JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

No. 41

THE KINGDOM OF CAMBODIA
PHNOM PENH WATER SUPPLY AUTHORITY

THE STUDY ON PHNOM PENH WATER SUPPLY SYSTEM IN THE KINGDOM OF CAMBODIA

FINAL REPORT

VOLUME 2 : MAIN REPORT

NOVEMBER 1993

TOKYO ENGINEERING CONSULTANTS CO., LTD.
in association with
NIHON SUIDO CONSULTANTS CO., LTD.

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ABBREVIATIONS

CCWTP	Chamcar Morn Water Treatment Plant
CIF	Cost, Insurance and Freight
CIP	Cast Iron Pipe
cmd	Cubic meters per day
COD	Chemical Oxygen Demand
CPI	Consumer Price Index
DCIP	Ductile Cast Iron Pipe
EOJ	Embassy of Japan
FC	Faecal Coliform
FIRR	Financial Internal Rate of Return
GDP	Growth Domestic Product
IBRD(WD)	International Bank for Reconstruction and Development (World Bank)
JICA	Japan International Cooperation Agency
l/s	Liters per second
Min.	Minutes
Mn	Manganese
NGO	Non-Governmental Organizations
ODA	Official Development Assistand
OXFAM	Oxford Famine
O/M	Operation and Maintenance
PPWSA	Phnom Penh Water Supply Authority
PPWTP	Phum Prek Water Treatment Plant
PVC	Polyvinyl Chloride Pipe
RPM	Revolutions per minute
SS	Suspended Solids
TC	Total Coliform
UNDP	United Nations Development Program
UNHCR	United Nations High Commissiom for Refugee
UNICEF	United Nations Children's Fund
UNTAC	United Nations Transitional Authority in Cambodia
URS	Urgent Rehabilitation Schemes
URW	Urgent Rehabilitation Works
USAID	Untied States Agency for International Development
WHO	World Health Organization
WL	Water Level
WTP	Water Treatment Plant

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1 Background

After the signing of Paris Agreements in November 1991, Cambodia with the aid of international organizations and funding countries has started reconstruction and restoration of the infrastructure of the country deeply damaged during the long civil war.

The population of Phnom Penh Municipality is now estimated to be about 0.7 million and is the biggest city in the country. The Municipality's water supply system, which was constructed between 1895 and 1960, has deteriorated profoundly. Its capacity has decreased from 140,000 m^3 per day before the civil war to 63,000 m^3 per day today, because of destruction of the facilities and its neglected maintenance during the war, lack of spare parts equipment and other materials and shortage of power supply.

The severe service inadequacy is becoming a keen social problem of the community. The manpower shortage, due to loss of experienced personnel, especially engineers in the civil war, makes it very difficult to operate and maintain the water supply system properly.

Under the circumstances mentioned above, the State of Cambodia made an official request to the Government of Japan for the technical assistance for the rehabilitation and improvement of the water supply system. In response to the request, the Government of Japan has decided to conduct the Master Plan and Feasibility Study on Phnom Penh Water Supply System (hereinafter referred to as "the Study").

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for implementation of the technical cooperation programs of the Government of Japan, undertakes the Study in close cooperation with authorities concerned of the State of Cambodia.

The Study Team organized by JICA was dispatched to Phnom Penh in February 1993. They stayed in Phnom Penh until May 1993, to conduct the on-site survey and data collection. After the analysis works in Japan from May to July, the Interim Report was submitted to the authorities concerned of the State of Cambodia in August 1993. This Final Report is prepared in accordance with the Scope of Work, and presents the outcome of the Study carried out both in Cambodia and Japan.

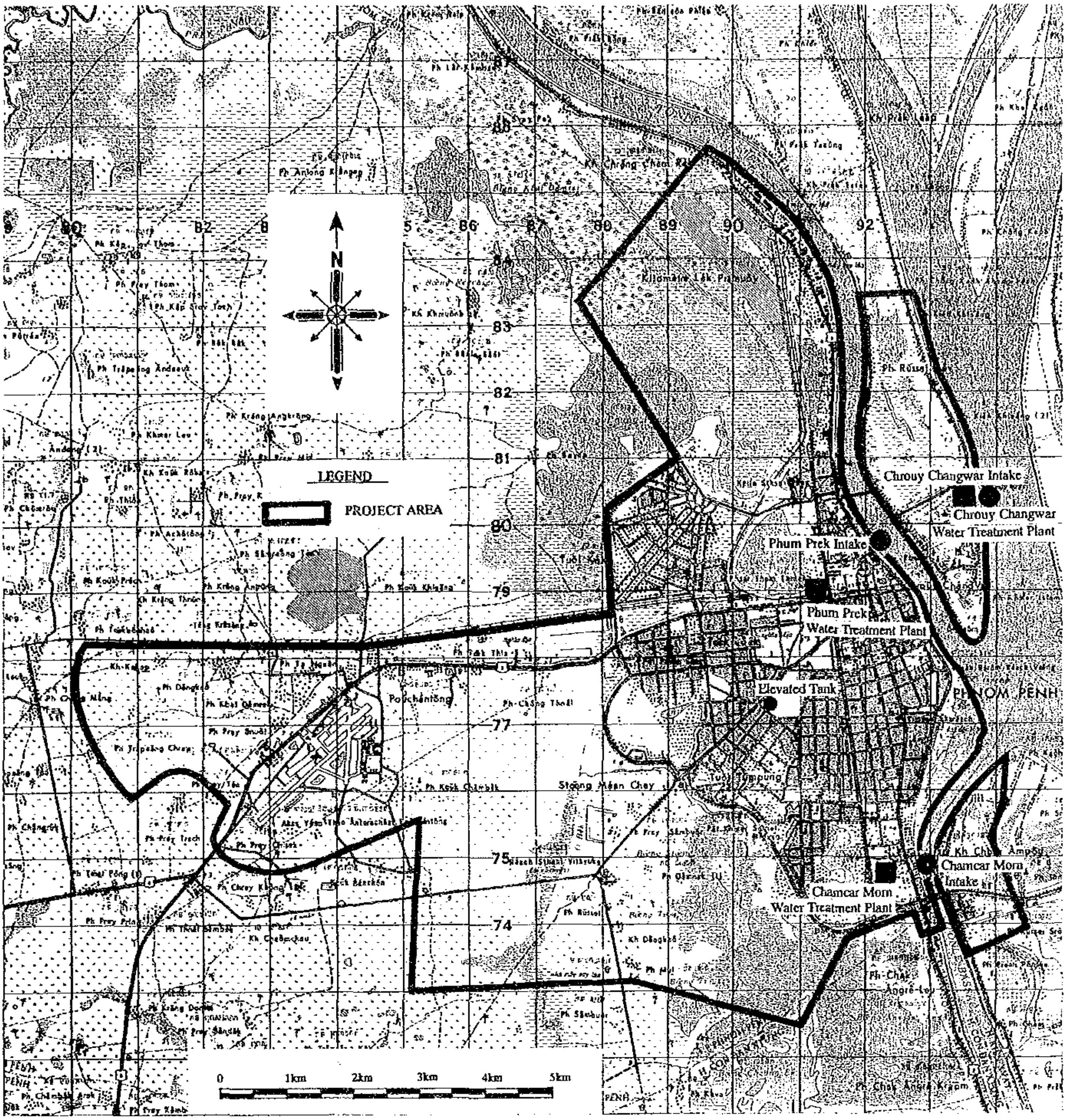


Fig. - 1.1 PROJECT AREA

1.2 Objectives of the Study

The objectives of the Study stated under the Scope of Work were:

(1) to formulate a master plan for water supply system in Phnom Penh Municipality;

(2) to formulate an urgent rehabilitation project of existing facilities, and;

(3) to carry out a feasibility study for the priority project identified in the master plan study.

However, item (3) was not conducted in this study, since a priority project originally considered as a candidate for the feasibility study (expansion of Phum Prek treatment plant)became a part of the urgent rehabilitation works (see Chapter 6) and a feasibility study on other project identified under the Master Plan should be carried out at a later date.

1.3 Study Area

The study area covers the present urbanized area of Phnom Penh Municipality for the master plan. Urgent rehabilitation study covers the area and projects identified in the master plan study. The project area for master plan is shown in Fig-1.1.

1.4 Contents of the Study

The Study comprises field surveys and data collection in Cambodia and analytical and design work both in Cambodia and Japan, and more specifically includes the following work items:

1.4.1 Study in Cambodia

(1) Collection and review of the following available data

- Economic conditions
- Natural conditions
- On-going water supply projects and planning
- Topographical, geological and hydrological maps
- Field survey for existing facilities

(2) Water sources study
(3) Water quality analysis
(4) Distribution network study
(5) Water leakage study
(6) Institutional and management capability assessment

1.4.2 Study in Japan

(1) Delineation of service area
(2) Population and water demand projection
(3) Alternative for system and facilities
(4) Rough estimation of cost
(5) Implementation schedule
(6) Identification of priority projects
(7) Operation and maintenance
(8) Recommendation for strengthening the institution and management
(9) Project evaluation
(10) Identification of urgent rehabilitation project
(11) Preliminary design
(12) Cost estimation
(13) Implementation schedule
(14) Operation and maintenance

1.5 Undertaking of the Study

The State of Cambodia has accorded privileges, immunities and other benefits to the study team, and through the authorities concerned, taken necessary measures to facilitate smooth conduct of the Study.

The Government of Japan, through JICA, has taken necessary measures to dispatch the Study Team to Cambodia and to transfer technology to the Cambodia counterpart personnel in the course of the Study.

1.6 Composition of the Report

The Report is composed of the following three volumes.

VOLUME 1	SUMMARY REPORT
VOLUME 2	MAIN REPORT
VOLUME 3	URGENT REHABILITATION PROJECT PORTION
VOLUME 4	APPENDICES

1.7 Study Organization and Staffing

The study was carried out by the Study Team under the supervision of the JICA through an Advisory Committee.

The Study Team and the Advisory Committee members are as follows:

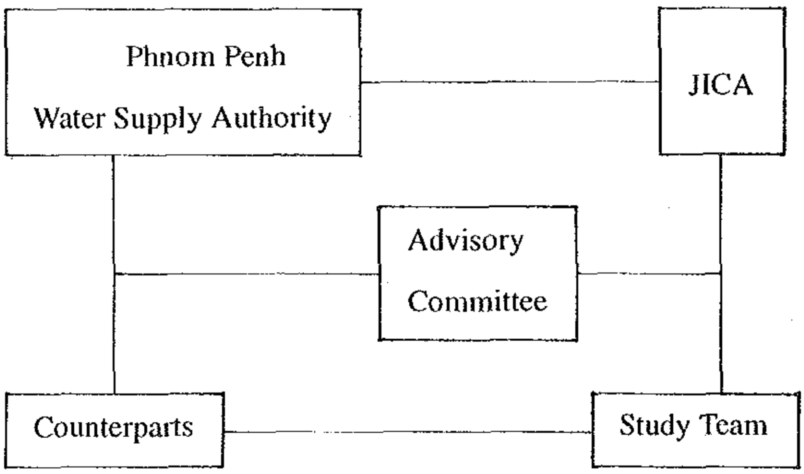
Members of the Study Team

Heiichiro MAKINO	: Team Leader, Tokyo Engineering Consultants (TEC)
Hiroshi MACHIDA	: Water Supply Planning, Nihon Suido Consultants (NSC)
Kazufumi MOMOSE	: Hydraulic Geology (TEC)
Kaoru SUZUKI	: Water Treatment Plant Planning, Water Quality (TEC)
Mamoru TAKUMI	: Water Treatment Plant Design (NSC)
Katsutoshi IWASAKI	: Network Planning (TEC)
Christopher J. COMERFORD	: Network Design, SAFEGE
Bertrand CLOCHARD	: Network Design, SAFEGE
Hironobu TAMAZAWA	: Water Leakage Survey, Fuji Techom
Takayuki TANGE	: Mechanical Design (NSC)
Kazumi KANIE	: Electrical Design (TEC)
Shiro JIMBO	: Cost Estimation (TEC)
Osamu WAKAMOTO	: Institution and Management (NSC)
Osamu NAKAGOME	: Project Evaluation (TEC)

Members of the Advisory Committee

Yasumoto MAGARA	: Chairman of the Committee Director, Dep. of Water Supply Engineering, The Institute of Public Health, Ministry of Health and Welfare
Haruo IWAHORI	: Network Planning, JICA Development Specialist
Hiroaki YOSHIDA	: Water Supply Planning, Chief of Treatment Works, Waterworks Bureau of Kawasaki City
Tohru MAKI	: Operation and Management, Director, Service and Management Division, Waterworks Bureau of Nagoya City

The Phnom Penh Water Supply Authority (PPWSA) acted as the counterpart agency to the JICA Study Team and provided the team with counterpart staff. A schematic diagram of the organizational structure is shown below.



CHAPTER 2

GENERAL CONDITIONS

2. GENERAL CONDITIONS

2.1 Natural Conditions

2.1.1 Topography

Cambodia is located in the southwest part of the Indochina Peninsula. It has an area of 181,035 km^2 and forms a shallow, wide basin. The central three quarters of the basin is named the Central Plain. Phnom Penh, the capital city of the state is situated in the south of the Central Plain about 11°35' N latitude and about 105° E longitude. The country is divided by the Mekong River and the Sap River with the "Great Lake" being a part thereof. Phnom Penh is located west of the confluence of the above two rivers. From there, the Mekong river and Basak, a branch of the Mekong river, flows to their lower delta in Viet Nam and finally to the South China Sea.

The ground height of the city along the Mekong River is more than 10 m above sea level which decreases progressively to about 5 m towards the southwest of the city. In the north, the BLD-URSS road runs from east to west having a height of 11.0 m and protects the city from flooding in the northern part. A bank road with a height of more than 10.0 m surrounds the southwest side of the city and protects it from flooding. Boeng Kak in the north and Boeng Trabek Thom in the south are low swamp areas serving as stabilization ponds for sewage in the dry season, and as detention ponds in the rainy season.

2.1.2 Geology

Due to the diastrophism during the Pliocene epoch until the Quaternary period, the land subsides along faults from northwest to southeast formed by the Tonle Sap Lake basin. Phnom Penh stands on a thin alluvium deposit which overlays weathered rock and clay on the base. cf Section 3.2.2.

2.1.3 Climate

Cambodia belongs to the Asian tropical monsoon zone. There are two main seasons in the year, dry and rainy seasons. The dry season starts from end of October and ends in April while the rainy season lasts from May to November. In the dry season, a low temperature wind blows from the north. In the rainy season, wind with moisture from the Gulf of Siam blows and provides rain irregularly upto a distance of about 200 km from the sea. This rainfall becomes weaker towards the Cardamom Mountains. During this season, Phnom Penh City suffers from inundation at riverside areas.

A. Temperature

According to the statistic report of Capital Phnom Penh in 1983, the average temperature in Phnom Penh during each month of the year is as follows:

Table-2.1 MONTHLY AVERAGE TEMPERATURE

unit: °C

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
26.0	27.4	28.7	29.4	28.3	27.9	27.3	27.7	26.2	26.9	26.6	25.8

(Period of observation : 1931-1944)

Annual average temperature	: 27.4°C.
Hottest month	: April (29.4°C.)
Coolest month	: December (25.8°C.)
Deviation of temperature of the past years	: 3.6°C.
Highest temperature	: 40.5°C.
Lowest temperature	: 14°C.

B. Rainfall

At Pochentong International Airport the records are as follows:

Table-2.2 MONTHLY AVERAGE RAINFALL

unit:mm

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
9.1	10.2	37.9	78.3	139.5	145.4	155.6	160.5	229.2	257.1	138.0	44.2	1,405

The pattern of precipitation is normally intense and often stormy.
At Pochentong, the average number of rainy days in each month of the past years are shown below:

Table-2.3 MONTHLY AVERAGE NUMBER OF RAINY DAYS

unit:day

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1	1	3	6	15	15	16	17	19	18	10	4	125

C. Wind and Humidity

In Phnom Penh City, from November to January wind blows from the northeast. From February to April the climate is influenced by wind from the southeast. The average annual relative humidity at Pochentong is 78%. In September, the average humidity is 84.5%, but in February or March it reaches a low of 66.6%. In the wet season, the monthly average humidity is shown in Table-2.4.

Table-2.4 MONTHLY AVERAGE HUMIDITY IN WET SEASON

unit: %

MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
80.1	80.7	83.1	82.6	84.5	83.2

2.2 Socio-Economic Conditions

2.2.1 Social Aspects

2.2.1.1 Social Index

Basic indicators including health, nutrition and education are tabulated in Table-2.5, in comparison with the conditions of two neighboring countries.

Table-2.5 COMPARISON OF HEALTH, NUTRITION AND EDUCATION OF THREE NEIGHBORING COUNTRIES

	Cambodia	Laos	Vietnam
Basic Indicators:			
Under-5 Mortality Rate	188 *1	148	52
Under-1 Mortality Rate	120	101	39
GNP Per Capita (U.S. Dollar)	- *2	200	240
Life Expectancy at Birth	50 *3	50	63
Total Adult Literacy	35	-	88
% of Age-group enrolled in Primary School	83	110	102
Health:			
% of Population with Access to Safe Water ('88-'90)			
Urban	40	50	50
Rural	15	32	40
Total	18	35	42
% of Population with Access to Adequate Sanitation ('88-'90)			
Urban	53	49	70
Rural	8	5	60
Total	13	13	62
% of Population with Access to Health Services ('88-'90)			
Urban	80	-	100
Rural	50	-	75
Total	53	18	80
1 Year Old Immunized			
Tuberculosis	54	34	91
Diphtheria	40	22	88
Polio	40	22	88
Measles	34	20	88

Table-2.5 COMPARISON OF HEALTH, NUTRITION AND EDUCATION OF THREE NEIGHBORING COUNTRIES (CONTINUED)

Nutrition:			
% of Infants with Low Birth Weight	-	18	17
% of Children suffering from Underweight			
Moderate & Severe	20	37	42
Severe	3	-	14
Average Index of Food Production Per Capita ('71-'81 100)	140	110	131
Daily Per Capita Calorie Supply as % of Requirements ('88-'90)	96	111	103
Education:			
Adult Literacy Ratio (%)			
Male	48	-	92
Female	22	-	84
Number of Sets per 1000 Population			
Radio	107	89	107
TV	8	5	38
% of Grade 1 Enrollment reaching Final Grade of Primary School	50	38	57
Secondary School Enrollment Ratio ('86-90)			
Male	45	31	43
Female	20	22	40

Note: *1 This is more than twice the Asia average of 83 per 1,000.

*2 180 U.S.Dollars is an estimate by the Asian Development Bank.

*3 This is the lowest figure among Asian countries and one of the lowest in the world.

- Crude death rate of adults was 18/1,000 in 1989, this is almost twice as high as the average of 8.6/1,000 for the Asia Region.
- Crude birth rate of 40/1,000 is probably the highest in Asia, reflecting a total fertility rate of 4.5 births per woman of reproductive age, which is well above the average of 3.2 for Asia.

Source: The State of The World Children, 1993, UNICEF

2.2.1.2 Demography

The national population in 1992 is estimated to be about 9.0 million. Composition of the population by sex and age is shown in Table-2.6. Of the total population, approximately 88 percent, or about 7.93 million, live in the rural areas.

Table-2.6 POPULATION BY SEX AND AGE

Age Group	Sex Male	Female	Total	Female Age Group Total %	Total Pop. %
0 - 4	867,097	843,153	1,710,250	49.3	19.0
5 - 14	1,260,184	1,260,184	2,520,368	50.0	28.0
15 - 17	225,033	225,033	450,066	50.0	5.0
18 - 64	1,875,424	2,175,168	4,050,592	53.7	45.0
65 & over	118,817	151,222	270,039	56.0	3.0
Total	4,346,555	4,654,760	9,001,315	51.7	100.0

Note: In the age groups, 5 to 14 and 15 to 17, the number of males equal the number of females. It doesn't seem realistic.

Source: Department of Statistics, Ministry of Planning, Cambodia

The age group profile shows that percentage of young population is high and will remain so in the foreseeable future, as the population grows at a rate between 2.5 and 3.0 percent per annum.

The life expectancy during the period 1960-1965 was 45 years and it fell down to 35 years during the period 1970-1975. Though it has recovered significantly, the present 50 years figure is still very low.

Due to war and social disruption, women outnumber men significantly in the age groups of 18 to 64, and 65 and over. Adult women also comprise 35 percent of all heads of households in the rural area, 70 percent of the total labor force are women. In a society where men have taken the dominant position in social and economic activities, the situation requires considerable attention.

The war damages are felt, by over 350,000 people who were permanently disabled, or victimized by millions of land mines laid during the internal wars that lasted from the 1960s to 1980s.

2.2.1.3 Health

Table-2.7 and 2.8 show the data of morbidity and mortality by major diseases, in the whole country and Phnom Penh area respectively.

All of these diseases are poverty-linked. Malaria is predominant and most fatal. Particularly vulnerable are pregnant women and young women. Diarrhea, dysentery, typhoid and cholera, all intestinal infectious diseases, are also significantly prevalent seen as in Table-2.7. This is most probably due to the poor conditions of drinking water supply in the whole country.

In Phnom Penh area, morbidity of Diarrhea is still high, owing to poor sanitary conditions. Malaria is low compared with the whole country's case, possibly due to availability of better medical care.

Table-2.7 MORBIDITY AND MORTALITY DUE TO MAJOR DISEASES IN CAMBODIA

Yr	Malaria M'bid	Malaria M'tal	Diarrhea M'bid	Diarrhea M'tal	Dysentery M'bid	Dysentery M'tal	Typhoid M'bid	Typhoid M'tal	Cholera M'bid	Cholera M'tal
'80	199,667	601	620,353	849	430,008	423	7,587	188	1,603	50
'81	87,703	386	597,502	449	389,633	190	6,790	142	907	45
'82	71,527	493	539,674	518	302,101	178	33,569	132	1,884	129
'83	59,367	515	463,916	412	143,063	138	3,571	58	1,118	63
'84	41,043	349	296,643	246	103,075	74	3,790	38	407	14
'85	70,338	813	279,771	434	113,700	102	12,495	51	127	22
'86	71,865	521	289,737	196	122,817	68	3,525	46	448	21
'87	66,390	587	298,709	140	119,308	83	3,092	14	474	55
'88	62,614	388	378,230	134	166,866	88	2,546	6	112	0
'89	53,783	342	174,536	50	98,808	50	2,631	4	47	2
'90	46,051	495	111,289	66	71,559	28	2,885	32	5	0
'91	163,282	347	117,790	110	73,952	13	6,657	36	775	97

Note :The mortality figure is that of the confirmed morbid patients.
Source :Ministry of Health, Cambodia, 1992

Table-2.8 MORBIDITY AND MORTALITY DUE TO MAJOR DISEASES IN PHNOM PENH (JAN. TO SEPT.,1992)

	Malaria		Diarrhea		Dysentery		Typhoid		Cholera	
	M'bid	M'tal	M'bid	M'tal	M'bid	M'tal	M'bid	M'tal	M'bid	M'tal
Child	346	9	4,904	47	N.A.	N.A.	861	N.A.	0	0
Total	1,703	45	8,385	51	2,718	21	2,122	6	0	0

Source: Planning and Statistics Office, Health Department, Ministry of Health

Access to health services is extremely limited, as shown in Table-2.5.

The ratio of population per physician is 12,000 in Cambodia, 7,371 in Laos, 5,930 in Thailand and 3,362 in Vietnam. The ratio of population per nurse in Cambodia is 6,300, far less than the average in Asia which is 1,674.

2.2.1.4 Education

As shown in Table-2.5, the adult literacy ratio is 48 % for male and 22 % for female. This is comparatively low as compared with other Southeast Asian countries.

The education system in Cambodia is similar to that in France, its former suzerain country, and has changed only slightly in 1979.

The higher level education has been reconstructed and developed with the assistance of the ex-Soviet Union and Eastern Europe countries. Until recently, the post-secondary training institutions focused on producing as many graduates as possible, with little emphasis on quality.

For the vocational training and technical education system, instructors, key staff equipments and spare parts were provided by CMEA (Council for Mutual Economic Assistance) countries. With the collapse of those countries' political and economic system, the assistance has been virtually withdrawn and many teaching staff have gone home, leaving fewer less experienced staff.

2.2.2 Economy

2.2.2.1 Management of Economy and Inflation

Report on the socio-economic situation in 1992 and the Plan for 1993, prepared by the Council of Ministers, announces, "Overall, notwithstanding the (government) efforts deployed, expenditures cannot be covered by revenues. Therefore, financial aid from the international community is indispensable for covering deficit."

The report also states, "In 1992, total revenue accounted for 58 % of the total expenditures of the government. The bulk of these expenditures went to public administration, and security." Regarding financial and monetary situation it says, "Expansionary monetary policy, i.e. printing money for financing specific expenditures, in particular, social welfare, administration, defense and security, constitutes a major cause of inflation".

In summary, 1) there was a shortage of about 42 % of the total expenditures in 1992, 2) the deficit is to be covered by foreign aid, 3) a large portion of the expenditure is possibly spent on security, 4) the deficit if covered by printing money will cause inflation.

Table-2.9 shows the quarterly data of consumer prices index (CPI) both parallel market and official exchange rates.

The parallel market exchange rate fluctuates remarkably once in a while. For instance, in March 1993 it went up to 6,000 Riels per U.S. Dollar, stayed there for a few days and fell down to stay in the range 3,500-4,000 Riels per U.S. Dollar through April to May. Rumor of political unrest and speculation were said to be the cause.

Table-2.9 CONSUMER PRICES INDEX AND EXCHANGE RATES, 1988:1-1992:1 (PERCENT)

Year: Q'ter	CPI	Inflation Ratio	Parallel Market E.R.	Official E.R.	Official E.R./ Parallel E.R.(%)
88:1	100.00	NA	139	100	28.1
88:2	108.12	NA	140	100	28.6
88:3	126.34	NA	153	142	7.2
88:4	123.94	NA	160	142	11.3
89:1	123.99	23.99	178	150	15.7
89:2	160.43	48.38	197	190	3.6
89:3	236.95	87.56	220	190	13.6
89:4	259.09	109.02	300	218	27.3
90:1	311.01	150.83	380	345	9.2
90:2	400.67	149.75	480	380	20.8
90:3	618.50	161.02	675	510	24.4
90:4	678.20	161.76	613	600	2.1
91:1	765.35	146.09	691	600	13.2
91:2	931.51	132.49	905	800	11.6
91:3	1,706.63	175.93	1,125	1,000	11.1
91:4	1,037.76	53.01	550	520	5.5
92:1	1,194.46	56.07	935	880	5.9

Note: 1) Inflation Ratio is calculated as follows:

$$\frac{\text{CPI at a certain Year:Quarter}}{\text{CPI at the same Quarter of previous Year}} \times 100$$

2) E.R. denotes Exchange Rate, Riels for U.S. Dollar.
3) Official E.R./Parallel E.R. is calculated as follows.

$$\frac{\text{Parallel E.R. - Official E.R.}}{\text{Parallel E.R.}}$$

Source: National Bank of Cambodia

2.2.2.2 Hardships of Life and Necessary Income

Suppressed by inflation, the people are enduring considerable hardship in their daily lives. The income level is very low. The average salary of about the 150,000 or so civil servants, from ministers to the lowest clerical positions in the state, province and municipal governmental organizations, is about 38,000 Riels per month. Even after including family allowance and subsidies for electricity and water, the total monthly income for a highly paid official is about 60,000 Riels. This should be compared to the fact that a 20 cigarette pack, a liter of drinking water in plastic container and a bowl of rice soup cost 2,800, 2,000 and 4,000 Riels respectively.

Interviews with people at different levels of social strata revealed that:

1) A minimum wage per day for unskilled labor is about 3,000 to 4,000 Riels.
2) An inexperienced hotel maid is paid about 200,000 to 240,000 Riels per month. In addition, food and uniform are provided free of charge.
3) The minimum living cost for the lowest income families is probably about 200,000 Riels per month.
4) A middle class family needs at least about 400,000 to 600,000 Riels per month.

2.2.2.3 Economic Policies

Following the Paris Accord on October 23, 1991, the United Nations Transitional Authority in Cambodia (UNTAC) was assigned by the UN Secretary-General, to coordinate all external assistance to this country.

Accordingly, the economic policies were prepared by the agencies representing the United Nations. Quoting in two publications namely "Cambodia, Agenda for Rehabilitation and Reconstruction, The World Bank, June 1922" and "Cambodia, Socio-economic Situations and Immediate Needs, ADB/IMF/IBRD/UNDP", major points of the policies are explained.

From the macro-economic viewpoint, two objectives are to be pursued:(1) rehabilitation of critical public services and infrastructures, (2) restoring and sustaining economic stability.

These two objectives are in conflict, as (1) will increase the burden of the budget. Currently, the budget deficit is the main source of inflation that is damaging economic stability. To minimize the conflict, the new administration should try to balance the budget by increasing revenues and by decreasing expenditures. Further external aid of appropriate nature and magnitude needs to be provided.

Strong, corrective actions need to be taken regarding public administration and civil services by: (1) downsizing the present administrative structure of the central, provincial and municipal government bodies, (2) re-defining the local autonomy, (3) motivating civil servants by changing the present personnel management system, and (4) delineation of public organizations including the legislative and administrative organizations, party organizations, semi-public sector entities, etc.

For increasing state revenue, improvements are needed by:(1) rationalizing import duty structures while increasing average tax rates, (2) making assessments on CIF based on market values rather than official prices, (3) codifying separate turnover and profit taxes, (4) imposing tax based on book turnover and book income, (5) introducing urban property tax and agricultural land tax, (6) strengthening the Customs and Tax Departments, (7) computerizing tax administration, and (8) improving assessment, collection, audit and litigation procedures.

Budget management need to be improved by:(1) planning of fund allocation, based on "policy-oriented" rather than "necessities-oriented" decisions, (2) focusing public spending on "short-term rehabilitation priorities", both at the national and provincial levels, (3) monitoring and controlling the effects of expenditure and the performance of relevant agencies' execution.

Management of state properties needs immediate and serious attention as the present transitional and un-controlled situation leads to their dissipation and loss by unlawful procedures including cannibalization and embezzlement.

Presently, cross-debts among the public administrative agencies, state enterprises, banks and private sectors are interlinked and no agency appears to be in overall control. Clarifying and changing the present situation is urgently needed.

As a long-term policy, privatization of public enterprises is a constructive direction, which needs to be taken for rehabilitation and reconstruction of the economy.

2.2.2.4. United Nations' Assistance

In the Appeal by the Secretary General of the United Nations for Cambodia's Immediate Needs and National Rehabilitation, issued in April 1992, an assistance plan totaling 595 million U.S. Dollars, excluding technical assistance and humanitarian aid programs, was proposed. The breakdown is:

A. Repatriation, incl. UNHCR operation, food aid.................................. 116
B. Support of Resettlement, incl. refugees, displaced persons, demobilized soldiers, mine risk awareness 83
C. Maintenance of Essential Services, incl. food security, agriculture inputs, health, water, sanitation, education, training 120
D. Public Utilities & Infrastructures, incl. transportation, telecommunication, power, water/sanitation in urban area, fuel 150
E. Public Administration, incl. economic management, public sector financing, capacity building 126

2.2.3 Institutional Issues

2.2.3.1 Lack of Clear Delineation of Legislative and Executive Roles

The report, "Cambodia, Agenda for Rehabilitation and Reconstruction, World Bank, June 1992" points out that "The National Assembly exercises the legislative powers but the Constitution of the State of Cambodia does not provide for a clear delineation of the respective roles of the executive and legislative branches. In principle, laws can apply to all fields of state action except those specifically reserved to the State Council and the Council of Ministers. The right to initiate legislation is not limited to the members of the Assembly or to the administration. This arrangement is typical of socialist systems but confuses the distribution of responsibilities between legislative and executive branches."

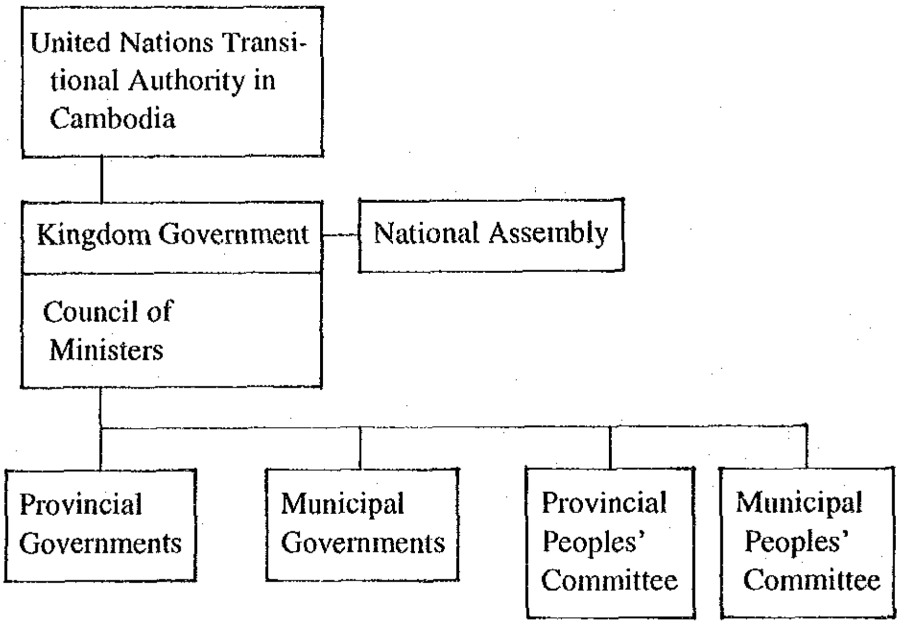
Cambodia has been under a single political party's control virtually from 1979 to the present. As in the case of many other countries, the party officials occupy dominant positions in the legislative and administrative organs, thus building the party's as well as the individuals' power base moving towards dictatorship.

As agreed at the Paris Conference in 1991, the general election was held in May 1993, After the election, the present system will be reformed from the grass roots towards separation and independence of the legislative, executive, and judicial powers.

2.2.3.2 Existing System of the Kingdom

Fig-2.1 shows the legislative and executive structure of the Kingdom of Cambodia.

Fig-2.1 LEGISLATIVE AND EXECUTIVE STRUCTURES



Note: key persons often occupy positions and seats in both the administrative and legislative bodies at same levels.

2.2.3.3 Water Supply Service

Water supply services in Cambodia are ruled by Decree No. 32 of the Council of Ministers. A decree is not a law but an administrative order by government.

The Water Supply Authority is defined as the monopolistic state enterprise for supplying water and was given autonomy by a decree in December 1987.

From January 1988 to June 1991, the Phnom Penh Water Supply Authority (PPWSA) was managed as an autonomous public enterprise losing money continuously. In July 1991, the autonomy of the PPWSA was suspended and it was placed under the control of the Phnom Penh Municipal government.

Presently, the PPWSA is controlled by the No.1 Deputy Mayor acting on behalf of the municipality while the PPWSA Director runs the day-to-day operation of water supply.

In Chapter 4, details about Decree No. 32, status of the PPWSA, PPWSA's reporting to the municipality and other procedural matters are explained.

2.2.3.4 Electricity Supply Service

Another state enterprise, in charge of electricity supply in Phnom Phen was losing money under the state government's control for some years. The government then off-loaded the responsibility to the municipality.

Reportedly, the major cause of the deficit was shortage of revenue from sales, as collecting money from customers who were complaining strongly regarding unsteady and unreliable power supply was not easy.

The municipality proposed wise separation and partial privatization. Under the new system, the municipality provided wholesale power to private transformer owners and let them retail to the customers.

A new regulation was formed for the implementation of the new system by which unreasonable pricing by private transformer owners was strongly forbidden. The regulation has however been disobeyed. The transformer owners have been always willing to pay the official tariff rate from their profit and thus the municipality has been able to collect tariff satisfactorily. All parties except the customers were happy with the result.

In May 1993 it was rumored that the state government took back the wholesale business from the municipal government.

Water is also sold in wholesale and retail, as explained in a subsequent section.

CHAPTER 3

EXISTING WATER SUPPLY SYSTEMS

3. EXISTING WATER SUPPLY SYSTEMS

3.1 Present Service Level

3.1.1 Population

In 1992 Phnom Penh had a population of 700,000. The city of Phnom Penh is divided into seven administrative districts. Each district has a population of approximately 100,000. Details of the population distribution are given in Section 5.1.

3.1.2 Service Area and Population Served

The total service area of 77.75 km^2 covers four inner districts in the so-called "protected areas from flooding by construction of inner dams.(28.7 km^2)" and some parts of the outer suburban area (49.05 km^2). The outer suburban area comprises of:

a) Chbar Ampouv 1, Chbar Ampouv 2, Beung Toum Poun and Stung Meanchey subdistricts in Mean Chey district,
b) KM-6, Russey Keo, Toul Sangke and Toek Tla sub-districts in Russey Keo district and
c) Kakab sub-district in Dang Kor district.

Water distribution in the area is considered inadequate due to very thin distribution mains which only are available. Served population in the inner four districts was about 400,000 and in the outer suburban area was around 130,000 in 1992. The total service population is therefore about 530,000.

3.1.3 Present Water Production and Consumption

Accurate current per capita consumption is not known. There are no bulk meters on the outlets of the two working treatment plants. Water pressure throughout the city is so low that lots of users have installed cisterns, usually with no stop valves, to receive water 24 hours insofar as available. However, water is supplied to the inner four districts for a limited period of time every day. Based on the service population of 400,000, the daily average water production, at the rate of 63,000 m^3/day and the leakage ratio of 50 percent, the average consumption is estimated to be around 80 liters per capita per day (lpcd). This level is significantly lower than that in the 1960s.

In the 1960s, public utilities and urban services were generally able to meet the country's requirements. In 1970, the annual water production from the three treatment plants, viz. Churouy Chang War, Chamcar Morn and Phum Prek reached 78,000 m^3/day. Considering the population served at that time of approximately 400,000 persons out of a total population of 700,000 persons, the per capita consumption is calculated to be about 200 lpcd including losses due to leakage.

3.1.4 Present Water Demand

Based on the assumptions mentioned below, the present unsuppressed demand is estimated to be about 138,000 m^3/day (daily maximum base). Reasoning for the assumptions is discussed in Section 5.2.

* daily average consumption	: 100 liters per capita per day (including both domestic and non-domestic consumption)
* leakage ratio	: 50 percent
* daily maximum consumption	: 1.3 times the daily average consumption

3.2 Water Resources

3.2.1 Surface Water

3.2.1.1 Mekong River

The salient features of Cambodia are seen in the lower reaches and tributaries of the Mekong River, which provides the double function of annual flood in the wet season and drainage in the dry season. The Mekong River is the longest river in Southeast Asia and 12th in the world, and is among the first ten in terms of annual volume flow. The Mekong River enters Cambodia at the northeast from Laos, first forming rapids over ledges of rock and then further downstream flowing across the large inner plain of central Cambodia where it is joined by numerous lesser tributaries.

Each year about 475,000 million m^3 of water empties into the ocean off the delta. At

Pakse in Lower Laos, where the drainage area accounts for 69 percent of the total area, the maximum discharge (57,800 m^3/sec) is more than 50 times the minimum discharge (1,600 m^3/sec).

The flow of the Mekong is closely related to the rainfall pattern. The water level starts to rise at the onset of the wet season (April-May), reaching a peak in August, September or October. It then falls rapidly until December, and afterwards recedes slowly during the dry period of the year, or "dry season", to reach its lowest level in March/April, just before the onset of the monsoon.

At Phnom Penh, the Mekong has four arms, the "Quatre-Bras", where the Sap River, the Bassac River and the inflowing and outflowing branches of the Mekong River join. The Sap River is the recharge and discharge stream of a large western basin, which contains the Sap River, a great lake of 2,500 km^2. The Sap River ("Great Lake") is a huge natural reservoir for flood flows of the Mekong River, which rises gradually in June to full flood in October, then declines to low flow in March, April and May. When the stage of the Mekong River rises, water backs up the Sap River 200 km into the Sap River, raises the lake level by more than 8 m, and inundates large areas of adjacent low-lying land.

The Sap River attenuates the flows in the delta downstream of Phnom Penh considerably by storing a part of the flood flow in July, August and September and releasing it in the period October-April. During the flood season, the water level in the Mekong rises faster than that in the Sap River and excess water is fed into it through the Sap river thus storing part of its flood water in some 70 billion m^3 of storage of the Great Lake. When the Mekong water level goes down, the flow in the Sap River reverses and the Great Lake releases water into the Mekong, both stored Mekong flood water and the yield of its own catchment area.

The Mekong River is influenced by tides at Phnom Penh, and its sediments have formed a vast delta that covers a broad expanse extending southward across South Vietnam to the South China Sea.

3.2.1.2 Water Level at Phnom Penh

The Interim Mekong Committee, established in 1957 under the aegis of the United Nations, has been collecting hydrologic and meteorological data. The Committee has published, each year since 1960, the "Lower Mekong Hydrologic Yearbook" which covers:

- measurement of gauge height and discharge; collection of sediment, bed

material, and water quality samples at hydrologic stations;
- measurement of precipitation, evaporation, wind movement, radiation, humidity, atmospheric temperature and seismological activities at meteorological stations.

Discharge is usually the most concerned data for planning of water supply system but discharge data is not important for this study. Amount of water necessary for the Phnom Penh water supply system is and will account for less than 0.5 percent of the minimum flow of the Mekong river. The water demand will be some 5 m^3/sec in 2010 while the minimum discharge is 1,250 m^3/sec.

Table-3.1 HYDROLOGIC DATA OF MEKONG RIVER AT PHNOM PENH (during 1960 - 1973)

minimum discharge	**1,250 m^3/sec**	**on 10 October 1961**
minimum gauge height	1.22 m	on 7 May 1960
maximum discharge	**49,700 m^3/sec**	**on August 1961**
maximum gauge height	11.08 m	on 10 October 1961
average discharge	**13,131m^3/sec**	

sources for the Phnom Penh water supply system. The water levels of the three rivers were collected and analyzed.

The Hydrological Department of the Ministry of Agriculture has maintained three gauging stations; the Mekong river at Phnom Penh, the Sap river at the Phnom Penh Port and Bassac river at Phnom Penh. All the locations (described in the Table-3.2) are relatively close to the existing intake points.

The gauge heights in the three stations were compared for the years 1972 and 1973. The measured gauge heights were adjusted to the M.S.L. Hatien datum. As shown in Fig-3.1 through Fig-3.4, levels in the Bassac river and the Sap river are higher than those in the Mekong river from October to April while the former two levels are lower than the latter from April to October. For both cases the differences are at most 20 cm.

The gauge heights of the for Mekong river and Bassac river are shown in Appendix for 1963 to 1992. The data up to 1979 were obtained from the "hydrologic yearbook" of the Interim Mekong Committee whereas the data from 1980 to 1992 were from the Hydrological Department. From those data the annual lowest gauge heights are summarized in Table-3.5. The annual lowest levels range 1.6 to 1.80 meters in both the Mekong and the Bassac rivers. The lowest levels, 1.45 m in the Mekong and 1.41 m in the Bassac, occurred in 1969. Although there are data for the Sap river for two years, the lowest levels were almost equal to the other two rivers after adjustment to the zero gauge heights which are shown in Table-3.2 to 3.4.

Elevation of the intake facilities can be designed based on the 1.4 m plus some allowance.

Table-3.2 CHARACTERISTICS OF GAUGE HEIGHT STATIONS
Mekong River at Phnom Penh

Location

Lat.11°35.07'N, Long. 104°56.33'E, in Phnom Penh Chrouy
Changwar peninsular near the Phnom Penh water supply pumping station,
2.8 km upstream of "Quatre Bras" confluence, and 332 km from the sea.

Gauge and Datum

Bubble gauge and water stage recorder referred to vertical staff gauge
fixed on the foot bridge pier of the water supply pumping station.
Zero of gauge elevation 1.08 m below M.S.L.Hatien datum.

Drainage Area: 663,000 km^2

Records Available

Two daily gauge readings for the whole year.
T.P. stage records at Phnom Penh (Port)

Complete or near complete:	1898-1911,1913-18,1921-73
Fragmentary records:	1894-97,1912,1919-1920
City waterworks stage records:	1930-73

Remarks

Rating at all stages is very strongly affected by backwater.
At stages above gauge height 8.00 m, very extensive overbank flooding
commences on the left bank and by-pass flow escapes to the Sap river
over the right bank

Table-3.3 CHARACTERISTICS OF GAUGE HEIGHT STATIONS
Bassac River at Phnom Penh

Records Available

Public Works stage record:	
Complete or near complete:	1898-1911,1913-18,1921-73
Fragmentary records:	1894-97,1912,1919-1920
City waterworks stage records:	1930-73
Bubble gauge records:	since 3 August 1960
Daily discharge:	since 1 January 1964

Remarks

Station not rated for period of prominent tidal variation or gauge height lower than 2.50m.

Table-3.4 CHARACTERISTICS OF GAUGE HEIGHT STATIONS
Sap River at Phnom Penh Port

Location

Lat.11°34.3'N, Long.104°55.9'E, located on the stone pitching in front of quay No.1 of the port on the south bank of Tonle Sap in Phnom Penh Port and about 325 km from sea.

Gauge and Datum

Vertical staff gauge Zero of gauge elevation at M.S.L. Hatien datum.

Records Available

Public Works stage records:	
Complete or near complete:	1898-1911,1913-18,1921-73
Fragmentary records:	1894-97,1912,1919-1920

FIG-3.1 WATER LEVEL DIFFERENCE
BASSAC, PHNOM PENH IN 1972

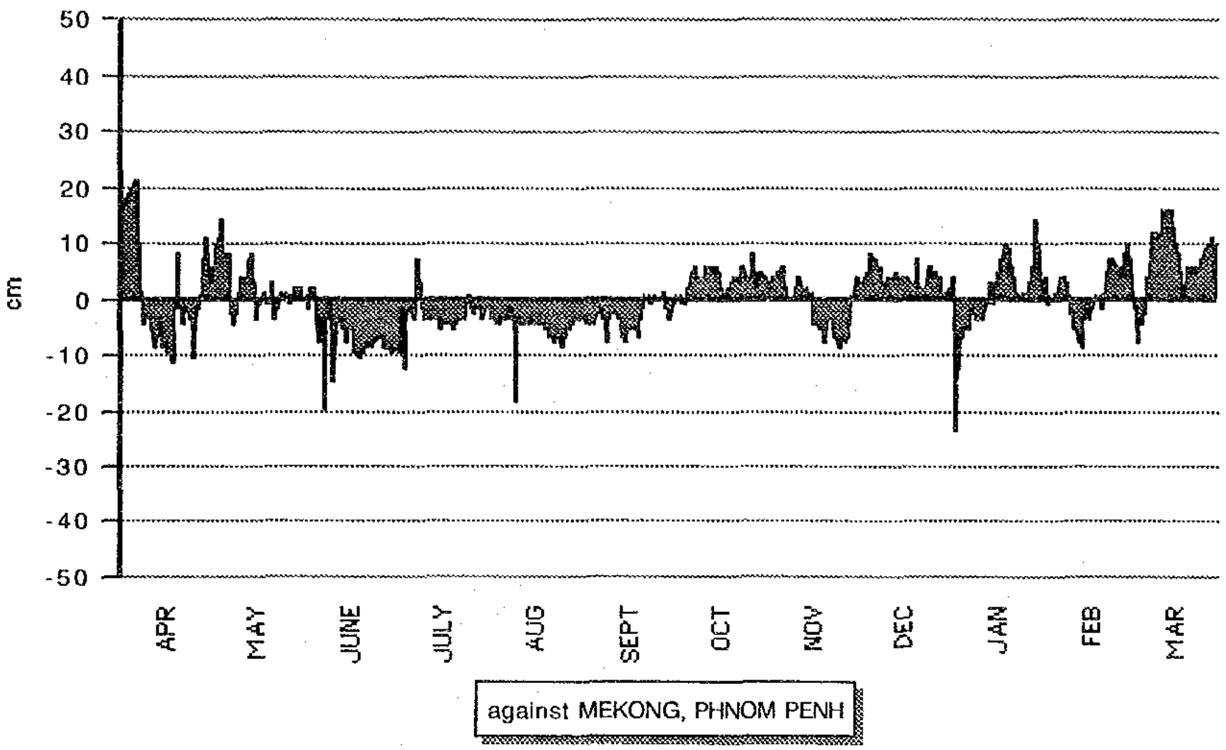


FIG-3.2 WATER LEVEL DIFFERENCE
SAP, PHNOM PENH PORT IN 1972

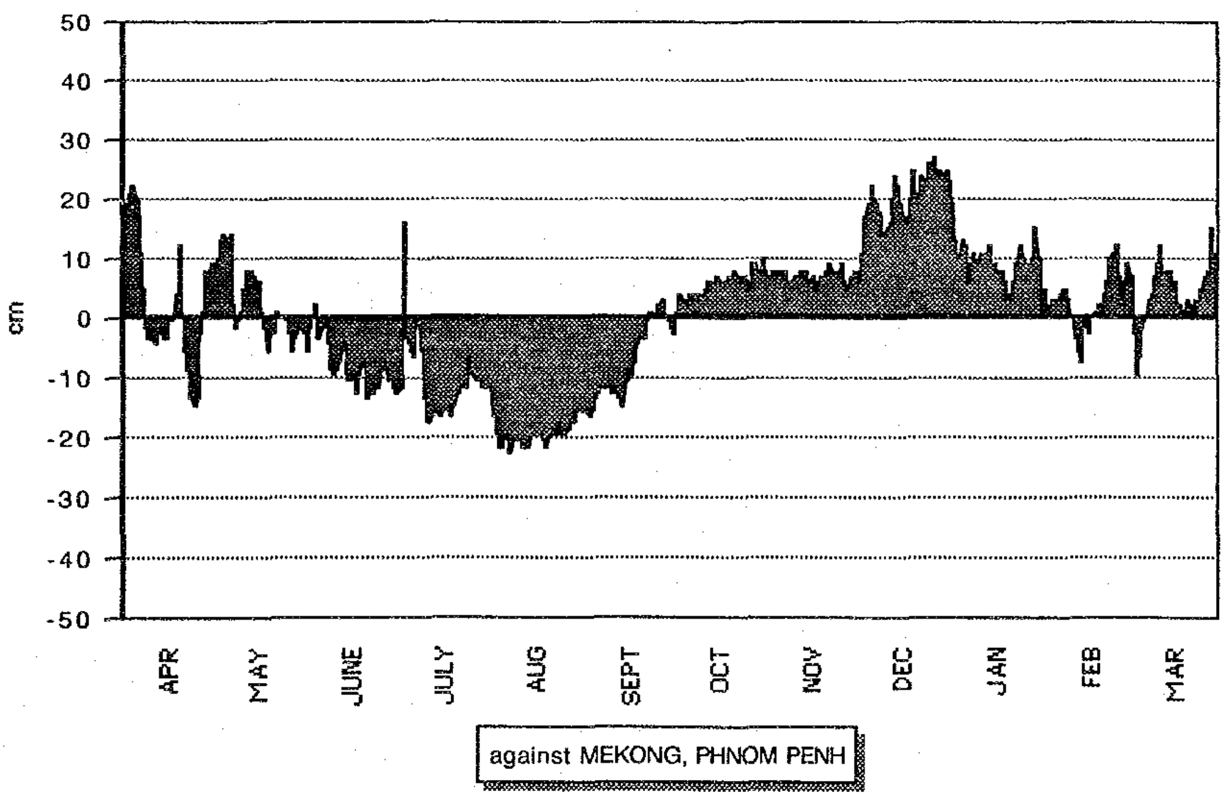
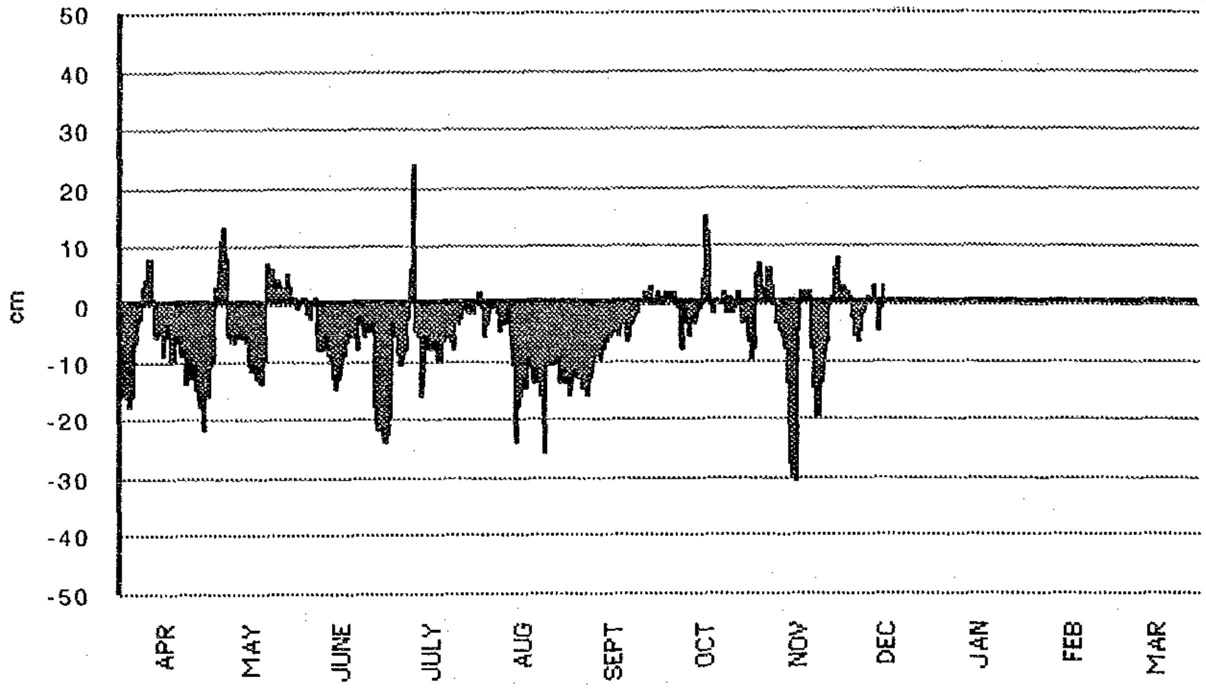


FIG-3.3 WATER LEVEL DIFFERENCE

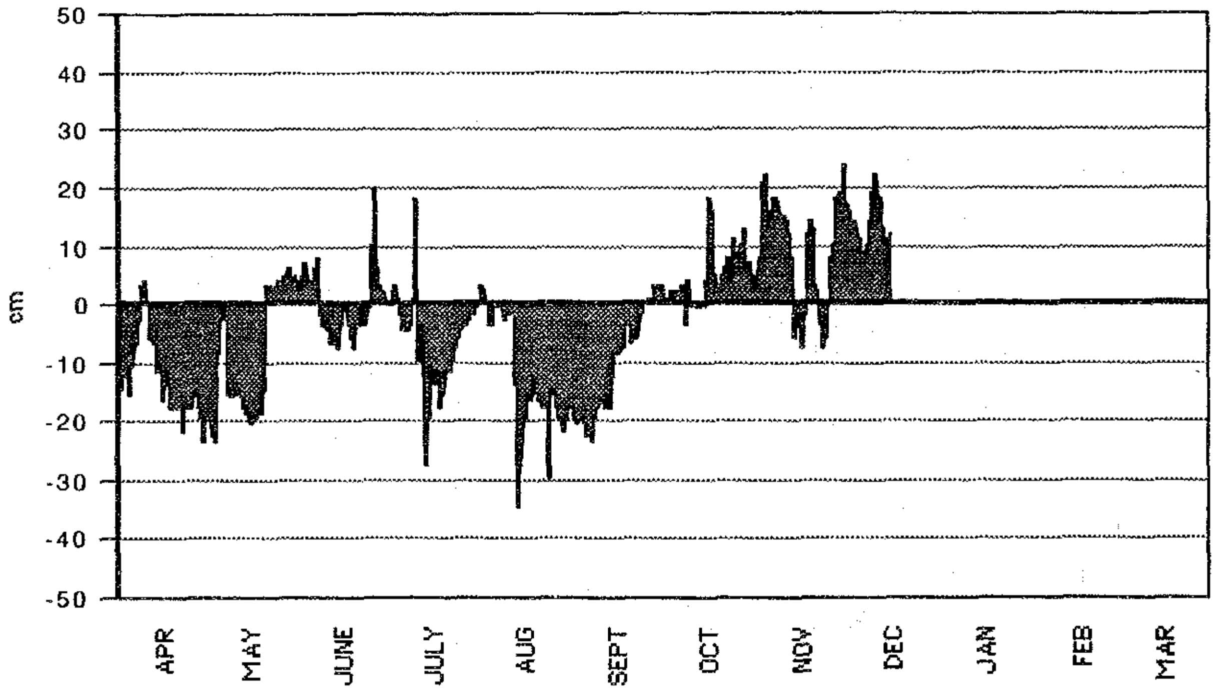
BASSAC, PHNOM PENH IN 1973



against MEKONG, PHNOM PENH

FIG-3.4 WATER LEVEL DIFFERENCE

SAP, PHNOM PENH PORT IN 1973



against MEKONG, PHNOM PENH

Table-3.5 ANNUAL LOWEST GAUGE HEIGHT (meter)

YEAR	MEKONG Phnom Penh	BASSAC Phnom Penh	SAP Phnom Penh Port
1963	1.61 May 21	n.a.	n.a.
1964	1.79 April 09	1.72 April 09	n.a.
1965	1.60 April 28	1.67 April 30	n.a.
1966	n.a.	n.a.	n.a.
1967	1.70 April 06	1.66 April 08	n.a.
1968	1.67 April 11	1.66 April 11	n.a.
1969	1.45 May 28	1.41 April 28	n.a.
1970	1.72 April 04	1.60 April 04	n.a.
1971	1.72 May 07	1.70 May 06	n.a.
1972	1.68 May 14	1.66 May 10	0.64 May 28
1973	1.84 May 01	1.62 May 02	0.56 May 02
1974	1.86 April 21	1.80 April 23	n.a.
1975	n.a.	n.a. n.a.	n.a.
1976	n.a. n.a.	n.a. n.a.	n.a.
1977	n.a. n.a.	n.a. n.a.	n.a.
1978	n.a. n.a.	n.a. n.a.	n.a.
1979	n.a. n.a.	n.a. n.a.	n.a.
1980	n.a. n.a.	n.a. n.a.	n.a.
1981	1.89 May 15	1.72 April 16	n.a.
1982	1.83 May 04	1.92 May 04	n.a.
1983	1.65 April 10	1.74 April 11	n.a.
1984	1.71 April 27	1.78 April 27	n.a.
1985	1.82 April 13	1.76 April 17	n.a.
1986	1.86 May 01*	1.69 April 22	n.a.
1987	1.58 April 08	1.67 April 13*	n.a.
1988	2.24 May 01	1.76 April 02	n.a.
1989	n.a. n.a.	1.65 May 03	n.a.
1990	n.a. n.a.	1.62 April 23	n.a.
1991	1.84 March 07	1.66 April 13	n.a.
1992	1.76 May 09*	1.70 April 30	n.a.
1993	1.72 April 09	n.a. n.a.	n.a.
	1.45 1969	**1.41 1969**	

* no data between January 1 and May 7 in 1981, April 1 and April 30 in 1986 and March 1 and May 8 in 1992.

3.2.2 Groundwater

The purpose of this section is to describe and evaluate the availability of groundwater in suburban Phnom Penh. The description and evaluation are based on the following data sources:

1) "Ground-Water Resources of Cambodia" prepared in 1977 under the auspices of the United States Agency for International Development (USAID) based on test drilling data and well records in 1960-63, and
2) Drilling data and well records recorded, since 1983 by the Ministry of Health assisted by UNICEF.

(1) USAID report

To study the hydrogeology and hydrology of the environs of Phnom Penh, an analysis was made in 1977 of all the available records of wells within a 7-km radius, centered at the western edge of the city. The well locations are shown on Fig-3.5 and the records are summarized in Table-3.6.

Records of 26 wells were available. Of these, drillers' logs were available for 21 wells. The logs of 8 wells were graphically interpreted at the geological cross section I-I' in Fig-3.6. Only 8 wells were productive, 2 were foundation test holes, and the other 16 were dry or nonproductive.

Of the 15 wells drilled in the western environs of Phnom Penh (Dang Kor district), only 2 were productive. Six wells drilled in Pochentrong Village were all reported non-productive.

Three productive wells were drilled in Srok Kien Svay in the Chbar Ampou subdistrict, Mean Chey district of Phnom Penh just across the Monivong bridge over the Basak river. (See Table-3.6, wells KSv 1,2,3). No logs are available, but the wells are shallow (17 m,17 m and 13 m, respectively) and all are moderately productive (45, 50 and 60 l/min).

The geological section I-I' on Fig-3.6 is an interpretation of the available data. Four units are recognized: young alluvium, old alluvium, weathered rock and clay, and hard crystalline rock. The young alluvium consists of red and yellow clay, silt and sand. The old alluvium has yellow-brown laterite, and considerable coarse sand and fine gravel, with smaller amounts of silt and clay. The weathered rock is made up of layers of basalt and basalt tuff interlaminated with alluvial sand, gravel, silt and clay. The hard crystalline rock is basalt and granite.

the environs of Phnom Penh. No artesian aquifers were found, the area being underlain at depths ranging from 18 to 80 m by hard crystalline rock. The best well yielded was 200 l/min, and the average of seven productive wells was 80 l/min. The average depth of the productive wells was 23.5 m with a range from 13 to 41 m. The nonproductive holes averaged 61 m deep, the medium one was 51 m, and the range was from 15 to 297 m. No report on the quality of water is available, but the water is used for a variety of purposes.

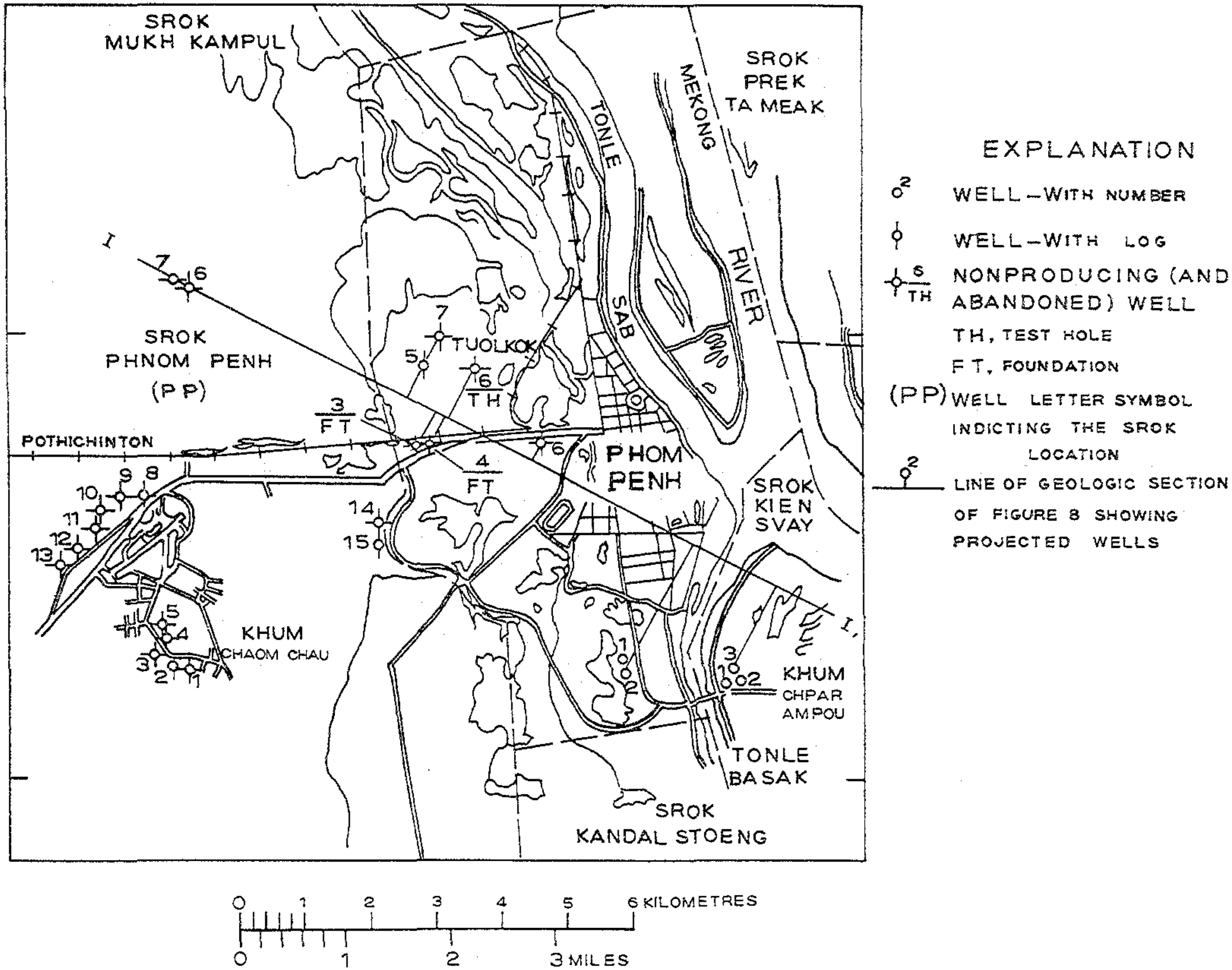
(2) UNICEF record

UNICEF has been assisting activities of the Ministry of Health providing wells for village since 1983. As many as 7,425 wells were dug in Cambodia by the end of 1992. The Numbers and types of wells are shown in Table-3.7. Out of the 7,425 wells, 1,011 wells were in the Phnom Penh area, as shown in Table-3.8, mostly suburban three districts: Mean Chey, Dang Kor and Russey Keo.

Table-3.6 RECORDS OF WELLS IN THE ENVIRONS OF PHNOM PENH

Well no.	Town or village	Locality	Date	Well Depth completed (meters)	Yield (liters per minute)
Ville de Phnom Penh					
VP 1	5th Quarter	Tuol Tumpung	7-3-61	34.1	2 **80**
VP 2	do	do	8-8-6	29.2	**25**
VP 3	Tuol Kork	Sangkum College	7-7-61	62	foundation test
VP 4	do	do	7-15-61	70	foundation test
VP 5	do	?	12-11-61	13	**200**
VP 6	do	Police Academy	7-7-60	296.7	Dry
VP 7	do	Atelier CEE	1-20-63	23	Dry
VP 8	Pochentrong Bld.	Pochentrong apartment	5-15-61	173	Dry
Srok Kien Svay (Mean Chey District)					
KSv 1	Chbar Ampou Svai	Pagoda 800m.east of Monivong bridge	7-10-61	17	**45**
KSv 2	do	do	7-15-61	17	**50**
KSv 3	do	do	7-17-61	13	**60**
Srok Phnom Penh (Dang Kor District)					
PP 1	KhumChom chau	Military Barracks	1-27-62	60	Poor
PP 2	do	do	2-8-62	41	**100**
PP 3	do	?	2-21-62	62	Dry
PP 4	do	?	2-20-62	26	Poor
PP 5	do	?	2-22-62	14.7	Poor
PP 6	KhumPochenton	Phumi Chres	8-19-61	70	Dry
PP 7	do	do	8-26-61	51	Dry
PP 8	do	Potchentong	9-6-61	42	Poor
PP 9	do	do	9-16-61	53	Poor
PP 10	do	Transport Barracks	03-15-63	22	Dry
PP 11	do	do	3-19-63	18	Dry
PP 12	do	Bonteay Sao Pan	4-12-61	58	Dry
PP 13	do	do	---	62	Dry
PP 14	KhumChomchau	Stung Mean Chey	3-7-62	42	Dry
PP 15	do	do	3-14-62	41	**200**

104°05' Fig-3.5 WELL LOCATIONS 104°55'



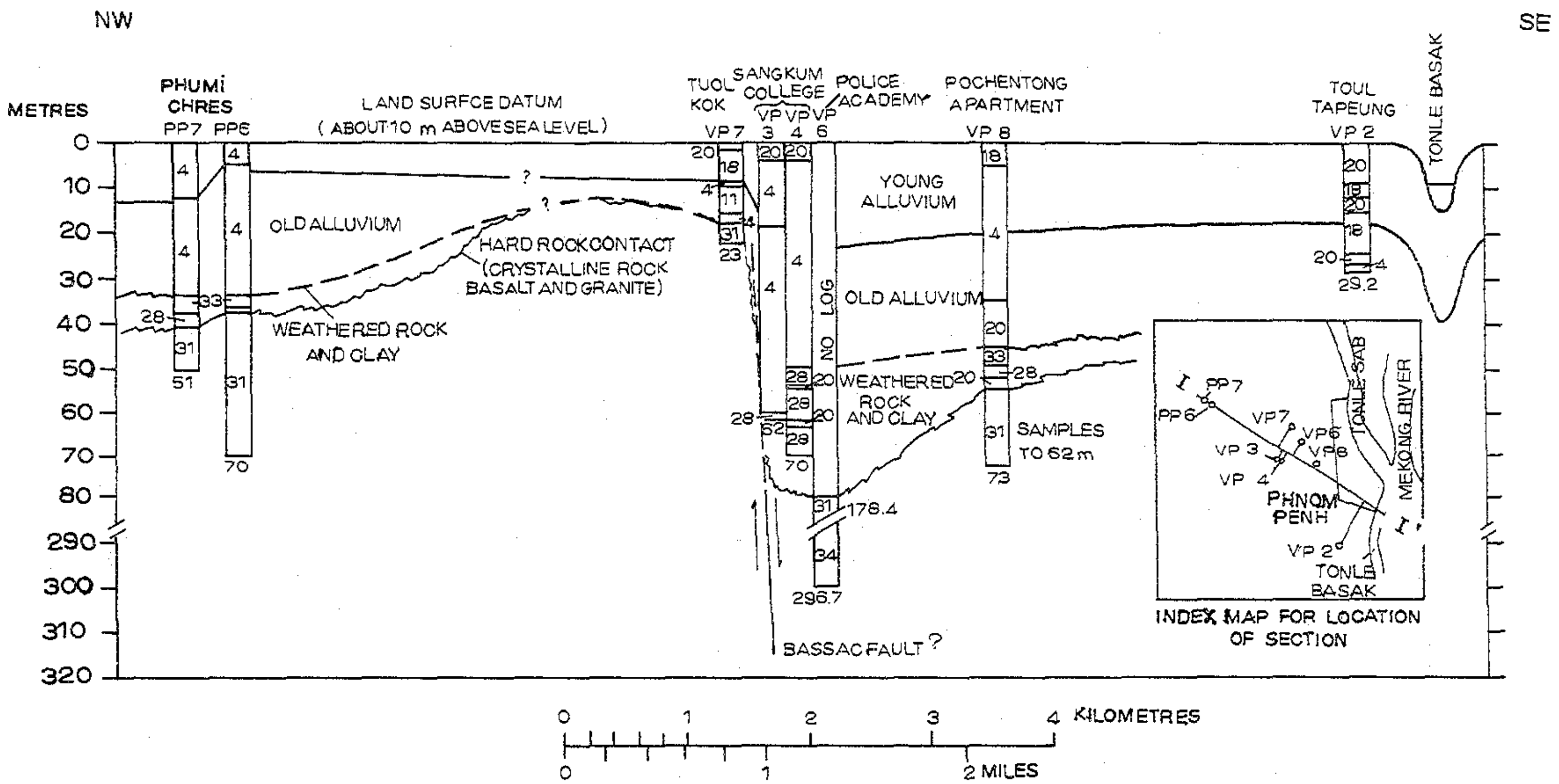


Fig-3.6 GEOLOGICAL CROSS SECTION

Table-3.7 NUMBER OF WELLS DUG BY UNICEF IN CAMBODIA
(BY YEAR)

Year	For Mechacical		For a Main		Rehabilitation Ancient Well		Rehabilitation Traditional Well		Total	
1983	10	-6							**10**	-6
1984	22	-5	2						**24**	-5
1985	37	-15	51						**88**	-15
1986	265	-47	17	70					**352**	-47
1987	465	-68	37	-20	20	282			**804**	-88
1988	807	-142	146	-25	57	-9	357-2		**1367**	-178
1989	732	-105	63	-26	53	-8	76	-1	**1024**	-140
1990	599	-87	222	-23	3	-2	2		**826**	-112
1991	581	-90	515	-39	1				**1097**	-129
1992	753	-155	1079	-129	1				**1833**	-244
TOTAL	**4271**	**-680**	**2162**	**-262**	**205**	**-19**	**787**	**-3**	**7425**	**-964**

- = denotes those facilities which are not in use as of 1993.

Table-3.8 NUMBER OF WELLS DUG BY UNICEF IN CAMBODIA
(BY PROVINCE)

Province	For Mechacical		For Main		Rehabilitation (Ancient Well)		Rehabilitation (Traditional Well)		Total	
Phnom Penh	205	-54	705	-102	4		97		1011	-56
Kandal	703	-91	609	-46	41		260		1613	-137
Kg.Sepu	808	-128	1	-1	49		159	-2	1017	-131
Prey Veng	110	-12	117	-12					227	-24
Takeo	877	-134	179	-27	30	-6	121		1207	-167
Kampot	406	-67	38	0	7	-3	17		468	-70
Kg.Chhang	520	-87	77	-9	29	-4	85		711	-100
Kg.Chan	438	-33	190	0	44	-6	46	-1	718	-40
Others	204	-74	246	-65	1	0	2	0	453	-139
TOTAL	**4271**	**-680**	**2162**	**-262**	**205**	**-19**	**787**	**-3**	**7425**	**-964**

- = denotes those facilities which are not in use as of 1993.

Table-3.9 DEPTH AND YIELD OF WELLS

Name of District	Kind of Well	Name of Sub District	Number of Well	MIN	DEPTH(m) MAX	AVG	YIELD(m^3/h) MIN	MAX	AVG
Dang Kor	PIT	ALL	70	0	48	1.90	4.3	0.1	
Dang Kor	DEEP	1 - 9	35	12	47	31.8	0	12.0	2.9
Dang Kor	DEEP	10	34	13	81	36.8	0	3.8	1.3
Dang Kor	DEEP	11 -12	20	19	82	50.8	0	12.0	2.4
Dang Kor	DEEP	13 -14	17	15	69	35.0	0	7.0	1.7
Dang Kor	DEEP	15	18	24	44	33.7	0	9.0	1.6
Dang Kor	Shallow	1	13	15	30	23.0	0	2.0	1.3
Dang Kor	Shallow	2	36	15	35	20.6	0.3	3.0	1.2
Dang Kor	Shallow	3 - 8	32	9	35	20.8	0	2.5	1.1
Dang Kor	Shallow	9	14	15	26	20.1	0	1.5	1.1
Dang Kor	Shallow	10 -15	19	12	36	23.9	0	0.8	0.7
Dang Kor	Shallow	ALL	114	9	36	21.4	0	3.0	1.1
Dang Kor	???	ALL	45	0	0	0	0	0.0	0.0
Dang Kor	ALL	ALL	353	0	82	20.3	0	12.0	1.1
Mean Chey	Shallow	1	6	18	25	21.3	2	3.0	2.7
Mean Chey	Shallow	2	52	13	27	21.3	2	4.0	2.3
Mean Chey	Shallow	3	77	13	34	22.9	0	6.0	2.5
Mean Chey	Shallow	4	42	15	26	22.3	1	3.5	2.4
Mean Chey	Shallow	5 - 6	15	20	45	31.5	0	3.0	1.6
Mean Chey	Shallow	7	73	14	40	26.9	0	4.0	1.7
Mean Chey	Shallow	8	65	15	38	24.9	0	4.0	1.3
Mean Chey	Shallow	A2	21	13	40	25.2	0	2.0	1.2
Mean Chey	Shallow	A3 - A6	5	9	26	19.4	0	3.6	1.3
Mean Chey	DEEP	ALL	11	24	45	34.5	0	18.0	5.5
Mean Chey	PIT	ALL	26	0	30	1.2	0	7.0	0.3
Mean Chey	ALL	ALL	393	0	45	22.7	0	18.0	1.9
PP.VILLE	Shallow	ALL	34	16	33	22.6	0	2.0	1.3
PP.VILLE	DEEP	ALL	51	10	100	36.5	0	40.0	5.1
PP.VILLE	PIT	ALL	13	0	0	0	0	0.0	0.0
PP.VILLE	ALL	ALL	98	0	100	26.9	0	40.0	3.1
Russey Keo	Shallow	1	9	0	36	21.1	0	3.5	1.4
Russey Keo	Shallow	2 - 3	48	20	36	26.3	0	3.5	2.0
Russey Keo	Shallow	4	50	18	37	25.5	0	2.7	11.8
Russey Keo	Shallow	5	37	16	31	23.7	0.3	6.0	2.3
Russey Keo	Shallow	6	38	12	36	21.8	0	4.5	1.9
Russey Keo	Shallow	7	24	15	46	26.4	0	2.8	1.8
Russey Keo	Shallow	10	12	14	40	24.6	0	1.0	0.3
Russey Keo	Shallow	11 - 12	7	18	31	24.4	0	2.0	0.9
Russey Keo	Shallow	???	9	15	34	23.1	0	2.0	0.6
Russey Keo	DEEP	ALL	21	22	93	40.0	0	3.6	1.1
Russey Keo	PIT	ALL	0						
ALL	ALL	255	0	93	25.8	0	6.0	1.7	

Note: Locations of districts and sub-districts are shown in Fig-5.2.

3.3 Water Quality

3.3.1 Water Quality Criteria

It is almost 100 years since the first water treatment plant started in Phnom Penh. In this long period of operation there were a lot of problems in both the treatment facilities and in the distribution/service facilities, which adversely affected the quality of water distributed.

Cambodia has no water quality standard for drinking water. Therefore, it is recommended that the PPWSA adopt the WHO's New Guidelines for drinking water. Each item of water quality can be judged based on the WHO Guidelines that are shown in Appendix B.

3.3.2 Water Quality Analysis

Due to lack of recent data on water quality, the Study Team conducted water quality sampling and analysis four times with an interval of 10 days between each sampling from March to May, 1993.

The sampling locations covered the three rivers which are potential future water sources and ten points for tap water as shown in Fig-3.7 and Table-3.10.

The water quality parameters analyzed in the field and in the laboratory are as follows:

1) Field parameters

- ambient temperature	(°C)
- water (sample) temperature	(°C)
- odour	
- electric conductivity	(US/cm)

2) Laboratory parameters analyzed in Cambodia

- pH	
- chlorine(OCl^-)	(mg/l)
- turbidity	(NTU)
- suspended solids(S.S.)	(mg/l)
- chromium, hexavalent(Cr^{6+})	(mg/l)
- copper(Cu^{2+})	(mg/l)
- fluoride(F^-)	(mg/l)

- iron, total(Fe)	(mg/l)
- nitrogen(NO_2^--N)	(mg/l)
- sulfate(SO_4^{2-})	(mg/l)
- COD (Mn)	(mg/l)
- zinc(Zn)	(mg/l)
- total manganese(Mn)	(mg/l)
- cyanide(CN^-)	(mg/l)
- aluminum(Al)	(mg/l)
- faecal coliform	(per 100 ml)
- total coliform	(per 100 ml)
- bacteria	(per ml)

3) Laboratory parameters analyzed in Japan

- alkalinity	(mg/l)
- arsenic	(mg/l)
- cadmium	(mg/l)
- lead	(mg/l)
- mercury(total)	(mg/l)
- nitrate nitrogen(NO_3^--N)	(mg/l)
- nitrogen ammonia(NH_3-N)	(mg/l)
- phosphorus(as PO_4^{-3})	(mg/l)
- chlorophenothane	(μg/l)
- DDT	(μg/l)
- trihalomethanes	(μg/l)
- 1,1,1-trichloroethane	(μg/l)
- trichloroethylene	(μg/l)
- tetrachloroethylene	(μg/l)

All sample locations were clear with no odor. The water appeared to be clean, colorless with apparently good quality. The ambient temperature and water temperature during sampling were respectively in the range of 27.0°C-32.0°C. The results of analysis are summarized in Appendix B.

3.3.3 Raw Water Quality

The quality of raw water was expected to deteriorate due to increasing soil erosion and pollution caused by increasing industrial development and urbanization in the upstream area. However, the river water quality is assessed to be suitable for use as a source of water supply under the existing conditions. Fig-3.8 shows the present tendency of pH and turbidity of raw water.

Suitability of the river water currently used at the treatment plants is discussed later in the description of each system.

3.3.4 Treated and Tap Water Quality

The quality of treated water at the Phum Prek WTP, the Chamcar Morn WTP and that of water distributed and sampled at taps was evaluated. Water quality is in conformity with the WHO's Guidelines for drinking water with respect to all measured parameters except residual free chlorine and faecal coliform. Fig-3.9 shows the results of the analysis of treated water at each water treatment plant.

In general, the bacteriological and chemical parameters of tap water measured by the Study Team conform with the WHO's Guideline. However, consistent availability of residual free chlorine and the absence of coliform bacteria does not always guarantee the quality of tap water. Fig-3.10 shows the results of the analysis selecting four sampling points out of ten points as the representative points in each service area.

Considering the results of the analysis conducted in the on-site study, tap water quality in dry season is not safe enough for drinking because of total coliform number and residual chlorine concentration.

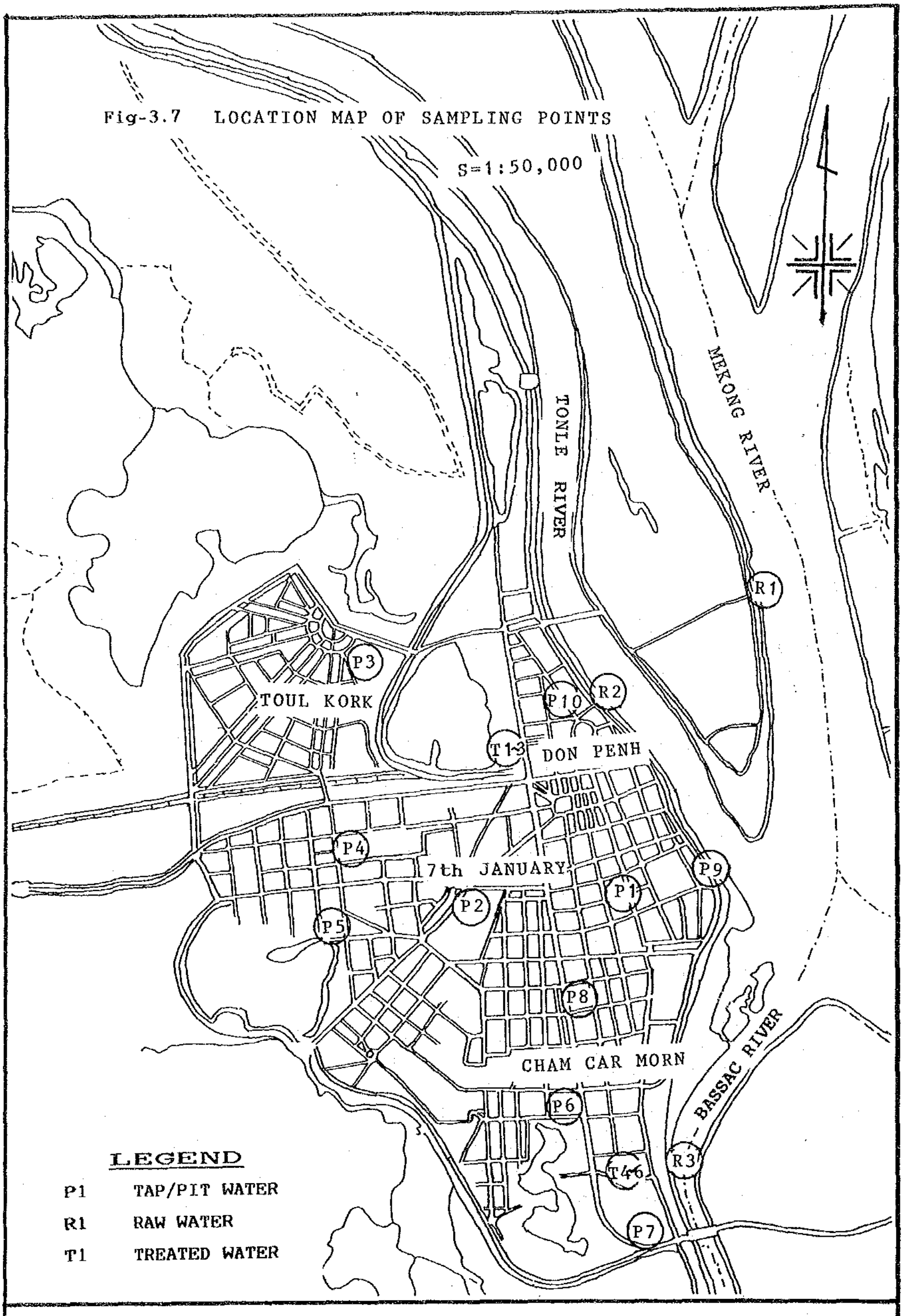


Fig-3.7 LOCATION MAP OF SAMPLING POINTS

Table-3.10 LIST OF WATER SAMPLING LOCATIONS (1/2)

No. of Water Sampling	Location of Sampling Point	Water to be Sampled	Remarks
R 1	Mekong River Chruoy Chang War WTP	Raw Water	Intake Tower
R 2	Sap River Phum Prek WTP Intake	Raw Water	Receiving Well
R 3	Bassac River Chamcar Morn WTP Intake	Raw Water	Intake Well
T 1	Phum Prek WTP Flocculation Basin	Treated Water	
T 2	Phum Prek WTP Sedimentation Basin	Treated Water	
T 3	Phum Prek WTP Filter Tank	Treated Water	
T 4	Chamcar Morn WTP Flocculation Basin	Treated Water	
T 5	Chamcar Morn WTP Sedimentation Basin	Treated Water	
T 6	Chamcar Morn WTP Filter Tank	Treated Water	

Table-3.10 LIST OF WATER SAMPLING LOCATIONS (2/2)

No. of Water Sampling	Name/No. of Street/Road	Water to be Sampled	Remarks
P 1	St. 240/51	POTABLE WATER From TAP/PIT	
P 2	Achar Hemcheay & St. 182	"	
P 3	Toul Kork St. 283/516	"	
P 4	Kampuchea Viet Nam St.	"	
P 5	Keo Bony Road St. 150	"	
P 6	St. 95/932	"	
P 7	St. 99/474	"	
P 8	St. 334/93	"	
P 9	Behind Lenine Road	"	
P10	St. 47	"	

Fig-3.8 pH AND TURBIDITY OF RAW WATER

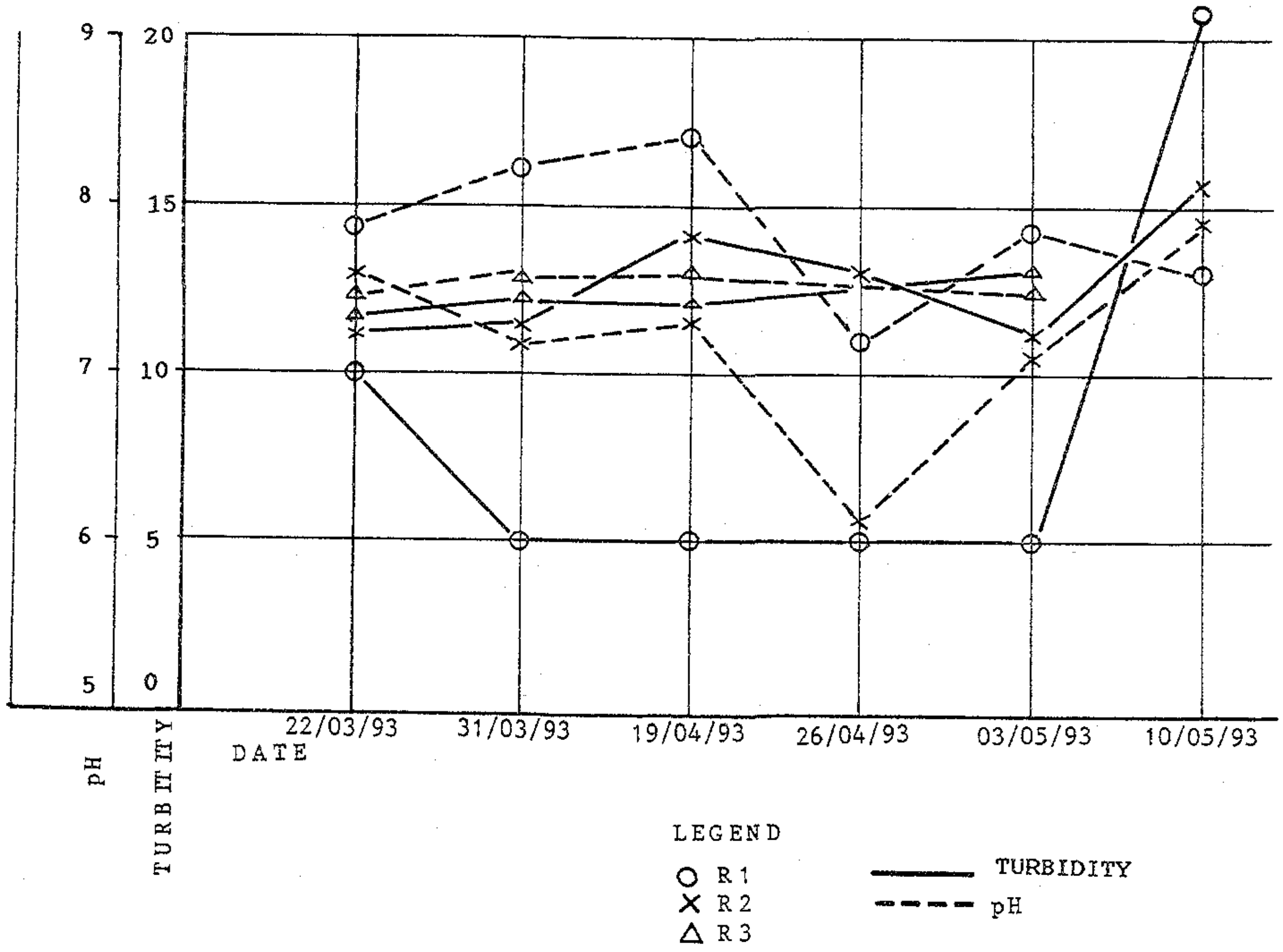


Fig-3.9 pH AND TURBIDITY OF TREATED WATER AT WTP

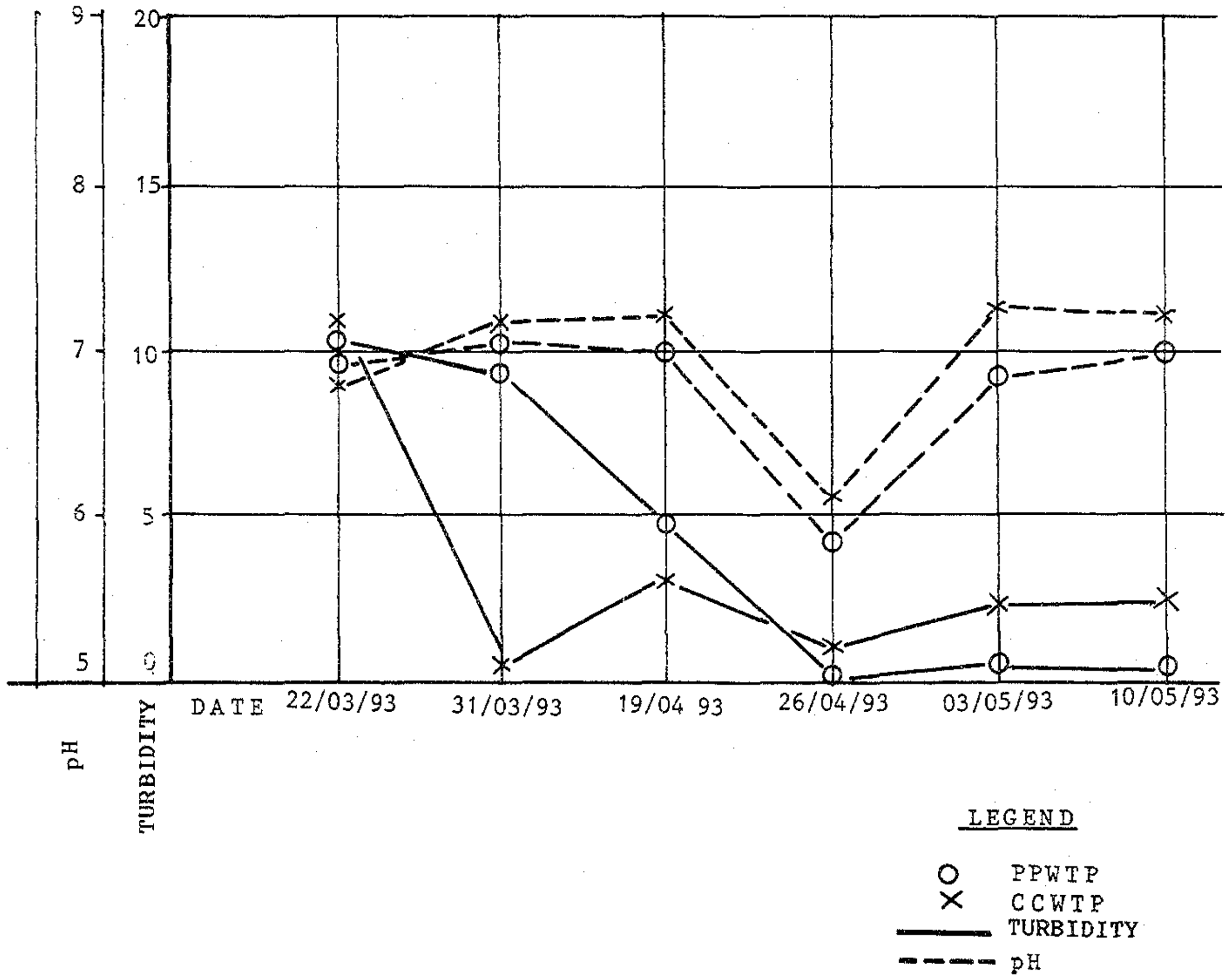
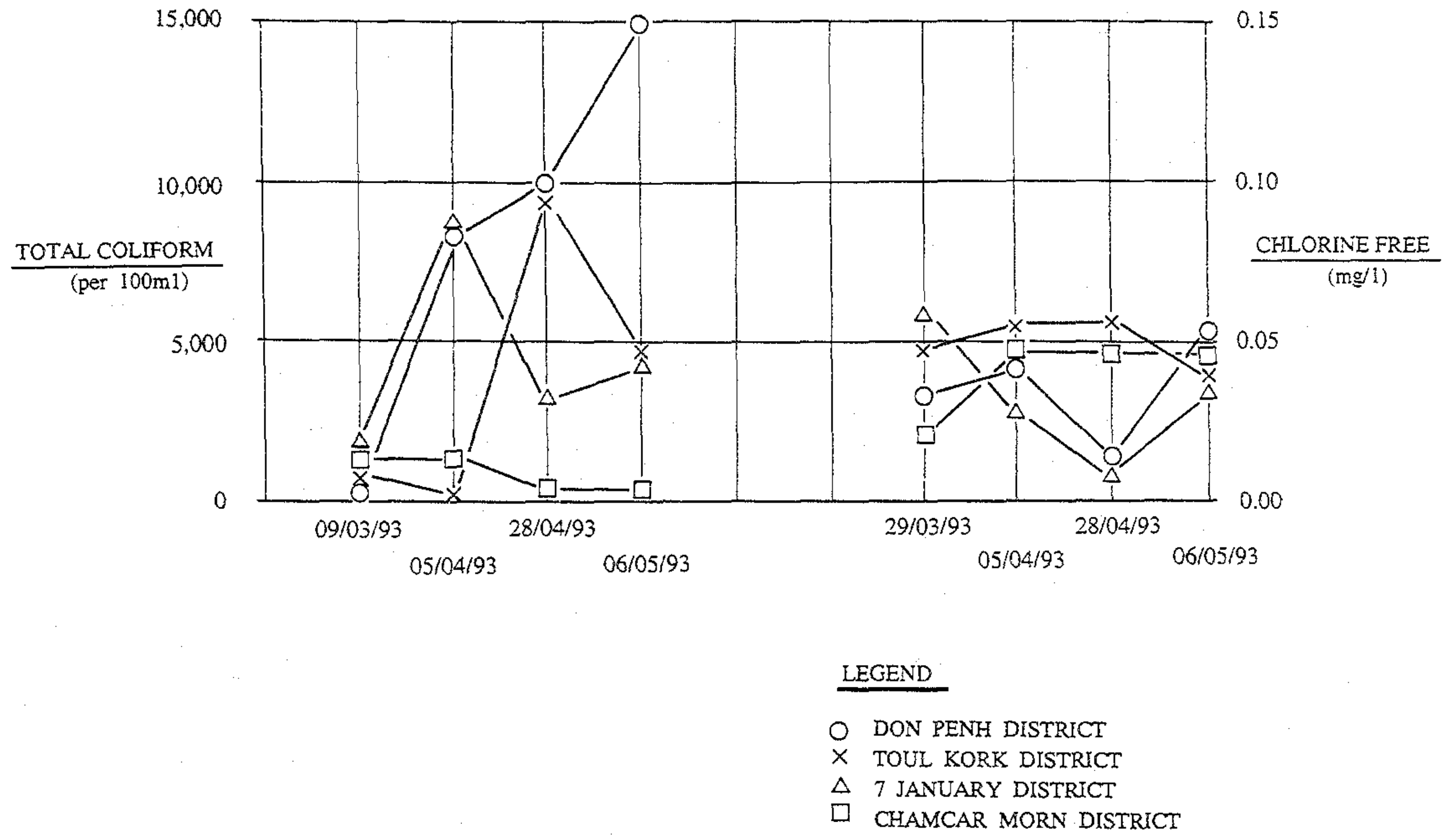


Fig-3.10 TOTAL COLIFORM AND CHLORINE FREE OF TAP WATER



3.4 Existing Water Supply System

Phnom Penh has two types of water supply systems: a public system owned and operated by the PPWSA, and privately operated systems. The private systems are operated by Sofitel Cambodiana and Floating Hotels. In this section, the public water supply system is presented.

The groundwater in the Phnom Penh area is poor in both quantity and quality as described in the preceding section. Therefore, all systems depend totally on surface water sources. At present, the public water supply system of the PPWSA consists of three sub-systems (See Fig-1.1).

a) Phum Prek System supplying 56,000 m^3/day diverted from the Sap river,
b) Chamcar Morn System supplying 7,000 m^3/day diverted from the Bassac river and
c) Chrouy Changwar System, with a design capacity of 30,000 m^3/day with water from the Mekong river. The operation of this system has been abandoned since 1983 due to deterioration of the facilities.

The problems common to all facilities are: i) deterioration and malfunction in connection, and absence of preventive maintenance because of lack of experienced staff and spare parts, ii) non-existence of adequate and appropriate operation manuals, and iii) poor records and ledgers for operation and maintenance.

Among the three sub-systems in Phnom Penh , the operation of the Chrouy Changwar treatment plant and its system have been suspended.

The total length of distribution pipes is estimated to be about 277 km with diameters ranging from 60 mm to 800 mm. The material of the pipes is mostly cast iron. The pipes were installed between 1895 and 1960.

An elevated tank with 2,000 m^3 capacity is located at the center of the city, near the Olympic stadium. This cannot be operated because of low pressure.

3.4.1 Phum Prek System

3.4.1.1 Outline

The Phum Prek water treatment plant was built in Phnom Penh in 1966 with a capacity of with a capacity of 100,000 m^3/day. The plant was originally planned as a 200,000 m^3/day plant and a facility with half the capacity was constructed as the first step. The raw water is taken from the Sap river. The plant was damaged during the civil war like all other plants. Now the plant has been rehabilitated with assistance from various aid organizations. However, only about 56,000 m^3/day of treated water has been produced because of a shortage in power supply.

3.4.1.2 Water Source

The features of the Sap river and the quality of its water are as follows:

a) Large fluctuation of river water level
   The high water level (HWL) and low water level (LWL) at the Sap river intake tower are as follows:
   HWL +10.90 m
   LWL + 1.58 m

b) Long-lasting high turbidity of river water in rainy season
   High turbidity (higher than 200° NTU) continues for two to three months during the rainy season.

c) Water quality of the Sap river and that of the Mekong rivers are not always similar to each other.
   The turbidity of the Sap river is generally higher than that of the Mekong river in the dry season, and vice versa in the rainy season.

d) In the dry season the Sap river always flows from upstream to down stream, and in the rainy season the flow reverses at high tides.

The discharge of the Sap river is about 5,000 m^3/sec on the average in the rainy season, although the flow direction becomes opposite in the dry season. The river flow, therefore, does not influence the intake capacity for water supply from the standpoint of the quantity.

The quality of the Sap river water can be said to be of a typical river. Conductivity is about 0.1 μS/cm, and alkalinity 30 - 35 mg/lit. Fluoride is found to be about 0.3 - 0.6 mg/lit. In addition ammonium nitrogen is 0.2-0.7 mg/l.

3.4.1.3 Plant Operation

The operation of the plant is administered by the Production Department under the Director of PPWSA. The number of operational staff at the plant are 39 at present. The day-to-day maintenance is conducted by the Technical Department, which has 20 staff members. The spare parts are procured by the Production Department in coordination with the Financial Department.

The modes of plant operation during day time and during night time are shown below:

a) Day time

Operation Hours: 5 a.m. - 6 p.m. (13 hours)
Combination of Pumps
Raw Water of Pumps: 2,200 m^3/hr x 2 sets = 4,400 m^3/hr

Distribution Pump: 2,100 m^3/hr x 1 set = 2,100 m^3/hr
- do - 900 m^3/hr x 2 sets = 1,800 m^3/hr

Total 3,900 m^3/hr

Distribution Capacity: 3,900 m^3/hr x 13 hr = 50,700 m^3...[1]

b) Night time

Operation Hours: 6 p.m. - 5 a.m. (11 hours)
Combination of Pumps:
Raw Water of Pumps: 2,200 m^3/hr x 1 set = 2,200 m^3/hr

Distribution Pump 900 m^3/hr x 1 set = 900 m^3/hr

Distribution Capacity: 900 m^3/hr x 11 hr = 9,900 m^3 ...[2]

At night, the output of the raw water pump and the distribution pump are 2,200 m^3/hr and 900 m^3/hr respectively, and the balance (treated water) (1,300 m^3/hr)

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1. Total rated distribution capacity is 60,000 m^3/day.
2. However measured distribution quantity was 56,000m^3/day in April 1993.

is stored in the service reservoirs. When the reservoirs become full, the raw water pump is stopped until the day time. Such night time operation is employed because of power supply shortage during night time. Operating 900 m3/hr pump in the night time means keeping the treated water in the distribution pipes. Specifications of existing distribution pumps are shown in Appendix N.

3.4.1.4 Plant Facilities

Fig-3.11 through Fig-3.13 show general plan and hydraulic profile.

1) Civil Works

a) Intake Tower

The intake tower made by steel sheet-piles forming a cylinder with an inside diameter of 10.7 m is located on the right bank of Sap river. On the cylindrical structure, a rectangular raw water intake pump house (Width 10.0 m x Length 11.0 m, reinforced concrete) is constructed. There is a steel access bridge between the pump house and the river bank. The installed main equipment is as follow:

Inlet gates	Height 1.0 m x Width 1.1 m x 4 sets
Raw water intake pumps	Diameter 500 x Quantity 2,200 m3/hr x Height 21.0 m x 85 kw x 3 sets
Other equipment	Traveling crane, access bridge, anti-water hammer device.

Of the four inlet gates, two are fully opened and not operational. The remaining two cannot be closed completely. As for the raw water intake pumps, one set is out of order. The crane is operational. The supply of spare parts are largely insufficient, and therefore maintenance works have been unsatisfactory.

b) Raw Water Main

The raw water mains consist of two lines of cast iron pipe between the intake tower and the receiving well at the water treatment plant.
Diameter 700 mm x Length 1.3 km x 2 lines

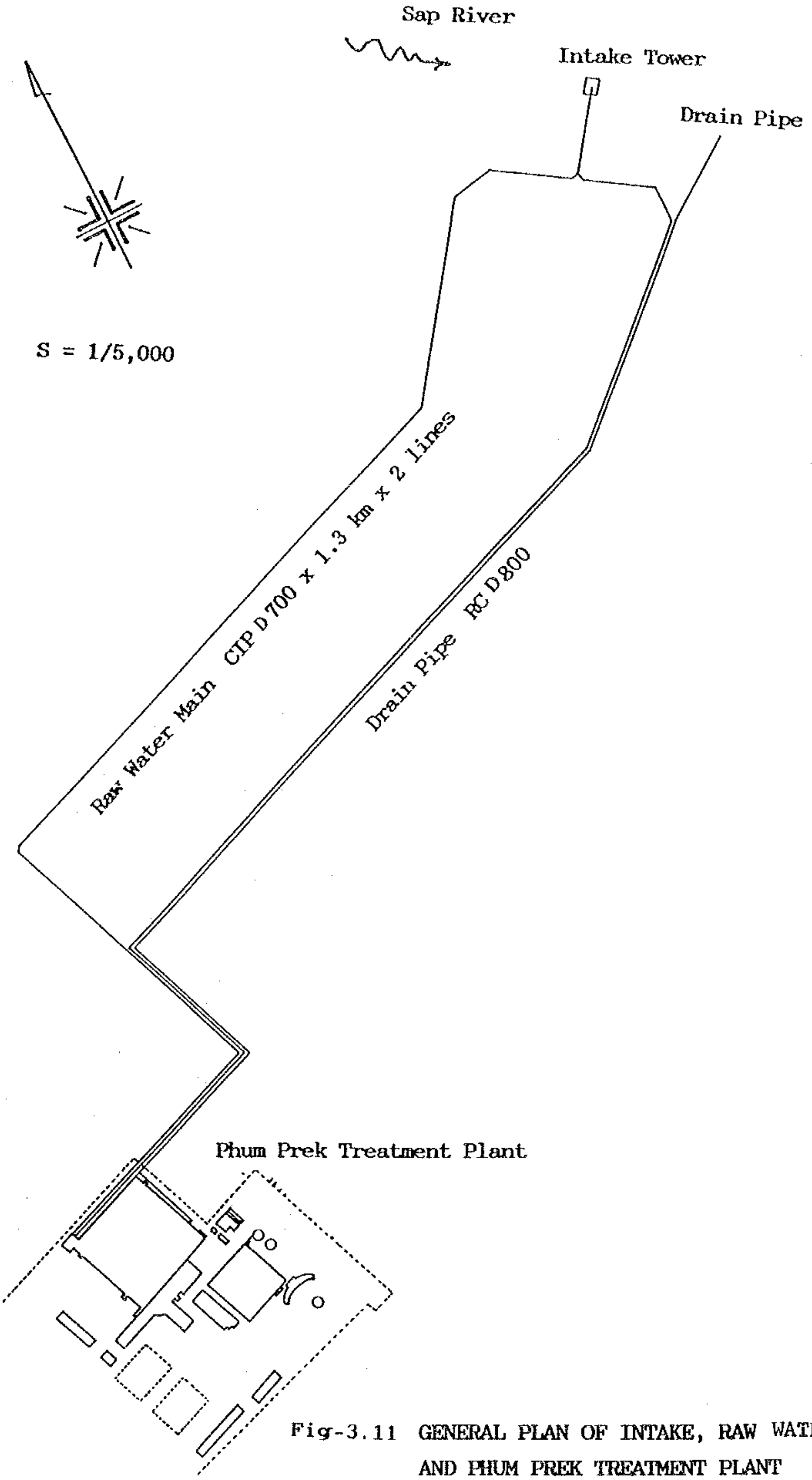


Fig-3.11 GENERAL PLAN OF INTAKE, RAW WATER MAIN AND PHUM PREK TREATMENT PLANT

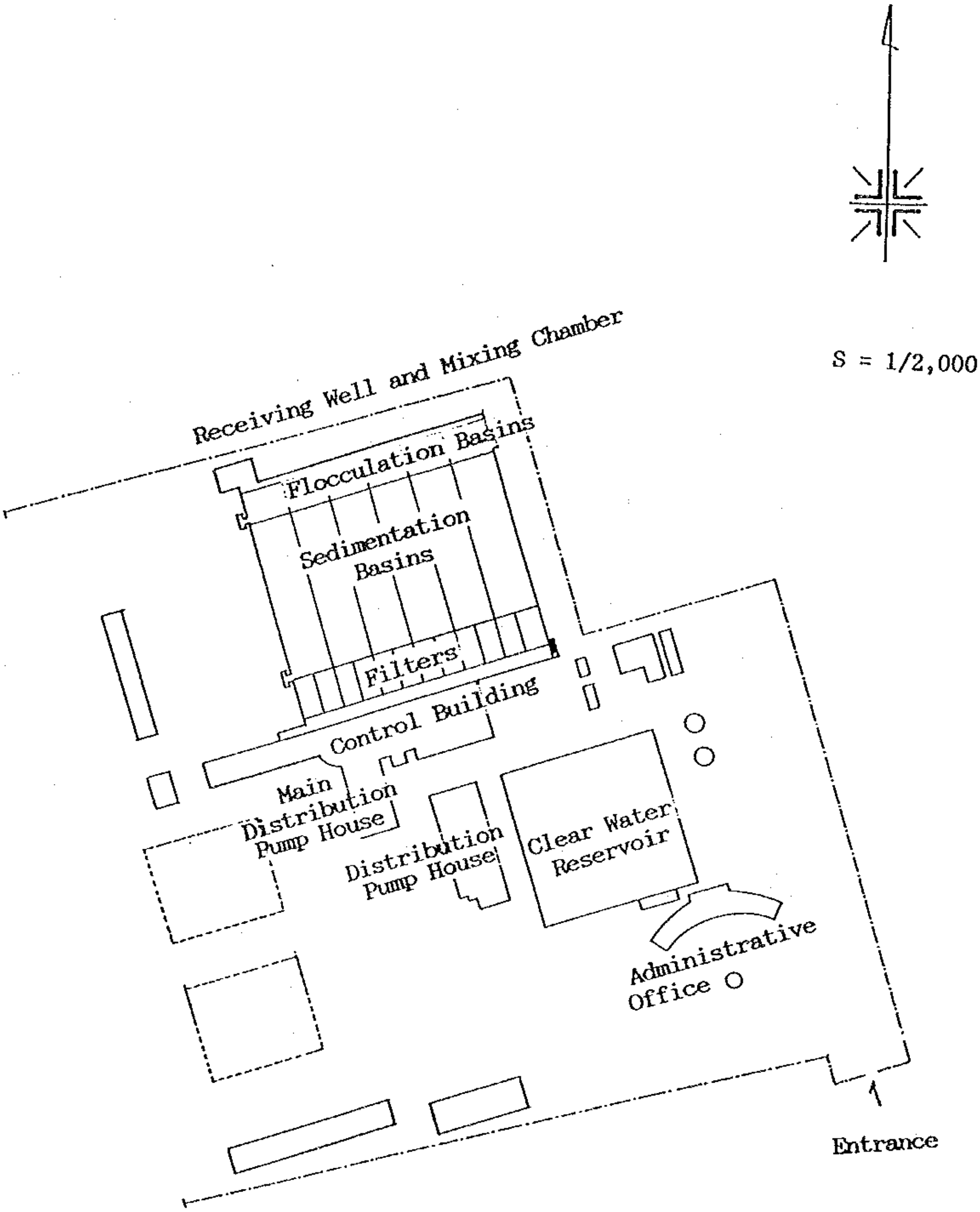
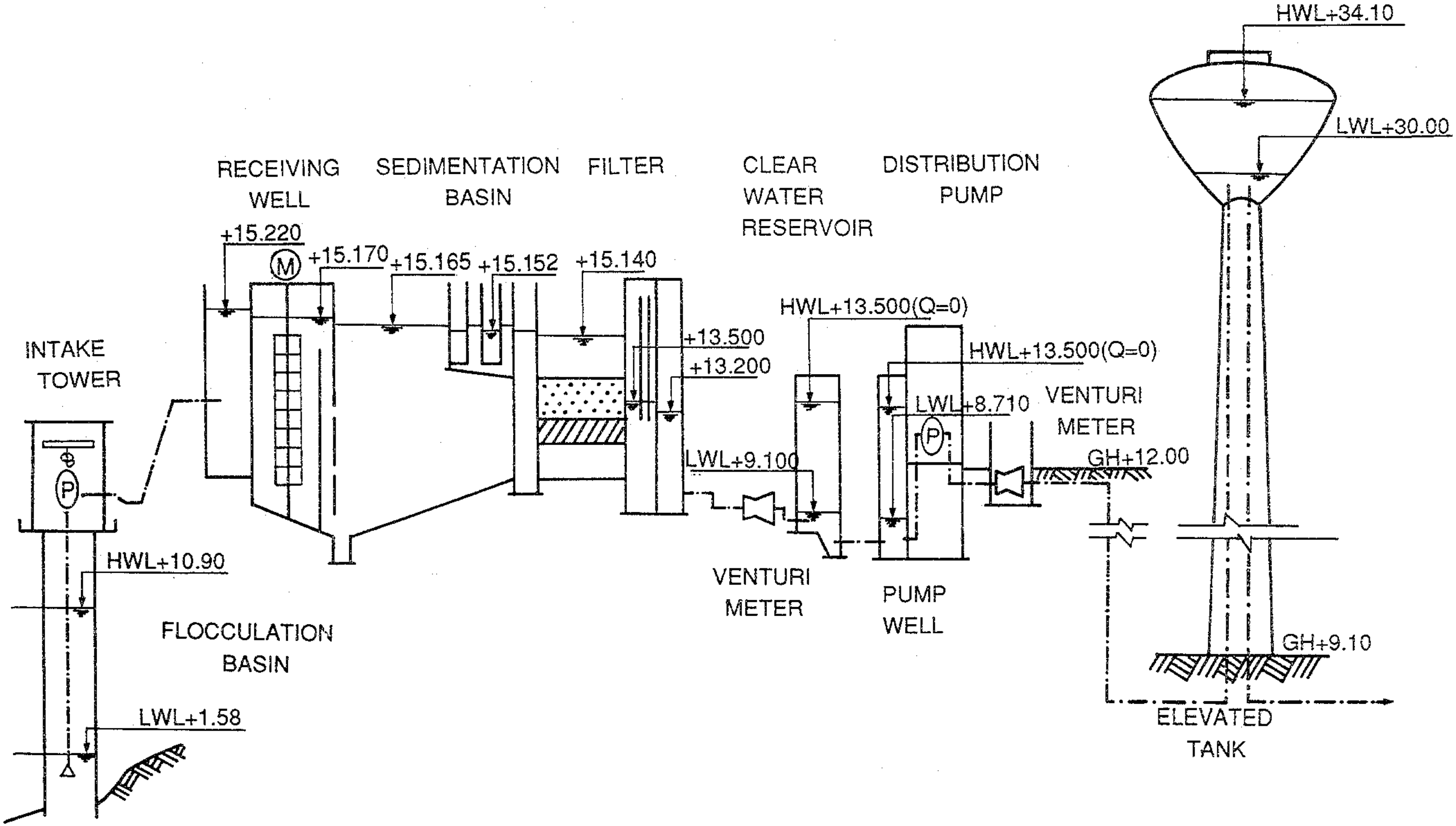


Fig-3.12 GENERAL PLAN OF PHUM PREK TREATMENT PLANT

Fig-3.13

HYDRAULIC PROFILE OF PHUM PREK TREATMENT PLANT

scale : NON



The raw water mains are corroded with ferruginous scale and much scale is settled on the bottom of receiving well in the water treatment plant. Along the mains, the power cables for the intake pumps are laid from the treatment plant. The drain pipe, D800 mm, of reinforced concrete is installed for the spill water from the receiving well and filter back washed water.

c) Receiving Well

The raw water mains, D700 mm, are connected to the reinforced-concrete receiving well. The well is equipped with three overflow weirs through which spill water is conveyed to the Sap river.

Receiving well	Width 5.2 m x Length 5.0 m x Depth 6.5 m
Volume	170.0 m^3
Detention time	2.4 min
(Design capacity of the plant = 1.2 m^3/sec)	
Overflow weir	Width 1.35 m x 3 Nos.
Drain valve	Diameter 100 x 1 set

The receiving well was designed for a future capacity of 200,000 m^3/day. Sediment is expected to lie at the bottom.

d) Mixing Chamber

The two mixing chambers are placed downstream of the receiving well each with a steel gate. There is a distributor to dose chemicals on the slab of the mixing chamber. At present only alum solution is mixed with raw water and lime slurry is not dosed because the mixing equipment and slurry conveying pipe are out of order.

Mixing Chamber	Width 2.9 m x Length 2.7 m x Depth 2.5 m x 2 units
Capacity	20 m^3 x 2 Chambers
Detention Time	0.5 min
Flash Mixer	Diameter 0.32 m x 348 rpm x 4.0 kw x 2 sets
Inlet Gate	Height 1.0 m x Width 1.0 m x 2 sets
Outlet Gate	Height 1.0 m x Width 1.0 m x 2 sets
Stop Valve	Diameter 80 x 2 Nos. (for drain)

Both of the inlet gates are completely opened and cannot be closed due to corrosion of the body of the gates and their guide channels, and the raw water is not equally divided into the two chambers. The dosing point of chemicals is not appropriate. Repair of the lime dosing equipment and the slurry conveying pipe are necessary.

e) Flocculation Basin

The raw water mixed with chemicals is brought to the raw water dividing ditch, where it is equally distributed to the six flocculation basins. The twelve (12) inlet valves are installed between the raw water dividing ditch and the flocculation basins. The flocculation system is a mechanical type.

Flocculation Basins	Width 8.0 m x Length 11 m x Depth in Center 3.27 m x 6 unit
Capacity	288 m^3/unit
Detention Time	24 min
Flocculators	Diameter 4.5 m x Height 2.5 m x 2.5-3.7 rpm x 1.3/2.0 kw x 2 sets/basin x 6 basins

Although two inlet valves per basin are installed and fully opened, all the valves cannot be closed because of corrosion. When it becomes necessary to empty any flocculation or sedimentation basin for desludging, additional steel plates are always kept near the valves. Several puddles and shafts of the flocculator need to be repaired. Drain valves consisting of 18 top type (D 200) are leaking.

f) Sedimentation Basin

The sedimentation basin is of the conventional horizontal flow type, and the basins are desludged manually by flushing water from taps arranged around the flocculation and sedimentation basins. Between the flocculation and sedimentation basins, there are no gates and valves but the so-called wooden Split Rolls to accelerate sedimentation of flocks.

Sedimentation Basin	Width 11.0 m x Length 53.0 m x Depth in Center 2.52 m x 6 units
Capacity	1,47 m^3/unit
Detention Time	2.0 hr
Split Rolls	Lumber, Width 11.0 m x 3 Nos. x 6 Basins
Drain Valves	Top Valve Diameter 200 mm x 3 sets/basin

Drain Valves	Top Valve Diameter 200 mm x 3 sets/basin x 6 basins
Outlet Gates	Width 0.8 m x Height 1.4 m x 6 basins
Flushing Water Taps	Diameter 32 mm x 4 tap/row x 8 rows

Along the walls of the flocculation and sedimentation basins, several structural cracks probably caused by irregular subsidence are observed. Water leaks/flushes out from the cracks at the time of desludging which are carried out every 3 to 4 weeks, depending on the turbidity of raw water. Drain valves need to be repaired because of leakage. Stocked hoses and nozzles used for the flushing are severely inadequate in number.

g) Filter

The type of filter is rapid sand filter with backwash by means of air and water. Surface wash is not applied. The filter is planned to be operated at the operation gallery where operation tables are arranged. Every table is set to control two filters. The dimension and numbers are shown below:

Filter cell	Length 11.9 m x Width 4.5 m x 12 units
Filter bed area	53.6 m_2/units
Filtration rate	164.2 m/day (Nor.), 179.1 m/day (Max.)
Underdrain system	Porous slab (50 mm thickness)
Depth of filter sand	1.0 m
Effective diameter	0.45 mm - 0.7 mm
Coefficient	1.4 and less
Maximum head loss	1.64 m

One of filter beds is currently under repair and all filters are going to be repaired under a project financed by France. The inlet gates are of an automatic-closing type by means of a float during backwash. As the inlet gates set between the settled water channel and filters are closed during backwashing, much of the sludge settles in the settled water channel.

h) Service Reservoir

The filtered water is conveyed by two lines of D700 mm CIP to the service reservoir. The flow of filtered water was originally planned to be measured by venturi meters, but they are not used presently.

Service reservoir	Width 50.0 m x Length 50.0 m x Effective Depth 4.4 m x 1 unit
Effective capacity	11,000 m^3
Detention time	2.6 hr
Drain pipe	Diameter 800 mm with a gate valve

The drain pipes were removed when new reservoir was constructed under an aid from the USSR 1). Eventually the reservoir has been unable to be empty.

i) Control Building

The control Building is composed of the following:

Entrance hall
Administration office
Control room
Main distribution pump house
Generator room
Subsidiary equipment room
Chemical dosing rooms with chemical dosing gallery
Laboratory
Stores and others

2) Mechanical Equipment

All spare parts for mechanical equipment are in severe short supply to properly maintain the equipment. Therefore it is difficult to carry out any preventive maintenance under the present condition despite great efforts made by the plant staff.

Oxford Famine (OXFAM), an English NGO, has been engaged in the rehabilitation of the plant and proposed to urgently repair or replace the plant machines by the end of 1992. However, most of the equipment remained unrepaired due to lack of budgetary arrangement for improvement by the Government for the civil works.
The detailed condition of the equipment is given in the equipment list in Appendix H and Appendix I.

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1) Construction of the New reservior was suspended and is completed.

3) Electrical Equipment

The condition of the electrical equipment is similar to the mechanical equipment due to several short supply of spare parts. Laying of a cable without a conduit seems to accelerate the deterioration of some parts of the cable installed. In addition, the power cables, which were installed for temporary use, are still used in the distribution pump house without protection for the operators and the equipment itself. All electrical protection devices are omitted in the plant.

Proper maintenance has not been conducted for the electrical equipment due to lack of not only electrical engineers but also spare parts. Further, complete negligence of operation and maintenance during the Pol Pot regime has accelerated the deterioration of all electrical equipment.

The main findings of the field reconnaissance surveys are given in the electrical equipment list in Appendix H and Appendix I.

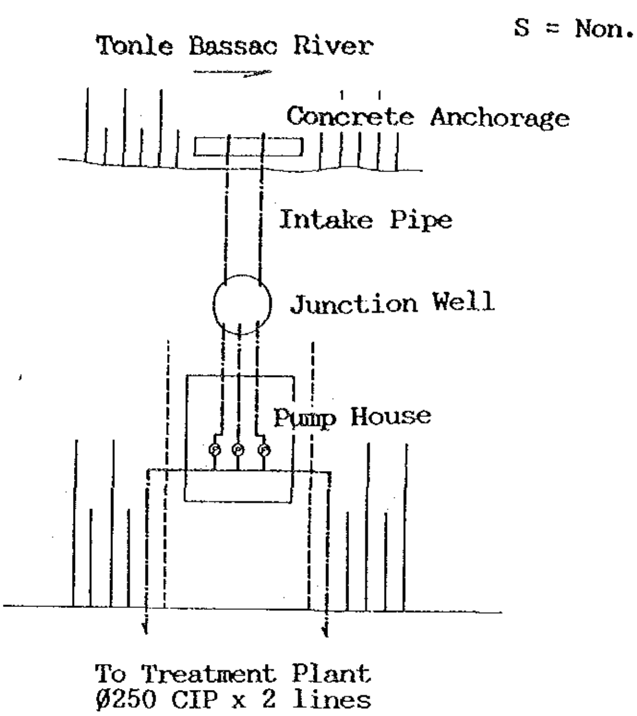
3.4.2 Chamcar Morn System

3.4.2.1 Outline

The Chamcar Morn treatment plant was constructed as the second plant in Phnom Penh in the southern part of the Municipality with 10,000 m^3/day capacity in 1957 to meet the increasing water demand. The raw water was obtained from Tonle Bassac river. During the Pol Pot regime, the Plant was abandoned and heavily damaged due to lack of operation. After the liberation day, the Plant was repaired temporarily by the Water Supply Authority. Rehabilitation during 1985 to 1988 under assistance from the USSR to restore the original capacity of 10,000 m^3/day was done. At present, the actual output is only about 7,000 m^3/day mainly because of unstable supply of electricity and deterioration of the facilities.

The treated water is distributed by distribution pumps directly. In the premises of the plant, a water filling stand is provided for tank trucks to supply areas with no distribution network or poor supply. The general plan of the Chamcar Morn plant is shown in Fig-3.14 and hydraulic profile is shown in Fig-3.15.

CHAMCAR MORN INTAKE FACILITIES



CHAMCAR MORN TREATMENT PLANT

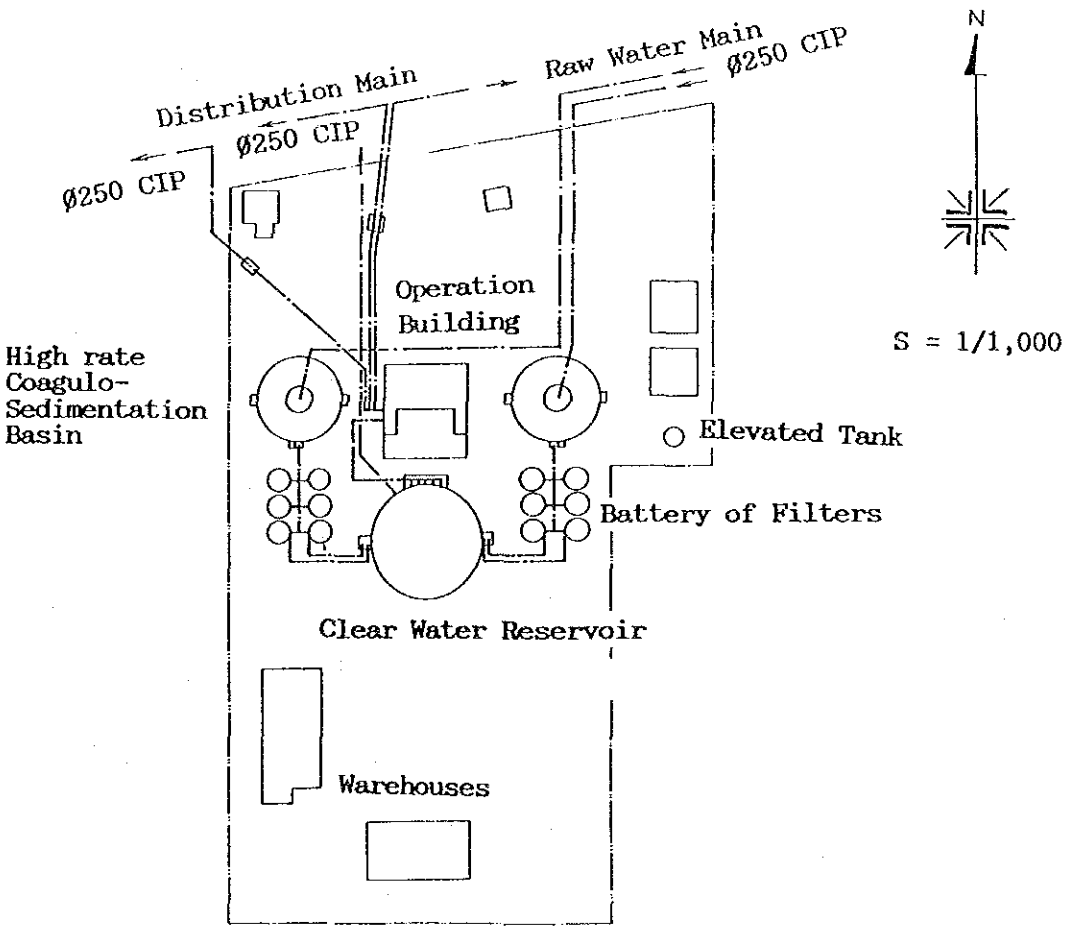
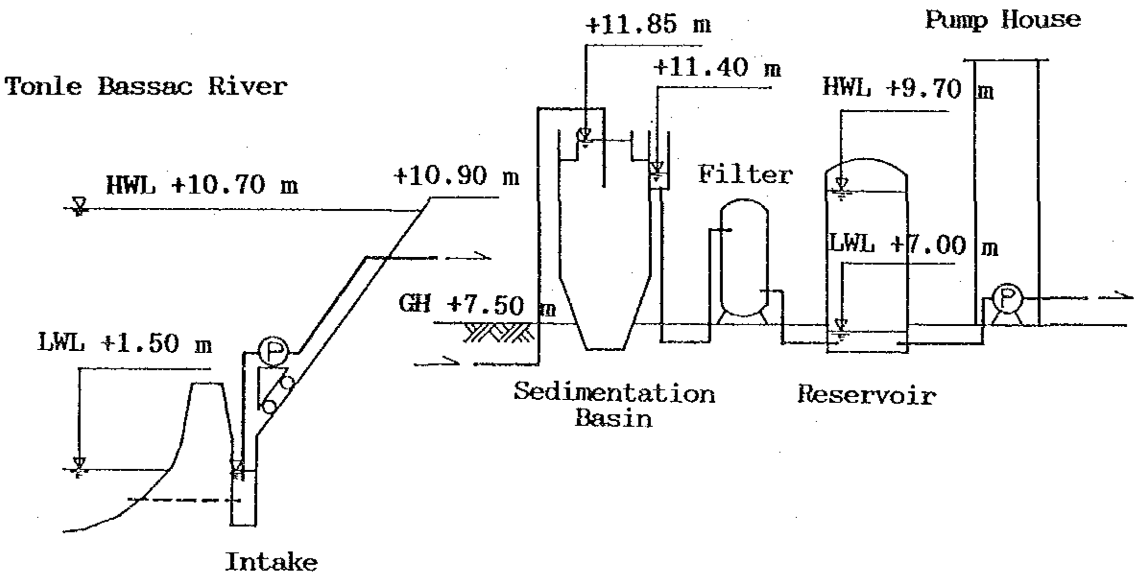


Fig-3.14 GENERAL PLAN OF CHAMCAR MORN INTAKE & TREATMENT PLANT

CHAMCAR MORN TREATMENT PLANT



Scale = Non.

Fig-3.15 HYDRAULIC PROFILE OF CHAMCAR MORN TREATMENT PLANT

3.4.2.2 Water Source

The raw water of the plant is obtained from the Bassac river through intake pumps. The features of the raw water of the Bassac river are quite similar to that of the Sap river, and are as follows:

a) Large fluctuation of river water level
   The magnitude of water level fluctuation resembles the Sap river as stated in the previous section.

b) Long-lasting high turbidity in rainy season
   As the water of the Bassac river is not always mixed with that of the Sap river adjacent to the confluence of these rivers, the condition of raw water in terms of turbidity is similar for both rivers.

c) Water quality of Bassac and Mekong rivers do not necessarily resemble due to their confluence condition. This is because both rivers flow without mixing their waters.

The maximum discharge of Bassac river is about 5,000 m^3/sec and the yearly average is about 2100 m^3/sec. The river flow therefore does not influence the intake capacity of the water supply.

The quality of Bassac will be quite similar to the Sap river due to the flow conditions as stated above.

3.4.2.3 Plant Operation

The operation of the plant is controlled by the Production Department under the Director of PPWSA. The total staff number is about 23 persons at present. Maintenance has been conducted by the Technical Department as in the case of the PPWTP. The spare parts arrangement was made by the Production Department in coordination with the Financial Department.

The plant is operated 24 hours in contrast to intermittent operation of the PPWTP. The reason for this is the comparatively limited power requirements of the plant.

3.4.2.4 Plant Facilities

1) Civil Works

a) Intake Facilities

The Intake facilities of the Chamcar Morn treatment plant consist of a) intake pipes dipped into the Bassac river with concrete anchorage, b) a junction well made by reinforced concrete, c) a pump house which is set on two cable-car-like skid to adjust its height according to the river level, d) raw water pumps and e) an anti-water hammer device.

Item	No. of unit	Description
Intake pipe	2	D350 mm CIP
Junction well	1	Diameter 2.5 m RC x Depth 4.5 m
Pump house	1	Width 2.8 m x Length 9.7 m (steel made)
Raw water pump	3	Diameter 200 mm x Diameter 125 mm x Quantity 290 m^3/hr x Height 30 m x 37 kw (1 standby)
Anti-water hammer	2	0.9 m^3/tank x Pressure 3.0 kg/cm^2 x 2 tanks

The raw water pumps operated under the same conditions as all other equipment, encounter difficulties due to lack of engineers and spare parts, although all efforts are made towards maintenance by the staffs.

b) Raw Water Main

The two water mains, D250 mm CIP, are used to convey raw water to the plant. The mains are in an acceptable condition, although ferruginous scale had formed inside it.

c) High Rate Coagulation-Sedimentation Basin

The raw water conveyed from the Bassac river flows into two high rate coagulation-sedimentation basins in the plant. Originally, the basins were constructed as slurry circulation types with revolving wing motors. When the basins were reformed in 1985 under assistance from the then USSR, both revolving wing motors were replaced with hydraulic mixing types equipped with water jet nozzles and impellers.

Sedimentation Basin	2 units
Dimensions	Dia.10.8 m x Depth 4.5 m
Capacity	360 m^3/basin
Detention Time	1.7 hr
Aver. overflow rate	43 mm/min
Appurtenances	Hydraulic jet mixers nozzles
	Settled water collection system
	Drain system

The mixing of chemicals, aluminum sulfate and lime, with raw water is not always effective at present, and it is necessary to improve the mixing system of the basins.

d) Pressure Type Filters

The settled water is conveyed to two batteries of filters set beside the basins. Under the USSR assistance the filters were to be replaced with new ones. Several steel filter tanks were transported to the site and some others are still left at the Kompong Som port undelivered due to lack of local budget necessary for transporting them.

Pressure type filters	12 units in 2 batteries
Dimensions	Dia.3.0 m x Height 2.4 m
Filter bed area	7.1 m^2/unit
Volume of filter vessel	910 m^3/ unit

Filtration rate	128 m/day
Appurtenances	Inlet and Outlet Piping, Backwashing and Drain Systems

The filter media in about half of the 12 filters have badly deteriorated and several valves in the piping need to be repaired. The PPWSA intends to sieve the filter sand for improvement, but the work has not yet been carried out.

e) Service Reservoir

Filtered water is conveyed through four D200 mm CIP pipelines to the clear water reservoir. Under the USSR assistance it was planned to construct two additional reservoirs in the same plant premises, and the design was completed. But the construction was postponed after the change of regime in Russia.

Service reservoir	1 unit
Dimensions	Dia.15.0 m x Height 3.0 m
Effective storage volume	500 m^3
Detention Time	1.2 hr

The drain pipe, D600 mm, for disposal of waste water from the plant is laid between the reservoir and the public drain system.

f) Operation Building

The operation building is composed of the following:

Administration room
Distribution pump room
Chemical dosing rooms
Laboratory
Stores and others

In the operation building, the laboratory is set but not used at present. The chemical and biological tests necessary for the operation of the plant have been carried out at the central laboratory located in Phum Prek treatment plant.

2) Mechanical Equipment

Some deteriorated components of the mechanical equipment were replaced under the assistance of the former USSR between 1985 and 1988. But, the present condition of mechanical equipment is critical with shortages of spare parts. This is quite similar to the conditions at the other plants.

3) Electrical Equipment

The conditions of electrical equipment in the plant resembles that of other plants. All electrical equipment are being operated under critical conditions, and almost every part needs to be repaired. Drastic improvement needs to be conducted at the earliest occasion.

3.4.3 Chrouy Changwar System

3.4.3.1 Outline

To supply water to the central area of the Phnom Penh, the Chrouy Changwar water treatment plant was constructed in 1895 under a contract with the French company CEEI with a planned capacity of 30,000 m^3/day. The raw water was obtained from the right bank of Mekong river. After the first expansion, the capacity was 17,500 m^3/day. It became 30,000 m^3/day after the second expansion in 1920. The treatment capacity was increased to 45,000 m^3/day by the improvement in 1959 under assistance from Japan. The treated water was conveyed through 4 lines of submerged transmission mains across the Sap river-bed. The plant, however, has not been operated since 1983 because of the failure of the power cable and transmission mains and deteriorated plant facilities.

3.4.3.2 Water Source

The features of the raw water of Mekong river are shown below:

a) Large fluctuation of river discharge and water level:

According to the Yearbook released by the Mekong Committee in 1961, the maximum discharge was 49,700 m^3/sec in the rainy season and the minimum discharge was 1,250 m^3/sec in the dry season.

b) High turbidity and long-lasting turbid conditions during rainy season. Annual records of the Kaolieo treatment plant in Laos indicate that in a high turbidity period of more than 500 NTU of turbidity lasts for about 4 months. Records in 1982 and 1983 of the Chrouy Changwar water treatment plant show that the maximum turbidity was low compared to the Kaolieo records.

c) Water quality of the Mekong and the Bassac rivers do not necessarily resemble each other due to their confluence condition.

The distinctive characteristics of the Mekong river are high turbidity and pH, although the figures are rather low compared with the Kaolieo data of Vientiane, Lao PDR. According to the Study Team's field survey, pH was about 8.4 in April 1993. Generally at times of high turbidity, alkaline agents to keep optimum pH range for the coagulation are not required. In case of low turbidity, significant amounts of coagulants may be needed because of high alkalinity and pH.

3.4.3.3 Plant Facilities

The layout of the facilities is shown in Fig-3.16.

1) Civil Works

a) Intake Tower

The oldest intake facilities constructed at the establishment stage was wrecked and their foundations remain in the river bed. An intake tower made with well-sinking method in 1959 is the only stracture remaining. The tower and the bank are connected with a steel access bridge. Two inlet gates are equipped with screens to take river water according to the water level. The main equipment is as follows:

Item	No.of units	Description
Inlet gate	2	Height 1.0 m x Width 1.0 m
Raw water intake	4	Diameter 250 x Quantity 10.0 m^3/hr x Height 18.0 m
Pump		x 55 kw
Access bridge	1	Width 1.5 m x Length 27.0 m Steel Truss
Other equipment		Pump House, Hanging Hooks, Lighting fixtures

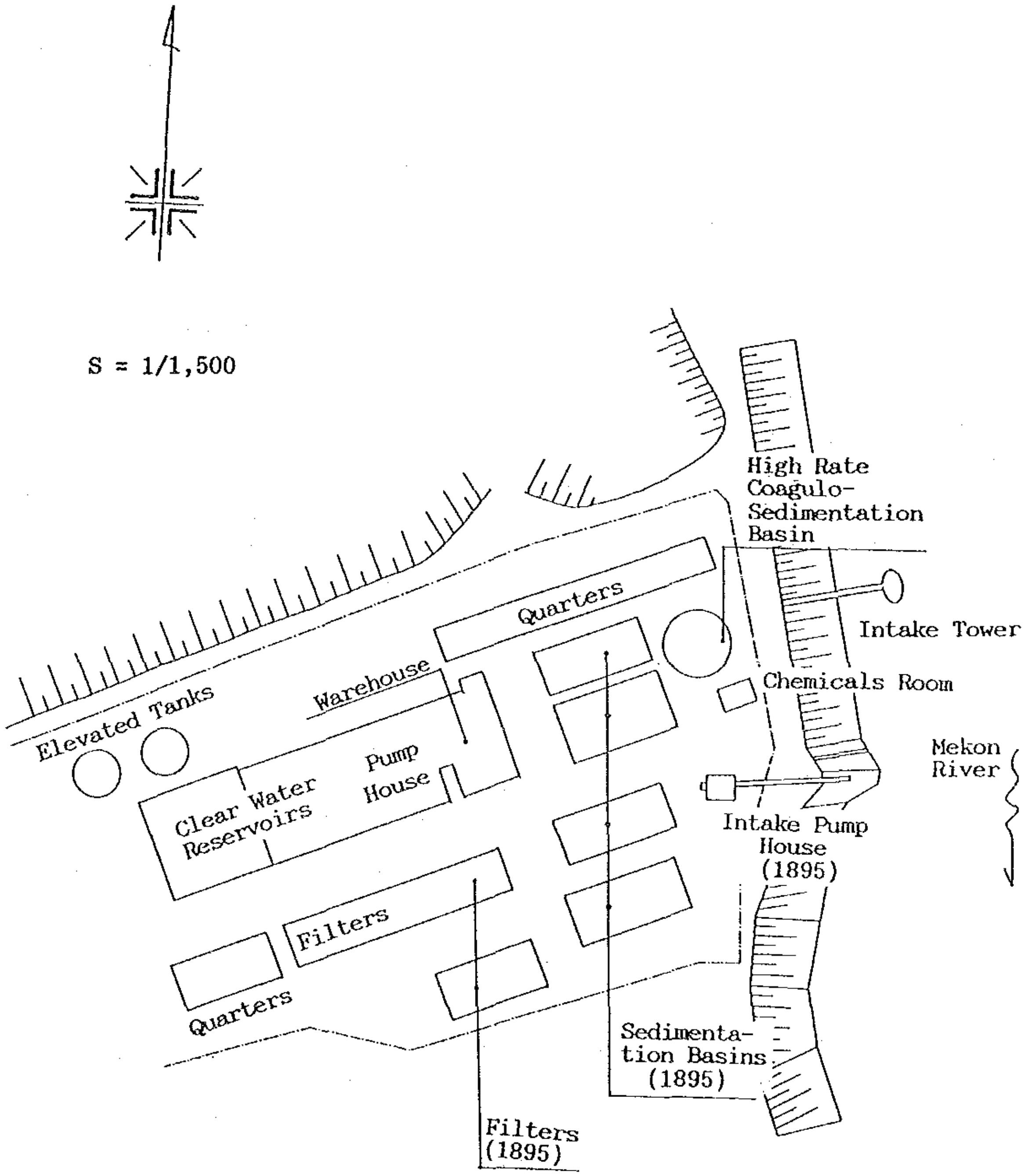


Fig-3.16 GENERAL PLAN OF CHROUY CHANGWAR TREATMENT PLANT

As the electric power is not supplied to the plant due to damaged power cables, both mechanical and electric equipment can not be tested. However, all equipment is appearently heavily damaged because of lack of operation for a long time.

b) High Rate Coagulation-Sedimentation Basin

The basin was constructed in 1959 when the plant was expanded to the capacity of 45,000 m^3/day with the above intake tower and part of filters. The main features are as follows:

Item	No.of unit	Description
High Rate C.S. Basin	1	Dia.15.0 m x Height 5.2 m
Capacity		700 m^3/basin
Detention Time		1.3 hr
Aver. overflow rate		50 mm/min
Appurtenances		Mixing Equipment, Settled water collecting launders, Drain piping

While the concrete structures remain undamaged, the corrosion of the steel structures has excessively progressed. Plants and weeds have grown on the sedimented sludge.

c) Filter

At the time of the last expansion, filters were constructed inside the filter-house after demolition of the old filters. The main features of the filters are described below:

Item	No.of unit	Description
Clear water reservoir	2	Width 25.0 m x Length 25.0 m x effective depth 3.0 m
Effective capacity		3,750 m^3
Detention time		3.0 hr

The eastern part of the reservoir is used as the suction well for distribution pumps.