REPUBLIC OF KENYA

NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT (FEASIBILITY STUDY)

FINAL REPORT

VOLUME (II) MAIN REPORT

MARCH 1994

JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF LOCAL GOVERNMENT

NIPPON KOEI CO., LTD.
NIHON SUIDO CONSULTANTS CO., LTD.

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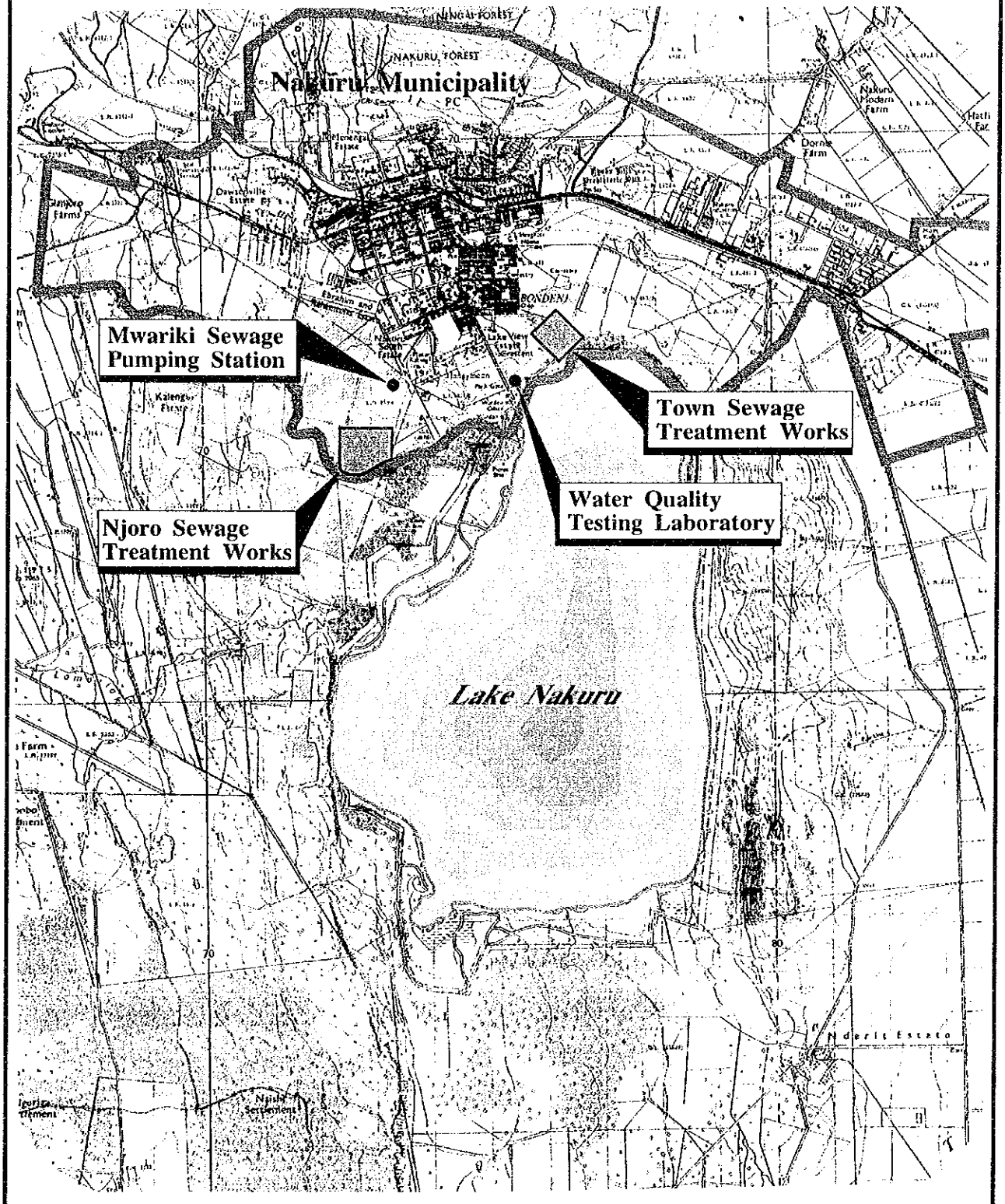

THE REPUBLIC OF KENYA	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT	TITLE
MINISTRUY OF LOCAL GOVERNMENT	JAPAN INTERNATIONAL COOPRATION AGENCY	**Location Map**

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. Background to the Project

The Nakuru Sewage Works Rehabilitation and Expansion Project (the Project) is located within a catchment area of Lake Nakuru. The lake is one of two conservation areas in Kenya registered under Ramsar Convention and is world-wide famous for unique wildlife and ecology. Adjacent to the lake Nakuru Municipality with administrative area of 69 km^2 is extended and its has estimated population of about 360,000. In 1991 the Greater Nakuru Water Supply Project, Eastern Division, Stage 1 (the GNWSP) was completed to cater for increasing potable water demand in the municipal area and is capable of supplying a safe water of 13,300 m^3/day. The commissioning of the GNWSP directly leads to increase sewage generation from the municipal area, whereas the existing sewage treatment works have been seriously over-loading and deteriorated. It is therefore important to the Government of Kenya to promptly rehabilitate and expand the sewage treatment works.

2. Objective of the Study

The objective of the Study is to conduct a feasibility study of the Project.

3. Existing Sanitary Services

Water Supply : The public water supply bears almost all the present potable water demand in the municipal area. The average daily supply of the existing systems was 22,080 m^3/day during the last 5 year. It is recommended that NMC takes adequate counter measures such as installation of more water meter, leakage detection and prevention programme, elimination of illegal connection, etc. in order to reduce un-accounted for water which is currently as high as 40 - 50 %. Upon commissioning of the GNWSP, water consumption per capita is estimated at 98 litter per day.

Sewerage : Public sewer network covers an area of 12.85 km^2 only over a central par of the municipal area. A sewer connection ratio is 85 % at present within the sewered area. There are two sewage treatment works in the municipal area : one is Njoro STW with a daily treatment capacity of 3,600 m^3/day with waste stabilization pond process and the other is Town STW with a daily treatment capacity of 3,400 m^3/day with trickling filter process. The total volume of sewage was 8,999 m^3/day on an average during the last 5 years and BOD concentration of the influent is far exceeding the design value. It is indispensable to rehabilitate and expand the existing sewage treatment works.

NWCPC is now implementing the Nakuru Sewerage Project which realizes a new sewage treatment works with a daily treatment capacity of 6,000 m^3/day with the waste stabilization pond process at Njoro STW.

Septic tank and pit latrines are the most common on-site wastewater treatment facilities in unsewered area. Septage from such facilities are exhausted and dumped directly into sewers by PHD, being one of over-loading causes on sewage treatment works.

Industrial wastewater : Although some of existing industries are provided with own simple pre-treatment facilities, they are not properly functioning due to insufficient capacity and poor maintenance and emitting pollution loads including heavy metals and toxic materials into public sewer. The industrial wastewater hampers sewage treatment process and is recognized to be major pollution source in the lake basin area.

Stormwater drainage : A systematic storm water drainage system encompasses an area of 374 ha in a central part of the municipal area. Main drain is connected directly to Lake Nakuru and washes down oil, garbage, sediments, etc. during storm draining, being one of pollution sources.

Domestic and industrial refuses : Both domestic and industrial refuses are disposed to the municipal dumping site located at western rim of the municipal area. Their volumes were 23,040 ton and 4,956 ton in 1992 respectively. Although a controlled tipping method is employed at the dumping site, no proper measures are being taken against environment of the surrounding area and protection of groundwater resources.

4. Proposed Water Pollution Control Plan

The water pollution control plan has been elaborated in order to cope with the increasing sewage owing to additional potable water supply by the GNWSP.

Sources of pollution : Pollutant loads flows into Lake Nakuru through rivers such as Njoro, Makaria, and Nderit, Town stormwater drainage channel, and springs scattering along the lake. The Njoro river carries the effluent from Njoro STW.

Forecast sewage volume : The volume of sewage from the existing sewered area was forecast at 16,200 m^3/day after commissioning of the GNWSP. Accordingly there

is a deficit of 3,200 m^3/day in sewage treatment capacity even after completion of the on-going Nakuru Sewerage Project.

Wastewater Standards : The Government of Kenya established "Wastewater Standards for Discharge into Lake Nakuru" (the Wastewater Standards) in June 1993. The standards has been technically appraised by the Study Team and adopted as fundamental in formulating water pollution control plan.

Proposed water pollution control plan : It is hardly attainable to reduce man-made pollutants only by rehabilitation and expansion of sewage treatment works. The proposed water pollution control plan therefore comprises structural and non-structural measures and the structural measures are recommended to be realized in advance of non-structural measures.

(A) Structural measure

(1) Sewage treatment works
- Rehabilitation of existing works
- Installation of additional treatment facilities such as rock filter and grass plot at existing works
- Construction of the new 3,200 m^3/day sewage treatment works, composing of waste stabilization pond, rock filter and grass plot, at Town STW

(2) Sludge treatment and disposal
- Construction of drying bed at sewage treatment works to treat sludge generated from the works and septage from on-site wastewater treatment facilities
- Disposal of dried sludge to dumping site to be newly designated by NMC, preferably outside the lake catchment area
- Monitoring quality of dried sludge to ascertain its availability for agriculture

(3) Stormwater drainage
- Construction of a stormwater retention pond at Town STW to remove inorganic matters, oil, solid waste, sediments, etc.

(4) Septage treatment and disposal
- Treatment at sludge drying bed and/or dispose to the new damping site depending on quality

(5) Industrial waste disposal
- Designation of a specific dumping site with adequate environmental protection

- Reduction of volume of waste by means of dewatering or compression or other method.

(B-1) Non-structural measure, Short Term Plan

(1) Water-related legislation
- Approval and enactment of Municipal Council of Nakuru (Trade Effluent) By-laws
- Amendment of Water Act to provide protection of water resources and Local Government Act in line with the provisions of the By-laws
- Enactment of National Environmental Bill

(2) Overall institutional support
- Enhancement of activity of Inter-ministerial Working Group

(3) Monitoring activity
- Monitoring of pollutants loads, water quality of Lake Nakuru and quality and quantity of river and industrial waters through establishment of a Water Quality Testing Laboratory

(B-1) Non-structural measure, Medium/Long Term Plan

(1) Control of regional and urban development control

(2) Formulation of master plan for Lake Nakuru basin development

(3) Formulation of master plan for sewerage development

Forecast pollutant load reduction : With implementation of the proposed pollution control plan, pollution load into Lake Nakuru is expected to reduce as forecast below :

(Unit : ton/year)

Pollutant Load	Present	After GNWSP	After Structural Measures	After Non-structural Measures
BOD	1,471	3,809	886	856
T-P	547	-	-	103
T-N	167	-	-	51

The current Study lays emphasis on pollution control through sewage treatment works and stormwater drainage system. At present, of the total BOD pollutant load, 43 % accrues from the sewage treatment works. With the proposed rehabilitation and expansion of sewage works it is forecast to decrease to 10 %.

5. Preliminary Design

The preliminary design was performed for sewerage facilities, sludge drying bed, stormwater retention pond, and water quality testing laboratory. Sewerage facilities comprise Mwariki pumping station, sewage treatment facilities, control office at Town STW and staff houses.

Mwariki pumping station : It is proposed to re-build a generator house and to replace existing three pumps, each cutter type with a capacity of 1.5 m^3/min, with new ones.

Sewage treatment facilities : BOD, SS and fecal coliform of influent are 800 mg/L, 700 mg/L and 10^8/100 mL respectively, whereas target values of those of effluent are set at 15 mg/L, 15 mg/L and 10^3/100mL respectively. Through technical and economic comparative study, it is concluded that a combination of waste stabilization ponds, rock filter and grass plot is the most feasible treatment process. Final configuration of the sewage treatment works will be as summarized below :

(Unit : number)

Treatment Unit	Njoro STW		Town STW	
	3,600 m^3/day Line	6,000 m^3/day Line	3,400 m^3/day Line	3,200 m^3/day Line
Anaerobic pond/ other	Anaerobic : 3	Anaerobic : 3	Clarifier : 2 Trickling filter : 1	Anaerobic : 3
Facultative pond	2	2	2	2
1st maturation pond	2	2	2	2
2nd maturation pond	2	2	2	2
3rd maturation pond	2	2	2	2
Rock filter	2	2	2	2
Grass plot	2	4	2	2

A control office is proposed to be newly constructed at Town STW and it has a floor area of 120 m^2 including workshop space. It is also proposed to provide additional staff houses : 4 at Njoro STW and 10 Town STW. Houses are the Kenyan Standard Type D, having floor area of 30 m^2.

Sludge drying bed : Sludge generation volume from anaerobic pond is estimated at 20 m^3/day for the entire Njoro STW and 6.6 m^3/day for the 3,200 m^3/day line at Town STW. For treatment of these sludges it is proposed to construct a sludge drying bed at each sewage treatment works. One at Njoro STW has a dimension of 82 m in width, 159 m in length and 1.2 m in effective depth and that in Town STW is in 48 m, in width, 92 m in length and 1.2 m in effective depth. It is recommended that the dried

sludge be dumped at the new disposal area, which will be designated by NMC away from Lake Nakuru.

Stormwater retention pond : A stormwater retention pond is located in Town STW and has a storage capacity of 14,300 m^3, corresponding to runoff volume generated from a probable rainfall of 42 mm/day with a return period of 5 years. It is 77 m in width and 135 m in length at normal operation level and effective depth of 1.5 m.

Water quality testing laboratory : Water quality monitoring plan has been elaborated and it is basically classified into (a) lake water quality, (b) river, drainage channels and springs, (c) industrial and sewage treatment works effluent, and (d) rivers and drainage during storm drainage. The laboratory is proposed to be sited in the vicinity of Education Center in the Lake Nakuru National Park and has a floor area of 350 m^2.

6. Operation and Maintenance

Basic guidelines for operation and maintenance : For the sewerage system and stormwater retention pond, basic guidelines for operation and maintenance are proposed, which basically comprise daily routine work and periodical works. The former is proposed to be carried out directly by WSD, while the later will be executed by either contractor and/or WSD. It is also proposed to change operation mode of the existing trickling filter at Town STW for better operation performance.

Operation and maintenance equipment : For a sustained operation and maintenance of the project facilities, it is concluded that there is a need for strengthening operation and maintenance equipment of WSD. An inventory of the required operation and maintenance equipment is prepared and consists of workshop equipment, operation and maintenance equipment and laboratory equipment for Njoro STW.

7. Construction Plan and Cost Estimate

Construction period : It will be required a 23-month period at the shortest to complete the proposed construction work including a period required for design and bidding. A net construction period will extend over 16 months.

Construction cost : The construction cost is estimated at US$ 22,830,000, comprising US$ 11,201,000 in foreign currency and US$ 11,629,000 in local currency.

Operation and maintenance cost : The annual operation and maintenance cost is estimated at US$ 102,600 for sewerage system.

8. Organization and Management

Organization for Project Implementation : The Urban Development Department of the MOLG will be an executing agency of the Project. It is proposed to establish a Project Office under management of UDD to implement the Project.

Organization for Operation and Maintenance : WSD will have direct and overall responsibility for operation and maintenance of the project facilities. In order to achieve this objective and implement successfully the Trade Effluent By-laws, it is proposed to strengthen the WSD in terms of manpower and financial resources.

9. Evaluation of the Project

Environmental Impact Assessment : The environmental impact assessment was accomplished in compliance to an environmental impact assessment form which was prepared through a cooperation of NES and MOLG. It is concluded that there will be no serious negative impact due to construction and operation of the project facilities.

Financial and Economic Evaluation : Financial internal rate is calculated at 1.8 % only. The project might be not viable as far as NMC procures the investment capital through LGLA, which normally imposes interest rates of 7 to 13 % per annum. Economic internal rate is calculated at 18.6 %, which is higher than the opportunity cost of capital of 10 %. The project is therefore feasible from economic view point.

Overall Evaluation : The Project contributes not only to alleviate the pollutant loads into Lake Nakuru but also makes it possible to put the GNWSP into actual operation. It is foreseeable that positive impact will greatly outweigh any potential negative impacts such as odour nuisance and sludge generation due to construction of waste stabilization pond. It is strongly recommended that the Project be realized as earlier as possible.

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ABBREVIATION AND LOCAL TERMS

1. Abbreviation 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	=	hertz

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
℃	=	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/s, cu.m/s	=	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/day, cu.m/day	=	cubic meter per day
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/scc/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 litre
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, Nakuru Municipal Council
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	=	The 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

1. INTRODUCTION

1.1 Background to the Project

The Nakuru Sewage Works Rehabilitation and Expansion Project (hereinafter referred to as the Project) is located in Nakuru Municipality, the capital of Rift Valley Province. The Nakuru Municipality is not only the fourth largest urban centre in Kenya, following Nairobi, Mombasa and Kisumu, but also the largest urban centre within a drainage area of Lake Nakuru. Lake Nakuru including its surrounding area has been designated as one of national parks in Kenya and is world-wide famous for millions of flamingoes. It is one of conservation areas registered under the Ramsar Convention.

The municipality however has long been subjected to a rapid population growth and progressive economic and industrial development activities. The population in the municipality is forecast at 361,000 for 1993, while it was only in 92,900 according to the 1979 Census. Such rapid population growth is considered to be mainly attributed to a continuous rural-urban migration, being supported by incessant development activities in the municipal area.

In view of Lake Nakuru environment, the Nakuru Municipality has been identified as the major source of pollution load. It is evident that pollution load generation has been increasing year after year keeping pace with the population growth and various activities by human beings. It is unavoidable that portion of such pollution load discharges into Lake Nakuru through sewerage and stormwater drainage systems, natural rivulets, channels, etc. owing to geographic condition, thus threatening to the very delicate ecology of Lake Nakuru.

It is therefore important for GOK to implement the Project as promptly as possible in order to create adequate environment for peaceful co-existence of human beings and natural environment. In order to accomplish this goal GOK launched the Project and requested GOJ to extend a technical assistance for a feasibility study for the Project (the hereinafter referred to as the Study). The Study was achieved in a joint effort of the Kenyan counterpart and JICA Study Teams.

1.2 Organization and Management of the Study

At the Kenyan side both IWG and counterpart team were organized, while at the Japanese sides both Technical Advisory Committee and Study Team were also organized by JICA.

(1) IWG

IWG was organized aiming at coordinating, addressing, and ensuring various political and technical issues necessary for harmonizing the development activities by human beings and the environment of Lake Nakuru among the government ministries and organizations concerned. It is constituted by the representative of the Office of President, MOLG, MOF, MOLPP, MOLRRWD, MOC&I, NWCPC, and KWS.

(2) Counterpart team

The counterpart team was composed of the following staff :

Study Coordinator	:	Mr. F. Mulli, MOLG
Sr. Sewerage Engineer	:	Mr. J. N. Maina, MOLRRWD
Sr. Sewerage Engineer	:	Mr. C. G. Kamau, NMC
Sewerage Engineer	:	Mr. B. G. Kibetu, MOLRRWD
Sewerage Engineer	:	Mr. H. G. Kigenyi, MOLRRWD
Water Quality Analyst	:	Mr. S. P. M. Kiai, MOLRRWD Mr. E. K. Tangus, MOLRRWD
Environmental Expert	:	Mr. R. M. Ndetei, KWS Mr. R. Thampy, WWF
Socio-economist	:	Mr. K. K. Yegon, MOLG

(3) JICA Study Team

Team Leader	:	Mr. K. Endo, Nippon Koei Co., Ltd.
Deputy Team Leader/Sewage Treatment Planner	:	Mr. T. Naka, Nippon Koei Co., Ltd.
Structural Design Engineer	:	Mr. N. Takahashi, Nihon Suido Consultants Co., Ltd.
Facility Engineer	:	Mr. S. Taguchi, Nippon Koei Co,. Ltd.
Water Pollution Control Planner	:	Mr. K. Sasaki, Nihon Suido Consultants Co., Ltd.
Water Quality Analyst	:	Dr. S. Kugaprasatham, Nihon Suido Consultants Co., Ltd.
Institutional Specialist	:	Dr. W. N. Thitai, Nippon Koei Co., Ltd.
Construction Planner/Cost Estimator	:	Mr. K. Yamazaki, Nippon Koei Co., Ltd.
Surveyor/Geotechnical Engineer	:	Mr. T. Fujii, Nippon Koei Co., Ltd.
Environmental Expert	:	Mr. M. Fujii, Nippon Koei Co., Ltd.
Economic & Financial Expert	:	Mr. T. Tashino, Nihon Suido Consultants Co., Ltd.

(4) JICA Technical Advisory Committee

Chairman	:	Dr. K. Sato, Research Co-ordinator for Wastewater Treatment, Water Quality Control Department, Public Works Research Institute, Ministry of Construction
Member	:	Mr. M. Yamada, Co-ordinator, Japan Sewage Works Agency, Tokyo Branch

2. THE STUDY AREA

2.1 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 Menengai Crater and lake areas. Their catchment areas are 293, 77, 315, 520, 116 and 361 km^2 respectively. The lake acts as the receptacle of all wastewater and drainage water from the drainage area including the Nakuru Municipality. A basin map of the lake is shown in Fig. 2-1. 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.

Nakuru Municipality is located at approximately 160 km northwest of Nairobi, the capital of Republic of Kenya. The municipal area of 69.2 km^2 extends over the southern slope of Menengai Crater and bounds with Lake Nakuru National Park on the south. The altitude of the municipal area varies widely from around El. 1,750 m at the southern boundary to about El. 2,100 m in the northern boundary.

2.2 Climate

There are two distinct seasons in a year. Hot and dry climate prevails during the period from December to February, while wet and relatively cold climate dominates during the period from March to May. The climatological features of the Study Area are recorded at Showground Synoptic Station in the Nakuru Municipality and are as summarized below:

(1) Air temperature

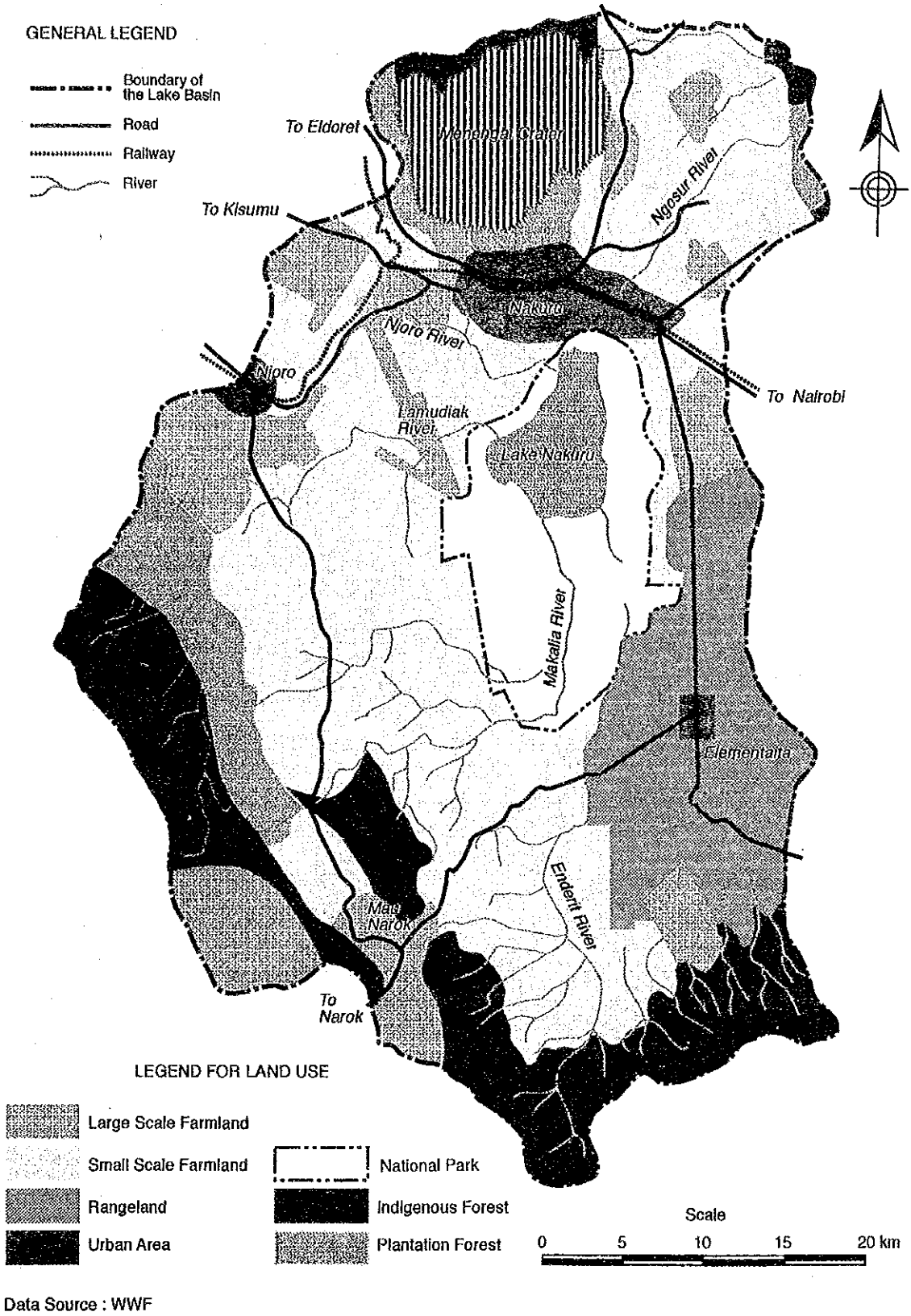
The monthly mean maximum and minimum temperatures are 25.4°C and 10.8°C respectively on the average during the period from 1990 to 1992. Yearly variations of the maximum and minimum temperatures are as little as around 4°C, while diurnal variation is as large as about 19°C at the maximum in January/February.

(2) Rainfall

The annual rainfall is 1,019 mm on 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.

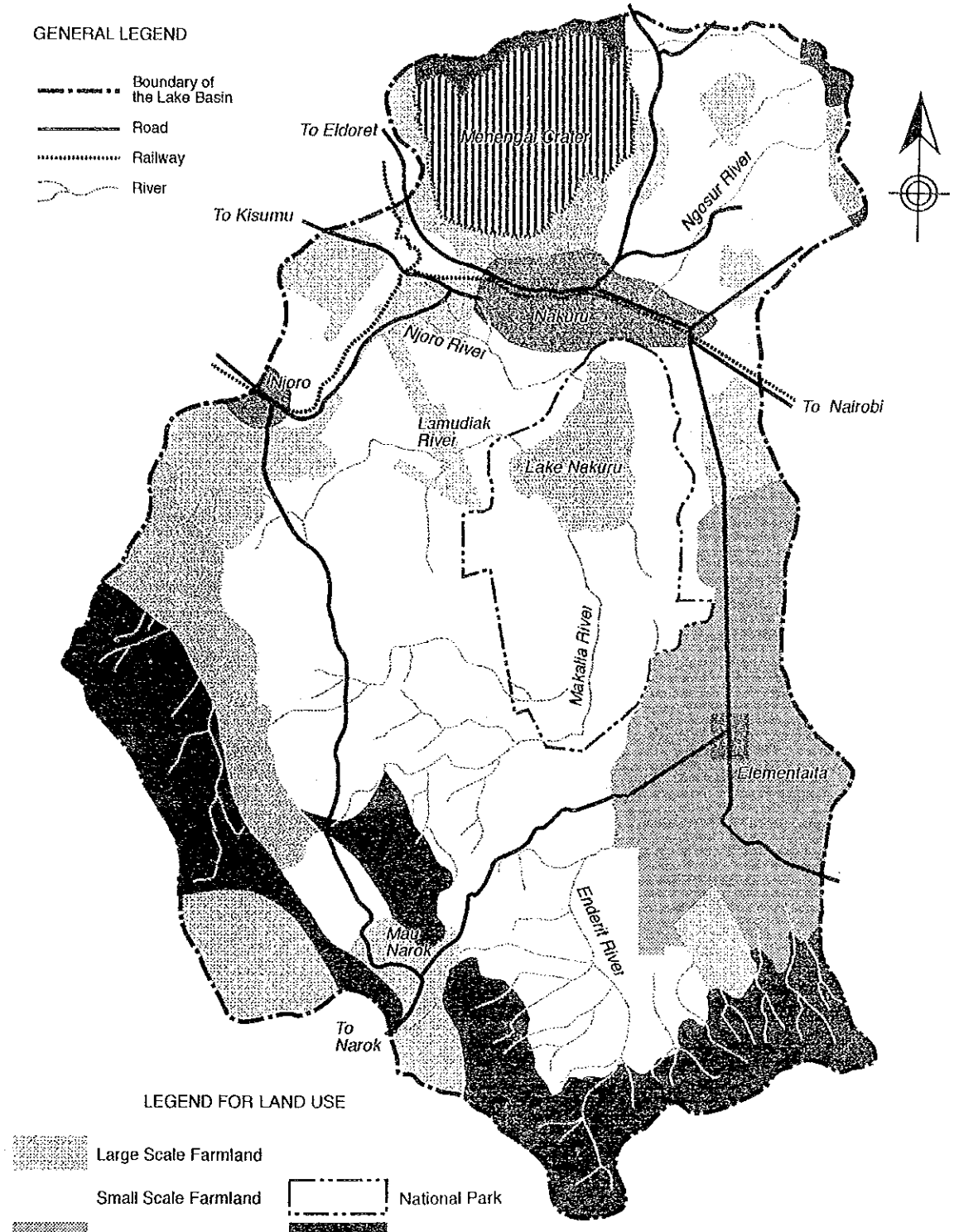
The amount of rainfall varies largely from year to year. It is not rare that Lake Nakuru exposes its bottom extensively in severe drought years such as 1988 due to decrease of inflow.

Fig. 2-1



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

Fig. 2-1



Data Source : WWF

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

(3) Evaporation

The annual evaporation is 1,884 mm on 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 lagoon type of sewage treatment process should be introduced.

(4) Wind speed and direction

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

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

2.3 Hydrology

Most of the rivers have small catchments, being less than 300 km^2, and their catchment areas are mostly covered by (a) secondary grasslands, (b) upland acacia wood lands, savanna and bushland and (3) upland evergreen and semi-deciduous bushland. 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 some extent of a base flow of the Njoro River.

2.4 Geological and Soil Conditions

A full description of the geotechnical investigation is complied in Supporting Report A in Volume III.

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

Test drilling was carried out at three locations at Njoro STW and two locations at Town STW. Depth of each borehole was 15 m from the ground surface. The standard penetration and borehole permeability tests were conducted at intervals of 1 m and 1.5 m respectively, along the bore hole.

According to the results of test drillings, within a depth of 10 m below the ground surface, sedimentary layer composed of volcanic silt, sand, ash and pumice is predominant at both Njoro and Town STWs. Characteristics of the sedimentary layer is as summarized in Table 2-1.

Table 2-1 Geological Characteristics of Sedimentary Layer

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, the sites are in general suitable to construct the contemplated ponds and soils are usable for construction of embankment with appropriate compaction. It should however be noted that sandy soil layer with N value of 4 - 5 exists at the depth of 3 m below the ground surface and has a comparatively high permeability coefficient of 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 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 the laboratory test. The results of the laboratory test can be concluded as follows:

(1) Unit weights of silt and sand are only 1.03 - 1.08 and 1.12 - 1.19 ton/m^3 respectively.

(2) Soils are characterized by very fine particles and natural moisture contents of silt is 51 - 59% at Town STW and 45-51% at Njoro STW, while those of sand at Njoro STW is only 20 - 21%.

(3) Silt available at the sites can be used as embankment material with appropriate moisture control and compaction.

2.5 Present Environment of Lake Nakuru and National Park

2.5.1 Chronological Events for Formation of Lake Nakuru National Park

Lake Nakuru National Park is one of the most famous parks in Kenya. The birds and wildlife form unique spectacular display that attracts thousands of domestic and foreign tourists into the park every year. The national park area is about 188 km^2, including the lake itself. The history of Lake Nakuru National Park started after its nomination for conservation as a bird sanctuary. The present park has grown through various steps as presented in Table 2-2.

Table 2-2 Chronological Events of Lake Nakuru National Park

Year	Chronological Events
1960	Area of conservation for bird sanctuary
1961	The southern two thirds was put under protection of the Kenya National Parks. The ceremony was officiated by a bird authority, Sir Peter Scott.
1964	Birds sanctuary, whole lake and a small strip of land around the lake.
1968	The whole lake and the surrounding shore (about 6,000 ha) was officially declared a National Park.
1972	WWF raised fund to facilitate expansion to 22,000 ha of land.
1973	WWF represented by Prince Bernhard of Netherlands and President of WWF signed a conservation agreement with GOK. The agreement supported a park extension programme.
1974	Park expanded to the present size (188 km^2) with assistance of WWF and other conservation bodies.
1976	Whole park area fenced by chain link
1986	Solar electric fence installed with 12 wires, 6 of which are live. Each wire carries 5 kV.
1989	Nominated on the list of Ramsar Convention

(Data source : KWS and WWF)

2.5.2 Physical Conditions of Lake Nakuru

Lake Nakuru has a surface area of 43 km^2 at its level El. 1,758.5 m, although it varies largely depending on the level. Its bottom elevation is at around El. 1,756 m.

Lake Nakuru is one the of four broad shallow soda lakes in Kenya : Nakuru, Elementeita, Bogoria and Magadi, which lie in a semi-arid basin of internal drainage and their water levels and salinities fluctuate drastically in response to changes in rainfall and evaporation.

The water in these lakes has a high mineral concentration due to gradual leaching of volcanic soils releasing salts mainly of sodium, bicarbonate ($NaHCO_3$) and carbonate ($Na_2 CO_3$) from surrounding catchment areas which drain into the lake. Lack of outlets in these lakes also contributes greatly to their high alkalinity and salinity.

Fig. 2-2 shows the lake level fluctuation at Lake Nakuru during the past six decades. The level have changed substantially during the recorded period. In the years 1933, 1939, 1947, 1961, and 1987, the lake dried up completely. It is believed that in the dried up periods the floor of the lake had been subjected to wind erosion resulting in clouds of alkaline dust being blown over the surrounding area. The highest level stand at 4.37 m recorded in August 1979.

2.5.3 Ecological Consideration

(1) Vegetation

46.7 % of the National Park area is covered with bush land and only about 23.1 % is covered with grasses. The foreshore only contributes 11.7 % while woodlands make up 18.7 %. This vegetation distribution pattern is likely to influence the abundance and special distribution of the mammals to be found within the park.

(2) Birds

Table 2-3 presents the observation records in January 1992 and January 1993 for the six most abundant birds.

Table 2-3 Observation Records of Birds in Lake Nakuru National Park

Birds	January 1992	January 1993
Greater Flamingo	4,323	612
Lesser Flamingo	320,300	750,169
White Pelican	14,426	4,607
Gray Headed Gull	8,145	1,207
Great Cormorant	3,238	578
Little Grebe	6,708	1,232

(Data source : KWS)

Lesser Flamingo is identified as the most predominant bird in Lake Nakuru, but its number changes from time to time. As shown in Table 2-3, the number of lessor flamingoes in Lake Nakuru in 1993 was more than two times that in 1992. However the total number of flamingoes in Lake Nakuru, Bogoria and Elementaita remained almost unchanged as shown in Table 2-4.

Table 2-4 Distribution of Lesser Flamingo

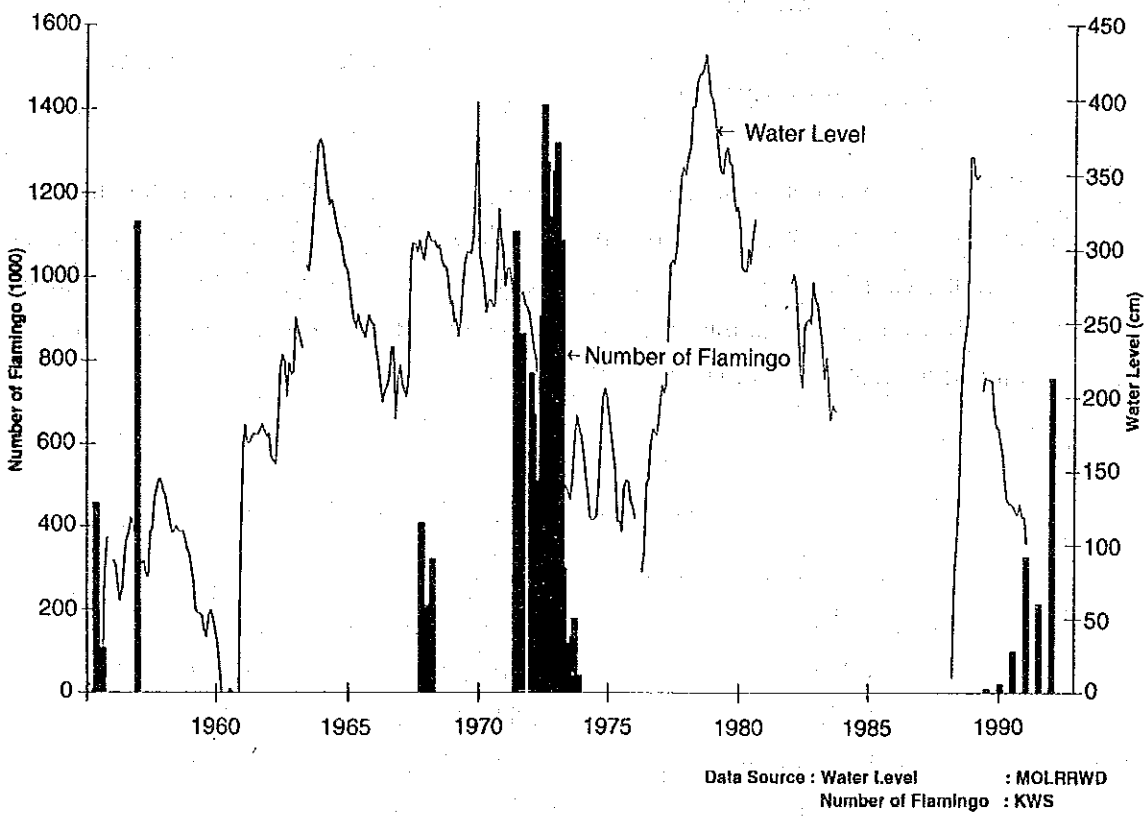
Lake	Jan. 1992	Jan. 1993
Nakuru	320,300	750,169
Bogoria	754,200	268,139
Elementeita	94,080	2,497
Total	1,168,580	1,021,805

(Data source : National Museum of Kenya)

This fact indicates that flamingoes move from one lake to another from time to time. The departure of flamingoes is believed to be related to food availability in these lakes and for breeding purpose. Only Lake Natron, which is located in Tanzania, is identified in the Rift Valley as a breeding environment. It is said that this is attributed to the soil type which is suitable for nest building. A relation between the number of flamingoes and the lake level is as shown in Fig. 2-2.

Before introduction of Tilapia in 1960 from Lake Magadi, the bird life of the lake was poor compared to the present situation. Except for flamingoes, there were few other birds. Since the introduction, more than 50 species of fish eating birds have been recorded, and the number and variety of birds have become abundant in the lake.

Fig. 2 - 2



Data Source : Water Level : MOLRRWD
Number of Flamingo : KWS

THE REPUBLIC OF KENYA MINISTRY OF LOCAL GOVERNMENT	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE RECORDS OF WATER LEVEL AND NUMBER OF FLAMINGOES IN LAKE NAKURU

(2) Mammals

Also KWS staff in cooperation with volunteers have carried out monitoring of the number of mammals monthly and/or quarterly since 1978. The monitoring results in 1990 and 1991 are as presented in Table 2-5.

Table 2-5 Mammal Monitoring Record in 1991

Mammal	Number in 1990	Number in 1991
Waterbuck	4,979	4,649
Impala	4,658	4,147
Warthog	1,181	1,339
Buffalo	406	392
Thomson's Gazelle	405	1,301
Grants Gazelle	192	589
Zebra	252	162
Eland	58	75
Giraffe	105	98
Redbuck	24	70
Dikdik	28	24
Bush buck	16	5
Hippopotamus	10	35
Rhinoceros	7	19

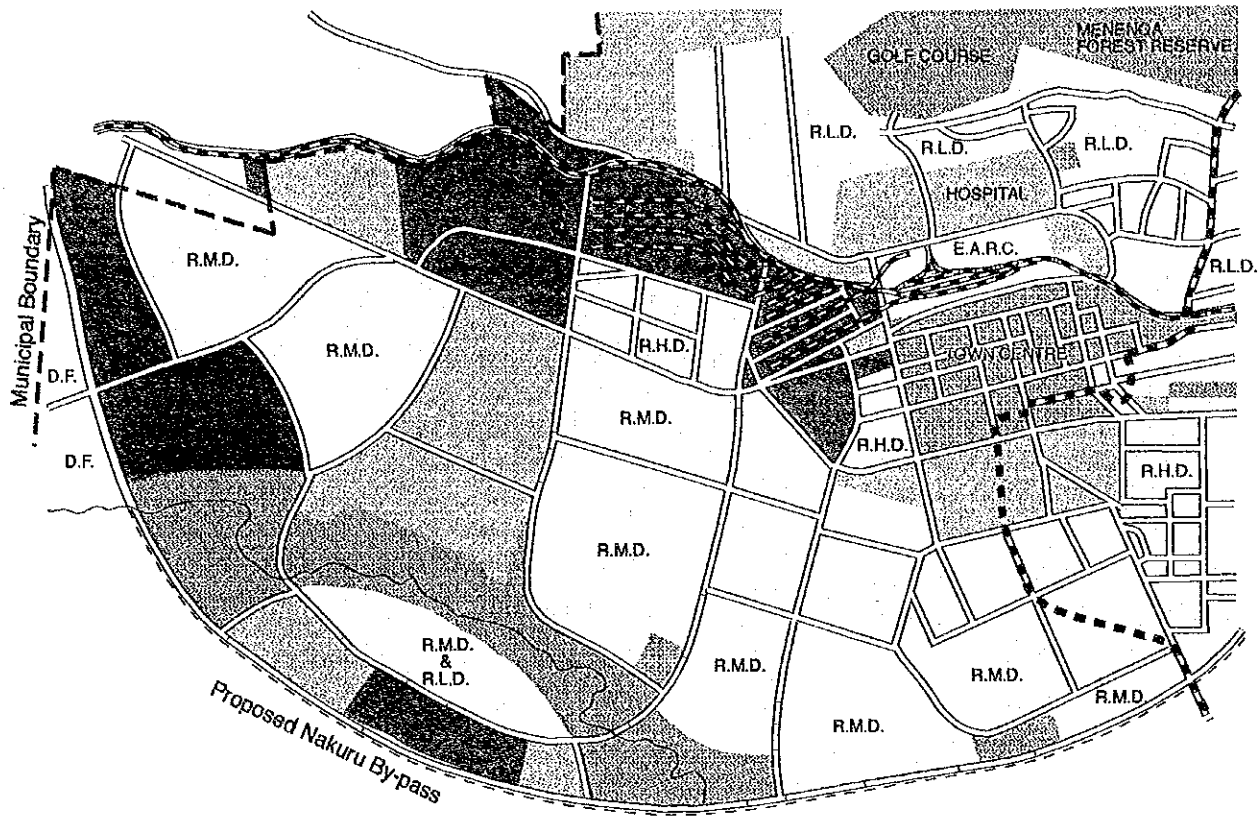
(Data source : KWS)

Both electric and chain fences have been erected around the National Park to prevent any mammals moving out from the park. Therefore the number of each mammal is more accurately recorded than the number of birds. Migration of mammals in and out of the park is therefore not possible. Distribution of mammals within the park however varies from time to time.

2.6 Physical Development Plan of Nakuru Municipality

A physical development plan of the Nakuru Municipality has been mapped by the municipal council as shown in Fig. 2-3. According to the map, the municipal area is planned to be expanded to 72.6 km^2 and is classified into six land use categories as presented in Table 2-6.

Fig. 2 - 3



LEGEND

	Residential	R.H.D.	Residential High Density
	Industrial	R.M.D.	Residential Medium Density
	Commercial	R.L.D.	Residential Low Density
	Recreation	D.F.	Deferred
	Public Purposes	- - - -	Catchment Division between Town Site and Njoro River Site after Construction of the Interception Sewer

THE REPUBLIC OF KENYA	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILITATION AND EXPANSION PROJECT	TITLE PHYSICAL DEVELOPMENT PLAN OF NAKURU MUNICIPARITY
MINISTRY OF LOCAL GOVERNMENT	JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 2-6 Proposed Physical Development Plan of Nakuru Municipality

Land Classification	Area (km^2)	Proportion (%)
Residential area	25.5	35.1
Industrial area	7.9	10.9
Open space	11.9	16.5
Public purpose land	15.1	20.9
Commercial area	1.4	1.9
Utility purpose land	2.9	4.0
Others	7.8	10.7
Total	72.6	100.0

(Data Source : NMC)

It is foreseeable that the proposed physical development plan would result in augmenting pollution load generation unless otherwise adequate precautions are taken up. It is recommended that every development activities be coordinated and controlled systematically by the IWG for conservation of Lake Nakuru.

2.7 Population

Although the population census was conducted in 1989, it is not available for the current study. NMC has also no population data of the recent years. After consultation with MOLG and WSD of NMC, it was decided to adopt the population data presented in "Greater Nakuru Water Supply Project, Eastern Division, Stage-1 Final Design Report, August 1997".

In the above-said report, it is reported that estimated population is 240,000 in 1987 and is forecast to grow to 361,000 in 1993. The average growth rate is therefore as high as 7.0 per cent per annum, mainly owing to rural-urban migration.

3. EXISTING SANITARY SERVICE SYSTEMS

3.1 Public Sanitary Service System

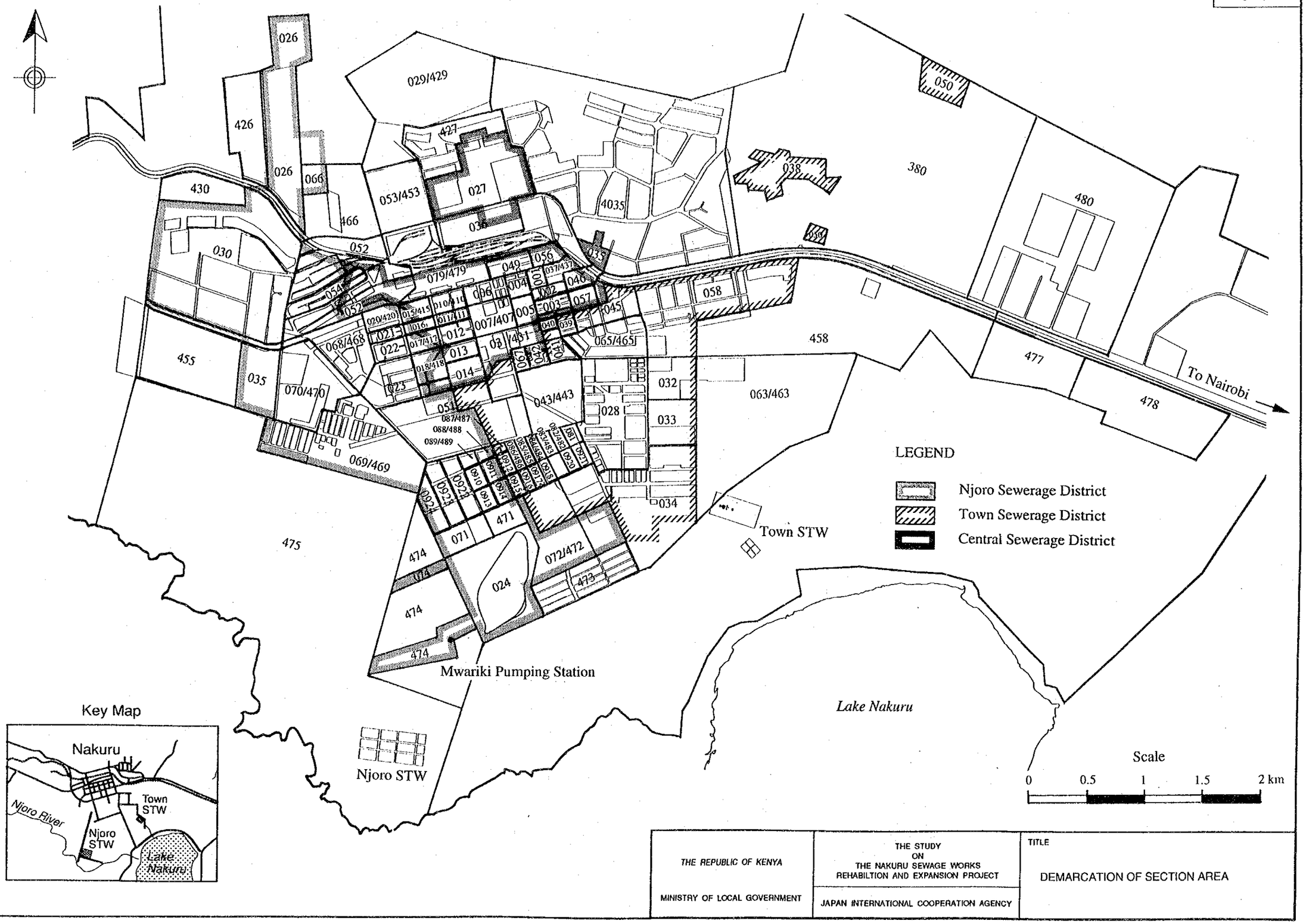
The public sanitary services in Nakuru Municipality covers potable water supply, sewerage, garbage collection and disposal and health care. The municipal area is divided into two: one is the Town area excluding Lanet area (hereinafter defined as the Town area) and the other is Lanet area (hereinafter referred to as the Lanet area), in view of the existing service system.

Details of the existing sanitary services are reported in Supporting Report C in Volume III. The sanitary services in Town area are systematically managed so that NMC issues only one bill to each registrant for monthly payment. The Town area is sub-divided into a number of sections and NMC's billing system systematically records the numbers of registrants in each section by types of the services. Fig. 3-1 presents the demarcation of the section areas. As of April 1993, there are 14,904 pipe water served registrants in the municipal area, of which 9,538 and 11,674 registrants are also served with the sewerage and dustbin services respectively, as shown in Table 3-1.

The Lanet area is provided with specific water supply facilities by MOLRRWD. The sewerage system is however extended only to the 3rd Kenya Rifles, being one of the five military services in the area, and it is connected to the Town STW of WSD.

At present, water supply and sewerage services are administered and managed by WSD and dustbin service by PHD. PHD also extends such services as sludge exhausting of on-site wastewater treatment facilities and health care.

Fig 3 - 1



THE REPUBLIC OF KENYA MINISTRY OF LOCAL GOVERNMENT	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILTION AND EXPANSION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE DEMARCATION OF SECTION AREA

Table 3-1 Numbers of Water Supply and Sewerage Registrants (1/2)

Section No.	Njoro Sewerage District				Town Sewerage District				Central Sewerage District				Total			
	Area (ha)	Water Served Registrants (nos.)	Sewer Served Registrants (nos.)	Non-sewer Served Registrants (nos.)	Area (ha)	Water Served Registrants (nos.)	Sewer Served Registrants (nos.)	Non-sewer Served Registrants (nos.)	Area (ha)	Water Served Registrants (nos.)	Sewer Served Registrants (nos.)	Non-sewer Served Registrants (nos.)	Area (ha)	Water Served Registrants (nos.)	Sewer Served Registrants (nos.)	Non-sewer Served Registrants (nos.)
1. Sewer Served Area																
01	0.0	0	0	0	0.0	0	0	0	2.4	72	71	1	2.4	72	71	1
02	0.0	0	0	0	0.0	0	0	0	2.8	71	71	0	2.8	71	71	0
03/403	0.0	0	0	0	0.0	0	0	0	5.4	594	123	471	5.4	594	123	471
04	0.0	0	0	0	0.0	0	0	0	3.6	36	36	0	3.6	36	36	0
5	0.0	0	0	0	0.0	0	0	0	3.7	0	0	0	3.7	0	0	0
06	0.0	0	0	0	0.0	0	0	0	6.4	82	82	0	6.4	82	82	0
07/407	0.0	0	0	0	0.0	0	0	0	9.6	84	80	4	9.6	84	80	4
010/410	0.0	0	0	0	0.0	0	0	0	4.2	19	13	6	4.2	19	13	6
011/410	0.0	0	0	0	0.0	0	0	0	2.2	12	10	2	2.2	12	10	2
012	0.0	0	0	0	0.0	0	0	0	4.2	23	22	1	4.2	23	22	1
013	0.0	0	0	0	0.0	0	0	0	3.9	70	68	2	3.9	70	68	2
014	0.0	0	0	0	0.0	0	0	0	8.5	82	81	1	8.5	82	81	1
015/415	0.8	3	2	1	0.0	0	0	0	3.0	26	22	4	3.8	29	24	5
016	0.8	7	7	0	0.0	0	0	0	1.2	16	16	0	2.0	23	23	0
017/417	2.3	8	6	2	0.0	0	0	0	1.5	9	6	3	3.8	17	12	5
018/418	3.9	8	7	1	0.0	0	0	0	2.6	8	7	1	6.5	16	14	2
020/420	3.6	20	19	1	0.0	0	0	0	0.0	0	0	0	3.6	20	19	1
021	1.6	26	26	0	0.0	0	0	0	0.0	0	0	0	1.6	26	26	0
022	4.9	28	28	0	0.0	0	0	0	0.0	0	0	0	4.9	28	28	0
023	14.9	140	139	1	0.0	0	0	0	0.0	0	0	0	14.9	140	139	1
024	53.3	821	792	29	0.0	0	0	0	0.0	0	0	0	53.3	821	792	29
026/260	47.8	224	196	28	0.0	0	0	0	0.0	0	0	0	47.8	224	196	28
027	0.0	0	0	0	0.0	0	0	0	45.8	33	31	2	45.8	33	31	2
028/428	0.0	0	0	0	63.9	122	114	8	0.0	0	0	0	63.9	122	114	8
030	133.9	128	119	9	0.0	0	0	0	0.0	0	0	0	133.9	128	119	9
031/431	0.0	0	0	0	0.0	5	5	1	22.0	12	9	3	22.0	18	14	4
032	0.0	0	0	0	18.5	81	78	3	0.0	0	0	0	18.5	81	78	3
033	0.0	0	0	0	19.4	39	39	0	0.0	0	0	0	19.4	39	39	0
034/434	23.6	249	247	2	70.3	640	633	7	0.0	0	0	0	93.9	889	880	9
035	0.0	0	0	0	0.0	0	0	0	5.4	31	30	1	5.4	31	30	1
036	0.0	0	0	0	0.0	0	0	0	14.1	199	199	0	14.1	199	199	0
037/437	0.0	0	0	0	0.0	0	0	0	3.8	58	54	4	3.8	58	54	4
038	0.0	0	0	0	20.4	130	101	29	0.0	0	0	0	20.4	130	101	29
039	0.0	0	0	0	3.2	56	56	0	0.0	0	0	0	3.2	56	56	0
040	0.0	0	0	0	1.6	34	34	0	0.0	0	0	0	1.6	34	34	0
041	0.0	0	0	0	4.7	118	117	1	0.0	0	0	0	4.7	118	117	1
042	0.0	0	0	0	2.5	34	34	0	1.0	15	15	0	3.5	49	49	0
043/443	0.0	0	0	0	33.7	153	144	9	0.0	0	0	0	33.7	153	144	9
045	0.0	0	0	0	18.2	37	35	2	0.0	0	0	0	18.2	37	35	2
046	0.0	0	0	0	0.0	0	0	0	2.9	4	4	0	2.9	4	4	0
049	0.0	0	0	0	0.0	0	0	0	4.2	87	86	1	4.2	87	86	1
050	0.0	0	0	0	14.0	1	0	1	0.0	0	0	0	14.0	1	0	1
051/451	41.0	6	5	1	19.2	3	2	1	0.0	0	0	0	60.2	9	7	2
052	63.8	3	3	0	0.0	0	0	0	0.0	0	0	0	63.8	3	3	0
054	7.8	125	123	2	0.0	0	0	0	0.0	0	0	0	7.8	125	123	2
055	18.8	193	180	13	0.0	0	0	0	0.0	0	0	0	18.8	193	180	13
056	0.0	0	0	0	0.0	0	0	0	2.8	47	47	0	2.8	47	47	0
058	0.0	0	0	0	65.9	611	600	11	0.0	0	0	0	65.9	611	600	11
065/465	0.0	0	0	0	20.8	124	117	7	0.0	0	0	0	20.8	124	117	7
066	4.7	2	2	0	0.0	0	0	0	0.0	0	0	0	4.7	2	2	0
067	0.0	0	0	0	2.0	5	5	0	0.5	1	1	0	2.5	6	6	0
068/468	19.1	86	81	5	0.0	0	0	0	0.0	0	0	0	19.1	86	81	5
069/458	63.6	1,519	1,321	198	0.0	0	0	0	0.0	0	0	0	63.6	1,519	1,321	198
070/470	34.3	362	278	84	0.0	0	0	0	0.0	0	0	0	34.3	362	278	84

Table 3-1 Numbers of Water Supply and Sewerage Registrants (2/2)

Section No.	Njoro Sewerage District				Town Sewerage District				Central Sewerage District				Total			
	Area (ha)	Water Served Registrants (nos.)	Sewer Served Registrants (nos.)	Non-sewer Served Registrants (nos.)	Area (ha)	Water Served Registrants (nos.)	Sewer Served Registrants (nos.)	Non-sewer Served Registrants (nos.)	Area (ha)	Water Served Registrants (nos.)	Sewer Served Registrants (nos.)	Non-sewer Served Registrants (nos.)	Area (ha)	Water Served Registrants (nos.)	Sewer Served Registrants (nos.)	Non-sewer Served Registrants (nos.)
071	9.9	327	309	18	0.0	0	0	0	0.0	0	0	0	9.9	327	309	18
072/472	19.8	509	502	7	13.2	339	335	4	0.0	0	0	0	33.0	848	837	11
074	21.6	121	109	12	0.0	0	0	0	0.0	0	0	0	21.6	121	109	12
079/479	0.0	0	0	0	0.0	0	0	0	65.6	28	19	9	65.6	28	19	9
081	0.0	0	0	0	1.7	56	55	1	0.0	0	0	0	1.7	56	55	1
082/482	0.0	0	0	0	1.8	85	79	6	0.0	0	0	0	1.8	85	79	6
083/483	0.0	0	0	0	1.3	44	36	8	0.0	0	0	0	1.3	44	36	8
084/484	0.0	0	0	0	1.4	61	58	3	0.0	0	0	0	1.4	61	58	3
085/485	0.0	0	0	0	1.6	62	61	1	0.0	0	0	0	1.6	62	61	1
086/486	0.0	0	0	0	1.7	85	84	1	0.0	0	0	0	1.7	85	84	1
087/487	0.0	0	0	0	0.8	17	15	2	0.0	0	0	0	0.8	17	15	2
088/488	1.0	23	18	5	0.0	0	0	0	0.0	0	0	0	1.0	23	18	5
089/489	1.2	11	2	9	0.0	0	0	0	0.0	0	0	0	1.2	11	2	9
091/491	11.5	275	240	35	12.6	258	224	34	0.0	0	0	0	24.1	533	464	69
092/492	22.9	365	316	49	4.6	64	55	9	0.0	0	0	0	27.5	429	371	58
471	7.3	485	0	485	0.0	0	0	0	0.0	0	0	0	7.3	485	0	485
INS	0.0	39	38	1	0.0	49	48	1	0.0	48	48	0	0.0	136	134	2
Sub-Total	639.7	6,113	5,115	998	419.0	3,314	3,164	150	233.3	1,767	1,251	516	1292.0	11,194	9,530	1,664
2. Un-sewered Area																
380	-	-	-	-	-	-	-	-	-	-	-	-	403.0	354	0	354
426	-	-	-	-	-	-	-	-	-	-	-	-	27.0	296	0	296
427	-	-	-	-	-	-	-	-	-	-	-	-	24.3	41	0	41
029/429	-	-	-	-	-	-	-	-	-	-	-	-	75.0	6	1	5
430	-	-	-	-	-	-	-	-	-	-	-	-	20.5	228	0	228
4035	-	-	-	-	-	-	-	-	-	-	-	-	240.9	0	0	0
053/453	-	-	-	-	-	-	-	-	-	-	-	-	25.6	11	5	6
455	-	-	-	-	-	-	-	-	-	-	-	-	50.3	151	0	151
458	-	-	-	-	-	-	-	-	-	-	-	-	21.7	239	0	239
063/463	-	-	-	-	-	-	-	-	-	-	-	-	121.4	4	2	2
466	-	-	-	-	-	-	-	-	-	-	-	-	34.5	4	0	4
473	-	-	-	-	-	-	-	-	-	-	-	-	23.8	227	0	227
474	-	-	-	-	-	-	-	-	-	-	-	-	75.6	598	0	598
45	-	-	-	-	-	-	-	-	-	-	-	-	598.0	853	0	853
477	-	-	-	-	-	-	-	-	-	-	-	-	36.0	166	0	166
478	-	-	-	-	-	-	-	-	-	-	-	-	67.5	357	0	357
480	-	-	-	-	-	-	-	-	-	-	-	-	221.0	175	0	175
Sub-Total	-	-	-	-	-	-	-	-	-	-	-	-	2066.1	3,710	8	3,702
TOTAL	639.7	6,113	5,115	998	419.0	3,314	3,164	150	233.3	1,767	1,251	516	3358.1	14,904	9,538	5,366

Note: (1) Sec. 425, 510, 511, 520 and 540 are all outside the municipal area.
(2) Accordingly total number of registrants for water supply and sewerage services are 14,904 and 9,538 respectively.
(3) INS: Institutions

(Data source NMC)

3.2 Potable Water Supply System

3.2.1 Public Water Supply System

It is not exaggerated to say that a whole of inhabitants in Nakuru Municipality depends on public water supply for their domestic use.

The Town area is dependent on two water treatment works and three borehole fields for its source of potable water supply. The average monthly source water supply quantity was 22,079 m^3/day during the period from January 1988 to February 1993, of which nearly 70% derived from the borehole fields. The quantity of water supply have been subject to a large fluctuation owing to operational condition of pumping facilities in the borehole fields. According to the WSD's record, unaccounted for water is very large being around 40 - 50%. It is recommended to deploy such measures as installation of more number of water meters at consumers, leakage detection and reduction programme, etc. to reduce such target amount of un-accounted for water.

The Lanet area is fed by one waterworks and a deep well. The quantity of source water supply is 1,300 m^3/day on average, of which 260 m^3/day is delivered to the 3rd Kenya Rifles.

In 1991, the Greater Nakuru Water Supply Project, Eastern Division, Stage 1 was completed by NWCPC. This project is capable of supplying potable water amounting to 13,300 m^3/day to the municipality by a full treatment of the surface runoff from the Malewa River, but its actual operation has been suspended as a precaution until adequate measures are accomplished by GOK to prevent probable adverse effect on ecology of Lake Nakuru owing to increasing sewage resulting from the augmented water supply.

3.2.2 Private Water Supply Facilities

There are 8 deep wells owned by industrial enterprises in the Town area, which are mainly used for making up of and/or emergency source in case of failure of the public water supply. It is estimated that average daily water abstraction is 640 m^3/day.

3.3 Wastewater Treatment System

3.3.1 Public Sewerage System

(1) Sewered area and connection ratio

There are two sewage treatment works, Njoro and Town STWs at present in Nakuru Municipality. The existing sewer network covers mainly a central part of the Town area as shown in Fig. 3-2 and is divided into three sewerage districts: 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 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.

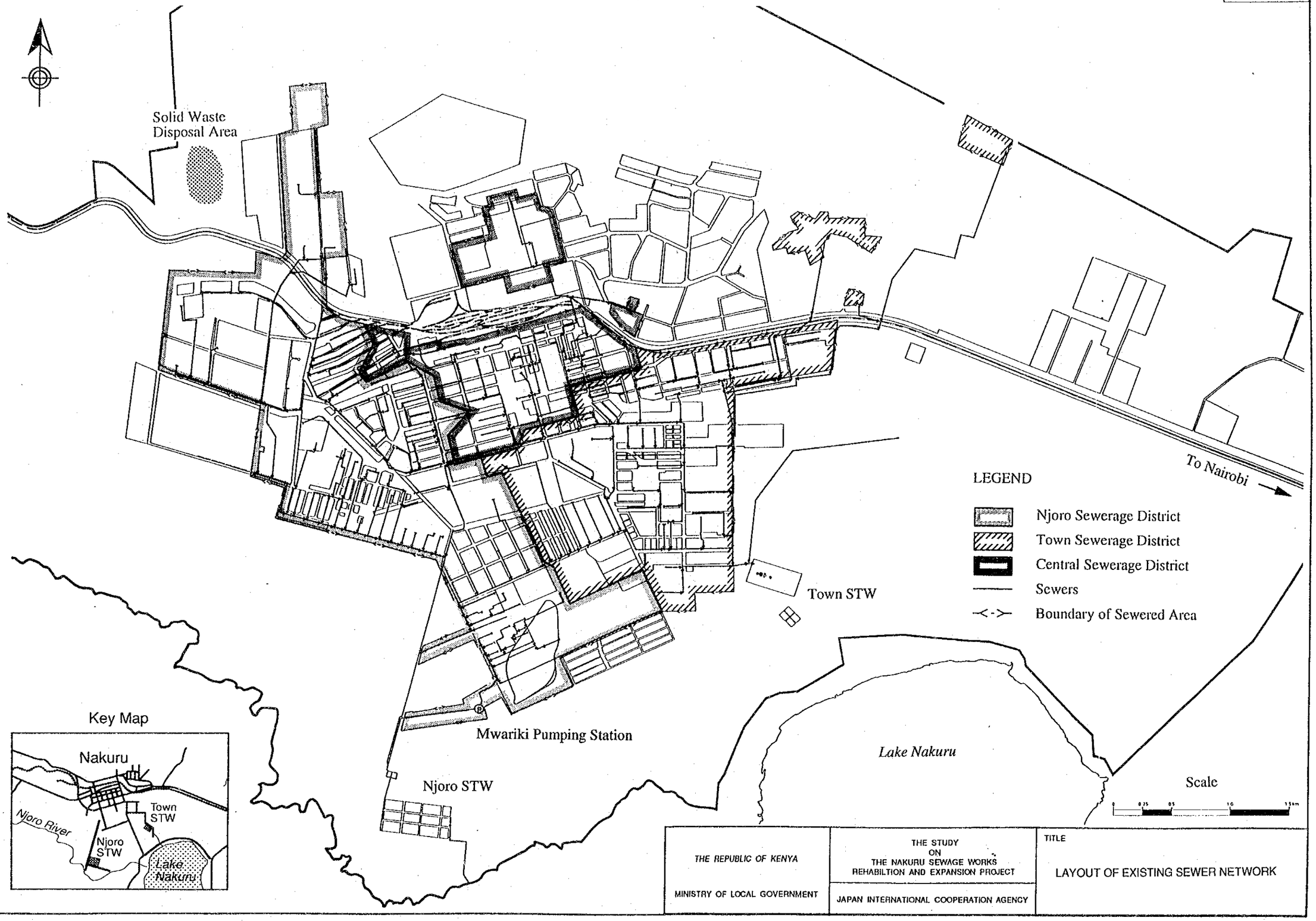
The number of sewerage served registrants 9,530 in total, consisting 5,115 in Njoro SD, 3,164 in Town SD and 1,251 in Central SD, while that of portable water served registrants is 11,194. A sewer connection ratio is therefore 85.1% at present. There are 1,664 non-sewer served registrants within the sewered area. It is noted that WSD continues their effort to connect such non-sewered registrants into sewers to create amenity living environment.

(2) Sewers

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

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 according to the WSD's record. The Sewer Section of WSD is poorly provided with adequate equipment to tackle such problem effectively and rationally.

Fig 3-2



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(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 and is of waste stabilization pond type. It consists of three lines of stabilization ponds, each line comprising of facultative, first maturation, second maturation and third maturation ponds. The treated sewage is discharged to the Njoro River. The Njoro STW has however been operating under a severe over-loading condition for many years. The average monthly inflow was 5,897 m^3/day during the period from 1988 to 1992 and BOD concentration of inflow is more than 700 mg/L at present. For almost 20 years since their completion in 1973, the ponds have operated without proper maintenance works. As a result, some ponds have reduced their storage capacity due to sedimentation resulting in reducing a retention period to 32 days from the original 37 days. Especially the facultative ponds are likely to be operated in a state of anaerobic and their arrangement is judged to be in appropriate when compared to the present quality and quantity of influent. Because of over-loading and reduced storage capacity, quality of effluent from the sewage works is badly degraded, in terms of BOD 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 of 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 over-loading condition. The average monthly inflow was 3,470 m^3/day and BOD concentration of inflow is also more than 500 mg/L. The Town STW has experienced frequent stoppage due to failure of mechanical and electrical facilities. It appears that the works is not operated properly during the night time due to absence of operating staff. The quality of effluent is more than 100 mg/L in terms of BOD.

As noted in the above, both the sewage treatment works have been subjected to severe over-loading 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 the adequate non-structure measures to control the industrial wastewater, which is the major pollution load contributor.

(4) Sewage generation factor and rate of rainwater mixture

The sewage generation phenomena under the present condition was analyzed in order to facilitate the forecast of sewage generation after commissioning on additional water supply of 13,300 m^3/day. Details of the study are presented in Supporting Report D in Volume III.

The analysis focuses on a dry weather flow and a rate of rainwater mixture. For estimate of the dry weather flow, the following simple mathematical model was employed:

$$Qw = Ks \{(Qs \times Rs / Rw1) + Qp + Ql\}$$

where,

Ks	:	sewage generation factor,
Qw	:	sewage inflow
Qs	:	source water supply for Town area,
Rs	:	number of sewerage registrants in Town area,
Rw1	:	total number of water registrants in Town area,
Qp	:	private water supply,
Ql	:	source water supply for Lanet area,

In due consideration of sewage treatment process characteristics and climatological condition, it is appraised that a sewage generation factor is 0.55 and a rate of rainwater mixture is equivalent to 20% of the dry weather flow.

(5) Treatment and disposal of sludge

The Town STW is provided with 10 sludge drying beds, while the Njoro STW has only a temporary one. At the Town STW, sludge is being sold out to the farmers, but is normally kept for a long period at the site. The Njoro STW has so far rarely practiced the sludge removal from its facilities due to financial constraints and lack of adequate maintenance equipment.

(6) Re-use of treated sewage

The treated sewage is wholly discharged into Lake Nakuru through the natural river and drainage channel. Thus re-use of treated sewage is not being taken seriously. However, in and around the Town STW, a number of inhabitants cultivate "Sukumawiki" (Kales) by using portion of raw sewage illegally as irrigation water. The WSD is to announce to the farmers to abandon such operation.

3.3.2 On-site Wastewater Treatment Facilities

Septic tanks, cesspools, and pit latrine are the dominant on-site wastewater disposal facilities in unsewered area. According to the questionnaire survey, 89% of the total households have pit latrines and the remaining 11% septic tanks in the unsewered area. About 99.5% of the total households surveyed showed interest in being connected to the public sewer as one of the sanitary services.

Septage from those population are desludged by the PHD using an exhauster. They are normally dumped into sewer lines located nearby. The average volume of septage disposal was at 16.4 m^3/day in 1991 and 14.4 m^3/day in 1992. The present septage disposal method is judged to be one of causes for over-loading of sewage treatment works. The alternative disposal method is therefore proposed as described in the succeeding sub-section 4.4.1 of this report.

3.3.3 Industrial Wastewater Pre-treatment Facilities

The Study Team carried out questionnaire survey on existing industries with assistance of WSD, in which industrial wastewater pretreatment facilities were one of the questions. Supporting Report B of Volume III contains detailed information on such facilities.

Some of individual industries are provided with simple wastewater pretreatment facilities as summarized in Table 3-2. Most of the facilities were not functioning properly due to either insufficient capacity or poor maintenance. Carry-over of settled solids and fat/oil, and extreme temperatures and pH were observed in the effluent to public sewer. For example, effluent temperatures as high as 48°C were observed for the effluent from edible oil manufacturing industries and effluents from textile industries showed high temperatures (40°C) and high pH (10.1).

Table 3-2 Industrial Wastewater Pretreatment Facilities in Nakuru Municipality

Industry	Pretreatment Facilities	Purpose	Maintenance Condition	Remarks
Textile (Spinning, weaving) and dyeing	Equalization/ retention/ sedimentation	Reduction of extremes in pH, temperature. Removal of settleable matter	Good	Extreme temperature, and pH of effluent
Edible Oil Extraction	Fat/oil trap	Removal of fat/oil	Fair ~ Poor	Extreme temperature, carry over of accumulated fat
Tannery [Hide processing and chrome tanning]	Equalization/ retention/ sedimentation tanks	Removal of settleable matter, fat and scum	Extremely poor	Carry over of sludge, short-circuiting, high pH
Milk processing	Fat/oil traps	Removal of fat/oil	Fair	-
Soap manufacturing	Fat/oil traps	Removal of fat/oil	Fair	-
Soap manufacturing	Septic tanks	-	-	Not connected to sewers
Dry-cell manufacturing	Filtration	Recycling of water	Good	Process stream not connected to sewer
Electroplating	Cyanide oxidation, chromic acid reduction and filtration	Removal of toxic material	Good	Not connected to sewer

(Data Source : Study Team)

Sludges produced from the pretreatment facilities is estimated at about 1,020 ton/year and are dumped at the Municipal Dumping Site. Some of them contain heavy metals particularly from electroplating and dry-cell manufacturing, and are potential polluters of groundwater and land along the storm drainage of the Municipal Dumping Site. Tannery is the largest contributor of sludge to the Municipal Dumping Site, about 900 ton/year.

3.3.4 Nakuru Sewerage Project

Preceding to the current Study, Nakuru Sewerage Project is in progress by NWCPC. This project particularly aims at expanding Njoro STW by means of construction of additional waste stabilization ponds to reduce over-loading condition and to meet increasing sewage after commissioning of additional potable water supply of 13,300 m^3/day. It has a treatment capacity of 6,000 m^3/day and is programmed to bring the project into operation by the middle of 1994.

3.4 Stormwater Drainage

Fig. 3-2 depicts a general layout of the stormwater drainage network in Nakuru Municipality. The drainage system is completely separated from the sewer network. Stormwater drainage network can be divided into three main networks: (1) Central Drainage System which serves the most of the central built-up districts in the municipality, and the other two are (2) Eastern Drainage System and (3) Western Drainage System, both of which cover mainly the residential areas of the eastern and western parts of the municipality respectively.

The Central Drainage System covers the area of 374 ha. Its main drain runs into Lake Nakuru after joining effluent from Town STW. This drainage system carries not only stormwater but also part of domestic and industrial wastewater and is one of the main sources of pollution loads into Lake Nakuru.

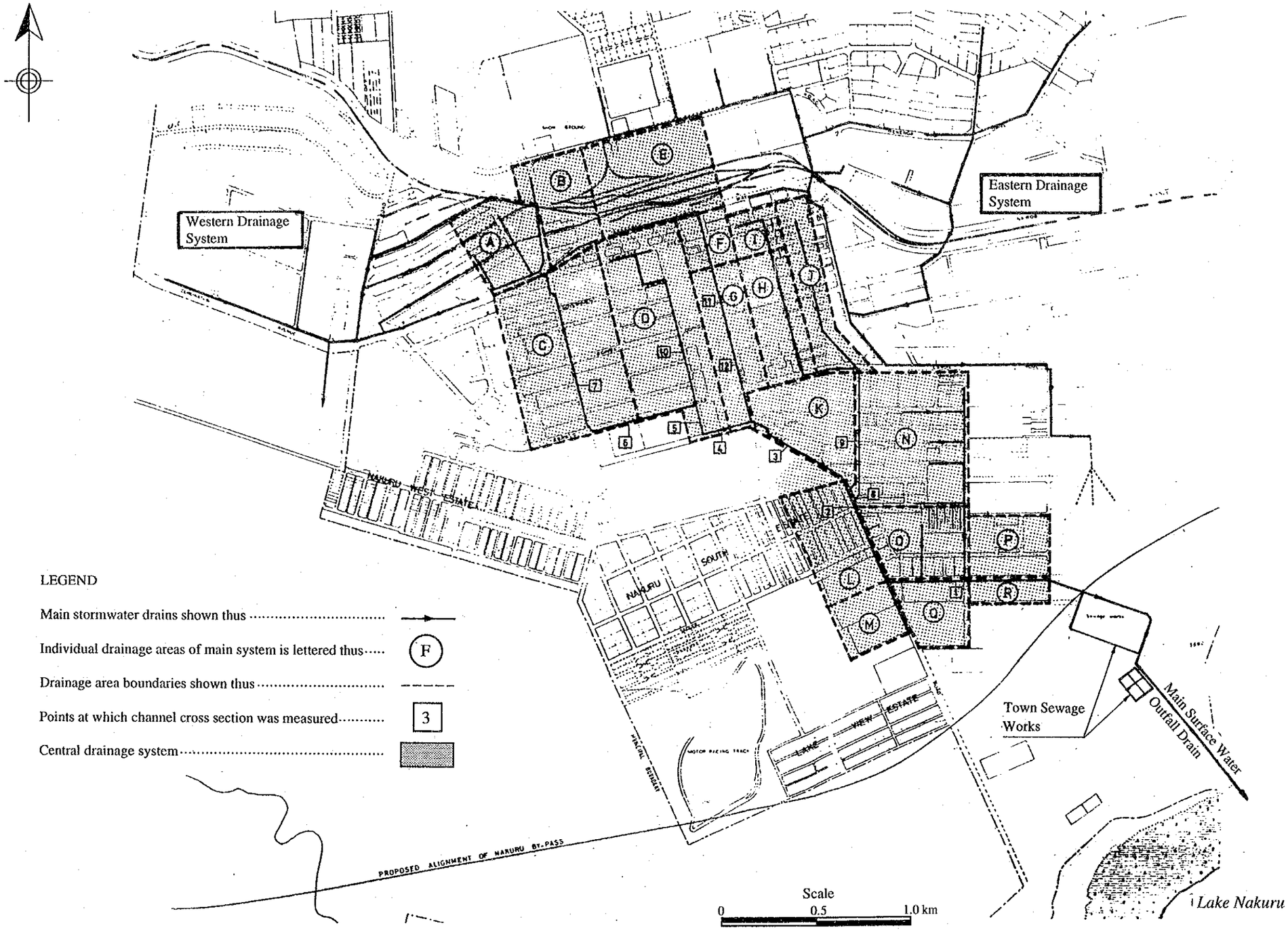
The Eastern and Western Drainage Systems collect mainly stormwater and sullage. Main drain of the Eastern System splits out into an irrigation network at about 800m north of Town STW and drainage water is used for irrigation without treatment. The main drain of the Western System disappears underground at around 1.0 km before reaching the Njoro River. According to the questionnaire survey, a large number of inhabitants in the southern part of the municipality strongly desires to be provided with drainage system.

3.5 Domestic and Industrial Refuses

PHD of NMC manages dustbin service and disposal of refuse collected. The municipal area is divided into 10 districts and garbage collection is in principle made twice a week by 12 teams by using 12 refuse vehicles. The refuse collected is transported to a damping site located in the western rim of the municipality as shown in Fig. 3-2. A controlled tipping method is being employed at the damping site.

Also according to the PHD, industrial waste is normally stored in factories' yards and then transported to the above-said dumping site by the factories themselves. According to the PHD's record, quantity of domestic refuse is increasing year after year; 7,461 ton/year in 1987 to 23,040 ton/year in 1992, while the industrial waste varied between 9,493 ton/year in 1988 to 3,792 ton/year in 1990.

Fig. 3 - 3



[Source : Preliminary Design Report on Sewage Treatment Works (Town Site), 1978]

THE REPUBLIC OF KENYA MINISTRY OF LOCAL GOVERNMENT	THE STUDY ON THE NAKURU SEWAGE WORKS REHABILTION AND EXPANSION PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE GENERAL LAYOUT OF STORMWATER DRAINAGE NETWORK

3.6 Public Health Services

PHD also assumes responsibility for the public health including medical care and such services as preventive, cleansing, ambulance, hearse and mortuaries. As a part of the medical care, NMC operates and manage 5 health centers, 6 dispensaries and 5 hospitals with total 100 beds.

A questionnaire survey was conducted on the on-site wastewater treatment facilities in July 1993 in randomly selected areas in the Study Area. The survey included questions such as (1) satisfaction to the present sanitary condition, (2) required public services to improve the present sanitary condition and its priority, (3) experience of suffering from waterborne diseases, and (4) type of diseases suffered. The results of the survey are as summarized in Table 3-3.

Table 3-3 Needs for Improvement of Sanitary Services

	Description	Proportion of Interviewees (%)
(1)	Present sanitary condition	
	- Satisfaction	0
	- Unsatisfaction	100
(2)	Required public services	
	- 1st priority : Sewerage	67.9
	- 2nd priority : Stormwater drain	14.5
	- 3rd priority : Water supply	9.9
(3)	Experience of waterborne diseases	76.7
(4)	Kind of diseases	
	- Malaria	62.6
	- Typhoid	14.1

(Data source: Study Team)

4. WATER POLLUTION CONTROL PLAN

4.1 Estimate of Pollutant Loads

4.1.1 General Description

Preliminary estimate of pollutant loads has been made based on the data and information collected during the field work in Nakuru and analytical work carried out in Japan. It should however be noted that the current survey, investigation and analytical work have been programmed to be completed within various limited conditions such as period, timing, frequency, climatological condition, equipment etc. Although the Study Teams have made every efforts to complete the study within a given condition, it is recommendable that survey and investigation be continued to accumulate more qualitative and quantitative data than obtained through the current Study for further upgrading the pollutant load estimate presented in this report. It should therefore be noted that an attempt made under the current study is a benchmark for future survey and investigation.

The preliminary estimate of pollution load and pollution control plan presented herein are the summary quoted from the Supporting Report E in Volume III.

4.1.2 Sources of Pollution

Pollution sources, in general, are classified into two, depending on how pollution is emitted or discharged into the receiving body: one is point sources that discharge pollutants in a discernible and discrete manner through various means and the other is non-point sources that discharge pollutants area-wide into the water body in an indiscernible manner. Further, pollution can be grouped into two whether it originates from human activities or not: (a) anthropogenic or man-made pollution and (b) others.

To assess intensity and mechanism of pollution that affects water quality of Lake Nakuru, it is fundamental to identify whether the pollution source is a point or non-point source. Pollution sources are summarized in Table 4-1.

Table 4-1 Classification of Pollution Sources

	Pollution Sources	Point or Non-Point	Man-made or Others
1)	Domestic	Point	Man-made
2)	Industrial	Point	Man-made
3)	Commercial, Public & Recreational	Point	Man-made
4)	Stormwater Runoff	Point and non-point	Man-made
5)	Agriculture & Livestock	Non-point	Man-made
6)	Wild Animal	Non-point	Others
7)	Natural Plant	Non-point	Others

(Data Source: Study Team)

Pollution from the sources (1) through (5) closely relates to the water consumption. Inflow of the above pollutants to Lake Nakuru are mainly through rivers and channels, and their typical features are outlined below:

(1) Rivers

There are five major river systems feeding Lake Nakuru. They are Njoro, Makalia, Nderit, Lamudiak and Ngosor and their catchment areas are 293 km^2,315 km^2, 520 km^2, 166 km^2 and 77 km^2 respectively. Of the five river, the Njoro river is blessed with a perennial flow throughout the year and has an urban center, Njoro town with the estimated population of 15,000 in its catchment area. The river receives treated effluent from Njoro STW. Both the Lamudiak and Ngosor rivers disappear before joining Lake Nakuru.

(2) Town stormwater drainage channel

The outline of town stormwater drainage is reported in Section 3.4 of this report. In dry season, a flow of sullage discharged from the residential area is observed in the channel. Most of it is used for irrigation near Town STW. In built-up areas, even a little rainfall (>3 mm/day) results in surface run-off. During rainfall, brown and dark colored stormwater that contains garbage and oils enters into the lake through the channel. At about 500 m upstream from the influence to the lake, the flow rate increases gathering treated effluents from Town STW.

(3) Others

Several springs exist around the lake. They are those near the camp site, Lion Hill and Baharin Spring where infiltrated surface water appears again, discharging into the lake throughout the year. Apparently, they are not related to man-made pollution. However, it is often that such spring water contains high concentration of pollutant loads because of organic matter from marshland.

There are two hotels in the national park, which accommodate more than one hundred tourists a day. One is Lion Hill Lodge on an eastern hill and the other is Lake Nakuru Lodge in a south-east plain of the lake. It is however confirmed that effluents from the hotels do not affect the water quality of Lake Nakuru.

From the above, all influent channels, rivers and springs are not necessarily identified as probable sources of pollution as summarized in Table 4-2.

Table 4-2 Type of Influents and Pollution

Source of Pollution	Man-made Pollution	Others
The Njoro River	Yes	Yes
The Makalia River	No	Yes
The Nderit River	No	Yes
Town Stormwater Drainage Channel	Yes	No
Baharin Spring	No	Yes
Spring near Lion Hill	No	Yes
Spring near Camp Site	No	Yes

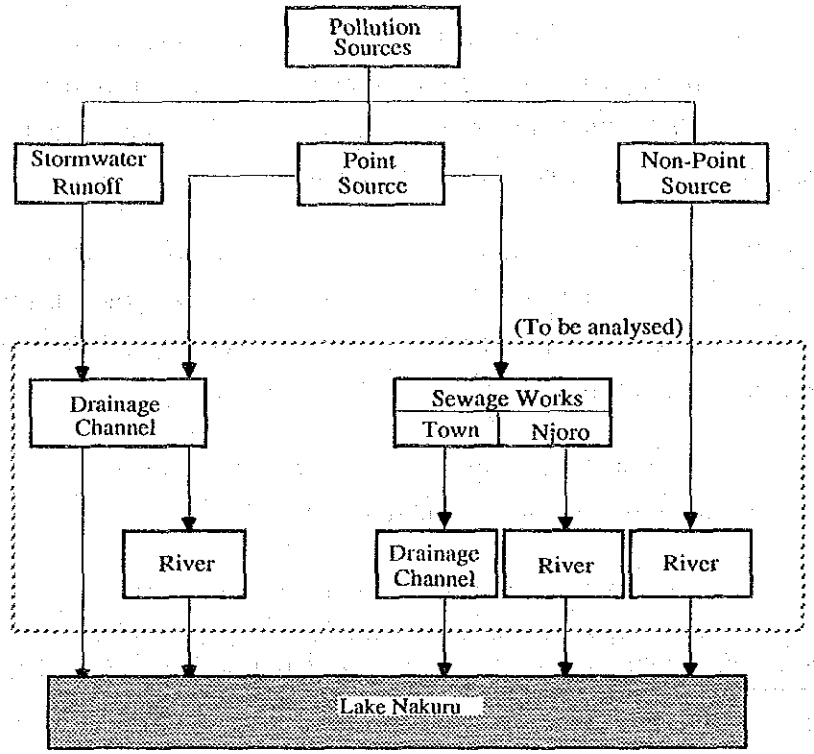
(Data source: Study Team)

4.1.3 Method of Estimate

(1) Pollution Process

Pollutants discharged from sources enter into rivers, storm channels and sewers in various forms of liquids and solids. Some of them are collected and treated at the existing sewage treatment works and are deposited and accumulated in the channels and river, and the remaining reaches Lake Nakuru. Fig. 4-1 illustrates the typical process of pollution on the lake water. Present survey and study are focused on the process when pollutants discharge into rivers, channels, sewage facilities and the lake in a discernible manner.

Fig. 4-1 Pollution Process



(Data Source: Study Team)

(2) Methods of Estimation

Pollutant loads are estimated separately for point source, stormwater (point & non-point source) and non-point source. Sources for each category in the Lake Nakuru catchment are as follows:

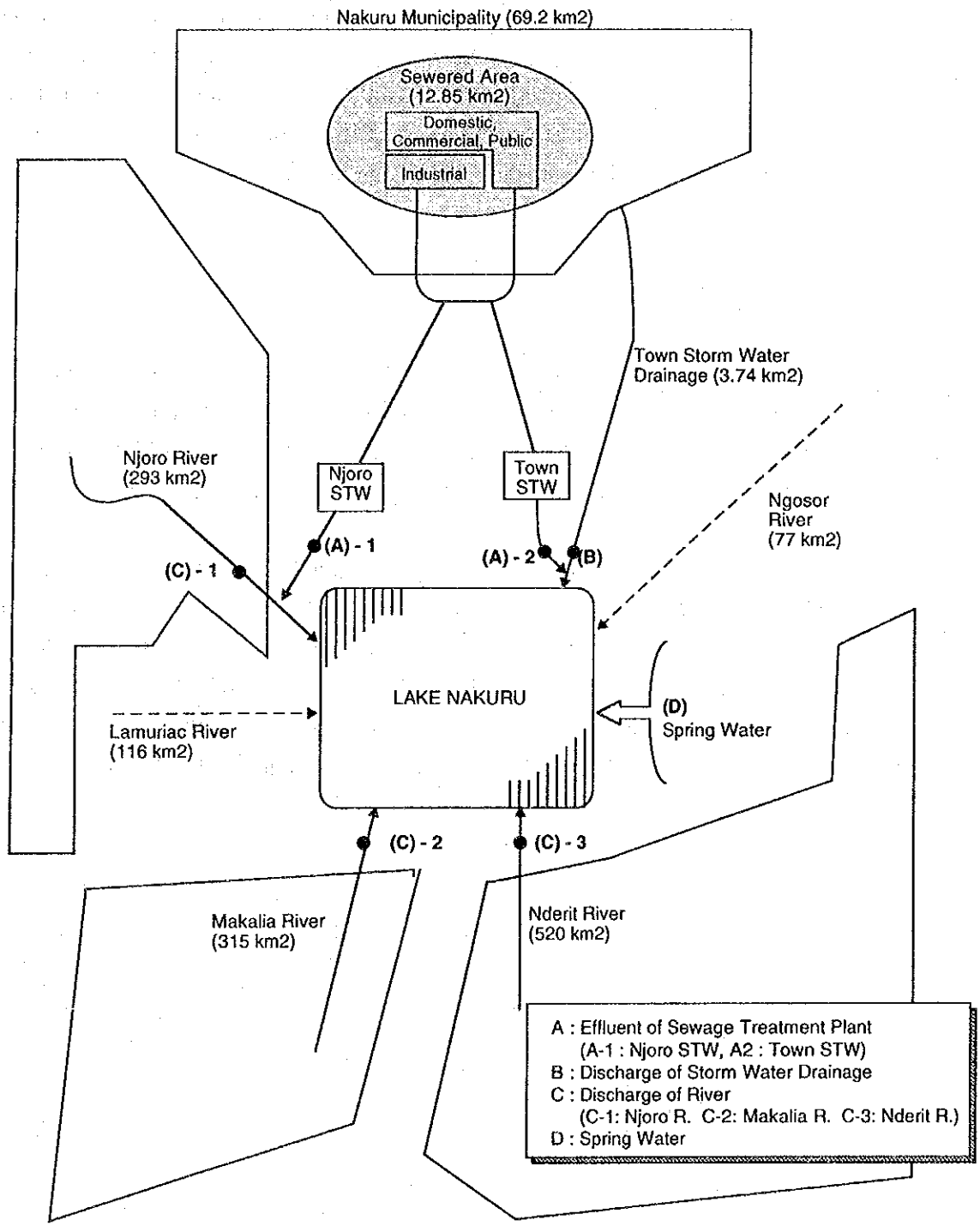
(a) Point source pollution

Under this category pollutant loads through sewage treatment works, namely, Njoro and Town STWs are estimated. The route of this pollution is shown as (A) in Fig. 4-2.

(b) Stormwater pollution

The route of this pollution is shown as (B) in Fig. 4-2. For other drainage areas, stormwater pollution is accounted for in the annual estimate of pollutant loads through rivers and springs.

Fig. 4 - 2



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(c) Non-point source pollution

Non-point source pollution is transported through rivers and springs to Lake Nakuru. They are Njoro River, Makalia River, Nderit River, Baharin Spring and two more springs (Spring near Special Camp Site and Spring near Lion Hill) in the eastern part of Lake Nakuru. Estimation was based on the water quality survey and flow rate data. The route of this pollution is shown as (C) &(D) in Fig. 4-2.

4.1.4 Forecast of Sewage Generation

Sewage generation under the additional water supply is forecast by the same of mathematical model as presented in the preceding sub-section 3.3.1 of this report. The forecast is however made under conditions that the sewer connection ratio and sewage generation factor reach 92% and 0.60 respectively when the Project puts into service.

The process of sewage generation calculation is given in Table 4-3. It is forecast that the sewage generation amounts to 16,186 m^3/day after the additional water supply, an increase of 8,001 m^3/day compared to the 1991/92 dry weather flow. Even after completion of the Nakuru Sewerage Project, there is a deficit in sewage treatment capacity. It is concluded that a new sewage treatment works with a daily capacity of 3,200 m^3 be realized. In this context, it is recommended that the new treatment works be located at Town STW.

Table 4-3 Forecast of Dry Weather Flow with Additional Water Supply

Description	Unit	Present Condition (Dec. 1991 - Feb. 1992)	Condition after Additional Water Supply by Greater Nakuru Water Supply Project
1. Public Water Supply Services			
Total number of water served registrants	nos.	14,904	14,904
Registrant in sewered area	nos.	11,194	11,194
2. Public Sewer Services			
Sewer served area	ha	1,285	1,285
Sewer connection ratio, overall		0.64	0.69
Sewer connection ratio, sewered area		0.55	0.62
Sewer served registrants	nos.	9,530	10,298
3. Total Quantity of Source Water Supply			
3.1 Public Supply System			
Existing systems in Town Area	m^3/day	21,969	24,604
Greater Nakuru water supply Project Eastern Division	m^3/day	-	13,300
Existing system in Lanet Area	m^3/day	1,300	1,300
3.2 Private supply system	m^3/day	640	640
Total	m^3/day	23,909	39,844
4. Estimated Quantity of Source Water Supply to Sewered Area			
4.1 Public supply system			
Existing system in Town Area	m^3/day	14,038	16,977**
Greater Nakuru Water Supply Project Eastern Division	m^3/day	-	9,124**
Existing System in Lanet Area	m^3/day	260	260
4.2 Private supply system	m^3/day	616	616
Total	m^3/day	14,914	26,977
5. Forecast of Dry Weather Flow			
Sewage generation factor		0.55	0.66
Forecast dry weather flow	m^3/day	8,185*	16,186

* : 1991/92 dry weather flow

** : Quantity of source water supply multiplied by overall sewer connection ratio

(Data source: Study Team)

4.1.5 Estimated Pollutant Loads into Lake Nakuru

In order to measure the impact of the additional water supply, pollutant loads are estimated for the following conditions:

Case-1 : Present conditions
Case-2 : After additional water supply of 13,300 m^3/day

For the Case-2 the following conditions are set forth:

(1) Additional water supply : 13,300 m^3/day to be distributed only to Nakuru Municipality.

(2) Sewerage condition :
- Same condition as described in the sub-section 4.1.3 of this report.
- The augmented sewage of 8,001 m^3/days flows directly into Lake Nakuru without treatment.
- BOD concentration is 800 mg/L, which corresponds to 75% non-exceedance probable value according to the Nakuru Sewerage Project.

(3) Other condition : Stormwater drain served area, socio-economic condition, industrial activity, land use and agricultural activity remain the same as the present throughout the catchment area of Lake Nakuru.

The estimated pollution load through the respective route is estimated for both cases as given in Table 4-4

Table 4-4 Estimate of Pollutant (BOD) Loads into Lake Nakuru

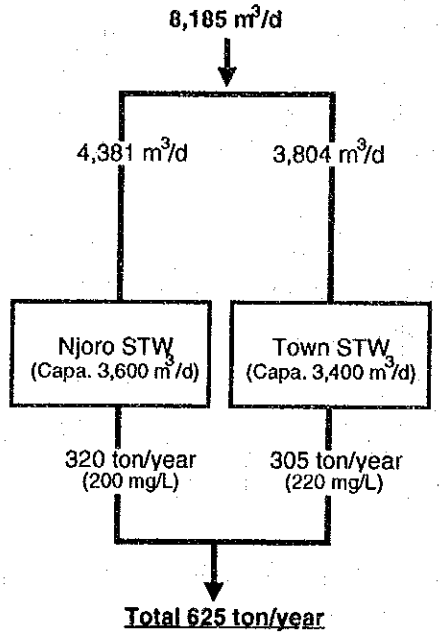
Route of Pollution Load		Case - 1		Case - 2	
		Amount (ton/year)	Proportion (%)	Amount (ton/year)	Proportion (%)
(1)	Sewage works	626	43	2,964	78
(2)	Storm water drainage	161	11	161	4
(3)	Rivers and springs				
	- Njoro river	356	24	356	10
	- Makalia river	122	8	122	3
	- Nderit river	152	10	152	4
	Springs	54	4	54	1
	Total	1,471	100	3,809	100

(Data source: Study Team)

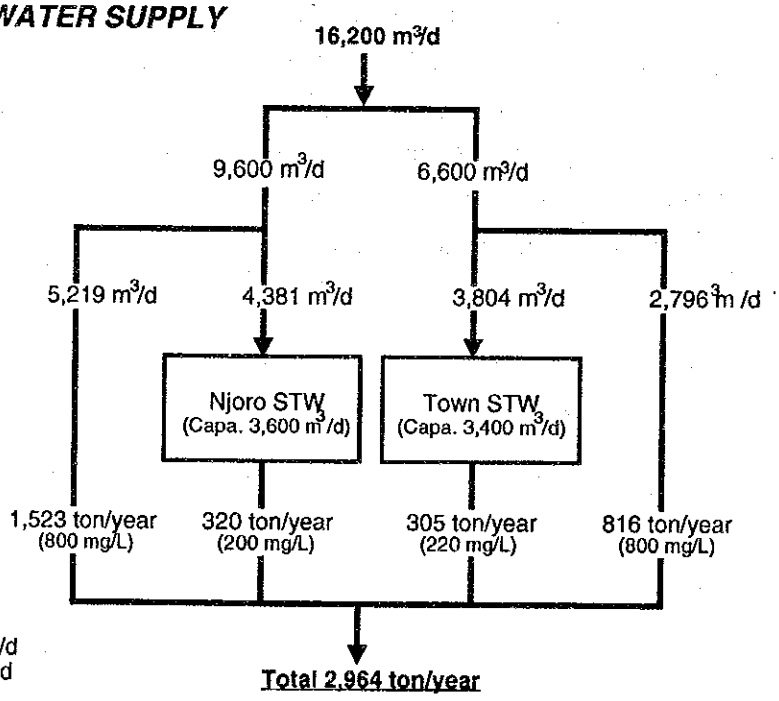
Pollutant (BOD) load into Lake Nakuru is forecast to amount 3,809 ton/year, corresponding to 259 % of the present load, if no countermeasure is taken up in line with the additional water supply of 13,300 m^3/day. The BOD pollution loads other than the sewage works remain the same as the present value, since it is assumed that there is no particular activity in increasing man-made pollution. Under the present condition, the BOD pollution load through the sewage works accounts for 43% of the total load, whereas it reaches as high as 78% after the additional water supply. Fig. 4-3 depicts the quantity of BOD pollution load through the sewage treatment works. To this end it is strongly recommended that adequate countermeasures be taken up to control the increasing man-made pollutant inflow into Lake Nakuru exceeding the present conditions.

Fig. 4 - 3

PRESENT CONDITION



AFTER ADDITIONAL WATER SUPPLY



Note : Volume of sewage is expressed in unit of m3/d and that of pollutant load in unit of ton/year.

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4.2 Effluent Quality Standards

4.2.1 Wastewater Standards for Discharge into Lake Nakuru

Table 4-5 shows the "Wastewater Standards for Discharge into Lake Nakuru" (Wastewater Standards), which specify 22 parameters.

Table 4-5 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

(Data Source : MOLG)

The above standards are reviewed and appraised in the light of the similar standards of other countries and from the view point of sewage treatment.

(1) BOD_5 and COD_{Cr}

The effluent standards for BOD_5 and COD_{Cr} values are 10 mg/L and 30 mg/L respectively. Raw domestic wastewater contains organic mater which are biodegradable. The ratio of BOD_5/COD_{Cr} is in the range of 0.7 - 0.8. During biological treatment of sewage most of the biological matter are oxidized and broken down into simple compounds and converted into bacteria or algae which appear as suspended solids in the effluent. Dissolved matter remaining in the treated effluent is hardly biodegradable matter. Therefore, ratio of BOD_5/COD_{Cr} will decrease in the effluent.

The ratio can be as low as 0.2. This means COD_{Cr} value will be more than 50 mg/L, for a treated effluent BOD_5 of 10 mg/L. According to the effluent standards of West Germany enacted in 1989, ratio of BOD_5/COD_{Cr} for an effluent BOD_5 of 40 mg/L is 0.27 while that for 15 mg/L is 0.2. These are for domestic wastes with an influent concentration of about 250 - 300 mg/L. For Nakuru, BOD_5 concentration of domestic wastes based on per capita BOD_5 of 40 g/d and 80 l/d water consumption would be about 500 mg/L. It means that the wastes are in a concentrated form and the concentration of non-biodegradable matter will also be higher. Further, these non-biodegradable matter will neither consume oxygen nor become pollutant load when discharged into the lake. Thus, the effluent COD_{Cr} standard of 30 mg/L is the most stringent and is beyond the limit that can be achieved by biological treatment assuming only domestic wastes are treated. The problem is aggravated when industrial water and night soil/septage are discharged into the sewerage system.

In Nakuru, night soil/septage emptied from cesspools and septic tanks are discharged into the sewer system. Night soil is in a concentrated form and septage contains more non-biodegradable matter, resulting in lower BOD_5/COD_{Cr} ratio. BOD_5/COD_{Cr} ratio of industrial wastes is highly variable. Most food processing industrial wastes contain more biodegradable matter while some chemical industrial wastes may contain hardly biodegradable matter.

In summary, COD_{Cr} standard of 30 mg/L is the most difficult to achieve even for domestic wastes. When industrial wastes and night soil/septage are discharged together with domestic wastes, the standard is impractical to be achieved by biological treatment. Effluent COD_{Cr} standard of 30 mg/L is not compatible with the BOD_5 standard of 10 mg/L.

(2) Nitrogen

Standards for free ammonia and nitrogen as Nitrates are specified at 1 mg/L and 5 mg/L respectively. Free ammonia concentration depends on the pH and temperature. Assuming effluent temperature of 25°C, Table 4-6 shows the ammonium (NH_4-N) nitrogen concentration for pH values of 7 to 9 and 10.5 (pH of Lake Nakuru).

Table 4-6 Concentration of Ammonium Nitrogen (NH_4-N) at Different pH Values for Free Ammonia Concentration at 25°C

pH	7	8	9	10.5
Free Ammonia, mg/L	1	1	1	1
NH_4-N, mg/L	190.6	19	1.9	0.06

(Data Source : Study Team)

At present actual average influent concentration of total nitrogen is about 273 mg/L, with an average influent NH_4-N concentration of 43.6 mg/L (Town), and 57 mg/L (Njoro). Highly efficient treatment methods are necessary, to achieve these standards.

It is however noted that, according to MOLRRWD, the values were specified focusing only the protection of Tilapia in Lake Nakuru from the toxicity of free ammonia. Toxicity of free ammonia to fish are researched for rivers and freshwater lakes. In case of lake Nakuru, Tilapia grows in a high pH environment. Ammonium ion entering the Lake through River Njoro and Town Storm Drainage may possibly escape into atmosphere in the mixing zone with the lake water due to increase in pH and high surface area for gas transfer.

Since Lake Nakuru has no outlets and acts as a sink for its catchment area, its preservation requires various control measures to reduce pollutant loads. The wastewater Standards is one of the tools. Application of this tool has to be based on step by step improvement of control measures. The effluent standards proposed are drastic. Its implementation has socio-economic impact to the drainage area of Lake Nakuru. Some revision are necessary especially for effluent COD_{Cr} and nitrogen concentrations.

4.2.2 Municipal Council of Nakuru (Trade Effluent) By-laws

Reduction of industrial wastewater loads into the sewerage system will subsequently reduce the pollutant loads discharged into Lake Nakuru and protect the sewage treatment works from harmful chemicals. Table 4-7 shows the Municipal Council of Nakuru (Trade Effluent) By-laws (Trade Effluent By-Laws), which specifies 37 parameters.

Table 4-7 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 Kjeldahi 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, effluent should not contain any toxic matter or any matter that will cause blockage and damage to sewers. Inflammable material and tar should not be present in the final effluent entering the sewer.	

(Data Source : NMC)

Maximum concentrations of BOD_5 and COD_{Cr} are specified as 500 and 1,000 mg/L, respectively. pH range is also specified between 6.5 - 8.0. In addition, discharge of the following materials into public sewers is prohibited.

(1) Calcium carbide
(2) Chloroform
(3) Condensing water
(4) Degreasing solvents of mono-di-trichloroethylene type
(5) Volatile petroleum products
(6) Inflammable solvents (e.g., carbon disulphide or any other products which produce inflammable vapors in the sewer
(7) Substances likely to interfere with the free flow in the sewers or to damage the sewers (refuse, glass, sand, solid waste, fibers, leather, textiles, plastic, cement, calcium hydroxide, bitumen).

Further, NMC determines the maximum concentration of substances and other matter.

The Trade Effluent By-laws vests powers for prosecution of defaulters. Following observations are made on the draft standards:

(1) Compliance Date

Draft By-laws have not specified any compliance date. In order to comply with the proposed by-laws it would become necessary for the industries to take up such measures as effluent pretreament, process modifications for reducing waste generation and reuse-recycling of effluents. Pretreatment requires building of facilities, financial investment and land for pretreatment facilities, and will impose not only a heavy financial overburden on industries but also require a long period for its realization.

Considering the above factors for compliance, it is recommended that an earliest possible compliance date be set considering the time necessary for design and construction of pretreatment facilities.

(2) Parameters

Table 4-8 shows the comparison of the standards related to health (ie. toxic and carcinogenic materials), between draft standards for NMC and Japan.

Table 4-8 Comparison of Parameters Related to the Health (ie. toxic materials)

Item	Limit	
	Nakuru	Japan
Cadmium (Cd), mg/L	0.01	0.1
Cyanide (CN^-), mg/L	0.2	1
Lead (Pb), mg/L	2	1
Hexavalent Chromium (Cr^{6+}) mg/L	0.05	0.5
Arsenic (As), mg/L	0.02	0.5
Mercury (Hg), mg/L	0.01	0.005
Alkyl Mercury, mg/L	N/A	not detectable
PCB, mg/L	Nil	0.003
Organo phosphorous Pesticides, mg/L	Nil	1

Note: N/A : Not Available
(Data Source : NMC & Study Team)

Except for lead, all parameters are very stringent for Nakuru. Treatment of toxic materials are difficult in sewage treatment works. They interfere with the functioning of biological treatment processes and restrict the reuse or disposal of sewage sludge and effluent.

The proposed standards related to toxic materials will be beneficial from the viewpoint of safe operation of sewage treatment works and sewage sludge disposal.

On the other hand, pretreatment of industrial effluents might produce industrial sludges containing high concentration of toxic materials and adequate measures for their safe disposal is necessary.

It should be noted that average BOD concentration of domestic waste in Nakuru is about 500 mg/L, while that of Japan is about 250 mg/L.

The Trade Effluent By-laws are stringent for all industries comparing the average domestic waste concentration of 500 mg/L. Considering the Wastewater Standards to be satisfied by Nakuru Municipal Council, it is necessary to conduct investigation on the total nitrogen and phosphorous concentrations that can be accepted into the public sewerage system.

Limit for ammoniacal nitrogen is specified at 20 mg/L while total kjeldahl nitrogen is set at zero which is impossible (note: total kjeldahl nitrogen = organic nitrogen + ammonia nitrogen). Specifying zero concentration for total kjeldahl nitrogen (or

organic nitrogen) is incompatible with BOD (500 mg/L) and COD (1,000 mg/L) values specified. Revision is necessary.

In summary, the proposed standards are very stringent especially for heavy materials. Revision is necessary for some parameters. Specifying a target date for earliest possible compliance is recommended for smooth enforcement of Trade Effluent By-Laws.

4.3 Basic Considerations for Pollution Control Plan

From the analysis of pollution sources and pollutant load estimate, and discussion of Wastewater Standards, the following points have become clear.

(1) Under the present conditions, sewage treatment works are the major source of man-made pollution (43% of total annual BOD) followed by the Town Stormwater Drainage Channel.

(2) Influent sewage concentrations are extremely high, 800 mg/L in terms of BOD, owing to highly polluted industrial wastewaters and low domestic water consumptions. Harmful materials are also discharged to the sewage treatment works from the industries. Control of industrial wastewaters is necessary to improve the effluent quality as well as to protect the sewage treatment processes from harmful chemicals. The Wastewater Standards on the other hand specify very strict BOD value of 10 mg/L. This indicates a BOD removal rate as high as 99%, which seems to be hardly attainable only by a normal sewage treatment technology.

(3) Pollutant load will be drastically increased through the sewage treatment works with the commissioning of additional water supply if no countermeasures are taken.

(4) The Wastewater Standards cannot be met by sewage treatment only. Heavy metals shall be controlled at their sources as they interfere with the biological sewage treatment processes and causes problems for sludge disposal. Pesticides cannot be removed at the sewage treatment works and accordingly be controlled at their sources. Effluent COD standard is unrealistically low to be achieved by sewage treatment processes.

(5) Although stormwater drainage bears only about 11% of the pollutant (BOD) load at present, it has been affecting the environment of Lake Nakuru. In order to keep the shoreline of the lake clean and to ensure amenity of animal beings, it is required to eradicate inflow of oil and other materials.

(6) For every catchment areas of the rivers feeding Lake Nakuru, major source of pollutant load generation is, in general, assessed to be livestock, wildlife, agricultural activities and other human activity on the riparian lands. Especially animals, which are supposed to be the predominant among the others, always moves around the catchment area so that it is hardly possible to control its pollution. However it may be possible to control the other sources with a special attention to harmful material such as heavy metal and pesticide by means of introduction of appropriate regulation /by-laws.

(7) The Njoro town is likely to grow rapidly keeping pace with expansion of Nakuru Municipality. Adequate precaution needs to be taken up within an overall framework of Lake Nakuru environment conservation so as not to create additional pollution sources.

Considering the above, water pollution control plan is proposed mainly consisting of structural and non-structural measures to reduce man-made pollutants arising from the additional water supply of 13,300 m^3/d. The plan will be realized in a stage-wise way and the structural measures are considered to be achieved in advance of the non-structural measures.

4.4 Proposed Pollution Control Plan

4.4.1 Structural Measures

The structural measures involves five major components as described below:

(1) Sewage treatment works

Three measures are particularly proposed as described below. Details of structural plan are reported in Chapter 5 of this Report.

(a) Rehabilitation of existing sewage works

Effluent BOD value of Njoro and Town STWs are estimated at 233 mg/L and 161 mg/L respectively under the present conditions. Those value are far exceeds the Wastewater Standards. Therefore the rehabilitation of existing facilities is highlighted to raise their efficiency and is proposed to be taken place as early as possible. In particular the existing waste stabilization ponds at Njoro STW is planned to be remodeled to increase treatment capability.

(b) Installation of additional treatment facilities at existing sewage works

As reported in detail in Supporting Report H, it is judged that the waste stabilization pond treatment process with rock filter and grass plot is the most technically and economically sound and compares favourably with other alternative treatment processes in terms of pollution load reduction . In order to further polish effluent from existing sewage treatment facilities, the rock filter and grass plot are proposed to be installed as additional treatment process at the existing sewage works and Nakuru Sewerage Project.

(c) Expansion of sewage works

In order to cope with increasing sewage, it is proposed to expand Town sewage treatment work by 3,200 m^3/day. The proposed treatment process is a combination of waste stabilization ponds, rock filters and grass plots.

Table 4-9 summarizes the process and configuration of the sewage treatment works rehabilitation and expansion plan.

Upon completion of the above measures, it is expected that BOD concentration would be reduced to around 15 mg/L in influent into Lake Nakuru.

(2) Sludge treatment and disposal

Sludge generating from the sewage treatment works increases with increase of sewage and would cause another pollution load into Lake Nakuru depending on treatment and disposal. The volume of raw sludge is estimated at 7,300 m^3/year for the Njoro STW and 2,410 m^3/year for the new 3,200 m^3/day line at Town STW. It is proposed that these raw sludges will have to be treated at sludge drying bed, which will be newly constructed at the respective sewage treatment works.

Table 4-9 Process and Configuration of Sewage Treatment Works Rehabilitation and Expansion

Description	Unit	Present Condition	After Nakuru Sewerage Project	After Implementation of the Project
1. Quantity of Sewage Flow	cu.m/day	8,185	16,200	16,200
Present	cu.m/day	8,185	8,185	8,185
Increase by Augmented Water Supply	cu.m/day	-	8,015	8,015
2. Total Treatment Capacity	cu.m/day	7,000	13,000	16,200
2.1 Existing Njoro STW				
Treatment Capacity	cu.m/day	3,600	3,600	3,600
Anaerobic Pond	cu.m/day	1,000	1,000	3,600
Facultative Pond	cu.m/day	3,600	3,600	3,600
Maturation Pond	cu.m/day	3,600	3,600	3,600
Additional Treatment	cu.m/day			3,600
2.2 Existing Town STW				
Treatment Capacity	cu.m/day	3,400	3,400	3,400
Primary Clarifier	cu.m/day	3,400	3,400	3,400
Trickling Filter	cu.m/day	3,400	3,400	3,400
Secondary Clarifier	cu.m/day	3,400	3,400	3,400
Facultative Pond	cu.m/day	-	-	3,400
Maturation Pond	cu.m/day	450	450	3,400
Additional Treatment	cu.m/day	-	-	3,400
2.3 New Njoro STW (under construction)				
Treatment Capacity	cu.m/day	-	6,000	6,000
Anaerobic Pond	cu.m/day	-	6,000	6,000
Facultative Pond	cu.m/day	-	6,000	6,000
Maturation Pond	cu.m/day	-	6,000	6,000
Additional Treatment	cu.m/day	-	-	6,000
2.4 Expansion by the project				
Treatment Capacity	cu.m/day	-	-	3,200
Anaerobic Pond	cu.m/day	-	-	3,200
Facultative Pond	cu.m/day	-	-	3,200
Maturation Pond	cu.m/day	-	-	3,200
Additional Treatment	cu.m/day	-	-	3,200
(Expansion + Rehabilitation)				

At the Town STW, the dried sludge is being used by farmers at their cultivated land, while according to the results of sludge quality test, mercury have been detected at one time, although its value of concentration is less than the standard values of other countries. It should also be noted the facts that there are a large number of factories within the sewered area, some of which discharge the heavy metals and toxic materials without proper pre-treatment into sewer. Although it is preferable to make dosage of the dried sludge on cultivation area, it is recommended to monitor the quality of sludge carefully so as not create the environmental problem.

Under the current study, it is therefore proposed that the dried sludge will be hauled and disposed to the dumping site. The NMC should designate an appropriate dumping site away from Lake Nakuru and take adequate pre-cautions as well as institute proper dumping method to prevent the adverse effects on the surrounding areas and natural resources. Fig. 4-4 shows schematically the present and proposed sludge treatment and disposal methods.

(3) Septage treatment and disposal

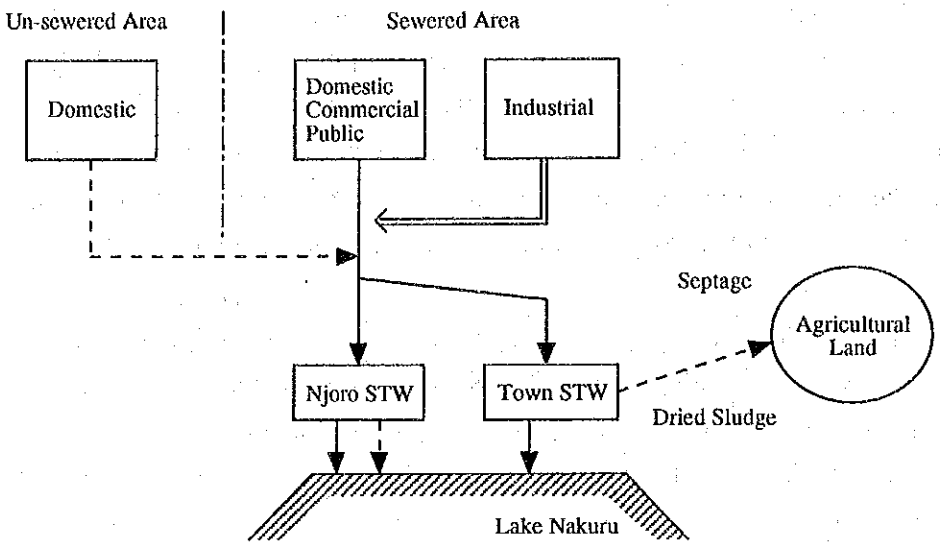
As noted in the sub-section 3.3.2, the PHD releases more than 14 m^3/day of septage collected from cesspools/septic tank into public sewer, being one of the main causes for over-loading on the sewage treatment works. It is proposed to treat such septage soils at the sludge drying beds at either Njoro and Town STWs after their construction. The dried sludge will be disposed in the same manner as the dried sludge. However, depending on quality, septage would be allowed to be hauled to and dumped directly at the disposal area. The present and proposed methods are also shown in Fig. 4-4.

(4) Stormwater Retention Pond

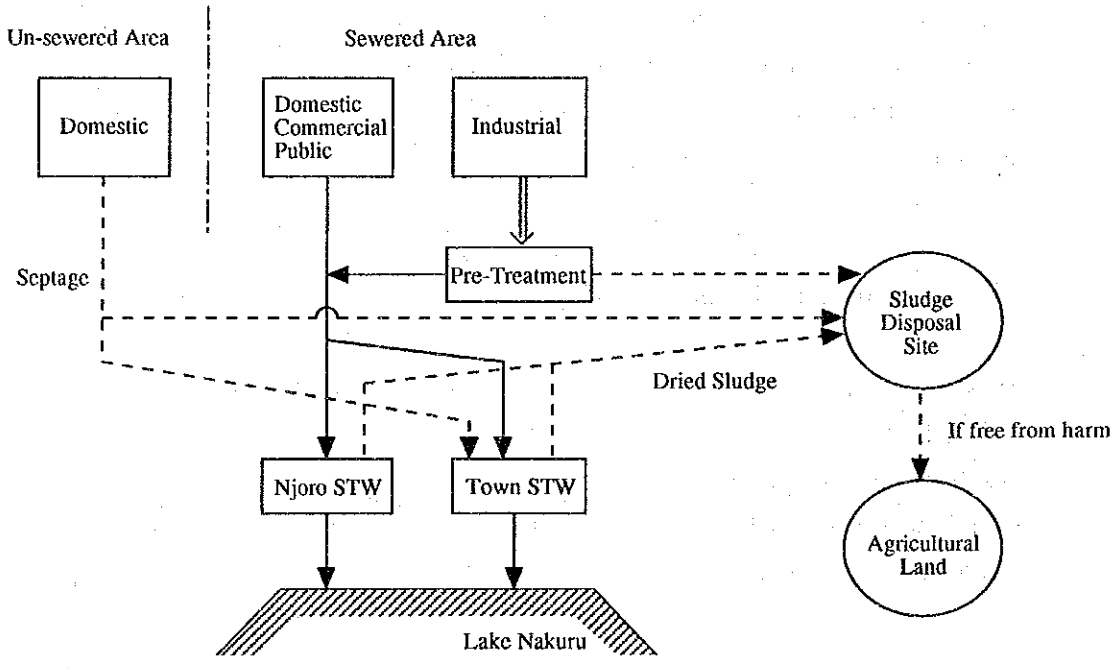
It is proposed to construct a stormwater retention pond in the vicinity of existing Town STW. The drainage water will be retained temporarily at the pond before discharging into the lake so that oil, inorganic matters, solid waste, sediments, etc., could be eliminated. The construction of the stormwater pond has long been contemplated by KWS.

Fig. 4 - 4

Present Condition



Proposed System



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