BASIC DESIGN STUDY REPORT
ON
THE PROJECT
FOR
KHARTOUM SEWERAGE REHABILITATION
IN
THE REPUBLIC OF THE SUDAN

MARCH, 1989

JAPAN INTERNARONAL COOPERATION AGENCY

BASIC DESIGN STUDY REPORT
ON
THE PROJECT
FOR
KHARTOUM SEWERAGE REHABILITATION
IN
THE REPUBLIC OF THE SUDAN

MARCH, 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to a request from the Government of the Republic of the Sudan, the Government of Japan decided to conduct a Basic Design Study on the Project for Khartoum Sewerage Rehabilitation and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Sudan a study team headed by Mr. Ichiro Setoh, the Japan Regional Development Corporation from November 19 to December 22, 1988.

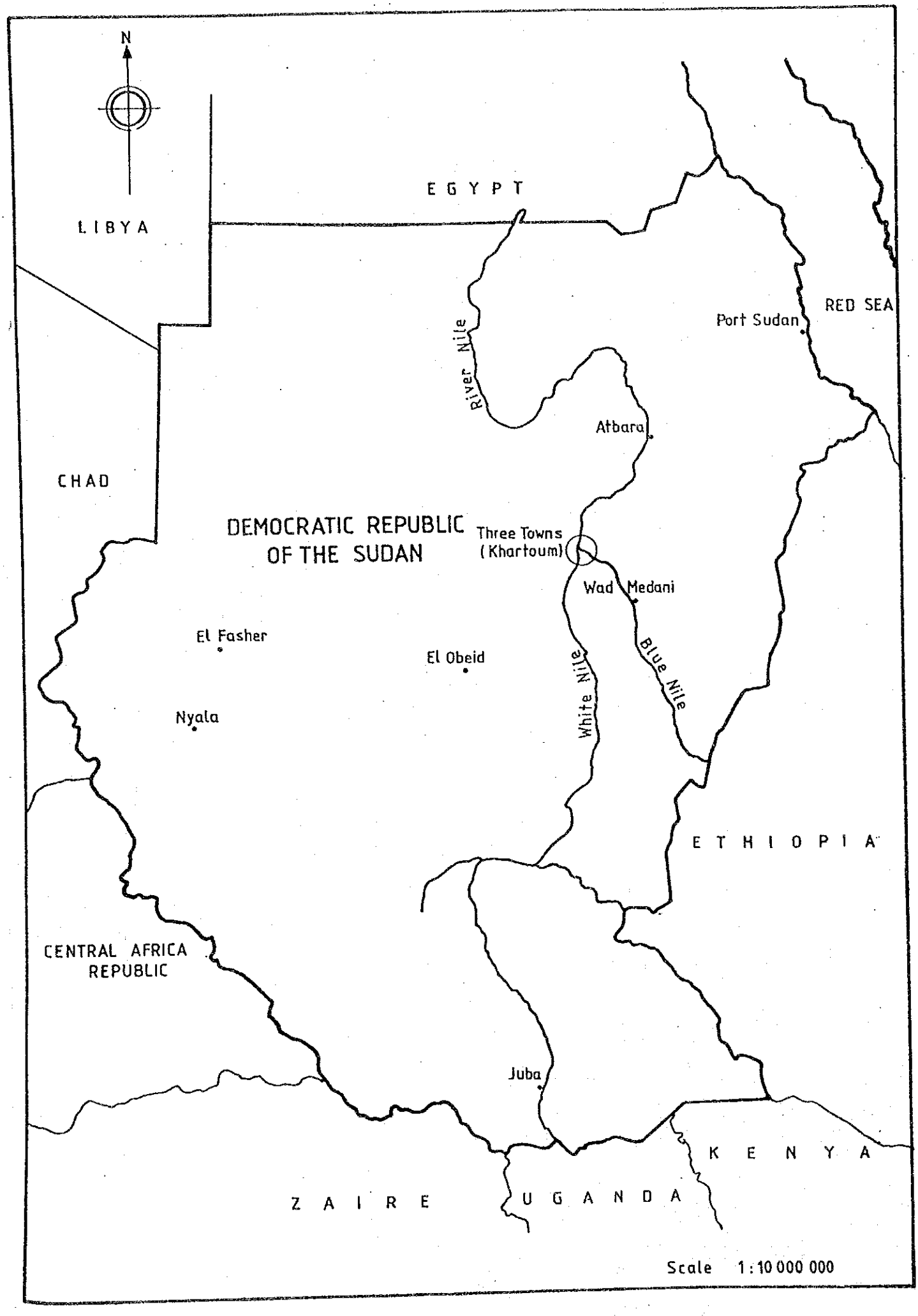
The team exchanged views with officials concerned of the Government of Sudan and conducted a field survey in Khartoum. After the team returned to Japan, further studies were made. Then, a mission was sent to Sudan in order to discuss the draft report and the present report has been prepared.

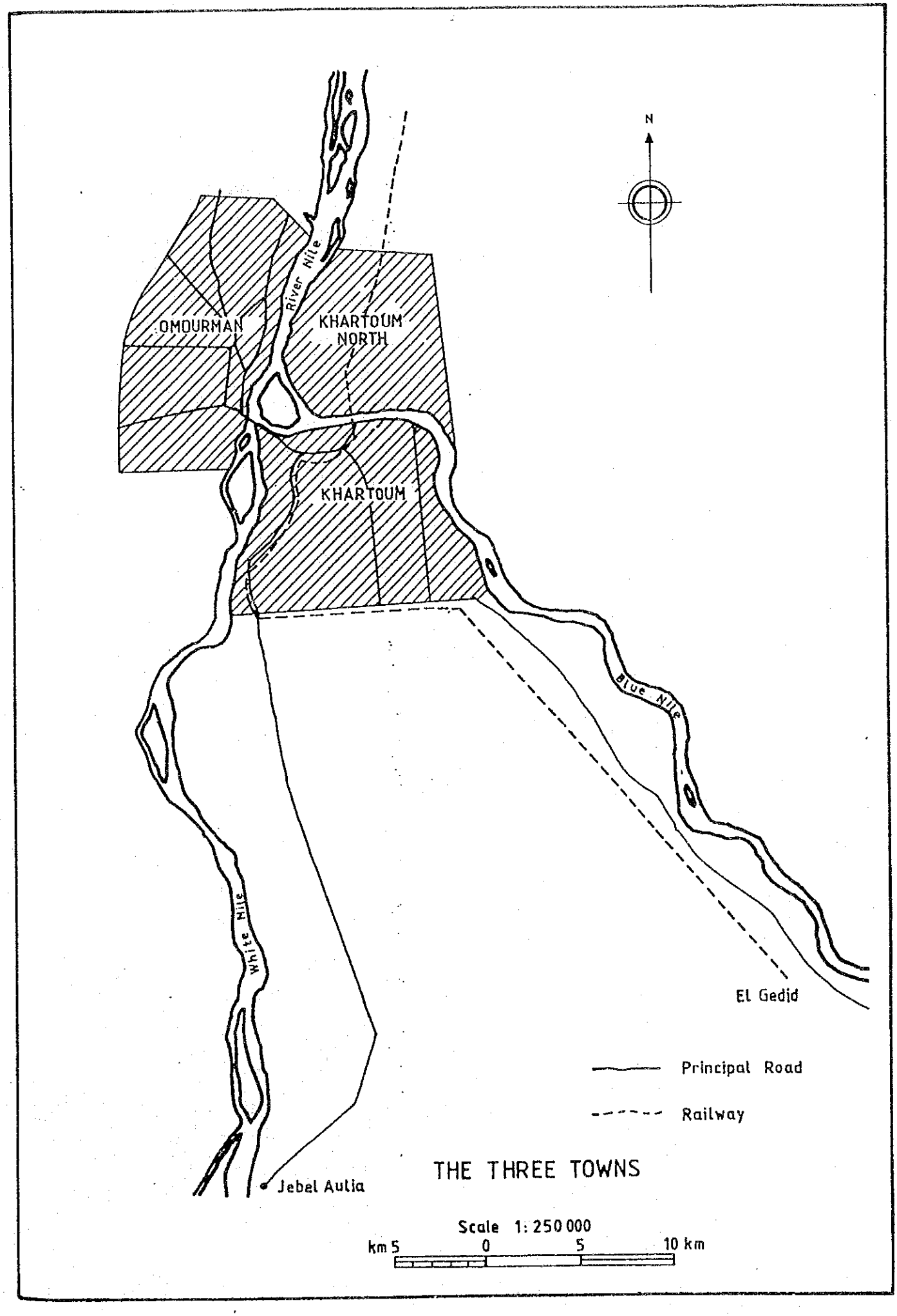
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

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

March, 1989

Kensuke Yanagiya
President
Japan International Cooperation Agency


N
LIBYA
EGYPT
RED SEA
Port Sudan
River Nile
Atbara
CHAD
DEMOCRATIC REPUBLIC
OF THE SUDAN
Three Towns
(Khartoum)
Wad Medani
El Fasher
El Obeid
White Nile
Blue Nile
Nyala
ETHIOPIA
CENTRAL AFRICA
REPUBLIC
Juba
KENYA
ZAIRE
UGANDA
Scale 1:10 000 000


N
OMDURMAN
River Nile
KHARTOUM NORTH
KHARTOUM
Blue Nile
White Nile
El Gedid
Principal Road
Railway
Jebel Aulia
THE THREE TOWNS
Scale 1: 250 000
km 5
0
5
10 km

Photos

Photo – 1 Sewage Leakage in NCK

Photo – 2 Broken Rising Main

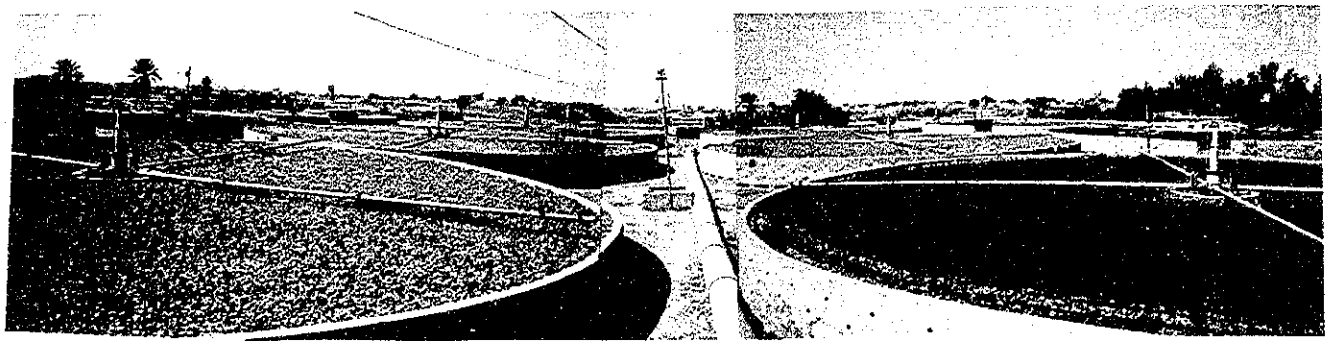


Photo − 3 Bio-Filter (Goaze STP)

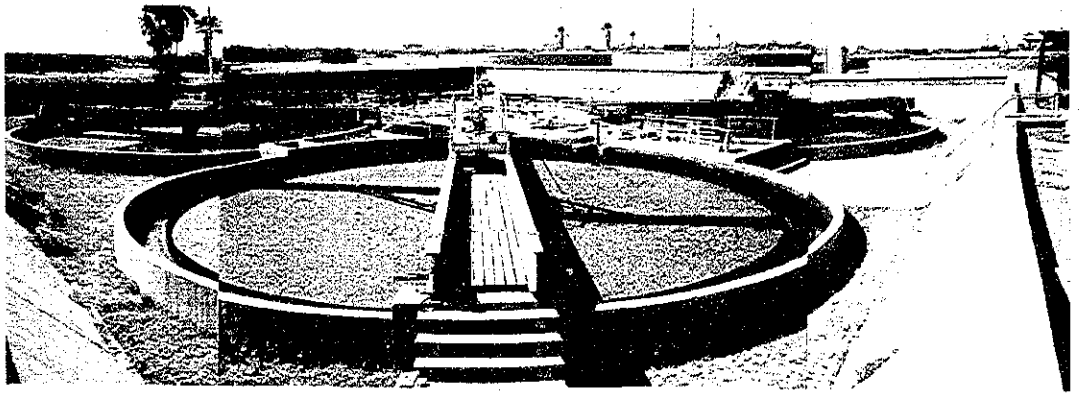


Photo − 4 Humus Tank (Goaze STP)

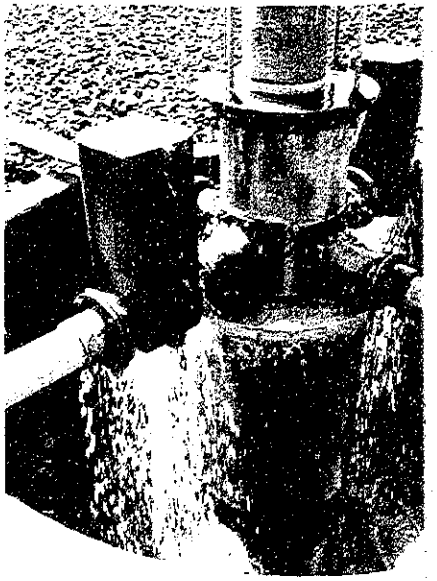


Photo − 5 Water Seal of Center Support Column (Goaze STP

Photo − 6 Broken Side Wall of Bio-Filter (Goaze STP)

Photo - 7 The Whole View of Pumping Station

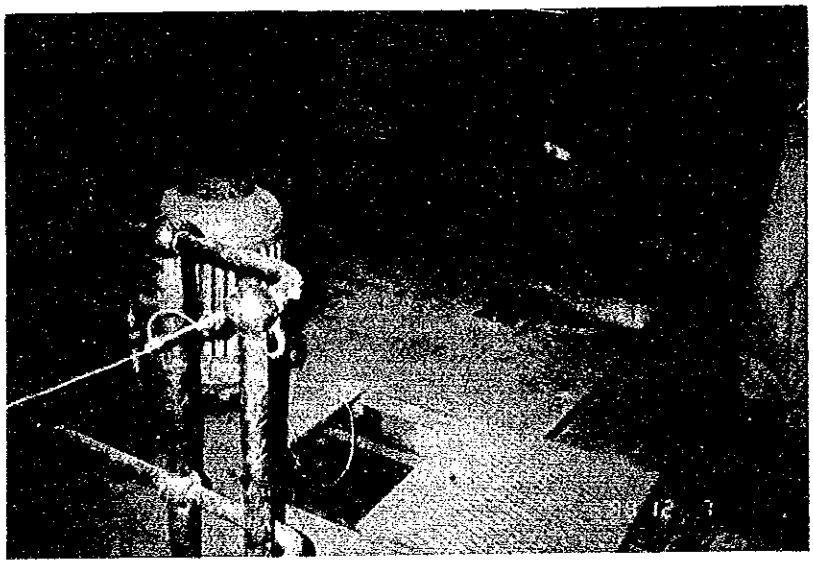


Photo - 8 Inside of Pumping Station

Photo − 9　The Whole View of Soba STP (1)

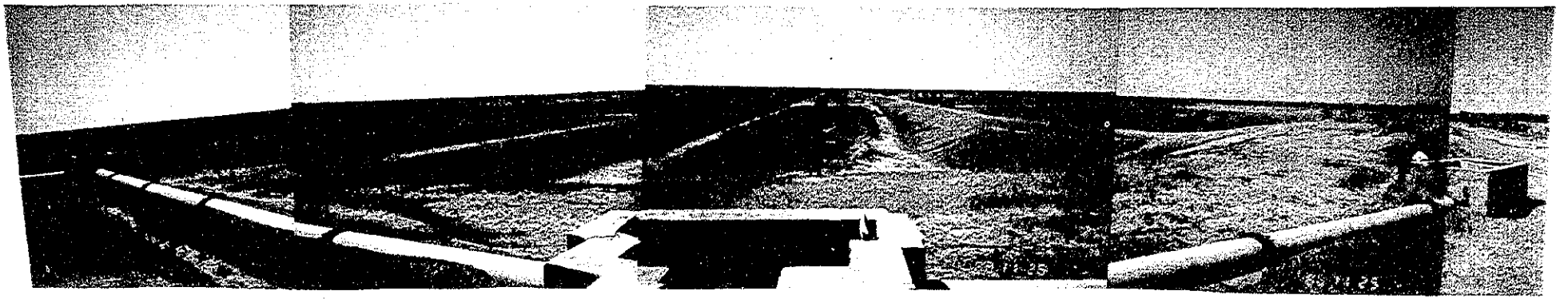


Photo − 1 0　The Whole View of Soba STP (2)

Summary

SUMMARY

Khartoum, the capital of the Republic of the Sudan, is located in the eastern central part of the country, at the confluence of the Blue Nile and the White Nile. The city is the center of all political, economic, educational and cultural activities as well as the converging point of international and domestic transport in the Sudan. It consists of three towns, namely: Khartoum, Khartoum North and Omdurman. Many government offices, foreign embassies,banks, private offices and hotels are concentrated in Khartoum.

Construction of the sewerage system for Khartoum, was started in 1954 and completed in 1960. Subsequently expansion work on the system was done to cope with the growth of population and rapid development of the city. Included was the Soba STP which was constructed in 1985 to relieve the original treatment plant, the Goaze STP which had become overburdened.

Presently, the Soba STP has ceased operation due to leakages brought about by damage to the influent rising mains. The general deterioration of facilities, inadequate maintenance, breakdown of pump facilities and sewer pipes, have all caused frequent sewage overflows in the service area. Environmental sanitation conditions in the area are likewise getting worse and it is becoming a very serious social problem.

On the other hand, among economical development plans in the Sudan, improvements in health, sanitation and infrastructure were of highest importance in the past. These environmental sanitation are also one of high priority fields in the policies of the present 4-Year Economic Development Plan.

In response to the situation, the Government of Sudan formulated a master plan in 1981 to promote the development and expansion of the sewerage system. Due to financial constraints, however, only a few of the projects recommended in the master plan were actually implemented. As a result, the Government of Sudan sent a request to the Government of

Japan for grant aid cooperation to help finance and immediately implement rehabilitation of the existing sewerage facilities.

In response to the request, the Japanese Government agreed to carry out a basic design study for rehabilitation of the sewerage system in Khartoum and, subsequently, the Japan International Cooperation Agency (hereinafter referred to as JICA) dispatched a Study Team for 35 days from 19 November to 22 December, 1988.

The mission confirmed the contents of the request and the Project through meetings with concerned officials of the Government of Sudan, after which it studied the feasibility of the Project. The scale of required facilities, basic planning and design policies and equipment requirement were also later discussed.

After the study team return to Japan, a draft of the basic design study report was prepared. It confirms the feasibility of the Project, and incorporates basic design of facilities and equipment and operation-maintenance plan based on analysis and study of results on field survey. Then, JICA dispatched a Study Team from 26 February to 9 March 1989 in order to explain the draft final report. The following contents of the Project were confirmed.

The Project is aimed at restoring the sewerage system to its original capacity and level of efficiency as well as at improving environmental sanitation conditions in the area through rehabilitation of existing facilities.

The Project Area adopted for purposes of the study is the design service area of the existing system which is 1,175 ha. The target year for planning is 1996, or 5 years after forecasted completion of the Project.

Service population and sewage flows used in the design are as follows:

Design service population	: 72,200
Design flow	: 31,420 cu.m/day (average)
Domestic	: 12,620 cu.m/day

Commercial, public facilities : 14,300 cu.m/day
Industrial : 4,500 cu.m/day

Major facilities planned for the Project are pumping stations, rising mains, influent trunk sewers and a treatment plant.

(1) Pumping Station Facilities

Five (5) of the existing 13 pumping stations, namely: No. 1, No. 7, No. 8, No. 12 and No. 14, will require rehabilitation consisting of replacement of mechanical and electrical equipment as well as lighting, safety devices and other auxiliary facilities. Two (2) new pumping stations (No. 20 and No. 21) will be constructed due to integration of the Goaze Sewage Treatment Plant (hereinafter referred to as Goaze STP) with the Soba Sewage Treatment Plant (hereinafter referred to as Soba STP).

(2) Sewage Treatment Plant

The existing Soba STP, which employs the stabilization pond method of sewage treatment, will be utilized as the sole treatment plant for the whole system for ease in maintenance and low operation costs. These ponds are large enough to accommodate the 31,420 cu.m/day design capacity without any need for expansion. However, the influent pumping station, administration building, and generator building will have to be reconstructed and pipes and related fixtures will have to be replaced. Major facilities in the plant consist of the influent pumping station, flow measurement devices, distribution system, 4 units of anaerobic ponds, 2 units of facultative ponds, and 2 units of maturation ponds.

(3) Rising Main Facilities

Existing rising mains which are scheduled to be rehabilitated are the pressure mains from Pump Stations No. 1, No. 7, No. 8, No. 12 and No. 14 (ø150 mm - ø300 mm, length = 3.94 km) and the pressure mains from Pump Stations No. 6, No. 9, No. 10 and No. 15 (ø300 mm - ø600 mm, length = 8.24 km).

(4) Trunk Sewer to Soba STP

A gravity flow type box culvert with inside cross-sectional dimensions of 800 mm x 800 mm and a length of 3 km will be constructed since the Goaze STP was abandoned.

If the Japanese Grant Aid Program is adopted, the period required for all the construction work, which is divided into two overlapping phases of 12 months each, is estimated at total of approximately 23 months.

The estimated cost for the Project borne by Sudan is approximately 21 million Yen or 724 thousand LS.

Exchange Rate : US$ 1.00 = LS 4.50 = 130.53 Yen
LS 1.00 = 29.01 Yen

Contents of the Project in each phase are as follows.

Phase 1

1) Improvement of Pumping Station No. 14
2) Construction of Pumping Station No. 20
3) Improvement of Ponds in Soba STP
4) Replacement of Rising Mains from Pumping Stations No. 1, 6, 7, 8, 14, and 15

Phase 2

1) Improvement of Pumping Stations No. 1, 7, 8, and 12
2) Construction of Pumping Station No. 21
3) Construction of a Trunk Sewer to Soba STP
4) Construction of Influent Pumping Station in Soba STP
5) Replacement of Rising Mains from Pumping Stations No. 9 and 10

Implementation, operation and maintenance of this Project, will be administered and arranged by the National Capital Khartoum.

Being the center of the capital city of Republic of the Sudan, the

corporations, private establishments and it is the largest commercial area in the country. It has, however, a sewerage system which is severely deteriorated and performing at a very low level of efficiency, thus creating a blighted environment and a serious social problem.

Implementation of the Project will restore existing facilities to original capacity and efficiency. It will also improve the living conditions for approximately 72,000 residents and sanitary conditions for about 200,000 office workers who gather at offices in the Project Area, and restrict out breaks of waterborne diseases.

Moreover, a greater volume of treated water from the sewage treatment plant will be made available for reuse as irrigation water in the Green Belt area, thereby promoting an expansion program for the area. The provision of an infrastructure like this Project in the center of Khartoum will not only improve the living environment for residents but will contribute greatly to the stimulation of economic activities and development. It has been deemed therefore, that this Project is beneficial and deserving of a Grant Aid Program from the Japanese Government.

Since the Project places high priority on the improvement of major facilities and fosters urgent rehabilitation of existing facilities, the following recommendations have been made for more effective:

(1) Review and improvement of the Master Plan should be done to determine possible changes in future plans. It is hoped that expansion of the service area is also implemented apart from improvement of the existing service area.

(2) A drainage system for surface run-off should be constructed.

(3) Adequate management of facilities should be effected through augmentation of maintenance personnel and establishment of systematic management procedures.

(4) Sufficient budget should be obtained and set aside for the procurement of necessary spare parts for proper maintenance.

Abbreviation

ABBREVIATION

NCK	:	National Capital Khartoum
JICA	:	Japan International Cooperation Agency
WHO	:	World Health Organization
EPA	:	Environmental Protection Agency, U.S.A.
PPPED	:	Prospects, Programmes and Policies for Economic Development
GDP	:	General Domestic Product
FY	:	Fiscal Year
DO	:	Dissolved Oxygen
pH	:	Hydrogen Ion Concentration
BOD	:	Biochemical Oxygen Demand
COD	:	Chemical Oxygen Demand
SS	:	Suspended Solid
PS	:	Pumping Station
STP	:	Sewage Treatment Plant
cu.m	:	Cubic Meter
LS OR ŁS	:	Sudanese Pound
PVC	:	Polyvinyl Chloride
AC	:	Asbestos Cement

Table of Contents

Basic Design Study Report

on

The Project for Khartoum Sewerage Rehabilitation

in

the Republic of the Sudan

Table of Contents

1. Introduction

CHAPTER 1 INTRODUCTION

Planning for the sewerage system of Khartoum dates back to 1939 when the estimated service population was only 29,000. After some updating and modifications were made on the original plan, construction of the system with design population of 80,000 people started in 1954. The system has been substantially completed and by the period between 1960 and 1963, the entire Ammarat area was sewered. Goaze Sewage Treatment Plant, (hereinafter referred to as Goaze STP), with a capacity of 14,550 cu.m/day was inaugurated and put into operation in 1959 and biological treatment facilities (Biological Filters or Trickling Filters) were added in 1963. Following the growth of population and urbanization of the existing sewered area of Khartoum, sewage influent to Goaze STP increased in quantity. In order to cope with this contingency, a new facility called the Soba Sewage Treatment Plant (hereinafter referred to as Soba STP) which has a capacity of 20,450 cu.m/day and employs the stabilization pond method of treatment was constructed in the South Green Belt Area of Khartoum. Connection of pressure mains from the existing sewer system to this plant was also completed in 1986.

Present problems of the existing sewerage system in Khartoum are:

(1) Existing sewerage system facilities, such as pumping stations, rising mains and sewage treatment plants which were constructed in the 1960s or earlier, have generally deteriorated and therefore are performing at reduced efficiency.

(2) Soba STP has not been used due to frequent leakage of pressure mains.

(3) Stoppage of the operation of pumps and leakages of rising mains often cause overflow of sewage on streets, thereby contributing to the already adverse conditions.

(4) Heavy traffic on some main streets have been disturbed repair works on leaky rising mains.

(5) Raw sewage, which flows into the Goaze STP, passes the plant without any treatment and the effluent conveyed to Green Belt for irrigation use. Some of the raw sewage overflows from the plant and spills into the nearby swamps causing adjoining residents to complain of bad odor, flies, mosquitoes, and other ill-effects.

Under such circumstances, National Capital Khartoum, (hereinafter referred to as NCK), which operates the Khartoum Sewerage System, entrusted a British consulting firm with the study of Sewage System for Khartoum and Omdurman and the construction of a new system on Omdurman. However, due to financial constraints, only small and urgent works were implemented, hence the system has not really functioned as what it has been intended for. This has prompted the NCK to send a request to the Japanese Government through the Government of Sudan in September 1987 for a grant-aid cooperation for immediate and practical solution to the sewage problems.

In response to the said request, the JICA dispatched a basic design study team headed by Mr. Ichiro Setoh, Senior Officer, Urban Development Construction Department of the Japan Regional Development Cooperation for 34 days from November 19 to December 22, 1988. The team reviewed the contents of the plan, held meetings with officials of concerned Sudanese Government agencies and carried out field surveys needed for the formulation of basic design concepts.

Results of the study were recorded and compiled to form the basic framework of the agreement between the two countries which was signed on November 29, 1988 by the leader of the team and Acting Undersecretary of Planning, Ministry of Finance and Economic Planning of Sudan. It is on the basis of the conditions of the agreement that further studies on the detailed technical aspects of the project were performed.

This Report compiles the results of these discussions and studies, as well as the review of the contents of the basic design concepts. Organization, itinerary and records of activities of the team are also attached in Appendix.

2. Background of the Project

CHAPTER 2 BACKGROUND OF THE PROJECT

2.1 Profile of the Country

2.1.1 Physiography and Demography

Republic of the Sudan is located on the northeastern part of the African Continent. Extending approximately 2,250 km from north to south and spanning Latitude 4 N to 22 N, the country has an area of approximately 2.5 million sq.km. The White Nile River and the Blue Nile River which originate in Uganda and Ethiopia, respectively, traverse central Sudan before they join at Khartoum to form the Main Nile River which flows northward to Egypt.

Sudan is bounded by eight countries, namely: Egypt on the north; Ethiopia on the east; Kenya, Uganda and the Republic of Zaire on the south; and the Central African Republic, Chad and Libya on the west. It fronts the Red Sea on the northeast. The country lies mainly on an immense plain ranging from 300 m to 500 m in elevation with mountainous areas rising to 3,000 m on the west. On the northern part are the desert regions with the Nubian Desert and the Libyan Desert occupying the eastern and western portions, respectively. The central part of the country around Khartoum is a fertile alluvial zone while on the south are the tropical rain forest zones.

The country has a population of 21.59 million in 1983 which grew at an annual average rate of 2.9 percent from the period 1973 to 1983. Population count is predicted to reach 34 million by the year 2000.

2.1.2 Administrative Organization

The administrative organization of the Government of Sudan which is headed by a Prime Minister is shown in Table 2-1.

Commissioner General of National Capital Khartoum is a same rank as a Minister.

Table 2-1 Administrative Organization
(December, 1988)

Prime Minister ------

- Ministry of Defense
- Ministry of Agriculture and Natural Resources
- Ministry of Energy and Mining
- Ministry of Industry
- Ministry of Finance and Economic Planning
- Ministry of Irrigation and Water Resources
- Ministry of Education
- Ministry of Social Welfare and Zakat
- Ministry of Cabinet Affairs
- Ministry of Justice and Attorney General
- Ministry of Internal Trade, Commerce
- Ministry of Foreign Affairs
- Ministry of Culture and Information
- Ministry of Youth and Sports
- Ministry of Interior
- Ministry of Health
- Ministry of Works, Housing Planning and Public Utilities
- Ministry of Labour and Social Affairs
- Ministry of Foreign Trade
- Ministry of Public Communication
- Ministry of Local Government
- Ministry of Transport
- Ministry of Animal Resources
- Ministry of Public Service and Administrative Reforms
- Ministry of Religious Affairs and Endowment
- Ministry of Refuge Affairs and Relief
- Ministry of Tourism and Hotels

2.1.3 National Economy

Like in most developing countries, the economy of Sudan is agriculture-based, its principal agricultural activities being cotton-growing. However, unlike some of its African and Middle East neighbors, Sudan is not an oil producing country. In 1981, 78 percent of the working population were engaged in agricultural production of all forms. Agriculture accounted for 35 percent and 31 percent of the Gross Domestic Product (GDP) in 1981 and 1983, respectively. Lately, however, the shares of agriculture in the working population and in the GDP have been on the decline because of 3 years serial drought etc. In the manufacturing sector the operation of factories has likewise slowed down due to the shortage of raw materials and imported parts/components which condition is in turn traced to the scarcity of foreign currency, lack of facilities for power generation, inadequacy of support infrastructure, insufficient number of skilled workers, among other reasons. As a measure to increase productivity of public enterprises, the government is encouraging free enterprise, but even with this move it will take time for the manufacturing industries to get back on the track to growth. This slack in agricultural and industrial production inevitably results to shortfall in the supply of staple food and other basic commodities and consequently to the spiraling of prices.

Suspension of regional development in the southern part of the country has made the economic situation worse. Because of this problem, the government was forced to suspend the development of oil fields which were estimated to produce between 50,000 to 150,000 barrels of crude oil daily. Various other projects were discontinued, including the plan to convert the south Suad Marshland into a large granary, putting to waste (if the civil disorder is not resolved and the projects are not revised) investments already made.

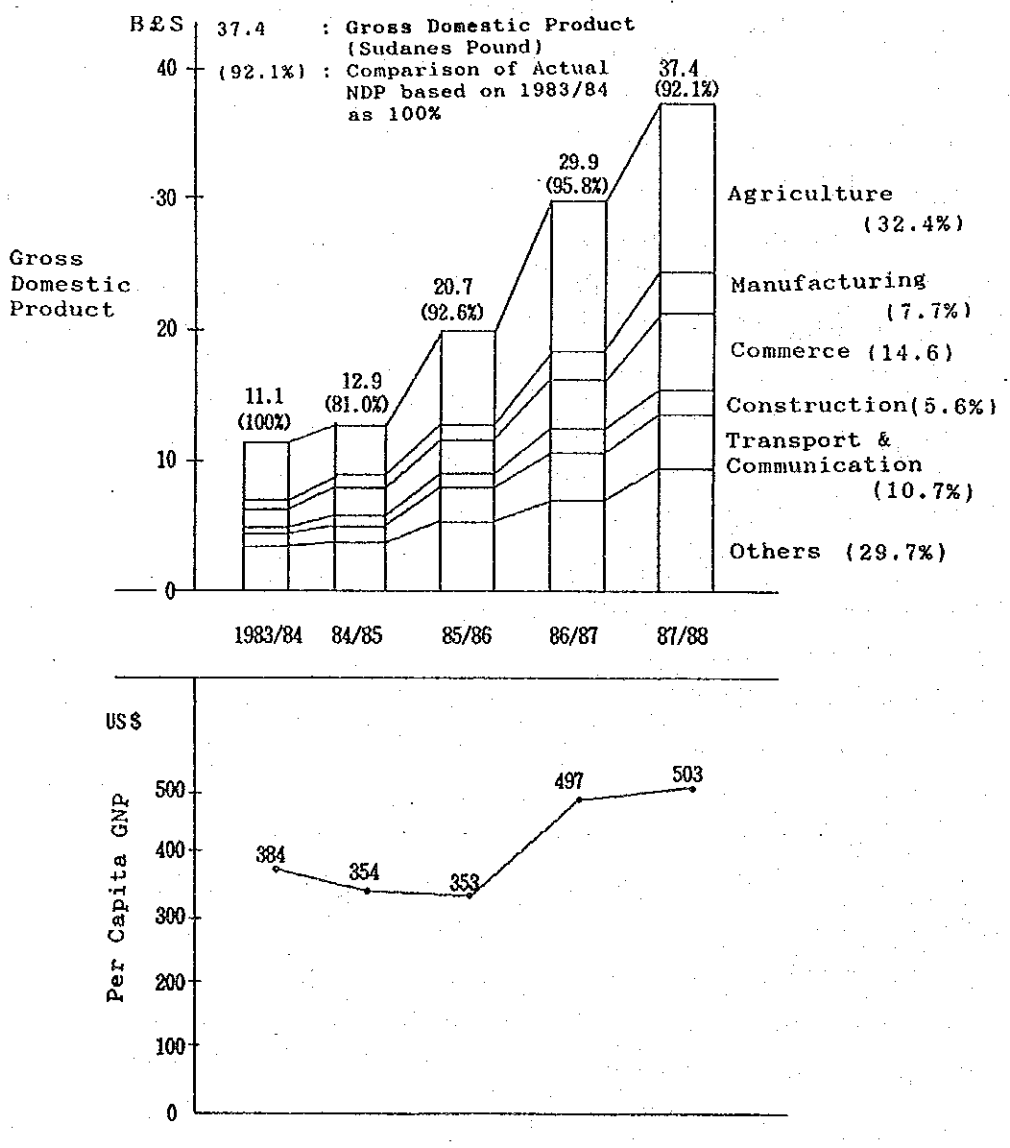
Moreover, the heavy foreign debts incurred by the government to finance ambitious domestic investment plans in the mid-1970s are exerting constant pressures on the Sudanese economy. Because of these onerous obligations, the economic situation continues to worsen even with the leniency of foreign creditors. In spite of the rescheduling of foreign debt servicing on several occasions in the past, the payment of princi-

pals and interest after the rescheduling was still not satisfactory.

Confronted with the three formidable internal and external problems -- the stagnation of agriculture and industry, political unrest in the south and the heavy burden of foreign debts -- the economy of Sudan is seen to continue experiencing difficulties for some time.

Gross domestic product and capital gross national product is shown Figure 2-1. Total exports and import, international balance of payments price index and official exchange rate is shown in Table 2-2, 2-3, 2-4, 2-5 respectively.

Figure 2-1 Gross Domestic Product and Capita Gross National Product



Source : Department of Statistics

Table 2-2 Total Exports and Import (Units: Million ₺S)

	1982/83	1983/84	1984/85	1985/86	1986/87
Exports	1,096	1,307	1,549	1,510	2,133
Imports	2,348	2,185	3,440	3,559	3,848
Balance	-1,252	- 879	-1,981	-2,049	-1,715

Table 2-3 International Balance of Payments (Unit: Million US$)

	1982/83	1983/84	1984/85	1985/86	1986/87
Exports	797	881	832	508	673
Imports	1,621	1,392	1,785	1,237	1,182
Balance	- 824	- 511	- 953	- 728	- 509
Current Balance	- 737	- 439	- 722	- 583	- 435
Total Balance	-1,561	- 940	-1,675	-1,311	- 944

Table 2-4 Price Index (1983 = 100)

	1982/83	1983/84	1984/85	1985/86	1986/87
Price Index	100	142	201.6	282.1	366.8

Table 2-5 Official Exchange Rate (₺S/US$)

November 09, 1981	0.90
November 15, 1982	1.30
October 21, 1984	2.10
February 09, 1985	2.50
October 03, 1987	4.50*

Note: On October 25, 1988, Open Market Rate was newly applied. The rate at the end of November 1988 was 1US$ = 11.50 ₺S.

2.1.4 National Development Plans

Since it was installed as an independent country, Sudan has formulated and carried out the following economic plans: (1) the Three-Year Plan (1957-1959); (2) the 10-Year Socio-Economic Plan (1961-1970); (3) the new 7-Year Development Plan (1971-1977) which was extended for two years from and original five-year plan; and (4) the 6-Year Economic Development Plan (FY 1977-78 to FY 1982-83) which was the first stage of the three-stage long-term plan up to FY 1994-95. None of these plans were realized on the targetted timetable mainly because of the inadequate over-ambitious goals set for them, disorganized and inappropriate economic policies, inappropriate coordination among different government agencies, the oil crisis and other adverse developments in the economic environment. Since 1978, economic management based on austerity measures has been adopted, with an economic stabilization plan implemented under the guidance of the IMF. The country's economic planning has been shifted since FY 1982-83 to the Three-Year Economic Development Master Plan of the annual rolling type in accordance with the economic stabilization plan, virtually suspending the 6-Year Economic Development Plan before its completion.

The period from FY 1982-83 to FY 1984-85 of the Prospects, Programmes and Policies for Economic Development (PPPED-I) was defined as the first plan period. This plan incorporated a Three-Year Public Investment Plan and an economic policy action program, in consideration of a 10-year long-term perspective from FY 1981-82 to FY 1991-92 (during which time a real term GNP growth rate of 5.6 percent was envisaged). The Three-Year Public Investment Plan focuses on: (1) rehabilitation and increased efficiency of existing production facilities, particularly those for agriculture-related industries including the sugar and textile industries, (2) completion of projects under construction, and (3) solution of the problem of inadequate infrastructures which deters the development of export-oriented and import-replacing industries; as well as identifies required projects. The economic policy action program further sets the framework of economic policy for the three-year period.

This framework of economic policy spelled out definitive measures necessary for attaining the following goals: (1) production increase, (2)

improvement of the country's trade balance, (3) stronger control on external debts, (4) demand control and fund distribution, (5) utilization of domestic funds, and (6) revitalization of the private sector, among others.

The target figures were reviewed in the PPPED-II, which was formulated following the first, and also in the fourth Three-Year Plan for Public Investment (plan period - FY 1983-84 - 1985-86), which formed part of PPPED-II.

In this way, the PPPED-II underwent a rolling process one year later, as scheduled. However, the atmosphere for the implementation of the plan was dampened by the long-drawn drought and political unrest in the south. It was during this situation that the PPPED-III was formulated in October 1984.

Public Investment at the 6th 3-Year Program, Sectional Allocation of the 6th 3-Year Program and Sectional Allocation of the 4-Year Program is shown in Table 2-6, 2-7 and 2-8.

Table 2-6 Public Investment at the 6th 3-Year Program

(Unit: Million £S, %)

Item	1984/85 (Actual)*	1985/86	1986/87	1987/88
Investment (Nominal)	453	744	1,027	1,375
Increasing Rate Compared to Year Before	---	48	60	34
Inflation	27	40	30	25

Source: Twenty Sixth Annual Report 1985: Bank of Sudan

Note : Tentative Value

Table 2-7 Sectional Allocation of the 6th 3-Year Program

(Unit: Million £,%)

Field	1985/86 Investment	Rate	1986/87 - 87/88 Investment	Rate	1986/87 - 87/88 Investment	Rate
Agriculture	247	33	648	27	895	28
Manufacturing	44	6	251	10	295	9
Transport & Communication	138	19	475	20	613	20
Energy & Mining	89	12	387	16	476	15
Water Supply	22	3	115	5	137	4
Public Service	72	10	229	10	301	10
Regional Development	92	12	207	8	299	10
Reserve	40	5	90	4	130	4
Total (Nominal)	744	100	2,402	100	3,146	100

Source: Twenty Sixth Annual Report 1985: Bank of Sudan

Table 2-8 Sectional Allocation of the 4-Year Program

(1989/90 - 92/93)

Field	Public Investment (Million £S)
Agriculture	4,157.8
Manufacturing	1,628.9
Energy & Mining	2,657.5
Transport & Communication	2,600.2
Construction & Social Service	4,399.6
Total	15,444.0

2.2 Profile of the Sewerage System in National Capital Khartoum

2.2.1 Administrative Organization

The sewerage system in Khartoum is managed by the Sanitary Engineering Department under the General Manager for Engineering in National Capital Khartoum. The Organization of National Capital Khartoum and the Sanitary Engineering Department is shown in Figure 2-2.

Number of employees of the Sanitary Engineering Department is as follows:

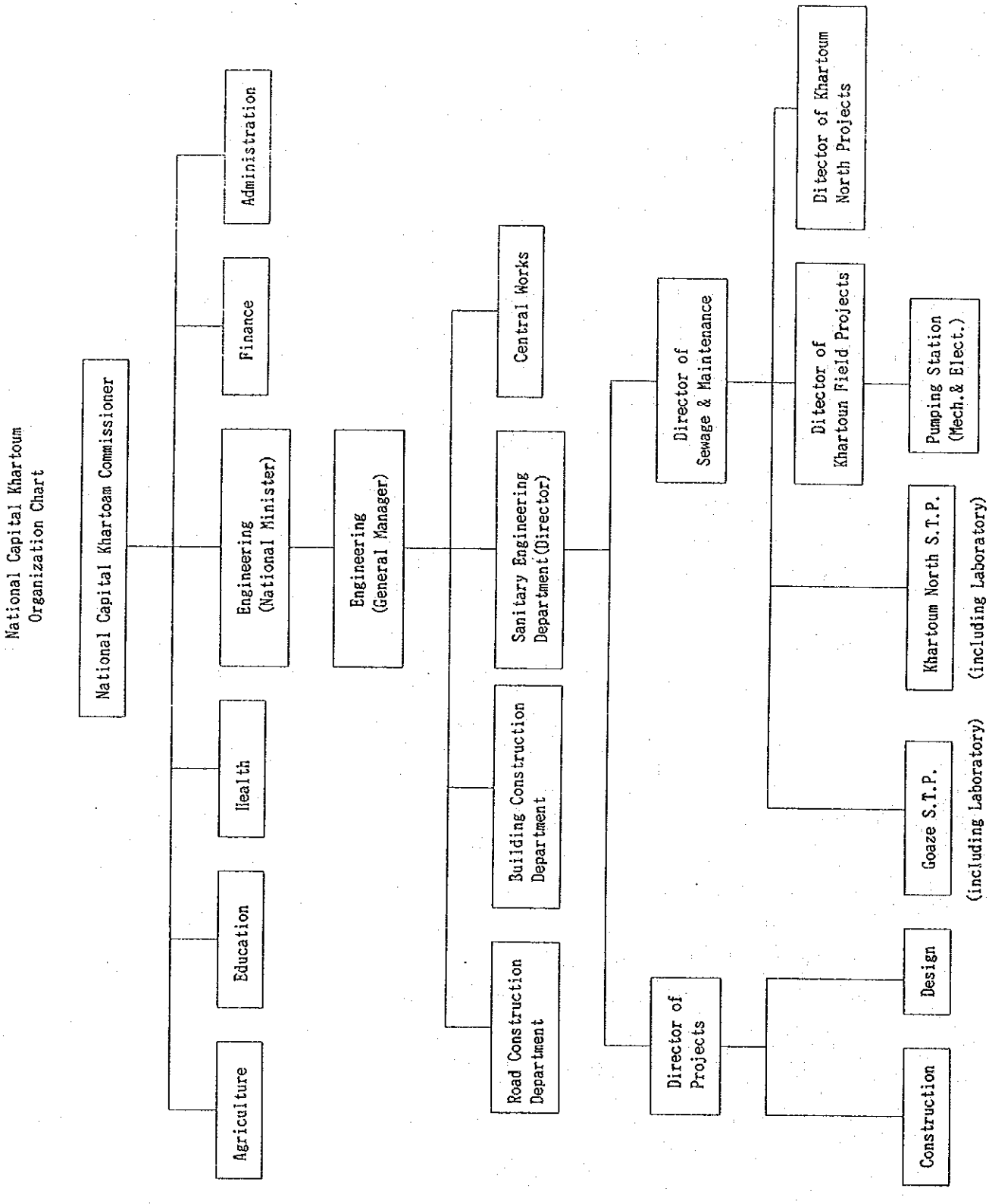
Maintenance and Operation of Collection System and Pump Stations (3 shifts)	130
Goaze Sewage Treatment Plant	117
Engineer and Technician	43
Development Planning	40
Skilled Worker - Mechanical and Electrical	15
Unskilled Worker and Guard	107
Clerk, etc.	24
Driver	40
Khartoum North	87
Total	603

2.2.2 Administrative System and Budget

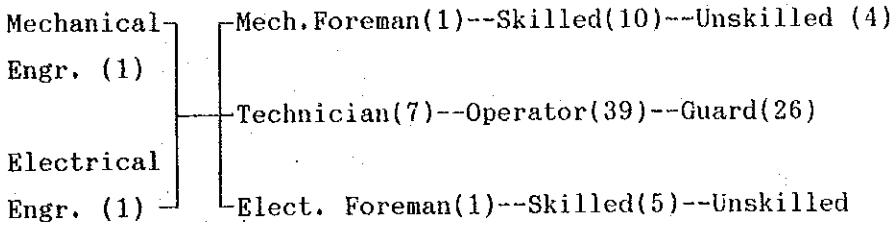
(1) Administrative System

The head office of the Sanitary Engineering Department is located in the center of Khartoum where directors, engineers and clerks work for the total planning, design, administration and management of the sewerage system.

Figure 2-2 Organization Chart

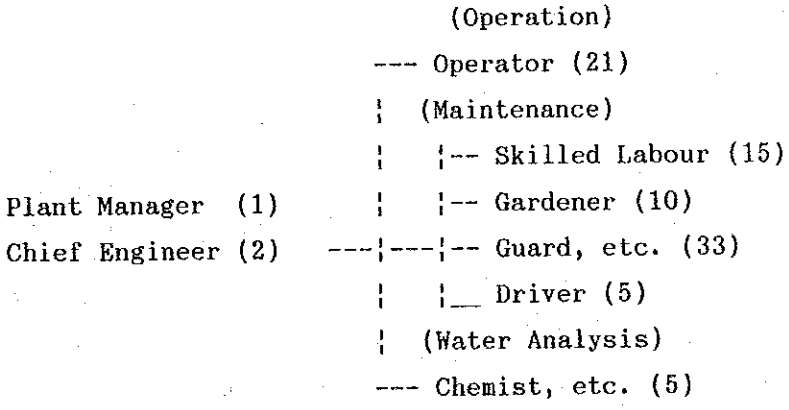


The organizational set-up for the operation and maintenance of pumping stations which is led by electrical engineer is diagramed below:



The 13 pumping stations are divided into four (4) blocks, with each block provided with a regular crew for operation and maintenance purposes. One operation and maintenance group consists of technicians, operators, skilled labours, unskilled labours and guards. Operators work eight (8) hours in three (3) shifts and guards work 12 hours in two (2) shifts.

Goaze STP is headed by a plant manager who is backed up by personnel shown in the organizational diagram below:



Maintenance of sewerage or collection facilities are taken cared of by an organization headed by a civil engineer who is aided by a group of 37 members consisting of a civil foreman, skilled labours and unskilled labours.

(2) Budget

Budgetary items for the Sanitary Engineering Department consists of wages of all employees, office running expenses and expenses for the operation and maintenance of sewerage system in Khartoum North. The budget for the National Capital Khartoum is as follows:

	(Unit: £S)
Maintenance of Pumping Stations	65,000
Maintenance of Sewers	60,000
Maintenance of Gozae STP	40,000
Laboratory in Goaze STP	5,000
Maintenance of Soba STP	20,000
Temporary Labour	3,000
Protective Equipment & Clothing	20,000
Tools	1,400
Others	50,000
Total	304,000

2.2.3 Present Condition of Sewerage Facility

(1) Background

Planning of the sewerage system for Khartoum started back in 1939 when the estimated service population was only 29,000. After updating and modifications on the original plans to suit current conditions, construction of the system with a design population of 80,000 was commenced in 1954. The system was substantially completed and by the period between 1960 and 1963 the entire Ammarat area was sewered. The Goaze STP with a capacity of 14,550 cu.m/day was inaugurated and put into operation in 1959 and biological treatment facilities (Biological Filters/Trickling Filters) were added in 1963. Following the growth of population and urbanization of the existing sewered area of Khartoum, sewage influent to Goaze STP increased in quantity. In order to cope with this contingency, a new facility called Soba Sewage Treatment

Plant with a capacity of 20,450 cu.m/day of the stabilization pond method of treatment, was constructed in the South Green Belt Area of Khartoum. Connection of rising mains from the existing sewage collection system to this plant was also completed in 1986.

(2) Existing Facilities

A general overview and basic information of the existing Khartoum sewerage system are exhibited in Figures 2-3 and 2-4 and Table 2-9. The original design of the sewerage system developed in 1954 made use of the following criteria and considerations:

Service Population	80,000 persons
Flow Per Capita	182 liters/day
Average Daily flow	14,550 cu.m/day
Maximum Rate of Flow	3 times of average daily flow

The Goaze Sewage Treatment Plant has the following features.

Average Daily flow	14,550 cu.m/day
Inlet Works	3 Units Constant Velocity Grit Channels
	2 Units Horizontal Bar Screens
	1 Unit Screenings Washer
	1 Unit Flow Recorder
Primary Sedimentation	4 Units Circular Tanks, 14 m diameter
Biological Filters	16 Units Circular Beds, 32 m diameter
Humus Tanks	4 Units Circular Tanks, 14 m diameter
Sludge Digesters	2 Units Circular Open Tanks, 20 m diameter
Grit Drying Beds	12 Units 20 m x 15 m each

On the other hand, a bird's eye view of the Soba Sewage Treatment Plant is shown in Figure 2-5. It has the following features:

Average Daily Flow	20,450 cu.m/day
Inlet Works	2 Units Bar Screen

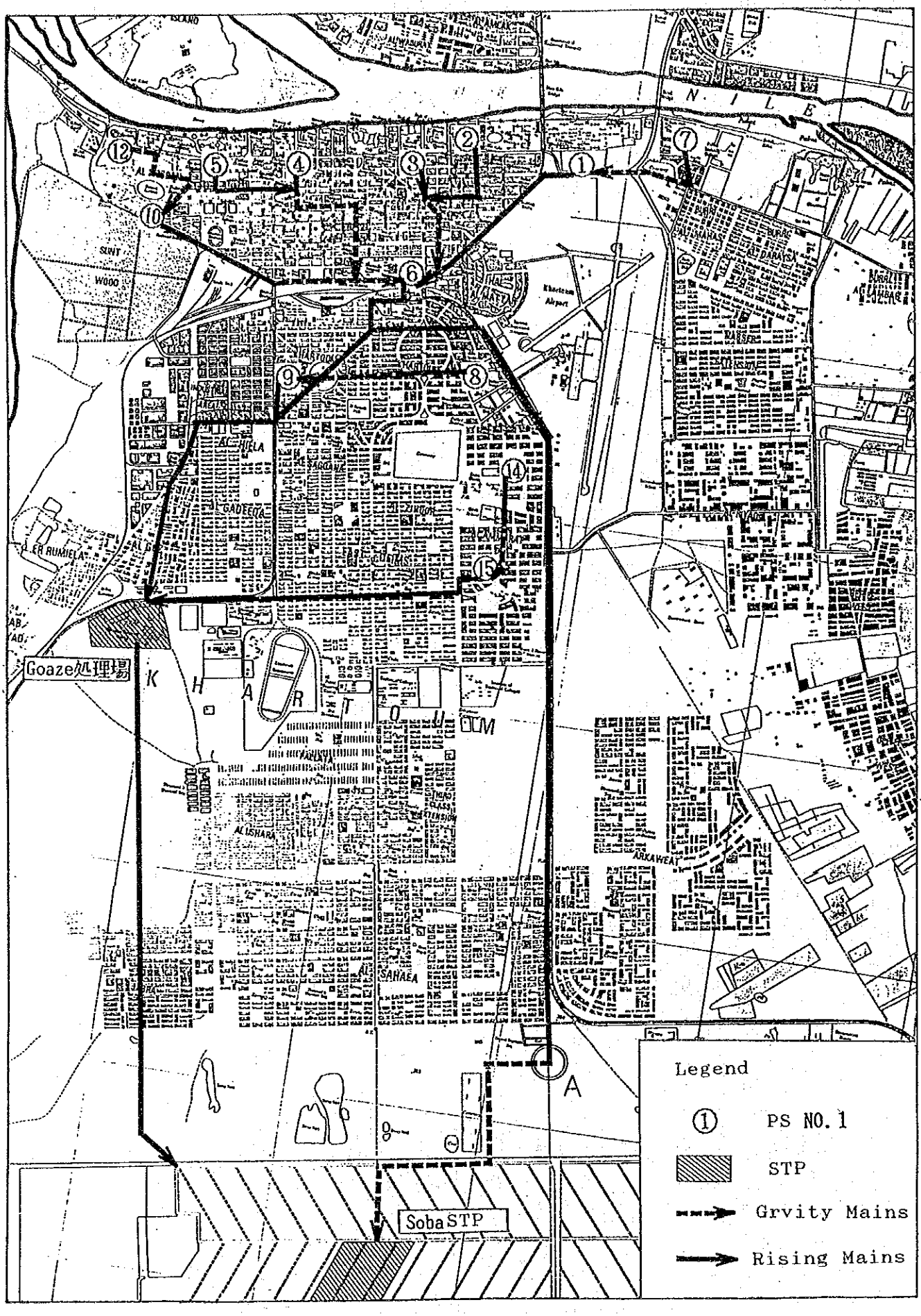


Fig. 2-3 Existing Sewerage system in Khartoum

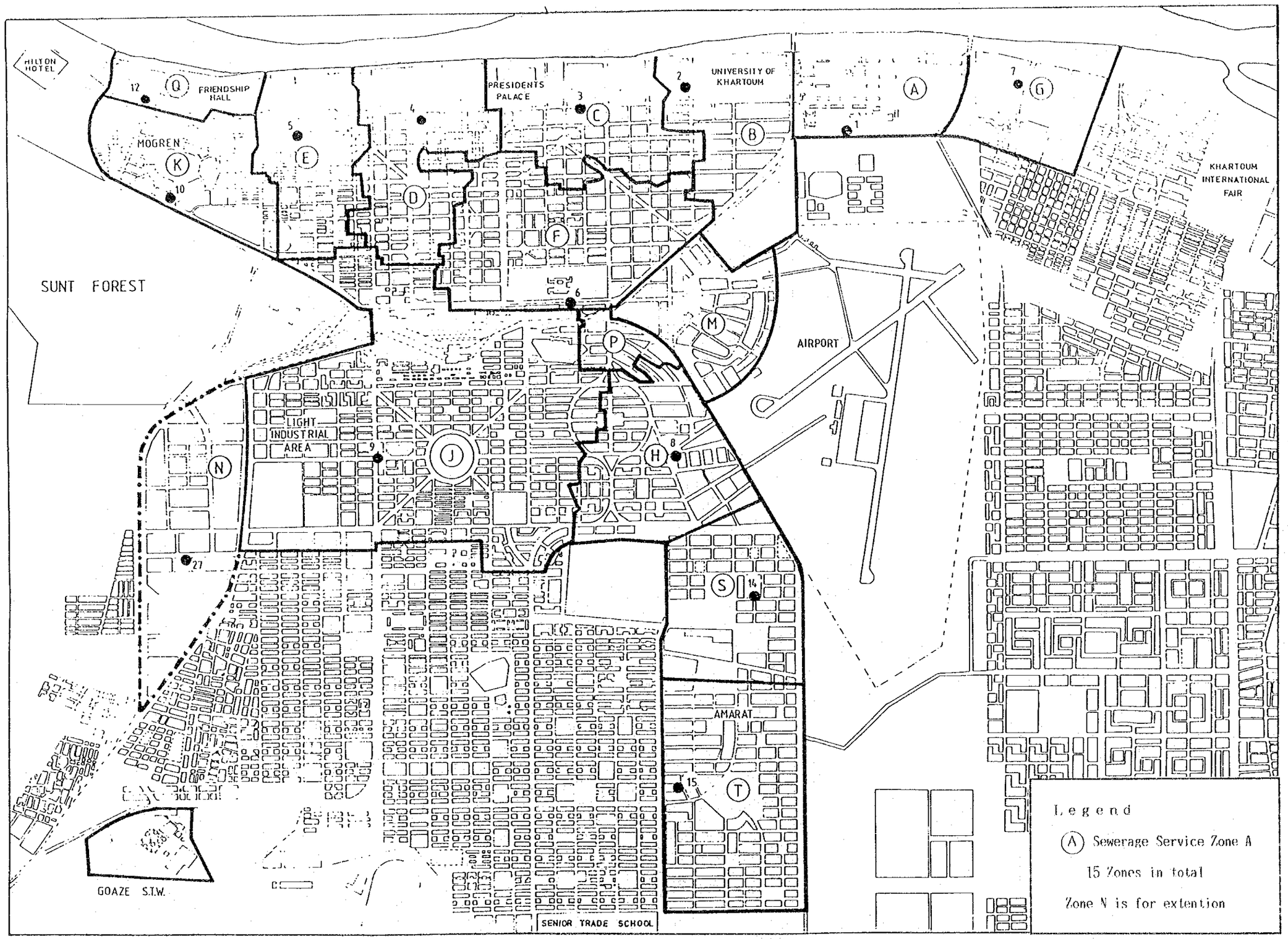


Fig. 2-4 Sewerage Service Zones

Table 2-9 List of Sewers

INVENTORY OF THE SEWERAGE NETWORK

Drainage zone	Zone Area (ha)	Length of Sewer (m) 150	175	200	225	250	300	350	400	450	500	600	700	Number of Manholes
A	32.5	-	1896	-	268	1746	-	-	-		1126	-	-	72
B	89.5	126	4110	-	-	384	633	156	-	-	-	-	-	67
C	77.0	-	7586	-	91	-	400	-	-	-	-	-	-	96
D	79.9	-	8231	-	196	-	252	323	242	82	-	-	-	123
E	61.4	-	5706	-	1123	-	197	-	-	-	-	-	-	96
F	109.0	132	12046	-	268	-	326	1603	201	256	796	731	453	212
G	13.3	-	1396	219	24	-	-	-	-	-	-	-	-	26
H	85.2	-	10825	-	1176	-	-	-	-	-	-	-	-	146
J	280.3	-	32811	124	669	-	1786	1166	695	957	-	-	-	492
K	62.5	-	5955	-	915	73	48	-	-	-	-	-	-	96
M	43.6	-	3940	-	205	-	545	-	-	-	-	-	-	65
P	16.1	-	2307	-	-	-	-	-	-	-	-	-	-	31
Q	17.6	-	393	-	-	658	-	-	-	-	-	-	-	14
S	88.6	-	8563	-	240	-	-	146	-	-	-	-	-	110
T	119.1	-	16906	6	145	173	373	474	179	20	-	-	-	215
Total	1175.4	258	122663	349	5329	3034	4560	3941	1317	1315	1922	731	453	1861

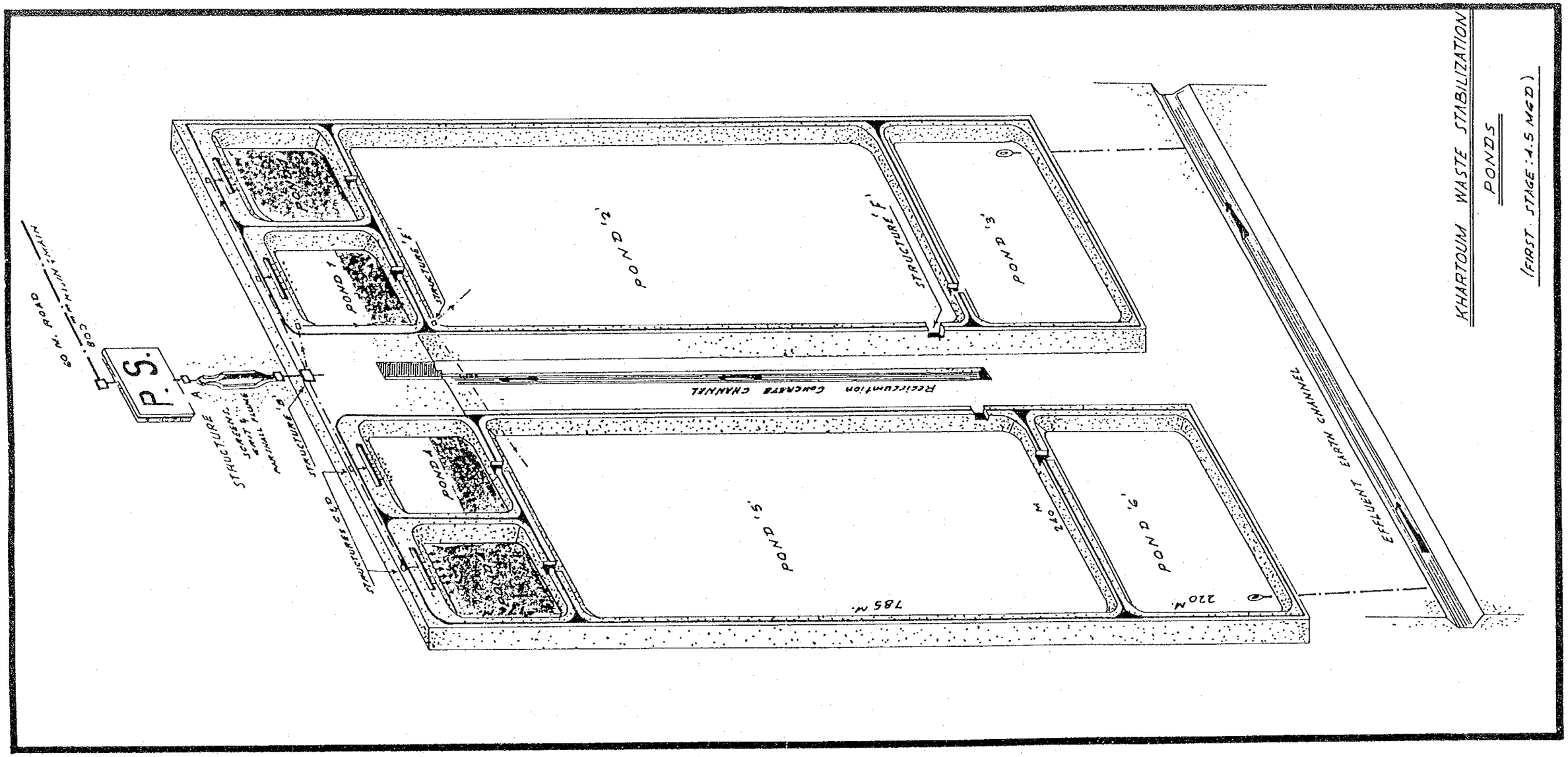


Fig. 2-5 Bird View of Soba STP

1 Unit Flow Recorder

Waste Stabilization Ponds,

2 Units each consisting of:

2 Units Primary Ponds
100 m x 174 m
1 Unit Secondary Pond
240 m x 785 m
1 Unit Maturation Pond
240 m x 220 m

The Pumping Station has the following features:

Pumping Station	Specification & Quantity	Condition
No. 1	1.8 cu.m/min x 13 m x 9.3 kw x 1 unit (V)	Under Maintenance
	3.6 cu.m/min x 19 m x 34 kw x 1 unit (S)	Under Maintenance
	1.8 cu.m/min x 13 m x 9.3 kw x 1 unit (V)	Operation
No. 2	2.1 cu.m/min x 44.4 m x 37 kw x 2 units (V)	Operation
No. 3	2.1 cu.m/min x 44 m x 37 kw x 2 units (V)	Under Maintenance
	2.4 cu.m/min x 11 m x 11 kw x 1 unit (V)	Operation
No. 4	4.5 cu.m/min x 7.6 m x 15 kw x 1 unit (V)	Operation
	6.8 cu.m/min x 7.3 m x 20 kw x 1 unit (V)	Broken
	4.5 cu.m/min x 7.6 m x 15 kw x 1 unit (V)	Broken
No. 5	1.8 cu.m/min x 9 m x 10 kw x 1 unit (V)	Operation
	2.7 cu.m/min x 10.3 m x 15 kw x 1 unit (V)	Broken
No. 6	22.5 cu.m/min x 21.5 m x 145 kw x 3 units (S)	Operation

Pumping Station	Specification & Quantity	Condition
No. 7	0.7 cu.m/min x 10.8 m x 3.7 kw x 1 unit (V)	Operation
	2.1 cu.m/min x 8.5 m x 7.5 kw x 2 units (S)	Operation
No. 8	3.6 cu.m/min x 19 m x 34 kw x 1 unit (S)	Operation
No. 9	9.0 cu.m/min x 18.5 m x 75 kw x 1 unit (V)	Broken
	6.3 cu.m/min x 19.8 m x 45 kw x 1 unit (V)	Operation
No. 10	1.8 cu.m/min x 12 m x 9.3 kw x 2 units (S)	1 unit, Operation 1 unit, Broken
No. 12	0.9 cu.m/min x 8 m x 3.7 kw x 1 unit (V)	Operation
No. 14	2.7 cu.m/min x 35 m x 30 kw x 1 unit (S)	Under Maintenance
	1.8 cu.m/min x 16 m x 13.5 kw x 1 unit (S)	Broken
	1.4 cu.m/min x 9.5 m x 11 kw x 1 unit (V)	Operation
No. 15	4.1 cu.m/min x 21 m x 35 kw x 1 unit (V)	Operation
Soba	26.8 cu.m/min x 20 m x 151 kw x 2 units (S')	1 unit, Operation 1 unit, Broken

Note: V - Two-floor type vertical shaft centrifugal pump
S - Dry well type submersible pump
S' - Submersible pump

(3) Present Problems

1) Existing sewerage system facilities such as pump stations, pressure mains and sewage treatment plants which were constructed in the 1960s have generally deteriorated and therefore are performing at reduced efficiency.

2) Frequent leakages of pressure mains to the Soba STP cause suspension of the plant operation.

3) Stoppage of the operation of pumps and leakages of rising mains often cause overflow of sewage on streets, thereby contributing to the already adverse sanitary condition.

4) Heavy traffic on some main streets have been disturbed repair works on leaky rising mains.

5) Raw sewage which flows into the Goaze STP passes the plant without any treatment, with the effluent conveyed to Green Belt for irrigation use. Some of the raw sewage overflows from the plant and spills into the nearby swamps causing adjoining residents to complain of bad odor, flies, mosquitoes and other ill-effects.

2.3 Profile of Sewage-Related Facilities

National Capital Khartoum comprises of Khartoum (the Project Site), Omdurman and Khartoum North. Omdurman has no sewerage system while Khartoum North has an existing system mainly for industrial wastewater.

Having four (4) pumping stations and a sewage treatment plant, the facilities in Khartoum North were originally designed in the 1960's and constructed early in the 1970s through assistance from the USAID. In 1974, the second phase of construction was planned with all equipment and material supplied through a grant aid from West Germany. The Sudanese Government however, could not provide enough budget to commence construction work, so all supplied materials have been kept in storage for more than ten years. At the moment, the German Consultant, which developed the original design, is studying ways and means for the effective utilization of these idle materials. The existing plant uses sedimentation and biological treatment methods such as the oxidation pond, which at present conditions is inadequate for treatment of wastewater. This is so because wastewater from factories is not pre-treated before it leaves the factories, hence treatment requirements is in.pa creased well above the original design values. Moreover, the lack of pre-treatment in factories allows inflow of strong pollutants which

cannot be removed by sedimentation and biological treatment.

2.4 Sewerage Projects Financed by International Aid

The following are on-going or proposed foreign-assisted sewerage projects in Khartoum and Khartoum North:

Project Site	Donor	Scope
Khartoum North	Arab Development Bank	Review of Expansion Project for Sewerage System
Khartoum	Arab Development Bank	Improvement of Pumping Station
Khartoum	Japanese Grant Aid (Proposing)	Sewerage Rehabilitation (Sewers, Pumping Stations and Sewage Treatment Plants)

2.5 Background and Content of the Request

2.5.1 Background of the Request

Construction of the sewerage system for Khartoum started in 1952, with the old downtown area as its initial coverage. Then followed the construction of the Goaze Sewage Treatment Plant in 1959. Since that time, the government has expanded the sewerage system and constructed the new Soba Sewage Treatment Plant in 1985 in order to cope with expansion of commercial and residential areas and increase in population. Presently, however, the condition of the sewerage system has deteriorated; pipes are damaged and clogged at many sections throughout the system. Consequently, the Soba Sewage Treatment Plant is out of commission. The Goaze Sewage Treatment Plant is not effectively operating because of its declining efficiency and the increased sewage inflow volume. Moreover, environmental sanitation conditions in the downtown area of the city has grown worse due to the overflow of sewage.

The Khartoum Master Plan for Sewerage was prepared by British consultants, Watson Hawksley in 1981. The government has taken every possible

measure to implement the program, but only a small portion of the program has so far been implemented due to budgetary constraints. To improve the present condition of the sewerage system in Khartoum, the Government of the Republic of Sudan requested for a grant-aid cooperation to finance the required rehabilitation works on sewerage system including pumping stations and sewage treatment plants.

2.5.2 Scope of the Request

The scope of work of the project as stipulated in the request for the Japanese grant-aid cooperataion on September 1987 is as follows:

(Phase I)

(a) Modification of pipe work at No. 6 Pump Station.
(b) Installation of new electrical switchgears and controls at all pump stations.
(c) Construction of new main sewers at western part of Zone J.
(d) Modification of pressurized main sewer.
(e) Provision of lighting and safety access ladders for all pump stations.
(f) Provision of sump pumps.
(g) Rehabilitation of Goaze Sewage Treatment Plant
    - o Pumps (sludge pumps, final effluent pumps, recirculating pumps, grit pumps)
    - o Rotating arms of biofilter
    - o Flow meter for raw sludge and final effluent
    - o Sludge scrapers (primary sedimentation and humus tanks)
    - o Grit chamber structure
(h) Equipment, instruments and chemicals for laboratory at Goaze Treatment Plant.
(i) Rehabilitation of PS Nos. 1, 7, 8, 12 and 14
(j) Pressure main of PS Nos. 15 to Goaze Sewage Treatment Plant
(k) Pressure main of PS No. 1 to PS No. 6

(Phase II)

(l) Construction of new pumping station on pressure main from PS No. 6

which is 4.5 km from Soba Sewage Treatment Plant.

Average flow : 20 MGD

Peak flow : 30 MGD

(m) Construction of pressure main for 4.5 km length from the above mentioned pump station to Soba Sewage Treatment Plant.

(n) Rehabilitation of Soba Sewage Treatment Plant.

3. Overview of the Project Site

CHAPTER 3 OVERVIEW OF THE PROJECT SITE

3.1 Location

Khartoum is located at the confluence of the White Nile River and the Blue Nile River, on coordinates 15° 36'N Latitude and 32° 33'E Longitude. It lies on the eastern central part of Sudan, about 380 metres above sea level. More specifically, Khartoum forms part of and is situated in the southern part of the so-called National Capital Khartoum, together with the Khartoum North and Omdurman districts.

3.2 Level of Development and Population

Khartoum is the site of many governmental offices, foreign embassy, banks, offices of public and private companies, hotels and other urban and business establishments. The existing sewerage system in Khartoum covers largely government and commercial office areas and first class residential areas, as well as some second class residential areas and industrial areas. The presence of the various offices, particularly, increases considerably the daytime population.

The trend of population growth for each district of National Capital Khartoum is as follows:

Year	Khartoum	Omdurman	Khartoum North
1955-56	97,516	116,231	46,852
1964	173,500	185,380	80,010
1973	333,906	299,399	150,989
1983	476,267	526,337	341,187

3.3 Natural Conditions

The weather in Khartoum is generally hot and dry except during the rainy season from July to September. The period from April to June, especial-

ly, is characterized by daytime temperatures often rising to more than 50 degree Centigrade and by the occurrence of sandstorms locally known as "Habib". Summary of monthly rainfall, relative humidity and monthly mean rainfall in Khartoum for the year 1975, 1980, 1985 and 1988 are shown in Table 3-1.

Majority of the area lies on within elevations ranging from 379 m to 383 m above sea level, with high points of about 385 m on the south.

Table 3-1 Total Monthly Rainfall, Relative Humidity and Monthly Mean Temperature

Month	Total Monthly Rainfall (mm)				Relative Humidity (%)				Monthly Mean Temp. (°C)			
	1975	1980	1985	1988	1975	1980	1985	1988	1975	1980	1985	1988
January	TR	0	0	0	27	23	25	29	22.5	23.9	26.1	23.3
February	0	TR	0	0	20	18	17	26	26.5	24.9	22.8	24.5
March	0	TR	0	0	18	13	15	21	28.9	29.7	30.1	29.8
April	0	0	0	0	23	11	13	15	31.5	33.0	31.4	32.5
May	H.2	0.7	9.1	TR	18	18	25	19	34.6	35.1	34.3	35.7
June	TR	H.2	3.1	TR	28	29	30	30	33.9	34.1	33.9	35.1
July	0.9	60.5	16.4	65.9	37	54	41	42	32.5	31.3	31.9	31.9
August	50.1	19.2	0.3	301.4	61	47	39	59	29.5	31.7	32.7	29.9
September	47.8	11.0	9.9	46.3	53	47	37	51	30.9	33.5	33.1	32.0
October	0	1.2	0	1.9	28	24	23	27	32.1	33.1	33.2	32.7
November	0	0	0	X	16	23	23	X	29.2	27.9	28.1	X
December	0	0	0	X	33	30	31	X	23.8	24.6	24.7	X

TR: Trace (X): Not Available

The geologic composition of the substrata in the area proposed as the site for new pumping stations is the Gezira formation. This geologic formation extends 40 m to 50 m deep in the areas south of Khartoum and has an average depth of 20 m in Khartoum.

The Gezira formation consists of a sequence of interbeded clay, silt and gravel and can be divided into two layers as follows:

(1) Upper layer - dark gray to brown and yellowish clay and silt, sometimes sandy and gravelly, kankar horizons being common; and

(2) Sandy layer - sand with interfingering silt and clay lenses, occasionally gravel and with kankar in thin beds only.

The Gezira clay is hard and very strong in its dry stage but becomes very highly plastic with much of its strength lost when wet. It expands when wet and contract when dry and is likely to cause construction problems during the rainy season.

Hydrogeologic and hydrologic patterns and records of extreme occurrences are given as follows:

(1) Groundwater levels in a particular area depend upon its distance from either of the two Nile rivers, that is, the groundwater level is shallow if the place is near the river and is deeper as the distance from the river increases.

(2) Water level of the Nile rivers begins its gradual rise from July and reaches its peak in late August. It starts to recede in September with the lowest level usually occurring in March.

(3) For the period from 1970 to 1979, the highest recorded water level elevation of the White Nile River was 379.86 m and that of the Blue Nile River was 380.14 m. Khartoum was flooded in both instances, the average river bank elevation being only around 379.00 m above sea level.

3.4 Health and Sanitation Conditions

Statistics on the number of cases of epidemic diseases from October 1988 are listed in Table 3-2 below:

Table 3-2 Number of Cases of Epidemic Diseases
October 1988

Diseases	Khartoum	Omdurman	Khartoum North	Total
Dysentery	375	-	-	375
Leashmania	73	-	-	73
Whooping Cough	5	18	-	23
Measles	1	25	3	29
Mumps	84	212	16	312
Chicken Pox	1	2	-	3
Tetanus	-	-	-	-
Typhoid	50	37	149	236
Infectious Hepatitis	82	88	48	218
Diptheria	-	-	-	-
Malaria	3,486	5,923	1,946	11,355

Heavy rains in August 1988 caused flooding, huge damage to property and destruction of houses. Prolonged stagnation of flood waters has caused the breeding of malarial mosquitoes resulting to the alarming incidence of malaria as shown in Table 3-3. The excessive storm run-off aggravated by poor drainage facilities has also caused the overflow of sewage and the spread of water-borne diseases.

In the northern part of Khartoum, where many houses and offices are concentrated, has deteriorated heavily due to poor maintenance caused by lack of spare parts, technology and organization. As a consequence, all pumping stations are overloaded, sewage flooding caused by leaking rising mains is often experienced. The Goaze STP is so completely deteriorated that the water that leaves the plant has the same quality as the raw sewage. Some factories on the northwest discharge their

wastewater without any treatment and some illegally constructed houses have no adequate toilet facilities. The present health and sanitary condition is therefore quite poor so that some urgent improvement programs should be considered.

Number of case of epidemic diseases and the dead in NCK is shown in Table 3-3.

Table 3 – 3 Number of Cases of Epidemic Diseases and the Dead in NCK

YEAR	1985		1986		1987	
Diseases	No. of cases	No. of the Dead	No. of cases	No. of the Dead	No. of cases	No. of the Dead
Dysentery	80,000	572	85,000	600	65,000	300
Leashmania	599	5	—	—	—	—
Whooping Cough	—	—	—	—	—	—
Measles	1,346	67	—	—	—	—
Mumps	—	—	—	—	—	—
Chicken Pox	—	—	—	—	—	—
Tetanus	64	21	87	1	590	145
Typhoid	400	134	200	10	150	36
Diptheria	85	19	128	3	—	—
Malaria	4,047	225	33,926	102	150,000	141

3.5 Infrastructure

3.5.1 Utilities

(1) Electricity

The electric power supply of Khartoum is being operated by the National Electric Corporation (NEC) and the existing pumping stations and sewage treatment plants as well. Power outages, which occur about 3 times a week for a period of around 3 hours each time, are often experienced. To cope with these emergencies, some shops, hotels, first class residences and offices have their own stand-by generators to avoid inconvenience.

Before, some existing sewerage facilities had their own generators such as the 250 KVA in Goaze STP, the 500 KVA in Soba STP and in Pumping Station No. 6, among others. The budget for the procurement of spare parts is limited, hence damaged generators remained unrepaired except the one in Pumping Station No. 6.

Following the increase of demand for electricity in Khartoum, condensers for power-factor improvement were installed to prevent voltage drop in the distribution lines.

(a) Power Source

(i) Incoming Voltage

In Goaze STP, Soba STP and Pump Stations No. 1, No. 6 and No. 8, the electric power drop from 11 KV to 433 V/250 V is effected through transformers and then distributed to nearby houses. Pump Stations No. 7, No. 12 and No. 14 power is supplied by distribution lines (415 V/240 V).

(ii) Voltage and Frequency

415 V/240 V (3 phase, 4 lines), 50 Hz

(b) Electric Rate Schedule

(i) Houses

Basic Charge

: Single Phase 2.5 ŁS/Consumer/Month

Three Phases 7.5 ŁS/Consumer/Month

Charge for Used Amount

: Under 75 kwh	0.15 ŁS/kwh
75 kwh to 200 kwh	0.19 ŁS/kwh
200 kwh to 500 kwh	0.36 ŁS/kwh
over 500 kwh	0.60 ŁS/kwh

(ii) Public Use (Under 100 KVA)

Basic Charge : 7.5 ŁS/Consumer/Month

Charge for Used Amount

: till 250 kwh	0.26 ŁS/kwh
250 kwh to 1000 kwh	0.23 ŁS/kwh
over 1000 kwh	0.22 ŁS/kwh

(iii) Agricultural Use (More than 100 KVA)

Basic Charge : 3.0 ŁS/H.P./kwh

Charge for Used Amount

: 0.18 ŁS/kwh

(iv) Factories

		High Voltage (LS/KVA)	Low Voltage (LS/KVA)
Basic Charge :	Per Service Capacity	1.5	1.5
	Per Maximum Demand	4.5	4.0
Charge for Used Amount :	Under 30,000 kwh	0.21	21
	30,000 kwh to 80,000 kwh	0.19	20
	80,000 kwh to 130,000 kwh	0.18	19
	Over 130,000	0.17	18

(2) Telephone

Telephone facilities in Khartoum are deteriorated and lines are limited, so only some hotels, first class residences, offices and public users are equipped with this convenience. Most sewerage facilities either have no telephones or their sets are out of order. Hence, even if telephone is available, communication between the main sewerage system office and field offices would be difficult especially in emergencies.

(3) Water Supply

The water supply of Khartoum is being operated by the National Urban Water Corporation (NUWC). Water supply distribution is often suspended because of the acute water shortage caused mainly by rapidly growing demand. The design of pumping stations, there fore, must provide for safeguards to avoid suspension of water for pumps.

In the Soba STP, water supply is not a problem since the source is located within the plant site, the STP being located far from the existing service area of the NUPC.

(4) Gas and Other Fuels

There are no gas supply lines in Khartoum. Gas cylinders of liquefied petroleum gas or wood are used as fuel. Liquified petroleum gas or electricity will be used as heat source in this Project, such as for domestic purposes and water analysis in the administration building of Soba STP.

3.5.2 Transportation of Equipment and Materials

The unloading port for imported equipment and materials for this Project will be in Port Sudan which fronts the Red Sea. Based on experiences, unloading and customs clearance require quite a long period of time. Another long period is needed for inland transportation from Port Sudan to Khartoum because of distance and poor condition of roads.

4. Outline of the Project

CHAPTER 4 OUTLINE OF THE PROJECT

4.1 Purpose of the Project

This Project aims to improve the health, sanitation and living environment of the residents of Khartoum, by rehabilitating its existing sewerage system. To achieve the given objective, the superannuated pumping stations and some related sewers will be repaired. The existing Goaze and Soba sewage treatment plant will be rehabilitated with the assistance of grant aid from the Government of Japan.

4.2 Study on the Project

4.2.1 Study on the Proposed Project

(1) Request for Grant Aid

The proposed project described in the technical aid proposal which was submitted to the Government of Japan by the Government of Sudan on September 1987 is as shown in 2-5-2.

(2) Basic Policy of Project Components

After discussion with the Sudanese Government, the following basic policies regarding the project components were determined with consideration given as the results of the field study.

(a) This is an improvement project for the existing facilities. Therefore, the scope of the basic design shall be limited to the items with the highest priority.

(b) Facility planning shall be efficient and economical to perform the improvements rapidly.

(c) Planning shall provide for maximum utilization of the existing sewerage facilities.

(d) In preparing the facility planning and operation system, the natural conditions, social and economic circumstances, local electric supply conditions and maintenance situation shall be taken into consideration.

Following the above mentioned basic policy, the study and evaluation on the capacity of the Khartoum Sewerage System (existing sewers, pump stations, treatment plants) will be carried out and the facilities requiring rehabilitation and modification will be selected.

Contents of the proposal and result of field survey is shown in Appendix. Existing sewerage system in Khartoum is shown in Figure 2-3.

(3) Evaluation of existing system

1) Goaze STP

The present status of Goaze STP is as follows:

(a) All mechanical and electrical facilities are superannuated and a large part of them are out of order and have been shut down. All these facilities need to be rehabilitated.

(b) Plumbings and sewer lines can be used with some modifications, but sludge lines are heavily damaged and clogged so these need to be replaced.

(c) The grit chamber and bio-filter are corrupted and civil structures are broken in some portions, thereby needing some repairs.

(d) Treated sewage is sent to the irrigation canal in Green Belt near the Soba STP by an effluent pump.

(e) Although the maintenance costs are shouldered by Sudan, difficulties will still be encountered in enforcement of proper maintenance of the rehabilitated plant with existing treatment methods.

The rehabilitation work of the Goaze STP under the ordinary operation will be very expensive and as mentioned in item (e), the maintenance and management level of this country bring doubts on how long the rehabili So, the most suitable plan will be determined by the comparison study regarding economy and difficulty in operation and maintenance, etc. for the two cases described below.

Case 1. Goaze STP rehabilitation plan

Case 2. Goaze STP abolition, Soba STP integration plan. (Including the construction works of new pumping station at Goaze, gravity main from Green Belt to Soba STP, and site work of new Soba STP)

The following table shows comparison of two cases.

Unit : Thousand Yen

	Case 1	Case 2
Construction Cost	Goaze STP Rehabilitation STP C 60,000 STP A 55,000 STP M 1,000,000 STP E 145,000 Work shop 10,000 Analysis room 10,000 Spar parts 60,000 Total 1,340,000(1.52)	a) Goaze Pumping Station C・A 40,000 M 90,000 E 78,000 Sub-total 208,000 b) Green Belt～Soba Trunk sewer 339,000 c) Soba Pumping Station C・A 45,000 M 120,000 E 81,000 Sub-total 246,000 d) Administration office, Work shop, Ware house 50,000 e) Site work 10,000 f) Tools, Spare parts, Chemicals etc. 30,000 合 計 883,000(1.00)
Evaluation	△	○

Note : C : Civil, A : Archtect, M : Mechanical, E : Electrical

	Case 1	Case 2
Difficulty in Maintenance	- Large number of maintenance crew with high technical level will be required.	- Large number of maintenance crews are not necessary, and maintain works can be done with low technic level.
	- Maintenance works during the operating time, will be concerned with various facilities such as sedimentation tank, bio-filter and sludge instruments, and these works must be done surely and periodically.	- Operation and maintenance works for instruments and equipmen are only for the inlet pumping station and other works are such as site weeding and removal of algae.
	- The drawing, digestion, drying works of sedimentded sludge must be always done and its volume will be large.	- The volume of sludge will be small, and its removal work will be needed every 2 to 3 years.
	- Ensurement of spare parts and repair for various mechanical and electrical equipment will be needed.	- Mechanical and electrical equipment are installed only in the inlet pumping station and their repair and spare parts are the same grade as other PS.
	- A bad odor is heavy and hearth flies will breed.	- Though the bad odor is relatively light, breeding of mosquitoes must be taken into concideration.
Evaluation	△	◎
Maintenance Cost	Electricity 143,000 LS/year	Electricity 164,000 LS/year
	Labour Fee 94 persons (Existing) 243,000 LS/year	Labour Fee 49 persons (Designed) 131,000 LS/year
	Repair, etc. 276,000 LS/year	Repair, etc. 29,000 LS/year
	Total 662,000 LS/year	Total 324,000 LS/year
Evaluation	△	○
Total Evaluation	×	◎

So, the rehabilitation work for Goaze STP shall be abandoned because of the low return of investment. Instead of this, a new pump station (No. 21) will be built and the existing rising main, by which the treated water is sent to the Green Belt near the Soba STP from the effluent pump, will be diverted. From Green Belt to the Soba STP, the sewage will flow through the newly built gravity main. Therefore, all sewerage facilities will be integrated and sewage will be treated at Soba STP.

2) Soba STP

Although the Soba STP was inaugurated in 1986, breakdown has often occurred at rising main from Pump Station No. 6 and cannot be operated now. Treatment method used is lagoon method and two series were constructed. The treatment flow in one series is as follows:

Anaerobic Facultative Maturation
Pond (2) --> Lagoon (1) --> Pond (1)--> Effluent (1)

Beaoued nandaenbdednceAbse bbenidõneeforandlodgstributtbn dckambes

which measure and divide the sewage from the lifting pump were superannuated. Due to their simple structure, accurate distribution cannot be expected from them.

Tightening and smoothing the dike and the replacement of the distribution device is needed. While the pump station is in proper operation and the generator can be used once the starter is repaired.

3) Pumping Stations

There are 13 pumping stations in Khartoum. Among them, pumping stations Nos. 4, 5, 9, 15 are under rehabilitation using Arab funds and Nos. 2, 3, 10, 12 are also under rehabilitation made possible by the donations of a private company. Both projects aim for completion by 1989-1990.(Details are shown in Appendix)

The largest pumping station No. 6, which pumps a large part of the sewage of Khartoum to Goaze STP, is in good operating condition. Pumping stations Nos. 1, 7, 8, 12 and 14, which are the scope of this rehabilitation project, had no countermeasures considered. All of the mechanical and electrical equipment have deteriorated and other pumps are left unrepaired since one pump which has not corroded has been running. All of the mechanical, electrical, lighting and ventilating equipment must be changed.

"New pumping station on rising main from Pump Station No. 6, which is a 4.5 km from Soba STP" in the request for the Project is indicated as point A in Figure 2-3 and at this point, the rising main is converted into gravity main. The necessity of this pump station must be studied considering the pumping capacity of Pump Station No. 6. But the location of the pump station must be in the middle of the rising main from Pump Station No. 6 to Soba STP, instead of the starting point of the gravity main (point A).

4) Rising Main

Asbestos cement pipe is used for the rising main. But this pipe often causes the breakdown due to their fragile structure. It also provides a serious hindrance to the operation of the pump stations. Routes where leakages or breakdowns usually occur as observed in Khartoum are as follows:

(i) Pumping Station No. 2 --> Manhole F187
(ii) Pumping Station No. 3 --> F187
(iii) Around Pumping Station No. 5
(iv) Pumping Station No. 6 --> Y-connection
(v) Pumping Station No. 15 --> Goaze STP

These asbestos cement pipes should be removed and other stronger pipes (Ductile Cast Iron Pipe) be used to replace them.

Systematic diagram of pumping stations and rising mains is shown in Figure 4-1 and comparison table of pumping materials is shown in table 4-1.

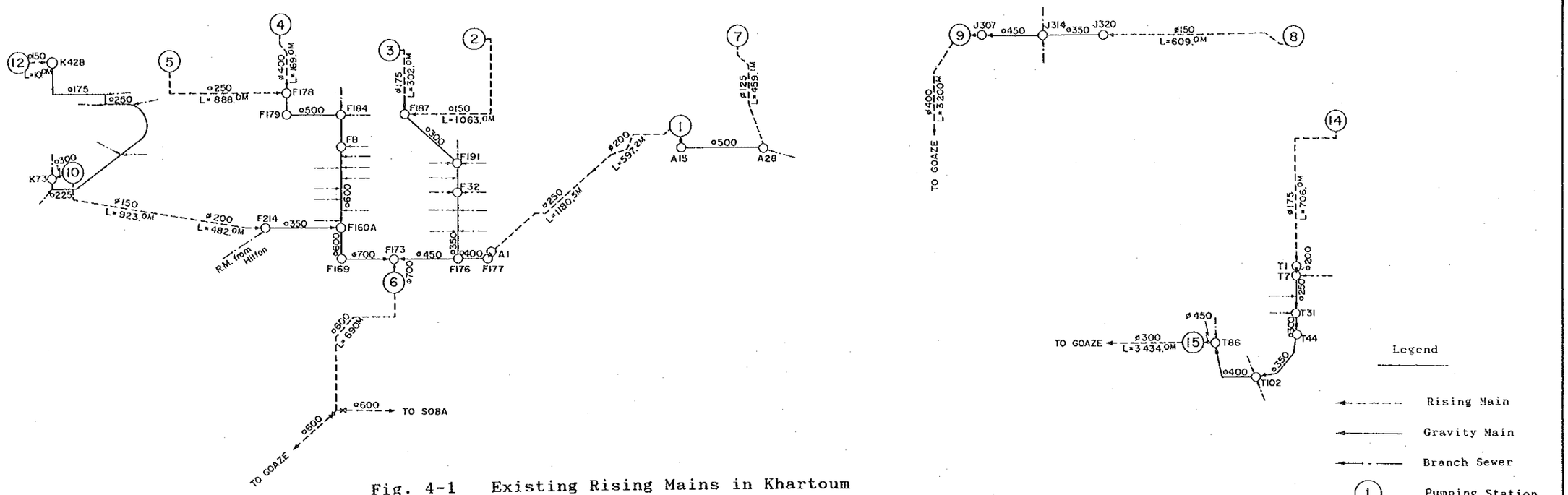


Fig. 4-1 Existing Rising Mains in Khartoum

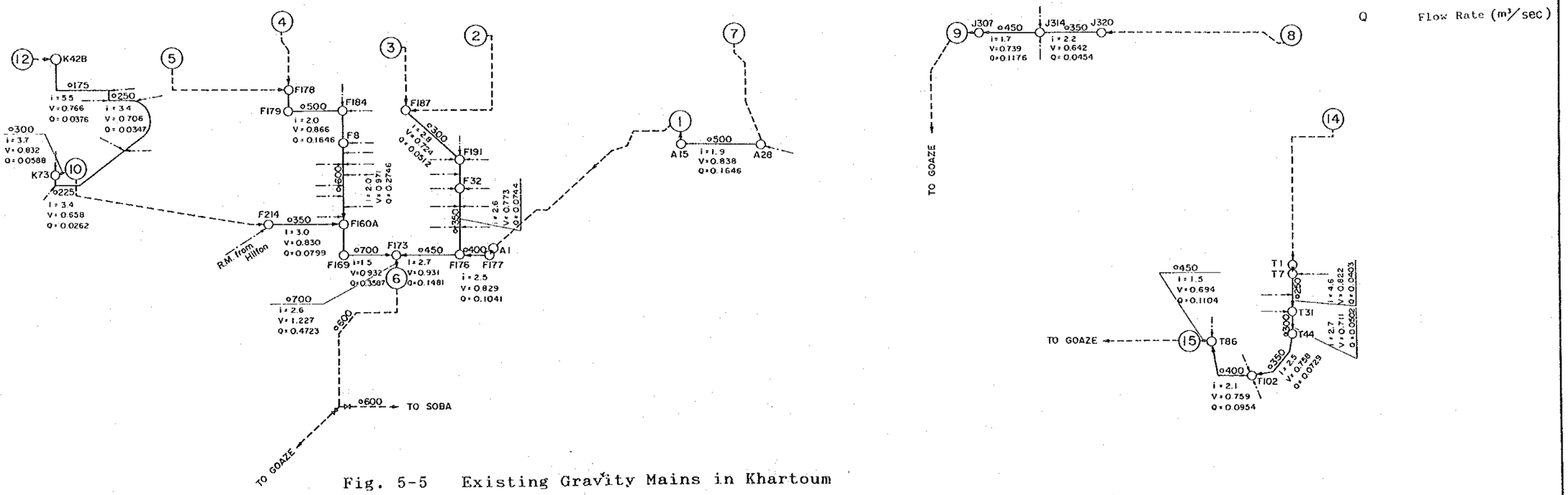


Fig. 5-5 Existing Gravity Mains in Khartoum

Table 4-1 Comparison of Piping Materials

Items \ Materials	Ductile Cast Iron Pipe	Asbestos Cement Pipe
Strength	Large ○	Small × Especially small diameter (less than 200 mm) are weak against axternal pressure, and breakage may occur under unequal loads.
Resistance against surging which occurs with the ON-OFF operating of pumps	Large ○	Small × Unsuitable for rising mains with a high pressure.
Resistance against shock	Large ○	Small ×
Auticorrosion	Good ○ In the acid soil, anti-corrosion countermeasure such as polyethylene coat, is advisable.	Good ○
Durability	○	△
Difficulty in Construction	Less difficults ○ Construction machine will be needed due to the weight.	Less difficults ○
Water tightness	Excellent ○	Good ○
Flexibility	Good ○ Flexible installation is possible within the allowable deflection angle.	Small × Flexibility is not available.
Cost	×	○
Total Evaluation	○	×

5) Performance of Pumping Station No. 6

In Pumping Station No. 6, three dry pit type submersible pumps (Ø300 mm X 25.5 cu.m/min X 21.5 m X 145 kw) were installed to deliver sewage to Soba STP. The rising main from this pumping station is Ø600 mm asbestos cement pipe with length of 9.2 km. As a result of the performance of the pumps, it is judged that the existing pumps cannot deliver the design flow (hourly maximum) to Soba STP.

PERFORMANCE CALCULATION OF PS NO. 6

1. Design Criteria

1.1 Design flow: 28.16 cu.m/min

1.2 Diameter and length of the rising main from PS No. 6 to the man hole which is located 4.5 km from Soba STP and converting point from pressure to gravity:

Diameter Ø 600 mm

Length	L=9.24 km	Ductile Cast Iron Pipe	1,790 m
		Asbestos Cement Pipe	7,450 m

1.3 Pump specification:
25.5 cu.m/min X 21.5 m x 145 kw x 3 (existing)

2. Calculations
Required total head from Pump Station No. 6 - Manhole

2.1 Actual head: ha

ha = ha1 - ha2
ha1 : Level at center of the influent pipe to manhole: 380.296 m
ha2 : Design water level of PS No. 6: + 375.440 m
ha = 380.296 - 375.440 = 4.856 m

2.2 Head loss: hf

i) Friction loss of rising main
(Hazen-Williams formula)

$$hf1 = \frac{10.666 \times (28.16/60)^{1.85}}{(100)^{1.85} \times (0.6)^{4.87}} \times 1{,}790\ m \times 1.1$$

$$+ \frac{10.666 \times (28.16/60)^{1.85}}{(100)^{1.85} \times (0.6)^{4.87}} \times 7{,}450\ m$$

$$= 12.44 + 25.26$$

$$= 37.70\ m$$

ii) Pumping loss

$$ha2 = 1.5\ m$$

So, the head loss will be -

$$hf = hf1 + ha2$$
$$= 37.70 + 1.50$$
$$= 39.20\ m$$

2.3 Total head = H

$$H = ha + hf$$
$$= 4.856 + 39.20$$
$$= 44.056$$
$$= 44\ m$$

Result of examination:

According to the above calculation, total head of 44 m is required for the existing pumps to deliver the design flow. But, the existing pumps in PS No. 6 have only 21.5 m of total head, hence

is not capable of delivering the design flow. Thus, a new pump station shall be located within the distance that PS No. 6 can reach. With this new pumping station, sewage can reach Soba STP. So, Pumping Station No. 20 is necessary.

4.3 Contents of the Project

According to the examination and evaluation on the capacity of existing facilities as described in 4.2, the rehabilitation plan for each facility was fixed as follows:

(1) Goaze STP

Most of the mechanical and electrical equipment in the Goaze STP has deteriorated and are out of order and not operated. To resume proper operation, the replacement of these equipments will be needed and entails a large expense and long working periods. On the other hand, assuming from the existing management system, maintenance techniques and financial requirements, it is doubtful whether proper maintenance will be carried out after rehabilitation. So, the rehabilitation of this plant will be abandoned, considering that there will be less benefit as compared to the investment.

According to the Khartoum Sanitary Engineering Department, inhabitants have been suffered from the bad smell and flies especially at summer time. The plant has been the subject of many complaints as power cuts disable effluent pump, thereby causing the odor.

There has been a transfer plan for this for a long time now. Hence, there is no objection to this abolition scheme. There is also some benefit to be derived as the site can be utilized as a good residential section. Instead of the plant, Pumping Station No. 21 will be built. Treated water will be sent to irrigation canal in the Green Belt near the Soba STP. The pressure manhole will be constructed at the starting point of the canal and the sewage will flow through the newly built gravity main to Soba STP. Therefore, the all sewerage system will be integrated and sewage

will be treated at Soba STP.

(2) Soba STP

Due to the abolition of Goaze STP, sewage inflow rate will increase from 20,450 cu.m/day to 31,420 cu.m/day. However, the capacity calculation in Chapter 5 showed that the plant has the capacity to handle this, expansion work will not be performed.

Principal construction works and facilities which will be built are as follows:

(a) Smoothing and tightening the dike
(b) Inlet and distribution chamber, influent and effluent channel, interpond connection channel
(c) In site pump station
(d) Sewage converting gate chamber
(e) Administrative office

(3) Pumping Stations

Scope of this project is Pump Stations Nos. 1, 6, 7, 8, 12 and 14, aside from the pumping stations which are under the rehabilitation using Arab Funds and donations from the private company. Facilities will be replaced are as shown below:

(a) Main pump, motor
(b) Electric facility
(c) Auxiliary facility (Valves, ventilating device, ladder etc.

While Pumping Station No. 20 will be installed at the middle point of Pumping Station No. 6 - Soba gravity main due to the pumping head shortage of Pumping Station No. 6 and Pumping Station No. 21, instead of the Goaze STP, will be built.

(4) Rising Mains

Asbestos cement pipes, which are used for the existing rising main will be removed and Ductile Cast Iron Pipe will be installed for

replacement. Reasons for adopting the Ductile Cast Iron pipe are:

(i) It has the strength to resist the surging which occurs with the ON-OFF operation of the pump station.
(ii) Anticorrosive
(iii) Mechanical joint is adaptable for disparative sinking (soil of this area is silt which swells when it is wet, and there is a probability for disparative sinking to occur due to leakage from the joint).

Scope of replacement includes the rising mains from the pump stations which will be rehabilitated as mentioned in (3) and the rising mains located downstream of these pumping stations namely rising mains from Pumping Stations Nos. 1, 6, 7, 8, 10, 12, 14 and 15 will be the scope of this project.

However, the distance from Pump Station No. 6 to Soba gravity main is quite long (9.2 km). So the replacement will be performed along the route PS No. 6 - Y-connection - African Road where leakages occur very often. PS No. 15 is now connected to the Goaze STP, but PS No. 20 is constructed in the middle of the route between PS No. 6 and Soba STP, rising main from PS No. 15 will be connected to the PS No. 21 so that it can reduce the pumping length.

(5) New Main Sewers at Western Part of Zone J

Above mentioned is the request from the Government of Sudan. J Zone is industrial district and they worry about industrial waste disposal from many factories. There is an existing gravity main reaching halfway to the proposed site of the pump station. There was a strong request to include the following items in the scope of this project.

(a) Construction of pump station
(b) Completion of gravity sewer

Taking into the consideration that the basic policy of this

project is rehabilitation of existing facilities, this item is judged to be out of scope. Consequently, the rehabilitated sewerage system of Khartoum will be as shown in Figure 4-2.

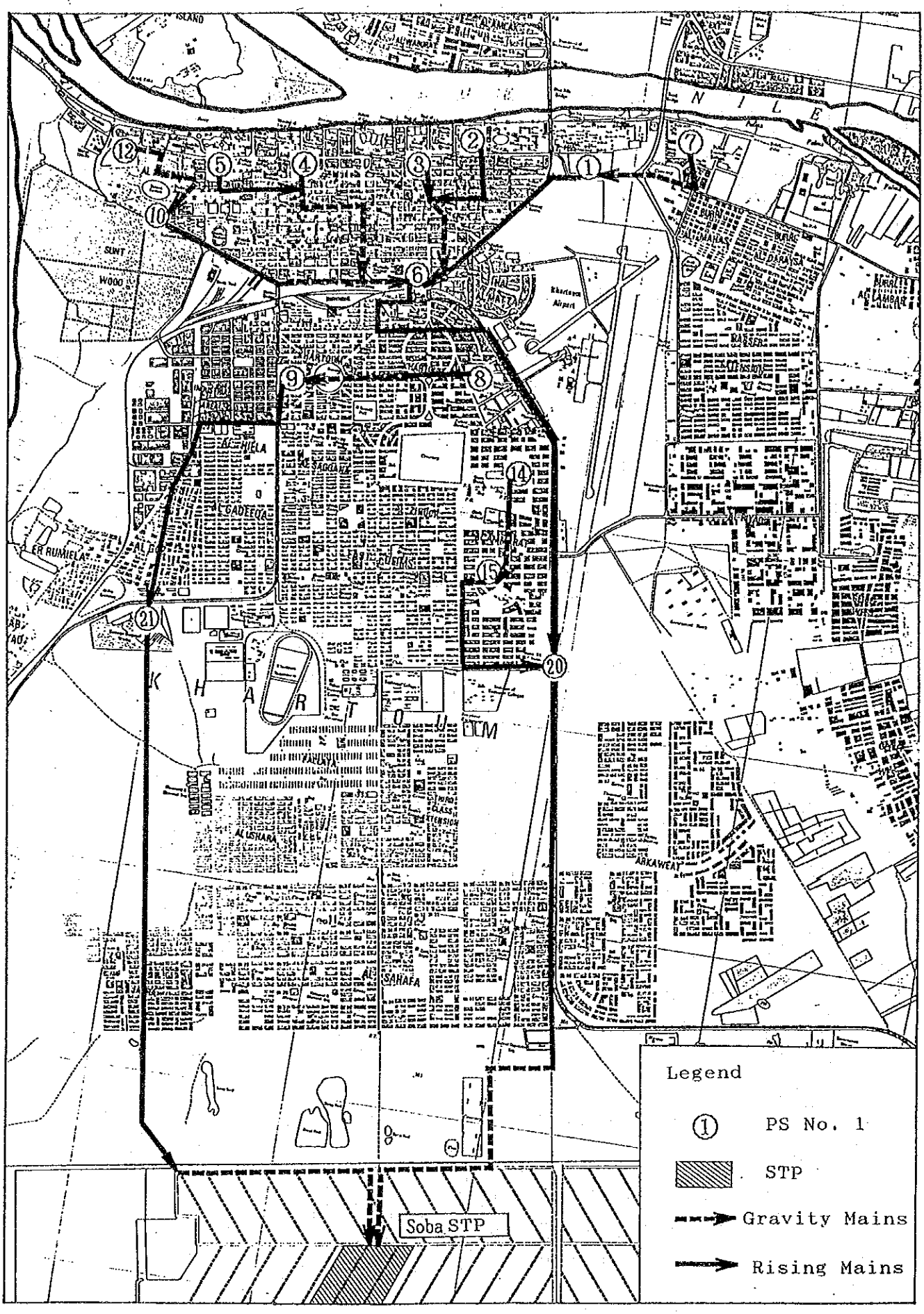


Fig. 4-2 Sewerage System in Khartoum (After the Project Completion)

5. Basic Design

CHAPTER 5 BASIC DESIGN

5.1 Basic Design Policy

The fundamental policies in establishing the basic design of the facilities are:

(1) The project is for the rehabilitation of the existing facilities and not for its expansion.

(2) The scope of rehabilitation will be limited to the minimum facilities necessary for gathering and treating sewage.

(3) Facilities which will be rehabilitated must be easily maintained.

(4) Machinery which requires high operating technics must be avoided.

5.2 Study on Basic Design Criteria

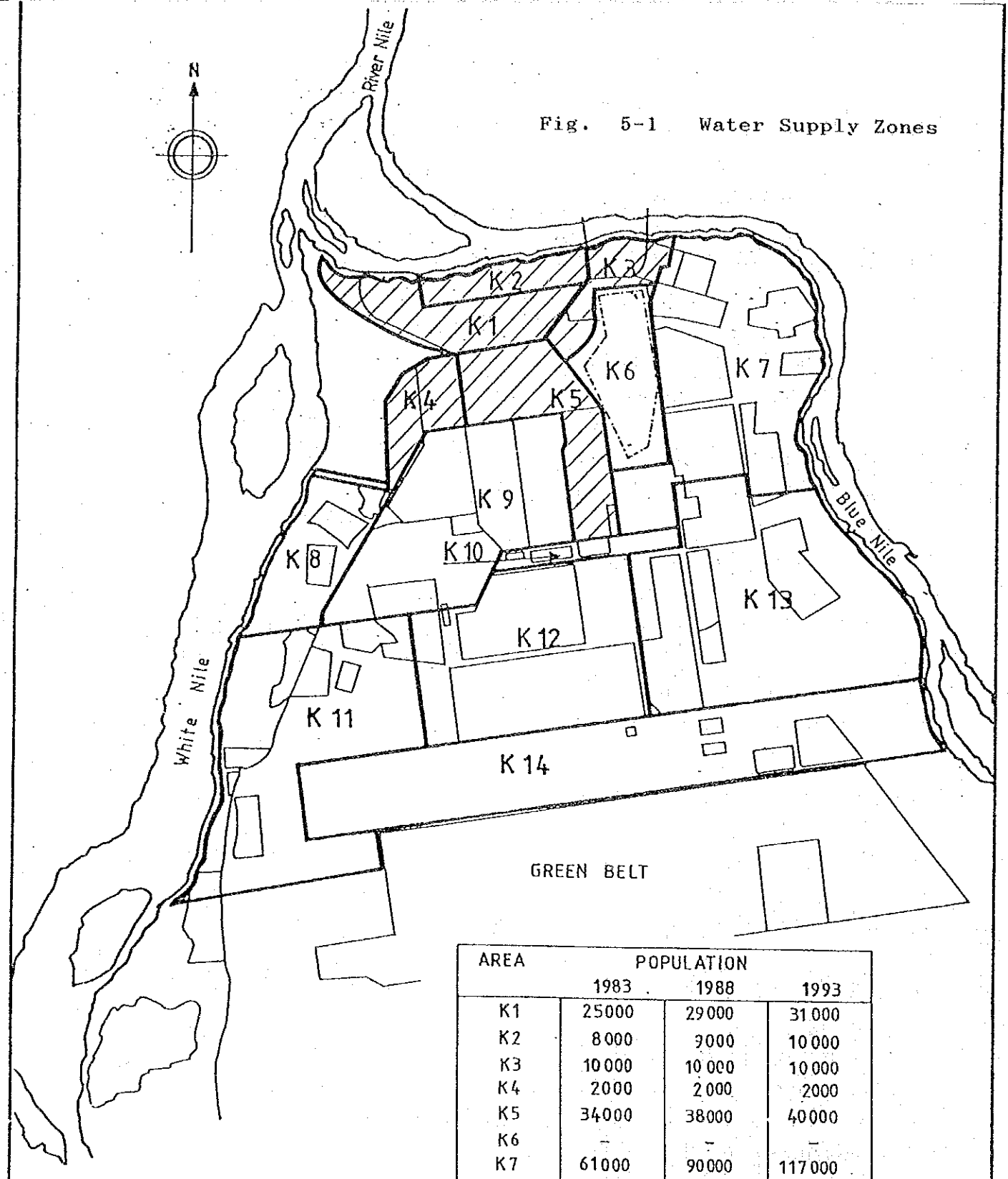
5.1.2 Sewerage Service Area

The Sanitary Engineering Department has been managing the sewerage service in Khartoum. It is divided in 15 zones, namely Zone A to Zone T although Zone N is not in service (see Figure 2-4). The sewerage system has been planned for the densely populated areas in Khartoum and they correspond to the water supply zones K1 - K2 (shown in Figure 5-1).

5.2.2 Estimated Sewage Flow

Sewage flow in 1996, which is 5 years from the completion of this project, has been estimated based on the data with regard to supplied water volume, population, sewage flow and master plan for water supply and sewerage system.

Fig. 5-1 Water Supply Zones



AREA	POPULATION		
	1983	1988	1993
K1	25000	29000	31000
K2	8000	9000	10000
K3	10000	10000	10000
K4	2000	2000	2000
K5	34000	38000	40000
K6	–	–	–
K7	61000	90000	117000
K8	27000	27000	27000
K9	63000	63000	63000
K10	1000	2000	3000
K11	86000	97000	106000
K12	137000	152000	164000
K13	73000	113000	157000
K14	1000	3000	4000

POPULATION DISTRIBUTION
ACCORDING TO WATER SUPPLY MASTER PLAN