AN ASSESSMENT OF WATER RESOURCES AND SUPPLY FOR THE JABOTABEK REGION 1985-2000

by

Didi Rasidi

A Practicum Submitted in Partial Fulfillment
of the Requirements for the Degree,
Master of Natural Resource Management

THE NATURAL RESOURCE INSTITUTE
UNIVERSITY OF MANITOBA
May, 1979

AN ASSESSMENT OF WATER RESOURCES AND SUPPLY FOR THE JABOTABEK REGION 1985-2000

by

DIDI RASIDI

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF NATURAL RESOURCE MANAGEMENT

To

My Wife, F. T. Rasidi

My Children:

Fiddiya, Rita and Eka

ABSTRACT

Water is essential for the existence of life and should be developed and managed in the best interest of society. Due to population increases and technological changes water becomes more economically valuable as time passes. Changing water requirements will occur in response to environmental and societal development. However, conflicts exist if water requirements exceed the water supply in terms of quality, quantity, time and location. These conditions are of concern to the Jakarta area where urban population, industrial and economic development is rapidly increasing.

This practicum investigates water resource potentials which may be used to fulfill the future requirements of the Jakarta area. Calculation of future water requirements for 1985 and the year 2000 shows that present water supplies are inadequate.

If future water requirements are compared to total water resource potentials, it can be demonstrated that future requirements can be met if structures for water storage and network systems for delivery water supply to users are built.

ACKNOWLEDGEMENTS

In recognition of the assistance provided in the preparation of this practicum, I thank many people including my supervisor and committee advisor (chairman), Prof. T. J. Henley, Acting Director of Natural Resource Institute, University of Manitoba, for his guidance and moral support. Likewise to the staff of the Natural Resource Institute for their cooperation and assistance.

I wish to thank the members of my advisory committee, Dr. J. A. Gray, Department of Economics and the Natural Resource Institute, University of Manitoba; Prof. C.Booy, Department of Engineering, University of Manitoba; Prof. R. Stock, Department of Geography, University of Manitoba; for their advice and time spent towards the completion of this practicum. Prof. Ian Gillies of the Natural Resource Institute also assisted in the completion of the practicum.

My gratitude to Mr. P. C. Benson and his staff of CIDA Coordinator for their cooperation and assistance and to CIDA for their financial support of the study.

A sincere thanks to Ir. Soeyono Sastrodarsono, Director General of Water Resources Development, Ministry of Public Works, and his staff and to Ir. Srigati Santoso, President Director of the Jatiluhur Authority, and his staff, for providing facilities during the undertakings of this study in Indonesia, as well as moral support.

I also wish to thank several Division Heads and Project Heads and other individual officials who could not be individually named in the Ministry of Public Works and the Government of Jakarta City for their advice and cooperation in the collection of data and field surveys in the study area during preparation of this practicum.

Finally, I owe a special thanks to Mr. Ivan M. Didiuk for his time and effort in reviewing this practicum and to Mrs. Sharon Kirsch, Mrs. Marie Klaus and Mrs. Emilie Novotny who patiently typed successive drafts of this practicum.

TABLE OF CONTENTS

TABLE OF CONTENTS CONT'D.

LIST OF TABLES

List of Tables Cont'd.

LIST OF FIGURES

GLOSSARY

Albedo - is reflected solar energy, expressed as a ratio of reflected light to the total amount falling on the surface. An albedo of 0.25, means that 25% of incoming solar energy is reflected back to the atmosphere. An albedo of 0.25 expresses the reflectivity of a green surface.

Agricultural water - in this practicum agricultural water shall refer to water needed to irrigate sawahs (flooded rice fields).

Crop Intensity - an indication of the ability of sawah to be planted during a year. If crop intensity 1, sawah can be planted once a year; if crop intensity is larger than 1, sawah can be planted twice a year. For example, if sawah has a 1.8 crop intensity, 100% of the sawah area can be planted in the wet season, but only 80% of the sawah area can be planted in the dry season. Crop intensity depends on water availability.

Domestic water uses - water used for drinking and household purposes.

Double crop rice - two plantings of rice a year during both wet and dry seasons by introducing irrigation systems.

Flushing water - water used for sewage network flushing in order to prevent stagnation of water in the drainage canals to dilute polluted water and to flush sediment and garbage.

Industrial water uses - water used for production processes such as raw material, cooling flushing, processing and general industrial uses.

Sawah - a type of agricultural land used mainly for growing rice which requires continuous water supply during growing periods.

Service water uses - water uses with other urban activities such as restaurants, hotels, shops, supermarkets, hospitals, and offices.

Single crop rice - one planting of rice a year during wet season, because in the dry season there is not enough water for growing rice.

CHAPTER I

INTRODUCTION

This practicum is a preliminary study in water resource planning to determine if "the water needs" of Jakarta and region can be met with the present water supply. If it is found that these water needs cannot be met, the study will proceed to estimate how much additional water supply is required and if sufficient water is available. If there is not sufficient water available, the study will explore the possibility of reducing water requirements by reducing unit consumption or changing the priorities of water allocation.

Chapter I presents the problem statement, sub-problems, objectives, limitations, methodology, description of data and structure of the study.

1.1 Problem Statement

The study area is located in West Java. This area includes the cities of Jakarta, Bogor, Tanggerang and Bekasi, the so-called JABOTABEK and surrounding agricultural area (Figure 1.1) which is approximately 650,000 hectares with a population of about 9.4 million (1978 estimate)[1].

The City of Jakarta is the political and economic center of Indonesia. The city has undergone rapid administrative, industrial and commercial development during the last decade. This development has been accompanied by a rapid population increase which has taxed public services and facilities.

---

[1] aritz, Eymond: Urban Development and Population Forecasts, Directorate General of W· ·er Resources, Ministry of Public Works, Jakarta, July, 19· , Appendix.

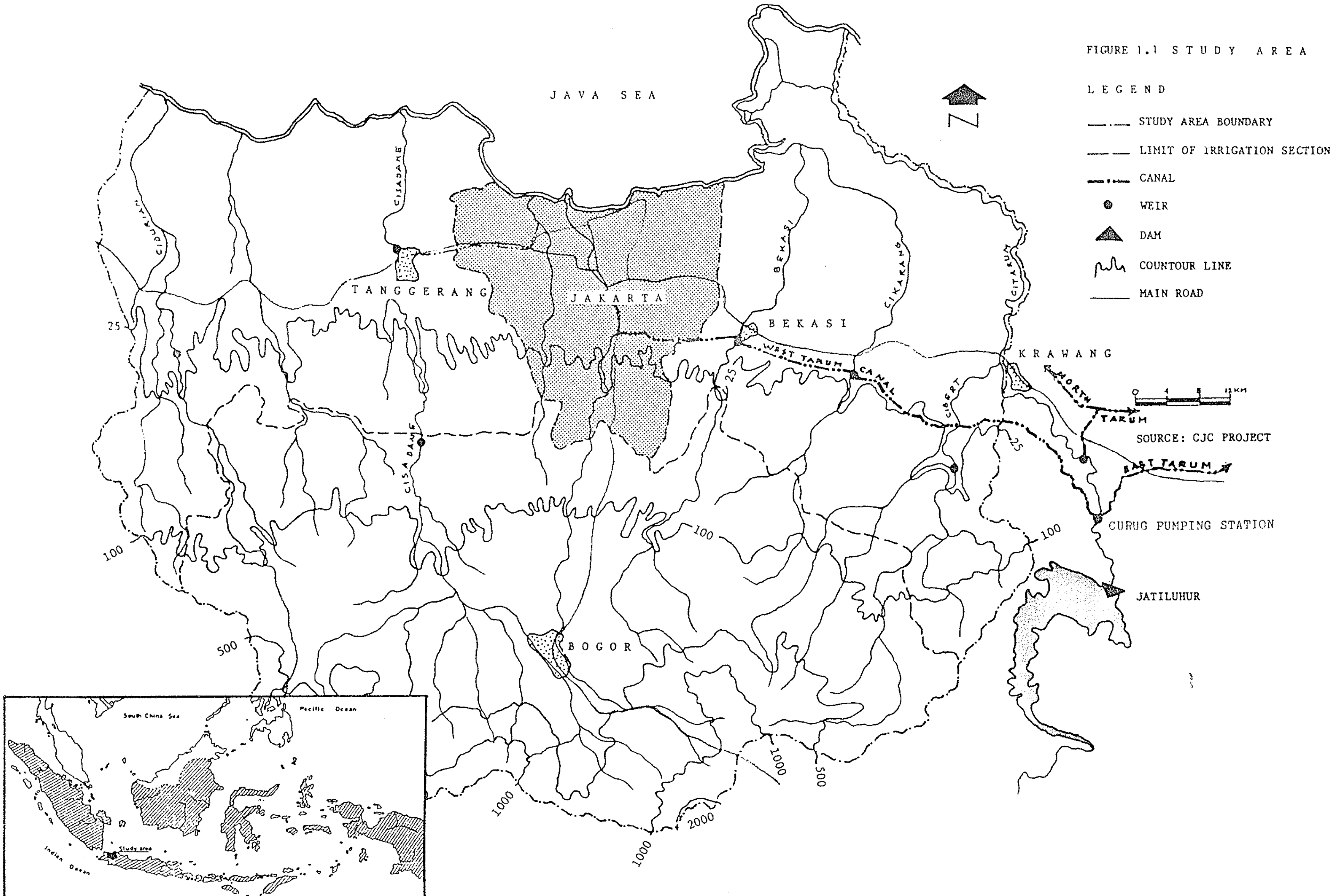


FIGURE 1.1 STUDY AREA

Jakarta's population was 2.9 million in 1961, 4.6 million in 1971, and an estimated 6.4 million in 1978. In the years 1975-1980, the city's population is expected to grow at the rate of approximately 4.4% per annum.[2]

The cities in the study area require large amount of water for domestic, industrial, service, and environmental purposes such as diluting sewage flushings. Present water supplies are insufficient, while water demand is growing at an accelerating rate. For example, the City of Jakarta has a total treated water supply 5.5 $m^3/_s$ including 20-25% network loss due to leaking and broken pipe.[3] This available water supply serves only 38% of the total population (1976) (consisting of 17% consuming 15 l/c/d and 21% consuming 120 l/c/d) and a portion of industrial water requirement. Domestic consumption per capita is under the existing standard unit, which ranges from 60 l/c/d to 160 l/c/d. The remaining 62% of people use shallow wells and direct surface water from nearby rivers.

The existing and future water resources for the cities are fully dependent upon surrounding agricultural areas where these resources are located. The agricultural areas also need large amounts of water to irrigate sawahs (flooded rice fields) that are presently being developed to produce more rice.

[2] Laritaz, Eymond: Urban Development and Population, 1977, 1961 and 1971's figures are census and an estimate rate for 1975 - 1980.

[3] Jakarta Water Drinking Company (PAM-Perusahaan Air Minimum).

Therefore, additional water resources must be added to the supply system if city and agricultural uses are to be sustained and an appropriate allocation and management scheme will also be required to fulfill future requirements.

1.2 Sub-problems

Additional problems to be analyzed in this practicum are:

(1) Jakarta and neighbouring cities (JABOTABEK) have experienced rapid population and industrial growth compared to the rest of the nation resulting in significant water utilization increases for these concentrated areas. This practicum will attempt to determine whether water requirements may be met with available water resources for this area in the years 1985-2000.

(2) Irrigation development in the agricultural areas surrounding Jakarta is the first priority of national agricultural development. This practicum will also attempt to determine whether the water resources potential may serve both urban and agricultural water requirements for the year 1985-2000.

1.3 Objectives

This practicum shall:

(1) estimate the present water supply of the JABOTABEK region;

(2) estimate JABOTABEK's water requirements for the period 1985 - 2000 under current practices of water use;

(3) estimate water requirements for surrounding agricultural areas for the period 1985 - 2000 under current agricultural practices;

(4) estimate the water resources potential under natural conditions for JABOTABEK and its surrounding agricultural areas for the period 1985 - 2000,

(5) determine whether the urban and agricultural water requirements for the period 1985 - 2000 can be met and how much storage capacity (m3) is needed to fulfill these requirements.

1.4 Limitations

This practicum has the following limitations:

(1) This practicum concentrates upon a physical analysis of the water resources under natural conditions and does not include engineering design and benefit cost analysis related to water resources.

(2) The discussion of water uses focuses upon urban and agricultural purposes (irrigation water) as the main objectives of water resources development. Additional objectives such as hydro-electric power, recreation, fisheries are fully dependent upon the primary objectives. These additional objectives are not discussed in this practicum.

(3) Reference to agricultural water use in this practicum refers to irrigation water for occupied sawahs.

(4) This practicum ignores water conservation possibilities.

(5) This practicum ignores changes in technology.

(6) This practicum does not examine the economics of water management in the study area.

(7) This practicum focuses on the quantity of water delivered to users and does not intensively examine water quality.

1.5 Methodology

The research method designed to achieve study objectives proceeds as follows:

(1) Reviews water decision-making policy and conflicts, and evaluate present conditions of water supply.

(2) Estimates water supply under present conditions. In this study, water supply estimates are derived primarily from current consumption data in urban and agricultural areas. Water supply is thus equal to water delivered by existing reservoir and network facilities.

(3) Estimates present and future demand generated by current water practices and prior water uses including domestic, industry, services, agriculture, flushing and dilution uses.

(4) Estimates present and future water resources potential under natural conditions.

(5) Evaluates water demand and supply in order to determine whether there is a surplus or deficiency of water supply.

(6) If there is a deficiency, estimates the additional water supply required to fulfill all demands.

(7) Evaluates additional water supply required and water resource potential on a yearly basis to determine whether the additional requirement can be met.

(8) If water requirement on a yearly basis can be served by the water potential, evaluates on a monthly basis to determine whether the additional water supply can be fulfilled by weirs and canal systems or in combination with reservoir (s).

(9) If reservoirs are needed, estimates storage capacity by using "Sequent Peak Analysis."

(10) If the water requirement on a yearly basis cannot be served by the area's water potential, cuts demand by reducing usage unit consumption or change water allocation by priority, or both. Procedures 8 and 9 are then repeated to secure an adequate water supply year round.

1.6 Description of the Data

Data has been collected from a variety of sources to support the study's methodology. Data is taken primarily from published and unpublished studies conducted by government agencies. The data includes raw data, previously analyzed data, forecasts and description of government programs. In substantive terms, the data comprises maps, climatological and hydrological data, population, urban and agricultural water uses and supply, land uses including urban and irrigation lands (sawahs), and other information dealing with water regulation, studies and developments.

Data were obtained from the Jatiluhur River Basin Authority, the Cisadane-Jakarta-Cibeet Water Resources Development Project (CJC), Cisadane Irrigation Project, Jakarta's Drinking Water Company (PAM), Jakarta's City Planning Division, National's Regional and City Planning, Directorate General of Water Resources Development, and the Statistical Central Bureau.

1.7 Structure of the Study

The study is organized in the following manner:

Chapter 2 - discusses water decision making policy and conflicts and present water supply. This provides the background for the estimation of future water requirements.

Chapter 3 - discusses and estimates urban and agricultural water requirements for the years 1985 - 2000.

Chapter 4 - discusses and estimates water resource potentials under natural conditions.

Chapter 5 - discusses and evaluates water requirements and water resource potentials on a yearly and a monthly basis to determine whether the requirements can be met or if a reduction in useage consumption unit or a change in the priorities of water allocation is required. A discussion of additional water storage capacity is also provided.

Chapter 6 - contain the conclusions of this study and recommendations for further study.

CHAPTER II

GOVERNMENT POLICY AND PRESENT WATER SUPPLIES

2.1 Introduction

This chapter will discuss government policies and regulations, the possibility of water use conflicts if demand exceeds supply, and present water supply.

2.2 Government Policies and Regulations

Water is one of the primary human needs which must be available in sufficient amounts at the proper time and at the right places. An ECAFE (Economic Commission for Asia and the Far-East) report states that:

> *Water is an essential element for the existence of life. Civilizations have developed, flourished and declined in direct relationship to the adequacy and wise use of their water resources, The water resource is limited as to quantity, time and geographical distribution. Hence, under natural conditions, it is not always available in the amounts, at the time or in the location needed for most advantageous use.*[1]

Because of the importance of water in our lives and its somewhat undependable supply due to the local natural environmental conditions, careful attention should be paid to managing water resources. The importance of water resource management is reflected in the Indonesian Consitution, article 33, paragraph (3):

---

[1]Economic Commission for Asia and the Far-East (ECAFE), Manual of Standards and Criteria for Planning Water Resource Projects, Water Resources Series No. 26, United Nations, New York, 1964, p. 1.

> *Land and water and natural riches contained therein shall be controlled by the state and shall be made available for use by the people.*[2]

This article is followed by a statement of Indonesian Government Policy on water resources management:

> *...water and water resources and natural resources contained therein are gifts of Almighty God, and shall be controlled by the state and utilized for the optimal welfare of the people in a just and equitable manner.*[3]

These statements clearly describe that the development and utilization of water resources is under government control. Specific water management policies are:

a) the determination of the conditions and procedures for general and project planning of water resources utilization, exploitation, policing and licencing;

b) the permanent regulation and implementation of water and its resources development, as well as water works managements including main structures and networks with the view to optimizing benefits;

c) the prevention of pollution of water and environments;

d) the survey and inventory of water resources;

e) the information system and special training program in the water resources field.[4]

According to the authority responsible for each aspect, there are three types of water management authorities, and their relationship is depicted in Figure 2.1.

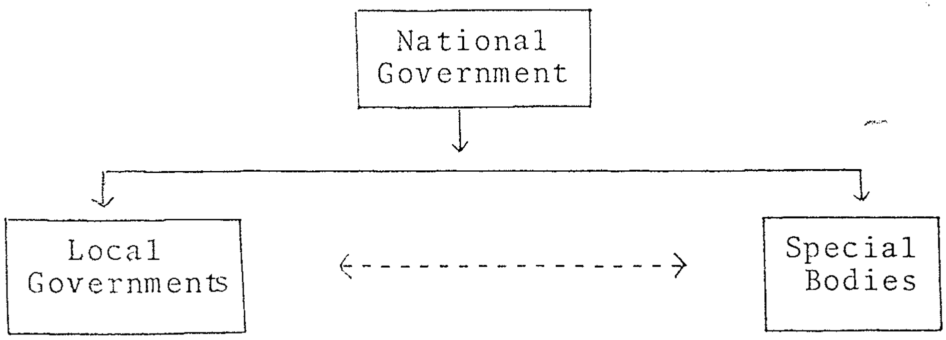
---

[2]Ministry of Public Works and Electric Power, Republic of Indonesia, The Development of Water Resources of Indonesia, March, 1976, p. IV-4.

[3]Ibid., p. IV-4

[4]Ministry of Public Works and Electric Power, Republic of Indonesia, Op.Cit., p. IV-6

Figure 2.1



Special bodies are established by the National Government to manage, for example, a development project in a particular river basin. An example of this is the Jatiluhur Authority which has the responsibility to manage the development of the Citarum River Basin and its tributaries.

There are a complex set of relationships in the study area between the National government, the governments of Jakarta and West Java and special bodies. Jakarta's existing water management system reflects this relationship. The national government finances water resource development and establishes primary regulations such as "the Government Policy Statement Dealing with the Jatiluhur Reservoir Operation Guidelines." The priorities set by these regulations are as follows:

> *In order to meet the various purposes of water uses, the reservoir operation will be carried out according to the following priority:*
>
> *Priority No. 1:* *Water Supply (domestic and industrial uses) and flushing water for Jakarta Special District;*
>
> *Priority No. 2:* *Irrigation water requirement;*
>
> *Priority No. 3:* *Production of electric power.*[5]

---

[5]Government Policy Statement on the Operation of Haji Juanda (Jatiluhur) Reservoir, Jakarta, May 1973, p.1.

The Jatiluhur Authority, which manages the reservoir, follows this Government Policy Statement and supplies water (untreated) to Jakarta, irrigates those sawahs in West Java which are under the Jatiluhur Authority jurisdiction, and produces electric power. The Government of Jakarta handles the management of this water under its own authority to fulfill all requirements, including processing and distribution of the treated water.

Regulations for sanitary engineering of drinking water may be described as follows:

(1) Drinking water source must guarantee a continuous supply of water.

(2) Well must be protected against pollution from outside according to the sanitary engineering requirements.

(3) Drinking water must meet the physical, chemical and bacteriological requirements and must not damage the equipment used in the water system.

(4) Any portion of the water distribution system must be free from anything which may endanger the public health.

(5) Regular tests with regard to the quality of drinking water must be made by the Office of Health.

(6) Water supply enterprises must obtain a permit from the government to develop water resources.

(7) The water supply enterprises must be responsible for everything regarding the operation of the water supply.

(8) People utilizing wells for drinking water must obtain a permit from the government.

(9) Individuals are prohibited from selling drinking water.[6]

These regulations also provide specific direction for connection, water rate, piping work and construction. The purpose of these regulations is to protect and secure the quantity and quality of drinking water which is used by Indonesian society.

2.3 Water Use Conflicts

World water consumption rapidly increases as society experiences economic and social progress. This tendency will be maintained and in many instances accelerated. Unfortunately, world-wide availability of useable water will remain more or less unchanged and may possibly be diminished if man-induced water contamination increases.

Water becomes more economically valuable as time passes. As a consequence, careful attention must be devoted to the utilization of this natural resource. A responsible organization, proper technology and management, and a wise policy are needed. This may ensure that water resources can be used more efficiently and effectively.

Effort is needed to plan and develop water resources in a flexible manner in order to fulfill changing environmental and societal conditions and requirements. Conflicts, however, exist if water requirements exceed the water supply in terms of quality, quantity, time and place .

This practicum deals with urban and agricultural water uses. Both water uses have a rapidly increasing demand for

---

[6] Nihon Suido, Master Plan for Jakarta Water Supply System, Part I, Report No. 18, Ministry of Public Works and Electric Power Republic of Indonesia, September 1972, p. 73-74. These regulations have been edited to correct grammatical errors in the original source.

water and one supports the other in the context of the economic development of the Jakarta area. Responsible management is needed in order to fulfill the area's water requirements and to ensure balanced water allocation.

To fulfill the condition of responsible water management the water requirements for each water use area must be known. This will be discussed in succeeding chapters.

2.4 Present Water Supply

An assessment of present water supply consists of urban water supply and agricultural water supply. Estimates of present water supply are mainly derived from current consumption data in urban and agricultural areas. Water supply is thus equal to water delivered by existing reservoir and network facilities.

2.4.1 Urban Water Supply

At present, urban water supply is available only in Jakarta which has a considerable amount. Jakarta's water supply is fed by:

a) Jatiluhur reservoir through the Curug Pumping Station and the West Tarum Canal (Figure 1.1). The allocation of water from this reservoir to Jakarta is designed for 14 m^3/s. The average actual capacity is about 80%, so available water is approximately 11.2 m^3/s.

This water supply is used for the Pejompongan Treatment Plant which has a total capacity $5m^3/s$. This plant is operated by PAM (Perusahaan Air Minum - Drinking Water Company of Jakarta) of Jakarta. The rest of the water (6.2 m^3/s) is used directly and for sewage flushing.

b) The Ciburial Springs, near Bogor, flow by gravity through 41 km of piping to Jakarta. The capacity of these springs is $0.3m^3/s$.

c) Ground water which is pumped from deep and phreatic aquifers as follows:

i. Approximately $0.1 m^3/_s$ of ground water is pumped from deep aquifers through deep wells by PAM of Jakarta.

ii. PAM of Jakarta estimated (1976) that there was $3.5 m^3/_s$ of ground water pumped from phreatic aquifers for domestic uses.

iii. PAM of Jakarta also estimated approximately $1.5 m^3/_s$ of ground water from phreatic aquifers and $0.6 m^3/_s$ from deep aquifers are pumped for industrial purposes.

Therefore total ground water which is pumped from deep and phreatic aquifer is about $5.7 m^3/_s$ (0.1 + 3.5 + 1.5 + 0.6).

The City of Bogor is presently supplied by the Ciburial Springs. According to PAM of Bogor the total capacity of these springs are $0.43 m^3/_s$.

The City of Tanggerang is supplied only by a small plant with a built capacity of 10 l/s. Most people utilize surface water (Cisadane River) and private shallow wells.

The total present urban water supply of the study area is:

a) surface water	(11.2 + 0.1)	=	$11.30 m^3/_s$
b) springs	(0.3 + 0.43)	=	$0.73 m^3/_s$
c) ground water		=	$5.70 m^3/_s$
	Total		$17.73 m^3/_s$

2.4.2 Agricultural Water Supply

Agricultural water supply consists of irrigation water for occupied sawahs. There are four types of sawah in Indonesia:

a) the "technical" irrigation systems that have permanent control structures on all head works and canals.

b) the "semi-technical" irrigation systems providing turnouts to control the flow of water, but without any measuring devices. Both technical and semi-technical systems are owned, operated and maintained by the Government.

c) the "simple" irrigation systems have minor works with temporary or no head-works, constructed, operated, maintained and owned by the farmers. These networks, especially in those places under the authority of the Public Works Department, can be considered as a step toward modern irrigated rice cultivation (technical systems).

d) the "rainfed" systems which are completely dependent on rainfall for the soil moisture.

According to Cisadane-Jakarta-Cibeet (CJC) Water Resources Development Project, the total area of all types of sawahs for 1975 was 253,985 hectares as indicated in Table 2.1.

Water supply has to be provided by an irrigation system or project feeding technical and semi-technical irrigation areas. Generally, under present conditions, technical irrigation systems have a crop intensity of 1.9 and semi-technical irrigation systems have a crop intensity of 1.7.

For the West Tarum irrigation system, main structures such as the reservoir (Jatiluhur), pumping station (Curug), weirs and main canal (the West Tarum Canal), as depicted in Figure 1.1, have been designed and built for the whole area as a technical irrigation system. Development is proceeding to complete secondary and tertiary structures and canals. This development will be completed in 1980. Thus there is sufficient water supp available fo a technical irrigation system.

Table 2.1 Irrigable Areas in 1975 (hectares)

Region/section	Technical	1/2 Techn.	Simple	Rainfed	Total
Tanggerang					
Cisadane-Prosida	40665	-	-	-	40665
Cidurian-Ranca Sumur	9050	-	-	-	9050
Others	-	6300	2880	16300	25480
Sub-total	49715	6300	2880	16300	75195
Bogor					
Cisadane-Empang	9730	6630	1645	3250	21255
Ciliwung-Katulampa	5820	300	1620	1020	8760
Others	2180	13930	15160	23670	54940
Sub-total	17730	20860	18425	27940	84955
Prosijat/Jatiluhur					
West Tarum	19900	22145	11360	19900	73305
South of West Tarum	1010	-	14680	4840	20530
Sub-total	20910	22145	26040	24740	93835
Grand Total	88355	49305	47345	68980	253985

Source: CJC Project Office (1978)

When development of secondary and tertiary structures is completed, this water can be delivered to the sawahs.

Crop water consumption is based on estimates of 1.2 l/s/ha in the coastal zone and 1.0 l/s/ha in the upper zone which have been used to design reservoirs, structures and canals. These figures will be used for estimation of present water supply availability.

Using Table 2.1, crop intensity ratios, and crop water consumption information, water supply for agricutural purposes can be estimated and is presented in Table 2.2.

Table 2.2 Available Water Supply for Agriculture in m^3/s

Region/Section	Wet Season	Dry Season	Yearly Average
Tanggerang	67.22	58.98	63.79
Bogor	38.59	30.56	35.24
Prosijat/Jatiluhur	89.17	80.25	85.45
Total	194.99	169.79	184.48

2.4.3 Total Water Supply

Step 2 in the methodology noted that water supply equalled water delivered to urban and agricultural areas by existing reservoir and network facilities. Thus it can be assumed that present water supply equals the sum of total water supplies calculated for urban and agricultural areas in Jabotabek region. In this connection, it should be noted that between 1975 - 1978 there were no significant developments in new additional water supply facilities. Thus, total present water supply is presented in Table 2.3 as follows:

Table 2.3 Total Present Water Supply in $m^3/_s$

Purpose	Wet Season	Dry Season	Yearly
Urban	17.73	17.73	17.73
Agriculture	194.99	169.79	184.48
Total	212.72	187.52	202.21

2.5 Conclusion

Water is essential for the existence of life and should be developed and managed in the best interest of society. For this reason, water resources development and utilization in Indonesia, is placed under government control. The Indonesian government finances water resource development, establishes policies and regulations, and operates water service facilities.

Water becomes more economically valuable as time passes. Changing water requirements will occur in response to economic, social and environmental development. However, conflicts exist if water requirements exceed the water supply in terms of quality, quantity, time and places.

This practicum deals with the allocation of water to urban and agricultural uses. At present, there is an available water supply of approximately 202.21 $m^3/_s$ or 6,370 million m^3 on an annual basis. This consists of 212.72 $m^3/_s$ or 3,900 million m^3 in the wet season and 187.52 $m^3/_s$ or 2,470 million m^3 in the dry season.

The following chapter will discuss future water requirements both for urban and agricultural purposes.

CHAPTER III

FUTURE WATER REQUIREMENTS, 1985 - 2000.

3.1 Introduction

This chapter will estimate water requirements for 1985-2000 for both urban and agricultural areas. For the purpose of this estimation, the chapter is divided into three sections. Section 3.2, Urban Water Requirements, will discuss population forecasting, unit water consumption and future water requirements for domestic, industrial and service consumption and for sewage flushing and dilution.

Section 3.3, Agricultural Water Requirements, will discuss general agricultural practices, crop water requirements for rice, rice double cropping water requirements, estimates of future irrigable areas, and future agricultural water requirements.

Section 3.4, conclusions, will state the total future water requirements for all purposes.

3.2 Future Urban Water Requirements, 1985 - 2000.

Urban water requirements are comprised of domestic, industrial and service uses, and sewage dilution and flushing uses. These requirements depend on overall growth patterns of population, urban activities and unit consumption. Therefore, the following discussion will encompass population forecasting, unit consumption for each activity and the calculation of future urban water requirements for the period 1985 - 2000.

3.2.1 *Population Forecasting*

Population growth is the major factor in projecting future urban water requirements. The projection in this practicum focusses on urban population growth in Jakarta and neighbouring cities, the so-called Jabotabek (Jakarta - Bogar - Tanggerang - Bekasi: see figure 3.1).

Several estimates of population increases are available. Estimates of natural increase range from 2.5% per annuam for Indonesia as a whole[1] to 3.0% per annum for Jabotabek[2] in the period 1975-1980. It should be noted at the outset of this analysis that population growth forecasting is extremely difficult due to the nature of the assumptions that underly the forecasts. For example, forecasts may assume that government population policies will not change substantially over the forecast period. Alternatively, it may be assumed that the certain population programs, such as transmigration programs, will be expanded substantially.

The following population growth scenarios are used for the purpose of this practicum.

---

[1] This estimate is based on the United Nations Demography Year Book, 1974, where a net increase of 2.89% per annum was indicated for the period 1965-1970; United Nation Statistical Year Book 1977, where a net increase of 2.6% per annum was indicated for the period 1970-1975; 1978 World Population Data Sheet of the Population Reference Bureau Inc., where a net increase of 2.4% per annum is indicated. A calculation based on three figures indicates that the natural increase rate increases by 11% every 5 years.

[2] Laritaz, Eymond: Urban Development and Population Forecasts. Cisadane-Jakarta-Cibeet Water Resources Development Study, Directorate General of Water Resources Development, Ministry of Public Works Jakarta, July 1977.

SCENARIO I: This scenario applies the natural population increase for Indonesia to Jabotabek. As a result of family planning programs, the crude birth rate decreases more rapidly than the crude death rate. Thus, natural population increase in Indonesia declines from 2.5% per annum (1995 - 1980) to 1.6% per annum (1995 - 2000).* This estimate will be applied to Jabotabek.

Constant net migration to Jabotabek continues at the present rate of 1.4% per annum.

SCENARIO II: This scenario includes the result of family planning programs mentioned in scenario I, plus additional programs. Thus, natural population increase in Jabotabek declines from 3.0% per annum (1975 - 1980) to 2.0% per annum (1995 - 2000). Net migration also declines from 1.5% per annum (1980 - 1985) to 1.2 per annum as a result of development outside the study area and transmigration programs (resettlement).**

---

*This estimate is based on the estimates presented in footnote 1, above.

**Laritaz, Eymond: Urban Development and Population Forecasts, 1977.

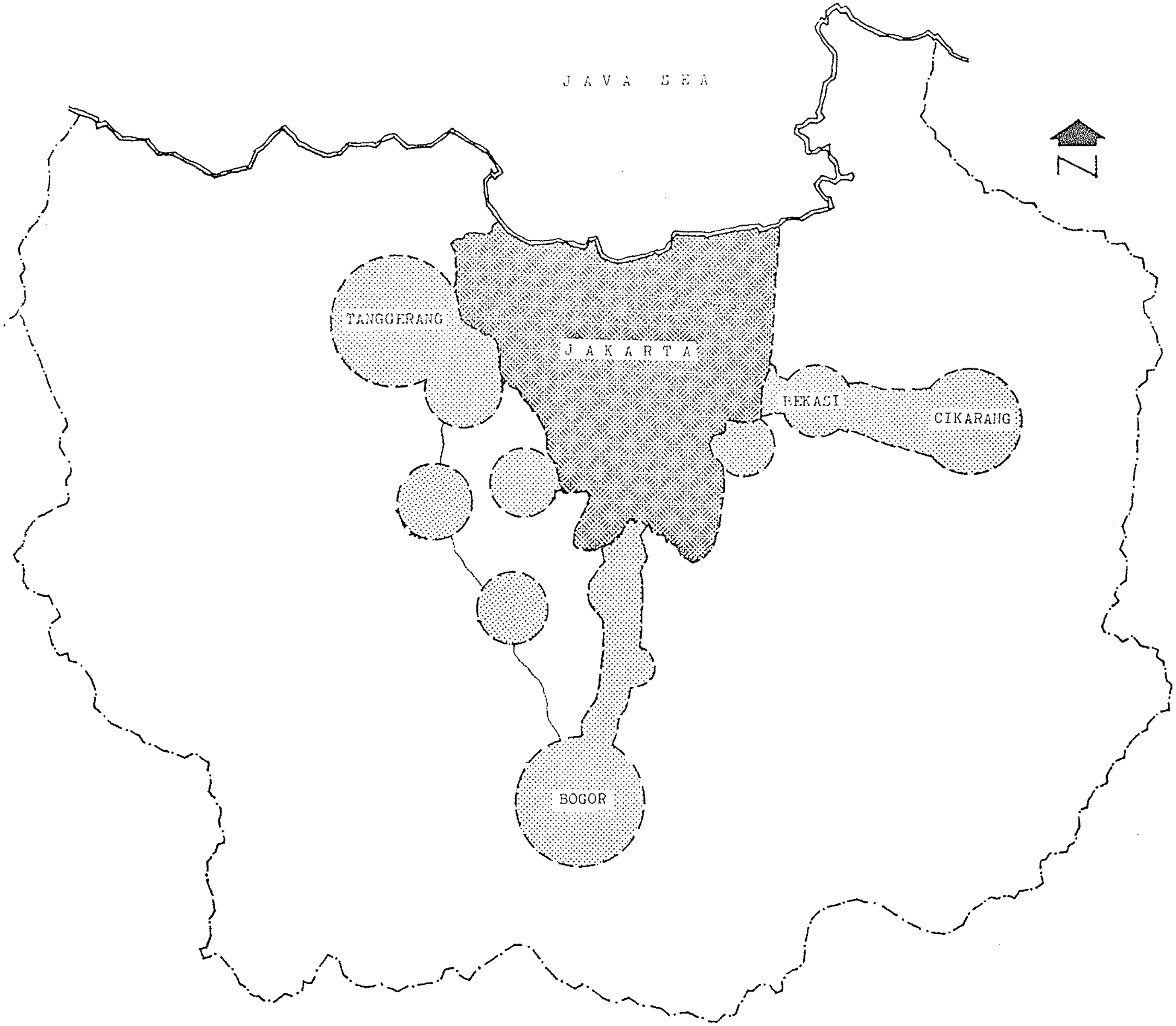


FIGURE 3.1

URBAN AREAS IN JABOTABEK IN 2000

LEGEND

URBAN AREA

STUDY AREA BOUNDARY

0 2 4 6 8 10 km

SOURCE : THE CJC PROJECT

SCENARIO III: In this scenario is a constant natural increase rate of 3.0% per annum and a constant net migration rate 1.4% per annum.

Using these scenarios and the 1975 population as a base figure, urban population of JABOTABEK for 1985 to 2000 can be calculated. The results are presented in Table 3.1

The information in Table 3.1 shows that under Scenario II population size is intermediate between estimates generated under the other two scenarios. Therefore this estimate will be used in the practicum for further calculations. The population of JABOTABEK in 1985, then, is projected to be about 9.5 million and in 2000 about 16.2 million.

Based on these figures and the expectation of economic development, categories of population, industrial and services employees can be calculated. These calculations are presented as follows:

1. Population Category: With regard to domestic water requirements, a primary consideration is to determine which percentage of the population will be able to invest in future private sanitary facilities. That is, which segments of the population will have an income exceeding the minimum (U.S. $173. per year in constant currency 1973 U.S. $). According to COB-Sogreah's Study based on Economics and Finance in Indonesia by Dr. Sumitro, the national income (in constant currency above) will increase by approximately 5.4% per year from 1975 to 1985 and 4.9% per year from 1985 to 2000.[3]

---

[3]COB-Sogreah, op.cit., p. 42. The income figure used by COB - Sogreah is an estimate of the income required for people to invest in private sanitary facilities.

TABLE 3.1 Population Estimate of JABOTABEK, 1975 - 2000

PERIOD	1975	.	1980	.	1985	.	1990	.	1995	.	2000
Scenario I*											
Natural Increase %		2.5		2.2		2.0		1.8		1.6	
Net Migration %		1.4		1.4		1.4		1.4		1.4	
Total Increase %		3.9		3.6		3.4		3.2		3.0	
Total Pop. (10^6)	6.2		7.5		9.0		10.6		12.4		14.4
Scenario II*											
Natural Increase %		3.0		2.7		2.6		2.3		2.0	
Net Migration %		1.4		1.5		1.4		1.3		1.2	
Total Increase %		4.4		4.2		4.0		3.6		3.2	
Total Pop. (10^6)	6.2		7.7		9.5		11.6		13.8		16.2
Scenario III*											
Natural Increase %		3.0		3.0		3.0		3.0		3.0	
Net Migration %		1.4		1.4		1.4		1.4		1.4	
Total Increase %		4.4		4.4		4.4		4.4		4.4	
Total Pop. (10^6)	6.2		7.7		9.6		11.9		14.8		18.4

*% per year.

Using these figures and the possible changes affecting income distribution within the population in the study area, the percentage of population able to invest in future private sanitary facilities can be estimated. Based on 1975 data, the population in this category constitutes 22% [4] of the total population. In 1985, approximately 37% and in 2000 is about 76% of the population will be included in this category.

This population category has a high water consumption per capita, while the balance of the population has a low water consumption per capita. The total population in each category and corresponding water consumption per capita is presented in Table 3.2.

Table 3.2 Population Categories by Water Consumption per Capita 1985 - 2000

Years	1985		2000	
	%	million	%	million
Population:				
1. Total	100	9.5	100	16.2
2. High Water Consumption	37	3.5	76	12.3
3. Low Water Consumption	63	6.0	24	3.9

[4] COB-Sogreah, op.cit., p. 47.

2. Participation Rates in 1985 - 2000: According to population forecasts by Laritaz, Eymond (1977) the participation rate in JABOTABEK will be 30% of the total population in 1985 and 35% in 2000. This consists of employment in industrial sector (secondary sector) and services (tertiary sector). The primary sector in urban areas is ignored because it is believed to be insignificant. Total employment for 1985 and 2000 for each sector can be calculated as shown in Table 3.3.

Table 3.3 Employment Estimate in Industrial and Services Sector 1985 - 2000

Category	1985		2000	
	% of Pop.	Million	% of Pop.	Million
Total Population	100	9.50	100	16.20
Employment in:				
1. Industrial Sector	7.8	0.74	12.2	1.98
2. Services	22.2	2.11	22.8	3.69
3. Total	30.0	2.85	35.0	5.67

Source: [1]Laritaz, Eymond, Urban Development and Population Forecasts, Cisadane-Jakarta-Cibeet Water Resources Development Study, Ministry of Public Works and Electric Power Directorate General Water Resources Development, July 1977, p. 60-61.

[2]Table 3.1 under Scenario II

Figures in Table 3.3 will be utilized in this practicum for further calculation of industrial and service sector water requirements.

3.2.2 Domestic Water Consumption

Several studies have been conducted in industrialized countries to determine the parameters governing domestic water consumption. Although the results of these studies are not directly applicable to Indonesia, their analysis is amenable to some extrapolation. A statistical water consumption study is an in-depth study, based on the calculation of several parameters. The parameters most commonly used, in decreasing order of importance, are: number of households, number of inhabitants per connected household, and family income.[5]

According to Professor Huisman, based on surveys carried out in The Hague (Netherlands) and in Tanzania, the per household consumption is based upon the following formula and parameters:

$Q = A + nP$, where:

Q = per household consumption,

A = a constant term corresponds to housework such as washing up, cooking, washing, miscellaneous cleaning activities,

P = a constant term corresponds to individual water use: baths, toilet flushing,

n = a number of persons per household.

By using this formula, Professor Huisman found that:[6]

a. for The Hague: Q 1/household/day = 120+nx50

b. for Tanzania: Q 1/household/day = 200+nx80

---

[5]COB - Sogreah, op.cit., p.16

[6]*Ibid.*, p.17

Over a large sample, average water consumption increases with the number of household appliances and sanitary facilities. This in turn is related to family income. However, statistical analyses in this field have often been disappointing for several reasons. Sometimes it is difficult to determine each users' income. Additionally, at equal incomes, households do not consume the same amount of water, basically because of cultural reasons. For example, some households will invest more in sanitary facilities than others, even if they use them less frequently.

From a water consumption study that has been carried out by Nihon Suido in 1976 over a sample of 123 families in Jakarta the total persons per household by level of income are:

a. high-income group: 8 persons/household

b. medium-income group: 10 persons/household

c. low-income group: 6.7 persons/household

d. the average: 8.5 persons/household[7]

Average water consumption for each group is:

a. high-income: 180 l/capita/day

b. medium-income: 160 l/capita/day

c. low-income: 60 l/capita/day

Approximately 87% of high-income and 76% of medium-income families in the sample are connected to the network. Other water sources were private wells used for either partial or total water supply. The average consumption for high and

---

[7]COR-Sogreah, op.cit., p.27

medium income groups was 170 l/capita/day. This would be higher if water supply from the network increased. The population using well water as a supplement to network water shows a per unit consumption of approximately 160 l/capita/day.

The low income consumption unit of 60 l/capita/day is a minimum physical requirement for:

a. 20 l/c/day: drinking, cooking, washing up;

b. 40 l/c/day: washing and cleaning.[8]

The last figure may appear to be high, but it is a reflection of Indonesia socio-cultural behaviour. Personal hygiene and clothes washing plays a more important role than in many other societies.

These consumption units change annually, as mentioned in the study of Jakarta's PAM supply over 5 years. This study shows the average overall rate of increase to be 5.0% per year, due to increasing unit consumption of 2.8% and an increase in subscribers of 2.2% per year. This figure also takes into account a rate of increase of approximately 1.4% per year due to improvement of the supply system. Therefore, the actual rate of increase is 1.4% per year (2.8% - 1.4%), or approximately 1.7 l/c/day per year (a half of 3.4 l/c/day per year.[9] Given this value, the maximum level of water consumption per capita would be:

a) 1976 160 l/c/day

b) 1985 175 l/c/day

c) 2000 200 l/c/day

---

[8]According to Concarplan-Sangkuriang estimates for the water supply program of rural area near Tanggerang.

[9]Jak[illegible]ta's PAM.

The minimum level of water consumption is a constant 60 l/c/day which meets minimum physical requirements.

Based on these figures and population estimates shown in Table 3.2, the domestic water requirements for 1985 - 2000 for JABOTABEK are presented in Table 3.4

Table 3.4 JABOTABEK's Domestic Water Requirements 1985-2000

Year	High Consumption			Low Consumption			Total
	Pop. Million	Unit l/c/d	Req. m^3/s	Pop. Million	Unit l/c/d	Req. m^3/s	Req. m^3/s
1985	3.5	175	7.1	6.0	60	4.2	11.3
2000	12.3	200	28.5	3.9	60	2.7	31.2

Note: Sample calculation for 1985 maximum unit consumption (3,500,000 x 175)/(24x3600) = 7100 l/s = 7.1 m^3/s

3.2.3 Industrial Water Consumption

Industrial water consumption includes water for processing, as a raw material and for general industrial uses. Water consumption for manufacturing depends upon the type of product to be manufactured, the technology used for the manufacturing process and the possibilities for water reprocessing. Therefore, often for a same product, specific needs may vary according to the technology used and whether water is reprocessed or not. Nevertheless, for the purpose of the study, a representative unit consumption estimate is needed. Standard unit consumption may be measured by per unit area or per unit employee.

A) Standard Unit Consumption - According to industrial water unit consumption studies there are two methods for calculating consumption for Jakarta and its surrounding area (JABOTABEK).

Table 3.5 Estimate of Industrial Water Used and Area in Jakarta 1971.

Type of Industries	Unit Consumpt (m^3/c/d.)	Number of Employees (d)	Consumption (m^3/d)	Area (ha)
Foodstuffs	1.10	6,169	6,786	20.4
Drinks	3.36	2,887	9,700	22.4
Textiles	1.18	15,066	17,778	112.5
Ready-made Clothing	0.11	2,135	235	7.8
Wooden wares	0.26	1,622	422	22.2
Publishing/Printing	0.38	6,282	2,387	11.8
Rubber goods	2.90	2,106	6,107	13.5
Chemicals	2.10	5,822	12,226	35.0
Ceramic	1.43	2,462	3,521	37.1
Metal goods	1.07	4,772	5,106	34.0
Electric appliances	1.00	4,124	4,124	21.5
Bicycle and parts	0.64	4,118	2,636	24.2
Others	1.51	9,443	14,259	66.6
		67,008	85,287	429.0

Source: Nihon Suido, Consultants, op.cit., pp. 49 and 53.

One method is based on industrial land area--the Nihon Suido approach. The other method is based on the number of employees--the COB Sogreah approach. These approaches can be described as follows:-

i. Nihon-Suido approach[10] - Nihon Suido used an estimate of 130m^3/ha/day for calculating the industrial water management for Jakarta. The figure was derived from an analysis of 4,500 factories and 67,000 employees in Jakarta with a unit consumption estimate derived from data collected by the Ministry of International Trade and Industry in Japan. Further an assumption was made that industrial technology would be more or less the same in the future. The analysis is shown in Table 3.5.

From Table 3.5, it is possible to calculate an average unit water consumption of 85,287/429 = 199 m^3/ha/day or about 200 m^3/ha/day. This figure has been verified by the actual water consump- of an industrial sample in Pulo Gading Industrial Estate (Jakarta) as shown in Table 3.6.

Table 3.6 Actual Industrial Water Consumption, 1971

Type of Industries	Actual Water Consumption (m^3/d)	Area of Land (100m^2)	Unit Consumption* (m^3/100m^2/d)	Estimated Wt. Cons. (m3/d)
Paper Product for package	650	608	2.11	1,280
Television Assembling	290	409	0.72	290
Sulfuric Acid	360	201	2.00	400
Paper Box	110	146	1.28	190
Total	1,410	1,364		2,160

Source: Nihon Suido, Consultants, op.cit., p.52
Note: *Unit Consumption was taken from data collected by the Ministry of International Trade and Industry of Japan.

[10] Nihon-Suido, Consultants, Study on Population and Water Requirement, Extension Project of Jakarta Water Supply System, Ministry of Public Works & Electric Power, Jakarta, March 1972, pp. 47-57.

Table 3.6 shows that average actual water consumption is 1,410 m^3/14 ha/day or is about 100 m^3/ha/d and a consumption estimate of 2,160/14 or about 150 m^3/d. The difference between the two figures may originate from differences in the manner of land use. In Pulo Gadung Industrial Estate, all buildings and facilities are spaciously arranged (using 100 m^3/ha/d), but the estimate of 150 m^3/ha/d is based on Japanese data which reflects more crowded layouts of industrial zones. Thus, the estimated unit consumption expressed in terms of area is higher than actual unit consumption. From these figures a ratio between the actual and estimated unit consumption is 100/150 or 0.67.

Using this ratio, average water consumption of all industries can be calculated as follows: 0.67 x 200 m^3/ha/day is approximately 130 m^3/ha/day. This figure may be applicable for estimating future industrial water consumption of Jakarta and its surrounding area. If this ratio is used for recalculation of the total consumption of Table 3.5, the estimated water consumption is 0.67 x 85,287 m^3/day or 57,142 m^3/day. This also indicates that unit consumption per employee is 57,142 m^3/67,008 employees or about 850 l/employee/day.

ii. COB-Sogreah Approach[11] - COB-Sogreah (1972) used 800 l/employee/day for industrial water consumption of Jakarta and surroundings in the Cisadane-Jakarta-Cibeet Water Resources Development Study. This figure is based on a survey of Jabotabek that studied 5000 industries within 150 industrial zones and in mixed zones outside these industrial zones. The findings

---

[11]COB-Sogreah, op.cit., pp. 53-56

were compared with flow measurements carried out by Coyne and Bellier (1975) in the study of Residual Quantities of Water from Industrial Zones of nearly 1000 industries. Some parameters which aided in determining these figures are:

1. specific consumption according to the number of employees as follows:

Number of Employees	Specific Needs (1/employ./day
1,000	1,000
10,000	900
50,000	850
100,000	800
500,000	750
1,000,000	740

2. the average of the Japanese industry is 795 1/employee/day for 3,500,000 employments;

3. the survey carried out at Pulo Gadung (Jakarta) estimated consumption of 660 1/employee/day;

4. the technology used for new industries will be practically the same as in industrialized countries;

5. the differences observed between the same types of industry, are essentially due to climatic conditions. More water is required in Indonesia for cooling purposes, due to a higher moist air temperature.

Based on these parameters, COB-Sogreah concludes that 800 1/employee/day may be applicable for Jakarta and its surrounding area.

Based on estimates from Nihon Suido (850 1/employee/day) and COB-Sogreah (800 1/employee/day), the mean value of 825 1/employee/day will be applied to the study area in this practicum.

Using this figure and estimates of industrial employment contained in Table 3.3, industrial water requirements can be estimated. These estimates are presented in Table 3.7.

Table 3.7 JABOTABEK Industrial Water Requirements 1985-2000.

	1985	2000
Employment in thousands	740	1980
Unit consumption in l/employee/day	825	825
Total requirements in m^3/s	7.1	18.9

3.2.4 Services Water Consumption

According to COB-Sogreah's estimate (1977), the unit consumption for services (e.g. hotels, restaurants offices) is 100 l/employee/day. This value will likely not grow significantly over time. The data in Table 3.8 indicates that unit consumption will remain constant as tertiary employment (services) increases. (See Table 3.3)

Table 3.8 JABOTABEK Tertiary Water Requirements 1985-2000.

Category	1985	2000
Employment in thousands	2,110	3,690
Unit consumption in l/employee/day	100	100
Total requirement in m^3/s	2.4	4.3

3.2.5 Flushing Water Requirement

The main purpose of flushing is to prevent stagnation of water in the canals in the dry season and to dilute the polluted water.

At present, 100 km. of existing drainage canals have to be freed from approximately 4 million cubic meters of solid waste and silt. Dredging these canals will be useless unless combined with an effective and enforced garbage collection system. The successful implementation of these measures will reduce the need for flushing water.

Flushing is needed particularly for the area located in the vicinity of the north part of Banjir (Flood) Canal encompassing approximately 24,000 ha (Figure 3.2). This area is essentially flat. The existing source for flushing water is Jatiluhur reservoir through the West Tarum Canal of the Jatiluhur network. (Figure 1.1) The available supply of flushing water in the dry season is already insufficient for the present canal system, which is an open canal used as a drain and sewage network.

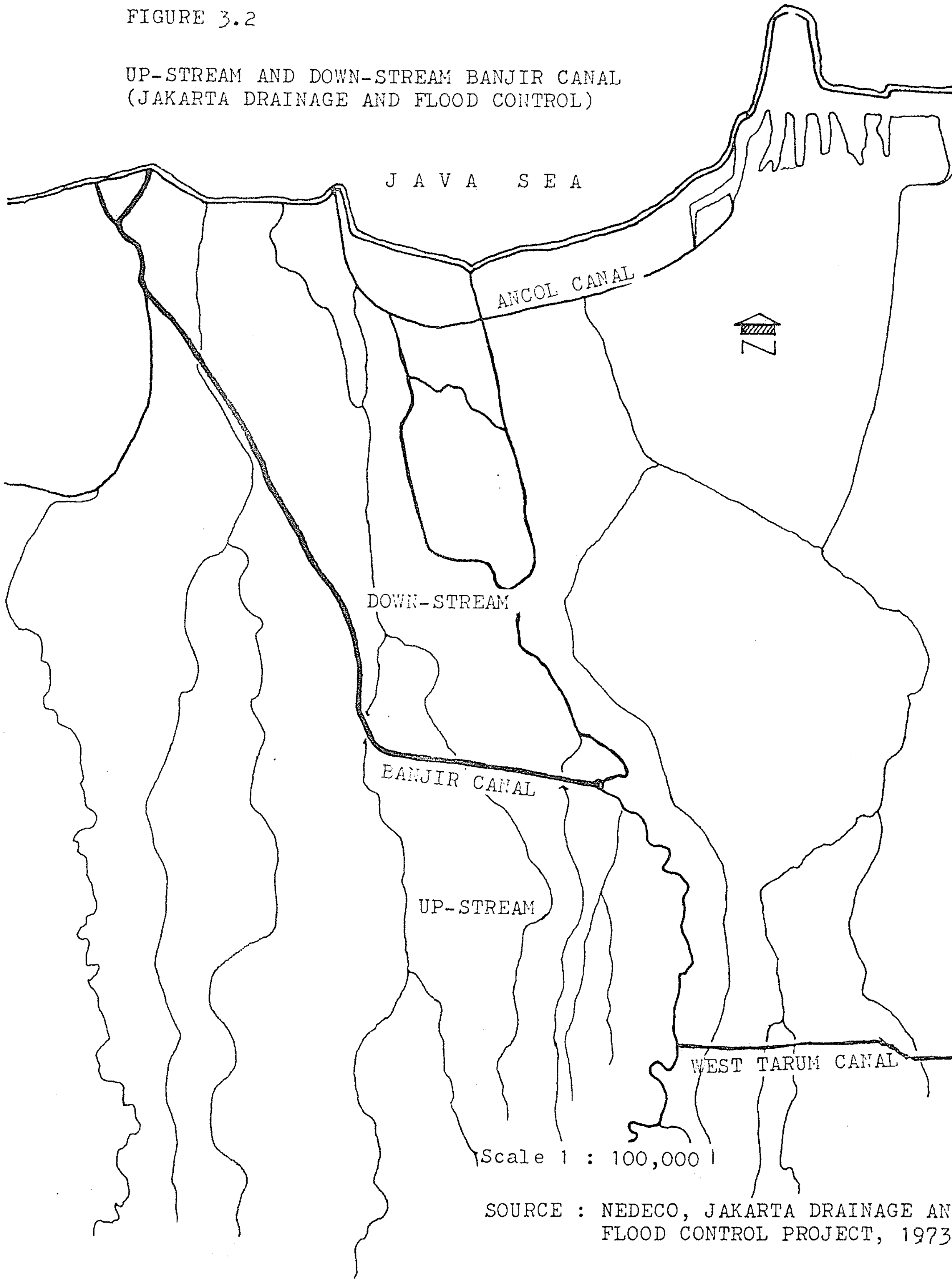
Flushing remains essential water requirements for flushing and will likely increase in response to population growth and urban activities growth even if a complete sewage system for liquid waste and collection of solid waste could be implemented.

According to Cisadane-Jakarta-Cibeet Water Resources Development Study (CJC) (1977), the main pollution problems are:

a. Industrial pollution is predominant, at present, only downstream of Pulo Gadung, and to a lesser extent in the Ciliwung and the Banjir Canal.

FIGURE 3.2

UP-STREAM AND DOWN-STREAM BANJIR CANAL
(JAKARTA DRAINAGE AND FLOOD CONTROL)



SOURCE : NEDECO, JAKARTA DRAINAGE AND FLOOD CONTROL PROJECT, 1973

b. Most measurable pollution comes from: domestic effluents from houses bordering rivers and canals; domestic effluents in secondary canals normally reserved for drainage purposes; and domestic garbage dumped directly into rivers. The Government of Jakarta Survey shows that roughly 250 m^3/day of domestic garbage may be disposed of in this manner.

c. Dumping grounds for domestic garbage are located along the streams, and in particular the Ciliwung upstream from Banjir Canal.

d. The cleaning products of septic tanks and waterproof tanks are discharged directly into the rivers.

Control of all these sources of pollution is a substitute for water flushing.

For future calculations, the domestic potential pollution unit has been established by the CJC study according to the evolution of the standard of living and is presented with three indicators in Table 3.9.

Table 3.9 Potential Pollution Capacity for 1985 and 2000

	1985	2000
BOD_5	30 g/capita/day	35 g/c/day
NH_4^+	2 g/capita/day	3 g/c/day
Detergents	0.3 g/capita/day	0.7 g/c/day

Source: CJC Project.

Flushing water is needed to fulfill the criteria for water quality that have been established by the Government of Jakarta, as depicted in Table 3.10. At present, these criteria are not fulfilled.

Table 3.10 Jakarta Water Quality Criteria

Criteria (mg/1)	Raw water for water supply	Irrigation Fishery ~ Industrial	Drainage
Dissolved oxygen (02) (minimum)	5	3	2
BOD (02)	5	20	30
Organic matters (KMn04)	10	30	50
Suspended Solids	200	200	200
NH_4^+ (N)	0.5	1	1
NO_2^- (N)	0.5	1	1

Source: COB-Sogreah, Cisadane-Jakarta-Cibeet Water Resources Development Study, Progress Report No. 2, March 1978, p. 37.

In calculating future water flushing requirements, Jakarta is divided into two sectors, upstream and downstream of the Banjir Canal (Figure 3.2). Upstream of the Banjir Canal water is needed especially for dilution and downstream of the Banjir Canal, water is needed for flushing.

a. Upstream of Banjir Canal

Table 3.11 shows potential pollution upstream of the Banjir Canal. The figures in this table are derived from the CJC Study.

Table 3.11 Potential Pollution Upstream Banjir Canal

Stream	BOD5 (kg/day)		NH_4^+ (kg/day)		Detergents (kg/day)	
	1985	2000	1985	2000	1985	2000
Kali Angke	29200	105000	1950	9000	290	2100
Kali Grogol	21100	33000	1410	2830	210	300
Kali Krukut	32650	45000	2180	3900	330	240
Ciliwung	42700	100500	2850	8600	430	2000
Sunter	46500	76750	3100	6600	465	1530
Cakung	21600	36400	1440	3120	220	730

Source: COB-Sogreah, op.cit., p. 49.

During the driest month of the average year, average natural monthly discharge for all the rivers will not exceed 9.7 m^3/sec. Domestic and industrial effluents represent 10.9 m^3/sec. in 1985 and 28.7 m^3/sec. in the year 2000. If these flow directly into the rivers without preliminary sewage treatment, the resulting overall discharge rate will be 20.6 m^3/sec. in 1985 and 38.4 m^3/sec in the year 2000. With dilution of 7.4 m^3/sec. and 25.3 m^3/sec. required to reduce ammonium concentrations which are now twice the level allowed by existing legislation, the discharge rate would be 28 m^3/sec. in 1985 and 63.7 m^3/sec. in 2000.

All above mentioned figures are presented in Table 3.12.

Table 3.12 Dilution Needs Upstream Banjir Canal After Waste Treatment in 1985 and 2000.

Stream	Angke	Grogol	Krukut	Ciliwung	Sunter	Cakung	Total
Residual Pol-ution by NH_4^+ (kg/day)	(390) 1800	(280) 570	(440) 780	(570) 1780	(620) 1320	(290) 625	
Effluent Dis-charge (m^3/s)	(1.6) 7.5	(1.3) 2.7	(1.8) 3.2	(2.4) 7.2	(2.6) 5.5	(1.2) 2.6	(10.9) 28.7
Natural Flow Rate (m^3/s)	2.4	0.2	0.3	5.5	1.0	0.3	9.7
Discharge w/o dilution (m^3/s)	(4.0) 9.9	(1.5) 2.9	(2.1) 3.5	(7.9) 12.7	(3.6) 6.5	(1.5) 2.9	(20.6) 38.4
Concentration w/o dilution (mg/1/NH_4^+)	(1.1) 2.1	(2.4) 2.5	(2.4) 2.6	(0.9) 1.6	(2.0) 2.4	(2.2) 2.5	
Admissible Concentration (mg/1/NH_4^+)	2.0	2.0	1.0	1.0	1.0	2.0	
Rate of Dilution	(0) 0	(0.4) 0.5	(1.4) 1.6	(0) 0.6	(1.0) 1.4	(0.2) 0.5	
Dilution needs (m^3/s)	(0) 0	(0.6) 1.5	(2.9) 5.6	(0) 7.6	(3.6) 9.1	(0.3) 1.5	(7.4) 25.3

Notes: Calculations are based on Table 3.11. The efficiency ratio of the sewage treatment process is 80%, and there is an average daily effluent content of 2.8 g/m^3 (NH_4^+) after treatment.

b. Downstream of Banjir Canal

The Masterplan for Drainage and Flood Control in Jakarta (NEDECO , December, 1972) states that daily water renewal is needed in the canal within the belt of the Banjir Canal. This area is approximately 24,000 ha. The unit water requirement for renewal on a hectare basis is estimated at 1 liter/s/ha. (this figure was used in the JABOTABEK Study Report, 1973). Thus, water required for flushing purposes is 24,000 x 1 liter/s = 24 m^3/s.

The dilution and flushing water requirement for pollution control in the rivers crossing the urban area, especially the center of Jakarta, are closely related to the successful implementation of an integrated sanitation program. Dilution can only be efficient as a means of control of residual pollution inherent in present conventional techniques of effluent collection and sewage treatment. For this program to meet water quality standards, the water requirements for dilution and flushing purposes will be 31.4 m^3/sec. in 1985, and 49.3 m^3/sec. in 2000.

3.2.6 *Total Urban Water Requirement 1985 - 2000*

All previous calculations of urban water requirements are based on net water requirements excluding water losses due to:

i. Network losses in treated water distribution principally at the connecting points between tertiary and secondary pipes and at the level of private connections. These losses increase with the age of the networks, especially for teritary networks. These losses vary between 15% of total consumption for new networks and 25% for older ones.[12]

Since networks in these urban areas are gradually developed, the average loss for the whole networks is assumed to be 20% of the total consumption or 25% of net consumption. For the purpose of this practicum, these estimates are sufficiently accurate.

ii. Processing losses in treatment plants constitute a portion of the internal requirements of the plant for water used in filter washing and mud disposal. This water loss is approximately 10% of raw water or about 11% of treated water, in the case of the existing Jakarta treatment plant.[13]

iii. Conveyance system losses during flow along canals (generally open canals without concrete lining) through evaporation, percolation and seepage are approximately 20% of net water conveyed at the urban intake.[14] This figure is adopted for the purpose of this practicum.

iv. Flushing water is needed particularly during the dry season, because during the wet season, local rainfall augments flushing water to some degree. Therefore, in the wet season rainfall accounts for about 50% of the flushing water and is an appropriate figure for this practicum.

Based on the aforementioned figures, gross urban water requirements for 1985 and 2000 can be estimated and are presented in table 3.13.

Total water requirements on a yearly basis are 1,917.37 million m^3 in 1985, and about 4,134.45 million m^3 in the year 2000.

---

[12] Estimated by the Jakarta's PAM

[13] The Jakarta's PAM

[14] According to experience of Jatiluhur Irrigation System during 1968 - 1977.

Table 3.13 Gross Urban Water Requirements 1985-2000 in m^3/s

Useage	1985 Wet Season	1985 Dry Season	2000 Wet Season	2000 Dry Season
Domestic	11.3	11.3	31.2	31.2
Industrial	7.1	7.1	18.9	18.9
Services	2.4	2.4	4.3	4.3
Sub-total	20.8	20.8	54.4	54.4
Technical losses 36% *	7.5	7.5	19.6	19.6
Sub-total	28.3	28.3	74.0	74.0
Flushing**	15.7	31.4	24.7	49.3
Sub-total	44.0	59.7	98.7	123.3
Conveyed loss 20%	8.8	11.9	19.7	24.7
Gross Water Required	52.8	71.6	118.4	148.0

Note: * Network loss 25%, processing loss 11%

**Wet seasons 50%, dry season 100%

3.3 Future Agricultural Water Requirements 1985 - 2000.

In this practicum, agricultural water is defined as water required to irrigate sawahs. Sawah is a type of agriculture that depends on water availability, either as rainfall, or irrigated water or both. This type of agriculture is predominant in Indonesia and is practised by most Indonesian farmers, especially in Java where the study area is located. This is a very essential agricultural practice that produces the staple food, the production of which does not meet the demand at the present time. For this reason, the Indonesian government gives priority to increased rice production in agricultural development.

There are two types of sawahs, single crop sawahs and double crop sawahs. Single crop sawahs produce rice only once a year due to a lack of water while double crop sawahs can be harvested twice a year due to a good irrigation system. Therefore, for the areas where there is no room for expansion of the area under cultivation, as in the study area, there may be potential for increasing production by changing single crop sawahs over to double crop sawahs.

One objective of this practicum is to estimate future agricultural water requirements related to irrigation developments designed change-over single crop sawah to double crop sawah. For the purpose of this estimation, the following section will discuss crop water requirements, the possibility of irrigation development, and future water needs for this type of agricultural practice.

1. Crop Water Requirements - Crop water requirements depend upon potential evapotranspirations (ETP), in relation with climatic conditions; soil cover, in relation with growing stage; and type of crop, in this case--rice.

a. Growing Stages - Crop water requirements for growing stages can be determined with the following formula:

ET = ETP x f

Where ET = evapotranspiration

ETP = potential evapotranspiration, calculated by PENMAN formula modified by PROSIDA - Nedeco (IDA - Irrigation Project.)

f = cropping factor, experimentally determined for Indonesia as follows:-

	monthly	or	half-monthly
1st month	1.10		1.02 - 1.20
2nd month	1.35		1.32 - 1.40
3rd month	1.30		1.35 - 1.24
4th month	1.05		1.12 - 0.95

b. Field Preparation - Nurseries -- Nurseries cover less than 5% of the gross area and are operated during the same period and in the same area of field preparation as sawah. Thus, it can be assumed that nursery water supplies are met by water supplied to the surrounding flooded fields.

Field preparation requires water for soil saturation, establishment of a water layer, evapotranspiration losses and percolation losses.

Zylstra-Van de Goor have proposed a formula of daily requirements for field preparation in mm/day (c) according to:

i. quantity of water needed for saturation and water layer in mm (b)

ii. value of potential evapotranspiration and percolation

(a) with a = ETP + P in mm/day;
(P = percolation)

iii. duration of field preparation period (T) in days.

The formula is:

$$c = a \frac{e^{\frac{aT}{b}}}{e^{\frac{aT}{b}} - 1}$$

Using this formula, PROSIDA-Nedeco recommended the following values:

i)	soil saturation	100 mm
ii)	water layer	100 mm
		200 mm (both for dry and wet seasons)

iii) time of field preparation: 45 days.

(c) Effective Rainfall: Re: (in mm/day)

i. Rainfall probabilities derived from historical data show the amount that can be expected in any period of time. For Indonesia, PROSIDA-Nedeco used the mean monthly rainfall occurring on a probability basis 8 years out of 10. This, of course, means that a shortage two years out of ten is expected.

ii. Effective rainfall for field preparation can be defined as 80% of probable rainfall with a maximum given by soil saturation + water layer requirement (Zylstra-Van de Goor formula)

Effective rainfall for growing stages can be defined as 60% of probable rainfall with a maximum given by f x ETP + P + Re. Effective rainfall of less than 1 mm/day is ignored.

(d) Water Layer: W (in mm/day)

Provision of 2.5 mm/day during two months after transplantation has to be made for water establishment.

(e) Percolation: P (in mm/day)

Percolation losses are dependent upon soil characteristics. For the study area the following figures are used:

i. for coastal plains: 1 mm/day

ii. for upper areas: 2 mm/day

(f) Field requirements: A (in mm/day)

i. for the field preparation stage: A = FP - Ref

with FP = soil saturation + water layer requirements (Zylstra)

Ref = effective rainfall for field preparation stage =

$0.8 \times R_{8/10}$

ii. for successive growing stages:

A = ET + W - Re + P

with ET = evapotranspiration = f x ETP

W = water layer requirements

Re = effective rainfall for growing stages

$= 0.6 \times R_{8/10}$

P = percolation losses

(g) Field Requirement: B (in l/sec/ha)

Field requirements given in mm/day (A) are converted into l/sec/ha (B) using relationships:

$$B = A \times 0.116$$

(h) Tertiary Water Requirements: C (in l/sec/ha)

Runoff is estimated to be 17% of water supplied to the tertiary unit. Thus B = 83% of C or the tertiary water requirement:

$$C = 1.2 \times B$$

(i) Intake Water Requirements: D (in l/sec/ha)

$$D = 1.4 \times B$$

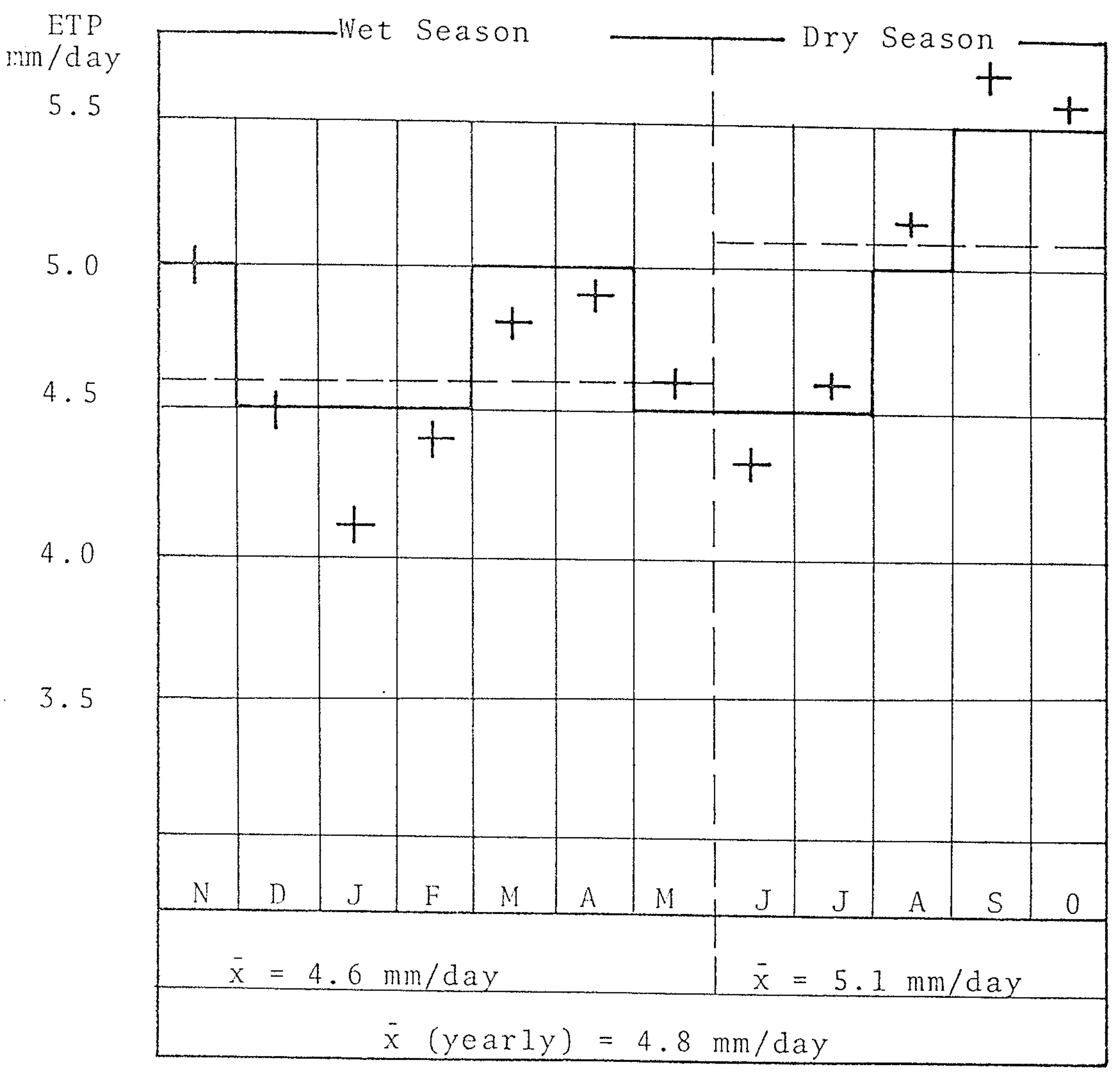
Conveyance efficiencies are estimated to be 87% which is quite reasonable for rice fields, as PROSIDA uses this figure for this area.

2. Water Requirements for Double Crop Rice

According to the CJC Study and PROSIDA's computations, potential evapotranspiration (ETP) has been calculated using a modified PENMAN method for the two major meteorological stations of Jakarta Observatory and Bogor. Evapotranspiration (ET = ETP x f) has been calculated for each growing stage in terms of the prevailing ETP. These results are shown in Figures 3.3 and 3.4.

For the purpose of water management, the area is divided into 8 homogeneous areas according to their average annual rainfall and their monthly distribution (this distribution varies over an east-west axis between Jakarta and Bogor). Average annual rainfall of each area has been adjusted to a round figure (1500, 2500, 3500, 4500 mm) and a proportional adjustment has been made for each month. The figures taken at Jakarta Observatory represent coastal areas having average annual rainfall 1500 and 2500 mm, and figures at Bogor represents the upper zones having average annual rainfalls of 3500 and 4500 mm. Figure 3.3 and 3.4 show that the adjusted ETP ranges from 3.5 to 5.5 mm/day. The adjustment is in rounded figures derived from an ETP computation. The accuracy of the computation is estimated to lie between 30% over a one month period and 10% over a one year period.

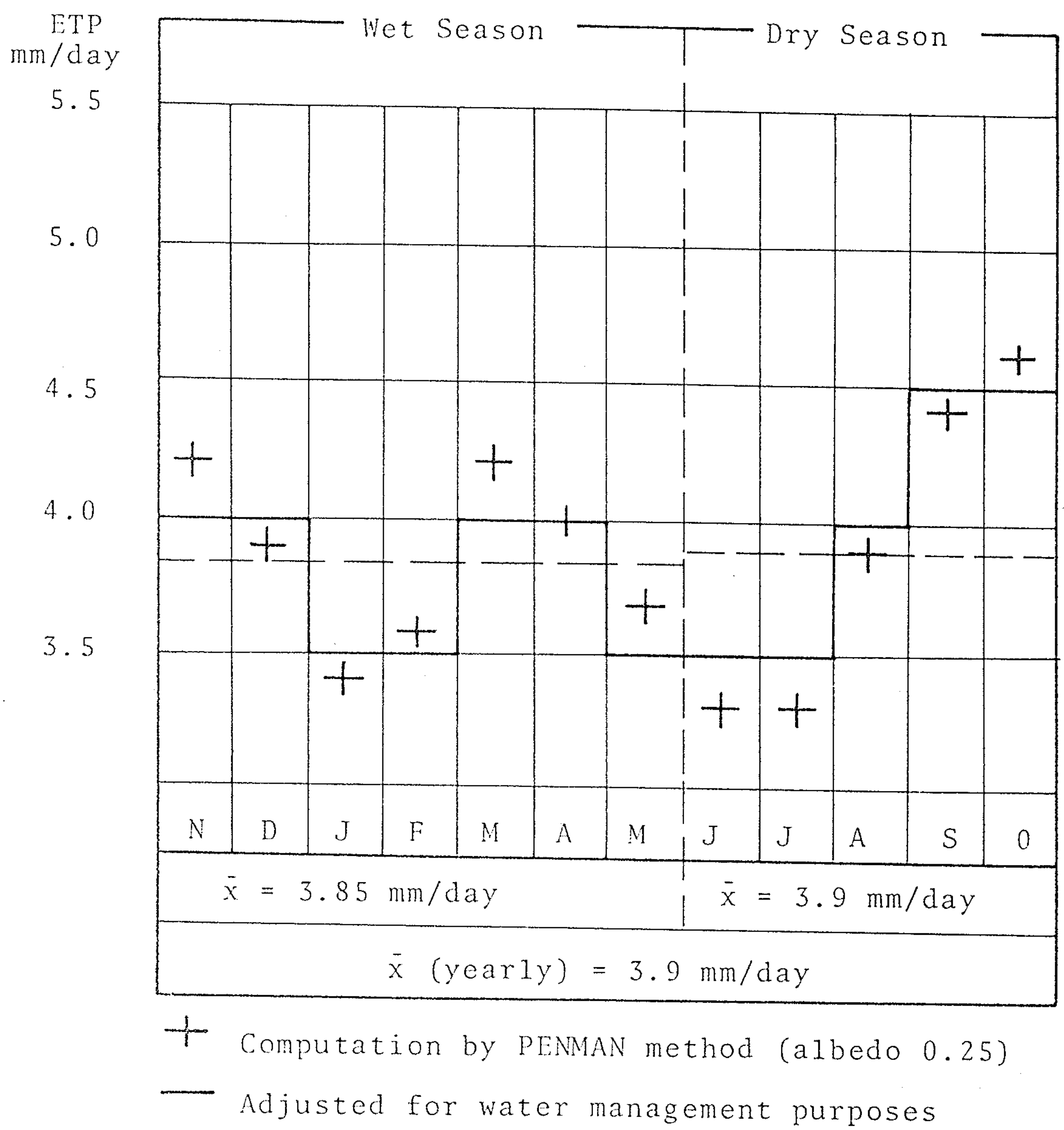
Figure 3.3: Potential Evapotranspiration, Jakarta Observatory



+ Computation by PENMAN method (albedo 0.25)

— Adjusted for water management purposes

Figure 3.4: Potential Evapotranspiration, Bogor Observatory



These figures are used for further calculations, such as the ET shown in Table 3.14.

Table 3.14: Evapotranspiration for Wet Sawah Paddy (Rice)

Growing Stage and f	ETP (mm/day) 3.5	4.0	4.5	5.0	5.5
	ET = ETP x f (in mm/day)				
Transplanting 1.02	3.6	4.1	4.6	5.1	5.6
Tillering I 1.20	4.2	4.3	5.4	6.0	6.6
Tillering II 1.32	4.6	5.3	5.9	6.6	7.3
Flowering I 1.40	4.9	5.6	6.3	7.0	7.7
Flowering II 1.35	4.7	5.4	6.1	6.8	7.4
Ripening I 1.24	4.3	5.0	5.6	6.2	6.8
Ripening II 1.12	3.9	4.5	5.0	5.6	6.2
Ripening III 0.92	3.3	3.8	4.3	4.8	5.2

By using the Zylstra-Van de Goor formula for presaturation requirements (200 mm) and duration of field preparation period (T) which is from 30 to 60 days, the field preparation water requirements can be calculated and are presented in Table 3.15.

Table 3.15 Field Preparation Water Requirements (mm/day)

T in days	ETP + P in mm/day							
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
30	8.9	9.2	9.6	9.8	10.1	10.4	10.8	11.1
35	7.9	8.3	8.6	8.9	9.2	9.6	9.9	10.2
40	7.3	7.6	7.9	8.2	8.6	8.9	9.3	9.6
45	6.7	7.1	7.4	7.8	8.1	8.5	8.8	9.2
50	6.3	6.7	7.0	7.4	7.7	8.1	8.5	8.8
55	6.0	6.3	6.7	7.1	7.4	7.8	8.2	8.5
60	5.7	6.1	6.4	6.8	7.2	7.6	8.0	8.3

Intake water requirements can be computed by using all formerly related data/figures and related effective rainfalls (Re and Ref). Finally, after selecting golongan systems[15] as the mechanism for providing the lowest water consumption and peak requirements, the intake water requirements for double crop sawah with golongan systems can be presented in Table 3.16.

---

[15]The Golongan system is a procedure for regulating the dates for planting the rice crops on parts of the irrigable area in order to: reduce irrigation water requirements at the beginning of wet season; avoid unduly high water requirements during the growing season by shifting the peak requirements periods resulting from the several plantings; fit available water supply. For example, an irrigation district has three gologans of more or less equal size. The first gologan starts land preparation, say January 1st, the second golongan starts in the middle of January, and the third golongan starts February 1st. By following this procedure, the peak requirements can be reduced. This makes water utilization more effective.

Table 3.16: Intake Water Requirements for Double Crop Sawah in l/s/ha.

(a) Wet Season

Zone and Rainfall	N	D	J	F	M	A	M	Average
Western								
1500 mm	1.45	1.00	0.45	0.45	0.70	1.20	1.35	0.94
2500 mm	1.05	0.85	0.40	0.30	0.45	0.85	1.00	0.70
3500 mm	0.75	0.80	0.35	0.25	0.40	0.45	0.75	0.54
4500 mm	0.40	0.55	0.15	-	0.10	0.25	0.55	0.29
Eastern								
1500 mm	1.20	1.05	0.70	0.55	0.75	1.00	1.35	0.94
2500 mm	1.00	0.90	0.50	0.40	0.50	0.70	1.10	0.73
3500 mm	0.75	0.70	0.25	0.10	0.20	0.40	0.85	0.46
4500 mm	0.55	0.60	0.15	-	0.05	0.15	0.80	0.33

(b) Dry Season

Zone and Rainfall	J	J	A	S	O	Average
Western						
1500 mm	1.35	1.05	0.95	1.10	1.35	1.16
2500 mm	1.15	1.05	0.95	1.10	1.10	1.05
3500 mm	0.85	0.80	0.75	0.70	0.75	0.77
4500 mm	0.75	0.80	0.70	0.60	0.50	0.67
Eastern						
1500 mm	1.30	1.05	0.95	1.10	1.20	1.12
2500 mm	1.30	1.05	0.95	1.10	1.15	1.11
3500 mm	1.30	1.05	0.95	1.00	0.95	1.05
4500 mm	1.10	1.05	0.95	0.90	0.80	0.96

Note: These figures represent 6 golongans with field preparation in the wet season starting in August to mid-October, and in the dry season from February to mid-April. Transplanting runs from mid-September to December for the first crop and from mid-March to June for the second crop.

3. Irrigation Area in 1985 - 2000

All suitable land for sawah in the study area is now occupied by "technical" irrigation, "semi-technical" irrigation, "simple" irrigation, and "rainfed" systems. Irrigation development will replace, to the greatest degree possible, the systems serving sawahs with technical irrigation systems.

The viability of this development depends on topographical characteristics in relation to water resource location and availability, and economic factors. With these considerations in mind at the CJC Project, estimated the total area of sawahs of all types in 1985 at 236,645 ha. Of this total, 139,905 ha would be served by technical irrigation systems as depicted in Table 3.17

Table 3.17: Total Sawahs in 1985, in ha.

Region/section	Technical	1/2-Techn.	Simple	Rainfed	Total
Tanggerang					
Cisadane-Prosida	37600	-	-	-	37600
Cidurian-Ranca Sumur	13300	-	-	-	13300
Others	-	4500	2300	18300	25100
Sub-total	50900	4500	2300	18300	76000
Bogor					
Cisadane-Empang	9025	5710	1645	2200	18580
Ciliwung-Katulampa	5190	300	1620	510	7620
Others	3500	13460	14000	20000	50960
Sub-total	17715	19470	17265	22710	77160
Prosijat/Jatiluhur					
West Tarum	62750	-	-	-	62750
South of West Tarum	8040	370	7485	4840	20735
Sub-total	70790	370	7485	4840	83485
Grand-total	139405	24340	27050	45850	236645

Source: CJC Project

While the total area of sawahs in 1985 decreases from the 1975 area (Table 2.1), the modern technical irrigated areas increase, allowing double cropping annually. This improvement will occur due to the government's efforts in agricultural and urban developments. The loss of sawah is due mainly to urbanization. Industrial and urban areas have been expanding rapidly into rural agricultural areas, and the location of new manufacturing complexes along the existing and newly developed main roads will consume still more agricultural land in the future.

Village growth, especially in the irrigated areas, the rehabilitation of the irrigation and drainage networks, the implementation of new schemes including road networks and the building of large reservoirs, will also contribute to the loss of sawahs.

This process is ongoing, as indicated by total sawahs in 2000 presented in Table 3.18.

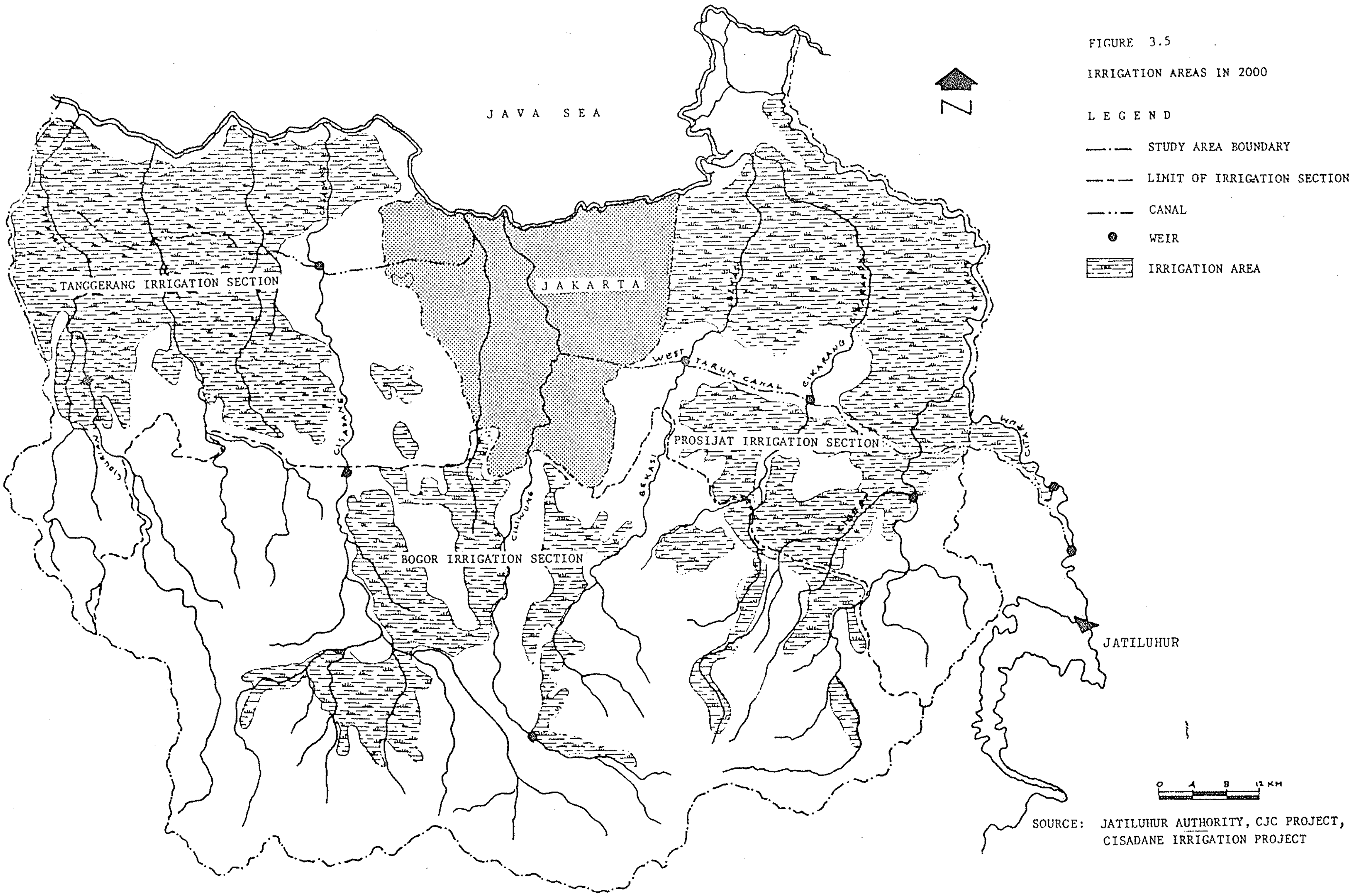
Table 3.18 shows that in 2000 some technical irrigation areas are forecast to decrease, such as in Tanggerang at Cisadane, Bogor at Empang, and in Jatiluhur at West Tarum as a result of urban growth of Tanggerang, Bogor, and Cikarang-Bekasi-Jakarta. The location of irrigation areas and urban growth is depicted in Figure 3.5.

Table 3.18: Total Sawahs in 2000, in ha.

Region/Section	Technical	1/2 Techn.	Simple	Rainfed	Total
Tanggerang					
Cisadane-Prosida	29900	-	-	-	29900
Cidurian-Ranca Sumur	12670	-	-	-	12670
Others	15240	-	-	5600	20840
Sub-total	57810	-	-	5600	63410
Bogor					
Cisadane-Empang	8220	-	-	1450	9370
Ciliwung-Katulampa	2580	-	-	-	2580
Others	3210	11180	14000	20000	48390
Sub-total	14010	11180	14000	21450	60340
Prosijat/Jatiluhur					
West Tarum	53800	-	-	-	53800
South of West Tarum	18000	-	-	-	18000
Sub-total	71800	-	-	-	71800
Grand-total	143620	11180	14000	27050	195550

FIGURE 3.5

IRRIGATION AREAS IN 2000



SOURCE: JATILUHUR AUTHORITY, CJC PROJECT, CISADANE IRRIGATION PROJECT

4. Water Requirements

Using a 2.0 crop-intensity for double-crop sawah served by technical irrigation systems and 1.8 for semi-technical systems, water requirements for 1985 can be calculated. The results derived from Table 3.16 and 3.17 are presented in Tables 3.19 and 3.20.

Table 3.19 Water Requirements for Rice Double Cropping for 1985

Region/Section	Net Irrigated Area Ha	Discharge ge m^3/s	Peak Discharge m^3/s	Requirements (106 m^3) Season Wet	Dry	Total
Tanggerang						
Cisadane-Pr.	37600	39.0	54.5	653.9	574.7	1228.6
Cidurian-Rs.	13300	13.8	19.3	231.3	203.3	434.6
Others	4500	3.	4.7	58.1	56.0	114.1
Sub-total	55400	56.4	78.5	943.3	834.0	1777.3
Bogor						
Cisadane-Em.	14735	9.0	11.8	148.3	134.5	282.8
Ciliwung-Kt.	5490	3.6	6.4	47.0	68.4	115.4
Others	16960	7.1	12.2	89.5	134.8	224.3
Sub-total	37185	19.7	30.4	284.8	337.7	622.5
Prosijat						
West Tarum	62750	64.0	84.7	1091.3	926.0	2017.3
South of W.T.	8410	7.1	9.8	113.0	110.7	223.7
Sub-total	71160	71.1	94.5	1204.3	1036.7	2241.0
Total	163745	147.2	203.4	2432.4	2208.4	4640.8

Table 3.20: Monthly Water Requirements for Rice-Double-Cropping for 1985 (m3/s)

Irr.Section	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Tanggerang												
Cisadane-Pr	54.52	37.60	16.92	16.92	26.32	45.12	50.76	50.76	39.48	35.72	41.36	50.76
Cidurian-Rs	19.29	13.30	5.99	5.99	9.31	15.96	17.96	17.96	13.97	12.64	14.63	17.96
Others	4.73	3.83	1.80	1.35	2.03	3.83	4.50	4.66	4.25	3.85	4.05	4.46
Sub-total	78.54	54.73	24.71	24.26	37.66	64.91	73.22	73.38	57.70	52.21	60.04	73.18
Bogor												
Cisadane-Em	11.05	11.79	6.16	3.68	5.89	6.63	11.05	11.27	10.61	9.95	9.28	9.95
Ciliwung-Kt	4.12	3.84	1.37	0.55	1.10	2.20	4.67	6.42	5.19	4.69	4.94	4.69
Others	6.78	9.33	2.54	-	1.70	4.24	9.33	11.45	12.21	10.68	9.16	7.63
Sub-total	21.95	24.96	10.07	4.23	8.69	13.07	25.05	29.14	28.01	25.32	23.38	22.27
Prosijat												
West Tarum	75.30	65.89	43.93	34.51	47.06	62.75	84.71	81.58	65.89	59.61	69.03	75.30
South of WT	8.41	7.57	4.21	3.36	4.21	5.89	9.25	9.84	7.95	7.19	8.33	8.71
Sub-total	83.71	73.46	48.14	37.87	51.27	68.64	93.96	91.42	73.84	66.80	77.36	84.01
Total	184.20	153.15	82.92	66.37	97.62	146.62	192.23	193.94	159.55	144.33	160.78	179.46

For the year 2000, a 2.0 crop-intensity could be used because at that time, the study area is served chiefly by technical systems. Thus, all irrigated areas are cultivated twice a year at full capacity. The water requirements for this are shown in Table 3.21 on a seasonal basis and in Table 3.22 on a monthly basis.

Table 3.21: Water Requirements for Rice-double Cropping for 2000

Region/Section	Irrigated Area Ha.	Discharge m^3/s	Peak Discharge m^3/s	Requirements 10^6 m^3 Season Wet	Dry	Total
Tanggerang						
Cisadane-Pr.	29900	30.9	43.4	518.7	457.0	975.5
Cidurian-Rs.	12670	13.1	18.4	219.7	193.7	413.4
Others	15240	12.9	17.5	196.8	210.8	407.6
Sub-total	57810	56.9	79.3	935.0	861.5	1796.5
Bogor						
Cisadane-Emp.	8220	5.2	7.0	81.9	83.4	165.3
Ciliwung-Ktl.	2580	1.8	3.4	21.9	35.7	57.6
Others	14390	6.5	11.5	77.0	127.0	204.0
Sub-total	25190	13.5	21.9	180.8	246.1	426.9
Prosijat						
West Tarum	53800	54.8	72.6	932.9	793.9	1726.8
South of W.T.	18000	16.1	23.4	245.7	263.3	509.0
Sub-total	71800	70.9	96.0	1178.6	1057.2	2235.8
Total	154800	141.3	197.2	2294.4	2164.8	4459.2

Table 3.22: Monthly Water Requirements for Rice-Double-Cropping for 2000 (m3/s)

Irr.Section	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Tanggerang												
Cisadane-Pr	43.36	29.90	13.46	13.46	20.93	35.88	40.37	40.37	31.40	28.41	32.89	40.37
Cidurian-Rs	18.37	12.67	5.70	5.70	8.87	15.20	17.10	17.10	13.30	12.04	13.94	17.10
Others	16.00	12.95	6.10	4.57	6.86	12.95	15.24	17.53	16.00	14.48	15.24	16.76
Sub-total	77.73	55.52	25.26	23.73	36.66	64.03	72.71	75.00	60.70	54.93	62.07	74.23
Bogor												
Cisadane-Em	6.17	6.58	2.88	2.06	3.29	3.70	6.17	6.99	6.58	6.17	5.57	6.17
Ciliwung-Kt	1.94	1.81	0.65	0.26	0.52	1.03	2.19	3.35	2.71	2.45	2.58	2.45
Others	5.76	7.91	2.16	-	1.44	3.60	7.91	10.79	11.51	10.07	8.63	7.20
Sub-total	13.87	16.30	5.69	2.32	5.25	8.33	16.27	21.13	20.80	18.69	16.96	15.82
Prosijat												
West Tarum	64.56	56.49	37.66	29.59	40.35	53.80	72.63	69.94	56.49	51.11	59.18	64.56
South of WT	18.00	16.20	9.00	7.20	9.00	12.60	19.80	23.40	18.90	17.10	19.80	20.70
Sub-total	82.56	72.69	46.66	36.79	49.35	66.40	92.43	93.34	75.39	68.21	78.98	85.26
Total	174.16	144.51	77.61	62.84	91.26	138.76	181.41	189.47	156.89	141.83	158.01	175.31

All the above figures on agricultural water requirements exclude losses of about 10% or approximately 11% of intake water requirements (net water requirements) during conveyence in the main canals. If these losses are accounted for, gross agricultural water requirements become 5151.3 million m^3 for 1985 and 4949.7 million m^3 for the year 2000. Gross agricultural water requirements on a monthly basis are depicted in Table 3.23

Table 3.23 : Gross Monthly Water Requirements for Rice-Double-Cropping for 1985 - 2000 (m^3/s)

Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1985	204.46	170.00	92.04	73.67	108.36	162.75	213.38	215.27	177.10	160.21	178.47	199.20
2000	193.32	160.41	86.15	69.75	101.30	154.02	201.37	210.31	174.15	157.43	175.39	194.59

3.4 Conclusion

Water requirements rapidly increase as mankind progresses economically and socially. Unfortunately, the supply of useable water will remain more or less unchanged and may possibly be diminished if man-induced water contamination increases.

Estimated urban water requirements for JABOTABEK, based on annual calculations, are 1,917 million m^3 for 1985 and 4,134 million m^3 for the year 2000. This means during 15 years between 1985 and 2000, water requirements will increase 116%.

Agricultural water requirements estimated on an annual basis are 5,151 million m^3 for 1985 and 4,950 million m^3 for the year 2000. These figures indicate that agricultural water requirements decrease by about 4%, due to reduction of irrigation areas as a result of urban and industrial developments, and village growth.

The overall water requirements for both urban and agricultural purposes amount to 7,068 million m^3 and 9,084 million m^3 for the years 1985 and 2000 respectively. This means that during the 15 years between 1985 and 2000, water requirements will increase approximately 29% or at an average annual rate of about 2%.

Now that water requirements in the future have been determined, the next chapter will examine available water resources.

CHAPTER IV

WATER RESOURCE POTENTIALS

4.1 Introduction

This chapter will investigate water resource potentials under natural conditions which may be utilized in this area to serve urban and agricultural water requirements for the period 1985 - 2000. Discussion will deal with climatological and topographical conditions which affect rainfall. Additional topics of discussion include run-off conditions; rainfall-runoff as a main source of surface water; and estimation of ground water. The concluding section will present the total water resources potential available to meet JABOTABEK's requirements.

4.2 Topographical and Climatological Conditions

The study area, from north to south, consists of three successive zones:

(1) A relatively flat coastal plain with low altitude. The major cities are located in this zone (Jakarta, Tanggerang, Bekasi) as are industrial centers and two principal irrigated areas; Cisadane Irrigation Project and Jatiluhur Irrigation Project.

(2) A hilly area with intermediate elevations. This zone is characterized by semi-technical and rural irrigation areas and plantation estates.

(3) A mountainous area with high elevation where streams originate.

The topographical variation ranging from 0m SWL (Sea Water Level) to 1500 m SWL (Figure 1.1) influences temperature, relative humidity and other climatological conditions as shown in

Table 4.1. In Table 4.1, Jakarta represents a lowland/coastal area and Bogor an area of intermediate elevation.

Table 4.1

Climatological Data for Jakarta and Bogor

		J	F	M	A	M	J	J	A	S	O	N	D
Temp. Max °C	Jakarta	30.1	30.1	31.2	32.1	32.4	32.1	32.1	32.2	32.8	33.0	32.2	31.3
	Bogor	29.5	28.5	30.4	30.7	30.6	30.5	30.3	30.8	31.4	31.5	30.8	30.2
Mean °C	Jakarta	26.3	26.3	26.9	27.5	27.7	27.2	27.0	27.1	27.6	27.8	27.3	26.7
	Bogor	25.0	25.1	25.4	25.8	25.9	25.8	25.5	25.4	25.8	26.2	25.7	25.6
Min	Jakarta	23.5	23.7	23.7	24.1	24.1	23.2	22.8	22.7	23.2	23.8	23.9	23.7
	Bogor	22.5	22.4	22.7	22.9	22.6	22.3	20.8	21.8	22.3	22.9	23.0	22.8
R-H Max %	Jakarta	96	96	96	95	95	94	92	90	89	91	94	95
	Bogor	98	99	97	98	96	95	95	93	94	94	94	97
Mean %	Jakarta	85	85	83	82	80	78	76	74	73	75	79	82
	Bogor	91	90	88	89	86	82	81	78	80	81	83	86
Min	Jakarta	66	67	63	62	59	55	54	51	51	54	59	62
	Bogor	74	73	69	70	67	62	62	57	58	59	66	64
Sun-shine %	Jakarta	39	47	57	68	70	71	78	83	82	71	56	48
	Bogor	27	32	51	55	56	51	49	60	63	59	48	41
Wind D	Jakarta	NW	NW	NW	E	E	E	E	E	N	N	N	NW
	Bogor	NW	NW	W	NE	NE	NE	NE	NE	NE	N	N	W
V m/s	Jakarta	1.6	1.7	1.5	1.5	1.6	1.6	1.8	1.7	1.8	1.8	1.9	1.5
	Bogor	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6
ETP mm/d	Jakarta	4.1	4.4	4.8	4.9	4.6	4.3	4.6	5.2	5.7	5.6	5.0	4.5
	Bogor	3.3	3.6	4.2	4.0	3.7	3.3	3.3	3.9	4.4	4.6	4.2	3.9

Source: CJC Project. Office, 1978

Note: R-H : Relative Humidity; D : Direction; V : Velocity
ETP ; Potential Evaporation.

Topographical and climatological conditions affect rainfall. In the coastal plain, mean annual rainfall is 1500 mm while in the mountain region mean annual rainfall is 5000mm. (see Figure 4.1) The coastal region has a higher water consumption compared to the mountain region. The mountain region may be considered as a conservation zone and the coastal region as a consumption zone.

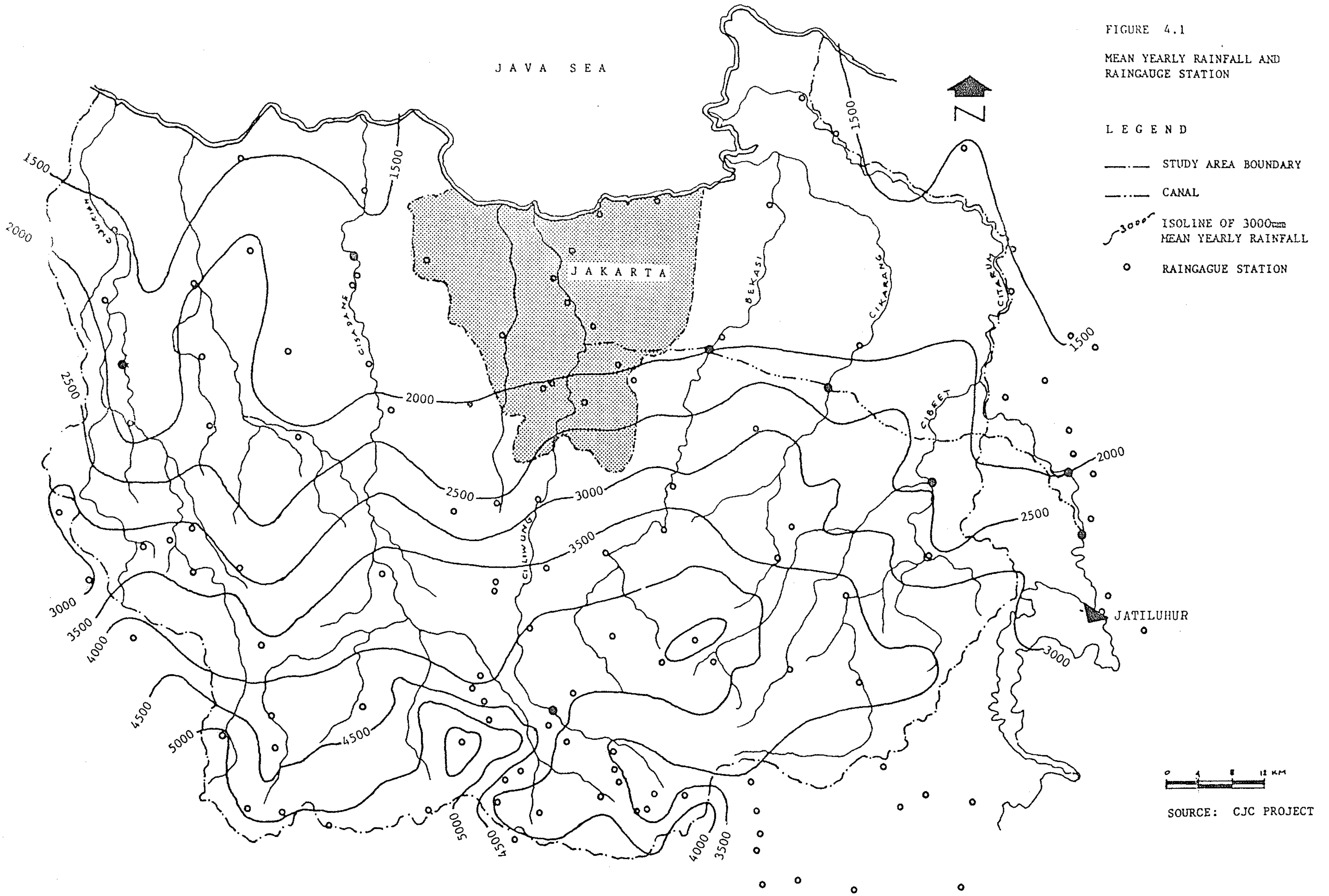


FIGURE 4.1

MEAN YEARLY RAINFALL AND RAINGAUGE STATION

Topographical and climatological conditions also affect run-off. In the coastal plain, mean annual run-off is 15 $l/s/km^2$ while in the mountain region run-off is 130 $l/s/km^2$. (see Figure 4.2) The difference in run-off rates is paralled by a difference in evapotranspiration (ETP) rates. The coastal zone has relatively higher ETP rates than the upland zone.

4.3 Rainfall-Runoff

The study has a dense rainguage network with more than 100 stations, which are identified in Figure 4.1. Several of these stations have long records. However, during the war from 1942 to 1945 and during the 1945-1949 period, records are missing.

The mean yearly rainfall of the area ranges from 1500 mm along the coast to 5000 mm in the mountainous area (Fig. 4.1). The monthly rainfall for each category of those ranges have a frequency of exceedance of 80%, as presented in Table 4.2.

Table 4.2. Mean Monthly Rainfall in mm/day

Mean Yearly Rainfall (mm.)	J	F	M	A	M	J	J	A	S	O	N	D
1500	5.3	4.4	3.0	2.0	1.5	0.9	0.7	0.4	0.5	1.1	2.1	3.4
2500	6.0	6.0	5.1	5.2	3.3	2.1	1.2	1.1	1.8	3.4	5.0	4.8
3500	8.5	8.6	7.8	8.0	7.0	4.1	2.5	2.3	3.3	6.1	7.3	6.5
4500	10.1	11.1	10.3	12.1	9.5	6.4	3.8	3.8	5.4	9.5	10.8	8.7

Source: CJC - Project Office,1978.

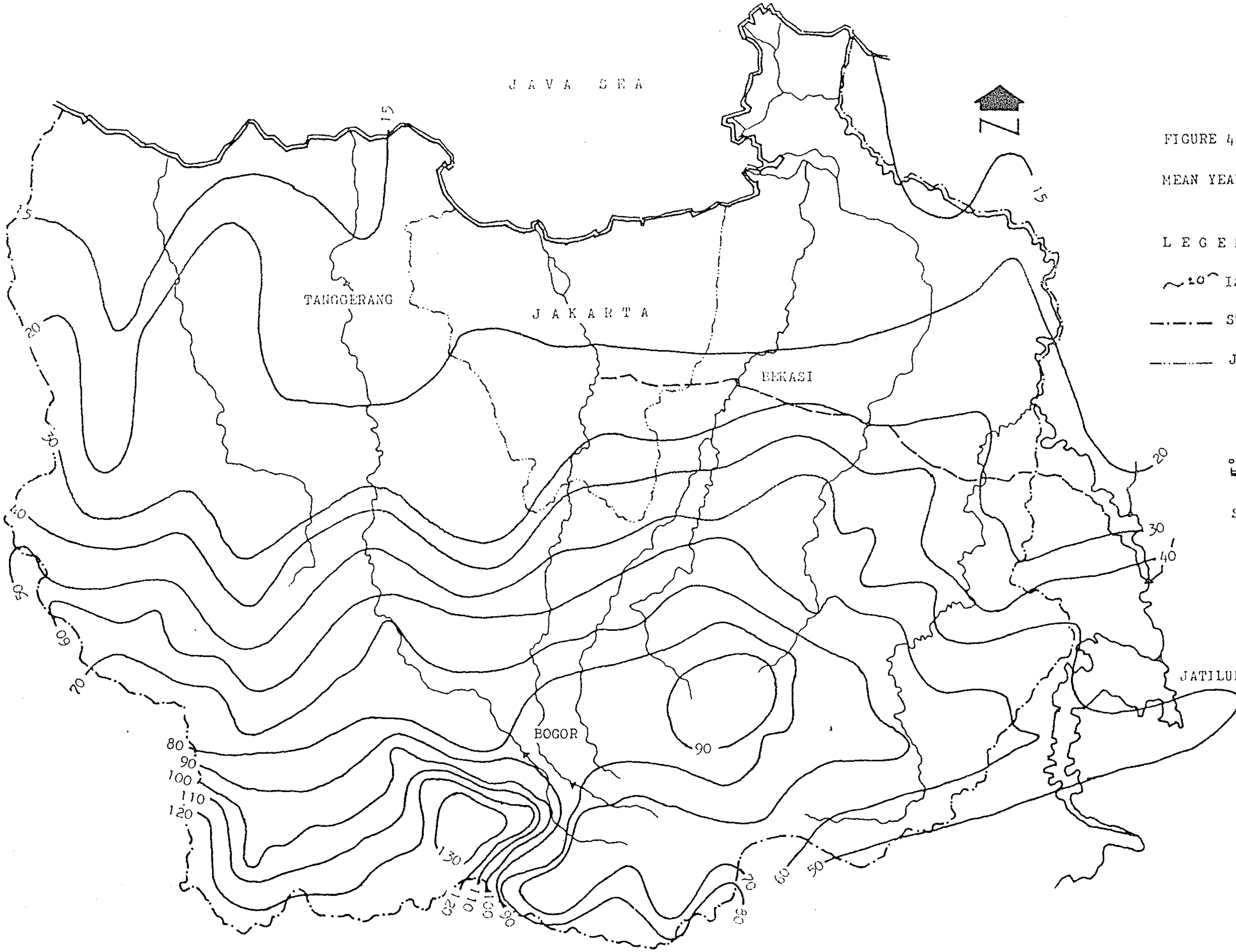


FIGURE 4.2

MEAN YEARLY RUN-OFF

LEGEND

ISOLINE OF 20 l/s/km2

STUDY AREA BOUNDARY

JAKARTA BOUNDARY

SOURCE : THE CJC PROJECT

According to the above table, rainfall occurs all year, but the heaviest rain occurs in the wet season from November to May. As a result, water must be stored during the wet season for needs in the dry season, because the water requirements for this season are higher due to increasing urban requirements for flushing purposes. Artificial lakes or reservoirs must be built to serve this purpose.

Monthly rainfall for a period of 50 years for selected stations and related catchment areas is summarized and presented in Table 4.3

Table 4.3 Seasonal Rainfall and Monthly Average in mm

Station/catchment (km2)	Period Years	Wet		Dry		Year
		Total	Av.	Total	Av.	
Cibeet-weir (507)	49	2497	357	803	161	3300
Cikarang-weir (238)	47	2699	386	774	155	3473
Bekasi-weir (412)	52	2583	369	1076	215	3659
Ciliwung-Rawajati (318)	50	2492	356	887	177	3379
Cisadane-Serpong (1074)	49	2678	383	1252	250	3930
Cidurian-Kopomaja (304)	44	2208	315	1062	212	3270

Source: CJC-Project.

Table 4.3 indicates that the average monthly rainfall for the dry season is approximately 50% of the wet season for overall catchments. Thus, management of this resource may be required if there is a water shortage in the dry season.

Effective management requires knowledge about the relationship between rainfall and runoff. The rainfall-runoff relationships of selected gauging stations is shown in Table 4.4 are based on a computer program incorporating rainfall and evapotranspiration (ETP) data.

Table 4.4 Rainfall-Runoff Relationship in mm/year

Gauging Station	Rainfall	Runoff (%)
Cibeet-weir	3300	2140 (65)
Cikarang-weir	3470	2160 (62)
Bekasi-weir	3660	2010 (54)
Ciliwung	3380	1690 (50)
Cisadane-Masing	3750	2620 (70)
Cisadane-Serpong	3930	2870 (73)
Cidurian	3270	2370 (72)
Average	3537	2266 (64)

Source: CJC Project office, computed by IBM 370 of Department of Public Works

From Table 4.4, the overall run-off is approximately 64% of the total rainfall. Only that portion can be stored or directly used or conveyed to consumers. The rest evaporates or infiltrates into the soil.

4.4 Available Surface Water

Runoff data is as important as surface water data. By relating runoff data to catchment areas, discharge figures can be obtained. The CJC-Project has computed monthly discharge for catchments in the study area, based upon 50 years of rainfall data. Seasonal discharge estimates are presented in table 4.5 and monthly discharge estimates are presented in table 4.6.

Table 4.5 Seasonal Discharge for Overall Catchments*

Catchment	(Km2)	Period	Wet Season ($m^3/5$)	Dry Season (m^3/s)	Year (m^3/s)
Cibeet at weir	507	49	49.0	13.9	34.4
Cikarang at weir	238	47	20.9	9.9	16.3
Bekasi at weir	412	52	32.6	17.4	17.0
Ciliwung-Rawajati	318	49	21.3	11.0	10.7
Cisadane at Masing	129	49	12.7	8.0	10.7
Cisadane-Serpong	1074	49	115.0	73.7	97.9
Cidurian-Kopamaja	304	44	27.2	16.4	22.8
Total			278.7	150.3	225.4

Source: CJC Project Office (1978)

From Table 4.5, it can be seen that the total discharge available in the dry season is only 67% of the average annual discharge (150.3/225.4 x 100%), while in the wet season, the available discharge is about 124% (278.7/225.4 x 100%). Thus the ratio between the dry season and the wet season discharge is about 1 to 2. The discharge difference between dry and wet seasons becomes higher if monthly discharge figures are used as shown in Table 4.6.

* The dry season comprises the months of June to October. The wet season comprises the months of November to May.

Table 4.6: Mean Monthly Discharge for Over-all Catchments (m3/s)

Catchment	WET-SEASON							DRY-SEASON				
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Cibeet at weir	32.1	37.8	61.8	63.5	58.0	51.9	38.1	19.5	13.6	9.1	9.6	17.8
Cikarang at weir	15.4	17.7	24.5	25.0	23.8	21.7	18.3	12.3	10.3	7.7	8.4	11.0
Bekasi at weir	26.0	26.7	36.0	37.8	34.9	37.0	30.1	20.9	15.9	14.2	14.9	21.3
Ciliwung-Rawajati	15.6	18.1	24.6	25.4	23.3	23.2	19.0	13.4	10.6	9.3	9.5	12.2
Cisadane-Masing	11.2	12.4	13.4	14.0	13.4	13.0	11.3	8.9	7.6	7.1	7.1	9.2
Cisadane-Serpong	102.0	104.0	120.0	120.0	120.0	124.0	116.0	80.6	67.1	62.2	68.3	90.3
Cidurian-Kopomaja	20.0	20.6	31.4	31.9	27.5	32.7	26.0	18.6	15.3	16.0	15.5	18.0
Over-all	222.3	237.3	311.7	317.6	300.9	303.5	258.8	174.2	140.4	125.6	133.3	179.8

Source: Computed by the CJC-Project (1978)

The discharge in the driest month (August) is 125.6 m^3/s, while in the wettest month (February) it is 317.6 m^3/s or two and one-half times greater. If total requirements exceed 125.6 m^3/s, part of the wet season discharge must be stored to maintain a continuous supply.

Based on Table 4.5, total surface water is about 7,108 million m^3 per year (225.4 m^3/s), consisting of 5,130 million m^3(278.7 m^3/s) in the wet season and 1,980 million m^3(150.3 m^3/s) in the dry season.

The existing water supply from the Jatiluhur reservoir (which is outside the study area) through the West Tarum Canal (Figure 1.1) supplies the city of Jakartah and sawahs in the eastern part of the study area. This water supply will continue to be available in the future. The design capacity of this canal is 85 m^3/s, but the actual amount conveyed is about 80% or approximately 68 m^3/s. This water facility can supply the city of Jakarta with about 11.20 m^3/s and sawahs with approximately

56.80 m^3/s. Thus, this water supply should be added to the previous figures of the surface water.

To provide adequate water in the dry season, part of the wet season discharge must be stored. Possible dam sites have to be determined. According to the Jatiluhur Authority and Cisadane-Jakarta-Cibeet Project's preliminary investigations based on topographical maps and hydrological data, some possible dam sites in the study area have already been determined. The findings are presented in Table 4.7 and Figure 4.3.

Table 4.7 Possible Dam Sites

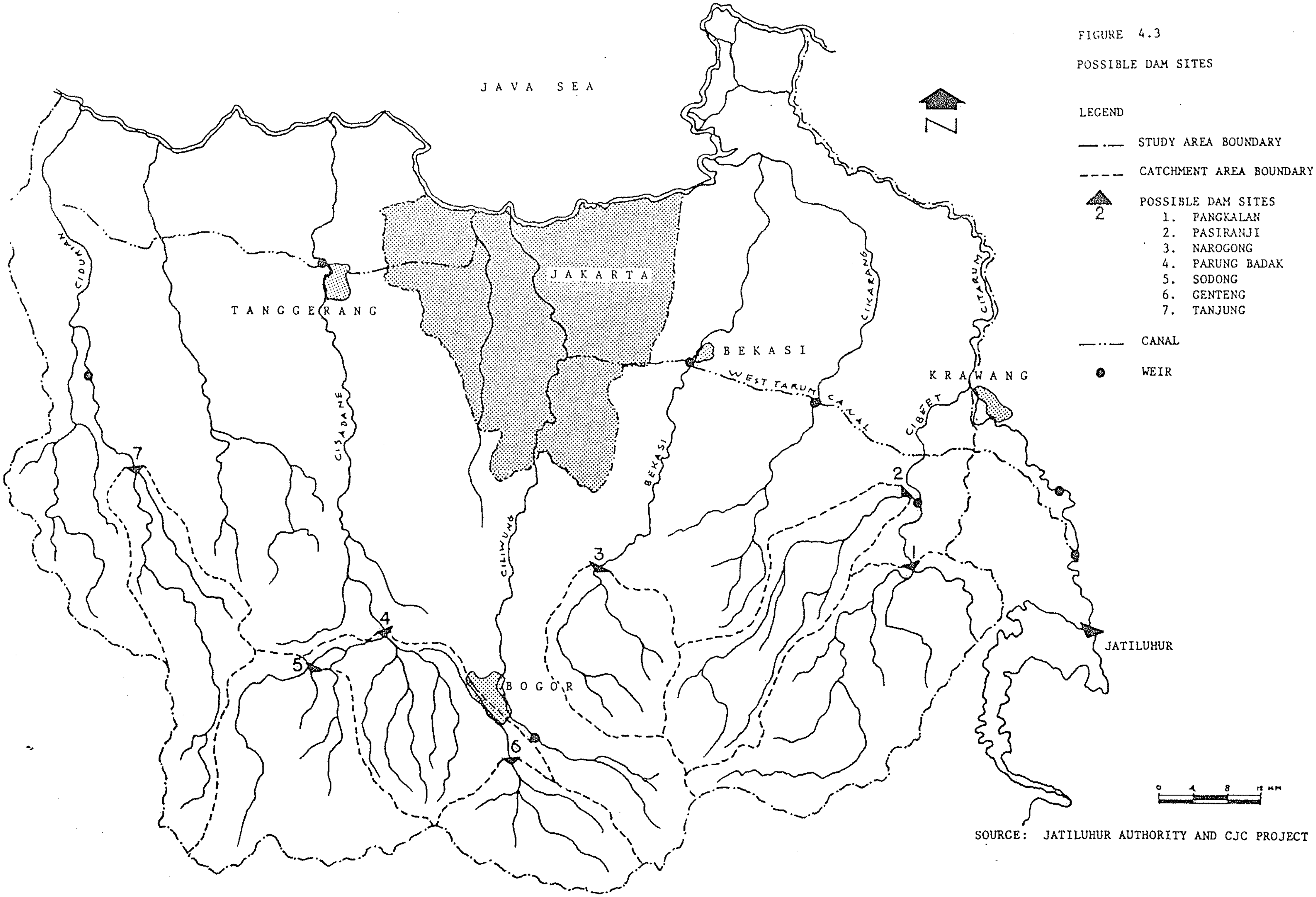
Dam Sites	River	Catchment (km2)	Live Storage (million m^3)
Pangkalan	Cibeet	479	900
Pasiranji	Cipamingkis	282	210
Narogong	Cileungsi	215	50
Parung Badak	Cisadane	859	950
Sodong	Cikaniki	383	500
Genteng	Cisadane	195	80
Tanjung	Cidurian	265	260
Total			2950

Source: Jatiluhur Authority and CJC Project

If all possible dam sites were used, the total live storage would be approximately 42% of the total available water. Water available in the dry season theoretically could be increased to 4,930 million m^3. However, the development of the dams depends upon the demand for water.

FIGURE 4.3

POSSIBLE DAM SITES



SOURCE: JATILUHUR AUTHORITY AND CJC PROJECT

4.5 Groundwater Available

According to "Geohydrological Investigation for Municipal Water Supply of Jakarta" by Prof. Dr. Soki Yamamoto (1972), the underground watertable of the Jakarta area is already heavily tapped. The study was based mainly on data recorded at the GSI (Geological Survey of Indonesia).

Based on Yamamoto's findings, present groundwater pumped (as mentioned in chapter 2, section 2.4) can be assumed as total ground water potential for future uses. This figure of 5.7 m^3/s, will be used for the purposes of this practicum.

4.6 Conclusion

Climatological and topographical conditions affect rainfall and runoff. In the coastal plain, mean annual rainfall is 1500 mm and gradually increases to 5000 mm in the mountain region, while mean annual runoff ranges from 15 $l/s/km^2$ to 130 $l/s/km^2$.

Rainfall provides surface water and ground water to this study area, and this is summarized in Table 4.8.

Table 4.8 Total Water Resources Potential

	Wet Season		Dry Season		Yearly	
	(m^3/s)	($10^6 m^3$)	(m^3/s)	($10^6 m^3$)	(m^3/s)	($10^6 m^3$)
Surface Water						
- Study Area	278.7	5,130	150.3	1,980	225.4	7,110
- Jatiluhur	68.0	1,251	68.0	893	68.0	2,144
Groundwater	5.7	105	5.7	75	5.7	180
Total	352.4	6,486	224.0	2,948	299.1	9,434

Table 4.8 shows that the total water resource potential on a yearly basis is 9.434 million m^3 comprised of 2,948 million m^3 or 224 m^3/s in the dry season, and 6,486 million m^3 or 352.4 m^3/s in the wet season. The difference in water potential between dry and wet seasons is significant and has important implications for water management. The difference is even higher on a monthly basis as shown in Table 4.9.

Table 4.9

Mean Monthly Total Water Resource Potentials in m^3/s

Source of Water	WET SEASON							DRY SEASON				
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Catchments	222.3	237.3	311.7	317.6	300.9	303.5	258.8	174.2	140.4	125.6	133.3	179.8
Jatiluhur	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0
Groundwater	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Total	296.0	311.0	385.4	391.3	374.6	377.2	332.5	247.9	214.1	199.3	207.0	253.5

The ratio between the driest month discharge (August, 199.3 m^3/s) and the wettest month discharge (February, 391.3 m^3/s) is 1 to 2. If water requirements are more or less constant during the year and if the requirement is more than 199.3 m^3/s, a portion of the water available in the wet season must be stored for use in the dry season. Whether this storage is needed or not will be discussed in the following chapter.

CHAPTER V

DISCUSSION

5.1 Introduction

This chapter will evaluate future water requirements, water supplies and water resource potentials. The discussion compares future water requirements with present water supplies to determine whether there is a surplus or deficiency in future water supplies. If there is a deficiency, the additional water supplies required will be estimated.

Evaluation of additional water supplies required and water resource potentials on a yearly basis to determine whether the additional requirement can be met will also be conducted. If water requirements on a yearly basis can be served by the water resource potential , evaluation on a monthly basis will be conducted to determine whether the additional water supplies can be provided by a weir and canal system or combined with reservoir(s). If a reservoir is needed, estimation of storage capacity by using "sequent peak analysis" will be made.

If the water requirement on a yearly basis can not be met by the area's water resource potential, measures to cut demand by reducing usage unit consumption, changing water allocation priorities, or both, will be considered. Previous procedures of analysis would then be repeated to secure an adequate water supply year round.

5.2 Future Water Requirements vs. Present Water Supply

The total water requirement has been estimated at approximately 7,068 million m^3 for 1985 and about 9,084 million m^3 for the year 2000. Present water supplies (chapter 2) are approximately 6,370 million m^3 annually. Thus, present water supply cannot serve future water requirements.

Therefore, additional water supplies are needed. The additional water supplies required amount to 698 million m^3 and 2,714 million m^3 annually for the years 1985 and 2000 respectively.

5.3 Future Water Requirement vs. Water Resource Potentials on a Yearly Basis

Total water resource potential includes present water supply. In chapter 4, section 4.6, the total water resource potential was estimated at 9,434 million m^3 annually, while the total water requirements are 7,068 million m^3 in 1985 and 9,084 million m^3 in 2000. If these water resources potentials can be delivered to consumers, all water requirements in 1985 and in the year 2000 can be served.

Therefore, measures to cut demand by reducing usage unit consumption or changing water allocation priorities are not necessary. The next step in the analysis, then, is to evaluate water resource potentials and water requirements on a monthly basis.

5.4 Future Water Requirement vs. Water Resource Potential on a Monthly Basis

This section will evaluate future water requirements and water resource potentials on a monthly basis to determine whether the water requirement can be met by a weir and canal system or a combination of the system with reservoirs. This evaluation is necessary because of the significant difference in water resource potentials between the wet season and the dry season, while water requirements are more or less constant, or even slightly higher in the dry season.

A calculation based on the assumption that all water resource potentials can be delivered by means of weirs and canal systems constitutes the first step in the analysis. In other words, water resource potentials would be equal to water supplies. Using this assumption, it is possible to deduce whether water requirements can be met by water potentials. The results are shown in Table 5.1 for the year 1985 and in Table 5.2 for the year 2000.

Table 5.1

Monthly Water Potential Surplus or Deficit, 1985 in m^3/s

	WET SEASON							DRY SEASON				
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Potential	296.0	311.0	385.4	391.3	374.6	377.2	332.5	247.9	214.1	199.3	207.0	253.5
Required	257.3	222.8	144.8	126.5	161.2	215.6	266.2	286.9	248.7	231.8	250.1	270.8
P - R	38.7	88.2	240.6	264.8	213.4	161.6	66.3	-39.0	-34.6	-32.5	-43.1	-17.3

Source : Tables 3.13, 3.23 and 4.9

Table 5.1 shows that monthly water requirements for five months in the year 1985 exceeds the water resource potential, even though total water resource potentials on a yearly basis exceed the requirement. For the year 2000, the deficit of water will become even larger due to increasing water demand, and this is shown in Table 5.2.

Table 5.2

Monthly Water Potential Surplus or Deficit, 2000 in m^3/s

	WET SEASON							DRY SEASON				
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Potential	296.0	311.0	385.4	391.3	374.6	377.2	332.5	247.9	214.1	199.3	207.0	253.5
Required	311.7	278.8	204.6	188.2	219.7	272.4	319.7	328.7	322.2	305.4	323.4	342.6
P - R	-15.7	32.2	180.8	203.1	154.9	104.8	12.8	-80.8	-108.1	-106.1	-116.4	-89.1

Source : Tables 3.13, 3.23 and 4.9

The data in Tables 5.1 and 5.2 indicate that water development by means of a weir and canal system will not solve the problem of meeting future water requirements. A water storage system is required to provide an adequate water supply.

5.5 Water Storage Capacity

Within the framework of accomodating water requirements, a certain water storage capacity must be determined. For this purpose, the "sequent peak analysis" will be utilized. This method adds up in series the monthly water surplus or deficit. Peak and low points are plotted on a graph and the difference between them is calculated. This difference represents the capacity of water storage required.

Using tables 5.1 and 5.2 and sequent peak analysis, water

Figure: 5.1

ESTIMATED STORAGE CAPACITY

REQUIRED IN 1985.

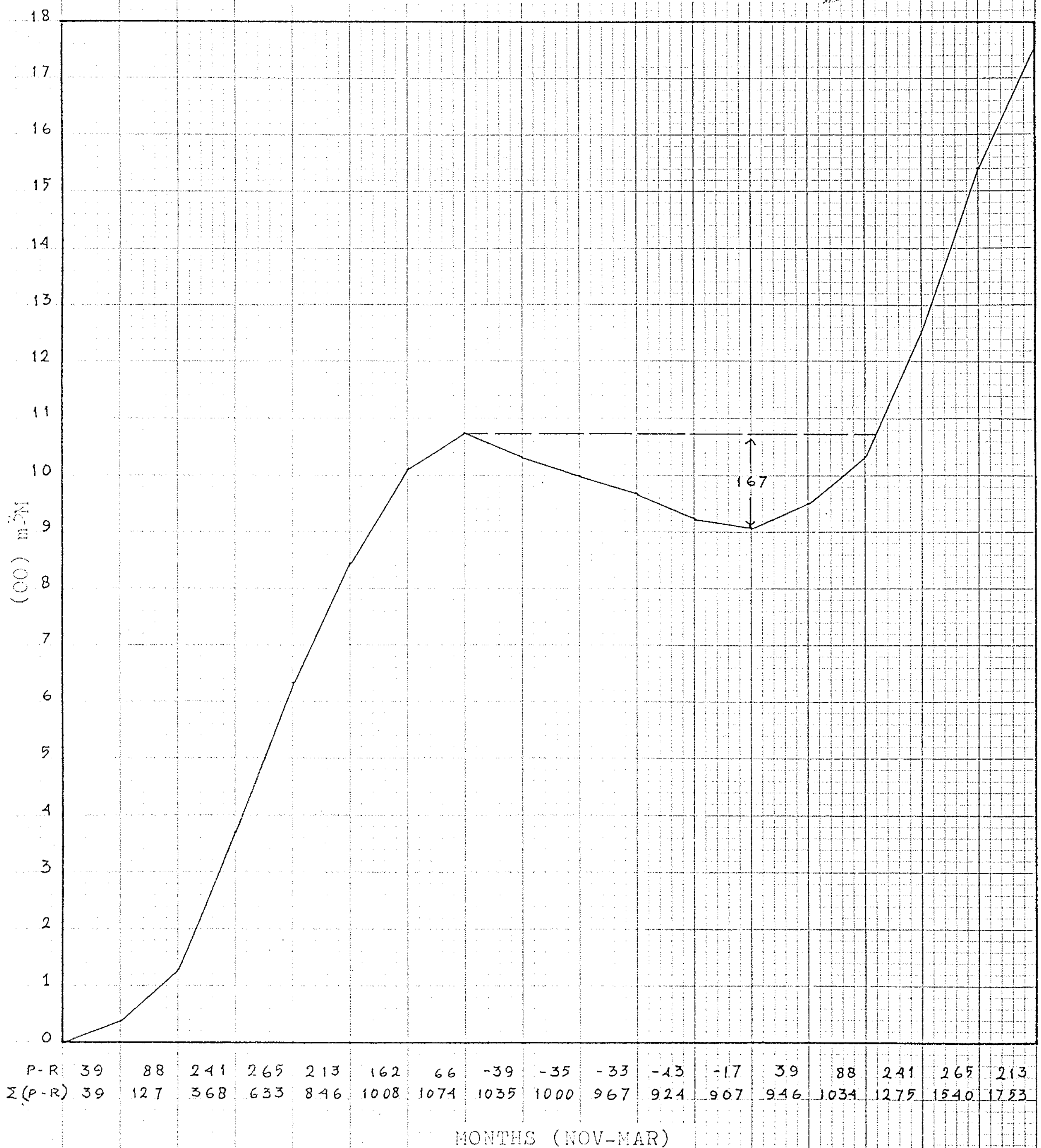
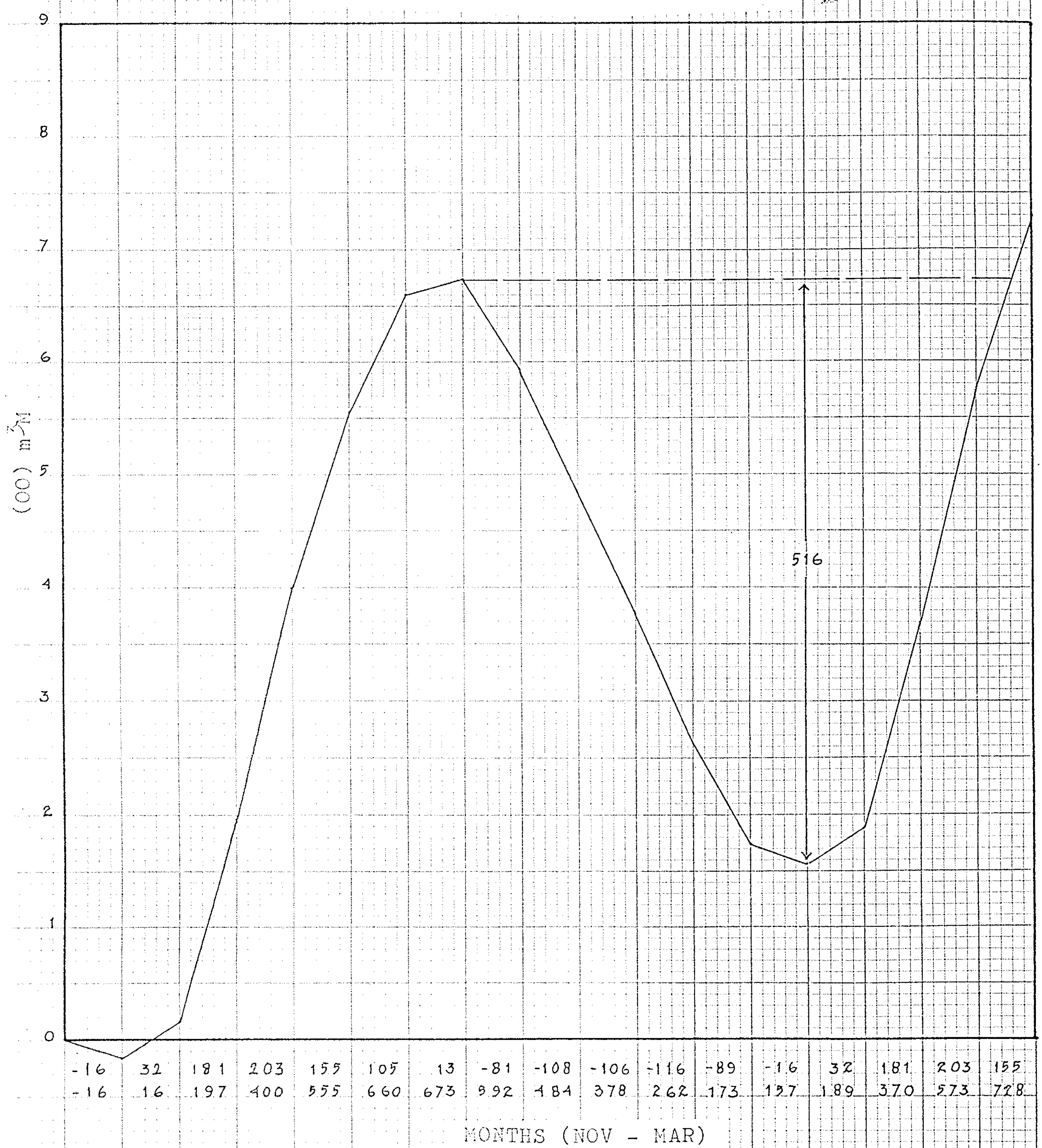


Figure 5.2:

ESTIMATED STORAGE CAPACITY

REQUIRED IN 2000.



storage for 1985 and 2000 respectively can be calculated as shown in Figure 5.1 and Figure 5.2.

From Figure 5.1 total water storage required for 1985 is (167 x 30.5 x 24 x 3000) = 440 million m^3 and for the year 2000 (516 x 30.5 x 24 x 3600) = 1,360 million m^3 is required. These results,in conjunction with Table 4.7, Possible Dam Sites, indicate how the storage capacity demanded could be developed.

5.6 Conclusion

Future water requirements in 1985 and in the year 2000 can not be served by existing water supplies. The deficits are about 698 million m^3 and 2,714 million m^3 annually for the years 1985 and 2000 respectively.

Evaluation on a yearly basis of water resource potentials with the assumption that these can be delivered to consumers, indicates that water potentials exceed the requirements. But an investigation on a monthly basis resulting surplus and deficit of water resource potential is also required. This investigation indicates that water storage is required to utilize water resource potentials to maintain an adequate water supply year round.

Sequent peak analysis indicates that water storage capacity demanded for the year 1985 is about 440 million m^3 and 1,360 million m^3 for the year 2000.

According to the assessment of possible dam sites, these water storage requirements can be developed.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

This chapter will summarize the findings of the study and will recommend areas for further study to ensure an appropriate water supply for future water requirements.

6.1 Conclusions

1. Water is an essential element for the existence of life and should be developed and managed in the best interest of society. For this reason, water resources development and utilization in Indonesia is placed under government control. The Indonesian government finances water resources development, establishes policy and regulation, and operates water utilization facilities.

2. Water requirements rapidly increase as mankind progresses economically and socially. Unfortunately, the availability of useable water will remain more or less unchanged and may possibly be diminished if man-induced water contamination increases. Changing water requirements will occur in response to environmental and societal development. However, shortages and water use conflicts exist if water requirements exceed the water supply, in terms of quality, quantity, time and location.

3. A problem of water availability for the JABOTABEK and neighbouring agricultural areas between the years 1985-2000 is evident. This practicum investigates present water supplies, future water requirements and water resource potentials to meet future water requirements in the area.

4. At present, there is an available water supply of approximately 202.21 m^3/s or is about 6,370 million m^3 annually. This consists of 212.72 m^3/s or 3,900 million m^3 in the wet season and 187.52m^3/s or 2,470 million m^3 in the dry season.

5. Estimated future urban water requirements for JABOTABEK, based on an annual calculation, are 1,917 milllion m^3 and 4,139 million m^3 for the years 1985 and 2000 respectively. During the 15-year period between 1985 and 2000, water requirements will increase 116% or an average of 7.7% per year.

6. Estimated future agricultural requirements on a yearly basis amount to 5,151 million m^3 and 4,950 million m^3 for the years 1985 and 2000 respectively. These figures indicate that agricultural water requirements decrease by about 4% during that period, due to reduction of irrigation areas as a result of urban and industrial development, and village growth.

7. The overall future water requirement amounts to 7,068 million m^3 and 9,084 million m^3 for the years 1985 and 2000 respectively. This means that water requirements will increase 29%, or at an average rate of about 1.9% annually between 1985 and 2000.

8. Water resource potentials are provided by rainfall as a source of surface water and groundwater. Investigation on a yearly basis gives a total water resources potential of approximately 9,434 million m^3 comprising 2,948 million m^3 or 224 m^3/s in the dry season, and 6,486 million m^3 or 352.4 m^3/s in the wet season. The difference in water potential between the dry and the wet seasons is significant. This difference is even higher on monthly basis, being 199.3 m^3/s in August and 391.3 m^3/s in February. This is a ratio of about 1 to 2.

9. Future water requirements for 1985 and 2000 cannot be served by the existing water supplies. Deficits are about 468 million m^3 in 1985 and 2,484 million m^3 in 2000.

   Evaluation of water resources potential on a yearly basis with an assumption that these can be delivered to consumers indicates that the future requirements can be met by water resource potentials.

10. An investigation on a monthly basis shows surpluses and deficits in water resource potentials. The analysis indicates that water storage may serve to maintain an adequate water supply year round. Sequent peak analysis indicates that water storage capacity required for 1985 is about 440 million m^3 and 1,360 million m^3 for the year 2000.

11. Based on an assessment of possible dam sites, these water storage requirements can be developed. Thus, in order to fulfill water requirements for urban and agricultural areas in the years 1985 and 2000, new reservoir(s) and network systems must be developed.

6.2 Recommendations

1. Further in-depth studies of the engineering, economic and environmental aspects of water resource development would be required to examine the following:

   a). Location of reservoir(s), which would also satisfy additional objectives such as hydro power, flood control, recreation and fisheries.

   b). Design of network systems, both for urban and agricultural purposes.

   c). Treatment plant systems for urban water uses, including network distribution systems for individual users.

2. The question of flushing water for dilution purposes should be reconsidered since water becomes more economically valuable as time passes. This could be one area for water conservation.

3. Water conveyance systems using concrete pipe may be considered since this would reduce water losses during conveying. Concrete systems rather than iron pipes could be considered for urban water network distribution systems. This is another area where water conservation could be achieved.

BIBLIOGRAPHY

1. Booy, C., Hydrology, Department of Civil Engineering, University of Manitoba.

2. Census and Statistical Office of Jakarta: Statistical Year Book of Jakarta 1977, Jakarta, December 1977.

3. Central Bureau of Statistics (CBS): Statistical Year Book Of Indonesia 1976, Jakarta, 1978.

4. Coyne et Bellier (COB): Preliminary Investigation of Possible Dam Sites Within the Area Under the Jatiluhur Authority's Jurisdiction, Jakarta, January 1972.

5. Coyne et Bellier (COB) - Sogreah: Cisadane-Jakarta-Cibeet Water Resources Development Study, Progress Report No.1, Directorate General of Water Resources Development, Ministry of Public Works, Jakarta, Augustus 1977.

6. COB-Sogreah: Cisadane-Jakarta-Cibeet Water Resources Development Study, Progress Report No.2, Directorate General of Water Resources Development, Ministry of Public Works, Jakarta, March 1978.

7. Directorate General of Water Resources Development: The Development of Water Resources in Indonesia, Jakarta, March 1977.

8. Directorate General of Housing, Building, Planning and Urban Development: JABOTABEK (Jakarta-Bogor-Tanggerang-Bekasi), Jakarta, 1973.

9. Directorate General of Housing, Building, Planning and Urban Development: JABOTABEK, Development Strategy for PELITA II, Jakarta, January 1975.

10. Economic Commission for Asia and the Far East (ECAFE): Manual of Standards and Criteria for Planning Water Resources Projects, Water Resources Series No. 26, United Nation, New York, 1964.

11. Garros: Hydrology of CJC Area, Directorate General of Water Resources, Ministry of Public Works, Jakarta, January 1978.

12. Government Policy Statement on the Operation of Haji Juanda (Jatiluhur) Reservoir, Jakarta, May 1973.

13. Government of Indonesia: Water Resources Law No. 11, Jakarta 1974.

14. Jatiluhur Authority: Hydrological Report, Jakarta, 1973.

15. Jatiluhur Authority: Cibeet Dam, Jakarta 1973.

16. Jatiluhur Authority: Progress Report 1970-1975, Jakarta 1977.

17. Laritaz, Eymond: Urban Development and Population Forecasts, CJC Water Resources Development Study, Directorate General of Water Resources Development, Ministry of Public Works, Jakarta, July 1977.

18. Leclaire, S.: Crop Water Requirement, CJC Area, Directorate General of Water Resources Development, Ministry of Public Works, Jakarta, July 1977.

19. Nihon Suido: Master Plan for Jakarta Water Supply System Part I, Extension Project of Jakarta Water Supply System, Directorate General of Housing, Building, Planning and Urban Development; Ministry of Public Works, Jakarta, Sept. 1972.

20. Nihon Suido: Master Plan for Jakarta Water Supply System Part II, Extension Project of Jakarta Water Supply System, Directorate General of Housing, Building, Planning and Urban Development; Ministry of Public Works, Jakarta, Sept. 1972.

21. Nihon Suido: Study on Population and Water Requirement, Extension Project of Jakarta Water Supply System, Directorate General of Housing, Building, Planning and Urban Development; Ministry of Public Works, Jakarta, March 1972.

22. Nedeco: Jakarta Drainage and Flood Control Project, Directorate General of Water Resources Development, Ministry of Public Works, Jakarta, February 1972.

23. Nedeco: Jakarta Drainage and Flood Control Project Phase II, Directorate General of Water Resources Development, Ministry of Public Works, Jakarta, April 1975.

24. Prosida (IDA-Irrigation Project): Rencana Pembagian Air Irigasi Cisadane (Cisadane Irrigation System, Water Distribution Program), Directorate General of Water Resources Development, Ministry of Public Works, Jakarta, August 1974.

25. Sumitro, Dr.: Indonesia Toward the Year 2000, Jakarta, February 1974.

26. Ulama, Muhamad and Sudibjo, Susanto: Pengembangan Sumber Daya Air Dan Pengembangan Wilayah Jatiluhur (Jatiluhur River Basin Water Resources Development), Jatiluhur Authority, Jakarta, 1976.

27. United Nations: Statistical Yearbook 1977, Department of International Economic and Social Affairs, Statistical Office, New York, 1978.

28. United Nations: Demographic Yearbook 1976, Department of Economic and Social Affairs, Statistical Office, New York, 1977.

29. Yamamoto, Soki, Prof. Dr.: Geohydrological Investigation for Municipal Water Supply of Jakarta, Directorate General of Water Resources Development, Ministry of Public Works, Jakarta, 1972.