JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF HYDRAULICS

THE REPUBLIC OF SENEGAL

THE STUDY ON URBAN DRAINAGE AND WASTEWATER SYSTEMS IN DAKAR CITY AND ITS SURROUNDINGS

MAIN REPORT

OCTOBER 1994

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

in association with

TOKYO ENGINEERING CONSULTANTS CO. LTD., TOKYO

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In this report, project costs are estimated based on March 1994 prices with an exchange rate of FF 1=FCFA 100 (FF 1=¥18.64).

Preface

In response to a request from the Government of the Republic of Senegal, the Government of Japan decided to conduct a master plan and feasibility study on Urban Drainage and Wastewater Systems in Dakar City and Its Surroundings and entrusted the study of Japan International Cooperation Agency (JICA).

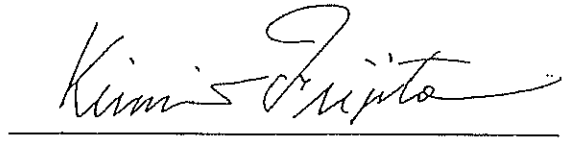
JICA sent to Senegal a study team headed by Mr. Akira Takechi, Pacific Consultants International (PCI) and composed of staff members of PCI and Tokyo Engineering Consultants Co., Ltd. four times between June 1993 and August 1994.

The team held discussions with the officials concerned of the Government of Senegal, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Senegal for their close cooperation extended to the team.

October 1994



Kimio Fujita
President
Japan International Cooperation Agency

THE STUDY ON URBAN DRAINAGE AND WASTEWATER SYSTEMS IN DAKAR AND ITS SURROUNDINGS

Mr. Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit you the final report entitled "THE STUDY ON URBAN DRAINAGE AND WASTEWATER SYSTEMS IN DAKAR AND ITS SURROUNDINGS". This report has been prepared by the Study Team in accordance with the contracts signed on 13 May 1993, 28 January 1994 and 2 May 1994 between Japan International Cooperation Agency and Pacific Consultants International.

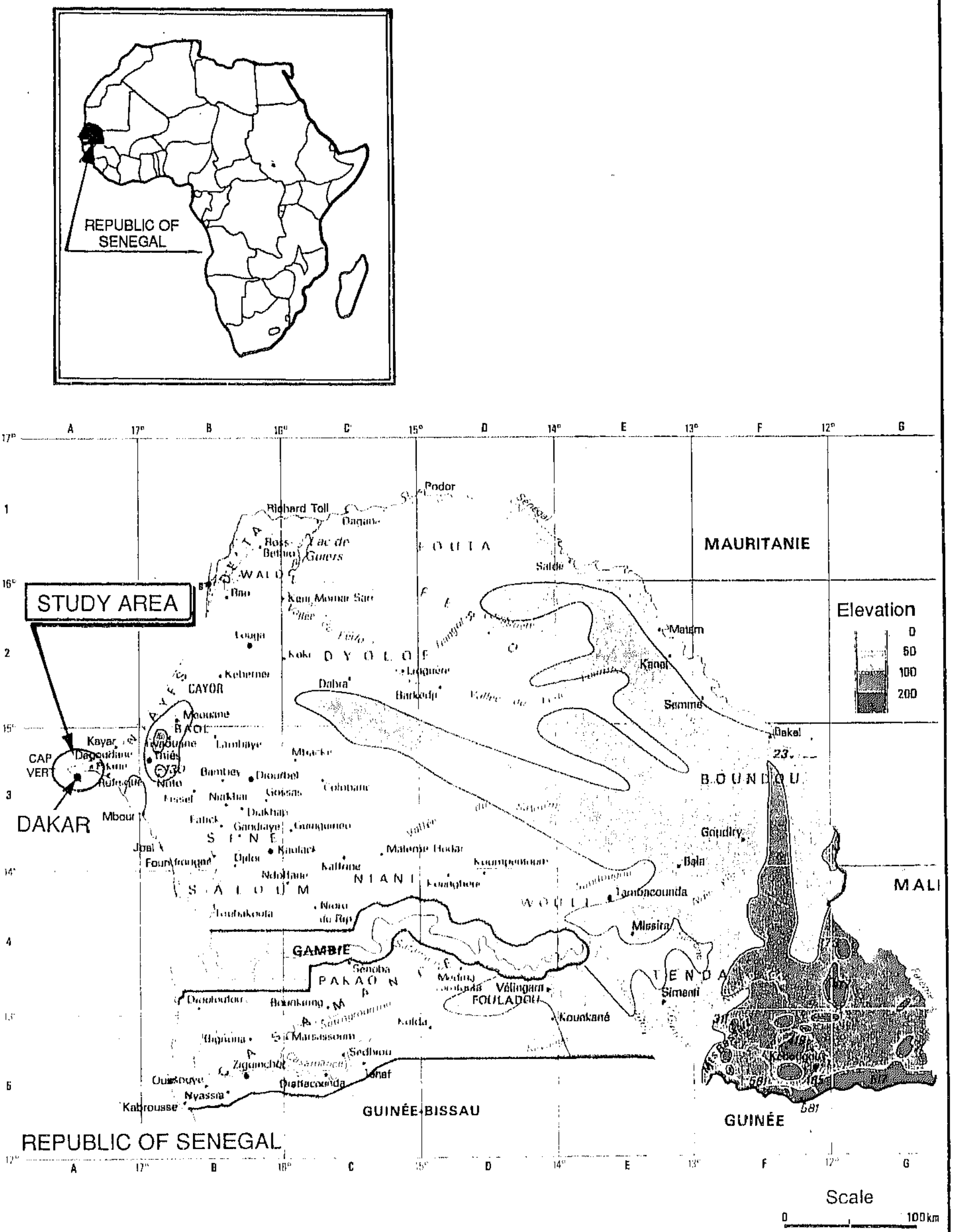
The report examines the existing conditions concerning urban drainage and wastewater systems in Dakar and its surrounding areas, and presents a master plan for development of urban drainage and wastewater systems and the results of a feasibility study on a priority project selected from the master plan.

The report consists of the Summary, Main Report, Supporting Report and Data Book. The Summary summarizes the results of all studies. The Main Report presents the results of the whole study including background conditions, formulation of the master plan, selection of the priority project and the feasibility study on the priority project. The Supporting Report describes in detail the same contents in the Main Report. The Data Book contains raw data uses in the Study.

All members of the Study Team wish to express grateful acknowledgment to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Senegal, and also to officials and individuals of the Government of Senegal for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study contribute to the improvement of the urban drainage and wastewater systems and the social and economic development in Dakar.

Yours faithfully,

Akira Takechi
Team Leader



LOCATION MAP

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PART I

GENERAL

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The city of Dakar, the Capital of Senegal, has the highest concentration of population in the nation and also the center of industry and commerce. The population of Dakar and the adjacent urban center Pikine was about 700,000 and 600,000 in 1988, respectively, and is expected to increase to about 1,400,000 each in 2010.

The progressing rapid urbanization in the suburban areas exacerbates the social and environmental problems. The sanitary conditions in the area is one of the most important problems to be addressed and the improvement of drainage and wastewater disposal systems is indispensable to maintain a favorable living environment.

To resolve the problems, the "Plan Strategique d'Assainissement de la Communaute urbaine de Dakar" (hereinafter referred to as "the Strategy Plan"), which included studies on present and future conditions in Dakar and its adjacent areas, and strategy to improve existing urban drainage and wastewater systems in the areas, was prepared by UNDP and the World Bank in 1991.

Under these circumstances, the Government of Senegal requested technical assistance from the Japanese Government in the formulation of a master plan for development of urban drainage and wastewater systems and a feasibility study of a high priority project from the master plan. In response to the request, a preparatory study team was sent to Senegal in December 1992 and both countries agreed to conduct the Study on Urban Drainage and Wastewater Systems in Dakar and its Surroundings. The Scope of Work for the Study was signed on December 17, 1992.

1.2 OBJECTIVES OF THE STUDY

The objectives of the Study are;

i) to draw up a master plan for development of the urban drainage and wastewater systems in the study area in 2010, including its phased implementation program, and

ii) to conduct a feasibility study on urban drainage and/or wastewater system(s) for a high priority project selected from the master plan.

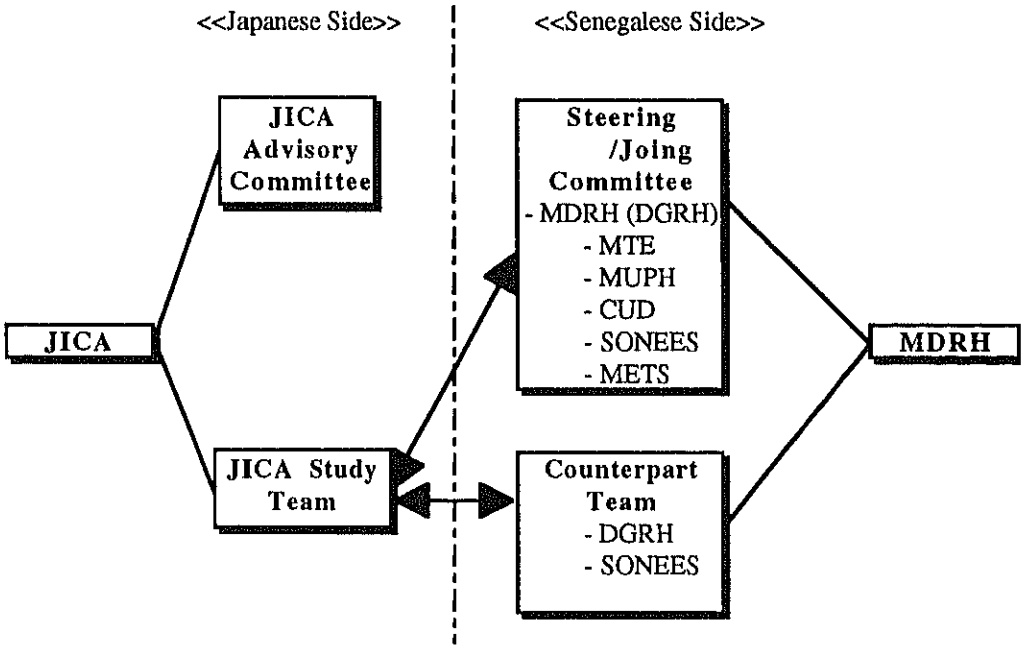
1.3 STUDY AREA

As shown in *Figure* 1.1, the study area covers the city of Dakar and its surrounding areas with an area of about 175 km^2, consisting of the Department of Dakar and the Department of Pikine.

1.4 STUDY ORGANIZATION

1.4.1 General Organization

A general organization for the study can be depicted as follows:



Note : JICA : Japan International Cooperation Agency
DGRH : Directorate of Rural Works and Hydraulics, MDRH
MDRH : Ministry of Rural Development and Hydraulics
MTE : Ministry of Tourism and Environment
MUPH : Ministry of Urban Planning and Habitat
CUD : Dakar Urban Community
METS : Ministry of Equipment, Transport and Sea
SONEES : Societe Nationale d'Exploitation des Eaux du Senegal

1.4.2 Japanese Organization

The official agency of the Japanese side to execute the study is Japan International Cooperation Agency (JICA). JICA has organized an advisory committee to ensure smooth and appropriate execution of the study.

The JICA Study Team consists of twelve members and the Advisory Committee consists of two members as shown below.

JICA STUDY TEAM

Name	Field in Charge
Akira Takechi	Team Leader / Sewerage Planning
Hiroyuki Shiraiwa	Urban Drainage Planning
Masafumi Miyamoto	Facilities Planning and Designing (Sewerage)
Ryo Matsumaru	Facilities Planning and Designing (Urban Drainage)
Jyudo Hagiwara	Facilities Planning and Designing (Treatment Plant)
Masahiro Kawachi	Water Quality / Industrial Wastewater Treatment
Arun Kumar Viswanath	Environment
Ryuji Yanai	Organization / Implementation Planning
Placide Meirsman	Urban Planning
Noboru Narushima	Construction Planning / Cost Estimation
Naomichi Ishibashi	Economic and Financial Analysis
Osamu Nogoshi	Survey and Soil Investigation

JICA ADVISORY COMMITTEE

Name	Field in Charge	Present Post
Yoshio Tano	Chairman / Sewerage Planning	Counselor, Japan Regional Development Corporation
Osamu Fujiki	Urban Drainage Planning	Chief, Research & Technology Development Dept., Japan Sewage Works Agency

1.4.3 Senegalese Organization

The executing organization of the Study of the Senegalese side is the Ministry of Rural Development and Hydraulics (MDRH). The MDRH coordinates with representatives of government offices concerned, as well as act as a primary counterpart to the Study Team.

A Steering / Joint Committee, which consists of representatives of organizations concerned to the Study to discuss with the Japanese side on progress and results of the Study and which is chaired by the MDRH, has been organized.

Members of the Counterpart Team, shown below, were sent from the Directorate of Rural Works and Hydraulics (DGRH), SONEES of MDRH and other concerned organizations.

Name	Field in Charge	Organization
Birama NDIAYE	General	DGRH/DHUA
M. Alioune BA	Sewerage	DGRH/DHUA
Cheikh FALL	Sewerage	SONEES
Ousmane CAMARA	Urban Drainage	SONEES
Ibrahima SOW	Urban Drainage	DGRH/DHUA
Fatoumata NIANG	Water Quality Analysis	SONEES
Papa Ibrahima DIONE	Water Quality Analysis	SONEES
Chikh SYLLA	Water Quality Analysis Environment	MTE
Alioune BAKHOUM	Organization	DGRH/DHUA
Baba COULIBALY	Organization	SONEES
Mame Pierre CAMARA	Economic/Finance	DCET/MEFP
Souleymane DIOP	Survey	DGRH/DHUA

1.5 REPORTS

The study reports prepared are as follows:

i) Main Report : English version and French version

ii) Supporting Report : English version and French version

iii) Summary Report : English version and French version

iv) Data Book: English version and French version

Since the urban drainage system and the wastewater system have been developed independently each other in parts of the study area and a master plan is to be based on the existing system, the proposed master plans for each system are prepared separately. This report consists of four parts; the master plan studies, which include from analysis of the existing conditions to the implementation program, for the urban drainage and the wastewater systems are presented in the Part II and the Parts III, respectively, while Part I and Part IV deal with the background information on the study area and the selection of the priority projects for the subsequent feasibility study that are common to both systems.

The main report presents the summarized results of the whole study. It consists of three Parts: Part (I) gives the Introduction that deals with background information of the study, Part (II) deals with master plan study and feasibility study of Wastewater System, and Part (III) deals with master plan study and feasibility study of Urban Drainage System.

The supporting report describes in detail the same contents presented in the main report. The summary report presents an executive summary of the results of the whole study and the data book contains basic data/information used in the study as well as some drawings.

TABLES AND FIGURES

FIGURE 1.1 STUDY AREA

CHAPTER 2

BACKGROUND OF STUDY AREA

CHAPTER 2 BACKGROUND OF THE STUDY AREA

2.1 NATURAL CONDITIONS

2.1.1 Topography and Geology

The topography of the study area is generally low with the highest elevation of 105 m at Les Mamelles. The western edge, the Dakar-Yoff Airport area, and southern parts, the Dakar urban area of the study area have relatively high elevation between 10 to 20 m, forming cliffs along the shoreline. Most of the eastern parts of the study area, Pikine, is low in elevation and is at a level of 0 m MSL in several places.

One of the remarkable topographic characteristics of the study area are closed basins that do not have outlets to other basins or to the sea. In the lower areas, these basins are known as "Niaye" that means low lands between sand dunes running parallel to each other. Among them, the Grand Niaye is a large low land, spreading out between Pikine and Dakar.

2.1.2 Climate

The climate of the study area is arid, having two distinct seasons; the rainy season and the dry season. Annual rainfall at Dakar-Yoff Airport ranges from 113 mm to 900 mm with an average value of 458 mm. Average monthly rainfall from 1947 to 1989 is shown in *Figure* 2.1. About 90% of the rainfall occurs in three months from July to September.

Monthly mean temperatures are shown in *Table* 2.1. Annual average temperature between 1955 and 1989 is about 24°C. The maximum temperature (31.8°C) and the minimum temperature (15.3°C) have been recorded in October and January, respectively.

Monthly mean relative humidities are shown in *Table* 2.2. The maximum and the minimum humidities have been recorded in September and December, respectively. The relative humidity is rather high for an arid climate, as the area is surrounded by the ocean.

Monthly solar radiation and monthly mean daily evaporation rate are shown in *Tables* 2.3 and 2.4

2.1.3 Water Pollution

1) Surface Water

Most of the natural streams in the study area do not have any base flow during the dry season, however, they convey storm water in the rainy season. Fresh water bodies of which water quality should be discussed, hardly exist in the area.

The water quality of the ocean seems to be rather important in this area, since the area is surrounded by the ocean and both treated and untreated wastewaters are directly discharged to the ocean. There is little water quality data available for the ocean in previous studies. The limited information is found in the Strategy Plan and "Projet D'etude, de réhabilitation , de protection et d'aménagement des Baies Dakar", which present the distribution of BOD and Dissolved Oxygen in Hann Bay and the distribution of biological indexes in Dakar Bay. Some extracts from the Strategy Plan are shown in *Figure* 2.2. These distribution patterns indicate diffusion of contaminants to the Bay from the outlets of factories and deterioration of the water quality in the harbor area by stagnation.

2) Groundwater

Table below shows major chemical characteristics of groundwater obtained from the SONEES water supply wells located in Mamelles and Thiaroye. The parameters that are mainly related to taste and operationability in water treatment such as chloride, bicarbonate, calcium, magnesium and sodium are considered to be within normal range of drinking water. However, existence of ammonium and nitrite indicates the possibility of fecal contamination in most of the wells in Thiaroye. Furthermore, high concentrations of nitrate are also observed in every well, particularly in the wells of Thiaroye.

Although there is no evidence of direct fecal contamination since no bacteriological data is available, it is natural to suspect direct fecal contamination from the observed concentrations of ammonium and nitrate. This would be more probable in the private wells where on-site sanitation facilities are located nearby. The level of nitrates, which is apparently exceeding the limit prescribed in the WHO's drinking water guidelines, may cause methemoglobinemia. These facts suggest that the groundwater in the area may be affected by seepage from on-site sanitation facilities, which are common in the area.

Major Chemical Characteristics of Groundwater from Some Water Supply Wells

(unit: mg/l)

Parameters	Thiaroye*						Mamelles*			
	F15	F17	F18	F19	F21	F22	Camp pénal	Terme Nord	Point M	Terme Sud
Chloride	25	25	29.6	30	30	25	14	20	10.2	16.6
Bicarbonate	48.8	48.8	109.8	48.8	48.8	48.8	195.2	195.2	122	195.2
Nitrate	143.9	175.2	285.6	174.9	266	268.3	11.7	13.3	15.8	21.25
Nitrite	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0	0
Ammonium	0.3	0.3	1.2	0.5	0	0.3	0.1	0	0.15	0.15
Calcium	56	48	68	56	48	64	32	40	16	48
Magnesium	29.1	38.8	26.7	38.8	43.7	38.8	24.3	24.3	14.6	34.02
Sodium	130	126		148	139	127				

Data Source: SONEES

2.2 SOCIO-ECONOMIC CONDITIONS

2.2.1 Administration

The Central government is composed of 28 Ministries and, among them, the Ministries relating to this study are;

Ministere de l'Hyraulique
Ministere de l'Economie, des Finances et du Plan
Ministere de l'Interior
Ministere de l'Environnement et de la Protection de la Nature
Ministere de l'Urbanisme et de l'Habitat
Ministere de l'Energie, des Mines et de l'Industrie
Ministere de la Sante Publique et de l'Action Sociale
Ministere de l'Equipement et des Transports Terrestres
Ministere de la Ville.

The administrative structure was reorganized in June, 1993, and Ministere du Developpement Rural et de l'Hydraulique(MDRH) was divided into two Ministries, namely, the Ministere de l'Agriculture and the Ministere de l'Hydraulique(MH). Since 1990 MDRH used to be a competent authority of wastewater system, however, in the reorganized structure, Ministere de l'Hydraulique took over the role.

Before the reorganization, Direction du Genie Rural et de l'Hydraulique(DGRH) of the MDRH had five (5) divisions described as below;

Division de l'Hydraulique Urbaine et de l'Assainissement (DHUA)

Division de l'Hydraulique Rurale (DHR)
Division de l'Entretien et de la Maintenance(DEM)
Division des Ressources en Eau(DRE)
Division du Genie Rural(DGR)

Even after the re-organization, DHUA is still in charge of sewerage projects.

The republic is divided into ten local governments named "Region". Each Region is composed of three Departments and organizations under the Department of the Municipality (Municipalite).

The head of "Region", "Departement" and "Municipalite" is known as "Gouverneur", "Prefet" and "Maire", respectively. Gouverneurs and Prefets are chosen by the authorities, while Maires are elected by the people.

Communaute Urbaine de Dakar (CUD) is the same organization as Region de Dakar.

2.2.2 NATIONAL ECONOMY

The gross domestic product (GDP) of the Republic of Senegal was 1,691.8 billion FCFA at market prices in 1992, according to the Ministry of Economy, Finance and Planning. The per capita GDP is estimated at 219,605 FCFA based on the estimated population in 1992. Assuming an exchange rate of 275 FCFA to the US dollar, the per capita GDP corresponds to US$ 799*. This economic level is the highest in the sub-Sahara African countries.

The primary, secondary and tertiary (including non-mercantile services) sectors account for 19.8%, 18.8% and 61.4%, respectively. The primary sector accounts comparatively small share and the secondary sector is given an important position, having a share approaching that of the primary sector. The primary sector is shrinking and the secondary sector is expanding in the past decade. The tertiary sector is maintaining the afore-mentioned level.

The economy of Senegal grew at an average annual rate of 2.2% for the ten years from 1982 to 1992. During the same period the national population is estimated to have increased from 6,038,000 to 7,703,826 at an average annual rate of 2.5%.

Over the above-mentioned ten years, the GDP defoliator grew at an average annual rate of 4.9%. So far as the latest five years from 1987 to 1992 are concerned, the average

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* This is before the devaluation taken place in January, 1994. After the devaluation, the per capita GDP is considered to be equivalent to US$400.

annual growth rate of the defoliator dwindled to 1.8%. However, the recent devaluation of FCFA in January, 1994 could raise the growth rate due to price increases of imported materials.

2.2.3 Population

The population of the study area is shown in *Table* 2.5, which are the estimates made by the Direction de la Prvision et de la Statistique and the Strategy Plan.

According to the "Population du Senegal" by Direction de la Prevision et de la Statistique, the population of the area in 1993 is about 1,580,000 and 2,908,000 in 2010. However, the Strategy Plan estimated the 2010 year population to be 3,009,000.

Since both estimates are similar and the estimates of the Strategy Plan are based on population projections on a unit basis obtained by dividing the study area according to landuse and housing types, the population estimated by the Strategy Plan is adopted as the population for the Master Plan along with minor adjustments that would reflect new development plans proposed after the Strategy Plan was prepared.

2.2.4 Landuse

The landuse in the study area prepared in 1989 is shown in *Figure* 2.3. However, it has been revealed by the aerial photographs taken in 1992 that urbanization is rapidly progressing in the north end of Dakar urban area and Pikine; the north edge of the Dakar urban area is expanding towards Ouakam and Grand Yoff and Pikine area has been fully developed except for some small low lying areas.

The future landuse pattern adopted in the study is shown in *Figure* 2.4.

2.2.5 Relevant Plans and Projects

There are two main plans that are closely related to this study; Water Supply and Sanitation Master Plan, 1973 and Strategy Plan of Sanitation, 1991. (Contents of each plan is reviewed in later sections.) However, there is no higher, broader level plan such as a regional development plan, comprehensive town planning plan etc. in the study area.

There are several plans or projects that concern improvement of sewerage or drainage systems for some parts of the study area. These are mentioned below:

- Drainage improvement project in Ouakam Area

- Drainage improvement project in Grand Yoff area
- Installation project of City Faycal (PROJECT DE RACCORDEMENT DE LA CITE FAYCAL)
- Project for sewage and stormwater sanitation at low point in HLM Las Parmas of Guediawaye (ASSAINISSEMENT DU POINT BAS DES HLM LAS PALMAS DE GUEDIAWAYE EAUX USEES ET PLUVIALS, DOCUMENTS D'APPEL D'OFFERES)
- Project for modification of the sewerage system in Parcelles Assainies ((MEMORUNDAM SUR LE FONCTIONNEMENT DU SYSTEME D'ASSAINISSEMENT DES PARCELLES ASSAINIES)
- Triangle Sud
- Sanitation Project of Camberene Village
- Boat Urban 2

Among the above, the first two projects are for construction of drainage facilities, which are considered to be parts of the Urgent Projects proposed in the Strategy Plan. Financing of main parts of each project has been committed by the French Agency.

The latter six projects have been proposed by the Ministry of Hydraulics and SONEES to improve the existing conditions of their sewerage system. While the project of City Faycal is expected to start shortly, there is no concrete implementation plan for the other projects.

Several housing development projects in the study area, which may affect the future population, have been identified as follows:

- Redevelopment of the military camp in the south of the Pikine railway station.
- Development of area located between Reboisement de Mbaw and Rufisque.
- Development in Malika.
- Other small developments.

In addition to the above, a conceptual plan for redevelopment of the Pikine Irregular area has been obtained. The plan includes a proposed road network and rearrangement of residential areas. While the plan has not been approved by any authority, a project that is considered to follow the concept, which includes regulating the land ownership and physical rearrangement, has been initiated in an area in the Pikine Irregular area under technical assistance of GTZ, Germany.

2.3 WATER USES AND WATER SUPPLY

2.3.1 Water Supply

1) Present water supply

The water supply system of SONEES covers the entire study area and thus the coverage is considered to be 100 % of the area.

There are two types of water distribution system; house connections and standpipes. Presently, about 60 % of the population in the study area are covered by house connections and the remaining 40 % are covered by standpipes. 3 to 4 % of the population are estimated to obtain their potable water from private wells because of the difficulty in access to the standpipes or other reasons.

The service coverage in term of population is considered to be about 95 %, though there is a large difference in per capita consumption rate between house connection users and standpipe users.

The water supply system in the study area is shown in *Figure* 2.5. The water sources of the system consist of "Local water source" and "Remote water source".

The major portion of water is distributed through four water reservoirs as shown in *Figure* 2.6. The study area is covered by four water distribution networks, each of which corresponds to the above-mentioned four reservoirs, and other networks receive water directly from the A.L.G. system, as shown in *Figure* 2.5.

Water output of each water source is summarized below:

System	Water Sources		Output (m^3/day)
Local	Mamelles		12,000
	Point B		7,000
	Thiaroye		7,700
	Sub-total		26,700
Remote	A.L.G.*	Lake Guiers**	38,300
		Wells	91,000
	Bonna	Pout Sud	15,800
		Sébikotane	25,000
	Sub-total		170,100
Grand Total			196,800

* About 20,000 m^3/day are used by towns and villages along the conveyance line.
** Surface water, others are groundwater.
NB: In addition, there is another system (Beer Thialane, 7,650 m^3/day) that supplies water to farm lands located out of the Study area. A total of water production including this system is 204,450 m^3/day.

(2) Future Development Plan

The future development plan for the water supply system in the study area was proposed in the Study on Reinforcement of Water Supply in Dakar Area (REINFORCEMENT DE L'APPROVISIONNEMENT EN EAU DE LA REGION DAKAR, 1988). The construction of the Cayor Canal is recognized to be only way to balance the future demands of the area. Therefore, the plan proposed the utilization of the water from the Cayor Canal by phased construction of water treatment plants as a medium-long term plan. In addition, the plan also proposed the following short term plans to supplement the shortage before water through the Cayor Canal is available:

- Urgent phase: Increase of 41,000 m^3/day by construction of 10 wells. The project has started since 1991.
- Intermediate phase: Construction of new wells in the northern coastal areas, doubling the force mains between Dakar and Geoul, and extension of the N'gnith water treatment plant.

The demand projection and proposed production capacity are shown in *Figure* 2.7.

2.3.2 WATER REUSE

Since the study area is situated in an arid zone, treated wastewater or even untreated wastewater is recognized as an important potential water source. There are several studies to investigate possibilities of re-use of treated wastewater mainly for agriculture use. While these studies cover necessary additional treatments, nutrition effects, yield effects, etc., demands of such treated water and methods of distribution have not been investigated.

There is no actual application of the re-use in the area, though two wastewater treatment plants are presently under operation. Instead, it is observed that raw wastewater is used for irrigation in some areas. While such raw wastewater may be the only available water source for such people who can not afford SONNES water or have difficulty in accessing to underground water, this could be a great concern in terms of hygienic problems for themselves and bacteriological/pathological contamination of their crops.

TABLES AND FIGURES

TABLE 2.1 MONTHLY MEAN TEMPERATURES (DEGREES C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daily Maximum	24.2	24.1	24.8	24.8	25.8	28.3	29.7	29.9	30.1	30.4	28.8	26.5
Daily Minimum	17.1	17.1	17.6	18.6	20.4	23.2	24.8	24.8	24.6	24.6	22.4	19.7
Average	20.6	20.6	21.2	21.7	23.1	25.7	27.2	27.3	27.3	27.5	25.6	23.1

Data Source: Strategy Plan

TABLE 2.2 MONTHLY MEAN RELATIVE HUMIDITIES (%)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daily Maximum	88.8	92.3	92.5	92.8	92	90.8	89.4	91.2	93.8	92.8	91	86.8
Daily Minimum	47.9	55.9	56.9	64.5	66.6	67.1	67.5	71	71.5	65.6	54.5	44
Average	68.3	74.1	74.7	78.6	79.3	78.9	78.5	81.1	82.7	79.2	72.8	65.4

Data Source: Strategy Plan

TABLE 2.3 AVERAGE MONTHLY RADIATION (10cal/sqcm/day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Radiation	82	86	94	99	96	86	75	69	73	83	84	77

Data Source: Strategy Plan

TABLE 2.4 MONTHLY AVERAGE DAILY EVAPORATION (mm/day)

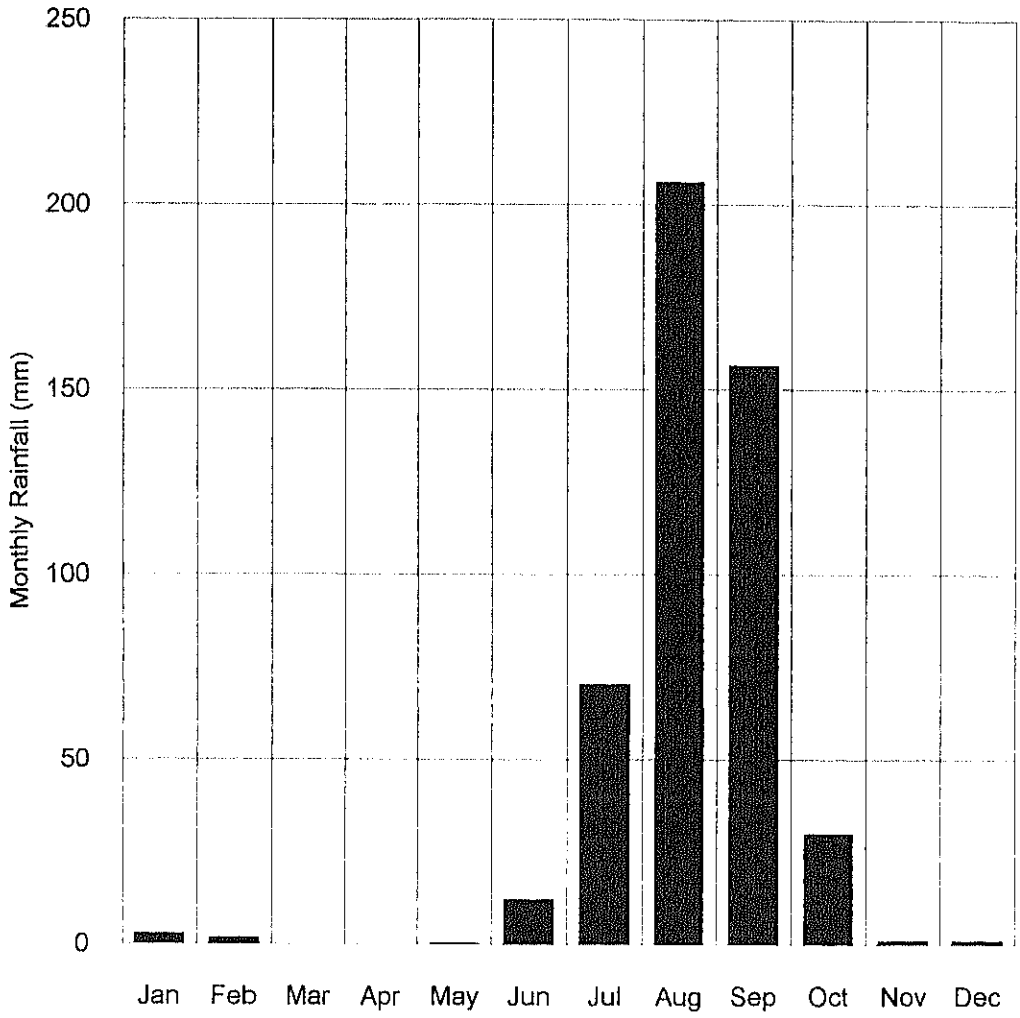
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daily Evaporation	3.4	2.9	3	2.6	2.4	2.6	2.8	2.3	1.9	2.5	3.3	4.2

Data Source: Strategy Plan

TABLE 2.5 POPULATION OF THE STUDY AREA

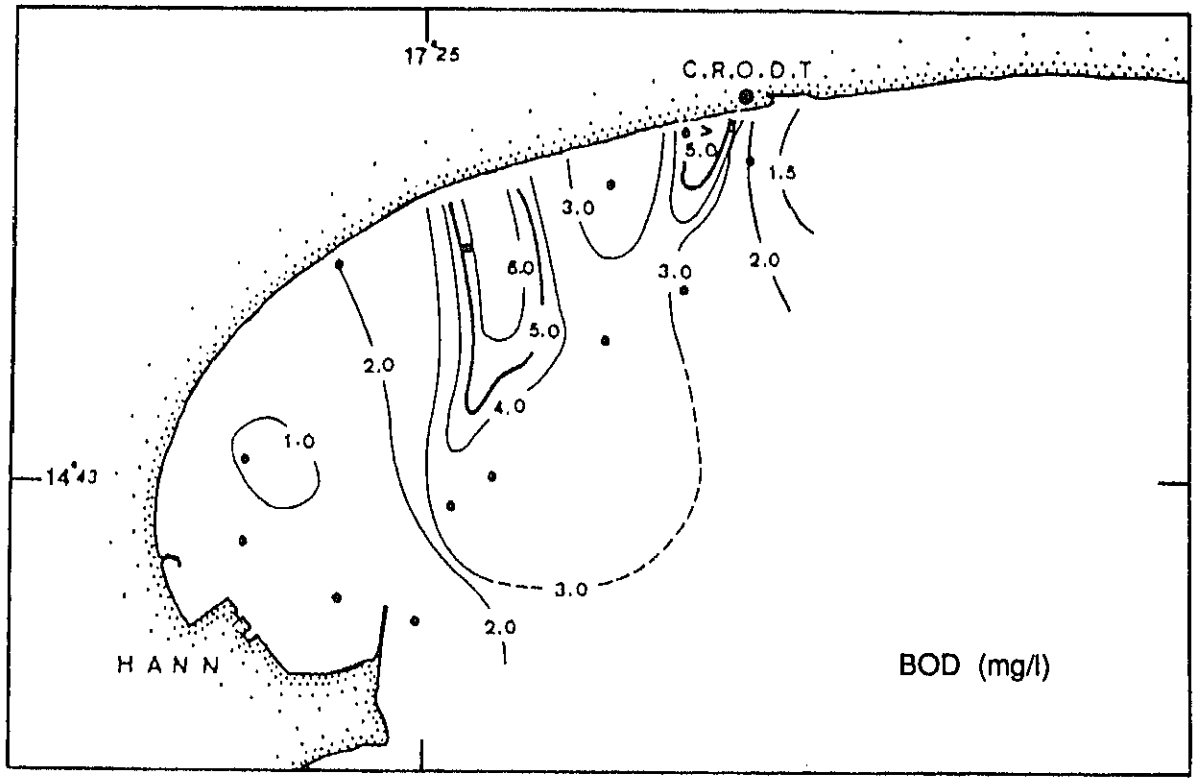
Year	Senegal	Dakar		Pikine		Study Area	
	DPS	DPS	SP	DPS	SP	DPS	SP
1980	5,734,000	566,000	566,000	420,000	420,000	986,000	986,000
1988	6,896,808	687,362	687,000	622,397	622,000	1,309,759	1,309,000
1983	7,913,090	767,194	-	812,344	-	1,579,538	-
1998	9,037,906	860,113	867,000	1,044,814	1,018,000	1,904,927	1,885,000
2001	9,774,093	919,683	931,000	1,206,540	1,179,000	2,126,223	2,110,000
2010	12,209,985	1,109,485	1,173,000	1,798,398	1,836,000	2,907,883	3,009,000

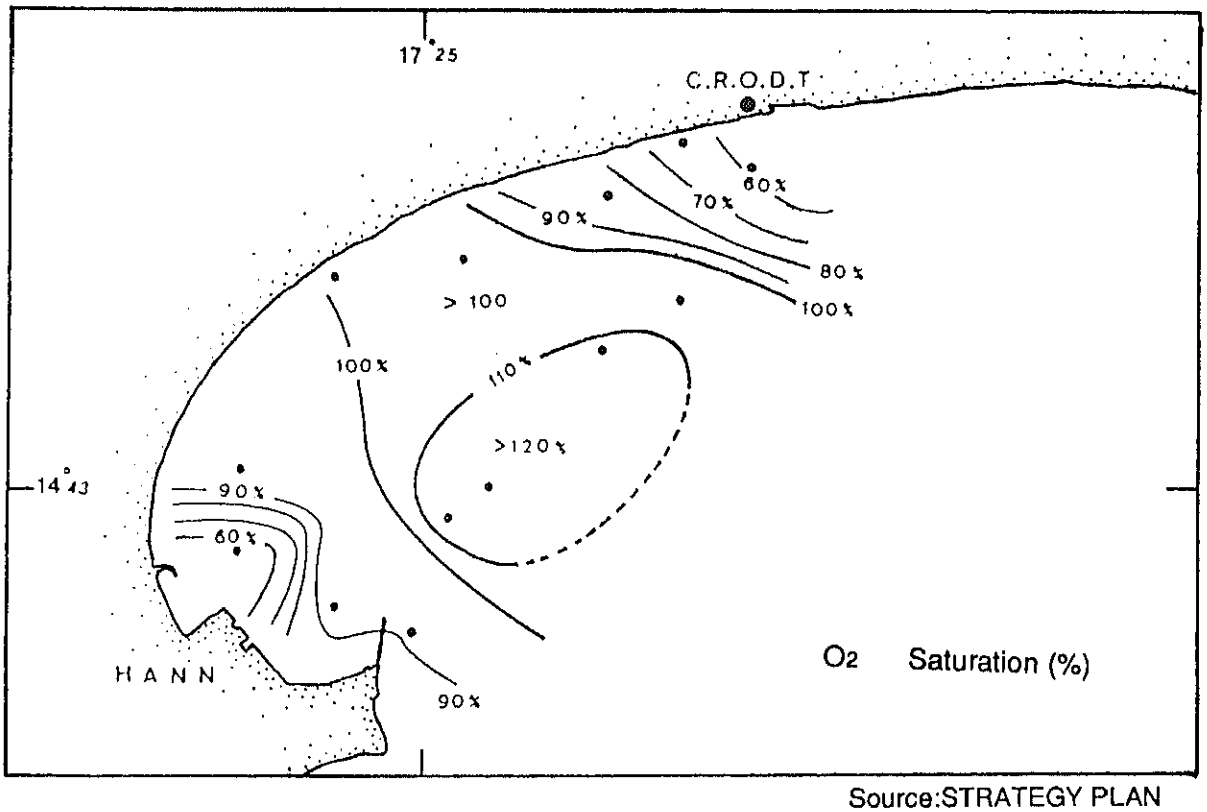
DPS: DIRECTON DE LA PREVISION ET DE LA STATISTIQUE
SP: STRATEGY PLAN



Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Rainfall (mm)	2.9	1.7			0.3	12	70	206	157	30	1.1	1.1

FIGURE 2.1 MONTHLY AVERAGE RAINFALL (1947-1989)





Source:STRATEGY PLAN

FIGURE 2.2 DISTRIBUTION OF BOD AND DISSOLVED OXYGEN IN THE HANN BAY

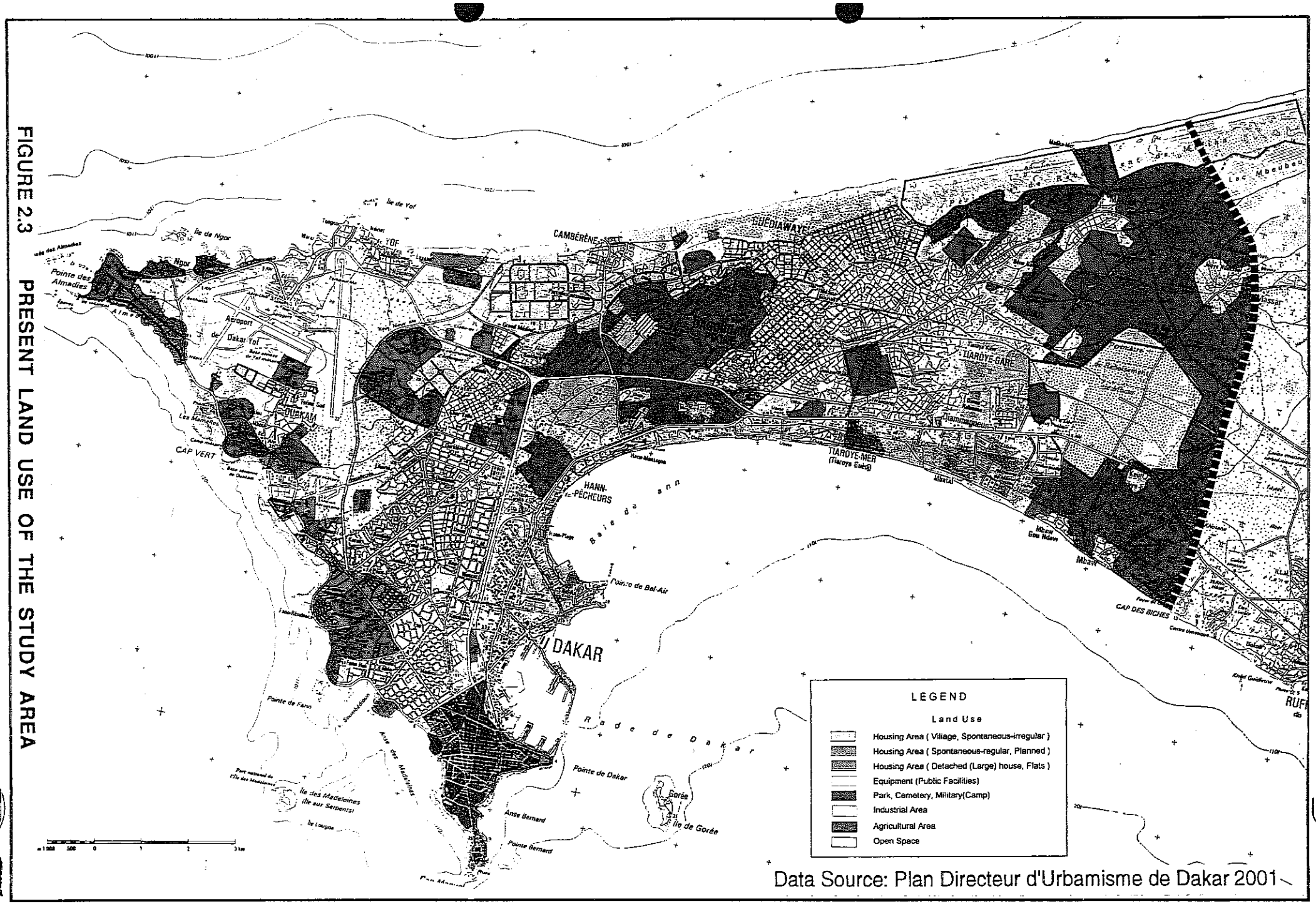


FIGURE 2.3 PRESENT LAND USE OF THE STUDY AREA

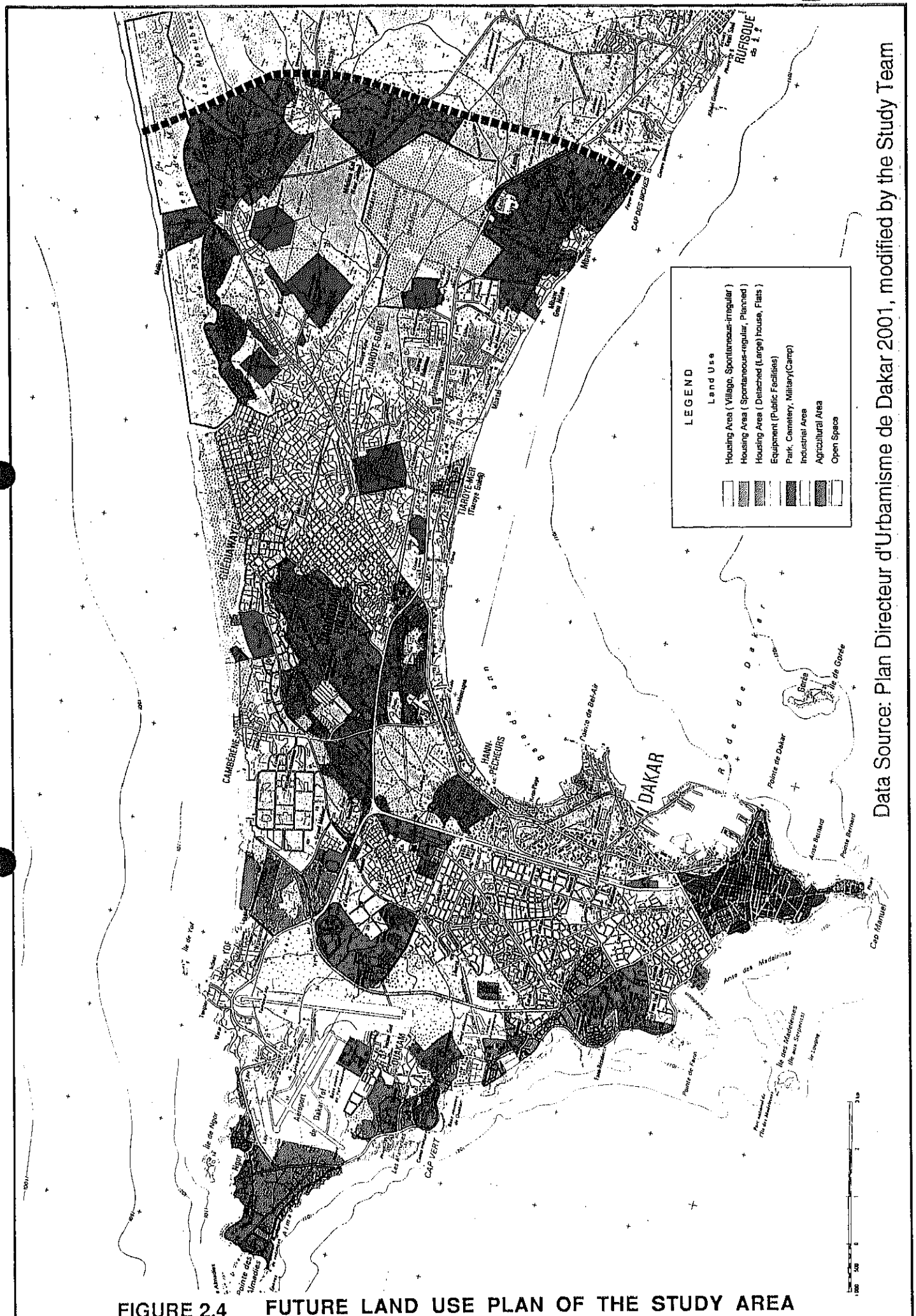
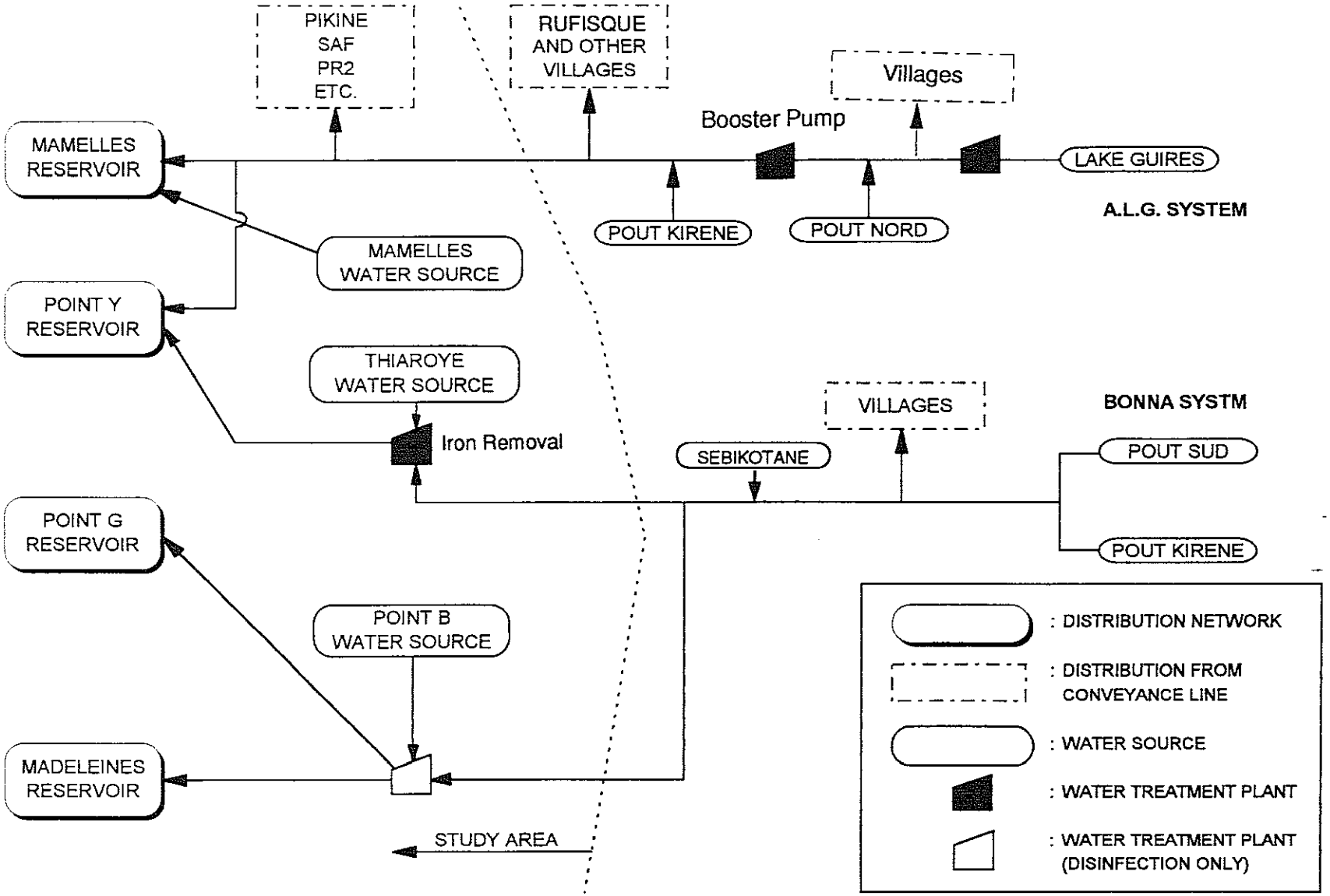


FIGURE 2.4 FUTURE LAND USE PLAN OF THE STUDY AREA



Source:SONEES 93

FIGURE 2.5 **CONCEPTIONAL EXPLANATION OF WATER SUPPLY SYSTEM IN THE STUDY AREA**

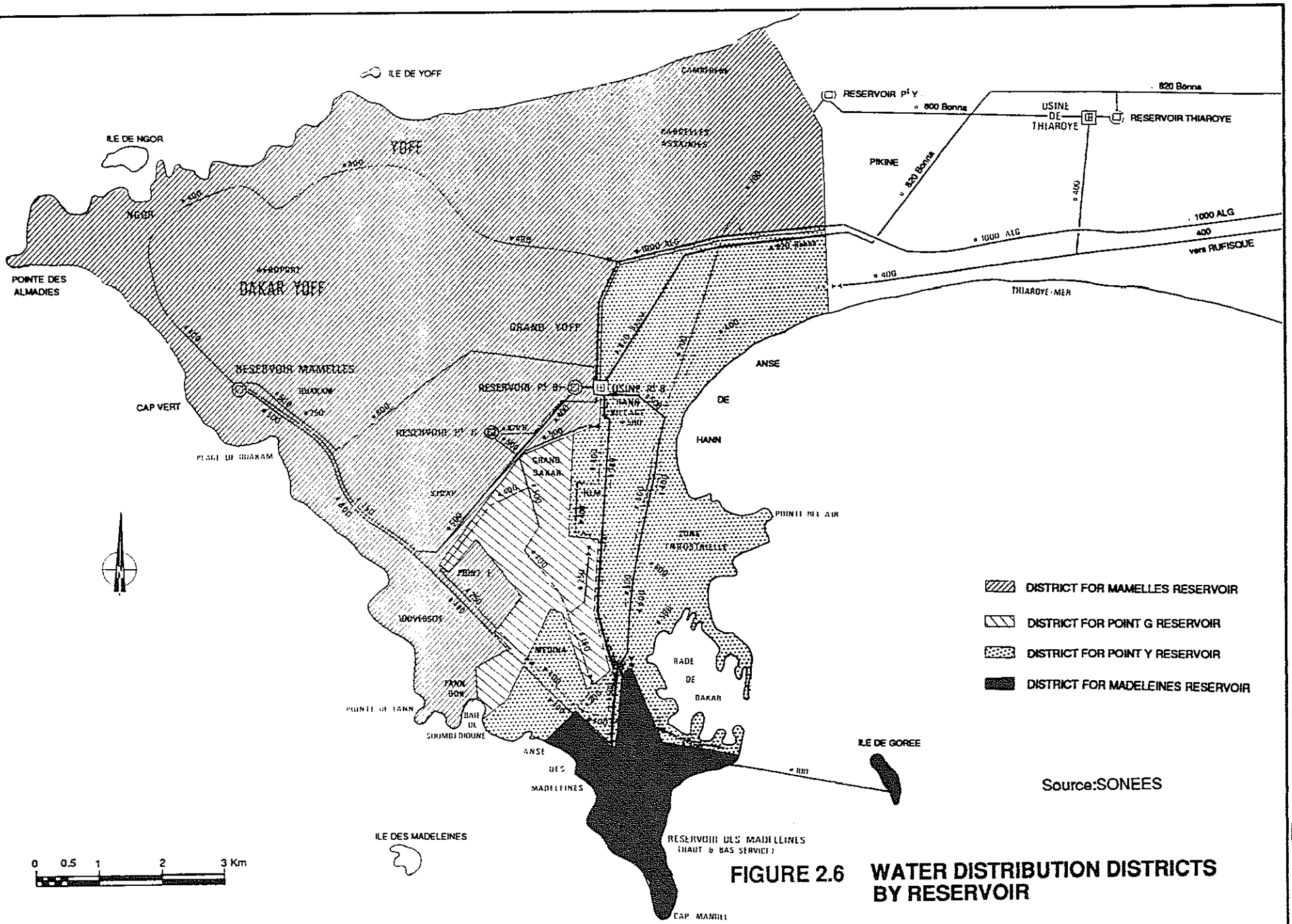


FIGURE 2.6 WATER DISTRIBUTION DISTRICTS BY RESERVOIR

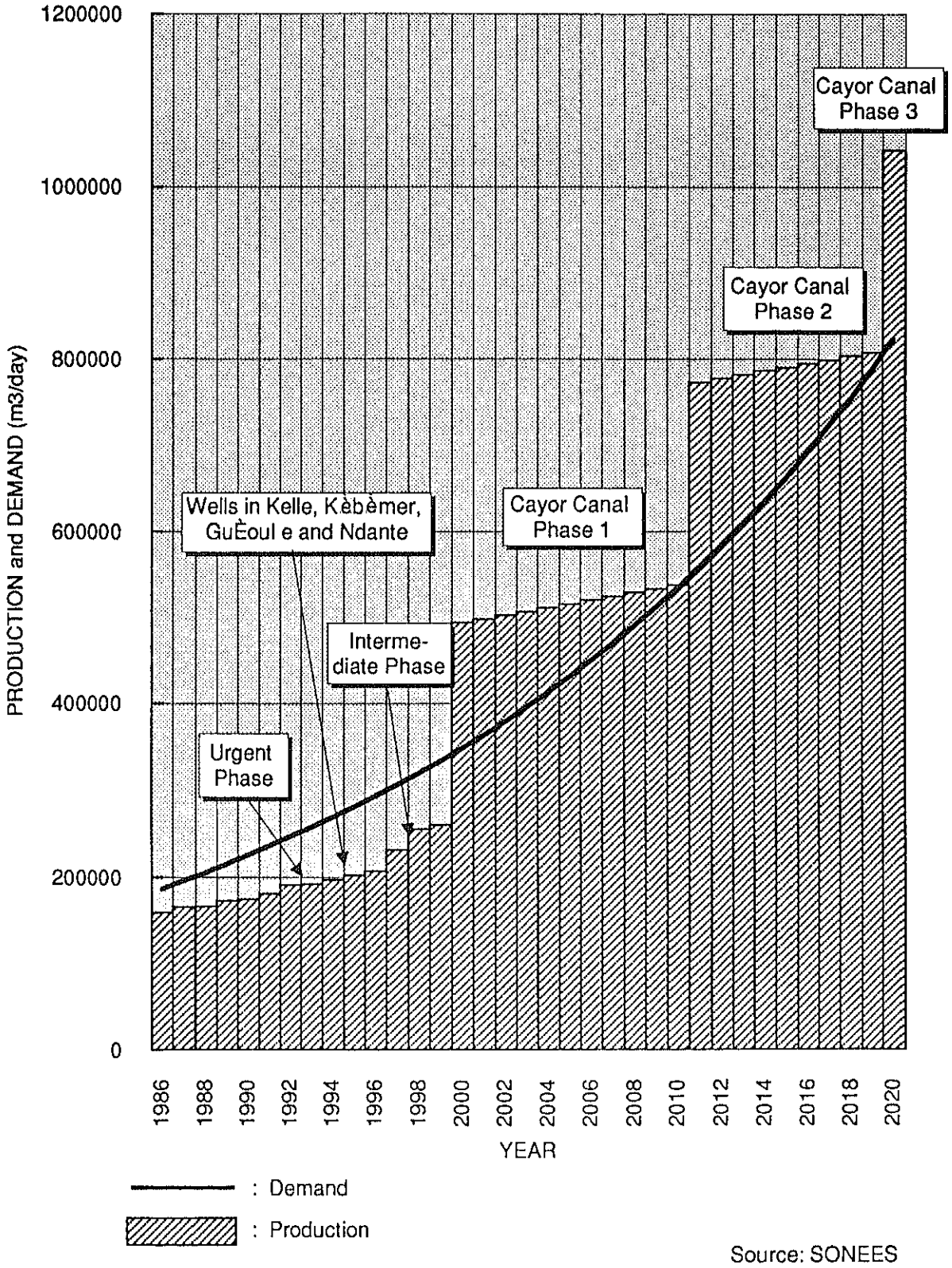
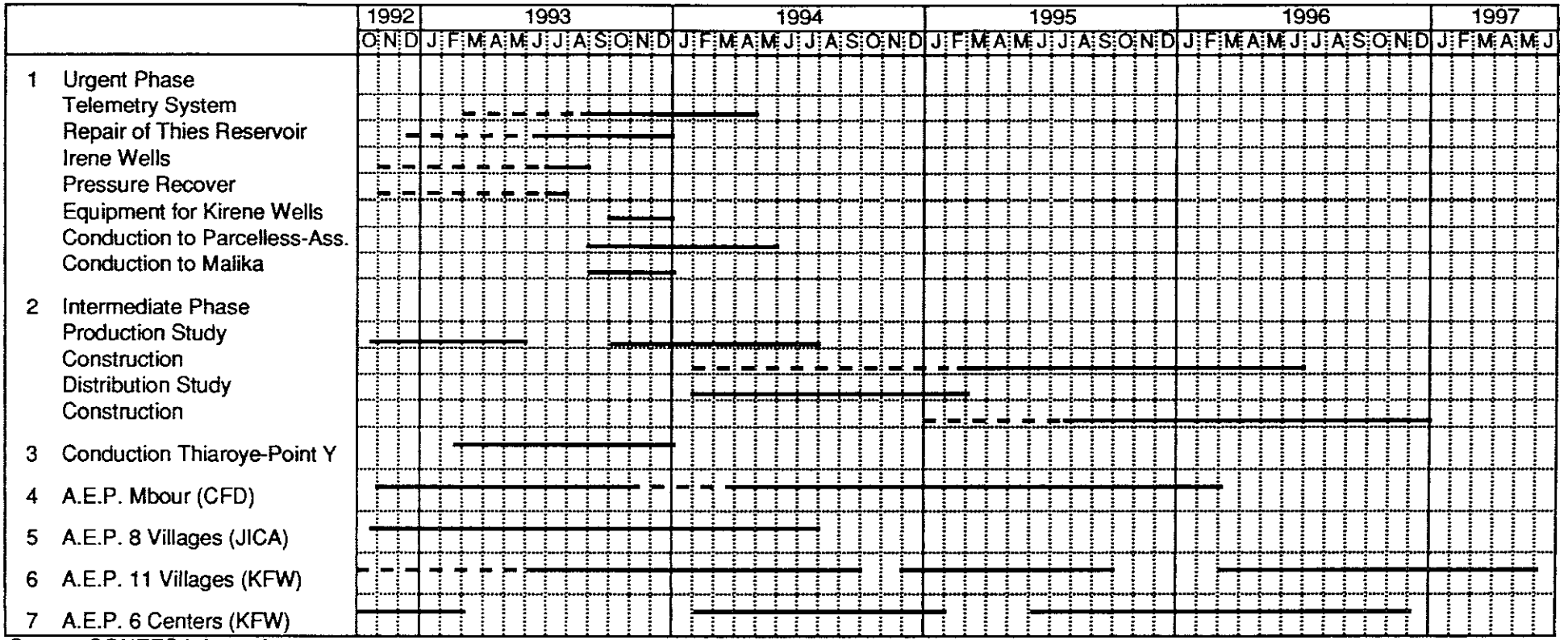


FIGURE 2.7 WATER DEMAND AND PRODUCTION PROJECTION (1986-2020)



Source: SONEES information

FIGURE 2.8 IMPLEMENTATION SCHEDULE OF CURRENT WATER SUPPLY PROJECTS BY SONEES

(FIG2-6.XLS, 11/9/1993)

PART II

WASTEWATER SYSTEM

CHAPTER 3

PRESENT CONDITIONS OF WASTEWATER SYSTEM

CHAPTER 3 PRESENT CONDITIONS OF WASTEWATER SYSTEM

3.1 OUTLINE OF THE SEWERAGE SYSTEM

Urbanized areas in the Study Area are provided with sanitary systems which can be classified broadly into two categories, viz. off-site system and on-site system. The off-site system is the conventional sewerage system collecting sewage from households and various kinds of buildings, such as government and private offices, hotels, restaurants and other public facilities. A sewerage system currently existing in the Study Area has been designed and constructed as a separate system which collect sewage and storm water runoff separately. The collected sewage is finally discharged to the sea either after or without treatment.

The on-site system is an individual sanitary system which deals with wastewater at the site of its origin. Several kinds of systems are found in the Study Area, from simple pit latrines which treat only human excreta to septic tank systems which treat sludge together with toilet wastes. In extreme case, houses which do not have any kind of sanitary system still exist in the Study Area.

The outline of the existing sewerage system, seaward areas and location of the main facilities is shown in *Figure* 3.1.

3.2 SEWERAGE SYSTEM

3.2.1 Coverage of Services

"Strategy Plan" has divided the Study area into 181 units by housing types shown below. Among 181 units, 79 units are provided with sewer network; these units correspond to the seaward area shown in *Figure 3.1.* Sewered areas and population are shown in *Table 3.1.*

The current sewered population is estimated to be 453,958, which accounts for 30 % of the total population of 1,517,400 in the Study Area. In the Strategy Plan, the sewered population was estimated to be 416,646, which accounted for 32 % of the total population of 1,296,010 in 1989. The sewered population increased by about 37,000 from 1989 to 1993. However, sewerage service ratio decreased slightly from 32 % to 30 % during the same period. This is an indication that the extension of the sewerage system has not caught up with the recent population growth.

In area wise, sewered area covers 34 % of the total Study area. However, the density of sewer network varies by units and the existing network has not necessarily enough capacity to deal with all the wastewater from the units.

3.2.2 Wastewater and Pollutant Load

1) Estimation of Wastewater Amount

Wastewater generated in the Study Area was estimated based on the current population and per capita water consumption rates. Per capita water consumption rate for each unit worked out in the Strategy Plan was used because no significant change was observed in the total water consumption. Wastewater produced in non-residential areas such as hospitals, military camps, and the university was estimated based on population equivalence. Industrial wastewater was estimated based on the unit wastewater flow per area (ha) which was worked out from the results of the survey conducted by the Study Team.

Wastewater flow collected by the sewerage system was estimated by units utilizing the sewerage connection ratio (which is the ratio of no. of houses connected to sewerage system to total no. of houses) of every unit, which was worked out from the Strategy Plan. Discharging ratios, which is the ratio of discharging flow into the sewerage system to the generated wastewater flow, were also used in estimating the collected flow.

2) Estimation of Pollutant Loads

Pollutant load (BOD) generated in the Study Area and collected by the sewerage system was estimated in the same manner as in the case of wastewater flow. The unit BOD loading rate is worked out to be 47 gpcd (gram per cpita per day) from the results of the field survey conducted by the Study Team.

Characteristics of the industrial wastewater taken from the 19 representative factories were analyzed by the Study Team. An average BOD concentration of the 18 factories except for the slaughter house (Abattoirs) is 240 mg/l. BOD concentrations are considered too low for the type of industries. BOD concentration of the wastewater generated by the same type of the industry in Japan is, therefore, used to estimate the industrial pollutant load. The average BOD concentration calculated by this is 920 mg/l.

3) Wastewater Amount and Pollutant Loads

Results of the above estimation are shown in *Table 3.2.*

As shown in the table, the total domestic wastewater flow including those generated in various kinds of non-residential areas is 168,074 m^3/day on a daily average basis. Industrial wastewater is estimated to be 12,914 m^3/day. Thus, the total wastewater is 180,988 m^3/day. Out of the total wastewater flow, 66,210 m^3/day, or about 37 % is being collected by the sewerage system at present.

A total of 86,209 kg BOD load is generated daily in the Study Area, of which 74,458 kg/day (86.4 %) is domestic in origin. The remaining 11,751 kg/day (13.6 %) is considered to be generated by industries (including the slaughter house). This industrial BOD load is equivalent to about 250,000 persons.

BOD load collected by the sewerage system is either treated or discharged to the sea directly. The balance of BOD load collected is as follows.

Balance of BOD Collected by the Sewerage System

	(kg/day)
Total BOD collected	31,241
Hann-Fann System	27,044
Camberene System	4,197
Reduction at WWTP	4,029
Total BOD discharged	27,212
Hann-Fann System	27,044
Camberene System	168

3.2.3 Facilities

1) House Connections and Sewer Networks

Wastewater from households flow into the public sewer network through house connections. A typical arrangement of the sewers and house connections is shown in *Figure* 3.2.

The total length of the sewer network is approximately 610 km at present. The diameter of the sewer pipes vary from 150 to 250 mm for branch and lateral sewers, and 300 up to 1,000 mm for secondary mains and collectors.

2) Pumping Stations

There is a total of 25 pumping stations in the Study Area. The name, type, capacity and total head are shown in *Table* 3.3.

3) Wastewater Treatment Plants (WWTPs)

There are five wastewater treatment plants in the public sewerage system. A few small scale wastewater treatment facilities exist, which were constructed and owned by private developers or contractors. However, these treatment facilities are out of order for various reasons and no treatment is carried out by them. Moreover, among the five wastewater treatment plants in the public sewerage system, only two plants, Camberene and Niaye, are receiving sewage at present. The present condition of the five treatment plants is described below.

(1) Camberene WWTP

Camberene WWTP was commissioned in December 1989. One process train was constructed as the first phase of the project. Design parameters of the first process train are as follows:

Population equivalence:	100,000 persons
Daily average flow (Q):	9,600 m^3/day
Peak flow:	16,800 m^3/day (1.75 Q)
BOD load:	6,000 kg/day
SS load:	9,000 kg/day
Raw sewage	
BOD concentration:	625 mg/l
SS concentration:	938 mg/l
Treated effluent	
BOD concentration:	20 mg/l
SS concentration:	30 mg/l

The plant was designed to have the complete secondary treatment by the activated sludge process. Excess sludge from the final sedimentation tank is returned to the primary sedimentation tank and sent to the sludge digestion tanks together with primary sludge. Two stage anaerobic digestion is conducted before the sludge is sent to sand drying beds.

The plan of the existing facilities and the hydraulic profile are shown in *Figures* 3.3 and 3.4 respectively.

(2) Niaye WWTP

Niaye WWTP is located in the eastern part of Grand Niaye near Pikine. The plant is surrounded by swamps and vegetable farms. The plant was constructed based on the proposal in the Water Supply and Sewerage Master Plan, 1973, to treat sewage from the Guediawaye and Sotiba areas. Currently the plant is not functioning as designed.

Design parameters of the plant are as follows:

Population equivalence:	7,600 persons		
Daily average flow (Q):	550 m^3/day		
Peak flow:	960 m^3/day (1.75Q)		
Grit chamber		Inhoff tank	
Surface loading:	30 m^3/m^2/hr.	Sedimentation tank:	550 m^3
Velocity:	30 cm/sec	Anaerobic digestion tank:	400 m^3
Oxidation pond		Infiltration pond	
Surface area:	5,000 m^2	Total surface area:	800 m^2
Depth of water:	1.2 m	Sludge drying beds	
Retention time	11 days (appr.)	Total surface area:	380 m^2

(3) Mbao WWTP

Mbao WWTP was constructed in 1982 by the Ministry of Industry to treat industrial wastewater from the factories in the industrial zone. However, this treatment plant has never been used until now.

The plant was designed as biological secondary treatment based on the activated sludge process. Minor additional facilities, such as an oil separator before primary sedimentation tank, were added. Design parameters are not available. However, judging from the size of the facilities, the plant seems to have a capacity of a few thousand m^3/day.

(4) Patte d'Oie I WWTP

Patte d'Oie I WWTP had been commissioned in 1971, and ceased to function in 1988 when conversion to the Camberene WWTP was completed. The plant was constructed to treat sewage from Patte d'Oie housing development area. The trickling filter process was adopted, and it served approximately 4,000 inhabitants, with a peak flow capacity of 60 m^3/hr.

(5) Patte d'Oie II WWTP

Patte d'Oie II WWTP was constructed in 1984, but has never been put into operation. The plant was designed to treat sewage from the extended Patte d'Oie housing development area. Conventional activated sludge process with mechanical aerators was adopted. Design parameters are as follows:

Daily average flow:	1,800 m^3/day
Peak flow:	3,696 m^3/day (2.05 x Daily average)
BOD load:	1,500 kg/day
SS load:	1,800 kg/day

4) Ocean Outfalls

There are two main ocean outfalls in the sewerage system, viz. Fann outfall at Pointe de Fann and Camberene WWTP outfall in Camberene village, in addition to three minor outfalls. There are some other wastewater discharges to the sea in the Study Area, such as open drainage channels which receive wastewater, industrial wastewater outfalls from factories in the industrial zone, and outfalls from large hotels. In this section, however, only five outfalls which are directly connected to the sewer network are discussed.

The quantity of sewage discharged on daily average basis at present is estimated as follows.

i	Fann	49,500 m^3/day
ii	Camberene	3,900 m^3/day
iii	Plateau	4,700 m^3/day
iv	Rue Mangin	2,400 m^3/day
v	Rue 9	1,000 m^3/day

Location of each outfall is shown in *Figure* 3.1 of the previous section.

3.2.4 Operation and Maintenance

Operation and maintenance of the sewerage system together with storm water drain pipes is being carried out by SONEES. According to the annual report prepared by SONEES, at the beginning of 1993, SONEES' two departments, viz. Network and Station Departments, maintain the following facilities.

- 610 km sanitary sewer pipes
- 157 km storm water pipes

- 40,000 house connections
- 27 pumping stations (including 2 for storm water drainage)
- 2 treatment plants (Camberene and Niaye)

3.2.5 Financial Conditions

1) Water Tariffs of SONEES

The water tariffs of SONEES are classified into three types, i.e. the tariff for urban consumers with connections, public stand tariff and the tariff for gardening crops growers. Each type is further classified into two categories by sewered area and unsewered area as shown in *Table 3.4.* Although, there is no tariff system for the sewerage, difference of the water charges between sewered area and unsewered area can be considered to be sewerage charge.

2) Financial Statements of SONEES

Income statement of SONEES is shown in *Table 3.5.* Costs of operation totals 14,782 FCFA, which slightly exceeds the revenue from water bill. Materials and supply costs are 5,736 million FCFA, accounting for 38.8 % of costs of operation. Personnel costs are 3,955 million FCFA, accounting for 26.8 %. These two regular cost items account for 65.6 % of the costs for operation.

Payment of interest is 2,039 million FCFA, accounting 13.8 % of the costs of operation. Depreciation amounts to 3,895 million FCFA, which is 26.3 % of the costs of operation. Net profits worked out at 107 million FCFA in 1991.

3.2.6 Relevant Plans

In this section, various future plans regarding the sewerage system in the Study Area are reviewed. Two main studies, viz. Water Supply and Sanitation Master Plan 1973 and Strategy Plan of Sanitation 1991, are described first and followed by a few improvement plans proposed by SONEES since 1991.

1) Water Supply and Sanitation Master Plan 1973 (PLAN DIRECTEUR, DAKAR ET SES ENVIRONS, APROVIONNEMENT EN EAU ET ASSAINISMENET)

The first comprehensive sewerage master plan was prepared in 1973 by NEDECO and LA HAYE. UNDP funded the study on the request of the Senegal Government.
The study consists of three subjects, viz. water supply, sanitary sewerage and storm water drainage. The study covers Rufisque in addition to Dakar and Pikine, which are the study area of the current study. Target year of the study is 2000.

Based on the existing conditions in 1968, the study proposed a sanitary sewerage system as shown in *Figure* 3.5. Apparently indicated in the figure, sewerage system does not cover all the urbanized areas in 2000. On-site sanitary systems, which though not described in the report, are proposed for the remaining areas, such as Pikine Irregular and a huge new development area northeast of Rufisque. All the wastewater collected by the sewer networks is to be discharged to the sea at a few centralized points. Treatment of wastewater before being discharged into the sea is not considered in the study.

It has been more than 20 years since the preparation of the study. Many deviations from the estimations are recognized in the Study Area. Therefore, proposals made by the study should be reconsidered.

2) Strategy Plan of Sanitation 1991 (PLAN DE STRATEGIE D'ASSAINISSEMENT POUR LA COMMUNAUTE URBAINE DE DAKAR)

The Strategy Plan has been prepared to cope with present problems in the field of sanitation and urban drainage in the Study Area. The plan was prepared in 1991 by BETUTURE, SETAME consultant and SONED AFRIQUE under the supervision of the World Bank, and financed by UNDP.

The Plan consists of two parts, viz. Mission 1 which deals with the present conditions and problems, and projections of population up to the year 2010, and Mission 2 which proposes the strategy for sanitation and urban drainage systems for 2010.

Present conditions in the Study Area were investigated in detail analyzing many aspects, such as socio-economic, urbanization, climatic, hydrogeologic, water supply, sanitation systems, agricultural, institutional and financial aspects. In particular, the entire urban area in the Study Area was divided into small units each of which had similar housing characteristics. Water supply and sanitation conditions were analyzed for each unit.

Future population projection were made for units based on the demographic trend observed in the Study Area and the development condition of each unit. Future wastewater quantities were estimated based on the population projection and water supply conditions in the Study Area. The latest water supply master plan and its implementation program are properly reflected in the Plan. Therefore, the projections of population and wastewater quantities in this report can be considered as the basis for the current Study.

Five scenarios were proposed to improve the sanitary condition in the Study area. These are as follows:

Scenario 1: Improvement of on-site system. Provision of septic tank of water-tight construction with a pit or pipe for seepage.

Scenario 2: Small bore sewer system or individual treatment system. This scenario was proposed for the houses whose water consumption is between 20 to 40 lpcd. In case of small bore sewer system, wastewater flows into a septic tank and a part of effluent discharges into a small diameter sewer and the remaining part infiltrate into the soil. Wastewater treatment by utilizing large water plants, such as water lettuce, is proposed for the individual treatment system.

Scenario 3: Connection to the existing sewerage system. This scenario was developed for the housing area where public sewers are already available.

Scenario 4: Construction of new sewer networks. This scenario was proposed for the existing high standard housing areas, newly developed housing areas and industrial areas.

Scenario 5: Extension of treatment capacity. This scenario is the result of scenarios 3 and 4.

The Study Area was divided into 7 sanitary districts based on the present sanitary facilities, sewerage networks in particular, and characteristics of the areas, such as housing type. Five scenarios mentioned above were applied to each sanitary district taking into account the physical and socio-economic conditions of the units included in the district. Division of sanitary districts and application of the scenarios are as follows and shown in *Figure* 3.6.

Sanitary District	Areas
1	Terre-Sicap, Sud Bourguiba
2	Villages
3	Almadies and West Coast
4	Port and Industrial Zone
5	Parcelles Assainies, Patte d'Oie, Grand Yoff
6	Pikine, Guediawaye, Thiaroye
7	Mbao free zone

Proposed Scenario for Each District

Sanitary District	SC.1	SC.2	SC.3	SC.4	SC.5
1	X		XXX	X	X
2	XXX	X			X
3	X	X		XXX	
4	X	X		XXX	XXX
5	X	X		XXX	XXX
6	XXX	X	X	X	X
7	individual or communal treatment of industrial wastewater				

Note: XXX For most of the units
X For a small number of units

When the scenarios are realized, the total and sewered population in 2010 will be as follows:

Sanitary District	1989			2010		
	1	2	3	1	2	3
1	375,011	0.869	325,769	638,251	0.923	589,645
2	221,891	0	0	501,513	0.018	9,220
3	34,534	0.241	8,328	79,478	0.693	48,018
4	2,220	0	0	9,630	0.110	963
5	195,673	0.289	56,557	512,297	0.689	352,157
6	462,305	0.024	11,061	814,297	0.154	125,188
7	0	0	0	0	0	0
Total	1,291,634	0.311	401,715	2,555,466	0.440	1,125,191

Note : 1. Total Population
2. Connection Ratio
3. Sewered Population

3) SONEES Proposals Since 1991

Three proposals regarding improvement of the existing sewerage system have been prepared by SONEES. Documents available regarding these three proposals are 1) Report on the Installation Project of Cite Faycal, January 1991 (PROJECT DE RACCORDEMENT DE LA CITE FAYCAL, MEMOIRE DESCRIPTIF), 2) Tender Documents for Sewage and Stormwater Sanitation at Low Point in HLM Las Palmas of Guedidawaye, September 1992 (ASSAINISSEMENT DU POINT BAS DES HLM LAS PALMAS DE GUEDIAWAYE EAUX USEES ET EAUX PLUVIALS, DOCUMENTS D'APPEL D'OFFRES), and 3) Memorandum on the Function of the Sewerage System in Parcelles Assainies, May 1993 (MEMORANDAUM SUR LE FONCTIONNEMENT DU SYSTEME D'ASSAINISSEMENT DES PARCELLES ASSAINIES

3.3 ON-SITE SYSTEM

3.3.1 Population relying on On-site System

The table below gives population by wastewater disposal types. Among a total population of 1.5 million, 870 thousand people are living in the area not covered by sewerage service and, in addition, 200 thousand people in the area covered by sewerage are not connected to sewers. Thus, about one million people, 67 % of the total, rely on the on-site system for their wastewater disposal. It can be said that the on-site system is presently a major facility for wastewater disposal in the study area.

Population by Wastewater Disposal Types

Area	Connection		Total
	Connected to sewers	Not connected to sewers	
Covered by sewerage system	453,960	192,089	646,049
Not covered by sewerage system	0	871,351	871,351
Total	453,960	1,063,440	1,517,400

3.3.2 Present On-site System in the Study Area

Table 3.6 shows methods of wastewater disposal by housing types. Typical on-site system in each housing type is summarized as below, based on the data in the table:

1) Type 1 (Village)

In this type, about 76% of the toilet are of the Turkish toilet without septic tank. Wastewater other than from toilet is discharged to the ground, street or penetration pit.

2) Type 2 (Spontaneous, Irregular)

More than 95% of the toilet are of the Turkish toilet without septic tank. Wastewater other than from toilet is discharged to the ground, street or penetration pit.

3) Type 3 (Spontaneous, Regular)

45% of this type are covered by a sewerage system. Thus, 16 % of the toilet are of flush type toilet that flushes out the excreta by pressured water. Major type of the toilet is still Turkish toilet mainly without septic tank. Wastewater other than from toilet is discharged to the ground, street or penetration pit in case of no sewerage system.

4) Type 4 (Planned)

About 70% of this type are covered by a sewerage system and 36% of the toilets are of the flush type. In case of no sewerage system, the Turkish toilet is a dominant type. Wastewater other than from toilet is discharged to the septic tank or to the penetration pit in case of no sewerage system.

5) Type 5 (Detached)

Most of this type (73%) are covered by a sewerage system. On-site system in this type relies on the Turkish toilet with or without septic tank. Wastewater other than from toilet is discharged to the septic tank or to the penetration pit in case of no sewerage system.

6) Type 6 (Flats)

This type is covered by a sewerage system. There is no on-site system in this type.

3.3.3 Operation of On-site Treatment

As mentioned above, toilet waste (excreta) disposal relies on the Turkish toilet with or without septic tank and wastewater other than toilet waste is discharged to the ground, road, penetration pit or septic tank in most of the on-site system in the study area.

In the Turkish toilet with soakaway, it is considered that the penetration has been intentionally adopted as a method of the final disposal. The Turkish toilet without a soakaway is considered to require periodical withdrawal of the accumulated excreta. However, it is considered that seepage from pits or tanks is penetrated into the ground because structures of such pits or tanks are not water proofed. This would be evident from the following facts mentioned in the Strategy Plan:

- 45 % of the Turkish toilet have never had a withdrawal of the excreta.
- 45% of the Turkish toilet have a withdrawal once a year.
- 7% of the Turkish toilet have a withdrawal once per two months.
- 2% of the Turkish toilet have a withdrawal once a month.

Therefore, in the present on-site system, all wastewater is finally penetrated into the ground though there are several routes such as with or without septic tank, and being discharged to pits, on to the ground or roads.