No. 2

JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF LOCAL GOVERNMENT
REPUBLIC OF KENYA

BASIC DESIGN STUDY REPORT
ON
THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT
IN
THE REPUBLIC OF KENYA

MAY 1994

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BASIC DESIGN STUDY REPORT ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT IN THE REPUBLIC OF KENYA
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PREFACE

In response to a request from the Government of the Republic of Kenya, the Government of Japan decided to conduct a Basic Design Study on the Nakuru Sewage Works Rehabilitation and Expansion Project and entrusted the study to the Japan International Cooperation Agency (JICA).

The Study was conducted in Japan from April to May 1994 under a contract between JICA and Nippon Koei Co., Ltd., and as a result, the present report was finalized.

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 Kenya for the close cooperation extended to the Study Team.

May 1994

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

May, 1994

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

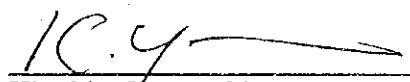
We are pleased to submit to you the Basic Design Study Report on the Nakuru Sewage Works Rehabilitation and Expansion Project in the Republic of Kenya.

This Study was conducted by Nippon Koei Co., Ltd., under a contract with JICA, during the period from March 25, 1994 to May 31, 1994. In conducting the Study, we have examined the feasibility and rationale of the Project with due consideration of the present situation in Kenya and formulated the most appropriate basic design for the Project under Japan's grant aid program.

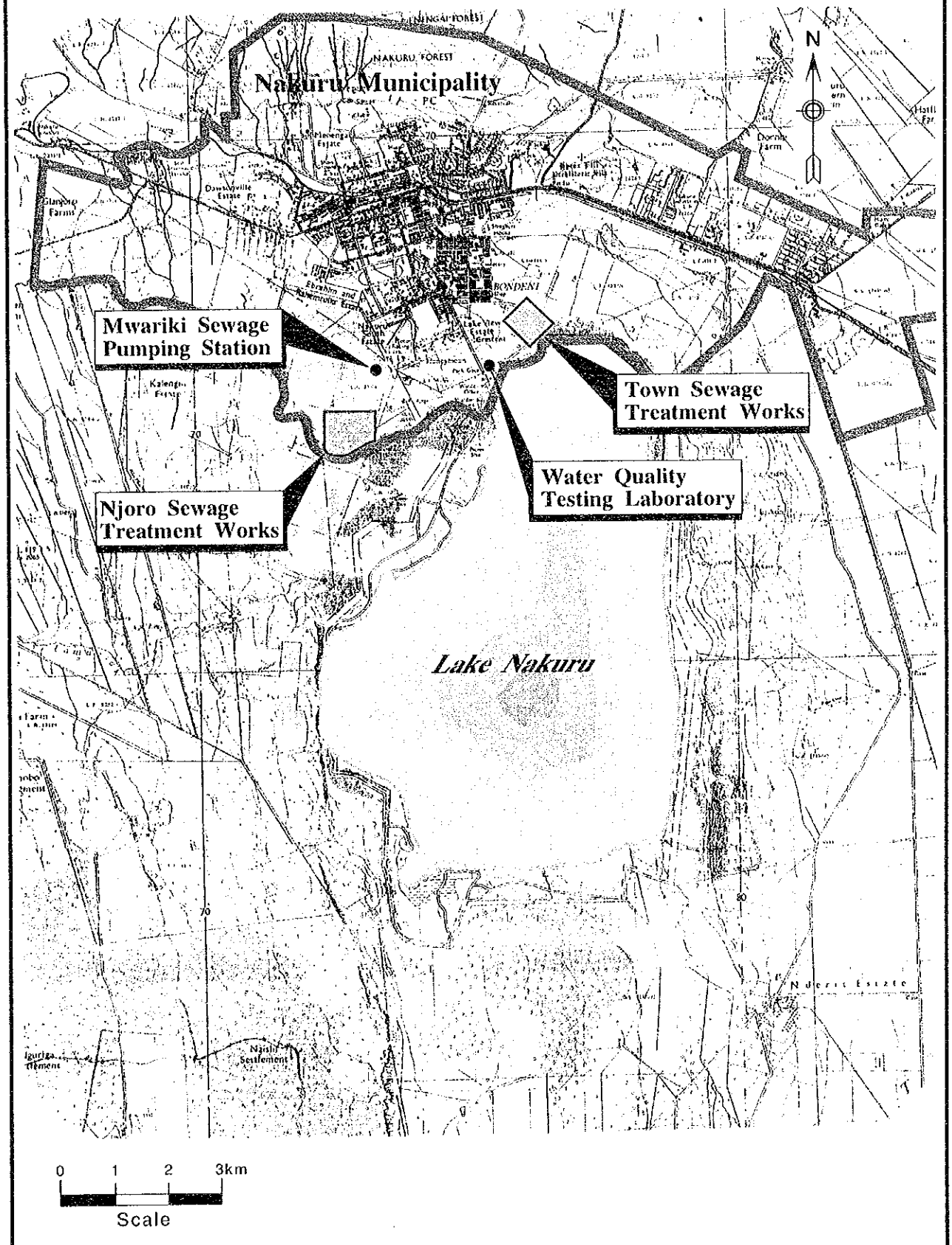
We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs, and the Ministry of Construction. We also would like to express our gratitude to the officials concerned of the Ministry of Local Government, the JICA Kenya Office, the Embassy of Japan in Kenya for their cooperation and assistance.

Finally, we hope that this Report will contribute to further promotion of the Project.

Very truly yours,



Kiyohito Yamazaki
Project Manager,
Basic Design Study Team on the
Nakuru Sewage Works Rehabilitation and
Expansion Project in the Republic of Kenya
Nippon Koei Co., Ltd.



THE REPUBLIC OF KENYA	THE BASIC DESIGN STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT	TITLE
MINISTRUY OF LOCAL GOVERNMENT	JAPAN INTERNATIONAL COOPRATION AGENCY	Location Map

Summary

Lake Nakuru, which has no outflowing stream, is one of the two conservation areas in Kenya, registered under the Ramsar Convention in July 1990 and is famous worldwide for its unique wildlife and eco-system, especially with the presence of millions of flamingoes. The lake is a natural receptacle for all the domestic and industrial effluent from the Nakuru Municipality which is located adjacent to the lake, approximately 150 km northwest of Nairobi. The municipality, however, has long been subjected to a rapid population growth and progressive economic and industrial development activities. The population of the municipality was estimated at 360,000 in 1993.

There are two sewage treatment works (STW) in the municipal area: the Town STW of trickling filter type and the Njoro STW of waste stabilization pond type. Both have been over-loaded due to rapid population and urbanization of the municipality.

In 1992 the Greater Nakuru Water Supply Project, Eastern Division - stage I (GNWSP) was completed to cater for increasing potable water demand in the municipal area and is capable of supplying a safe water volume of 13,300 m^3/day. The commissioning of GNWSP has directly led to an increase in sewage generation in the municipal area, while the existing sewage treatment works have been seriously over-loaded and deteriorated.

The international and national importance of preserving the precious eco-system of the lake requires the introduction of positive physical measures to counter possible effects of sewage inflow into the lake. It is therefore essential to implement the Project as soon as possible in order to create an adequate environment for harmonious co-existence of human beings and the natural environment.

Under such circumstances, the Government of the Republic of Kenya (GOK) launched the project and requested the Government of Japan (GOJ) to provide assistance for 1) the Nakuru sewage rehabilitation and 2) the Nakuru sewage master plan. GOK and GOJ discussed the request and decided to execute a feasibility study (F/S) for the sewage rehabilitation works. The Japan International Cooperation Agency (JICA) conducted the feasibility study and the result was accepted by GOK in January 1994. Subsequently, JICA carried out the basic design study on the Project in Japan from March to May 1994.

The main components of the GOK's request for grand aid were 1) rehabilitation and expansion of the Town and Njoro STWs, 2) rehabilitation of the Mwariki sewage pumping station, and 3) procurement of operation and maintenance (O&M) equipment for sewage facilities as a structural measure, and 4) construction of water quality testing laboratory including procurement of testing equipment as a non-structural measure, according to the water pollution control plan recommended in the feasibility study.

The Basic Design Study Team has examined the appropriateness of the respective components of the request . The results of examination are summarized below.

1) Town STW: This facility is operating under a severe overloaded condition in terms of sewage volume and loads such as inflow BOD concentration of more than 500 mg/l and 100 mg/l of effluent. The operation of the existing clarifiers and trickling filter is interrupted frequently due to the failure of mechanical and electrical facilities and absence of operating staff in night time.

2) Njoro STW: This facility which comprises stabilization ponds has been operating under a severe overloaded condition for many years. BOD concentration of inflow is more than 700 mg/l at present, and the lack of proper maintenance since the completion of the ponds in 1973 and a large volume of sludge sedimentation have reduced their capacity. The Njoro STW has substantially degraded in terms of effluent BOD which reaches more than 200 mg/l due to overloading, reduced storage capacity and quality.

3) Mwariki sewage pumping station: The station building is inclined due to differential settlement of its foundation. Of the three installed pumps, two have been out of order due to the lack of spare parts and insufficient maintenance.

4) Procurement of operation and maintenance equipment: The operation and maintenance of the existing sewage facilities are poor due to the lack of equipment, shortage of budget and staff. Strengthening of the equipment for sewage facilities is therefore, indispensable after the completion of rehabilitation and expansion works.

5) Water quality testing laboratory: Establishment of a water quality testing laboratory is indispensable to realize the water pollution control plan for Lake Nakuru as proposed in the F/S. GOK established the "Wastewater Standards for Discharge into Lake Nakuru" in 1993, and the Nakuru Municipal council (NMC) has drafted up the "Trade Effluent By-laws". It is a matter of vital importance to monitor pollution loads flowing into Lake Nakuru, the lake water quality and quantity, and the quality of industrial effluents. Especially, the monitoring of industrial effluents plays a significant role in the proper enforcement of the Trade Effluent By-laws. A water quality testing laboratory is very necessary for the successful implementation of the Trade Effluent By-laws.

6) Procurement of water quality testing equipment: Testing equipment for the proposed water quality testing laboratory is to be procured to meet the requirements of the water pollution control plan and the functions of the laboratory.

The basic design of each respective component is summarized below.

1) Town STW: This will be rehabilitated and expanded to 2 systems with 2 treatment lines having a 3,400 and 3,200 m^3/day capacity respectively and equipped with stabilization ponds, rock filters, and grass plots. A sludge drying bed, stormwater retention pond and control house will be constructed in the Town STW. The sedimented sludge at the existing ponds will be treated at the sludge dumping site which has been selected by GOK at the edge of Menengai forest, after grading the site and improving the existing access road. The sludge will be dried at the STW and hauled to the site through existing access road.

2) Njoro STW: Rock filters and grass plots will be constructed and connected to the existing 3,600 m^3/day line upon its rehabilitation, and to the 6,000 m^3/day line which is expected to be completed in September 1994. The sedimented sludge at the existing ponds will be hauled to the sludge dumping site.

3) Mwariki sewage pumping station: The building, mechanical and electrical facilities will be rehabilitated without modifying their locations and treatment capacity.

4) Procurement of operation and maintenance equipment: The type and number of equipment have been decided to meet the proposed operation and maintenance guideline after the completion of rehabilitation and expansion of sewage facilities, and the availability of spare parts and staff skillfulness. The O&M equipment has been classified into a workshop equipment group in the Town STW and another group.

5) Water quality testing laboratory: The laboratory will be constructed adjacent to the existing training center in Lake Nakuru national park. It will be a one-storied reinforced concrete structure having a floor space of approximately 350 m^2. The laboratory will have central, biological, analyzing, balance, and research rooms.

6) Procurement of water quality testing equipment: The equipment has been selected based on the water pollution control plan, effluent laws, water quality monitoring plan, ease of handling, cost, and other factors.

The required equipment and materials for the Project's construction works are mostly available in Kenya. Skilled labourers can be recruited at Nakuru and Nairobi. Mombasa port is capable of efficiently handling sea cargoes for the Project.

The Project will be implemented in 2 stages under the management and supervision of the Ministry of Local Government (MOLG) in association with the selected consultants. The 1st stage will comprise these components: 1) the Town STW with a control house, 2) the water quality testing laboratory and procurement of testing equipment, and 3)

procurement of operation and maintenance equipment. The 2nd stage will comprise the Njoro STW and Mwariki sewage pumping station.

The critical path works in both the 1st and 2nd stages of construction will be earthworks which will be approximately 0.3 million m^3 of excavation and embankment respectively for the Town STW, and 0.3 million m^3 of excavation and 0.15 million m^3 of embankment for the Njoro STW.

The Project will not only contributes to the alleviation of pollutant loads in the Lake Nakuru but also make it possible to put the GNWSP into actual operation. It is foreseeable that positive impacts will greatly outweigh any potential negative impacts such as odor nuisance and sludge generation due to the construction of waste stabilization ponds.

The followings are the recommendations that the countermeasure should be taken by GOK in order to preserve the precious natural environment of Lake Nakuru.

1) The sedimented sludge at the existing ponds of the Town and Njoro STWs should be treated at the dumping site at the edge of the Menengai forest selected by GOK.

2) The sludge dumping site for the sludge generated by both STWs after the completion of rehabilitation and expansion works should be located outside the catchment area of Lake Nakuru.

3) GOK should bear the cost for relocation of inner roads and telephone lines, fencing of STWs, general furniture for water quality testing laboratory and others, which have been estimated at approximately Kshs 28.0 million in total as broken down in Appendix 5.

4) Monitoring and industrial effluent control should be realized as early as possible according to the Trade Effluent By-laws in the by the trade Effluent Control Unit of the Water and Sewerage Department (WSD) which was recommended to be strengthened feasibility study. Monitoring of the activities for effluent control in Lake Nakuru should also be carried out as early as possible.

5) Sludge from septic tanks in unsewered area should be hauled to the sludge drying bed in the Town and Njoro STWs after the completion of rehabilitation and expansion works, and finally dumped at the site selected by GOK.

6) The "Wastewater Standards for Discharge into Lake Nakuru" and "Trade Effluent Standards for Discharge into Public Sewers" of GOK should be reviewed with regard to such parameters as CODcr, nitrogen, heavy metals, toxic material, and carcinogenic.

7) The urban and regional development plan for the catchment area of Lake Nakuru should be reviewed and adjusted by the Inter-ministerial Working Group (IWG) before its realization in terms of water pollution control in the lake.

8) Improvement of water distribution lines, increase of the number of water meters, and decrease of water losses in the Nakuru Municipality are necessary for ensuring appropriate measurement and construction of sewage facilities.

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ABBREVIATIONS AND LOCAL TERMS

1. Abbreviations of Measures

1.1 Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer
"	=	inch

1.2 Area

m^2, sq.m	=	square meter
ha	=	hectare
km^2, sq.km	=	square kilometer

1.3 Volume

cc	=	cubic centimeter
lit, l, L	=	liter
lcd	=	liter per capita per day
m^3, cu.m	=	cubic meter

1.4 Weight

mg	=	milligram
g	=	gram
kg	=	kilogram
t	=	ton

1.5 Time

s, sec	=	second
min	=	minute
h, hr	=	hour
d	=	day
yr	=	year

1.6 Money

KShs.	=	Kenya Shilling (unit of Kenya currency)
US$, $	=	US Dollar
¥	=	Japanese Yen

1.7 Electric Measures

A	=	ampere

V	=	volt
KV	=	kilovolt
KW	=	kilowatt
KWh	=	kilowatt hour
KVA	=	kilovolt ampere
Hz	=	herts

1.8 Other Measures

mS	=	milli Siemens
mmho	=	micromho = conductance
ppb	=	parts per billion
ppm	=	parts per million
MPN	=	most probable number
‰	=	per mil
%	=	percent
PS	=	0.736 kW
°	=	degree
'	=	minute
"	=	second
°C	=	degree centigrade
BOD	=	biochemical oxygen demand
COD	=	chemical oxygen demand
T-N	=	total nitrogen
I -	=	inorganic
O -	=	organic
T-P	=	total - phosphorus
DO	=	dissolved oxygen
pH	=	exponent of hydrogen ion concentration
TDS	=	total dissolved solids
SS	=	suspended solids
VS	=	volatile solids

1.9 Derived Measures Based on the Same Symbols

cm/sec	=	centimeter per second
m/s, m/sec	=	meter per second
cm^3/min	=	cubic centimeter per minute
m^3/sec, cu.m/sec	=	cubic meter per second
m^3/min, cu.m/min	=	cubic meter per minute
m^3/h, cu.m/h	=	cubic meter per hour

m^3/d, cu.m/d	=	cubic meter per day
lpcd	=	liter per capita per day
$m^3/m^2/day$	=	cubic meter per square meter per day
$m^3/sec/km^2$	=	cubic meter per second per square kilometer
kg/day	=	kilogram per day
ton/m^2	=	ton per square meter
$kg/day/km^2$	=	kilogram per day per square kilometer
mg/kg	=	milligram per kilogram
mS/cm	=	milli Siemens per centimeter
mg/L	=	milligram per liter
g/cm^3	=	gram per cubic centimeter

2. Other Abbreviations

BS	=	British Standards
JIS	=	Japanese Industrial Standards
ASTM	=	American Society of Testing and Material
GDP	=	gross domestic product
GNP	=	gross national products
GRDP	=	gross regional domestic product
El.	=	elevation
NOL	=	normal operation level
FOB	=	free on board
CIF	=	cost, insurance and freight
STW	=	sewage treatment works
Q'ty	=	quantity
Srl	=	serial
GL	=	ground level
SD	=	Sewerage District
EIA	=	Environmental Impact Assessment

3. Abbreviation of Organization

GOJ	=	Government of Japan
GOK	=	Government of Kenya
JICA	=	Japan International Cooperation Agency
KWS	=	Kenya Wildlife Service
MOENR	=	Ministry of Environment and Natural Resources
MOF	=	Ministry of Finance

MOALD	=	Ministry of Agriculture and Livestock Development
MOLG	=	Ministry of Local Government
MOLRRWD	=	Ministry of Land Reclamation, Regional and Water Development
MOC & I	=	Ministry of Commerce and Industry
MOL & S	=	Ministry of Land Settlement
MOTC	=	Ministry of Transport and Communication
MOTW	=	Ministry of Tourism and Wildlife
MOLMD	=	Ministry of Labour and Manpower Development
MOH	=	Ministry of Health
NES	=	National Environmental Secretariat
NWCPC	=	National Water Conservation and Pipeline Corporation
ODA	=	Overseas Development Administration, Britain
OECF	=	Overseas Economic Cooperation Fund, Japan
OP	=	Office of President
SOK	=	Survey of Kenya
WWF	=	World Wide Fund for Nature
NMC	=	Nakuru Municipal Council
PHD	=	Public Health Department, NMC
WSD	=	Water and Sewerage Department, NMC
Ramsar Convention	=	Convention on Wetlands of International Importance especially as Waterfowl Habitat
UNICED	=	United Nations Conference on Environment and Development
UNEP	=	United Nations Environment Programme
IMCE	=	Inter-Ministerial Committee on Environment
NCST	=	National Council for Science and Technology
KSTC	=	Kenya Science Teachers College
NEAP	=	National Environment Action Plan
IWG	=	Inter-ministerial Working Group
DDC	=	District Development Committee
UDD	=	Urban Development Department, MOLG
NGO	=	Non-Governmental Organization
KEWI	=	Kenya Water Institute, MOLRRWD
TECU	=	Trade Effluent Control Unit, WSD
WAB	=	Water Apportionment Board
WRD	=	Water Resources Division, MOLRRWD
AALAE	=	African Association for Literacy and Adult Education

ANEN	=	African NGO's Environmental Network
APEMAM	=	African Pesticide and Environment Management Foundation
AWF	=	African Wildlife Foundation
CARE	=	Care International
CHEK	=	Council for Human Ecology Kenya
ELCI	=	Environmental Liaison Center International
ICRAF	=	International Council for Research in Agroforestry
WCK	=	Wildlife Clubs of Kenya
IOCN	=	The International Union for Conservation of Nature
ACTS	=	African Centre for Technology Studies

CHAPTER 1 BACKGROUND OF THE PROJECT

1.1 Background of the Project

The Nakuru Municipality, the capital of Rift Valley Province and the fourth largest city of Kenya is located approximately 150 km northwest of Nairobi and adjacent to Lake Nakuru. The municipal area of 69.2 km^2 extends over the southern slope of the Menengai Crater and bounds on Lake Nakuru National Park to the south. The altitude of the municipal area varies widely from around El. 1,750 m to 2,100 m. The municipality however has long been subjected to a rapid population growth and progressive economic and industrial development activities. The population in the municipality was estimated at 361,000 in 1993.

Lake Nakuru, which has no outflowing streams or rivers, is a natural receptacle for all the domestic and industrial effluents from the Nakuru Municipality. The lake water is balanced only by evaporation. The lake is one of the two conservation areas in Kenya registered under the Ramsar Convention in July 1990 and is famous worldwide for its unique wildlife and eco-system, especially with the presence of millions of flamingoes.

There are two sewage treatment works in the municipal area: the one is the Njoro STW having a 3,600 m^3/day capacity using the waste stabilization ponds process, and the other is the Town STW with a 3,400 m^3/day capacity, using the tricking filter process. The total volume of sewage was 8,999 m^3/day on an average in the last 5 years and BOD concentration of the influent has been overloaded.

The Greater Nakuru Water Supply Project, Eastern Division-Stage I (GNWSP) was completed in January 1992 to cater for increasing potable water demand in the municipal area and is capable of supplying a safe water volume of 13,300 m^3/day. The commissioning of GNWSP has directly led to an increase in sewage generation in the municipal area and sewage eventually flows into the lake.

Preservation of the precious eco-system of the lake by introducing positive physical countermeasures against sewage inflow into the lake is essential. On the other hand, supplying of additional potable water from GNWSP is also important for human life in the municipality.

It is therefore important to take adequate measures as promptly as possible in order to attain harmonious co-existence of human beings and the natural environment.

GOK has organized IWG for coordination and supervision for various institutions that are geared towards the environmental protection and management of the lake. Figure 1-1

shows the institutional organization for environmental conservation and protection of Lake Nakuru as proposed by the F/S Study Team.

1.2 Outline of the Request and Its Main Components

Under the circumstances stipulated above, the Government of the Republic of Kenya (GOK) launched the Project and requested the Government of Japan (GOJ) in April 1990 to provide assistance on the following:

(1) Nakuru Sewerage Rehabilitation

There is an urgent need to rehabilitate and expand the existing sewage treatment capacity of the Nakuru Municipality. The current sewage effluent volume is 8,600 m^3/day while the treatment capacity is only 5,100 m^3/day. The urgency of this Project is underscored by the fact the completion of GNWSP in 1992 has delivered an additional potable water quantity of 13,300 m^3/day, whose sewage by-product will drain into Lake Nakuru. Urgent rehabilitation is therefore required to stem further environmental degradation of the lake.

(2) Nakuru Sewerage Master Plan

The master plan study will lay an emphasis on the establishment of a long-term optimum plan for sewage treatment, solid waste disposal and stormwater drainage systems within the Nakuru Municipality and its environs.

GOK and GOJ discussed the request agreed to take the following steps:

- to carry out the feasibility study for the Nakuru Sewage Works Rehabilitation and Expansion Project ((F/S).
- to provide a grant aid for the Project implementation if it is proved feasible and viable.

The Japan International Cooperation Agency (JICA) conducted the F/S during the period from May 1993 to March 1994, and the study result was accepted by GOK on 20th January 1994. The Minutes of meetings on the Draft Final Report of F/S is attached as Appendix-3.

During the meetings on the Draft Final Report of F/S, both sides have also discussed the urgent portions of the Project to be considered in the tentative scope of the Japanese Grant Aid. The results of discussions are detailed in the Minutes provided in Appendix-4.

The major components of the GOK's request are summarized below:

(1) Rehabilitation and Expansion of Facilities
- The Town Sewage Treatment Works with a control house
- The Njoro Sewage Treatment Works
- The Mwariki Sewage Pumping Station

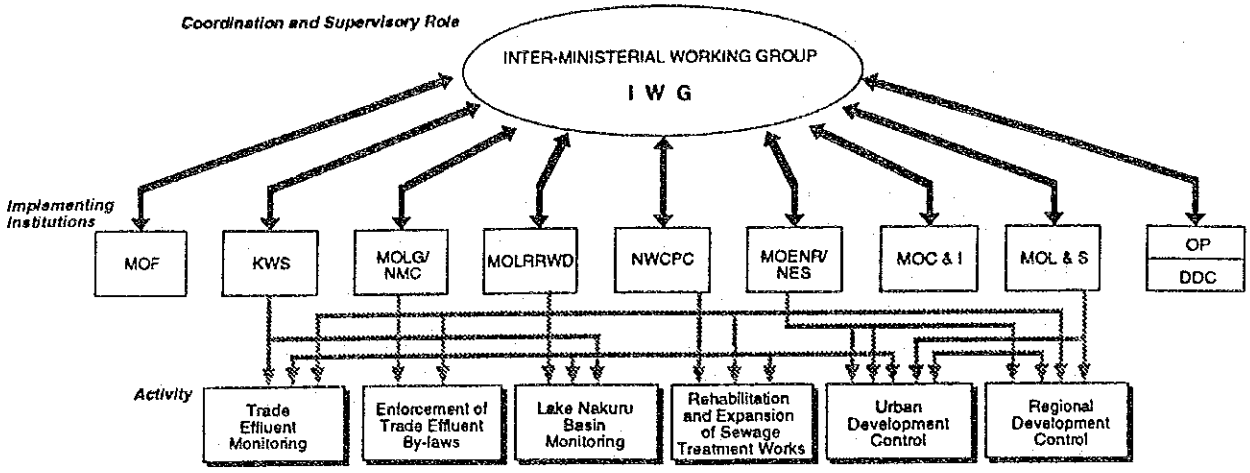
(2) Construction of the Water Quality Testing Laboratory

(3) Procurement of Equipment
- Operation and Maintenance Equipment for Sewage Facilities
- Testing Equipment for the Water Quality Testing Laboratory

1.3 Projects and/or Programs of Other Donors

The National Water Conservation and Pipeline Corporation (NWCPC) is implementing urgent expansion works for the Njoro STW which are intended to increase its treatment capacity to 6,000 m^3/day. These works are being funded from residual funds from the Overseas Economic Cooperation Fund (OECF) Loan for GNWSP.

NWCPC is the implementing agency for a study on the Nakuru Water Supply and Sanitation Project which is being financed by the African Development Bank. The project has also a Steering Committee chaired by the Director of Water Development with the NWCPC providing the secretariat and engineering services for the project and the Ministry of Local Government (MOLG) is a member of the Steering Committee.



Legend

Coordination and Supervisory Relationship

Activity Implementation Relationship

Abbreviations

MOF	- Ministry of Finance
KWS	- Kenya Wildlife Services
MOLG	- Ministry of Local Government
NMC	- Nakuru Municipal Council
MOLRRWD	- Ministry of Land Reclamation, Regional & Water Development
MOENR	- Ministryof Environment and Water Resources
MOC & I	- Ministry of Commence and Industry
OP	- Office of President
NWCPC	- National Water Conservation and Pipeline Corporation
MOL&S	- Ministry of Lands and Settlement
DDC	- District Development Committee
NES	- National Environment Secretariat

Figure 1-1 Proposed Institutional Organization for Environmental Conservation and Protection of Lake Nakuru Catchment Basin

CHAPTER 2 OUTLINE OF THE PROJECT

2.1 Objectives of the Project

In the short term, the objective is to improve the sewage water treatment capacity of the Nakuru Municipality, to treat the present sewage volume and the increased sewage water volume resulting from the Greater Nakuru Water Supply Project Stage I. In the medium and long term, the objectives are to maintain the water quality of Lake Nakuru at an acceptable level for conservation of nature and wildlife in and around Lake Nakuru and create adequate sanitary conditions for public health.

2.2 Study and Examination of the Request

Request : ***Rehabilitation and Expansion of the Town and Njoro STWs***

(1) Sewered areas and connection ratio

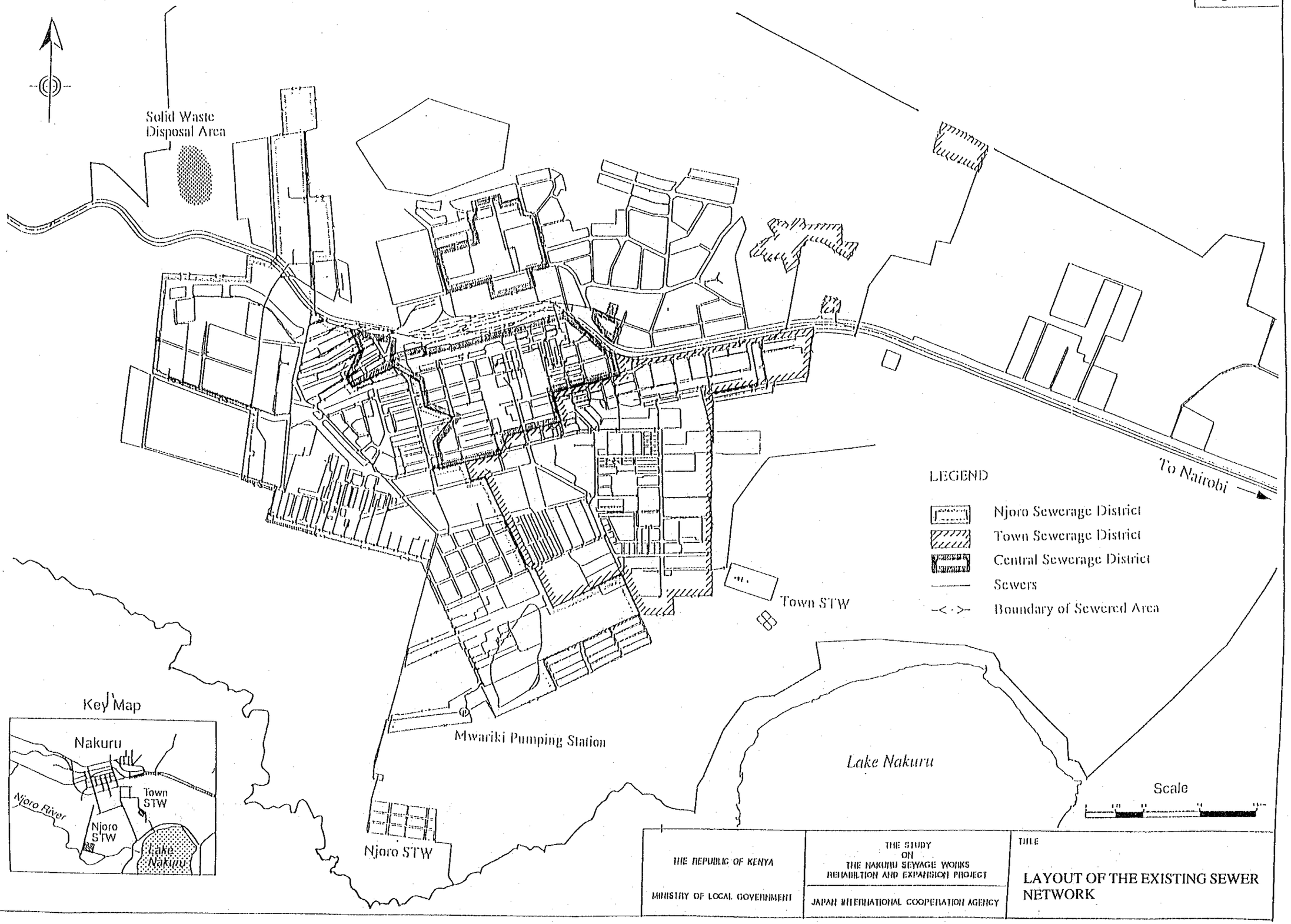
There are two sewage treatment works, the Njoro and Town STWs, in the Nakuru Municipality at present. The existing sewer network covers mainly the central part of the town area as shown in Figure 2-1 and is divided into three sewerage districts (SD): Njoro SD with an area of 6.33 km^2, Town SD with 4.19 km^2, and Central SD with 2.33 km^2. The Njoro STW receives sewage from the entire area of Njoro SD and a portion of Central SD, while the Town STW receives sewage from the entire area of Town SD, remaining area of Central SD, and Lanet area.

The number of sewage-served houses is 9,530 in total, consisting of 5,115 in Njoro SD, 3,164 in Town SD, and 1,251 in Central SD, while that of potable water-served registrants is 11,194 in total. There are 1,664 unsewered registrants within the sewered areas. The sewer connection ratio is therefore 85.1% at present. It is noted that WSD continues its efforts to connect the unsewered registrants to the service network in the future in order to improve the living environment.

(2) Sewers

The existing sewers range from 4 to 24 inches in diameter and their total length is 84.05 km. The existing sewer network is of gravity system, except the Langa Langa Housing Estate which is served by the Mwariki Pumping Station. The trunk sewer leading to the Njoro STW is 450 to 600 mm in diameter and 3,515 m in length, while that to the Town STW is also 450 to 600 mm in diameter and 3,980 m in length. Both of the trunk sewers are ascertained to be capable of carrying more than the planned discharge. The Mwariki Pumping Station is connected to the Njoro trunk sewer through a sewer with a diameter of 450 mm and a length of 300 m.

Figure 2-1


Solid Waste
Disposal Area
To Nairobi
LEGEND
Njoro Sewerage District
Town Sewerage District
Central Sewerage District
Sewers
Boundary of Sewered Area
Town STW
Mwariki Pumping Station
Njoro STW
Lake Nakuru
Key Map
Nakuru
Town STW
Njoro River
Njoro STW
Lake Nakuru
Scale
THE REPUBLIC OF KENYA
MINISTRY OF LOCAL GOVERNMENT
THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITION AND EXPANSION PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE
LAYOUT OF THE EXISTING SEWER NETWORK

According to the WSD's maintenance records, some parts of the sewer network have been subjected to frequent blockage mainly due to industrial waste, fats, sediments, etc., more than 470 times during a 13-month period from May 1992 to May 1993. The sewer section of WSD is not provided with adequate equipment to tackle such problem effectively and rationally.

(3) Sewage treatment works

(a) Njoro STW

The Njoro STW with a treatment capacity of 3,600 m^3/day was constructed in 1973 on the left bank of the Njoro River, applying the waste stabilization pond type. It consists of three lines of stabilization ponds, each line comprising facultative and first, second and third maturation ponds. The treated sewage is discharged into the Njoro River. The Njoro STW has however been operating under a severe overloaded condition for many years. The average inflow was 5,897 m^3/day on a monthly basis during the period from 1988 to 1992 and BOD concentration of the inflow is more than 700 mg/L at present. For almost 20 years since their completion in 1973, the ponds have been operated without proper maintenance works. As a result, the storage capacity of some ponds has been reduced due to sedimentation, resulting in a reduction of the retention period from 37 days to 32 days. Especially the facultative ponds are likely to be operated in a anaerobic state and their arrangement is judged to be inappropriate in view of the present quality and quantity of influent. Because of overloading and reduced storage capacity, the quality of effluent from the treatment works has substantially degraded, as reflected by a BOD value of more than 200 mg/L on an average.

(b) Town STW

The Town STW with a treatment capacity of 3,400 m^3/day was initially completed in 1956 and once rehabilitated in 1986. It is of conventional type, comprising a primary clarifier, a trickling filter, a final clarifier and four maturation ponds. The maturation ponds with a capacity of 450 m^3 were added in 1961. It is ascertained that the trickling filter is not equipped with sufficient ventilation facilities to properly maintain its function. This sewage works is also operated under overloaded condition. The average inflow was 3,470 m^3/day on a monthly basis and BOD concentration of the inflow is also more than 500 mg/L. The Town STW has experienced frequent stoppages due to the failure of mechanical and electrical facilities. It appears that the

works is not operated properly at night time due to the absence of operating staff. BOD concentration of the effluent is more than 100 mg/L.

As noted above, both of the sewage treatment works have been subjected to severe overloading in terms of sewage volume and loads. In order to preserve the quality of effluent at the specified level, it is absolutely necessary to improve the existing sewage treatment works and to introduce adequate non-structural measures to control the industrial wastewater, which is the major pollution load contributor.

Request : Rehabilitation and Expansion of the Control House in the Town STW

(1) Control office

At present, there is no appropriate office space in the Town STW although the sewage works superintendent has a small space in a building annexed to the digester tank. This building was constructed in 1956 but has seriously deteriorated. Especially its roof is not waterproof enough and it is supposed that reinforcement bars in roof slab might be in the a state of serious corrosion.

The administrative work is done in the extended small cabin and at the office in a wing of the existing building connected to the sludge digestion tank. The office suffers heavy leakages from its roof during rains and is required to be shifted to another place. The toilet seat in the office is broken. Most of electric bulbs were removed from the sockets in the existing building. No lights fixtures are provided in the small cabin.

It is therefore proposed to demolish the existing building and build a new office to ensure safe and proper operation and maintenance of the sewage treatment works.

(2) Storehouse

The new and worn out spare parts are kept in old steel containers positioned in front of the small cabin. A few electric tools, such as a 13 mm bench drilling machine and a bench grinder with 7" disks and other electric hand tools, are stored in the store room at the corner of a wing of the existing building.

Request : Rehabilitation and Expansion of the Mwariki Sewage Pumping Station

The pumping station was constructed in 1986 for pumping up the sewage collected from the Langa Langa Housing Estate into 600 mm trunk sewers. Three sets of submersible pumps with a 1.5 m^3/min capacity are installed in the pump pit adjacent to the generator house, two of them are standby. From the capacity and operation records of the pumps, the actual flow rate is assumed to be less than 1,000 m^3/day. Electric power is supplied from a low voltage electric pole near the pumping station through an underground cable. For

emergency power supply, a generator of 18.25 kVA and 240 V is provided in the generator house.

The mechanical and electrical facilities in the pumping station are shown in Table 2-1 below:

Table 2-1 Facilities in the Mwariki Sewage Pumping Station

Particulars	Quantity	Manufacturer	Model No.	Conditions
Submersible pump	3 sets	Flygt	3127180	Worn out and under repair
Stirrer	2 sets	(Nil)	(Nil)	Not functioning
Diesel generator	1 set	Lister	BG184	Good

(Source : F/S Team and WSD)

The operational conditions of the facilities were investigated during the F/S stage in August 1993 and the followings were observed:

(1) The inlet screen was cleaned completely. Many rubbishes and scums, however, were found on the surface of water in the underground sump tank through the screen, which might have caused abrasion of components of pumps and invited clogging of the pumps.

(2) Three sets of pumps were dismantled from the sump pit for repairing due to mechanical troubles such as damage of mechanical seals and burnt motor caused by choking fibrous wastes included in the sewage water.

(3) Two sets of stirring machines are not functioning due to the removal of driving motors from the dry chamber adjacent to the underground tank to which overflow water flows due to lack of automatic operation devices of the sewage pumps.

(4) There is no integrated control cabinets for the above facilities.

(5) The lifting equipment, a chain block, for maintenance has rusted. The hanging beam of the chain block is not located at the gravity center of the pumps.

(6) Civil structures including a steel screen provided at the inlet of the sump tank are sound. But a cabin leans to opposite side of the sump tank due to uneven settlement.

(7) Prospective coating on the steel manhole covers and the steel structures for lifting up pumps, which are located outdoor, have been damaged and corrosion was observed on the structures.

(8) There is neither a rest room nor a toilet attached to the pumping station. Operation staff who station round the clock use the toilet in the staff quarters.

(9) General spare parts for the electrical equipment including the power receiving equipment are available in the Study Area.

The existing three submersible pumps are in a worn out condition, thus all the three pumps are to be replaced with new ones. The pumps are of cutter type, 7.5 kW, 240 V, 1.5 m^3/min

Request : ***Construction of a Water Quality Testing Laboratory and Procurement of Testing Equipment***

(1) Source of Pollutant Loads

The pollutant load investigation has clarified the source, type, and quantity of pollutant loads discharging into Lake Nakuru from its drainage area. It is presumed that such investigation might have not been attempted so far. Through the investigation it has been recognized that there are three major routes of pollutant load sources : sewage treatment works, stormwater drainage channel, and rivers and springs, as depicted in Figure 2-2. The pollutant load through the sewage treatment works is accrued from the Nakuru Municipality and is the predominant among the three routes, followed by the stormwater drain which also originates from the Nakuru Municipality. Furthermore, pollutant loads can be grouped into man-made and others as shown in Table 2-2.

Table 2-2 Type of Influents and Pollution

Source of Pollution	Man-made Pollution	Others
The Njoro River (including effluent from sewage treatment works)	Yes	Yes
The Makalia River	No	Yes
The Nderit River	No	Yes
Town Stormwater Drainage Channel	Yes	No
Spring Water	No	Yes

(Source : F/S Team)

The above pollution process is schematically presented in Figure 2-2. The present study focuses on the process in which pollutants discharge into rivers, channel sewerage facilities and lake in a discernible manner.

(2) Evaluation of the Pollutant Load Condition in Lake Nakuru

Pollution in Lake Nakuru could be classified into a number of categories. In order to formulate efficient, rational and practical water pollution control plan, it is crucial to keep in mind the characteristics and effect of every category of pollutant load.

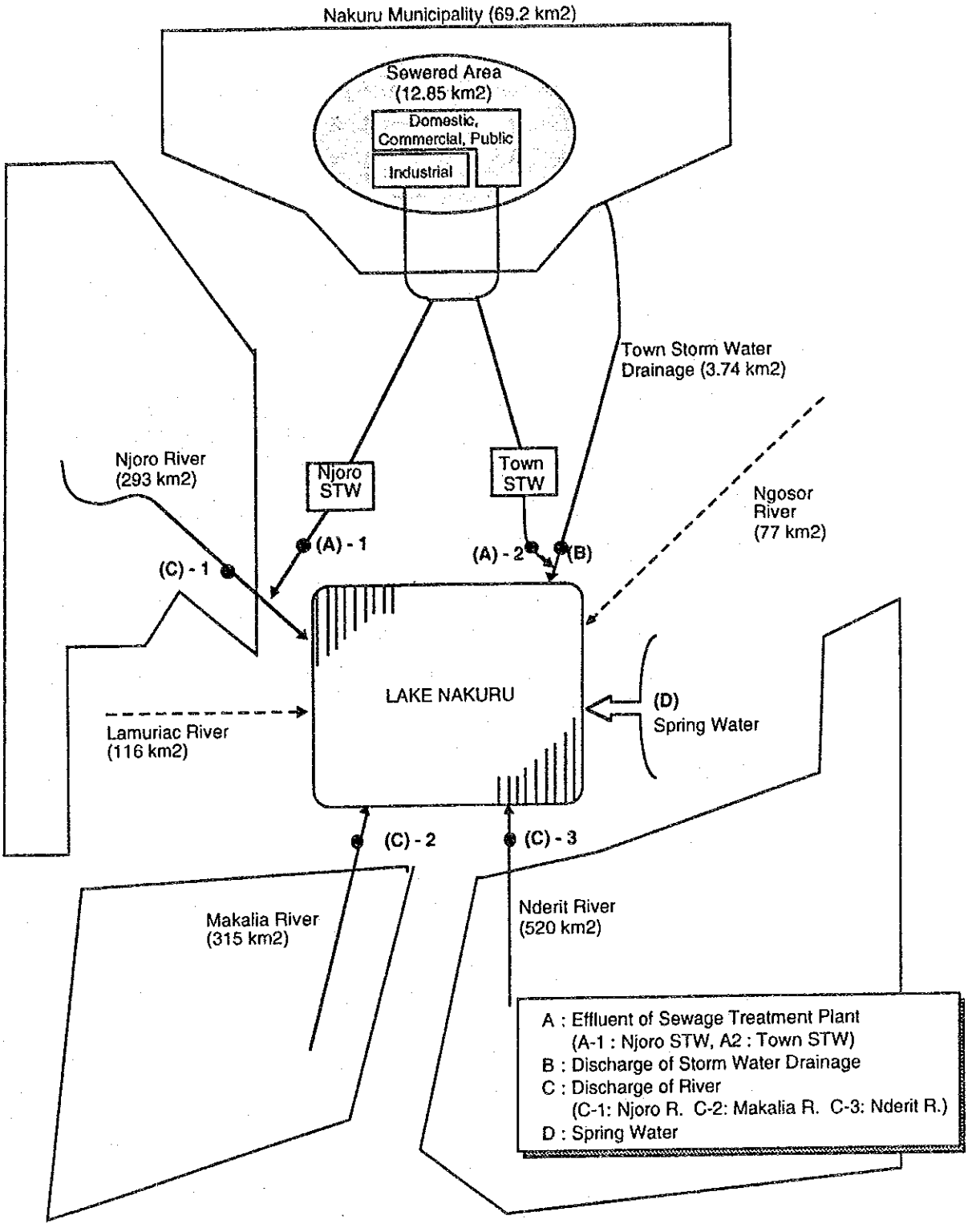


Figure 2-2 Routes of Pollutant Loads

(a) Organic matters

The previous investigation has revealed that the northern part of Lake Nakuru is in an anaerobic state owing to the accumulation of organic sedimentation, which might have originated mainly from the Nakuru Municipality and transported to the lake through sewage treatment works and stormwater drainage channels.

Under the current conditions, BOD load in Lake Nakuru is estimated at 1,471 tons/year, of which 43% is estimated to be accrued from the existing sewage works. Further industrial activities are estimated to contribute a large part of pollutant load being generated in the sewered areas. It is also estimated that 78% of the total pollution concentrates on the northern part of the lake since this part gathers the treated effluent from the sewage treatment works (43%), drainage water (11%) through the channel and streamflow of the Njoro river (24%).

According to the pollutant load estimate, the present organic pollution in Lake Nakuru is estimated as shown in Table 2-3. As the pollutant load reduction method will be applied, the rehabilitation and expansion of sewage works is anticipated to be effective.

Table 2-3 Present Organic Pollutant Load in Lake Nakuru

Route of Pollutant Load		BOD		COD	
		Amount (ton/year)	Proportion (%)	Amount (ton/year)	Proportion (%)
1.	Sewage works	626	43	807	42
2.	Storm water drainage	161	11	215	11
3.	Rivers and springs	684	46	894	47
	Total	1,471	100	1,916	100

(b) Nutrient

Two types of nutrients (Nitrogen and Phosphorus) are the limiting factor for algae nutrition.

Nutrient control is considered as a preventive measure against eutrophication in general. In the case of Lake Nakuru, algae generation is the most important issue from the viewpoint of flamingo feeding. Therefore, before establishing of a strict nutrient control measure, it will be necessary to conduct a detailed study of the relationship between nutrients and the eco-system of Lake Nakuru. The present nutrient loads in Lake Nakuru are summarized in Table 2-4.

Table 2-4 Present Nutrient Pollutant Loads in Lake Nakuru

Route of Pollutant load		T-N		T-P	
		Amount (ton/year)	Proportion (%)	Amount (ton/year)	Proportion (%)
1.	Sewage works	490.6	90	151.1	91
2.	Storm water drainage	12.4	2	12.5	7
3.	Rivers and springs	44.3	8	3.2	2
	Total	547.3	100	166.8	100

(c) Others

Heavy Metals

It has been clarified that the sources of heavy metals are industrial factories and only a limited number of factories generate heavy metal pollution. There are several industrial factories in the Study Area which are supposed to produce harmful heavy metals. However, in the water quality investigation, no heavy metals exceeding the standard value were detected.

The existence of heavy metals causes the water body to become toxic when their amount reached a certain level. Once they flow into the lake, they accumulate in the lake and/or in animals without dissolving. Thus heavy metals are dangerous to animals and human beings.

A strict control of heavy metals is recommended to be applied. As a measure against heavy metal pollution, a treatment at pollution source (at each industrial factory) is the most effective and efficient way and is widely adopted in a number of developed and developing countries.

Pesticides

Pesticides were not detected through the current water quality investigation. It is however known that pesticides damage the ecological condition. Adequate precautions aimed at regulating the use of pesticides will be required.

Oil

Oil once flowed into the lake covers its water surface, remains a long time and accumulates, in the lake. As a result, it obstructs oxygen supply to the lake. Oil must be eliminated to ensure animal activities.

Oil trace was actually found only in stormwater running through the existing drainage channel. The Kenya Wildlife Service (KWS) has in fact warned of oil inflow into the lake and is keen to take appropriate measures to prevent.

(3) Forecast of Sewage Augmentation

It is evident that the volume of sewage increases subsequent by to an increase in the water supply volume. In the present case, it is assumed that the additional water quantity of 13,300 m^3/day will be distributed evenly into the sewered and unsewered areas in proportion to the number of registrants for public water supply. It is forecast that the dry weather flow from the sewered areas will increase to 16,137 m^3/day. It is recognized that there will be a deficit in sewage treatment capacity even after the completion of the on-going Nakuru Sewerage Project. Accordingly it is recommended that the Town STW's capacity be expanded by constructing a new sewage treatment works having a daily treatment capacity of 3,200 m^3.

(4) Effluent Quality Standards

GOK established the "Wastewater Standards for Discharge into Lake Nakuru" (the Wastewater Standards) in June 1993, which are summarized in Table 2-5.

Table 2-5 Wastewater Standards for Discharge into Lake Nakuru

Parameter	Limit
pH	7.0 - 9.0
BOD_5 at 20 °C (filtered), mg O_2/L	10
COD_{Cr} (filtered), mg O_2/L	30
Temperature, °C	25±2
Total suspended solids, mg/L	15
Oil/grease	Trace
Nitrogen as nitrates, mg/L	5.0
Free ammonia (NH_3), mg/L	1.0
Total dissolved solids, mg/L	1,500
Chloride mg Cl/L	1,000
Total phosphorous, mg/L	5.0
Sulphides, mg/L	0.5
Sulphates, mg/L	500
Pesticides, mg/L	0.05
Phenols, mg/L	2.0
Hexavalent Chromium (Cr^{6+}), mg/L	0.05
Total chromium, mg/L	0.1
Copper, mg/L	0.05
Zinc, mg/L	0.5
Other metals in combination (except iron), mg/L	1.0

(Source : MOLG)

In addition, NMC has drafted up the "Municipal Council of Nakuru (Trade Effluent) By-laws" (the Trade Effluent By-laws) as shown in Table 2-6.

Both the Wastewater Standards and Trade Effluent By-laws were reviewed and appraised technically in the light of quality of sewage and the similar standards in other countries and from the viewpoint of sewage treatment process. The following are the conclusion and recommendations:

(a) The Wastewater Standards are stringent. It is recommendable to make minor revisions for such parameters as COD_{Cr}, nitrogen, heavy metals, toxic material, and carcinogenic compound.

(b) It is recommended that the Wastewater Standards be applied on a basis of step by step and the Trade Effluent By-Laws be enforced as soon as possible.

Table 2-6 Trade Effluent Standards for Discharge into Public Sewers

(Unit: mg/L)

Item	Concentration
Total suspended solids	600
Total non-volatile dissolved solids	3,000
BOD_5 at 20°C	500
COD	1,000
Phenols (total at connection point)	10
Detergents	15
Soaping oils and fats	10
Hydro carbons	20
Silver (Ag)	0.02
Arsenic (As)	0.02
Barium (Ba)	0.5
Cadmium (Cd)	0.01
Chloride (Cl)	1,000
Cyanide (CN^-)	0.02
Cyanide (CN) total	1
Cobalt (Co)	0.05
Hexavalent Chromium (Cr^{6+})	0.05
Total Chromium	3
Copper (Cu)	0.5
Mercury (Hg)	0.01
Ammonical nitrogen	20
Nickel (Ni)	0.5
Free ammonia	10
Total Kjeldahl nitrogen	Nil
Nitrite	0.5
Lead (Pb)	2
Total phosphate	30
Selenium (Se)	0.5
Tin (Sn)	0.5
Sulphite (SO_3)	2
Sulphate (SO_4)	1,000
Zinc (Zn)	0.5
Total nonferrous metals	0.5
Total soluble nonferrous metals	30
Pesticides	Nil
pH	6.5 - 8.0
Temperature	Not exceeding 35°C
In addition, effluents should not contain any toxic matter or any matter that will cause blockage and damage to sewers. Inflammable materials and tar should not be present in the final effluent entering the sewer.	

(Source : NMC)

(5) Pollution Control Plan

The proposed pollution control plan comprises structural and non-structural measures, and is envisioned to be implemented stagewise. The proposed control plan covers the following:

(a) Structural Measures
- Sewage treatment works
- Sludge treatment and disposal
- Septage treatment and disposal
- Stormwater retention pondage
- Disposal of industrial solid waste

(b) Non-structural Measures (for the shortterm)
- Water-related legislations
- Overall institutional support
- Monitoring activities

It is a matter of vital importance to monitor pollution loads flowing into Lake Nakuru, the lake water quality, and quantity and quality of industrial effluents. Especially the monitoring of industrial effluents plays a significant role in the proper enforcement of the Trade Effluent By-Laws. The water quality testing laboratory is one of the non-structural measures and is very important especially for successful implementation of the Trade Effluent By-laws. Therefore, it is concluded that a water quality testing laboratory should be constructed and provided with necessary testing equipment.

Request : Procurement of Operation and Maintenance Equipment for Sewerage Facilities

(1) Existing Operation and Maintenance Practice

(a) Sewer network

Cleansing of sewers is normally done using a Canon Jet, a wincing machine and other manual operating tools such as bamboo drain rods.

The Cannon Jet is composed of a water tank and exhausting tank and is capable of cleansing the sewer with a pressure of 250 bars and for a length of 60 m. This has however been worn out and subjected to frequent repairing.

The wincing machine is used for cleansing of sewers up to a maximum diameter of 24 inches and a length of 80 m.

The wincing machine is used for cleansing of sewers up to a maximum diameter of 24 inches and a length of 80 m.

Normally cleaning works are done at 10 locations per day.

(b) Mwariki pumping station

The station is attended by an operator throughout day and night. Pump operation is monitored and raking of trush is done manually.

(c) Town STW

In principle the STW is operated in accordance with the established operation manual. However, there has been a slight deviation and arbitrate operation deriving from experience sometimes prevails.

Inlet works

Trash, grit and other foreign materials are removed by means of manual raking and a grit removal machine. The quantity of trash and sediments is roughly estimated to be 8 fulval/day and 10 fulval/day respectively.

Primary clarifier

Desludging is done by operation of the Valve "V1", which is normally operated 3 times a day for 10-15 minutes, depending on the volume of sludge.

Trickling filter

The sewage is recirculated by the Pump "P1". There are three pumps, each having a capacity of 60 m^3/h with a float switch, and one of them is on stand-by. The pump is normally operated only when the staff is stationed at the works, in general between AM 6:00 - PM 6:00. During night time, electricity supply to the pumps is switched off. The trickling filter's operation stops when the recirculation pump is not operated and the inflowing discharge decreases to a certain limit.

Secondary clarifier

Desludging is made by operating of the Valve "V2" in the same way as the Valve "V1".

Desludging from the sump pit depends on the recirculation Pump "P2", each with a capacity of 22 m^3/hour and equipped with a float switch. One of the two pumps is on stand-by. The pumps are normally operated three times a

day, each operation ranging from one to two hours depending on the volume of sludge.

Digester

Transfer of sludge from the consolidation tank to the sludge sump is carried out by operating the Valve "V4". Its operation is almost the same as the Valve "V1". Desludging from the sludge sump is done by the two Pumps "P3", one of which is on stand-by. Each pump has a capacity of 22 m^3/hour and a duty pump is operated three times a day, each operation lasting 10-15 minutes.

Sludge from the digester is drained into the sludge drying beds by operating the drain valves once a week. Sediment deposit at the digester is normally evacuated at a frequency of three times a month.

Sludge drying bed

The return Pump "P4" is used to transmit sludge from the sludge drying beds. There are two pumps, one of which is on stand-by, each having a capacity of 60 m^3/hour and equipped with a float switch.

(d) Njoro STW

Inlet works

Routine maintenance is quite the same as the Town STW. The quantity of rugs and sediments is 3-4 fulval/day and 5 fulval/day respectively.

Anaerobic ponds

No particular operation and maintenance works are practiced normally.

Facultative and maturation ponds

The operation and maintenance are quite the same as the anaerobic ponds.

(2) Existing operation and maintenance equipment

(a) Sewage Section of WSD

Laboratory

The laboratory existing at the Njoro STW is annexed to the office room. The room space is sufficient for routine administrative and analyzing works. The instruments of the laboratory are listed in Table 2-7.

Table 2-7 Instruments of the Laboratory in the Njoro STW

No.	Particulars	Manufacturer	Model	Serial No.	Conditions	Remarks
1.	Manometric incubator	BS B5-Gerat	RA 138A	9268201	Good	For six bottles
2.	pH meter	WTW	pH91	38480277	Good	
3.	Oxygen meter	Syland	Simpiair-L	800690	No good	Broken
4.	Oxygen meter	YSI	54ARC	10178	No good	Broken
5.	pH meter	Orion	399A	80753	No good	Broken
6.	Turbidition meter	-	-	-	Good	
7.	Incutrab/2	HACH	2597A	3151	Good	
8.	Incubimeter	HACH	2173A	-	No good	
9.	Filter set	-	-	-	Good	
10.	Spectro photo meter	HACH	DR/2 2582-00	887	No good	No agents
11.	Deionizer	Elgastat	B.114	557	Good	
12.	Refrigerator	-	-	-	Good	Approx. 200 ltr
13.	Others	-	-	-	Good	

(Source : F/S Team and WSD)

Workshop in the Town STW

A small number of electric tools and other tools for repairs of the facilities are available in the Town STW as shown in Table 2-8.

Table 2-8 Instruments of the Workshop in the Town STW

No.	Particulars	Manufacturer	Model	Serial No.	Conditions	Remarks
1.	Bench drilling machine	Black & Decker	EK	-	Good	ø 13 mm
2.	Bench vice	-	5"	-	Good	
3.	Angle grinder	-	-	-	No good	ø 180 mm
4.	Double head bench grinder	-	7"	-	Good	ø 7"
5.	AC welder	Electra beekum	140W6	C88375	Good	46V, 30-140A

(Source : F/S Team and WSD)

(b) Cleansing Section

Table 2-9 presents a list of equipment owned by the Cleansing Section of PHD. At present 12 refuse collection vehicles are under operation and an exhauster for collection and disposal of sludge from the individual on-site wastewater treatment facilities.

The review results suggest that the operation and maintenance equipment for sewage facilities should be strengthened.

Table 2-9 Type, Model and Condition of Vehicles for Refuse Disposal

Registration No.	Year of Manufacture	Engine Type	Engine Capacity	Carrying Capacity	Type of Body	Condition
KLO 981	1968	Diesel	5700 cc	8790 lbs.	Rear loader comapctor	Undergoing repair
Z5205	1962	-	-	4750 lbs.	Side loader	Not good
KLG 157	1972	Diesel	5700 cc	10565 lbs.	Side loader compactor	Undergoing repair
KLU 516	1976	Diesel	5600 cc	4588 lbs.	Side loader compactor	Good condition
KSD 790	1978	Diesel	6224 cc	6200 kg	Side loader compactor	Good condition
KSG 043	1980	Diesel	6224 cc	6000 kg	Side loader compactor	Undergoing repair
KQY 676	1976	Diesel	5420 cc	6775 lbs.	Tanker	Not in working condition
KWE 053	1989	-	3908 cc	1150 lbs.	Minimatic. compacting system	Unserviceable
KWE 055	1989	-	3908 cc	1220 lbs.	Same as above	Undergoing repair
KWE 056	1989	-	3908 cc	1220 lbs.	Same as above	Undergoing repair
KWE 058	1989	-	3908 cc	1220 lbs.	Same as above	Good condition
KWE 060	1989	-	3908 cc	1260 lbs.	Same as above	Good condition
KWE 059	1989	-	5870 cc	13798 lbs.	Container lifting	Good condition
KWD 061	1989	-	5560 cc	13798 lbs.	Same as above	Good condition
KWE 05?	1989	-	5870 cc	11548 lbs.	Exhauster	Good condition
KWE 052	199?	-	8102 cc	-	Land crawler	Undergoing repair

Source : PHD, NMC

As examined above, existing operation and maintenance facilities are very poor. For a sustained operation of sewage treatment works upon the completion of rehabilitation and expansion, it is very important to strengthen the O&M equipment of the Water Sewerage Department (WSD).

2.3 Project Description

2.3.1 Executing Agency and Operational Structure

(1) Organization for Project Implementation

The Urban Development Department of MOLG will be designated as the executing agency of the Project. In order to manage and supervise the Project's construction works, it is proposed to construct a Project Office in Nakuru city, and its proposed organization is shown in Figure 2-3. The basic function of the Project Office will be the following:

(a) to arrange all the legal procedures for the implementation of the Project;

(b) to carry out surveys and investigations necessary for design and quality control of the works;

(c) to carry out tendering for the selection of the contractor;

(d) to execute the construction supervisory works;

(e) to undertake accounting and auditing of the contract works.

(2) Organization for Operation and Maintenance of the Project

WSD of NMC will have direct and overall responsibility for the operation and maintenance of the project facilities. In order to attain this objective, it is proposed to strengthen WSD, especially the Sewerage Service Sector in terms of manpower and maintenance equipment. For successful implementation of the Trade Effluent By-laws, it is proposed to organize a Trade Effluent Control Unit (TECU) within WSD. The proposed organization is shown in Figure 2-4.

(3) Financial Management

At the moment, the financial management of the WSD is under the control of the Treasury Department. The Sewerage Sector has been facing financial constraints: actual funds disbursement are far from desirous, being ranging from KShs. 2.93 million in 1988/89 to KShs. 5.93 million in 1993/94. Of the 1993/94 budget, only KShs. 1.4 million or 23.6% is allotted to the operation and maintenance of the existing facilities and KShs. 1.3 million and 0.8 million are for loan charges and computer services respectively. It is strongly recommendable that NMC allocate a sufficient fund for a sustained operation and maintenance of the sewerage system, which virtually and greatly contributes to the conservation and protection of the precious environment of Lake Nakuru and its surroundings.

Table 2-10 Annual Expenditures for Water, Sewerage and Health Services of NMC

Year	Overall NMC (Kshs.10^6)	Water Supply		Sewerage		Health	
		Amount (KShs 10^6)	Share (%)	Amount (KShs10^6)	Share (%)	Amount (KShs 10^6)	Share (%)
1988/89	73.20	13.35	18.2	2.93	4.0	13.40	18.3
1989/90	85.80	14.01	16.3	3.34	3.9	21.18	24.7
1990/90	103.64	17.18	16.6	5.06	4.9	22.80	22.0
1991/92	121.94	18.65	15.3	4.26	3.5	22.11	18.1
1992/93	121.70	20.81	17.1	4.94	4.1	29.82	24.5
1993/94	181.96	45.22	24.9	5.93	3.3	34.08	18.7

(Source : NMC)

Note : Probable value for 1992/93 and budget for 1993/94.

As shown in Table 2-10, only 3.3 % of the entire NMC budget for the fiscal year 1993/94 is allocated to the sewerage sector and this is inadequate. Detailed annual expenditures in the sewerage sector are shown in Table 2-11.

The 1993/94 fiscal year budget amounts to KShs 296,333. The amount may be categorized as follows :

	KShs
Salaries and wages	2,453,900
Operation and maintenance	1,391,660
Loan charges	1,281,060
Computer charges	800,040

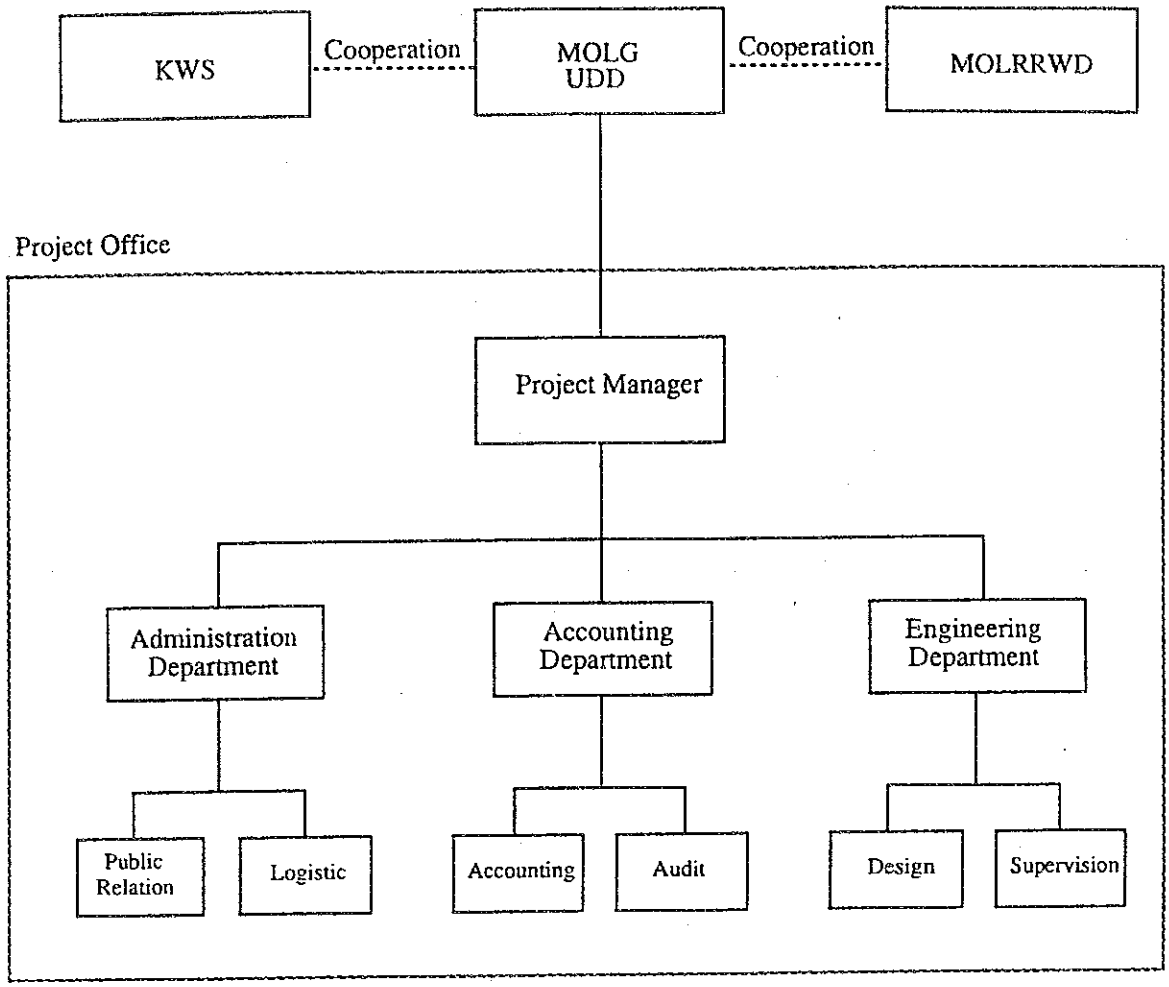
The annual budget corresponds to only KShs. 30 per inhabitant and the direct operation and maintenance share only 23.5 % of the total sewerage budget. It was not possible for WSD to expand sewers in recent years due to financial constraints. A financially autonomous status for WSD would help improve the situation.

Table 2-11 Annual Expenditures of Sewerage Sector of NMC

(Unit : Kenya Pound)

Items	1991/92			1992/93			1993/94		
	Sewage Treatment Works	Sewer Maintenance	Total	Sewage Treatment Works	Sewer Maintenance	Total	Sewage Treatment Works	Sewer Maintenance	Total
Salaries and wages	48,588	62,423	111,011	48,270	63,336	111,606	55,243	61,452	116,695
Superannuation fund	1,236	660	1,896	1,483	717	2,200	1,886	707	2,593
Provident fund	900	2,201	3,101	1,172	2,012	3,184	1,200	2,055	3,255
Subsistence allowance	99	0	99	1,000	0	1,000	1,000	0	1,000
Uniforms	984	894	1,878	2,750	1,500	4,250	3,000	2,000	5,000
Maintenance of buildings	0	0	0	2,000	0	2,000	3,000	0	3,000
Electricity	5,708	0	5,708	5,000	0	5,000	6,000	0	6,000
Water and conservancy	465	0	465	465	0	465	465	0	465
Repairs and maintenance	0	1,944	1,944	0	4,500	4,500	0	6,000	6,000
Rates and insurance	1,348	0	1,348	1,348	0	1,348	1,348	0	1,348
Laboratory equipment	228	0	228	1,500	0	1,500	2,000	0	2,000
Transport	10	1,780	1,790	350	6,000	6,350	250	8,000	8,250
Maintenance of plants	1,492	0	1,492	5,000	0	5,000	5,000	0	5,000
Maintenance of lagoons	0	0	0	4,750	0	4,750	3,200	0	3,200
Maintenance of septic tanks	0	0	0	0	500	500	0	0	0
Telephone	1,029	0	1,029	280	0	280	500	0	500
Hoses	0	1,216	1,216	0	7,000	7,000	0	7,000	7,000
Equipment, drain rods	0	0	0	0	800	800	0	3,350	3,350
Askari force	3,290	0	3,290	3,598	0	3,598	4,634	0	4,634
Cleaning materials	78	0	78	100	0	100	100	0	100
Loan charges	64,053	0	64,053	64,053	0	64,053	64,053	0	64,053
Safety equipment	0	0	0	0	0	0	1,000	0	1,000
Maintenence of sub pumps at Mwariki	0	0	0	0	0	0	3,750	0	3,750
Sewer extension	1,222	0	1,222	0	0	0	0	0	0
Maintenance of the sludge drying bed	0	0	0	3,750	0	3,750	3,750	0	3,750
Manhole cover	0	0	0	0	0	0	0	4,388	4,388
Computer services	0	10,966	10,966	0	13,685	13,685	0	40,002	40,002
Total	130,730	82,084	212,814	146,869	100,050	246,919	161,379	134,954	296,333

Note : Probable value for 1992/93 and budget for 1993/94
Source : NMC



MOLG : Ministry of Local Government
UDD : Urban Development Department
KWS : Kenya Wildlife Service
MOLRRWD : Ministry of Land Reclamation, Regional and Water Development

Figure 2-3 Organization Chart of the Project Office

Figure 2-4

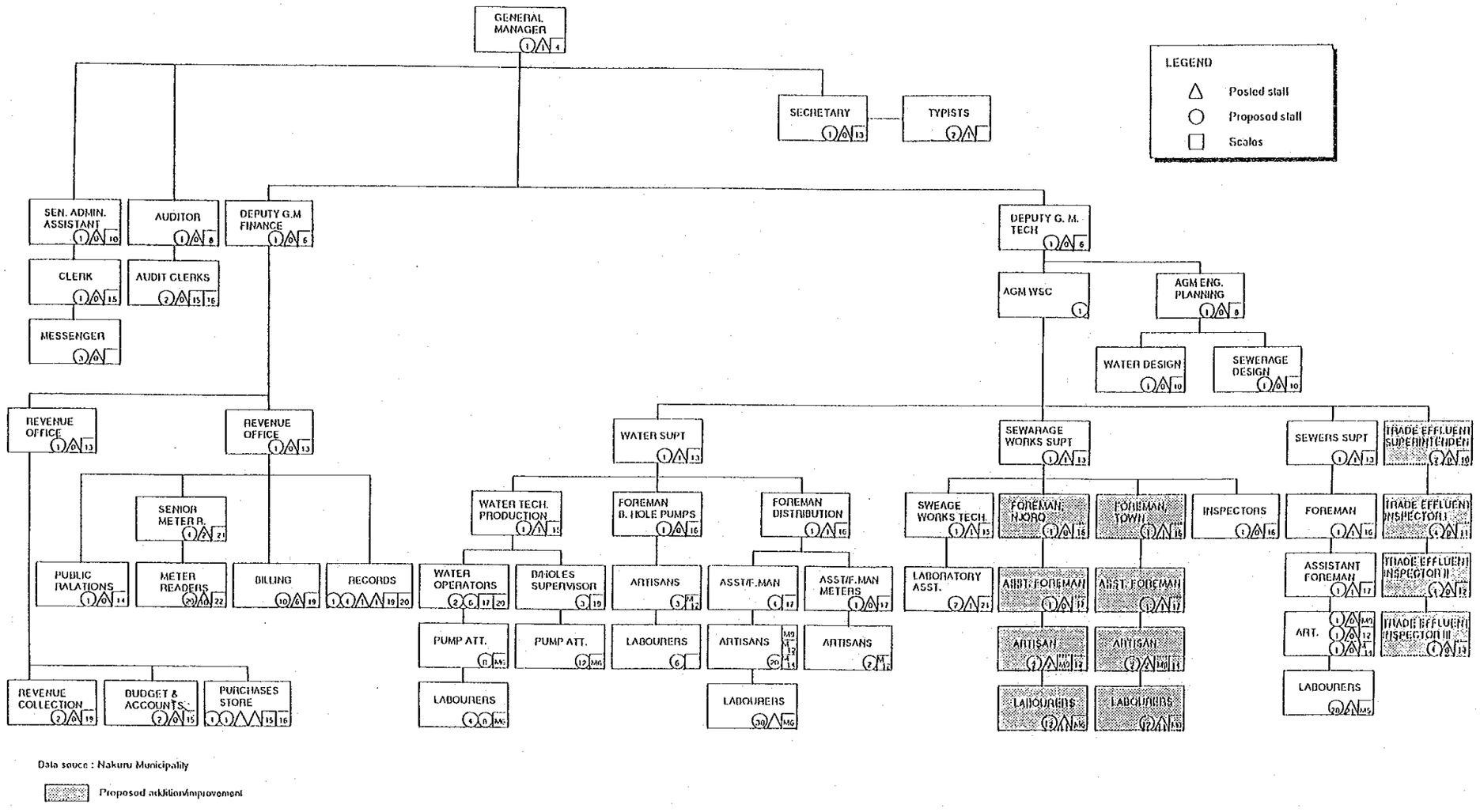


Figure 2-4 Proposed Improvement of WSD Organization

2.3.2 Plan of Operation (Activity)

(1) Sewage Treatment Works

The Town and Njoro treatment works including the Mwariki pumping station will be operated under the overall responsibility of WSD of NMC after the completion of the Project. These facilities will be operated after the strengthening of WSD as proposed in the F/S report.

WSD has no sufficient office space to accommodate its key staff. In order to attain autonomy of WSD and ensure efficient and rational management and administration, NMC is expected to take up necessary actions. The staffing proposed for the sewage sector in WSD is presented in Figure 2-6.

(2) Water Quality Testing Laboratory

The organization and management necessary for the water quality testing laboratory will be established in line with the proposal in the F/S report by JICA and MOLG as shown in Figure 2-5. MOLRRWD will have overall responsibility on pollution control monitoring under the cooperation of KWS and MOLG in the following aspects.

KWS will be in charge of regular sampling at the lake. MOLG/NMC will be in charge of regular sampling and testing, in compliance with the Trade Effluent Standards, of the sewage effluent from the treatment works. MOLG/NMC will also be in charge of testing industrial samples, and monitor water quality of bodies outside the jurisdiction of both KWS and NMC that also might lead to pollution of the lake.

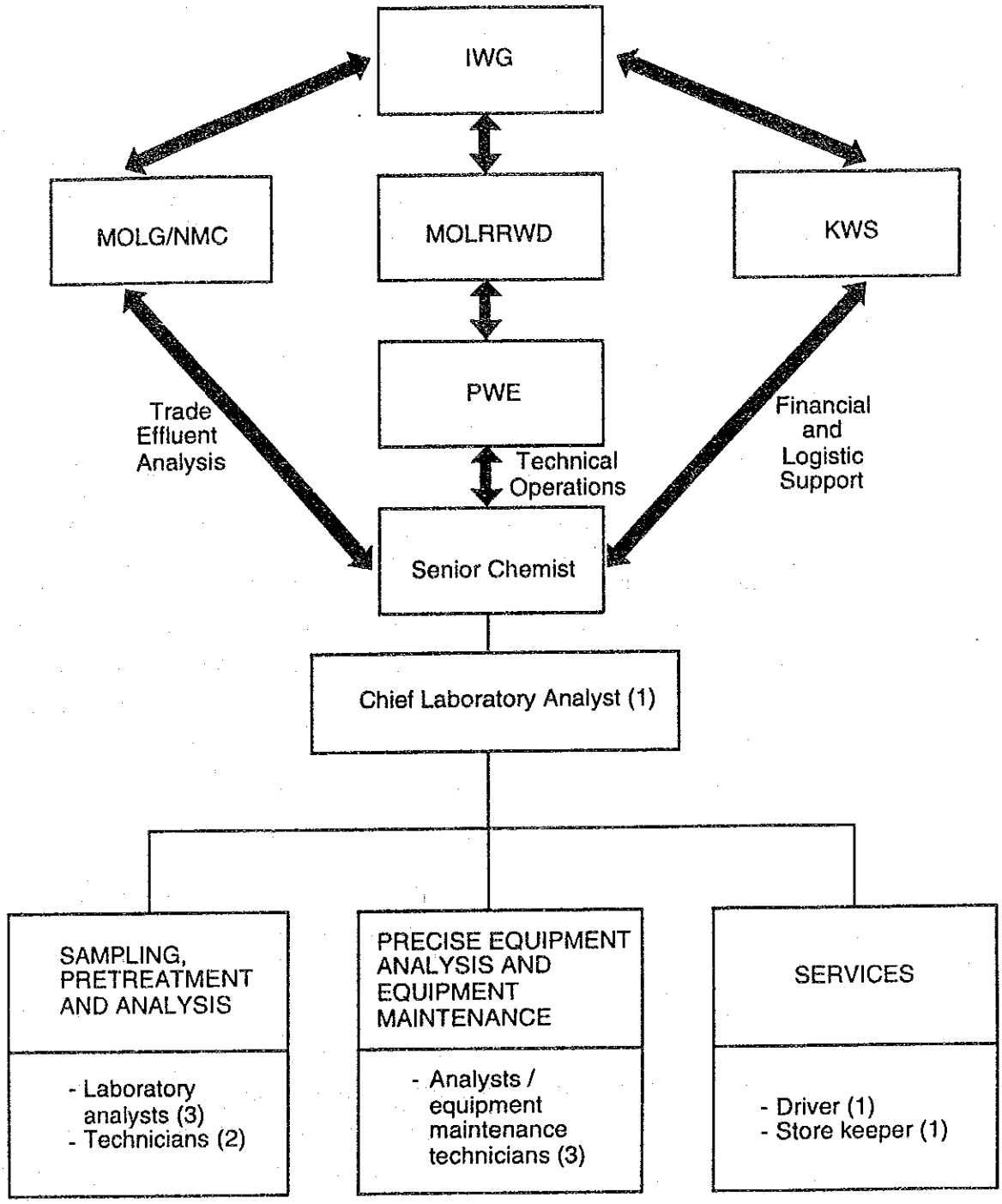
Necessary and adequate staff with relevant qualifications will be recruited from the Kenya Water Institute. The office of provincial water engineer should supplement any shortfalls in terms of management staff. The staff will have the qualifications identified in the F/S report as shown in Table 2-12.

Table 2-12 Qualification and Duties of Staff in the Proposed Water Quality Testing Laboratory

Staff	Qualification	Duties
1. Senior Chemist	- BSC (Chemistry) - Postgraduate (Environmental Chemistry) - 2 year experience in Water and Wastewater Analysis	- Head of Water Quality Laboratory for Technical Operation and Administration - Execute the Lake Nakuru monitoring programme - Ensure proper analyses of water and wastewater samples - Train and supervise junior staff - Prepare budget for laboratory operations - Prepare technical reports
2. Chief Laboratory Analyst	- BSc (Chemistry) - Post Graduate (Env. Chemistry)	- Analyze water and wastewater samples and compile technical reports - Supervise and train junior staff
3. Laboratory Analyst	- 'O' Level Graduate - Ordinary Diploma in Water Engineering or Water Technology from Kenya Polytechnic (HND added - advantage) Field experience in Trade - Effluent and analysis Training in Court Prosecution Procedures at Mombassa Polytechnic	- Analyze trade effluents, water and sewage samples - Compile technical reports - Maintain laboratory equipment
4. Laboratory Technicians	- 'O' Level Graduate - Ordinary Diploma in Water Engineering or Water Technology from Kenya Polytechnic and KEWI - Field experience in Trade Effluent Survey	- Analyze trade effluents, water and sewage samples - Ensure cleanliness in the laboratory
5. Analyst/ Equipment maintenance Technicians	- 'O' Level Graduate - Sewerage Inspector Certificate Kenya Water Institute - Field experience in Trade Effluent Survey	- Analyze water, sewage and trade effluent samples - Maintain laboratory equipment - Ensure cleanliness in the laboratory

The annual operation and maintenance cost for the water quality testing laboratory was estimated at approximately Kshs 2.0 million as broken down below.

Testing chemicals	:	Kshs 0.5 million
O&M cost for testing equipment	:	Kshs 1.0 million
Gasoline & other consumables	:	Kshs 0.5 million
Total	:	Kshs 2.0 million



Note: Numbers in parentheses indicate the number of staff proposed

Figure 2-5 Organization of the Proposed Water Quality Testing Laboratory

The budget for operation and maintenance will be provided by MOLG (NMC), MOLRRWD, and KWS at the ratios of 30%, 25%, and 45% respectively.

Due to the nature of the areas of concern, KWS/WWF will continue with current monitoring activities, and the laboratory should assist in expanding the scope of monitoring which has been limited due to a lack of adequate testing facilities. KWS and WWF are also involved in community-based environmental conservation activities which will be encouraged to continue and expand.

2.3.3 Location and Condition of the Project Site

(1) Location and Topography

The Study Area entirely falls within the drainage area of Lake Nakuru, which is a closed soda lake and drains an area of 1,682 km^2. The drainage area is divided into six sub-basins : Njoro, Ngosur, Makalia, Enderit, Lamudiak, and other minor river basins including the Menengai Crater and lake areas. Their catchment areas are 293, 77, 315, 520, 116, and 361 km^2 respectively. A basin map of the lake is shown in Figure 2-6. The lake surface area is about 43 km^2 at El. 1,758.5 m. The bottom of the lake is at around El. 1,756 m, being characterized by a very shallow water depth. The municipal area of 69.2 km^2 extends over the southern slope of the Menengai Crater and bounds on Lake Nakuru National Park to the south.

(2) Climate

The climatological features of the Study Area as recorded at Showground Synoptic Station in the Nakuru Municipality are summarized below:

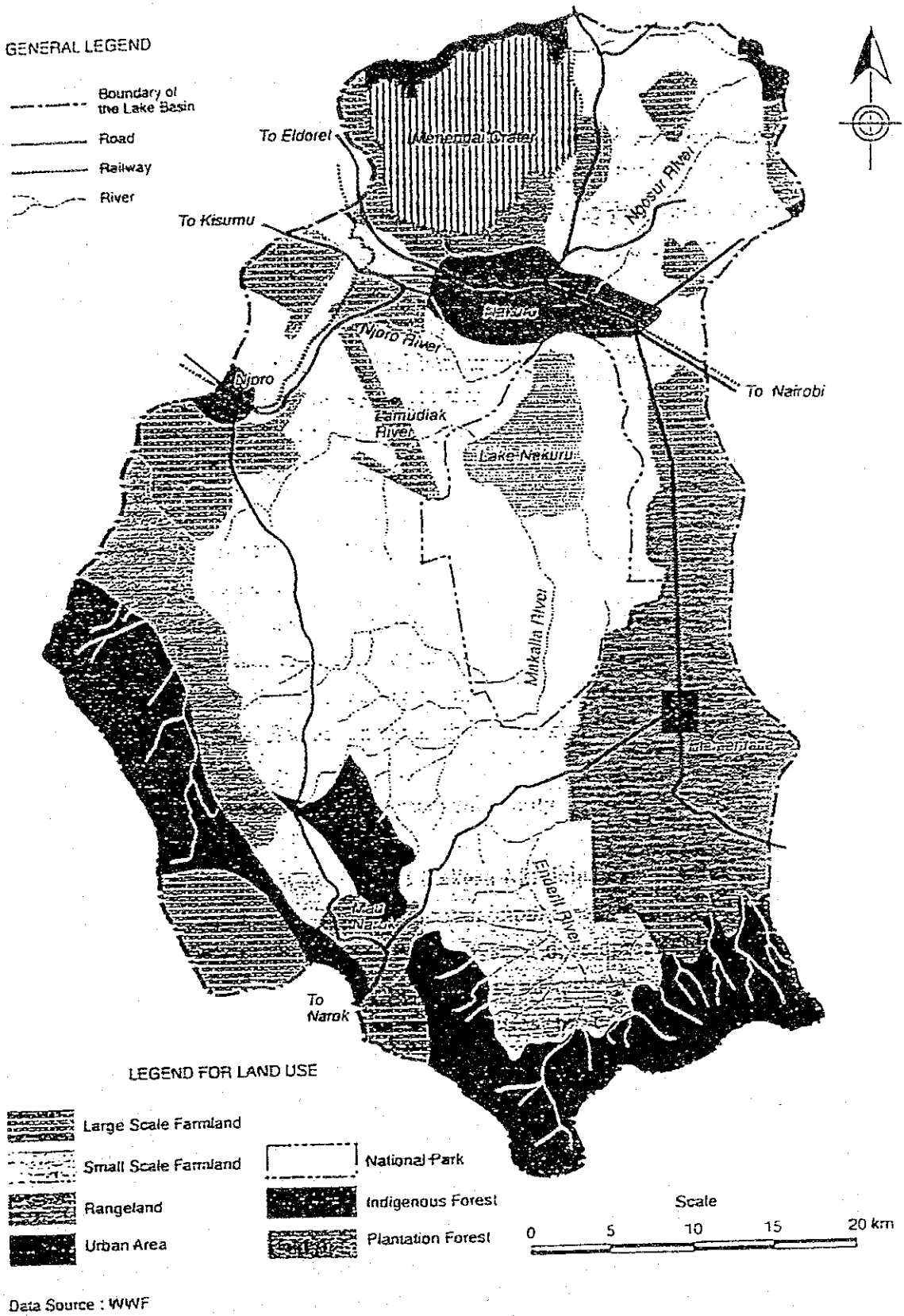
(a) Air temperature

The monthly mean maximum and minimum temperatures are 25.4°C and 10.8°C respectively on the average during the period from 1990 to 1992. Yearly variations of the maximum and minimum temperatures are as little as around 4°C, while seasonal variations are as large as about 19°C at the maximum in January/February.

(b) Rainfall

The annual rainfall is 1,019 mm on an average, ranging from 756 mm to 1,236 mm during a 5-year period from 1988 to 1992. Of the annual rainfall, nearly 40 % occurs during a three-month period from March to May.

Fig. 2-6



THE REPUBLIC OF KENYA	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT	TITLE
MINISTRY OF LOCAL GOVERNMENT	JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 2-6 MAP OF TEH LAKE NAKURU BASIN

The amount of rainfall varies largely from year to year. It is not rare that Lake Nakuru exposes its bottom extensively in severe drought years such as 1988 due to the decrease of inflow.

(c) Evaporation

The annual evaporation is 1,884 mm on an average, exceeding the annual rainfall by 865 mm. It is therefore expected that evaporation would reduce greatly the amount of treated sewage flowing into the lake if the lagoon type of sewage treatment process is introduced.

(d) Wind speed and direction

Winds are slight throughout the day and the year, only three knots at 0600 GMT and 9 knots at 1200 GMT on an average.

The early morning wind is in general in the south to southeast direction, blowing towards the town. However, it is unlikely to occur any serious odor problem since both the sewage treatment works are isolated from the inhabited areas and in the day time the wind direction changes predominantly from north to northeast.

(3) Hydrology

Most of the rivers have small catchments areas of less than 300 km2 which are mostly covered with (a) secondary grasslands, (b) upland acacia wood lands, savanna and bushland and (3) upland evergreen and semi-deciduous bushland. Being subjected to poor vegetation cover and uneven distribution of rainfall throughout the year, all the rivers excluding the Njoro River run dry during the dry season. The treated sewage from Njoro STW sustains to some extent the base flow of the Njoro River.

(4) Geological and Soil Conditions

The Study Area lies entirely in the Rift Valley which consists of a main rift, called also Gregory Rift, traversing the country from north to south, and a branch rift named Kavirondo, running from east to west through the Lake Victoria. The Study Area is covered with sedimentary soils formed as a result of sedimentation of the Menengai Crater or Old Lake Nakuru.

Test drilling was carried out in F/S at three locations at the Njoro STW and two locations at the Town STW. The depth of each borehole was 15 m from the ground surface. Standard penetration and borehole permeability tests were conducted at intervals of 1.0 m and 1.5 m respectively, along the boreholes.

According to the results of test drillings, within a depth of 10 m below the ground surface, sedimentary layers composed of volcanic silt, sand, ash and pumice are predominant at both the Njoro and Town STWs. Characteristics of the sedimentary layers are summarized in Table 2-13.

Table 2-13 Geological Characteristics of Sedimentary Layers

Description	Njoro STW	Town STW
N Value	5 - 15	10 - 20
Permeability coefficient (cm/sec)		
Silt layer	10^{-4} - 10^{-6}	10^{-4} - 10^{-5}
Sandy soil layer	10^{-3}	10^{-4}
Pozzolanic ash layer	10^{-5}	10^{-5}

The sedimentary layer is considered to be in a state of "well compacted" or "tight" form. Judging from these conditions, the sites are in general suitable for the construction of the contemplated ponds and the soils are usable for the construction of embankment with appropriate compaction. It should, however, be noted that a sandy soil layer with a N value of 4 - 5 exists at the depth of 3 m below the ground surface and has a comparatively high permeability coefficient in the order of 1 x 10^{-3} cm/sec. It is recommended to take up adequate measures for designing the waste stabilization ponds in order to prevent excessive seepage through their bottom.

At both the Njoro and Town STWs, one test pit was dug to a depth of 3 m below the ground surface and three soil samples were taken for laboratory testing. The results of the laboratory tests can be concluded as follows:

- The unit weights of silt and sand are only 1.03 - 1.08 and 1.12 - 1.19 tons/m^3 respectively.
- The soils are characterized by very fine particles and natural moisture contents of silt is 51 - 59% at the Town STW and 45-51% at the Njoro STW, while that of sand at the Njoro STW is only 20 - 21%.
- Silt available at the sites can be used as embankment material with appropriate moisture control and compaction.

2.3.4 Outline of Facilities and Equipment

The principal outline for the respective components is as follows.

(1) Mwariki pumping station
- rehabilitation of mechanical and electrical components including replacement of 3 sets of sewage pumps and the lifting equipment.
- renewal of the existing inclined control house.

(2) Town sewage treatment works
- rehabilitation of the existing 3,400 m^3/day line and construction of additional treatment facilities in this line.
- construction of a 3,200 m^3/day line as expansion.
- construction of a sludge drying bed.
- construction of a stormwater retension pond in the Town STW.
- renewal of the control office equipped with workshop in the Town STW.

(3) Njoro sewage treatment works
- rehabilitation of the existing 3,600 m^3/day line and construction of additional treatment facilities in this line.
- construction of additional treatment facilities for the 6,000 m3/day line which is under construction.
- construction of a sludge drying bed.

(4) Water quality testing laboratory
- construction of a water quality testing laboratory.

(5) Procurement of water quality testing equipment and operation and maintenance equipment
- procurement of water quality testing equipment for the water quality testing laboratory to be constructed newly, and the Njoro water quality testing room.
- procurement of operation and maintenance equipment for the sewage facilities and workshop in the control office of the Town STW.

2.3.5 Operation and Maintenance Plan

(1) Basic Guidelines for Operation and Maintenance

The guidelines are summarized in Table 2-13. The operation and maintenance works are basically classified into daily routine and periodical works. The periodical maintenance works could be divided into two categories depending on the nature and

volume of works. Heavy and infrequent maintenance works would be entrusted to an appropriate contractor, while the light and frequent work can be achieved directly by the staff of WSD with provision of appropriate equipment.

Table 2-14 Basic Guidelines for Operation and Maintenance

Description	Daily Routine	Periodical Work
(1) Sewerage System		
(1.1) Sewer network	- Removal of blockage - Cleansing of sewer - Leakage detection and protection	- Cleansing of sewer by block, preferably every 5 years by WSD
(1.2) Mwariki pumping station	- Monitoring of sewage inflow and pump operation - Removal of grit and sediment - Lubrication of mechanical equipment	- Maintenance and repair of mechanical and electrical works, by a contractor
(1.3) Sewage treatment works	- Removal of grit, scum, rubbish and other foreign materials at inlet and waste stabilization ponds - Monitoring of quantity and quality of influent and effluent - Lubrication of mechanical equipment - Grass cutting at WSPs and GPs	- Desludging at anaerobic ponds, every 6 months by WSD - Desludging and repair of associated works, when required, by a contractor - Sludge removal, washing and drying of rock fragments at RFs, preferably every 3 months, by WSD - Grade adjustment and refilling of watercourses by WSD as required, to avoid a short-cut flow - Sludge removal from rock filter drain pit as required.
(2) Stormwater Retention Pond	- Removal of rubbish, oil and other materials - Operation of outlet to make pond empty	- Removal of sediment deposit, preferably once in two years, by WSD

2.4 Technical Cooperation

The water quality testing laboratory was planned to be established in the Project. It is desirable that GOJ will provide technical cooperation to the laboratory staff by assigning an expert to the site for one (1) year to provide guidance on water quality testing method and analysis, monitoring method, sampling technique, and other technical matters. The technical cooperation is expected to commence at the time of installation of the water quality testing equipment and apparatuses, if so decided.

CHAPTER 3 BASIC DESIGN

3.1 Design Policy

(1) Principle of the Basic Design

For implementation of rehabilitation and expansion of the proposed facilities, the following principles are established to meet requirement for the conservation of water related environment.

- To increase existing treatment capacities by rehabilitation and expansion up to a level to be able to treat existing and predicted future wastewater quantity,
- To select economically and environmentally optimal structures in view of capital investment and operation and maintenance cost taking account of institutional and operational conditions by the authorities,
- To satisfy Wastewater Standards and Trade Effluent Standards for Public Sewers established by the authorities, and
- To facilitate monitoring equipment and facilities for water quality control in conjunction with the provision of the structures under rehabilitation and expansion programmes,

(2) Outline of the Structural Component

(a) Sewage treatment works

- To remodel the existing waste stabilization pond at Njoro sewage treatment works to increase treatment capacity.
- To install additional treatment facilities such as rock filters and grass plots at the new 6,000 m^3/day line at Njoro sewage treatment works to upgrade the quality of effluent.
- To add facultative and maturation ponds, rock filters and grass plots to the existing 3,400 m^3/day line at Town sewage treatment works to upgrade the quality of effluent.

(b) Sludge treatment and disposal

The quantity of raw sludge produced at the sewage treatment works is estimated to be 7,200 m^3/year for the entire Njoro sewage treatment works and 5,040 m^3/year for the entire Town sewage treatment works after the completion of rehabilitation and expansion works. It is necessary to treat the

sedimented sludge at stabilization ponds of both STWs which estimates the volume of 40,000 m^3 in wet condition. The sludge drying bed is concluded to be technically and economically feasible for sludge treatment.

It is to be noted that there are several industries emitting heavy metals and toxic materials without proper treatment into public sewers. It is anticipated that such materials settle in anaerobic ponds. It is therefore proposed to dump the dried sludge to a new dumping site, which should be designated by the GOK in a remote area from Lake Nakuru prior to commencement of construction works.

It is basic policy on the sludge treatment that sedimented sludge at both Town and Njoro existing ponds should be dumped to the edge of Menengai forest which was selected by the GOK, and be dumped to the site which is to be selected by the GOK for the generated sludge after the completion of rehabilitation and expansion works.

(c) Stormwater retention pond

A stormwater retention pond will be constructed in Town sewage treatment works in order to restrain the discharge of oil, inorganic maters, solid waste, sediment, etc. into Lake Nakuru, when heavy storm occurred over the Nakuru Municipal area.

(d) Water quality testing laboratory

It is of vital importance to monitor pollution loads flowing into Lake Nakuru, the lake water quality and quantity and quality of industrial effluents. Especially monitoring of industrial effluents plays significant role in the proper enforcement of the Trade Effluent By-Laws. The laboratory is allocated in the vicinity of the Training Center within Lake Nakuru National Park.

3.2 Study and Examination on Design Criteria

The planning conditions and design criteria have been established in order to achieve the basic design of various components of the sewage treatment works as follows:.

(1) Sewered Area

1,285 ha, same as the present sewered area

(2) Planned Sewage Volume

16,200 m^3/day in terms of dry weather flow, to be generated upon commissioning of Greater Nakuru Water Supply project Eastern Division, Stage I.

(3) Design Discharge for Structure Planning

The average daily discharge is applied to the design of sewage treatment works, and the hourly peak discharge for inlet works and pond connection pipes. The design discharge for sewage treatment works are given in Table 3-1.

Table 3-1 Design Discharge

Sewage Treatment Works	Sewage (m^3/day) Average daily	Maximum daily	Hourly peak
(a) Njoro STW			
3,600 m^3/day line	3,600	4,800	7,200
6,000 m^3/day line	6,000	8,000	12,000
Total	9,600	12,800	19,200
(b) Tow STW			
3,400 m^3/day line	3,400	4,500	6,800
3,200 m^3/day line	3,200	4,300	6,400
Total	6,600	8,800	13,200

(4) Water Quality of Influent and Effluent

BOD : Both the Kenya and Japanese teams reached conclusions in the stage of previous feasibility study through a number of discussions that (1) it is not possible to attain the effluent BOD_5 value of 10 mg/L set forth in the standards only by generally acceptable sewage treatment technology and (2) it is absolutely important to implement/enforce adequate non-structural measures such as pre-treatment of industrial wastewater in harmony with rehabilitation and expansion of existing sewage treatment works.

The project is recognized to be implemented as earlier as possible, whereas it is apparent that it takes a long period to control/regulate the quality of the industrial wastewater flowing into the public sewer. It is therefore essential to establish a realistic pollution control plan adaptable to circumstances prevailing in the Study Area. As initial step, it is proposed to rehabilitate and expand the existing sewage treatment works to properly treat the increasing sewage and reduce the BOD_5 concentration from 800 mg/L in influent to 15 mg/L in effluent. In subsequent step,

the standard value of BOD_5 concentration could be achieved with implementation/enforcement of the Trade Effluent By laws, which is being prepared by NMC to control harmful industrial wastes and limit the BOD_5 concentration to 700 mg/L when discharging into public sewers.

The BOD_5 concentration is supposed to be decreased to around 400-500 mg/L if the above said By-laws are successfully brought into effect. It is therefore expected that the effluent could consequently be upgraded to the level of the standard value of 10 mg/L.

SS : With effect of the rock filter and grass plots a target value is set at 15 mg/L.

COD : It is not possible to attain the value specified in the standards, less than 30 mg/L.

Nitrogen & Phosphate : Removal of the nutrients are expected to some extent but is difficult to assess quantitatively.

Heavy metals : Heavy metals, in general, tend to interfere with the biological process and settle and accumulate in the waste stabilization ponds because of the physico-chemical conditions within the waste stabilization ponds. Excessive accumulation will results in problems for sludge disposal. Therefore, source control is important and shall be exercised to control these pollutants at their sources.

The target value of effluent are accordingly set out as in Table 3-2.

Table 3-2 Target Value of Effluent

Item	Influent	Effluent (Target value)
BOD_5	800 mg/L	15 mg/L
Suspended solid	700 mg/L	15 mg/L
Fecal coliform	10^8/100 mL	10^3/100 mL
Air temperature at coldest month	16°C	16°C

(5) Sewage Treatment Process

(a) Njoro STW

3,600 m^3/day line	:	Waste stabilization ponds with additional treatment facilities composing of rock filters and grass plots
6,000 m^3/day line	:	Same as the above

(b) Town STW

3,400 m^3/day line	:	Existing conventional system associated with additional treatment facilities such as waste stabilization ponds, rock filter and grass plots
3,200 m^3/day line	:	Same as the Njoro STW

The sewage treatment process is designed to be dependent on a gravity flow system in order to minimize annual operation and maintenance cost.

(6) Design Calculation for Waste Stabilization Ponds

It is basically dependent on the "Design Manual for East Africa, Overseas Development Administration (UK), Lagoon Technology International, 1992" (hereinafter referred to as the "ODA Manual").

(7) Design Loads on Rock Filters and Grass Plots

The design loads are given conservatively referring to (1) the ODA Manual, (2) Rock Filter Design Standards, the State of Illinois, USA, and (3) Wastewater Engineering, McGraw-Hill International Edition. The comparison of design load for rock filters and grass plats is summarized in Table 3-3.

Table 3-3 Comparison of Design Load for Rock Filter and Grass Plots

Description	Unit	Loading Rate			
		ODA Manual	Illinois State Standards	Wastewater Engineering	Adopted
Rock filters	m3/rock m3/day	1.0	0.8	-	0.5
Grass plots	m3/ha/day	2,000-5,000	-	208-1,560	1,000

3.3 Basic Plan

3.3.1 Mwariki Pumping Station

The existing pump house is inclined due to differential settlement of the foundation. A new pumping station is proposed to build at the site of opposite to the existing pump house. The new building comprises approximately 30 m^2 for floor area including resting room for operator, laboratory and generator room. Design drawing is given in Figure 3-1.

The following mechanical and electrical works are required:

(a) Re-setting of a diesel generator at the new pumping station

(b) Replacement of three existing submersible pumps with the new ones. Each pump shall be of cutter model, 7.5 kW, 240 V and 0.75 m^3/min capacity.

(c) Installation of mercury level switch for stirrers.

(d) Installation of an integrated control cabinet for operation of pumps and stirres, including a changeover switch between Kenya Power and Lighting Co.

3.3.2 Njoro Sewage Treatment Works

Both the 3,600 m^3/day and 6,000 m^3/day lines are branched off into two lines, each having equal treatment capacity in parallel and consisting of waste stabilization ponds, rock filters and grass plots. General layout is given in Figure 3-2. Of the 6,000 m^3/day line, the waste stabilization ponds are planned to complete by the middle of 1994 under the Nakuru Sewerage Project.

The work comprises the construction of the following major structural components and the salient features of the sewage treatment works are given in Table 3-5:

(a) 3,600 m^3/day line

- Remodeling of the existing waste stabilization ponds to increase treatment capability
- Inlet pipes between the existing flow splitting chamber and the anaerobic ponds
- Pond connection pipes between the successive ponds including pond outlet and inlet structure
- Waste stabilization ponds, rock filters and grass plots
- Outlet works including an outfall on the left bank of the Njoro river

(b) 6,000 m^3/day line

- Pond connection pipes between the third maturation ponds and rock filters
- Rock filters and grass plots

(c) Rock filter drain pit

3.3.3 Town Sewage Treatment Works

General layout is given in Figure. 3-3.

The work involves the construction of the following major structural component and the salient features of the sewage treatment works are given in Table 3-6.

(a) 3,400 m^3/day line

- Ventilation at trickling filter
- Inlet pipe between the existing secondary clarifier and the facultative ponds
- Pond connection pipes between the successive ponds including pond outlet and inlet structures
- Waste stabilization ponds, rock filters, and grass plots
- Rock filter drain pits

(b) 3,200 m^3/day line

- Inlet works between the existing inlet and new anaerobic ponds
- Pond connection pipes between the successive ponds including outlet and inlet structures
- Waste stabilization ponds, rock filters and grass plots
- Rock filter drain pits

(c) Building works for control office

(d) Mechanical and electrical works

The mechanical works mainly cover the replacement of timeworn equipment in the 3,400 m^3/day line, while the electrical works are mainly to install control cabinet at various locations and relocation of existing distribution line. Table 3-4 summarizes the major mechanical and electrical works.

Table 3-4 Major Mechanical and Electrical Works

	Work Items	Unit	Quantity
(1)	Mechanical works		
	Drain pumps, 50 mm dia., H = 12 m, with mercury level switch	set	3
	Inlet gate, cast iron	set	2
	Coarse screen, SUS, at inlet	set	1
	Fine screen, SUS, at inlet	set	1
(2)	Electrical works		
	Main distribution board	set	1
	Distribution panel at grit chamber	set	1
	Control cabinet at deep well pumps	set	1
	Control cabinet at recirculation pumps	set	1
	Control cabinet at sludge dry bed pumps	set	1

(Data source : Study Team)

3.3.4 Sludge Treatment and Disposal

(a) Planning Conditions and Design Criteria

Characteristics of sludge

The sludge treatment and disposal have been planned under the following conditions and criteria:

Water content		
Raw sludge	:	90%
Dry sludge	:	50%
Density of dried solid	:	1,500 kg/m^3
Density of water	:	1,000 kg/m^3

Sludge treatment

In the waste stabilization pond process, most of sludge is produced in anaerobic ponds and is required to be desludged periodically in order to sustain the function. The sludge generated is proposed to dewater in the sludge drying bed, taking advantage of climatological condition and in view of saving operation cost.

Sludge disposal

The dried sludge will be disposed to the dumping sites, which will be designated by the NMC prior to implementation of the Project.

The JICA asked to the GOK in his questionnaire dated April 6th, 1994 on the sludge dumping site stipulated above, and the GOK answered in his reply sheet as attached in Appendix 7.

It is planned that sedimented sludge at both STWs are dumped to the selected site at the edge of Menengai forest upon necessary land grading the site and improvement of existing access road under the such circumstances. Sedimented sludge volume was estimated at approximately 40,000 m^3 and 10,000 m3 in wet and dry conditions respectively. The land grading of dumping site is to be planned by using this parameter for existing sludge treatment.

On the other hand, annual sludge generation is estimated at 12,240 m^3/year in total at both STWs in wet condition after the completion of rehabilitation and expansion works as broken down below.

Town STW	:	5,040 m^3/year
Njoro STW	:	7,200 m^3/year

It is strongly requested to select the site for treatment of generated sludge after the rehabilitation and expansion of both STWs to meet the requirement as recommended in the F/S report.

Sludge generated at the 3,400 m^3/day line at Town STW will continuously be treated by a digester and sludge drying bed simultaneously and then disposed to the dumping site.

(b) Design of Sludge Drying Bed

The sludge drying bed is sited within a compound of the respective sewage treatment works as given in Figure 3-2 and 3-3. It is estimated that the production of raw sewage amounts to 20 m^3/day for the entire lines of the Njoro STW and 6.6 m^3/day for the 3,200 m^3/day line of the Town STW.

The principal features of the sludge drying bed is given in Table 3-4 for Njoro STW and Table 3-5 for Town STW. The dried sludge will be reduced one fifth of the raw sludge in terms of volume so that the designed sludge dry bed capacity almost corresponds to the sludge generation volume for 10 years.

3.3.5 Stormwater Retention Pond

(a) Planning Conditions and Design Criteria

The stormwater drainage runs along the eastern boundary of the Town STW and washes out garbage, debris, oil and other materials during storm accumulated in the town area. According to the estimate, pollution load through the drainage is estimated at about 161 ton/year in term of BOD, constituting about 11% of total BOD load into Lake Nakuru. It is therefore recommended to construct a stormwater retention pond to remove the above-said matters.

The design parameters derived from the Preliminary Design Report on Sewage Treatment Works (Town Site), June 1988, which was prepared for NMC and MOLRRWD are given as follows:

<u>Design storm</u>

Return period	:	5 years
Storm duration	:	46 minutes
Rainfall intensity	:	42 mm/hour

Runoff estimate

Method	:	Rational
Catchment area	:	374 ha
Runoff coefficient	:	0.10 - 0.40, depending on land use
Volume of runoff	:	14,200 m^3

Sediment deposit

Sediment yield	:	0.04 $mm/km^2/year$
Sediment volume	:	150 $m^3/year$

The sediment deposit is estimated based on the sediment yield given by "Study on Construction of Dam in Malewa River System for Greater Nakuru Water Supply Project" prepared for MOLRRWD.

(b) Design of Stormwater Retention Pond

With construction of the additional and new sewage treatment facilities at the Town STW, it is required to relocate the existing stormwater drainage. The drainage is designed with the same dimensions and cross-sectional shape as the existing drains so as not to cause the adverse effect due to relocation.

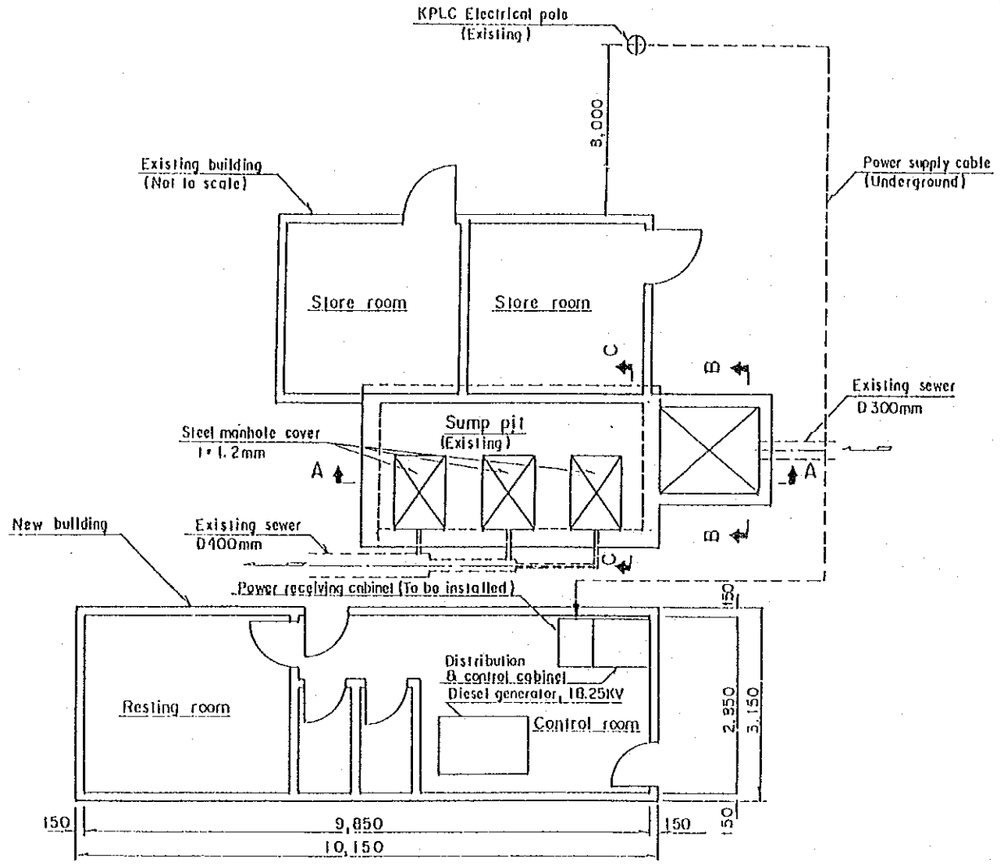
The stormwater retention pond is capable of absorbing a whole volume of the estimated stormwater and is connected directly with the stormwater drainage. Its principal features are shown in Table 3-5. An oil trap at its inlet and outlet structures to make the pond empty are provided.

3.3.6 Control Office

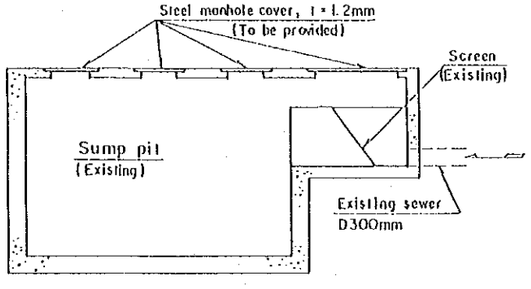
It is proposed to be sited within the compound of the Town STW and to be composed of office, workshop, spare part storage, lavatory and kitchen. Total floor area is approximately 120 m^2.

3.3.7 Water Quality Testing Laboratory

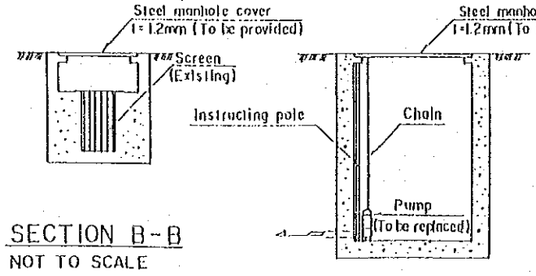
The site for the laboratory is selected within Lake Nakuru National Park in the vicinity of Training Center. The building is divided into a number of rooms including the testing rooms such as biological laboratory, central laboratory, analyzing laboratory, balance room and research room. It has a floor area of approximately 350 m^2 and is designed in frame structure, being reinforced concrete structure as shown in Fig. 3-4. Roof and wall are steel and concrete block structures respectively. For the respective category, sampling frequency and water quality testing items are proposed as shown in Tables 3-7 through 3-10 according to the proposed pollution control plan.



PLAN SCALE A

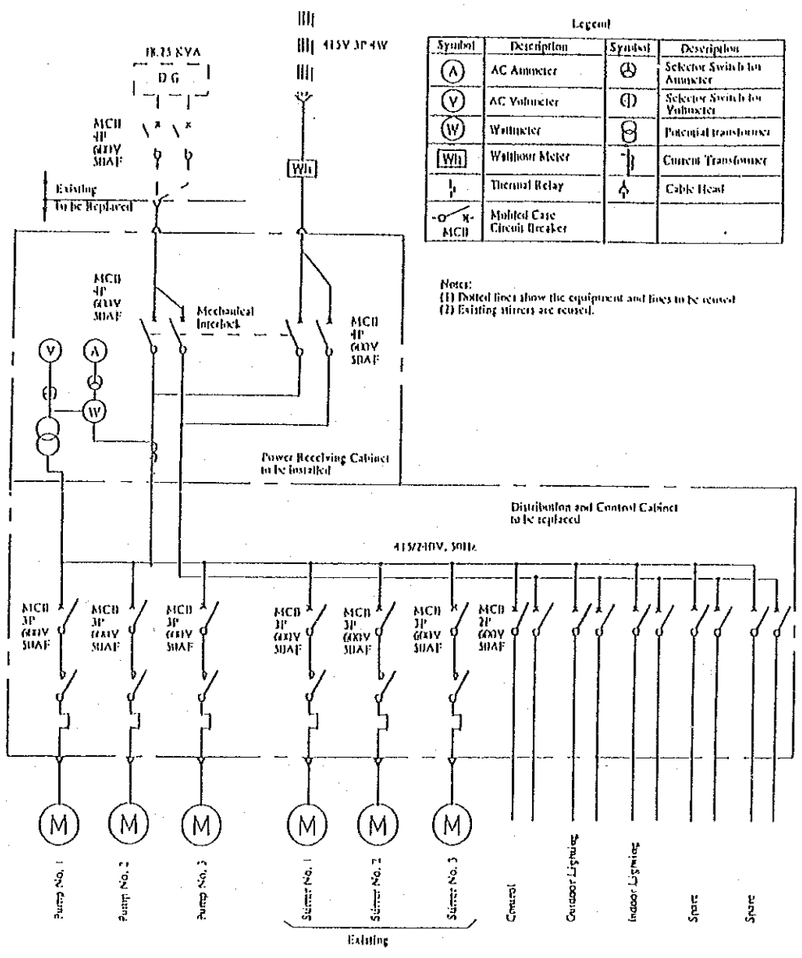


SECTION A - A NOT TO SCALE



SECTION B - B
NOT TO SCALE

SECTION C - C
NOT TO SCALE



Legend

Symbol	Description	Symbol	Description
A	AC Ammeter		Selector Switch for Ammeter
V	AC Voltmeter		Selector Switch for Voltmeter
W	Wattmeter		Potential transformer
Wh	Watthour Meter		Current Transformer
	Thermal Relay		Cable Head
MCB	Molded Case Circuit Breaker		

Note:
(1) Dotted lines show the equipment and lines to be removed
(2) Existing meters are reused.

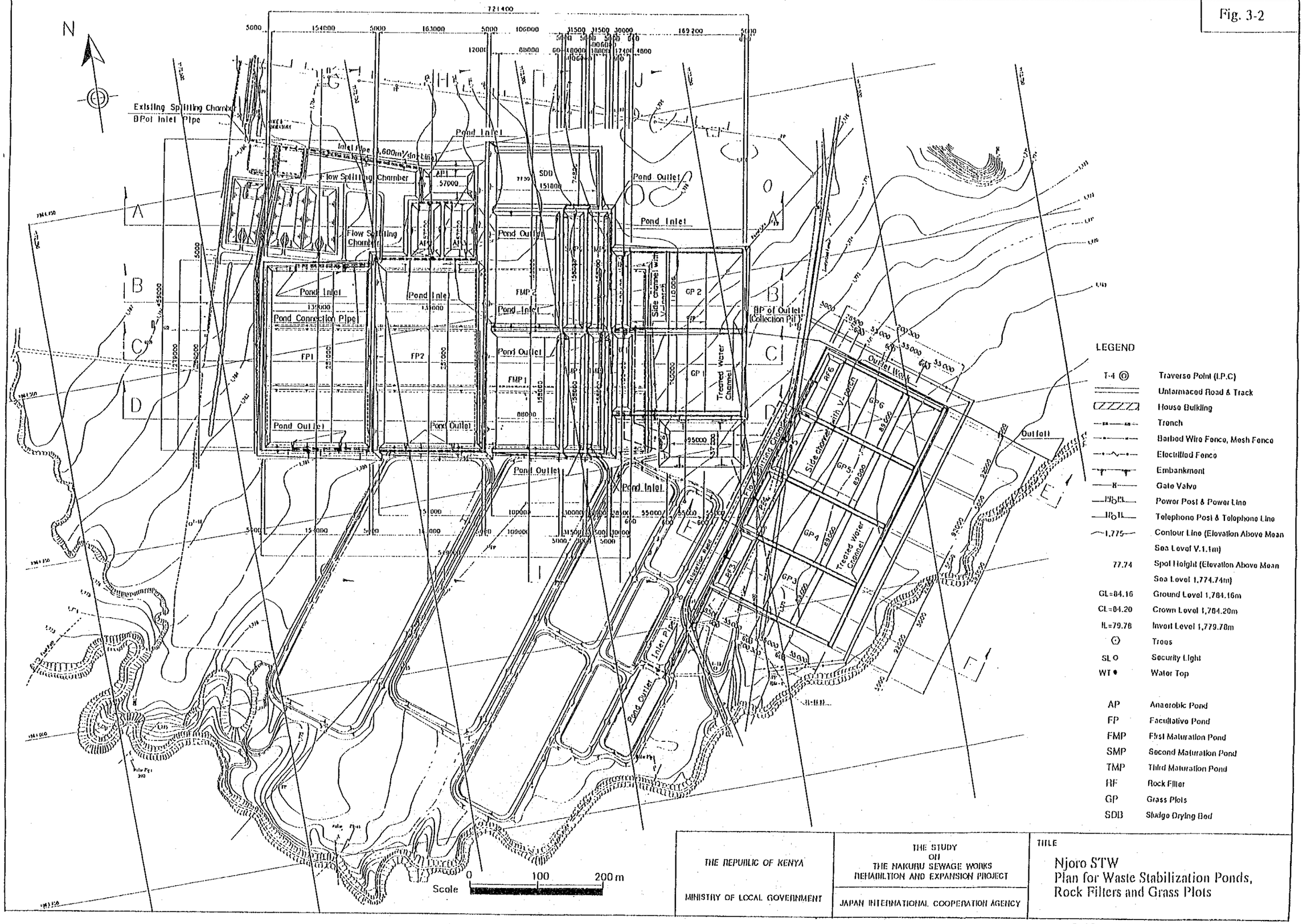
SINGLE LINE DIAGRAM

SCALE A 0 25 50m

Note :
(1) Diesel generator shall be removed from existing building and be installed at new building

THE REPUBLIC OF KENYA	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITION AND EXPANSION PROJECT	TITLE: Mwariki Pumping Station Electrical Works
MINISTRY OF LOCAL GOVERNMENT	JAPAN INTERNATIONAL COOPERATION AGENCY	3-11

Fig. 3-2

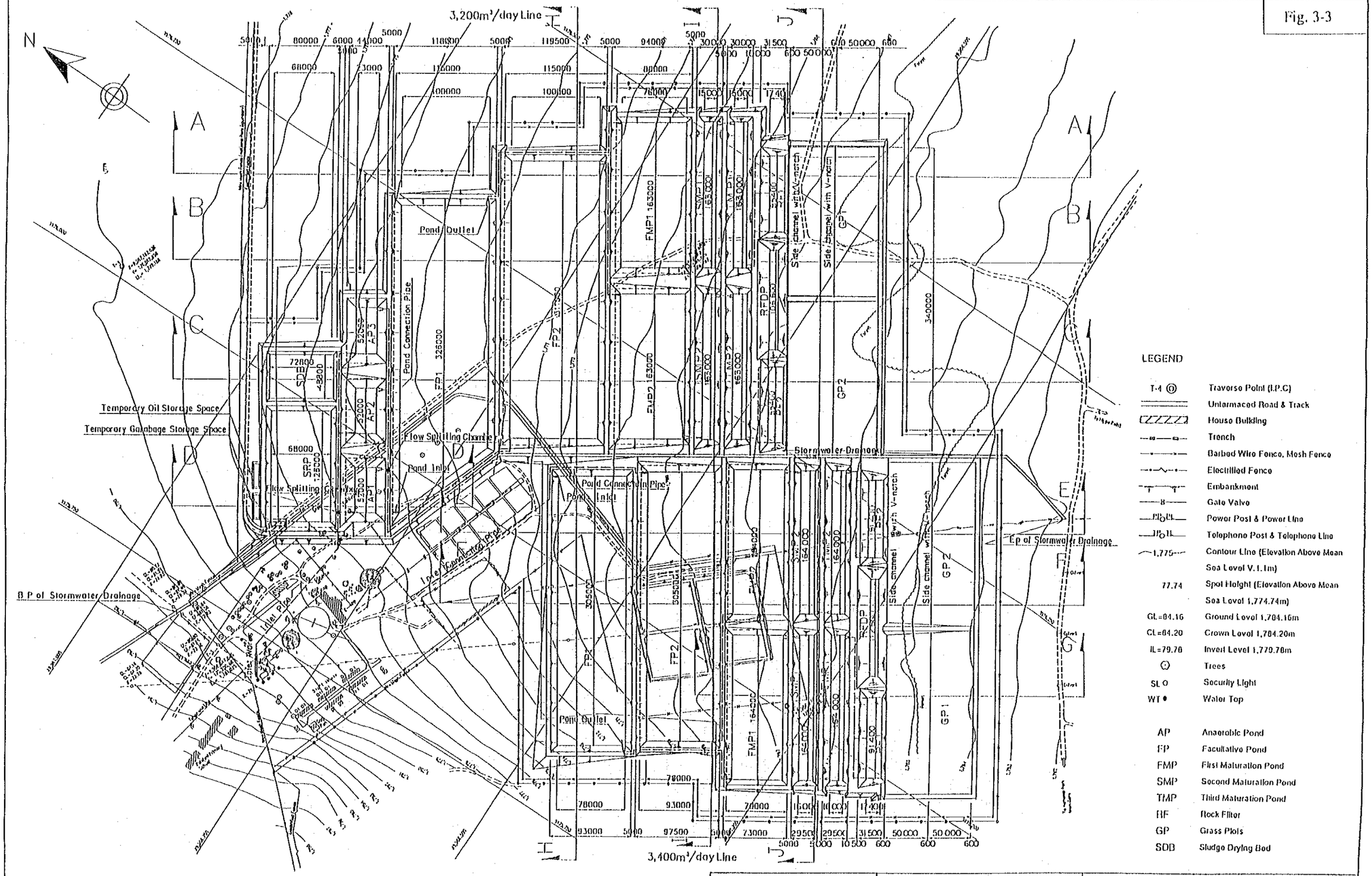


LEGEND

T-4 ◎	Traverse Point (I.P.C)
	Unlarmaced Road & Track
	House Building
	Trench
	Barbed Wire Fence, Mesh Fence
	Electrified Fence
	Embankment
	Gate Valve
	Power Post & Power Line
	Telephone Post & Telephone Line
1,775	Contour Line (Elevation Above Mean Sea Level V.1.1m)
77.74	Spot Height (Elevation Above Mean Sea Level 1,774.74m)
GL=84.16	Ground Level 1,784.16m
CL=84.20	Crown Level 1,784.20m
IL=79.78	Invert Level 1,779.78m
⊙	Trees
SL O	Security Light
WT ●	Water Top
AP	Anaerobic Pond
FP	Facultative Pond
FMP	First Maturation Pond
SMP	Second Maturation Pond
TMP	Third Maturation Pond
RF	Rock Filter
GP	Grass Plots
SDB	Sludge Drying Bed

THE REPUBLIC OF KENYA MINISTRY OF LOCAL GOVERNMENT	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITION AND EXPANSION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Njoro STW Plan for Waste Stabilization Ponds, Rock Filters and Grass Plots

Fig. 3-3



LEGEND

T-4 ◎	Traverse Point (I.P.C)
	Unfarmaced Road & Track
	House Building
	Trench
	Barbed Wire Fence, Mesh Fence
	Electrified Fence
	Embankment
	Gate Valve
	Power Post & Power Line
	Telephone Post & Telephone Line
1,775	Contour Line (Elevation Above Mean Sea Level V.1.1m)
77.74	Spot Height (Elevation Above Mean Sea Level 1,774.74m)
GL=84.16	Ground Level 1,784.16m
CL=84.20	Crown Level 1,784.20m
IL=79.78	Invert Level 1,779.78m
	Trees
SL ○	Security Light
WT ▼	Water Top
AP	Anaerobic Pond
FP	Facultative Pond
FMP	First Maturation Pond
SMP	Second Maturation Pond
TMP	Third Maturation Pond
RF	Rock Filter
GP	Grass Plots
SDB	Sludge Drying Bed

THE REPUBLIC OF KENYA MINISTRY OF LOCAL GOVERNMENT	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITION AND EXPANSION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Town STW Plan for Waste Stabilization Ponds, Rock Filters and Grass Plots

Table 3-5 Principal Features of Njoro Sewage Treatment Works

1. 3,600 m^3/day Line

(1) Inlet Connection Pipe

Design discharge (Hourly Maximum)	:	0.100 m^3/sec
Inlet water level	:	El. 1,786.1 m
Pipe diameter	:	D300 mm & D450 mm
Pipe length	:	315 m
Flow splitting chamber	:	1 no.

(2) Waste Stabilization Ponds, Rock Filters and Grass Plots

	Anaerobic Ponds	Facultative Ponds	First Maturation Ponds	Second Maturation Ponds	Third Maturation Ponds	Rock Filters	Grass Plots
Number of Ponds	3	2	2	2	2	2	2
Design Discharge (Average Daily)	1,800 m^3/d	1,800 m^3/d	1,800 m^3/d	1,800 m^3/d	1,800 m^3/d	1,800 m^3/d	1,800 m^3/d
BOD_5 Concentration							
Influent	800 mg/L	384 mg/L	115 mg/L	-	-	30 mg/L	-
Effluent	384 mg/L	34 mg/L	-	-	30 mg/L	-	15 mg/L
Normal Operation Level	El.1,784.5m	El.1,784.0m	El.1,779.0m	El.1,778.5m	El.1,778.0m	El.1,777.5m	-
			El.1,778.0m	El.1,777.5m	El.1,777.0m	El.1,776.5m	-
Ponds Dimension							
Bottom area	24m x 57m	139m x 251m	88m x 158m	18m x 158m	18m x 158m	17.4m x 97.4m	110m x 165m
Surface area at NOL	42m x 75m	151m x 263m	97m x 167m	27m x 167m	27m x 167m	27m x 107m	-
Effective depth	3.0 m	2.0 m	1.5 m	1.5 m	1.5 m	1.6 m	-
Effective volume	6,777 m^3	74,602 m^3	22,577 m^3	5,514m^3	5,514 m^3	3,667 m^3	-
Min. freeboard	0.5 m	0.5 m	0.5 m	0.5 m	0.5 m	0.5 m	-
Side slope	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	-
Retention Period	3.7 days	41.4 days	12.5 days	3.0 days	3.0 days		

(3) Pond Connection Pipes

AP - FP	D300 - 450 mm,	length 490 m, including one flow splitting chamber
FP - FMP	D300 mm,	length 375 m
FMP - SMP	D300 mm,	length 10 m
SMP - TMP	D300 mm,	length 10 m
TMP - RF	D300 mm,	length 160 m

(4) Outlet Works

Design discharge (Hourly Maximum)	:	0.100 ~ 0.222 m^3/sec
Dimension	:	W675 mm x W675 mm
Length	:	495 m
Outfall	:	W675 mm x H4.3 m

2. 6,000 m^3/day Line

(1) Rock Filters and Grass Plots

	Rock Filters	Grass Plots
Number of Ponds	4	4
Design Discharge (Average Daily)	1,500 m^3/day	1,500 m^3/day
BOD_5 Concentration		
Influent	30 mg/L	-
Effluent	-	15 mg/L
Normal Operation Level	El.1,771.1 m	-
Ponds Dimension		
Bottom area	17.4m x 97.4m	92m x 165 m
Surface area at NOL	27m x 89m	-
Effective depth	1.6 m	-
Effective volume	3,027 m^3	-
Min. freeboard	0.5 m	-
Side slope	1.0 : 3.0	-

(2) Pond Connection Pipes

TMP - RF D375 mm, length 835 m

3. Rock filter drain pit

(1) Pit

Number of Pit	:	1
Pit dimension		
Bottom area	:	37m x 95m
Effective depth	:	1.2 m
Effective volume	:	4,804 m^3
Side slope	:	1.0 : 3.0
Normal Operation Level	:	El. 1,768.7 m

(2) Pond Connection Pipes between RF and Pit

Number of Lines	:	4
Pipe		
Diameter	:	D300mm, D450mm, D600mm
Total length	:	791 m

4. Sludge Drying Bed

Number of Pond	:	1
Design Discharge (Average Daily)	:	9,600 m^3/day
Ponds Dimension		
Bottom area	:	74.8m x 151.8m
Surface area	:	82.0m x 159.0m
Effective depth	:	1.2 m
Effective volume	:	14,635 m^3
Side slope	:	1.0 : 3.0

Table 3-6 Principal Features of Town Sewage Treatment Works

1. 3,400 m^3/day Line

(1) Inlet Connection Pipe(SC-FP)

Design discharge (Hourly Maximum)	:	0.094 m^3/sec
Inlet water level	:	El. 1,779.5 m
Pipe diameter	:	D450 mm
Pipe length	:	460 m
Flow splitting chamber	:	1 no.

(2) Waste Stabilization Ponds, Rock Filters and Grass Plots

	Facultative Ponds	First Maturation Ponds	Second Maturation Ponds	Third Maturation Ponds	Rock Filters	Grass Plots
Number of Ponds	2	2	2	2	2	2
Design Discharge (Average Daily)	1,700 m^3/day	1,700 m^3/day	1,700 m^3/day	1,700 m^3/day	1,700 m^3/day	1,700 m^3/day
BOD_5 Concentration						
Influent	280 mg/L	84 mg/L	-	-	30 mg/L	-
Effluent	32 mg/L	-	-	30 mg/L	-	15 mg/L
Normal Operation Level	El.1,770.5m El.1,769.0m	El.1,786.0m	El.1,767.5m	El.1,767.0m	El.1,766.0m	-
Ponds Dimension						
Bottom area	78m x 305m	58m x 164m	16m x 164m	16m x 164m	17.4m x 91.4m	170m x 100m
Surface area at NOL	90m x 317m	67m x 173m	25m x 173m	25m x 173m	27m x 101m	-
Effective depth	2.0 m	1.5 m	1.5 m	1.5 m	1.6 m	-
Effective volume	52,320 m^3	15,827 m^3	5,181 m^3	5,181 m^3	3,454 m^3	-
Min. freeboard	0.5 m	0.5 m	0.5 m	0.5 m	0.5 m	-
Side slope	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	-
Retention Period	30.7 days	9.3 days	3.0 days	3.0 days	-	-
			Total	46.0 days		

(3) Pond Connection Pipes

FP - FMP	D300 mm,	length 310 m
FMP - SMP	D300 mm,	length 10 m
SMP - TMP	D300 mm,	length 10 m
TMP - RF	D300 mm,	length 95 m

(4) Rock Filter Drain Pit

(a) Pit

Number of pit	:	1
Pit dimension		
Bottom area	:	8.6m x 112.6m
Effective depth	:	1.2 m
Effective volume	:	1,701 m^3
Side slope	:	1.0 : 3.0
Normal Operation Level	:	El. 1,763.8 m

(b) Pond connection pipe between RF and Pit

Number of lines	:	6
Pipe		
Diameter	:	D300mm, D450mm, D600m
Total length	:	120 m

2. 3,200 m^3/day Line

(1) Inlet Works

Design Discharge	:	0.089 m^3/sec
Inlet water level	:	El.1,779.75 m
Coarse screen	:	W 0.6 m x H 1.2 m
Fine screen	:	W 0.6 m x H 1.35 m
Constant velocity grit removal channel	:	W 0.8 m x H 0.5 m x L 9 m
Parshall flume	:	Throat width 150 mm
Inlet pipe	:	D 300 mm, D 450 mm
Pipe length	:	460 m
Flow splitting chamber	:	1 no.

(2) Waste Stabilization Ponds

	Anaerobic Ponds	Facultative Ponds	First Maturation Ponds	Second Maturation Ponds	Third Maturation Ponds	Rock Filters	Grass Plots
Number of Ponds	3	2	2	2	2	2	2
Design Discharge (Average Daily)	1,600 m^3/day	1,600 m^3/day	1,600 m^3/day	1,600 m^3/day	1,600 m^3/day	1,600 m^3/day	1,600 m^3/day
BOD_5 Concentration							
Influent	800 mg/L	384 mg/L	115 mg/L	-	-	30 mg/L	-
Effluent	384 mg/L	33 mg/L	-	-	30 mg/L	-	15 mg/L
Normal Operation Level	El.1,775.0m	El.1,774.0m El.1,772.5m	El.1,770.5m	El.1,778.5m	El.1,769.5m	El.1,767.5m	-
Ponds Dimension							
Bottom area	23m x 52m	100m x 311m	76 x 163m	15m x 163m	15m x 163m	17.4m x 85.4m	160m x 100m
Surface area at NOL	41m x 70m	112m x 323m	85m x 172m	24m x 172m	24m x 172m	27m x 95m	-
Effective depth	3.0 m	2.0 m	1.5 m	1.5 m	1.5 m	1.6 m	-
Effective volume	6,099 m^3	62,276 m^3	20,256 m^3	4,899 m^3	4,899 m^3	3,240 m^3	-
Min. freeboard	0.5 m	0.5 m	0.5 m	0.5 m	0.5 m	0.5 m	
Side slope	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	1.0 : 3.0	-
Retention Period	3.8 days	42.0 days	12.6 days	3.0 days	3.0 days	-	-

(3) Pond Connection Pipes

AP - FP	D300 - 450 mm,	length 470 m, incl. one flow splitting chamber
FP - FMP	D300 mm,	length 370 m
FMP - SMP	D300 mm,	length 10 m
SMP - TMP	D300 mm,	length 10 m
TMP - RF	D300 mm,	length 50 m

(4) Rock Filter Drain Pit

(a) Pit

Number of pit	:	1
Pit dimension		
Bottom area	:	8.6m x 112.6m
Effective depth	:	1.2 m
Effective volume	:	1,613 m^3
Side slope	:	1.0 : 3.0
Normal Operation Level	:	El. 1,765.3 m

(b) Pond connection pipe between RF and Pit

Number of lines	:	6
Pipe		
Diameter	:	D300mm, D450mm, D600m
Total length	:	120 m

3. Sludge Drying Bed

(1) Sludge Drying Bed

Number of Pond	:	1
Design Discharge (Average Daily)	:	3,200 m^3/day
Ponds Dimension		
Bottom area	:	40.8m x 84.8m
Surface area at NOL	:	48.0m x 92.0m
Effective depth	:	1.2 m
Effective volume	:	4,726 m^3
Min. freeboard	:	0 m
Side slope	:	1.0 : 3.0

4. Stormwater Retention Pond

(1) Stormwater Drainage

Shape	:	Trapezoidal
Dimension		
Bottom width	:	1.10 m
Height	:	2.00 m
Side slope	:	1.0 : 0.475
Length	:	1,110 m

(2) Stormwater Retention Pond

Number of Pond	:	1
Normal Operation Level	:	El.1,777.0 m
Ponds Dimension		
Bottom area	:	68m x 126m
Surface area at NOL	:	77m x 135m
Effective depth	:	1.5 m
Effective volume	:	14,222 m^3
Min. freeboard	:	0.5 m
Side slope	:	1.0 : 3.0

Table 3-7 Monitoring Plan for Lake Nakuru and Industrial Effluents - Rivers, Drainage Channels and Springs

	Parameters	Njoro River		Town Stormwater Drainage Channel	Makalia River	Makalia River Mouth	Nderit River	Nderit River Mouth	Lamudiak River	Ngosorr River	Baharin Spring	Spring near Special Camp Site	Spring near Lion Hill	Annual Sub Total	Annual Total
		Before STW Discharge	River Mouth												
1	Flowrate	12	12	12	12	12	12	12	12	12	12	12	12	144	144
2	Temperature	12	12	12	12	12	12	12	12	12	12	12	12	144	144
3	pH	12	12	12	12	12	12	12	12	12	12	12	12	144	144
4	Conductivity	12	12	12	12	12	12	12	12	12	12	12	12	144	144
5	DO	12	12	12	12	12	12	12	12	12	12	12	12	144	144
6	ORP	12	12	12	12	12	12	12	12	12	12	12	12	144	144
7	BOD	12	12	12	12	12	12	12	12	12	12	12	12	144	144
8	COD	12	12	12	12	12	12	12	12	12	12	12	12	144	144
9	SS	12	12	12	12	12	12	12	12	12	12	12	12	144	144
10	T-N	12	12	12	12	12	12	12	12	12	12	12	12	144	144
11	NH4-N	12	12	12	12	12	12	12	12	12	12	12	12	144	144
12	NO3-N	12	12	12	12	12	12	12	12	12	12	12	12	144	144
13	T-P	12	12	12	12	12	12	12	12	12	12	12	12	144	144
14	PO4-P	12	12	12	12	12	12	12	12	12	12	12	12	144	144
15	Sechi Depth													0	0
16	Chlorophyll a													0	0
17	Plankton count													0	0
	HEAVY METALS														
18	Chromium (Cr)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
19	Hexavalent Chromium (Cr6+	6	6	6	6	6	6	6	6	6	6	6	6	72	72
20	Lead (Pb)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
21	Copper (Cu)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
22	Cadmium (Cd)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
23	Zinc (Zn)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
24	Nickel (Ni)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
25	Iron (Fe)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
26	Total Manganese (Mn)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
27	Cyanide (CN-)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
28	Total Mercury (Hg)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
29	Arsenic (As)	6	6	6	6	6	6	6	6	6	6	6	6	72	72
	OTHERS														
30	Oil	6	6	6	6	6	6	6	6	6	6	6	6	72	72
31	Anionic Surfactant (MBAS)	6	6	6	6	6	6	6	6	6	6	6	6	72	72

Table 3-8 Monitoring Plan for Lake Nakuru and Industrial Effluents - Industrial and Sewage Treatment Works Effluents

No.	Parameters	Organic 1 Waste Containing Effluents	Heavy 2 Metal Containing Effluents	Njoro STW Influent / Effluent	Town STW Influent / Effluent									Annual Sub-total	Annual Total
1	Flowrate	30	15	12	12									69	213
2	Temperature	30	15	12	12									69	213
3	pH	30	15	12	12									69	213
4	Conductivity	30	15	12	12									69	213
5	DO	30	15	12	12									69	213
6	ORP	30	15	12	12									69	213
7	BOD	30	15	12	12									69	213
8	COD	30	15	12	12									69	213
9	SS	30	15	12	12									69	213
10	T-N	30	15	12	12									69	213
11	NH4-N	30	15	12	12									69	213
12	NO3-N	30	15	12	12									69	213
13	T-P	30	15	12	12									69	213
14	PO4-P	30	15	12	12									69	213
15	Secchi Depth													0	0
16	Chlorophyll a													0	0
17	Plankton count													0	0
	HEAVY METALS														
18	Chromium (Cr)		8	12	12									32	104
19	Hexavalent Chromium (Cr6+)		8	12	12									32	104
20	Lead (Pb)		4	12	12									28	100
21	Copper (Cu)		6	12	12									30	102
22	Cadmium (Cd)		4	12	12									28	100
23	Zinc (Zn)		4	12	12									28	100
24	Nickel (Ni)		4	12	12									28	100
25	Iron (Fe)			12	12										
26	Total Manganese (Mn)			12	12										
27	Cyanide (CN-)		8	12	12									32	104
28	Total Mercury (Hg)		4	12	12									28	100
29	Arsenic (As)			12	12									24	96
	OTHERS														
30	Oil	10		12	12									34	106
31	Anionic Surfactant (MBAS)	10		12	12									34	106

Note: 1 - a total of 15 high organic strength factores are envisaged.
2 - a total of 7-8 heavy metal containing effluents are envisaged.
Frequency of sampling is twice per year.

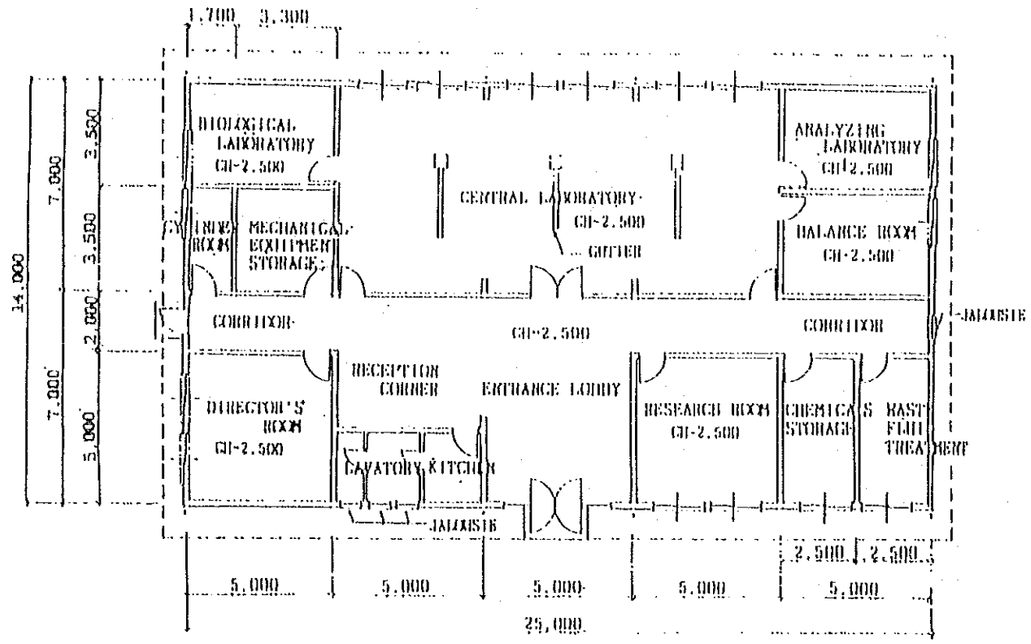
Table 3-9 Monitoring Plan for Lake Nakuru and Industrial Effluents - Lake Water Quality

No.	Parameters	LE1	LE2	LE3	LS1	LS2	LS3	Sediment						Annual Sub-total	Annual Total
1	Flowrate	-	-	-	-	-	-	-						0	213
2	Temperature	6	6	6	12	12	12	6						60	273
3	pH	6	6	6	12	12	12	6						60	273
4	Conductivity	6	6	6	12	12	12	6						60	273
5	DO	6	6	6	12	12	12	-						54	267
6	ORP	6	6	6	12	12	12	-						54	267
7	BOD	-	-	-	-	-	-	-						0	213
8	COD	6	6	6	6	6	6	6						42	255
9	SS	6	6	6	6	6	6	6						42	255
10	T-N	6	6	6	6	6	6	6						42	255
11	NH4-N	6	6	6	6	6	6	6						42	255
12	NO3-N	6	6	6	6	6	6	6						42	255
13	T-P	6	6	6	6	6	6	6						42	255
14	PO4-P	6	6	6	6	6	6	6						42	255
15	Secchi Depth	6	6	6	6	6	6	-						36	36
16	Chlorophyll a	6	6	6	6	6	6	-						36	36
17	Plankton count	6	6	6	6	6	6	-						36	36
	HEAVY METALS														
18	Chromium (Cr)	6	6	6	6	6	6	6						42	146
19	Hexavalent Chromium (Cr6+	6	6	6	6	6	6	6						42	146
20	Lead (Pb)	6	6	6	6	6	6	6						42	142
21	Copper (Cu)	6	6	6	6	6	6	6						42	144
22	Cadmium (Cd)	6	6	6	6	6	6	6						42	142
23	Zinc (Zn)	6	6	6	6	6	6	6						42	142
24	Nickel (Ni)	6	6	6	6	6	6	6						42	142
25	Iron (Fe)	6	6	6	6	6	6	6						42	42
26	Total Manganese (Mn)	6	6	6	6	6	6	6						42	42
27	Cyanide (CN-)	6	6	6	6	6	6	6						42	146
28	Total Mercury (Hg)	6	6	6	6	6	6	6						42	142
29	Arsenic (As)	6	6	6	6	6	6	6						42	138
	OTHERS														
30	Oil	6	6	6	6	6	6	6						42	148
31	Anionic Surfactant (MBAS)	6	6	6	6	6	6	6						42	148

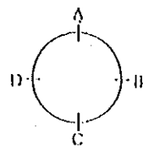
Table 3-10 Monitoring Plan for Lake Nakuru and Industrial Effluents - Rivers, Drainage Channels During Storm Drainage

	Parameters	Njoro River		Town Stormwater Drainage Channel	Makalia River	Makalia River Mouth	Nderit River	Nderit River Mouth	Lamudiak River	Ngosorr River	Baharin Spring	Spring near Special Camp Site	Spring near Lion Hill	Annual Sub-total	Annual Total
		Before STW Discharge	River Mouth												
1	Flowrate		2	5		2		2						11	224
2	Temperature		2	5		2		2						11	284
3	pH		2	5		2		2						11	284
4	Conductivity		2	5		2		2						11	284
5	DO		2	5		2		2						11	278
6	ORP		2	5		2		2						11	278
7	BOD		2	5		2		2						11	224
8	COD		2	5		2		2						11	266
9	SS		2	5		2		2						11	266
10	T-N		2	5		2		2						11	266
11	NH4-N		2	5		2		2						11	266
12	NO3-N		2	5		2		2						11	266
13	T-P		2	5		2		2						11	266
14	PO4-P		2	5		2		2						11	266
15	Sechi Depth													0	36
16	Chlorophyll a													0	36
17	Plankton count													0	36
	HEAVY METALS														
18	Chromium (Cr)		2	5		2		2						11	157
19	Hexavalent Chromium (Cr6+)		2	5		2		2						11	157
20	Lead (Pb)		2	5		2		2						11	153
21	Copper (Cu)		2	5		2		2						11	155
22	Cadmium (Cd)		2	5		2		2						11	153
23	Zinc (Zn)		2	5		2		2						11	153
24	Nickel (Ni)		2	5		2		2						11	153
25	Iron (Fe)		2	5		2		2						11	53
26	Total Manganese (Mn)		2	5		2		2						11	53
27	Cyanide (CN-)		2	5		2		2						11	157
28	Total Mercury (Hg)		2	5		2		2						11	153
29	Arsenic (As)		2	5		2		2						11	149
	OTHERS														
30	Oil		2	5		2		2						11	159
31	Anionic Surfactant (MBAS)		2	5		2		2						11	159

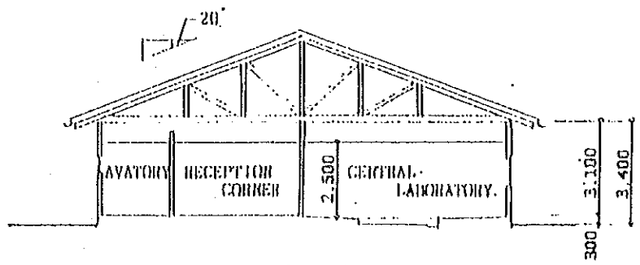
Fig. 3-4



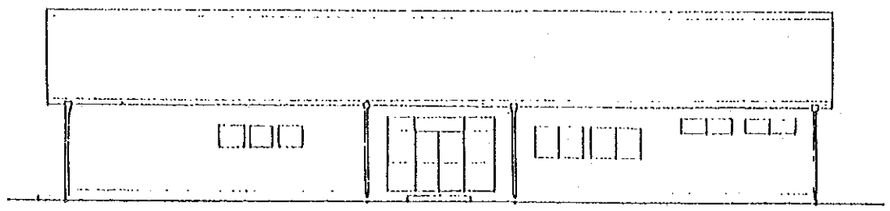
PLAN
FLOOR AREA: 350SQ.METERS



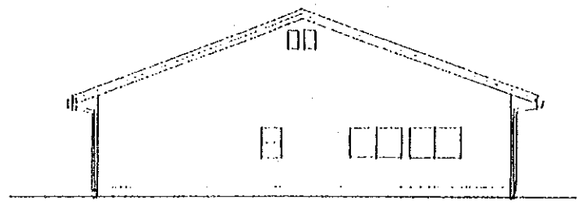
SCALE 1:200



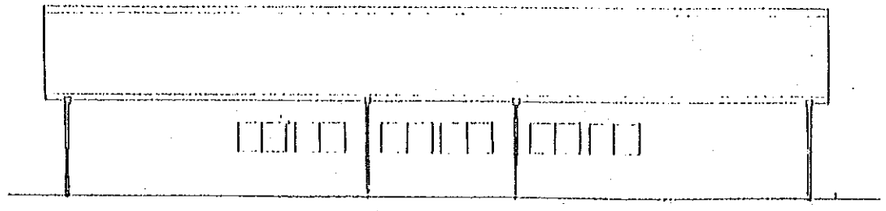
SECTION



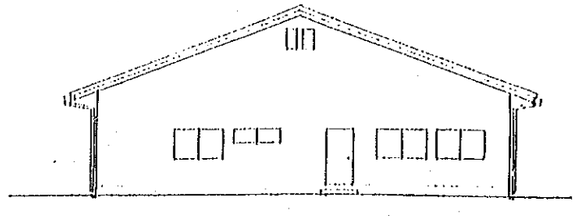
ELEVATION C



ELEVATION B



ELEVATION A



ELEVATION D

THE REPUBLIC OF KENYA MINISTRY OF LOCAL GOVERNMENT	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Building Works Water Quality Testing Laboratory, Plan and Elevation