness (10 mg/l CaCo3)	*30.0*	6.6	12.2	-	-	9.5	23.0	6.0	-	8.8	10.3	15.8	8.5	6.8	6.7	6.7
Calcium (10 mg/l CaCo3)	*19.0*	3.4	4.8	-	-	7.0	18.6	3.5	-	5.2	6.2	6.8	3.4	3.2	4.1	4.1
Magnesium (10 mg/l CaCo3)	*11.0*	3.2	7.4	-	-	2.5	4.4	2.5	-	3.6	4.1	9.0	5.1	3.6	2.6	2.6
Chloride (10 mg/l CaCo3)	*35.0*	1.0	2.5	-	-	1.5	2.5	1.0	-	2.0	2.0	1.5	1.5	2.5	1.0	1.0
Iron (mg/l)	*0.3*	0.06	0.60	-	-	0.35	0.80	0.25	-	0.25	0.35	0.35	0.40	0.35	0.16	0.15
Manganese (mg/l)	*0.1*	0.045	0.08	-	-	0.08	0.125	0.045	-	0.1	0.045	0.045	0.125	0.125	0.08	0.08
Disorved Oxygen (mg/l)	-	6.8	6.8	-	-	6.6	6.6	6.7	-	6.9	6.6	6.9	6.7	6.9	6.6	6.6
Nitrate (NO_3^- mg/l)	*50.0*	1.3	5.0	-	-	5.0	5.0	0.0	-	1.2	1.7	10.0	0.5	10.0	5.0	5.0
Nitrite (NO_2^- mg/l)	*3.0*	0.005	0.0	-	-	0.005	0.005	0.0	-	0.005	0.0	0.0	0.0	0.0	0.0	0.0
Ammonium (mg/l)	*0.5*	0.05	0.0	-	-	0.0	0.0	0.0	-	0.05	0.0	0.0	0.0	0.0	0.05	0.0
Phosphate (mg/l)	*12.0*	0.0	0.0	-	-	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Tubewells	SCAF (1)	SCAF (2)	Fahe (1)	Fahe (2)	Kouadio-kro	Liberia	Gabiadji (1)	Gabiadji (2)	Gabiadji (3)	Touredougou (1)	Touredougou (2)	Carrefour Kpote	Tiekoura-kro	Kpote (1)	Kpote (2)	Pt. Zuenoula
Physical Property																
Temperature (°C)	29.5	-	-	28.5	-	-	-	28.5	30.0	28.5	-	28.0	28.5	27.7	29.5	-
pH	7.1	-	-	6.8	-	-	-	6.4	6.8	6.5	-	6.4	6.0	7.5	7.2	-
Turbidity (NTU)	0.9	-	-	0.95	-	-	-	0.8	0.9	1.1	-	1.1	1.1	1.0	0.9	-
Color (mg/l Co/Pt)	10.0	-	-	5.0	-	-	-	5.0	10.0	15.0	-	5.0	15.0	10.0	5.0	-
Chemical Property																
Alkalinity (10 mg/l $CaCO_3$)	0.0	-	-	0.0	-	-	-	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	-
Alkalinity (bicarbonate) (10 mg/l CaCo3)	31.5	-	-	17.0	-	-	-	8.5	35.0	12.0	-	7.5	5.5	30.3	39.0	-
HCO_3^-(bicarbonate) (mg/l)	384.3	-	-	207.4	-	-	-	103.7	427.0	146.4	-	91.5	67.1	369.1	475.8	-
Hardness (10 mg/l CaCo3)	47.0	-	-	16.0	-	-	-	6.5	18.6	6.6	-	6.5	4.6	23.8	18.4	-
Calcium (10 mg/l CaCo3)	34.8	-	-	9.5	-	-	-	4.2	13.3	3.3	-	4.2	2.6	18.2	11.8	-
Magnesium (10 mg/l CaCo3)	12.2	-	-	6.5	-	-	-	2.3	5.3	3.3	-	2.3	2.0	5.6	6.6	-
Chloride (10 mg/l CaCo3)	2.5	-	-	2.5	-	-	-	1.0	2.0	1.0	-	1.5	1.5	2.5	2.0	-
Iron (mg/l)	0.30	-	-	0.65	-	-	-	0.25	0.19	0.25	-	0.35	0.30	0.35	0.20	-
Manganese (mg/l)	0.100	-	-	0.045	-	-	-	0.08	0.08	0.08	-	0.045	0.125	0.08	0.1	-
Disorved Oxygen (mg/l)	6.6	-	-	6.8	-	-	-	6.7	6.8	6.6	-	6.7	6.6	6.7	6.7	-
Nitrate (NO_3^- mg/l)	9.5	-	-	5.0	-	-	-	17.5	3.2	10.0	-	0.0	17.5	17.5	2.7	-
Nitrite (NO_2^- mg/l)	0.005	-	-	0.0	-	-	-	0.005	0.005	0.005	-	0.0	0.0	0.012	0.0	-
Ammonium (mg/l)	0.05	-	-	0.0	-	-	-	0.500	0.05	0.5	-	0.0	0.0	0.005	0.0	-
Phosphate (mg/l)	0.0	-	-	0.0	-	-	-	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	-

Note: * : Standard adopted for the rural water supply schemes by the Ministry of Economic Infrastructure

Fig. A.2.1 PERIOD OF COLLECTED DATA





List of Sub-basin in the Study Area

Name of Sub-basin	River	Area (km2)
A	Nire	70.0
B	Kpohn	28.5
C	-	13.5
D	-	2.5
E	-	2.3
F	-	2.9
G	Gonou	14.9
H	Geranova	8.5
I	-	13.7

Fig. A.4.1 SUB-BASINS IN THE STUDY AREA

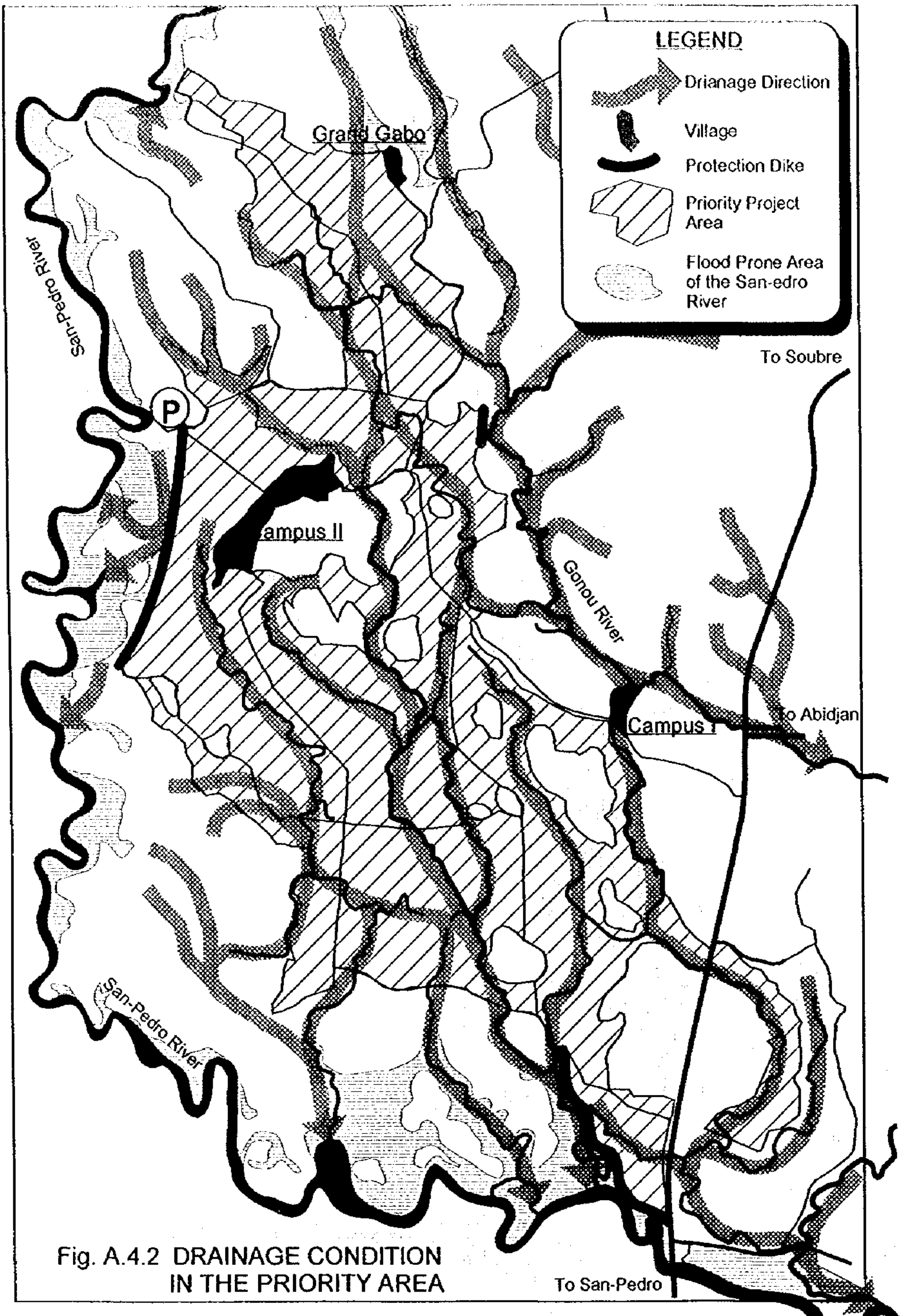


Fig. A.4.2 DRAINAGE CONDITION IN THE PRIORITY AREA

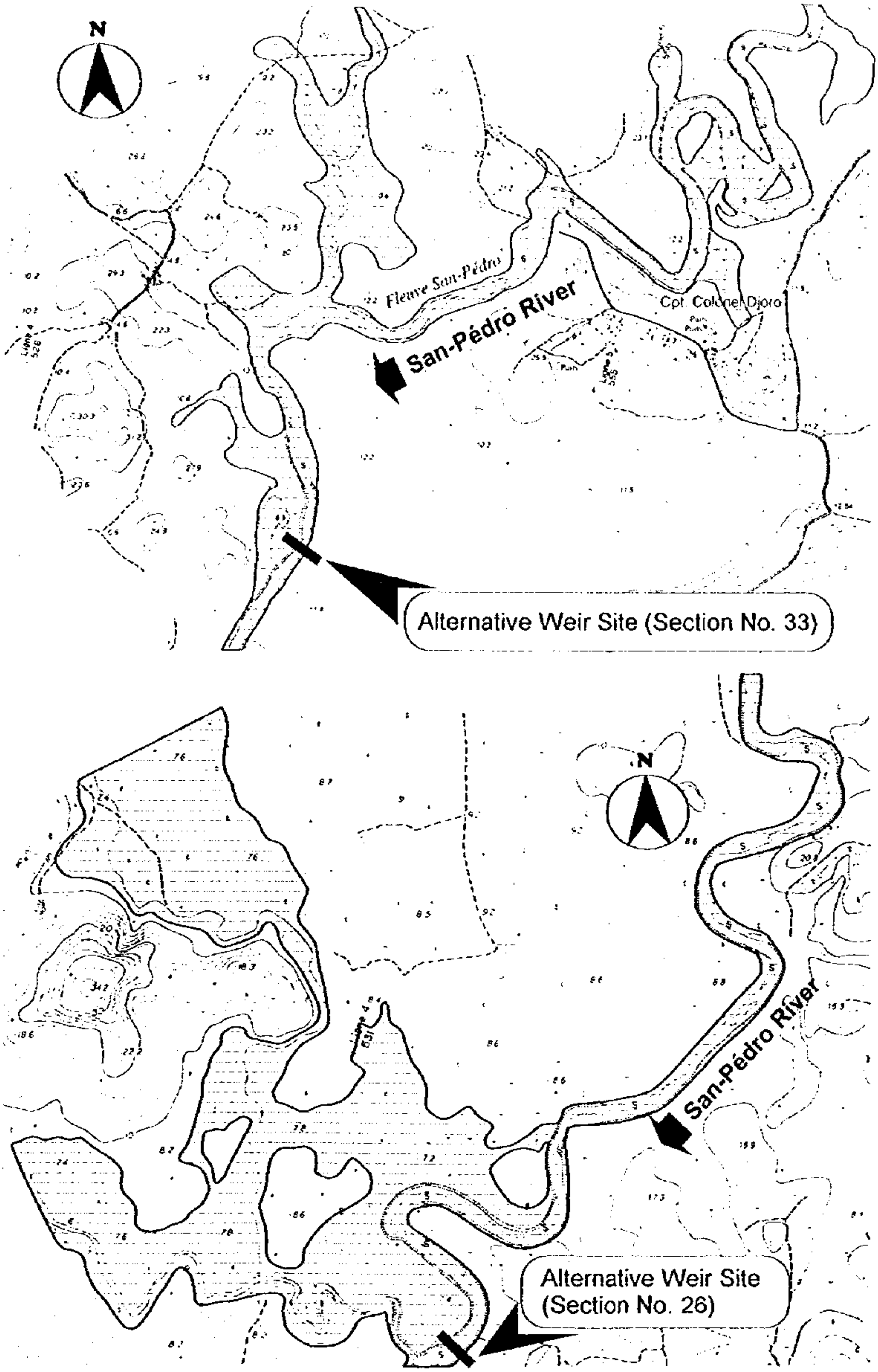


Fig. A.4.3 FLOOD AREA BY CONSRUCTION OF HEAWORKS

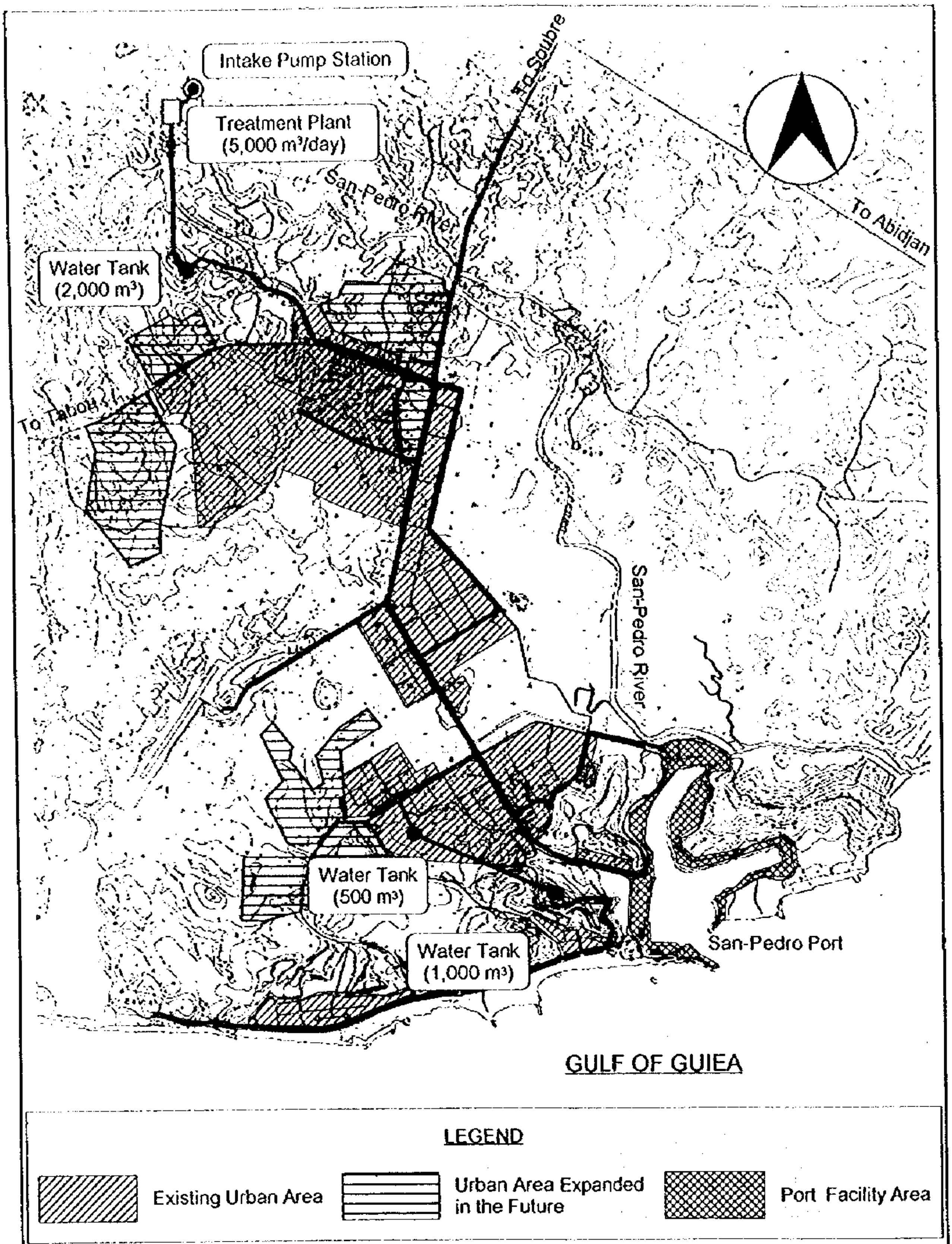


Fig. A.5.1 WATER SUPPLY SYSTEM FOR SAN-PEDRO MUNICIPARITY

(Unit: MCM)

Description	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
1. Upstream of Dam													
Run-off at San-Pedro Dam	*27.2*	*32.3*	*69.5*	*38.6*	*35.5*	*55.3*	*61.2*	*41.7*	*19.5*	*10.0*	*7.9*	*16.6*	*415.2*
Evaporation at Dam (8km²)	0.4	0.4	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.4	4.5
Irrigation Req. for Three (3) Areas	3.8	2.1	1.7	1.6	0.3	3.2	3.4	4.2	3.0	3.3	0.0	2.2	28.7
Reserve for Next Month	1.9	2.2	4.8	2.7	2.5	3.8	4.2	2.9	-9.0	-4.6	-3.7	-7.7	-
Storage in Reservoir (Max. 25 MCM)	1.9	4.1	8.9	11.6	14.1	17.9	22.1	25.0	16.0	11.3	7.7	0.0	-
Balance at Tail of Dam	*21.1*	*27.5*	*62.7*	*34.0*	*32.4*	*48.0*	*53.2*	*34.3*	*25.3*	*10.8*	*11.1*	*21.6*	*382.0*
(Possible Hydropower (hr))	(164)	(214)	(488)	(264)	(252)	(373)	(414)	(267)	(196)	(81)	(86)	(168)	(2,971)
2. Middle Reach from Dam to SODECI Intake													
Run-off downstream of Dam	0.8	1.9	9.3	2.5	2.2	1.1	1.5	0.9	0.7	1.2	1.0	0.8	23.8
Run-off from Kre River	2.5	5.7	28.5	7.8	6.7	3.5	4.5	2.6	2.0	3.7	3.1	2.3	72.8
Run-off from Kre - SODECI Stretch	0.4	0.8	4.1	1.1	1.0	0.5	0.6	0.4	0.3	0.5	0.4	0.3	10.4
Balance at SODECI	*24.7*	*35.9*	*01.6*	*45.4*	*42.3*	*53.1*	*59.8*	*38.1*	*28.2*	*16.2*	*15.6*	*25.0*	*489.0*
3. Downstream Reach from SODECI Intake to River Mouth													
Municipal Water Demand (SODECI)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.9	11.0
Balance after SODECI	*23.8*	*34.9*	*03.7*	*44.5*	*41.4*	*52.2*	*58.9*	*37.2*	*27.3*	*15.3*	*14.8*	*24.1*	*478.0*
Run-off after SODECI	0.2	0.4	2.0	0.5	0.5	0.2	0.3	0.2	0.1	0.3	0.2	0.2	5.0
Balance at River Mouth	*24.0*	*35.3*	*05.7*	*45.0*	*41.9*	*52.4*	*59.2*	*37.4*	*27.4*	*15.5*	*15.0*	*24.2*	*483.0*

Note: - The production capacity of 30,000 m³/day is considered for the future demand of the municipal water supply.
- Industrial water supply is not considered in the above balance, since no realistic industrial development plan does not exist.

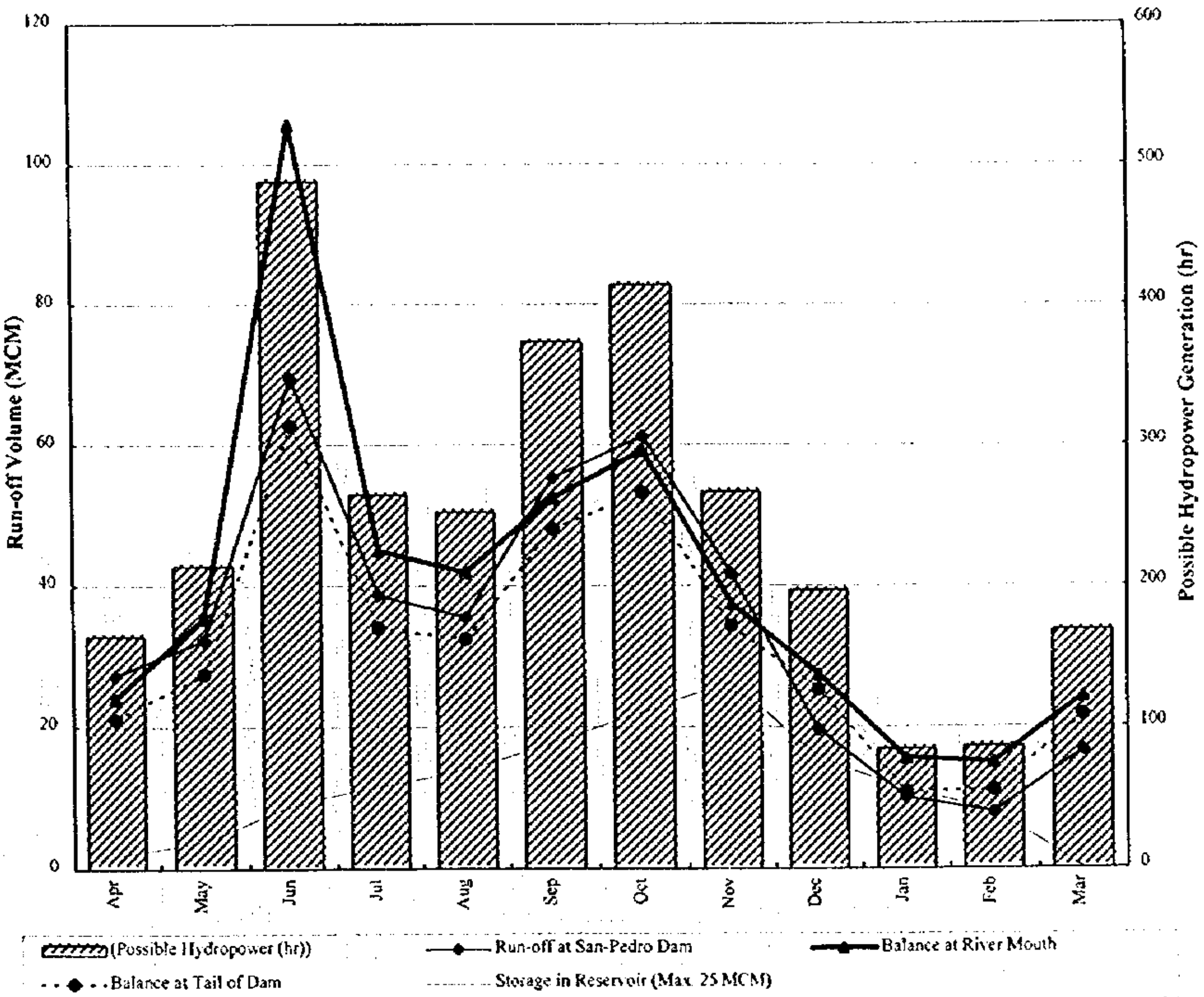


Fig. A.5.2 FUTURE WATER BALANCE IN SAN-PEDRO RIVER BASIN

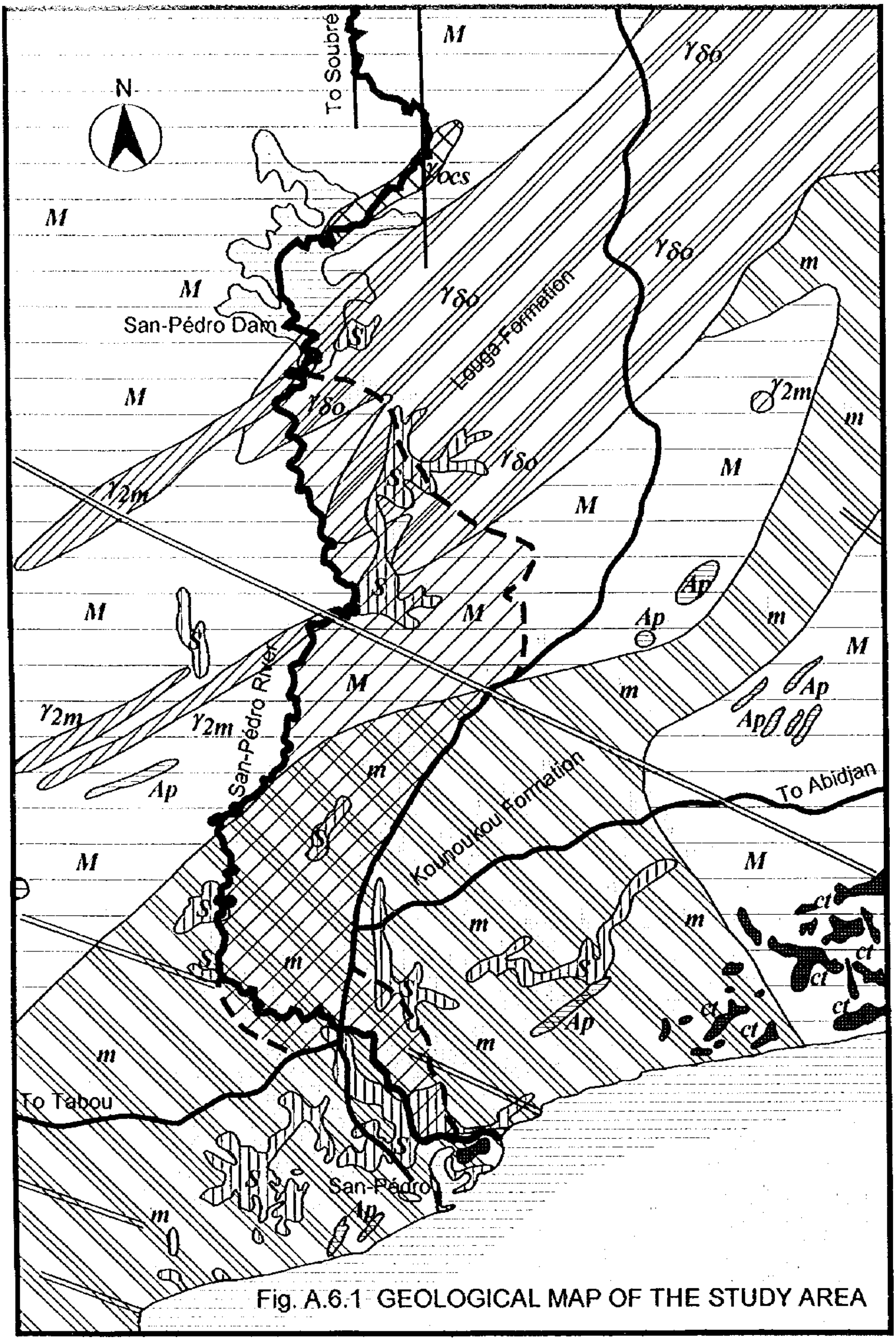
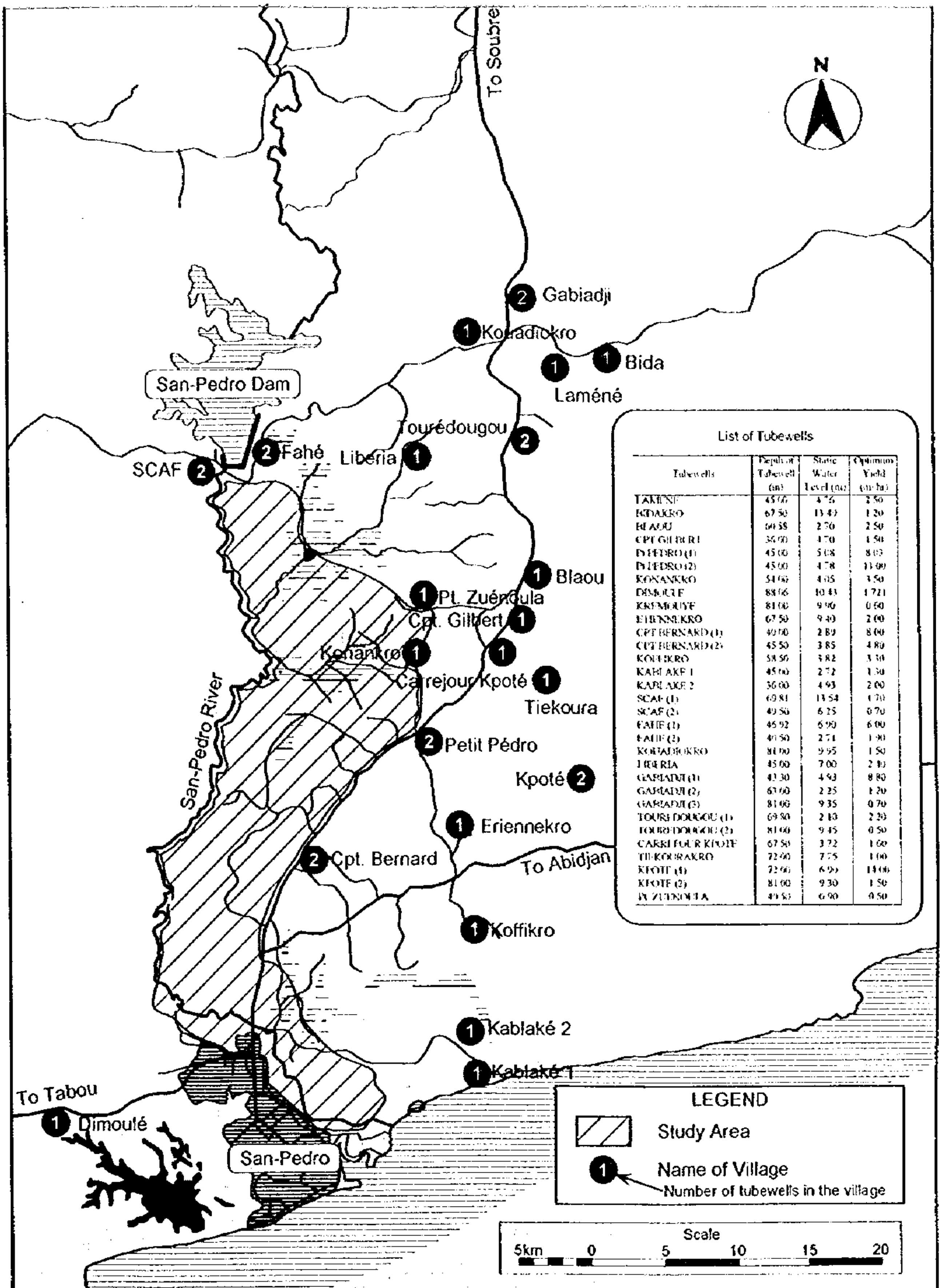


Fig. A.6.1 GEOLOGICAL MAP OF THE STUDY AREA



List of Tubewells

Tubewells	Depth of Tubewell (m)	Static Water Level (m)	Optimum Yield (m³/h)
LAMENE	45.00	4.76	2.50
BIDAKRO	67.50	13.40	1.20
BLAOU	60.55	2.70	2.50
CPT GILBERT	36.00	4.70	1.50
PT PEDRO (1)	45.00	5.08	8.00
PT PEDRO (2)	45.00	4.78	13.00
KONANKRO	54.00	4.05	3.50
DIMOULE	88.06	10.43	1.721
KREMOUYE	81.00	9.90	0.50
ERIENNEKRO	67.50	9.40	2.00
CPT BERNARD (1)	40.00	2.89	8.00
CPT BERNARD (2)	45.50	3.85	4.80
KOFFIKRO	58.50	3.82	3.30
KABLAKE 1	45.00	2.72	1.30
KABLAKE 2	36.00	4.93	2.00
SCAF (1)	69.81	13.54	1.70
SCAF (2)	49.50	6.25	0.70
FAHE (1)	45.92	6.90	6.00
FAHE (2)	40.50	2.71	1.90
KOUADIOKRO	81.00	9.95	1.50
LIBERIA	45.00	7.00	2.10
GABIADJI (1)	43.30	4.93	8.80
GABIADJI (2)	63.00	2.25	1.20
GABIADJI (3)	81.00	9.35	0.70
TOUREDOUGOU (1)	69.80	2.10	2.20
TOUREDOUGOU (2)	81.00	9.45	0.50
CARREFOUR KPOTE	67.50	3.72	1.00
TIEKOURAKRO	72.00	7.75	1.00
KPOTE (1)	72.00	6.90	14.00
KPOTE (2)	81.00	9.30	1.50
PT ZUENOULA	49.50	6.90	0.50

Fig. A.6.2 LOCATION OF EXISTING TUBEWELLS IN AND AROUND OF THE STUDY AREA