REPUBLIC OF KENYA
MINISTRY OF WATER DEVELOPMENT
NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION

STUDY ON CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM FOR GREATER NAKURU WATER SUPPLY PROJECT

FINAL REPORT

VOLUME V SUPPORTING REPORT (III)

ANNEX C Preliminary Environmental Study

DECEMBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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FEASIBILITY STUDY REPORT

ANNEX G

PRELIMINARY ENVIRONMENTAL STUDY

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Abbreviation and Local Terms

1. Abbreviation of Measures

1.1 Length

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

1.2 Area

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

1.3 Volume

lit, l	=	liter
lcd	=	liter per capita per day
cu.m, m^3	=	cubic meter
cu.m/day, m^3/day	=	cubic meter per day
MCM	=	million cubic meter

1.4 Weight

mg	=	milligram
mg/l	=	milligram per liter
g	=	gramme
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$1.00 = Ksh 23.0 = ¥ 150)
US$, $	=	US dollar
¥	=	Japanese Yen

1.7 Electric Measures

kV	=	kilovolt
kW	=	kilowatt
MW	=	megawatt
kWh	=	kilowatt hour
kVA	=	kilovolt ampere

1.8 Other Measures

mmho	=	micromho = conductance
ppm	=	parts per million
ppb	=	parts per billion
MPN	=	most probable number
‰	=	mill
%	=	per cent
PS	=	0.736 kW
°	=	degree
'	=	minute
"	=	second
℃	=	degree centigrade
n.a.	=	not available
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

1.9 Derived Measures Based on the Same Symbols

cu.m/sec, m^3/s	=	cubic meter per second
cu.m/day, m^3/day	=	cubic meter per day
t/ha	=	ton per hectare
lpcd	=	liter per capita per day

2. Other Abbreviations

BS	=	British Standards
JIS	=	Japanese Industrial Standards
ASTM	=	American Society for Testing and Material
GNP	=	gross national products

GDP	=	gross domestic product
GRDP	=	gross regional domestic product
El.	=	elevation
FWL	=	flood water level
FSL	=	full supply level
MSL	=	minimum supply level
HWL	=	normal operation level
LWL	=	minimum operation level
f.o.b	=	free on board
c.i.f.	=	cost, insurance and freight
ICB	=	international competitive bid
LCB	=	local competitive bid

3. Abbreviation of Organizations

MOA	=	Ministry of Agriculture
MENR	=	Ministry of Environment & Natural Resources
MOF	=	Ministry of Finance
MOLD	=	Ministry of Livestock Development
MOLG	=	Ministry of Local Government
MOTW	=	Ministry of Tourism & Wildlife
MOTC	=	Ministry of Transport & Communication
MORD	=	Ministry of Regional Development
MOWD	=	Ministry of Water Development
NES	=	National Environmental Secretariat
NWCPC	=	National Water Conservation & Pipeline Corporation
SOK	=	Survey of Kenya
KWS	=	Kenya Wildlife Service
NMC	=	Nakuru Municipal Council
NTC	=	Naivasha Town Council

ASTU	=	Anti-Stock Theft Unit
KYSTC	=	National Youth Service Training Center
GMB	=	Gilgil Military Barracks
KMB	=	Kenyatta Military Barracks
WWF	=	World Wide Fund for Nature
JICA	=	Japan International Cooperation Agency
OECF	=	Overseas Economic Cooperation Fund, Japan

I INTRODUCTION

1.1 General Description

1.1.1 Background

The Project is expected to directly benefit the inhabitants more than one million by augmenting and securing the safe water supply. On the other hand, it has been foreseeable that the Project would implicate the various effects on the natural and social environment, especially in Lake Naivasha and Lake Nakuru. It is indispensable to create an appropriate atmosphere for coexistence of the contemplated water supply and the natural and social environment.

Originally it had been programmed that MOWD performs a full scale environmental study concerning the Project but unfortunately it was not completed by the time of the Study. Accordingly JICA had extended a technical assistance to MOWD on the environmental study in accordance with additional request made by the Government of Kenya. The environmental investigation has been conducted during the Phase 2 and 3 Studies.

	Field Investigation Period	Home Office Work Period
Phase 2 Study	October to November, 1989	November,1989 to January, 1990
Phase 3 Study	May to July, 1990	July to September, 1990

This Annex G describes the findings of the environmental investigation throughout the Study period.

1.1.2 Scope of Work

The study was actually composed of two different levels being composed of the following studies :

(1) Preliminary environmental study for the proposed Malewa reservoir area and Lake Naivasha
- Field reconnaissance
- Ecological investigation
- Agriculture and Irrigation surveys

- Existing intake facilities survey
- Groundwater survey
- Water quality survey
- Lake Naivasha water balance study
- Data collection on environmental fundamentals

(2) Fundamental environmental study for Lake Nakuru
- Field reconnaissance
- Topographic mapping of Lake Nakuru
- Lake Nakuru water balance study
- Water quality analysis
- Data collection of environmental fundamentals

As for the data collection on the environmental fundamentals, the Study Team has focused the following items for data collection. The literatures and study reports collected are listed in Table G.1.1.

- General information on environment of African lakes and ecology
- Laws and regulations on environment by the Government of Kenya
- Studies on aquatic plant, papyrus, and salvinia in Africa
- General ecology, hydrology, and water quality of Lake Naivasha
- Aquatic flora such as papyrus, salvinia in Lake Naivasha
- Aquatic animals such as fish and zooplankton in Lake Naivasha
- Terrestrial animals in Lake Naivasha area
- General ecology, hydrology, water quality of Lake Nakuru area
- Terrestrial animals in Lake Nakuru area
- Mode of life of flamingos in Lake Nakuru and other saline lakes in Africa
- Aquatic plants such as Algae, diet of flamingos, in Lake Nakuru

Since the environmental investigation involves various fields such as wildlife, irrigation, hydrology, agriculture, horticulture, groundwater, vegetation, the Study Team has got in touch with the various governmental and non-governmental organizations concerned as listed hereunder and received valuable information.

(1) Governmental organizations
- Ministry of Water Development
- National Museum, Ministry of Home Affairs and National Heritage
- Kenya Wildlife Service, Ministry of Tourism and Wildlife

- National Environmental Secretariat, Ministry of Environment and National Resources
- Fisheries Department, Ministry of Regional Development
- Rift Valley Provincial Irrigation Unit, Ministry of Agriculture
- Meteorological Department , Ministry of Transport and Communication
- Nakuru Municipal Council, Ministry of Local Government

(2) Non-governmental organizations
- Elsamere Conservation Center
- World Wildlife Fund for Nature
- Department of Botany, University of Nairobi

For the completion of this environmental study, the Study Team is much obliged to Mr.Nyaoro, Hydrologist, Mr. Ndemwa, Chemist, Mr. Oronge, Assistant Engineer, and Mr. Waweru, Geologist of MOWD/NWCPC.

1.2 Study Area

1.2.1 Lake Naivasha Drainage Basin

The Lake Naivasha is situated at the eastern edge of the Kenya Rift Valley and is the second largest fresh lake in Kenya having a surface area of approximately 170 sq. km at El. 1,885 m, which is the highest of the Rift Valley lakes. The Eburru volcano reaches El. 2,800 m to the west and the Nyandarua or Aberdare range lies to the north and the east. The Mount Longonot, El. 2,776 m, is found to the south.

The lake drainage basin covers an area of approximately 3,400 sq. km, mainly comprising three sub-basins as follows:

Sub-basins	Drainage Area (sq.km)
Malewa River	1,653
Gilgil River	511
Lake Naivasha and minor rivers	1,237
Total	3,401

The Malewa River is the largest river sustaining 95% of inflow to Lake Naivasha. The second largest river is the Gilgil River. There are also a large number of another small tributaries flowing into Lake Naivasha. Among them, both the Karati and Marmonet rivers have relatively large catchment area but they supply with Lake Naivasha only seasonal flow. There is no river outgoing from the lake.

The Malewa River lies in floor of the Rift Valley. The Malewa River is named as the Wanjohi River in its upstream and it takes its origin in the western slope of the unnamed mountain with its summit altitude El. 3,886 m in the Abardare Range. The Wanjohi River flows down in rapid in the western slopes and at the foot of the Abardare Range and changes its course towards the northwest. It joints the Malewa River in the vicinity of Ndiara. In reach between Ndiara and Ol Kalou, the Malewa River forms two large bends and sharply changes its direction towards the south in the vicinity of Ol Kalou. It then runs through Malewa Gorge with a steep and narrow cliff for about 10 km and joints the Turasha River at about 8 km west from Gilgil town. The proposed Malewa damsite is approximately eight km upstream from the confluence point. The elevation at the confluence is approximately El. 1,960 m. The Malewa river finally debouches Lake Naivasha at about 7 km to the west from the Naivasha town.

The lake has three distinct parts, The first one is the main lake having a surface area of some 130 sq.km. The second one is connected to the main lake on the eastern side. An ancient volcanic crater rim has formed a crescent-shaped peninsula which shelters the Crescent Island Bay. The third one, on the south, is called " Lake Oloidien " or " Small Lake ", which is disconnected at present and saline lake. There are the irrigated lands of approximately 8,000 ha extending the shore of Lake Naivasha and they are depending on the lake, river and boreholes nearby for irrigation sources.

The general characteristics of the lake are summarized below.

	Descriptions	Unit	Values
(a)	Water level fluctuation : 1961-1984		
	- Maximum	El. m	1,886.9
	- Minimum	El. m	1,883.2
	- Average	El. m	1,885.2
	- Existing in July, 1990	El. m	1,884.6
(b)	Maximum water depth at average level		
	- Crescent Island Bay	m	13
	- Main lake	m	8
(c)	Lake surface area at average level	sq.km	185
(d)	Water volume at average level	10^6 cu.m	863
(e)	Average inflow by river		
	- Malewa river	cu.m/s	7.6
	- Gilgil river	cu.m/s	0.3
(f)	Average annual rainfall	mm	670
(g)	Average annual evaporation	mm	1,900

1.2.2 Lake Nakuru Drainage Basin

Lake Nakuru is located at the floor of Rift Valley and bounds with the southern boundary of Nakuru municipality. The lake is a part of the Lake Nakuru National Park with an international reputation for " the Lake of a million flamingos." It is very important tourism resources in Kenya, which is nowadays one of the most important foreign exchange earnings.

Its drainage area covers an area of approximately 1,536 sq.km comprising the following sub-basins.

Sub-basins	Drainage Area (sq.km)
Enjoro river basin	273
Makalia river basin	331
Enderit river basin	523
Lamudiac river basis	131
Ngosor river basin	80
Lake Nakuru and minor river basins	198
Total	1,536

Lake Nakuru is mainly fed by the Enjoro River. Its mean runoff is 0.8 cu.m/sec, which corresponds to 68 % of the total river inflow. There is no river outgoing from the lake.

The lake surface area is approximately 43 sq.km at El.1,760 m and varies largely with the lake level, since the lake is characterized by a shallow water depth. During the Phase 3 Study period, a topographic mapping for the lake and its surrounding has been conducted, which comprises of aerial photo survey covering 140 sq.km and sounding survey of the lake floor.

In addition to the river runoffs, the lake receives the sewage effluent from the Nakuru municipality through two sewage treatment works. The current rate of effluent is 8,600 cu.m/day in total, 3,200 cu.m/day through the Town Site works and 5,400 cu.m/day through the Njoro works.

The general characteristics of the lake are summarized below.

	Descriptions	Unit	Values
(a)	Water level fluctuation : 1959-1982		
	- Maximum	El. m	1,760.6
	- Minimum	El. m	1,756.3
	- Average	El. m	1,758.6
	- Existing level in July, 1990	El. m	1,758.5
(b)	Maximum water depth at average level	m	2.3
(c)	Lake surface area at average level	sq.km	43
(d)	Water volume at average level	10^6 cu.m	72
(e)	Average inflow by river		
	- Enjoro River	cu.m/s	0.8
	- Other rivers	cu.m/s	0.4
(f)	Average annual rainfall	mm/year	900
(g)	Average annual evaporation	mm/year	1,970

II PRESENT NATURAL AND SOCIAL ENVIRONMENT

2.1 Malewa River

2.1.1 River Water Quality

The water quality analysis has been carried out during both the Phase 2 and Phase 3 studies. During the Phase 2 Study, the water quality test was entrusted to the local laboratories, while that during the Phase 3 Study was more comprehensive than during the Phase 2 and was executed directly by the Study Team. The water quality of the Malewa River is, therefore, reported based on the results obtained during the Phase 3 Study.

(1) Water sampling

Water has been sampled during a three-month period since May, 1990 by the Study Team and NWCPC's counterpart at six monitoring points on the Malewa River as shown in Fig. G.2.1.

(2) Water quality analysis

The water samples have been analyzed for 11 items such as (a) Temperature, (b) Transparency, (c) Color, (d) pH, (e) Conductivity, (f) Turbidity, (g) Suspended Solid, (h) Dissolved Oxygen, (i) Chemical Oxygen Demand, (j) Nitrogen ; K-N, T-N, NO_3-N, and NO_2-N , and (k) Phosphorus ; T-P, PO_4-P.

All the equipment and materials necessary for the investigation were furnished by JICA and transferred to NWCPC at the end of June, 1990. During the absence of JICA Study Team from July to August this year, a monitoring investigation has been continuously carried out by the NWCPC's counterpart personnel.

(3) Present condition of river water

The result of the water quality analysis is shown in Tables. G.2.1 to G.2.2. and Figs.G.2.2 to G.2.8. Its summary is shown below.

Items			Value Observed	Average Value
(a)	Color of water	:	Water color No. 16 to 18, brown color muddy water	
(b)	Temperature	:	14.3 - 18.5 °C	16.8 °C
(c)	pH	:	7.78 - 8.24	8.04
(d)	Conductivity	:	110 - 240 µs/cm	157 µs/cm
(e)	Turbidity	:	14 - 70 mg/l	34 mg/l
(f)	DO	:	6.8 - 8.4 mg/l	7.2 mg/l
(g)	COD	:	4 - 15 mg/l	9 mg/l
(h)	NO_3-N	:	0.10 - 1.20 mg/l	0.89 mg/l
	NO_2-N	:	0.001 - 0.04 mg/l	0.021 mg/l
	K - N	:	1.05 - 2.70 mg/l	2.20 mg/l
	T - N	:	2.260 - 3.577 mg/l	3.088 mg/l
(i)	PO_4-P	:	0.04 - 0.13 mg/l	0.10 mg/l

2.1.2 Ecology

According to the literatures made so far available, the list of the terrestrial animals and the aquatic animals are as given in Tables G.2.3 and G.2.4. Terrestrial animals include eight species of mammals, ten species of birds, three species of reptiles, and two species of amphibians. Cheetah and Leopard, which are prohibited of trading by the Washington Convention, are reported to live within the Malewa river basin. In the proposed reservoir area, Rainbow Trout, Barbus, and Crayfish inhabit. There has been no commercial fishery in the river. The list of Phytoplankton and Zooplankton are shown in Tables G.2.5 and G.2.6.

2.1.3 Land and River Uses

The proposed reservoir extends over 3.85 sq.km below the dam crest level of El. 2,154 m. Majority of the area is classified into bushland. Most of the area is grazing land for cattle and 13.1 ha of the land are used for cultivation of maize as shown in Fig.G.2.9. Five households or approximately 30 peoples are living below El. 2,154 m.

Along the Malewa River between the proposed damsite and Lake Naivasha and the Turasha River between the intake and the confluence of the Malewa River, there are a number of water right as under-listed.

Categories of Water Rights	Malewa River				Turasha River			
	Low Flow Season		Flood Season		Low Flow Season		Flood Season	
	Nos.	Discharge (cu.m/s)	Nos.	Discharge (cu.m/s)	Nos.	Discharge (cu.m/s)	Nos.	Discharge (cu.m/s)
Domestic	16	0.007	-	-	-	-	-	-
Public	2	0.030	-	-	4	0.003	-	-
Minor irrigation	-	-	3	0.001	-	-	-	-
Industrial	-	-	1	0.028	-	-	-	
Power	-	-	1	0.008	-	-	-	-
General irrigation	-	-	8	0.068	-	-	2	0.010
Others	-	-	1	0.007	-	-	-	-
Total	18	0.037	14	0.112	4	0.003	2	0.010

2.2 Lake Naivasha

2.2.1 Lake Level Fluctuation

The lake level has been recorded by MOWD at a gauge station 2GD1, in the Lake Naivasha Hotel, for the period from 1933 to 1985. The recording at this station has unfortunately been abandoned since 1986. During the Phase 3 Study, the Survey of Kenya checked the altitude of the zero point of the staff gauge of 2GD1 and found that it had been set 3.82 m higher than the correct one. Therefore the former water level record is corrected by deducting 3.82 m. The Study Team also obtained the water level records having been continuously monitored by the Elsamere Conservation Center since 1950s up to date. The recorded lake level is given in Fig. G.2.10.

As shown in Fig. G.2.10, there has been a clear hydrologic cycle in the lake. A long spell of dry period lasted during the period from 1945 to 1957, keeping the lake level constantly below El. 1,882 m with the lowest level at El. 1,880.04 m in April, 1954. On the other hand, during the remaining periods, the lake was blessed with relatively abundant inflow and rainfall, though there were sporadically dry years. The recorded highest lake level was El. 1,886.09 m in January, 1965. In 1988, the most severe drought year in the last 25 years, the lake level descended to El. 1,882.0 m. The water level was surveyed at El. 1,884.63 on July 4, 1990.

2.2.2 Lake Water Quality

As the same as the Malewa River, the water quality analysis was conducted in both the Phase 2 and Phase 3 Studies. The water quality is, however, reported here in based on the results of the Phase 3 Study.

(1) Water quality analysis

During the Phase 3 Study, the water was sampled for a three-month period from May to July, 1990 at 15 points, evenly distributed over the lake surface area as shown in Fig. G.2.11, and further two different layers in a vertical direction : photic zone and aphotic zone. The water samples have been analyzed for the same 11 items as the case of the Malewa River.

(2) Present condition of lake water

The results of the water quality analysis is shown in Tables G.2.7 to G.2.12. and the horizontal distribution of analyzed value is shown in Figs. G.2.12 to G.2.25. The results are summarized below. The historical records of pH in relation to the lake level is shown in Fig.G.2.26.

Test items		Photic zone		Ahotic zone	
		Value Observed	Average	Value Observed	Average
(a) Color of water		Brown color water, color No. 15 to 17			
(b) Transparency	(m)	0.7 - 1.0			
(c) Temperature	(^oC)	20.1 - 21.2	20.7	19.8 - 20.7	20.3
(d) pH		8.31 - 9.03	8.68	8.41 - 9.04	8.67
(e) Conductivity	(μs/cm)	250 - 300	275	270 - 300	278
(f) SS	(mg/l)	10 - 15	13	10 - 15	13
(g) DO	(mg/l)	7.4 - 11.1	8.3	6.6 - 8.8	7.8
(h) COD	(mg/l)	29 - 61	39	32 - 55	39
(i) NO_3-N	(mg/l0)	0.50 - 0.90	0.89	0.50 - 1.10	0.80
NO_2-N	(mg/l0)	0.009 - 0.015	0.011	0.010 - 0.015	0.011
(j) PO_4-P	(mg/l0)	0.02 - 0.10	0.05	0.001 - 0.08	0.05

The quality of the lake water is as summarized below :

- High pH value of 9.04 was measured at the northeast part of the lake, where a lot of submerged plant are growing. It is presumed that photosynthesis by these plants increases the pH and DOvalues. DO value is high where pH is high.

- The lake water shows higher pH value and conductivity than that of the Malewa River.

- The lake water of Lake Oloidien is characterized by a high salinity. Its water quality and comparison to the main lake are given below :

Items		Value	Comparison to main lake
pH	:	9.64	
Conductivity	:	1,310 mg/l	more than 4 times
SS	:	43 mg/l	more than 2 times
COD	:	123 mg/l	more than 3 times
PO_4-P	:	0.78 mg/l	more than 15 times

2.2.3 Ecology

(1) General

The Study Team has conducted a field reconnaissance around the lake and investigated the ecosystem on a boat in the lake. Phytoplankton has been sampled from photic and aphotic zone of the lake by a water sampler. Zooplankton has been also sampled by a plankton net. These samples has been examined to grasp the sort and quantity of phytoplankton and zooplankton by using a microscope as the home office work in Japan.

The Study Team has collected data and information on the ecosystem in the lake, of which list is shown in Tables G.1.1. The vegetation map is shown in Fig. G.2.27.

(2) Aquatic plants (Macrophyte)

The aquatic plant in the lake is categorized into such three kinds as emerged, floating leaved, and submerged as shown in Fig.G.2.28. Although 9 species of the aquatic plants has been confirmed during the field investigation, there may be more species of aquatic plants. It has been reported that changes of the aquatic plants had taken place artificially or naturally.

Among the aquatic plants, Salvinia Molesta, and Papyrus are at present notable species from the environmental view point.

Category of aquatic plant	Scientific name	Common name
Emerged plant	Cyperus papyrus Persicaria sp. Cyperaceae sp.	Papyrus - -
Floating leaved plant	Salvinia Molesta Nymphaea.sp. Eichornia crassipes	Floating fem Water lily Water hyacinth
Submerged plant	Najas sp. Potamogeton Pectimatus Potamogeton sp.	Holly-leaved naiad Fennel-leaved pondweed -

It has been reported that changes of the aquatic plants had taken place artificially or naturally as described below.

- " Normal phase , 1930-1975 " Water lilies and submerged plants were dominant in the shallow water zone.

- " Reduced phase, 1975-1983 " Reduction in abundance of floating-leaved plants was noted in parts of the lake, and an increase in mobile mats of papyrus and raft of Salvinia. With introduction of both craytish and caypus all submerged and floating-leaved native plants were absent from the lake.

- " Recovery phase, 1985-1988 " First submerged, then floating-leaved plants and finally papyrus swamp returned to most area.

The vegetation changes in the last three decades since 1960 are summarized below.

Period (year) :	Vegetation changes
1961	: Salvinia was introduced
late 1960s	: Salvinia spread on the shore some 3 sq.km
1974	: Water lily disappeared in eastern part of the shore
1981	: Mobile mats of papyrus and rafts of Salvinia expanded to 15 sq.km
1982-1983	: No submerged or floating-leaved aquatic vegetation was found Floating vegetation was dominated by Salvinia
1984	: Papyrus mat was cleared from 15 to 2 sq.km for agriculture
1987	: Submerged, floating-leaved plants and Papyrus swamp were recovering

Among the aquatic plants, Salvinia molesta, Papyrus , and water lilies are at present notable species from the environmental view point.

(a) Salvinia molesta

Salvinia molesta is one of the tropical fern and floating leaved plant, refer to Fig.G.2.29. Although one piece of Salvinia molesta is more or less 10 cm long but increases explosively. It can occupy the surface of calm nutrent-rich water quickly. The Salvinia mat is easily movable by a wind.

At present, Salvinia Molesta are mainly spreading over approximately 15 sq. km over the northern side of the lake. There are several other fringing and floating swamps as shown in Fig.G.2.30. By forming the surface mat, it brings the following impacts on lake environment.

- Invading into and clogging intake facilities,
- Obstructing submerged plants growth owing to shading effect
- Increase in sedimentation of organic matter, and
- Reduction of oxygen concentration beneath mat.
- Impeding navigation,

Although much research works have been done so far, a causal relation between Salvinia and water quality has not cleared yet. Some studies suggests that the optimum conditions for Salvinia mats may be found where slightly moving water is transporting nutrient to the submerged leaves. The river outlets into the lake provide such an environment.

In order to prevent increase of Salvinia mats the following countermeasures are being considered by the Human Settlements Secretariat.

- Chemical control method by using herbicide
- Mechanical removal by machines
- Biological control by releasing Oyrtobagorou Singularies, enemy of Salvinia

(b) Papyrus

Papyrus is a dominant species of emerged plants and grows on shallows less than 1.5 m deep. Before 1983 Papyrus has fringed the lake shore extended to some 12 sq.km. In 1983 when the lake level declined, the large area having been occupied by Papyrus has reclaimed for agriculture. At present Papyrus area still grows at the mouths of the Gilgil and Malewa rivers on the eastern and northern part of the lake shore, where it trap floating matter contained in the river water.

(3) Plankton

The lists of species of Plankton observed are shown in Table G.2.13 and G.2.14. Total numbers of Phytoplankton cell are observed ranging from 6,300 to 15,000 / ml. Dominant species are Microcystics aeruginosa and Synedra sp.A. as shown in Fig.G.2.31. Aphanocapusa sp.A and Aphanocapusa sp.B, and Cylindrospermopsis raciborskii are also founded. As for Zooplankton, the total numbers of cell are in the range of 270 - 285 / litter. The dominant species are Brachiflorus, Filinia sp., and Diaphanosoma sp. Such species in general is bound in the eutrophic water.

(4) Aquatic animals

In Lake Naivasha, sports-fishing started from late 1920s and Tilapia (O.S. Niger) and Black Bass (M.S. Lacpecle) were initially introduced in 1925 and 1927 respectively. Before 1920s there were only a single specy of fish in the lake, an endemic zoo planktivorous small-tooth carp (Aplocheilichthyes antinorii). But now this fish died out.

In 1959 commercial fishing was opened. After that, many kind of fishers were repeatedly introduced for many purposes. But some of them disappeared now. Such introduction history is shown in Table G.2.15. At present Tilapia, Black-Bass, Crayfish are important for commercial fishing, and are most common in the lake. These fishes are strong against salinity and water pollution.

The principal kind of aquatic animal in Lake Naivasha is as follows:

(a) Tilapia

There are 2 species of Tilapia in the lake, Tilapia zillii and Oreochromis leucostictus. Tilapia is omnivorous, so feed on littoral vegetation and plankton.

(b) Black Bass

Black bass is important, not only for commercial fishing but also for sport fishing. Black-Bass is a predator, nowadays probably feeds on crayfish.

(c) Crayfish

Crayfish is also strong against water pollution and salinity, and eats aquatic plants and animal dead baby.

(5) Terrestrial animals

There are enormous kinds and numbers of birds. It is reported that the introduction of fish let to a dramatic increase in the numbers of fish-eating birds, such as fish agles, pelicans, cormorants and herons. And also it has been reported that numbers of the birds had fluctuated depending on mode of life of aquatic plants. Various kinds of mammals inhabit on bushland around the lake. Only Hippopotamus lives in the lake.

2.2.4 Groundwater Survey

The groundwater survey has been carried out aiming to grasp a relation between the lake level and the groundwater table during the period from May to July, 1990. The survey area is limited to the surroundings of Lake Naivasha, based on the Borehole Record the Location Map of the existing boreholes furnished by the MOWD.

(1) Hydrogeology

Alluvial plain is found on the north of the lake and very gentle piedmont slope of the Longonot mountains is on the south. On the east of the lake, comparatively steep slope of the edge of the Kinangop plateau is found and those of the Eburru mountains are on the west.

The terrain of the survey area is mainly composed of a series of tertiary volcanic and pyroclastic rocks interbeded with lake sediments, quaternary lake sediments, and a series of quaternary volcanic and pyroclastic rocks as shown in Figs.G.2.32 and G.2.33.

The series of tertiary volcanic and pyroclastic rocks is distributed from the northeast to the east to form the Kinangop plateau. The quaternary lake sediments, which are benthonic sediments of old Lake Naivasha, are distributed below El. 2,000 m with a thickness less than 30 m around the lake. The series of quaternary volcanic and pyroclastic rocks are distributed in the remaining area to form the Eburru and Longonot mountains. Alluvium overlays only the quaternary lake sediments being distributed over the north of the lake.

Since the alluvium in the area is distributed only in the north of the area and composed of mainly silt and clay less than 10 m in thickness, there is no very thick and extensive aquifer that can be found generally in alluvium being composed of sand or gravel. Groundwater in this area shows both of "Stratum water" and "Fissure water". The former is in the porous zone like coarse-grained sand of lake sediments or scoria of pyroclastic rocks. The latter is in fissured zone of volcanic rocks. Faces of the lake sediments or the volcanic/pyroclastic rocks are generally variable both horizontally and vertically, therefore many aquifers of small magnitude seem to exist in the area, refer to Figs.G.2.34 to G.2.36.

(2) Existing boreholes

Thirty one boreholes (22.6%) out of 137 existing boreholes are working, 37 boreholes (27.0%) are not working including 17 abandoned boreholes. 69 boreholes (50.4%) are unknown whether they are working or not. Most of all the working boreholes are used for irrigation. Although 10 farms out of 47 farms depends on borehole only for irrigation supply, other boreholes are used as supplement to the other main water source such as direct lake water pumping.

There are 137 boreholes in the surroundings of Lake Naivasha as shown in Fig. G.2.37. The information of the boreholes is listed in Tables G.2.16 to G.2.20. The existing borehole area is divided into six types in due consideration of regional topography, i.e. NP (North Plain), SP (South Plain), EL (East Plateau), WM (West Piedomont), EM (East Piedomont) and SM (South Piedomont). The characteristics of the boreholes in each type are shown in Tables G.2.21 and G.2.22.

There are some boreholes encountered saline water problem in the "NP" area especially on the south of the railway and in the "SM" area.

(3) Preliminary examination on lake level - groundwater table

Since geological log with sufficient accuracy has not been available, distribution and structure of each rock faces are not made clear. Judging from various surrounding geologic conditions, the groundwater seems to exist in many small magnitude aquifers distributed over different horizons as "Stratum water" or "Fissure water". Therefore it is impossible to prepare a groundwater contour map in the survey area.

There are many boreholes in which water levels are lower than or the same as the lake level. This, however, does not always suggest that the lake recharges the groundwater. If the lake always recharges groundwater, both of recharge and its reverse could be observed in two boreholes located closely each other. However it has been found out actually in the field that the water level of one borehole is higher than the lake level and that of the other is lower than the lake level.

Provided that aquifer exists on the bottom of the lake, rest level and struck level of all boreholes would be almost the same elevation. This, however, also contradicts with the actual record. The rest levels appears higher than the struck levels in many boreholes located in the "NP" or "SP" areas. It indicates that the groundwater around the "NP" or "SP" is under the conditions of confined water with high pressure. Mechanism of such high pressure is deemed to attribute to connection of aquifer and the lake bottom with high angle or by aquifer with steep dip. Both of the mechanism mentioned above are therefore not applicable in the surveyed area. Since the rest levels are nearly equal to the lake level, there may exist seepage flow of the lake water to the boreholes through permeable weathered zone because of imperfect seal. This concept is considered to be more realistic than the other concept of existence of the confined water with high pressure.

Furthermore, water levels in most boreholes, except boreholes in the "NP" or "SP" areas, are almost the same lake level with a difference within 10 m. As for these boreholes, the lake water also seems to seep into the boreholes considering the location of the boreholes in a limited area, of which location is shown in Fig.G.2.37. If the lake water seeped into the boreholes through the weathered zone, water level in the boreholes would lower following the decline of the lake level. If borehole pumps are set low enough, no problems will occur.

2.2.5 Land and Lake Water Use

All the land around the lake is privately owned. There are ranches, horticulture land, hotels, camp sites, and marinas, and a hostel. A circulating road with a total length of 75 km has been constructed along the lake shore.

The area around lake Naivasha is not only a large-scale ranching area but also a large-scale exportable crop production center in the Nakuru District. In particular, the horticulture crops export are being highlighted as one of the major foreign currency earning commodities. Owners of farms have formed an association named " Riparian Owners Association.'

Two luxury hotels are operated on the eastern lake shore as a leisure resort area on commercial basis. A yacht club has maintained a club house on the Crescent Island since 1931. There are two self camp sites and a hostel. The Elsamere Conservation Center contains a small museum and offers residential facilities for conservation researchers.

The lake water is being used for various purposes and 80 water rights have been registered by the WAB so far as summarized below.

Categories of Water Right	Low Flow Season		Flood Flow Season	
	Nos.	Discharge (cu.m/sec)	Nos.	Discharge (cu.m/sec)
General	40	0.039	-	-
Public	1	0.003	-	-
Small irrigation	-	-	16	0.002
Commercial	1	0.001	-	-
Power generation	-	-	1	0.008
Large irrigation	-	-	62	0.819
Others	-	-	1	0.030
Total	42	0.043	80	0.858

2.2.6 Agriculture

(1) General

Although there is a little discrepancy with the WAB's data, there are a vast irrigation land of 7,895 ha around Lake Naivasha, according to the Provincial Irrigation Unit. The irrigated areas by the water sources are as follows.

Categories of Water Abstraction	Nos. of farms	Total area (Acres)
Lake water only (direct or/via canal)	53	2,426
Open channel only	13	630
Bore hole only	8	1,888
River only	6	1,381
Lake & borehole	5	815
River Borehole	2	725
Open well & boreholes	1	30
Total	88	7,895

A door to door survey has been carried out to grasp actually the existing irrigation and agricultural situation in June 1990. The survey was completed for 47 farms, covering as large as 45,219 acres.

The location of farms registered were confirmed based on the Land Registration Map and the Water Rights Registration. The door to door survey has been conducted for one month since June 4, 1990. The survey was completed for 47 farms covering approximately 6,900 acres, which corresponding to more than 80% of the entire cultivated area with irrigation.

The questionnaire sheet included a number of items such as present agricultural land use, land holding, farm size, kind of planted crop, cultivated area, cropping pattern, present crop yield level, irrigated crops, source of irrigation water, irrigation method, relation between water quality and crop production, and problems encountered in drought years.

(2) Physical conditions

(a) Climate

Generally hot and dry climate prevails during the period from December to March, while rainy and relatively cold climate are predominant during the period from April to June (major wet season) and from October to November (minor wet season). The rainfall pattern has fluctuated year by year, which have greatly affected crop yield for the individual small farms.

The air temperature has not varied very much throughout a year. The maximum monthly mean temperature and the minimum one are 28.3 ^{o}C and 6.8 ^{o}C in February. Air temperature is very suitable for exportable crop productions such as cut-flowers, strawberry, and french beans.

(b) Soil

The soils around Lake Naivasha are classified into six categories as follows :

Classification	Texture	Organic matter content of top soil	Fertility
- Phaeozems	clay	high	high
- Cambisols	variable	variable	moderate
- Xerosols	clay	variable	variable
- Solonetz	clay	variable	low
- Regosols	clay	moderate to high	variable
- Lithosols	rock	variable	variable

The Phaeozems and Cambisols extend over the middle-west part of the lake. These soils are developed on sediments mainly from volcanic ahses. Xerosols, Solonetz, Regosols and Lithosols are developed over around the lake except the middle-west part of the lake.

(c) Agricultural land use

Out of the total land area of 45,219 acres, 7,431 acres are cultivated, of which 6,908 acres are irrigated. The irrigated lands are classified into fodder crops land of 3,543 acres and horticulture crops land of 3,365 acres as shown below.

The distribution of acreages by land use and location of the lake is summarized as follows :

Unit : acres

Land use	east	west	south	north	Total
Cropped with irrigation	656	432	1,202	1,075	3,365
Cropped without irrigation	285	8	0	230	523
Meadow with irrigation	362	825	87	2,269	3,543
Grass land	1,820	20,809	9,969	5,190	37,788
Total	3,123	22,074	11,258	8,764	45,219

According to the Farm Management Handbook of Kenya, Vol.II, Part B, the riparian land totalling 45,219 acres is included in the entire upper mid-land ranching zone (UM-6) and a part of the livestock and sorghum zone (UM-5). The area of UM-6 is about 23,500 acres (9,400 ha) and that of UM-5 surrounding UM-6 is about 75,200 acres (30,100 ha).

(3) Farming System

The land holding size by each farm ranges from 10 acres to 13,500 acres. The number of farms by holding size and location of the lake is as shown Table G.2.23. The cultivated area by kinds of crops are summarized in Table G.2.24. Majority of the area is cultivated for meadow. The horticulture crops includes vegetables, ornamental flowers, and fruits. The number of farms by type of crops are summarized below, and irrigated area by crop is shown in Table G.2.25 to G.2.29.

Type of crops	Number of farms	Major crops
Vegetable	12	Cabbages, Onions, French beans, Carrots, Tomatoes, Potatoes, Asparagus
Pasture	15	Lucern, Maize, Sorghum Rhodes grass and Nappir
Vegetable & Pasture	10	
Cut flowers	7	Astrcemerias, Carnation, Chrysanthemums, Ornithegdum, Tuberesen
Flower bulb	1	
Fruit	2	Strawberry, Apple, Orange
Total	47	

Most of vegetables are locally marketed. French beans and asparagus are mainly exported. Strawberries are grown mainly for European markets.

The cut flowers production is highlighted in this area. Most of flower growers gather in the south side of the lake. Cut flowers are planted throughout a year with a drip irrigation systems. The crop intensity is 200 percent on average. Some 30 million blooms a year are exported to European countries.

Generally there are two crop seasons for such vegetables as french beans, cabbages, carrot, leeks as shown in Figs.G.2.38 and G.2.39. The first crop season is a period from June to October and second one is from November to March. Land preparation and sowing are usually made at the end of the long rainy season and the short rainy season.

Meadow and pasture are planted throughout a year. Their harvests are usually gathered three times in a year. When orange, apples, grapes are growing, vegetable fruits, strawberry cultivation are prevailing.
Although the yield level of vegetables are not so high, qualities of vegetables are very high ; especially french beans, cabbage, and carrot.

(4) Source of irrigation supply

As a result of the door-to-door survey, the followings are noted.

- The farms around Lake Oloidien, a saline lake, use the fresh water from boreholes.

- Some farmers have reported that floating plants such as Salvinia Molesta and Water Hyacinth have stagnated for some period in front of their intake pumps or in the canals, resulting in clogging of the pumps.

- Some large farms have provided a small pond for water storage from where the water is boosted to the terminal point. Therefore their water abstraction are not affected by fluctuation of the lake level.

- Some flower growers are using the lake water after neutralizing pH value even at present to apply Gypsum and acidic fertilizers such as calcium ammonium nitrate, ammonium sulfate nitrate.

- According to the survey result, 32 farms out of 47 ones have reported that they have shifted pumps or extended canals by some tens meters to cope with set back of the shoreline in the 1988 drought period. A few farms deepened their boreholes by approximately 2 meters.

(5) Irrigation method

The sprinkler irrigation is the most popular method. However, a number of farmer have come to realize that much water is wasted by using sprinklers and therefore many farmers are using long hoselines to supply water to the cut flowers and other crops. Many farms growing flower and strawberries are supplying water by drip irrigation.

2.2.7 Fishery

A commercial fishery was initially commenced in the year of 1959. Major fishing target are Black bass, Tilapia, and crayfish. The Black bass was firstly introduced in 1927, Tilapia in 1956 and Crayfish in 1970. According to 1987 report, 83 boats were licensed but fifty ones were actually operated. Three of these boats were equipped with engines while the rest were of sail and oar type.

The annual fish catch has fluctuated from 692 tons at maximum in 1983 to 245 tons at minimum in 1985 as shown in Table G.2.30. In 1983, 78 % of the total catch weight was Tilapia, 17 % crayfish fish, and the rest Black bass. The market value was KShs 9.6 million in 1983, 64 % of the total value was Tilapia, 30 % Crayfish fish, and the rest Black bass.

2.3 Lake Nakuru

2.3.1 Lake Nakuru National Park

The Lake Nakuru is included in the Lake Nakuru National Park established in 1961, which has been a bird sanctuary of international reputation. The park was expanded from its initial boundaries that included the lake itself and its immediate shoreline to include the surrounding farms that formed a belt round the park for buffering the lake environment from the neighboring urban settlement of Nakuru Municipality, agricultural farms, and industries.

The present landscape of the park is characterized by hills, ridges, cliffs, rocky outcrops and lake basin. On the southern rim of the lake, the river mouth of the Makalia and Enderit rivers forms a flat grass land, some 60 sq.km, which is the major feeding ground of the wildlifes. The bird and wild animals life forms an unique spectacular display that attracts thousands of both local and foreign tourists into the par. There are two hotels in the park. The visitors had increased recently from 98,000 in 1983 to 129,000 in 1987 at a rate of 7.1 % per annum. The revenue collected in 1987 amounted some K.Shs 7.3 million. The rapid increase in visitors and revenues from them may be reflected the recent trend of increase in foreign tourists in Kenya.

2.3.2 Ecology

The Study Team has conducted a field reconnaissance on the ecosystem in the lake. Phytoplankton and Zooplankton has been also sampled in the same way as Lake Naivasha. These samples have been examined to identify their sorts by using a microscope as the home office work in Japan. The list of the aquatic flora, aquatic fauna, and wild animals has been prepared as shown in Tables G.2.3 and G.2.4.

Lake Nakuru is highly saline and eutrophic, owing to the vigorous growth of a blue-green algae named Spirulina, which supports a large number of algae-grazing Lesser Flamingo. There is also a lot of fish, Tilapia, which support a lot of White Pelicans.

The land is composed of bushlands in the east and west, grasslands and woodlands in the south and north, and other such types as forest, sedge marshes, swamp vegetation, and cliff vegetation. It exhibits a wide ecological diversity with characteristic of habitats that stretch from the lake through the shoreline and up to the escarpments and ridges. Especially the southern part of the lake shore is glass land and is the major feeding ground of the wildlifes.

(1) Aquatic flora

There are no tall aquatic flora growing in the lake. High saline and alkaline water is unsuitable for their growth. There is, however, an enormous concentration of blue-green algae, Spirulina Platensis, that forms the basis of all the food chains in the lake as shown in Fig.G.2.40. Spirulina platensis is a small filamentous alga living in alkaline and saline water, and is so prolific that the water is colored bright green.

It has been noted by many literatures that there is a relationship between chemistry, Spirulina, and Flamingoes, although it has not been clearly identified yet so far. Some literatures have reported some findings as below.

- Spirulina cannot survive in fresh water nor too extremely saline one.

- Spirulina is found in water ranging from 8.5 to 270 g per litter of total dissolved solids with an abundance of nutrients in circulation as well as a moderately high temperature.
- As Spirulina densities dropped, mean number of flamingos were correspondingly and drastically reduced as shown in Fig.G.2.41.

- At such times Spirulina densities dropped, diatoms and other species of blue-green algae (e.g. Anabaenopsis arnoldii) became the main primary producers. Tilapia almost certainly dominated primary consumers.

- Vigorous growth of several common Spirulina species occurs in water of high alkalinity and pH (over 7.5), (Beadle,1981). Although the optimum for growth was recorded as 20-60 mill percent, Spirulina have been found from high saline water up to 270 mill percent.

(2) Plankton

The list of plankton observed is shown in Tables G.2.31 and G.2.32. Total numbers of Phytoplankton cell are observed in a range of 147,000 to 208,000 / ml. Dominant species is Cryptomonadales, which reveals that the lake water is under eutrophic state.

(3) Aquatic fauna

There is a single species of small fish some 10 cm long, Tilapia Graham (Alcalicus graphami), which was introduced from Lake Magadi into the lake in 1961 as a mosquito control measure . Tilapia can tolerate a wide range of temperature and salinity; it is found in water with salinity up to about 40 mil percent, pH 10.5 and temperature 40°C.

(4) Birds

There are more than 30 species of bird found in the park. The most notable ones are Lesser Flamingo and White Pelican.

(a) Lesser Flamingo

Lesser Flamingo is a deep rose-pink small flamingo with a height of about one meter. This year very few Lesser Flamingoes are observed in Lake Nakuru but many in Lake Elmenteita. Lesser Flamingo has the following characteristics in its habits:

- Inhabitant in typically large alkaline or saline lakes and cannot survive long in fresh water.

- Sudden movement in enormous numbers to other lakes after resting for some period of time due to such causes as breeding, and shortage of spirulina density. Abundant available food supply, however, does not necessary attract Flamingoes.

- Feeding by a special tongue to extract Spirulina in size ranging 40-200 μm. Food requirement of individuals some 60 g in dry weight per day. Therefore a high density of Spirulina is indispensable for their habitat.

- Breeding in Lake Natron in North Tanzania. No breeding in Lake Nakuru has been recorded.

(b) White Pelican

With introduction of Tilapia in the lake, the obvious effect on the ecology of the lake has been the appearance of more than fifty species of fish - feeding birds. Among the birds, the Great White Pelican is the main predator. The Pelicans (Pelecanus anocrotalus) consume large quantities of fish (7.5 metric tons wet weight per day) and leave behind very little amount, if any to prey the other birds that include: the white-necked cormorants (Phalacrocorax carbo) and a variety of herons, egrets, terns, gulls, grebes, marabou Stork, African Fish Eagle and Kingfisher.

(5) Mammals

Large aquatic animals in Lake Nakuru include the Hippopotamus (Hippopotamus amphibus) and the clawless Otters (Aonyx Capensis). Over 70% of the Hippopotamus live in the pools of the northern shore rushy swamps where water is fresher due to the springs. The rushes give cover and shade of the Kikuyu grass (Pennisetum clandestinum) under Acacia trees which is preferred food for the Hippopotamus.

2.3.3 Lake Level Fluctuation

The lake level have been recorded by MOWD at the gauging station 2FC4 for a 34-year period from 1951 to 1984. The recording has unfortunately been interrupted since 1984. During the Phase III Study period, the altitude of the zero point of the staff gauge has been rectified; it was actually 2.7 m higher than the national datum level. The lake level records corrected are given in Fig. G.2.10. The lake level was surveyed at El. 1,758.5 m in July, 1990.

The lake level fluctuation shows almost the same tendency as the Lake Naivasha. During the recorded period, the highest level was recorded at El. 1,763.3 m in August, 1979, while it has been reported that the Lake Nakuru dried up in 1939, 1947, 1955, 1956 and 1961. In dry seasons before 1953, it has been reported that the lake had sometimes no water and the floor had been subjected to wind erosion resulting in clouds of alkaline dust being blown over the surrounding area. Most recently in 1987, the lake was almost dry leaving water on a very limited area.

2.3.4 Lake Water Quality

(1) Water quality analysis

The water sampling was carried out by the same manner as Lake Naivasha. 11 sampling points were distributed evenly over the lake area and the water were sampled from both the photic and aphotic zone as shown in Fig.2.42. The water samples have been analyzed for the same 11 items as the case of the Malewa River.

(2) Present condition of lake water

The results of the water quality analysis is shown in Tables. G.2.33 to G.2.37. and the horizontal distribution of analyzed value is shown in Figs. G.2.43 to G.2.53. The results are summarized below, of which figures in parenthesis show the averaged value:

< Lake Nakuru and River inflow>

Test items		:	Photic zone		:	Aphotic zone	
(a) Color of water		:	Dark brown color, color No. 18 to 21 (21)				
(b) Transparency (m)		:	0.2 - 0.5 (0.3)				
(c) Temperature (^oC)		:	24.2 - 26.8	(25.7)	:	20.5 - 25.1	(21.7)
(d) pH		:	10.34 - 10.62	(10.42)	:	10.36 - 10.72	(10.45)
(e) Conductivity (μs/cm)		:	16,960-17,760	(17,564)	:	16,900-17,760	(17,516)
(f) SS	(mg/l)	:	13 - 69	(24)	:	11 - 47	(19)
(g) DO	(mg/l)	:	6.3 - 13.2	(9.7)	:	1.8 - 13.7	(5.5)
(h) COD	(mg/l)	:	179 - 197	(191)	:	185 - 197	(191)
(i) NO_3-N	(mg/l)	:	15.5 - 25.0	(18.5)	:	14.6 - 18.9	(17.0)
NO_2-N	(mg/l)	:	0.019 - 0.044	(0.026)	:	0.017 - 0.040	(0.024)
(j) PO_4-P	(mg/l)	:	1.28 - 1.82	(1.55)	:	1.00 - 2.10	(1.68)

Note : Figures in parenthesis show the average value.

The lake water is characterized as follows :

- The lake water is extremely high alkaline having pH value more than 10.3 and the conductivity more than 17,000 μs/cm.

- The lake water is excessively in eutrophication judging from high concentration of N and P values.

- Low DO value was recorded in the aphotic zone. Especially, on the northern part of the lake (sampling point. 1), very low DO value is detected (shown in Fig. G.2.46 and G.2.51) probably due to a large amount of organic sediment .

Organic sediment consumes DO, and "sampling point. 1" is closely located to outlets of two sewage treatment plants.

- High DO value in the upper zone means it is saturated by photosynthesis by Plankton.

2.3.5 Sewage Inflow

(1) Sewage treatment works

The public sanitary service is provided within a very confined area of the Nakuru municipality. There are two sewage treatment works, named the Town treatment work and the Njoro one, with a total treatment capacity of 6,800 cu.m/day, while the actual quantity of sewage inflow has amounted to 8,820 cu.m/day. All the outflow from the treatment works is directly discharged into Lake Nakuru.

The sewage disposal in other area mostly depends on the pit latrine, septic tank, cesspool etc. There are three types of effluents discharging to Lake Nakuru.

(a) Storm water drains

This water goes directly to the lake and the source of water is from drains, roofs, roads and other outfalls from anywhere else.

(b) Sewage domestic effluents

The source of this flow is mainly from domestic discharge.

(c) Industrial effluents

Nakuru Municipality has a considerable number of industries. There are several industries manufacturing or dealing in a variety of chemical compounds ranging from agricultural fertilizers to highly toxic pesticides, detergents, oil and heavy metals. The effluents from these industries also find their way into Lake Nakuru through the sewage discharge system.

Since Lake Nakuru has no outlet, the end products of these chemicals from industries, water storm drains and domestic sewage effluents are finally drained into the Lake where they have been reported to cause pollution hazards. Certain pollutants, particularly organochlorines and heavy metals have a long-lasting toxic effect and as they continue increasing their concentrations in the Lake, they are predicted to have detrimental effects to this ecosystem in near future.

(2) Water sampling and water quality analysis

Sewage water in raw and after treatment has been sampled from the Town and Njoro treatment works. The water samples have been analyzed for the same 11 items as the case of the Malewa River. The results of the water quality analysis is shown as follows:

Test items			Town Treatment Works		Njoro Treatment Works	
			Before treatment	After treatment	Before treatment	After treatment
(a) pH		:	7.5	7.6	7.4	8.7
(b) Conductivity	(μs/cm)	:	990	960	1,060	1,250
(c) Turbidity	(mg/l)	:	165	51	230	19
(d) SS	(mg/l)	:	580	136	483	36
(e) DO	(mg/l)	:	0.8	0.8	1.2	6.9
(f) COD	(mg/l)	:	364	201	128	196
(g) T-N	(mg/l)	:	107	79	117	24
(h) K-N	(mg/l)	:	74	59	76	20
(i) NO_3-N	(mg/l)	:	33	20	40	4
NO_2-N	(mg/l)	:	0.3	0.1	0.3	0.02
(j) PO_4-P	(mg/l)	:	36	23	51	36

The followings are noted from the test:

- Such items as pH, conductivity, DO, and COD have showed of increased value after treatment in the Njoro treatment works. It is considered that the treated water is stored in lagoon where are plenty of nutrient salts such as N and P and Phytoplankton, resulting in increasing photosynthesis. The photosynthesis also results in increase in pH and DO.

- According to the laboratory test result of Njoro sewage treatment works, BOD value of sewage decreases by about 90% after treatment.

- The values of COD have been largely exceeding the effluent standards concluded between NMC and MOWD. The effluent standards are presented in Table G.2.39.

In addition to the above, it is to be noted that residues of different heavy metals (Arsenic, Tin, Copper, Zinc, Mercury and Cadmium) have been detected in different tissues of birds (liver and kidneys of Pelicans and Pink Flamingos) as well as in the fish (Tilapia graham) reported by Dejoux in 1981.

III FORECAST ENVIRONMENTAL IMPACT

3.1 Foreseeable Environmental Impacts

The implementation of the Project will create a reservoir on the Malewa River, reduce the inflow into Lake Naivasha, and contrarily augment the sewage effluent from the Nakuru municipality. The reduced inflow and augmented sewage will result in changing the water balance of both lakes. Therefore it is explicit that the Project will impact, more or less, the present natural and social environment. the following impacts have been identified to be foreseeable to occur at a full development stage of the Project, unless adequate countermeasure are taken up.

(1) Creation of proposed Malewa reservoir

- Innuudation of scrub or riverine trees
- Innuudation of cultivated area
- Resettlement of inhabitants
- Eutrophication of proposed reservoir
- Change of ecosystem

(2) Reduction of river flow on lower Malewa River

- Decrease of river runoff
- Difficulty of river water intake for irrigation
- Change of river water quality
- Change of aqua-ecosystem

(3) Change in Lake Naivasha Water Balance

- Decline of lake level
- Isolation of Crescent Island Bay
- Eutrophication of the lake
- Change of lake water quality
- Change of groundwater resources
- Difficulty of lake water intake for irrigation
- Shift of habitat of fishes
- Change of habitat of animal

(4) Change in Lake Nakuru Water Balance

- Rise of lake level
- Submergence of ring road and glass land around lake
- Change of water quality
- Change of eco-system

Among the above, the impacts having been identified to be major one are described hereinafter.

3.2 Proposed Malewa Reservoir Area

(1) Inundation of land and resettlement of inhabitants

The reservoir impounds an area of 3.9 sq.km, of which 13.1 ha is cultivated will be inundated below the dam crest level of El. 2,154 m. Five households needs resettlement.

(2) Eutrophication of reservoir

Water stored in a reservoir tends to be in eutrophic to some extent, mainly depending on the balance of the quantity of nutrient salts, contained in river inflow and outflow release, as well as stagnant time. In an eutrophic reservoir, increase in density of nutrients salts causes increase in the number of aqua flora including phytoplankton , increase of COD, low transparency, and eventually lowering water quality for drinking water.

The water quality of the proposed Malewa reservoir was forecast to by a numerical simulation model. This model is of matter cycle type that indicates quantitative change of six indices such as organic and inorganic nitrogen, organic and inorganic phosphorus, COD, and DO. The reservoir was assumed as a one-box with photic and aphotic layers. Active storage capacity of reservoir is 55.8 million cu.m at the high water level of El. 2,149 m.

Internal process of change among the indices is shown schematically in Fig. G.3.1. The basic equations of the model are shown in Table G.3.1.

It is assumed that the reservoir water quality just after impoundment is the same as the river water quality. The quantities of the inflow and outflow from the reservoir were assumed to be the average values during a 24-year period from 1961 to 1984 based on the result of the reservoir water balance study. The result is summarized as below.

Unit : mg / l

Index			Photic zone		Aphotic zone	
			Present River Quality :	After Impounding	Present River Quality :	After Impounding
(a)	T-P	:	0.126	0.132	0.126	0.125
(b)	I-P	:	0.068	0.012	0.068	0.047
(c)	T-N	:	2.920	3.056	2.920	2.889
(d)	I-N	:	1.390	1.822	1.390	2.001
(e)	COD	:	5.67	15.94	5.67	11.44
(f)	DO	:	7.26	10.24	7.26	1.45

COD value will be increased 16 mg/l, which is twice time as large as the present value of the Malewa river water, refer to Fig.G.3.2. The water quality analysis predicts that the reservoir will be eutrophic. It is also predicted that I-P and T-N values will not increase so much from the present level, which means the magnitude of eutrophication will remain at low level.

The total storage volume of the reservoir (72 million cu.m) is relatively small against the annual mean inflow discharge (100 million cu.m) and the annual mean discharge to be diverted to the Turasha intake (32 million cu.m). Therefore water to be stored in the reservoir is expected not to stagnate for a long period. It is also expected that water release from the reservoir will not cause acceleration of eutrophication of Lake Naivasha.

3.3 Lower Malewa River

If the water supply is made as planned, the Malewa dam will divert the water amounting to 166,000 cu.m/day at a full development stage. The reduction in stream flow occurs accordingly in the reach downstream from the dam, by some 27 % on average at the confluence of the Malewa and Turasha rivers. It is necessary to conserve the existing water right and aqua-eco system, function of river, etc.

3.4 Lake Naivasha

3.4.1 Change in Lake Water Balance

It is explicit that the implementation of the Project primarily reduces the inflow into Lake Naivasha, which subsequently causes to decline the lake level.

The water balance of Lake Naivasha is subjected to the direct precipitation on and evaporation from the lake, inflows into the lake by rivers, abstractions by existing intakes and change in subterranean flow. The lake level virtually fluctuates as a result in change in water volume in the lake. At first a water balance simulation model was constructed, and secondly the change of the lake level has been forecasted by using the model in relation to the quantities of the water supply after construction of the Malewa dam.

A variation in the lake water volume can be expressed by a water balance model having the following equation.

$$Vt + 1 = Vt + Pt + It + Rt - At - Et$$

Where,

Vt + 1	:	water volume in the lake after a time "t"
Vt	:	water volume in the lake at a time "t"
Pt	:	direct precipitation on the lake during a time "t"
It	:	inflows into the lake during a time "t"
Rt	:	change in subterranean flow during a time "t"
At	:	abstractions by existing intakes during a time "t"
Et	:	direct evaporation from the lake during a time "t"

Out of the above factors, it was possible to grasp quantitatively the precipitation, evaporation, lake level fluctuation and inflow into the lake as explained below.

- Precipitation : Rainfall records at RGs. 9036179, 9036214, 9036002, and 9036073

- Evaporation : Pan evaporation at Naivasha Meteorological Station for the period from 1961 to 1989
- Inflow : Runoffs of the Malewa River at 2GB1 for the period from 1931 to 1984 and runoffs of the Gilgil river at 2GA 5 for the period from 1961 to 1987.
- Lake level : Records observed at 2GD1 for the period from 1933 to 1985
- Elevation - volume Curve : As per Fig. G.3.3

Because of the availability of runoff record of the Malewa River, a simulation of the water balance was unfortunately limited to a 24-year period from 1961 to 1984. The simulation model was created on the monthly basis by means of a trial and error method. Such unknown factors as "Rt", "At" and "It" of the ungauged rivers were treated as a "black box" all together.

Figure G.3.4 presents a comparison of the recorded lake level and simulated lake level. A simulation model is judged highly accurate, having a coefficient of correlation of 0.99.

The future change of the lake level has been forecasted by using the model for the varied water supply quantities in order to grasp a sensitivity of the lake water balance.

Case No.	Water supply (cu.m/day)
Without the Project	0 : without supply
1	56,000
2	105,000
3	121,000
4	138,000
5	151,000
6	166,000 : full supply

The water supply quantity by the Stage 1 project (19,000 cu.m/day), the Kipipiri Project (6,100 cu.m/day), and the Ol Kalou Project (16,400 cu.m/day) are considered to be abstracted. The Kipipiri and Ol Kalou Projects are scheduled to be implemented upstream of the proposed Malewa dam site.

The initial lake level was set at El. 1,882.92 m in December, 1960. Since the effect of the withdraw of the stream flow appears for a long period, the water balance calculation was iterated until a new equilibrium balance is gained, assuming that the same hydrologic and climatological conditions during the period from 1961 to 1984 take place during the simulation period. Figure. G.3.5 shows the results of the simulated water balances. It is forecasted that the lake level and surface area declines and reduces respectively as tabulated below.

Items	Without the Project	Case No.					
		1	2	3	4	5	6
Water supply (m^3/day)	0	56,000	105,000	121,000	138,000	151,000	166,000
Rate to 2015 (%)	0	34	63	73	83	91	100
Lake level (El.m)							
Max	1,886.9	1,886.4	1,886.2	1,886.0	1,885.8	1,885.7	1,885.5
Average	1,885.2	1,884.8	1,884.3	1,883.9	1,883.6	1,883.4	1,883.1
Minimum	1,883.2	1,883.0	1,882.5	1,882.0	1,881.5	1,881.0	1,880.0
Fall of lake level (m)							
Highest	0	0.5	0.7	0.9	1.1	1.2	1.4
Average	0	0.4	0.9	1.3	1.6	1.8	2.1
Lowest	0	0.0	0.5	1.0	1.5	2.0	3.0
Lake area (sq.km)							
Highest	297	257	235	226	213	207	198
Average	185	170	156	150	145	143	139
Lowest	138	138	133	129	123	117	101

In addition to the above-mentioned calculation, its sensibility of increase in water supply quantities by the planned Kipipiri and Ol Kalou Projects from the Malewa River has been assessed. In the above Case 3, for example, its incremental rate of 10% or 20 % would incur the decrease of water supply of only 1,700 cu.m/day or 3,300 cu.m/day respectively. Judging from the result, it is concluded that the increase in water supply quantities by the planned Kipipiri and Ol Kalou Projects would not affect the lake level fluctuation.

3.4.2 Isolation of Crescent Island Bay

At the lake level below El.1,881 m, the lake bed between the island and the eastern shore of the lake would be exposed as shown in Fig.G.3.6. There would appear an another small lake in a dry period on the east of the Crescent Island. Otherwise a dredging work will be required in order to avid salifying lake water and to secure water traffic for fishery and tourism.

3.4.3 Change in Water Quality

The change in the lake water quality has been forecast by the same simulation model as adopted to the proposed Malewa reservoir for varied lake levels.

The water quality of the inflow into the lake was assumed to be the same as that of the lower Malewa River The amount of inflow in to the lake was also assumed to be the average value during a 24-year period from 1961 to 1984. The results are summarized below in relation to the lake level.

Lake level	DO (mg/l)		COD (mg/l)		T-N	T-P
(El.m)	Photic zone	Aphotic zone	Photic zone	Aphotic zone	(mg/l)	(mg/l)
1,883.1	9.6	8.3	38.9	38.3	3.33	0.3
1,883.4	9.6	8.1	38.8	38.1	3.34	0.3
1,883.6	9.6	8.0	38.6	37.9	3.34	0.3
1,883.9	9.6	7.8	38.1	37.4	3.35	0.3
1,884.3	9.6	7.7	37.8	37.0	3.35	0.3
1,884.8	9.6	7.2	39.3	38.3	3.40	0.3

The above result shows little change probably due to the fact that the decreased water quantity is quite smaller compared to the lake volume.

The salinity is expressed by electric conductivity. The electric conductivity was measured at 288 μs/cm in July, 1990. However, it is hardly to forecast quantitatively changes in pH and electric conductivity. According to the results of the lake water balance study, the lake level fluctuation with the Project would remain in the same fluctuation range recorded in the past. It is therefore assumed that electric conductivity and pH may be within the same fluctuation range as recorded in the past.

3.4.4 Impact on Ecology

The lake shore will set back some 3 km at maximum in the northeast part of the lake and surface area will reduce to 73 % as shown in Fig.G.3.6. The influence on the ecological environment due to above circumstance is predicted as follows:

- The lake water level is predicted to fall with the commencement of water supply. And it is forecasted that a part of aquatic plants area around shore line will dry out with the set back of the shore line.

- Decrease of the area of aquatic plants will affect on aquatic animals (such as Black-Bass, Tilapia, and Crayfish) inhabiting around there. Whereas, it is assumed that the amount of aquatic animals will decrease.

- The existence of fish-feeding birds (such as fish eagle, pelican cormorant and heron) will depend on the amount on fish. Some of them will leave the lake with the decrease of fish amount. Some of other kinds of birds (including duck and coot) feeding on the aquatic plants are also predicted to leave the lake.

3.4.5 Impact on Groundwater

It is hardly possible to state quantitatively the impact of the Project on the groundwater resources for a moment, since the investigation period was short and available data were limited. However, it is hardly likely that the groundwater resources will be affected seriously as far as the lake level maintains higher than the lowest level reached in 1988. It has been endorsed by such facts that there had been any serious draw down in the groundwater table and change in water quality in the 1988 drought year.

3.4.6 Impact on Agriculture

If the lake level falls extremely to El. 1,880 m, most of the existing pumping facilities eventually will become impossible to be operated properly for a long period, probably resulting in severe damages in horticulture crops and fodder production.

3.4.7 Impact on Fishery

The causal relationship between the water quality, aquatic plant, plankton, and the number of fish in the lake have not been cleared yet. It is explicit, however, that the fish catch area would decrease to a certain extent. Fig. G.3.7 shows the relationship between the lake level and the fish catch records since 1962, which shows such general tendency that the fish catch decreases as the lake level decline.

3.5 Lake Nakuru

3.5.1 Change in Lake Water Balance

With increased potable water supply and expansion of water - borne sanitary services in future, sewage effluent discharging Lake Nakuru naturally augment, which would result in a change of the present water balance and rise of the lake level. Such change will evidently be dominated largely by magnitude of the sewage inflow rate.

The water balance of the Lake Nakuru is principally the same as that of Lake Naivasha. The simulation model was developed also by means of a trial and error method. The hydrological and meteorological data adopted in the analysis are as follows.

- Precipitation	: Nakuru Railway Station from 1956 to 1989
- Evaporation	: Pan evaporation at Nakuru Meteorological Station during the period from 1958 to 1989
- Inflow	: Runoffs of the Njoro River (1959-1985) and Ngosor River (1957-1985)
- Lake level	: Records oserved at 2FC4 from 1951 to 1984
- Elevation - volume - area curve	: As per Fig. G.3.8

Due to the availability of the runoff record of the Njoro River, a simulation of the water balance was attained for a 24-year period from 1959 to 1982 on the monthly basis.

It is presumed that such three ungaged major rivers as the Makalia, Enderit and Lamudiac influence the water balance of the lake. These rivers are draining the same hydrologic region as the Njoro River. In the simulation analysis the monthly fluctuation of runoffs of these rivers are assumed to be proportional to runoff of the Njoro River. Their monthly mean amount was treated as a "black box" and set to minimize discrepancy between the recorded lake level and the simulated one.

Figure G.3.9 presents a comparison of the recorded lake level and simulated lake level. The simulation model is judged highly accurate, having a coefficient of correlation of 0.99.

Attempt was made to measure a sensitivity of the lake water balance against the sewage inflow rate. For this purpose, six sewage inflow rates, including the case assuming without Stage 2 Project, were arbitrarily selected. The augmented sewage inflow will continuously induce rising the lake level until a new water balance between the inflow and the evaporation is created. Thus the water balance calculation was iterated until the new water balance point is gained, assuming that the hydrological and climatological conditions during the period from 1959 to 1982 are repeated. The results of the water balance calculations are given for the respective sewage inflow rate as below and plotted in Fig.G.3.10.

Items	Without Stage 2 project	Case No. 1	2	3	4	5
Sewage inflow (m^3/day)	8,840	17,400	34,700	52,000	69,200	95,000
Rate to 2015 (%)	9	18	36	55	73	100
Lake level (El.m)						
Max	1,760.6	1,761.2	1,762.9	1,765.1	1,767.3	1,771.7
Average	1,758.6	1,759.3	1,761.0	1,763.3	1,765.6	1,770.1
Minimum	1,756.6	1,757.5	1,759.5	1,762.0	1,764.3	1,768.9
Rise of lake level (m)						
Highest	0	0.6	2.9	4.5	6.7	11.1
Average	0	0.7	2.4	4.7	7.0	11.5
Lowest	0	0.9	2.9	5.4	7.7	12.3
Lake area (sq.km)						
Highest	52.0	53.9	58.7	65.4	72.4	90.0
Average	43.7	46.7	53.2	59.9	67.2	81.2
Lowest	26.0	36.9	47.0	56.1	63.0	76.9

The impact on Lake Nakuru seems more serious than those on Lake Naivasha. The water supply to the municipality area increases year after year, and reaches as large as 135,800 cu.m/day in 2015 totaling the existing water demand (6,350 cu.m/day), the water demand by the Stage 1 Project (13,300 cu.m/day), and that by the Stage 2 Project (116,150 cu.m/day). Among five cases studied, the Case 5 shows the whole of the potential sewage effluent of 95,000 cu.m/day, corresponding to 70 % of the water supply to the municipality area in 2015, discharging into the lake after treatment by such treatment works as the Njoro treatment works.

3.5.2 Submergence of Road and Land

With increasing the lake level, the lake area naturally expands, in other works, a large extension of land and ring road along the lake rims will be submerged. The effects of the lake level rises on the land and road are shown in Fig.G.3.11 and summarized below.

Lake level	Submergence of Ring Road		Submergence of Land
El. 1,758.5 m	Existing lake level in July, 1990		0 %
El. 1,760.0 m	4 %,	Southern part	1 %
El. 1,761.0 m	12 %,	ditto	4 %
El. 1,762.0 m	26%,	Southern and northern parts	7 %
El. 1,764.0 m	65 %,	ditto	13 %
El. 1,766.0 m	70 %,	ditto	20 %
El. 1,768.0 m	74 %,	ditto	25 %
El. 1,770.0 m	90 %,	Eastern part	33 %
El. 1,772.0 m	100 %,	All of road is submerged	40 %

It is to be noted that at the lake level El. 1,771.7 m, the lake area envelops part of the Nakuru Municipal area of about 12 sq.km, the whole of the road encircling the lake, and the grass land of about 25 sq.km. The submergence of the land will create a severe problem on human activities and habitual condition of wildlife, while a large expenditure will be incurred for relocation of the ring road.

3.5.3 Change in Water Quality

The change in the lake water quality was forecast by the same simulation model adopted to the Malewa reservoir.

The quality of the inflowing water was assumed as follows:

- River water : Same as the present
- Sewage inflow : Same quality for the currently treated water, and raw sewage for increased sewage.

The amount of the inflow was indicated by the average value during a 24-year period from 1959 to 1982. The results are summarized below in relation to the lake level.

Lake level (El.m)	DO (mg/l)		COD (mg/l)		T-N (mg/l)	T-P (mg/l)
	Photic Zone	Aphotic Zone	Photic Zone	Aphotic Zone		
1,758.6	9.9	7.6	191.5	192.4	31.85	5.28
1,761.0	9.7	0.1	183.5	177.1	63.98	18.57
1,765.6	9.7	0.0	180.9	187.5	64.37	20.86
1,770.1	9.4	0.0	188.8	193.3	73.58	23.82

In Lake Nakuru, it is deduced that T-N and T-P will continue to increase over a considerable period of time. COD value is too high in present situation, so it is predicted that COD value may not change much. It is presumed that, with increasing sewage inflow, the lake area and volume expand proportionally, resulting in increasing the sedimentation and decomposition of organic matter (COD). The increased decomposition of organic matter will probably augment the consumption of oxygen, and the rise of water level will impede the supply of oxygen from the surface to the bottom, resulting in a great reduction of DO value to the level of almost nil in the aphotic zone.

In the present analysis, effect of decomposition of incremental organic sedimentation was not taken into account. The amount of organic sediment will naturally increase with increase of sewage in future. This will further result to detaliolate water quality. And very low DO value causes anaerobic decomposition.

Electric conductivity was measured at 17,540 μs/cm in July, 1990 and lake water volume was 76 million cu.m on that date. The lake water volume was predicted to increase proportionally with increase of sewage with low electric conductivity. It appears that the electric conductivity of the lake water way decrease with increase of the lake water volume.

3.5.4 Impact on Ecology

Particular attention should be led to the possible changes in the lake ecology due to the augmented sewage inflow.

As is recognized commonly, Lesser Flamingoes are the precious and representative bird in the lake, and depend on Spirulina for their food. The growth of Spirulina is sensitively influenced by salinity of the lake water. And Flamingoes normally feed on Spirulina in water depth less than one m. It is inferred that the increased sewage and resultant rise in the lake level would cause a great impact on a linkage among the water quality, Spirulina, and Flamingo.

It is hardly possibly to forecast quantitatively and qualitatively the impact of the sewage inflow on a complicated lake ecology at this stage. A comprehensive and systematic research is requisite to assess properly the present and anticipated future ecology.

3.6 Further Environmental Studies

There remains some environmental impacts that are hardly possible to be assessed quantitatively on the present natural and social environment at this stage, since the investigation period was short and available data were limited. A comprehensive and systematic further studies listed below are requisite to assess properly the impacts.

- Impact of increased sewage on ecosystem in Lake Nakuru, especially on a linkage among the water quality, Spiralina, Tilapia, white Pelican, and Flamingo.

- Impact of change of water volume of Lake Naivasha on change of pH of lake water, the fish catch amount and the growth of Salvinia and Papyrus.

IV CONSERVATION OF ENVIRONMENT

It has been pointed out in Section 3 of this report that the Project implicates various effects on the present natural and social environment, unless adequate counter measures should be taken up. On the other hand the Project will be prerequisite to ensure an increasing population and a sustained economic growth in the region.

It is, therefore, indispensable to create an appropriate atmosphere for coexistence of the contemplated water supply and the natural and social environments. A conceptual countermeasure is introduced herein, which is, however, subject to further verifications and study in later stage.

4.1 Malewa River

As noted in the sub-section 2.1.3 of this report, there exists a large number of water users in the downstream reaches from the proposed Malewa Dam and Turasha intake, which should be preserved even after completion of the Project to keep their benefits. Further some additional water needs to be maintained in a river channel throughout the year for conservation of aqua-eco system function of river, etc.

In consultation with the MOWD/NWCPC, the rates of the conservation flows have been estimated as set forth below, which are larger than the existing water rights and the ones derived from the prevailing practice.

River	Low Flow Season (cu.m/sec)	Flood Season (cu.m/sec)
Malewa River, downstream from dam	0.22	0.22
Malewa River, downstream from 2GB1	0.35	0.83
Turasha River	0.24	0.24

It is to be noted that the above conservation flows have been taken into consideration in formulating the proposed water development scheme.

4.2 Lake Naivasha

The conservation of the lake should be planned not only from the view point of natural environment but also from the national economic point of view. The lake is an important tourism resources and its water has been widely used for the cultivation of exportable horticulture crops. The excessive decline of the lake level will direct cause to loss the national benefit.

In order to alleviate the impact of the Project, it is a prince concern to reduce the water supply to a certain extent. By such measure the fall of the lake level could be reduced and naturally the magnitude of the impact is decreased.

It is very difficult to set forth the irreducible lowest lake level, but it is deemed that the lake level El. 1,882.0 m, recorded in the 1988 would be indicative. It is presumed that as far as the water supply is operated so as not to lower the proposed lowest level of El. 1,882.0 m even in the drought year like 1988, no serious problem is foreseeable based on the following facts.

(1) Most of the existing intake facilities have already adjusted their locations to cope with the lake level El. 1,882 m.

(2) Segregation of the Crescent Island Bay from the main lake is virtually eliminated as shown in Fig.G.4.1.

(3) Such level occurs very rarely and for a limited time in a year. The runoff of the Malewa river in 1988 correspond to a drought frequency one in 25 years.

(4) The water quality changes little and accordingly there will be no water quality problem in view of source of irrigation supply.

It has been verified through a water balance study the Project output will be reduced to 73 per cent of the initially envisaged quantity on a long term average, if the lowest lake level is set at El. 1,882 m.

4.3 Lake Nakuru

The impact on Lake Nakuru seems more serious than those on Lake Naivasha. If the whole of the potential sewage effluent of 95,000 cu.m/day, corresponding to 70 % of the water supply in 2015, discharges into the lake, the lake area will envelop a part of the Nakuru Municipal area of about 12 sq.km, the whole of the road encircling the lake, and the grass land of about 25 sq.km. The submergence of the land will create a severe problem on human activities and habitual condition of wildlife, while a large expenditure will be incurred for relocation of the ring road.

It would be unavoidable to introduce a dynamic physical structural measure to settle the augmented sewage inflow to the lake. There would be several opinions such as diversion of the sewage into the other basin, re-use of sewage, and combination of them.

TABLES

Table G.1.1 List of Information and Study Reports Collected

I. General

(Reference No.)

1.1 General Ecology

1) J.J.Symoens,Mary Burgis,Jhon J.Gaudet
The Ecology and Utilization of African Inland Waters
UNEP Reports and Proceeding Series 1 .... (1)

2) D.A.Livingstone & J.M.Melack
Some Lakes of Subsaharan Africa.
Lakes and Reservoirs (1984) .... (2)

3) Richard F.Yuretich
Possible Influence upon Lake Development in the East
African Rift Valley
Journal of Geology 1982 vol.90 p329-337 .... (3)

4) J.L.Richardson & A.E.Richardson
History of an African Rift Lake and Its Climatic
Implications.
Ecology Monographs,42,499-534(1972) .... (4)

5) Interim Report of the University of Leicester Research
in Hell's Gate National Park, Kenya .... (5)

1.2 Laws and Regulations

1) The Forests Act .... (6)
2) The Government Fisheries Protect Act .... (7)
3) The Fish Industry Act .... (8)
4) The Water Act .... (9)
5) Lake and River Act .... (10)
6) The Agriculture Act .... (11)
7) The Plant Protection Act .... (12)
8) The Wildlife Conservation and Management (Amendment) Act .... (13)
9) Kenya Standard Specification for Drinking Water .... (14)
10) Man-Made Water Reservoirs Environmental Impact
Assessment Questionnaire .... (15)

1.3 Water Quality of African Lakes

1) J.F.Talling & Ida B.Talling
The Chemical Composition of African Lake Waters
Int,Revue ges.Hydrobiol,50,3,421-463,(1965) .... (16)

2) John J.Gaudet and John M.Melack (1981)
Major Ion Chemistry in a Tropical African Lake Basin
Freshwater Biology (1981)11,309-333 .... (17)

II Lake Naivasha

2.2 General Hydrology

2.3 Water Quality

2.4 Aquatic Plants

2.4.1 Papyrus

Table G.2.1 Water quality in Malewa River Basin

Testing Items / St. No.	Kimuru River (River inflowi-ng throwgh of Dam site)	Olkalou River (River inflowi-ng throwgh of Dam site)	St. 1 (Up stream of Dam site)	St. 2 (Dam site Point)	St. 3 (Down stream of Dam site)	St. 4 (Down stream of Dam site)	Gilgil River (River draining to Lake Naivasha)	Total
Month. Day	Jun. 1	Jun. 14	Jun. 14	Jun. 15	Jun. 14	Jun. 14	Jun. 14	Min ～ Max (Ave)
Time	12 : 00	17 : 10	17 : 00	12 : 30	16 : 00	14 : 20	15 : 00	—
Depth (m)	—	—	—	—	—	—	—	—
Transpency (m)	—	—	—	—	—	—	—	—
Color of Water	16	16	16	17	18	18	17	16 ～ 18 (17)
Temperature (°)	14.3	18.0	16.5	15.7	17.0	18.5	17.5	14.3 ～ 18.5 (16.8)
pH	8.01	7.78	7.95	8.24	8.09	8.08	8.16	7.78～ 8.24 (8.04)
Conductivity (μs/cm)	110	160	130	130	240	200	130	110 ～ 240 (157)
Turbidity (mg/ℓ)	14	40	24	25	70	28	34	14 ～ 70 (34)
SS (mg/ℓ)	13	39	35	25	27	35	49	13 ～ 49 (32)
DO (mg/ℓ)	8.4	6.8	6.8	7.4	7.2	7.2	6.8	6.8 ～ 8.4 (7.2)
COD (mg/ℓ)	8	15	4	8	7	10	9	4 ～ 15 (9)
T-N (mg/ℓ)	2.260	3.391	3.166	2.700	—	3.577	3.431	2.260～ 3.577 (3.088)
K-N (mg/ℓ)	1.05	2.25	2.25	2.70	—	2.55	2.40	1.05～ 2.70 (2.20)
NH_4-N (mg/ℓ)	—	—	—	—	—	—	—	—
NO_3-N (mg/ℓ)	1.20	1.10	0.90	< 0.10	0.90	1.00	1.00	< 0.10～ 1.20 (0.89)
NO_2-N (mg/ℓ)	0.010	0.041	0.016	< 0.001	0.018	0.027	0.031	<0.001～ 0.041 (0.021)
T-P (mg/ℓ)	—	—	—	—	—	—	—	—
PO_4-P (mg/ℓ)	0.13	0.09	0.04	0.12	0.09	0.10	0.10	0.04～ 0.13 (0.10)

Table G.2.2 Water quality Monitored in Malewa River Basin

St. No. / Testing Items	St. 2 (Malewa proposed Dam site)					Total
Month. Day	Jun. 15	July. 5	July. 11	July. 17	July. 25	Min ~ Max (Ave)
Time	12 : 30	:	18 : 30	14 : 35	16 : 30	—
Depth (m)	—	—	—	—	—	—
Transpency (m)	—	—	—	—	—	—
Color of Water	17	16	—	19	19	16 ~ 19 (18)
Temperature (°)	15.7	—	—	—	—	—
pH	8.24	—	8.27	7.88	8.08	8.08~ 8.27 (8.12)
Conductivity (μs/cm)	130	104	65	71	74	65 ~ 130 (89)
Turbidity (mg/ℓ)	25	—	—	—	—	—
SS (mg/ℓ)	25	23	36	323	62	23 ~ 323 (94)
DO (mg/ℓ)	7.4	—	—	—	—	—
COD (mg/ℓ)	8	16	18	65	13	8 ~ 65 (24)
T-N (mg/ℓ)	2.700	—	—	—	—	—
K-N (mg/ℓ)	2.70	—	—	—	—	—
NH_4-N (mg/ℓ)	—	0.04	0.05	0.26	0.06	0.04~ 0.26 (0.10)
NO_3-N (mg/ℓ)	< 0.10	1.00	0.6	2.00	0.50	< 0.10~ 2.00 (0.84)
NO_2-N (mg/ℓ)	< 0.001	0.017	0.026	0.154	0.005	< 0.001~ 0.154 (0.041)
T-P (mg/ℓ)	—	0.49	ND	1.54	0.63	0.45~ 1.54 (0.89)
PO_4-P (mg/ℓ)	0.12	0.12	0.21	0.16	0.17	0.12~ 0.21 (0.16)

Table G.2.3 Terrestrial Animals in Study Area

	Malewa River Basin		Lake Naivasha		Lake Nakuru	
	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	Common Name
Mammals	Equus burchelli	Burchell's zebra	Syncerus caffer	African buffalo	Kobus ellipsiprymnus	Waterbuck
	Tragelaphus oryx	Eland	Hippopotamus amphibius	Hippopotamus	Aepyceros melampus	Impala
	Aepyceros melampus	Impala	Giraffa camelopardalis	Giraffe	Phacochoerus	Warthog
	Gazella thomsoni	Thomson's gazelle	Equus burchelli	Burchell's zebra	Syncerus	Buffalo
	Panthera pardus	Leopard	Alcelaphus buselaphus cokii	Coke's hartebeest	G. thomsoni	Gazella (Thomsons)
	Acinonyx jubatus	Cheetah	Connochaetes taurinus	Brindled gnu	G. granti	Gazelle (Grant)
	Lepus capensis	Cape hare	Tragelaphus oryx	Eland	Redunca fulvorufula	Reedbuck Mountain
	Herpestinae	Mongooses	Kobus ellipsiprymnus	Defassa waterback	Hippopotamus amphibius	Hippopotamus
			Aepyceros melampus	Impala	Aonyx capensis	Cape Clawless Otters
			Gazella thomsoni	Thomson's gazelle		
			Gazella granti	Grant's gazelle		
			Hyena hyaena	Striped hyaena		
			Cercop ithecus aethiops	Black-faced vervet		
			Hystrix cristata	North African crested porcupine		
			Heterohyrax brucei	Rock hyrax		
			Lepus capensis	Cape hare		
			Myocastor coypus	Coypu		
			Chiroptera	Bats		
Birds	Threskiornithidae	Ibises	Palecanus rufescens	White pelican	Pelecanus onocrotalus	White Pelican
	Turnicidae	Button quails	Phalacrocorax africanus	Long-tailed cormorant	Phoenicopterus minor	Lesser Flamingo
	Columbidae	Pigeons	Phalacrocorax carbo	White-necked cormorant	Chlidonias leucoptera	White Winged Black Tern
	Bucerotidae	Hornbills	Podiceps ruficollis	Little grebe	Larus cirrocephalus	Grey-Headed Gull
	Apodidae	Swifts	Egretta garzetta	Little egret	Phoenicopterus ruber	Greater Flamingo
	Hirundinidae	Swallows	Egretta intermedia	Yellow-billed egret	Ibis ibis	Yellow-Billed Stork
	Lanidae	Shrikes	Ardea goliath	Goliath heron	Himantopus himantopus	Black-Winged Stilt
	Nectariniidae	Sunbirds	Threskiornis aethiopicus	Sacred ibis	Pelecanus rutescens	Pink-Backed Pelican
	Sturnidae	Starligs	Hagedashia hagedash	Hadada ibis	Gelochelidon nilotica	Gull-Billed Tern
	Garvus albus	Pied crow	Plegadis falcinellus	Glossy ibis	Podiceps ruticollis	Little Grebe
			Ibis ibis	Yellow-billed stock	Platalea alba	African Spoon Bill
			Platalea alba	African spoonbill	Alopochen aegyptiaca	Egyptian Goose
			Leptoptilos crumeniferus	Marabou stork	Vanellus armatus	Blacksmith Plover
			Oxyura maccoa	Maccoa duck		
			Athya erythrophthalma	African pochard		
			Anas hottentota	Hottentot teal		
			Anas undulata	Yellow-billed duck		
			Plectopterus gambensis	Spurwing goose		
			Alopochen aegyptiaca	Egyptian goose		
			Dendrocygna viduata	Fulvous tree duck		
			Haliaeetus vocifer	African fish eagle		
			Buteo rufofuscus	Augur buzzard		
			Porphyrio porphyrio	Purple gallinule		
			Fulica cristata	Red-knobbed coot		
			Balearica regulorum	Crowned crane		
			Vanellus armatus	Blacksmith plover		
			Gallinago nigripennis	African snipe		
			Actophilornis africanus	African jacana		
			Larus cirrocephalus	Grey-headed gull		
			Ceryle rudis	Pied kingfisher		
			Motacilla aguimp	Africana pied wagtail		
Reptiles	Bitis arietans	Puff adder	Bitis arietans	Puff adder		
	Dendroaspis polylepis	Black mamba	Dendroaspis polylepis	Black mamba		
	Python sabae	African python	Phthon sabae	African Python		
			Lacertilia	A kind of lizard		
Amphibians	Pipidae	Clawed toads	Anura	Tree frog		
	Ranidae	True frogs				
Source:	Ase 1987	Wildlife Training School, Naivasha	Nakuru National Park Warden 1990			

Table G.2.4 Aquatic Animals in Study Area

	Malewa River		Lake Naivasha		Lake Nakuru	
	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	Common Name
Fish	Salmo gairdneri	Rainbow trout	Tilapia zillii	Tilapia	Alcalicus grahami	Tilapia
	Barbus amphigramma	Barbus	Oreochromis leucosticus	Tilapia		
			Micropterus salmoides	Black bass		
			Lebistes reticulata	Unknown		
			Barbus amphigramma	Barbus		
Invertebrate	Turbellaria	Planarian	Branchiura sowerbyi	Aquatic earthworm	——	——
	Oligochaeta	Earthworm	Limnodrilus hoffmeristeri	Aquatic earthworm		
	Decapoda	Crab	Chironomus	Midge		
	Procambarus clakii	Crayfish	Foraosipiennis	Midge		
	Ephemeroptera	Mayfly	Chironomidae			
	Anisoptera	Dragonfly	Procambarus clakii	Crayfish		
	Zygoptera	Dameselfly	Cladocera			
	Plecoptera	Stonefly	Ostracoda			
	Tricoptera	Caddisfly	Hemiptera			
	Coleoptera	Beetle	Chironomidae	Midge		
	Chironomidae	Midge	Culicidae	Mosquito		
			Ephemeroptera	Mayfly		
			Odonata	Dragonfly		
			Coleoptera	Beetle		
			Mollusca	Shellfish		
			Tridadida	Planarian		
			Micronecta spp.			
			Alma emini			

Source: Fisheries Department Naivasha 1989
Harper 1984, Mavuti 1981

Note: For Lake Nakuru, no detailed data and information are so far made available.

Table G.2.5 Phytoplankton Communities in Malewa River

Date:15, June, 1990

Method:Van don water bottle(500mℓ)

Unit:cells/mℓ

No.	Division	Class	Species (Station / Layer)	Upper
1	Cyanophyta	Cyanophyceae	Aphanocapusa sp. B	(2)
2	Chrysophyta	Bacillariophyceae	Fragilaria sp.	2
3			Gyrosigma sp.	2
4			Nitzschia spp.	9
5			Synedra sp. A	54
6	Chlorophyta	Chlorophyceae	Ankistrodemus spp.	4
7			Cosmarium sp.	2
			Total (cells/mℓ)	75

※( )=colony number

Table G.2.6 Zooplankton Communities in Marewa River

Date:15, June, 1990

Method:ventrical haul with planktonnet

Unit:individuals/sample

No.	Phylum	Class	Speices (Station / Layer)	Upper
1	Protozoa	Rhizopoda	Arcella sp.	30
2			Centrophyxis acureata	30
3			Difflugia sp.	120
4	Aschelminthes	Rotatoria	Brachionus calyciflorus	60
5	Arthropoda	Crustacea	Alona sp.	30
6			Cyclopoida	30
			Total (individuals/sample)	300

Table G.2.7 Water Quality of Lake Naivasha (1/3)

Testing Items / St. No.	1		2		3		4		5		6		7			8	
S·B	S	B	S	B	S	B	S	B	S	B	S	B	S	M	B	S	B
Month. Day	Jun. 5		Jun. 5		Jun. 5		Jun. 21		Jun. 4		Jun. 4		Jun. 4			Jun. 4	
Time	11 : 55		11 : 05		10 : 40		12 : 10		14 : 10		14 : 50		15 : 10			16 : 00	
Depth (m)	5.3		5.3		3.4		6.0		7.0		7.5		7.0			6.4	
Transpency (m)	0.7		0.7		0.8		0.8		0.8		0.8		0.7			0.7	
Color of Water	16		17		15		16		17		17		16			17	
Temperature (·)	20.6	20.3	20.1	20.1	20.1	20.1	20.5	19.8	21.2	20.5	21.2	20.6	21.0	20.7	20.4	21.0	20.7
pH	8.31	8.45	8.70	8.76	9.03	9.04	8.82	8.77	8.79	8.69	8.71	8.71	8.56	8.64	8.62	8.71	8.67
Conductivity (μs/cm)	250	270	280	280	300	300	280	280	270	270	270	280	270	300	270	280	280
Turbidity (mg/ℓ)	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
SS (mg/ℓ)	13	15	14	14	13	12	12	12	12	14	12	13	15	12	13	12	12
DO (mg/ℓ)	8.3	8.3	8.3	8.3	8.3	8.0	7.6	6.6	8.5	7.9	8.5	8.0	8.2	8.2	7.4	8.5	8.8
COD (mg/ℓ)	38	38	40	55	36	37	42	42	32	40	33	35	29	85	32	32	47
T-N (mg/ℓ)	−	−	3.610	3.410	−	−	−	−	−	−	−	−	2.910	4.110	3.210	−	−
K-N (mg/ℓ)	−	−	3.0	2.6	−	−	−	−	−	−	−	−	2.3	3.5	2.3	−	−
NH_4-N (mg/ℓ)	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
NO_3-N (mg/ℓ)	0.50	1.10	0.60	0.80	0.80	0.70	0.80	0.80	0.70	0.90	0.60	0.80	0.60	0.60	0.80	0.60	1.00
NO_2-N (mg/ℓ)	0.010	0.010	0.010	0.010	0.010	0.010	0.009	0.010	0.012	0.011	0.011	0.011	0.012	0.012	0.011	0.010	0.012
T-P (mg/ℓ)	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
PO_4-P (mg/ℓ)	0.04	0.06	0.09	0.07	0.04	0.08	0.05	0.03	0.03	0.05	0.04	0.08	0.06	0.05	0.04	0.05	0.02

Legend S : Surface, B : Bottom

Table G.2.8 Water Quality of Lake Naivasha (2/3)

Testing Items / St. No.	9		10		11		12		13		Total	
S·B	S	B	S	B	S	B	S	B	S	B	S	B
Month. Day	Jun. 5		Jun. 4		Jun. 4		Jun. 4		Jun. 4		Min ～ Max (Ave)	Min ～ Max (Ave)
Time	9 : 50		12 : 57		13 : 45		12 : 40		11 : 30		–	–
Depth (m)	5.7		7.2		6.5		5.7		4.3		3.4 ～ 7.5 (6.0)	–
Transpency (m)	0.8		0.8		0.7		0.8		1.0		0.7 ～ 1.0 (0.8)	–
Color of Water	17		16		16		16		15		15 ～ 17 (16)	–
Temperature (·)	20.1	20.0	20.7	20.5	21.0	20.6	20.7	20.5	20.8	20.0	20.1 ～ 21.2 (20.7)	19.8 ～ 20.7 (20.3)
pH	8.66	8.70	8.62	8.62	8.44	8.41	8.68	8.65	8.78	8.56	8.31 ～ 9.03 (8.68)	8.41 ～ 9.04 (8.67)
Conductivity (μs/cm)	280	280	270	270	270	270	280	280	280	290	250 ～ 300 (275)	270 ～ 300 (278)
Turbidity (mg/ℓ)	–	–	–	–	–	–	–	–	–	–	–	–
SS (mg/ℓ)	12	12	13	13	13	13	13	13	10	10	10 ～ 15 (13)	10 ～ 15 (13)
DO (mg/ℓ)	7.4	7.7	7.9	8.0	7.5	7.1	7.7	7.9	11.1	6.8	7.4 ～ 11.1 (8.3)	6.6 ～ 8.8 (7.8)
COD (mg/ℓ)	61	34	37	40	36	39	48	32	45	32	29 ～ 61 (39)	32 ～ 55 (39)
T-N (mg/ℓ)	–	–	–	–	–	–	–	–	–	–	2.910～ 3.610 (3.260)	3.210～ 3.410 (3.310)
K-N (mg/ℓ)	–	–	–	–	–	–	–	–	–	–	2.3 ～ 3.0 (2.7)	2.3 ～ 2.6 (2.5)
NH_4-N (mg/ℓ)	–	–	–	–	–	–	–	–	–	–	–	–
NO_3-N (mg/ℓ)	0.50	0.60	0.50	0.80	0.90	0.80	0.80	0.80	0.90	0.50	0.50 ～ 0.90 (0.68)	0.50 ～ 1.10 (0.80)
NO_2-N (mg/ℓ)	0.010	0.011	0.010	0.011	0.010	0.012	0.012	0.015	0.015	0.014	0.009～ 0.015 (0.011)	0.010～ 0.015 (0.011)
T-P (mg/ℓ)	–	–	–	–	–	–	–	–	–	–	–	–
PO_4-P (mg/ℓ)	0.03	0.01	0.10	0.08	0.02	0.04	0.08	0.07	0.05	0.04	0.02 ～ 0.10 (0.05)	0.01 ～ 0.08 (0.05)

Legend S : Surface, B : Bottom

Table G.2.9 Water Quality of Lake Naivasha (3/3)

Testing Items (St. No. / S·B)	14 (Malewa River)		15 (Small Lake)	
	S	B	S	B
Month. Day	Jun. 4		Jun. 17	
Time	18 : 00		15 : 00	
Depth (m)	—		—	
Transpency (m)	—		—	
Color of Water	—		17	
Temperature (°)	21.1		21.5	
pH	8.27		9.64	
Conductivity (μs/cm)	110		1310	
Turbidity (mg/ℓ)	—		—	
SS (mg/ℓ)	27		43	
DO (mg/ℓ)	—		—	
COD (mg/ℓ)	5		123	
T-N (mg/ℓ)	—		—	
K-N (mg/ℓ)	—		—	
NH_4-N (mg/ℓ)	—		—	
NO_3-N (mg/ℓ)	1.10		0.20	
NO_2-N (mg/ℓ)	0.020		0.002	
T-P (mg/ℓ)	—		—	
PO_4-P (mg/ℓ)	0.16		0.78	

Legend S : Surface, B : Bottom

Table G.2.10 Water Quality Monitored in Lake Naivasha (1/3)

St. No. / Testing Items	14 (River draining to Lake Naivasha)						Total
Month. Day	Jun. 14	Jun. 21	July. 5	July. 11	July. 17	July. 25	Min ~ Max (Ave)
Time	14 : 20	18 : 00	:	17 : 30	12 : 40	14 : 00	—
Depth (m)	—	—	—	—	—	—	—
Transpency (m)	—	—	—	—	—	—	—
Color of Water	18	—	16	—	21	18	16 ~ 21 (18)
Temperature (°)	18.5	—	—	—	—	—	18.5 ~ 21.1 (19.8)
pH	8.08	—	—	7.94	7.83	8.06	7.83~ 8.08 (7.98)
Conductivity (μs/cm)	200	—	107	83	73	82	73 ~200 (109)
Turbidity (mg/ℓ)	28	—	—	—	—	—	—
SS (mg/ℓ)	35	19	24	142	266	74	19 ~266 (93)
DO (mg/ℓ)	7.2	—	—	—	—	—	—
COD (mg/ℓ)	10	6	—	27	49	28	6 ~ 49 (24)
T-N (mg/ℓ)	3.577	—	—	—	—	—	—
K-N (mg/ℓ)	2.55	—	—	—	—	—	—
NH_4-N (mg/ℓ)	—	—	0.05	0.10	0.24	0.10	0.05~ 0.24 (0.12)
NO_3-N (mg/ℓ)	1.00	0.60	1.10	0.80	1.00	0.70	0.60~ 1.10 (0.87)
NO_2-N (mg/ℓ)	0.027	0.013	0.021	0.046	0.110	0.005	0.005~ 0.110 (0.037)
T-P (mg/ℓ)	—	—	0.09	0.05	1.43	0.89	0.05~ 1.43 (0.62)
PO_4-P (mg/ℓ)	—	0.11	0.10	0.10	0.34	0.17	0.10~ 0.34 (0.15)

Table G.2.11 Water Quality Monitored in Lake Naivasha (2/3)

Testing Items	St. No. / S·B	2										Total	
		S	B	S	B	S	B	S	B	S	B	S	B
Month. Day		Jun. 21		July. 4		July. 11		July. 17		July. 24		Min ～ Max (Ave)	Min ～ Max (Ave)
Time		11 : 30		10 : 00		16 : 10		10 : 45		12 : 26		—	—
Depth	(m)	5.3		5.4		5.4		5.4		5.2		5.2 ～ 5.4 (5.3)	—
Transpency	(m)	0.8		0.8		0.8		0.9		1.0		0.7 ～ 1.0 (0.8)	—
Color of Water		16		15		16		15		15		15 ～ 16 (15)	—
Temperature	(·)	20.6	20.1	—	—	—	—	—	—	—	—	—	—
pH		8.99	9.02	—	—	8.46	8.53	8.48	8.47	8.77	8.74	8.48～ 8.99 (8.68)	8.47～ 9.02 (8.69)
Conductivity	(μs/cm)	290	330	275	262	270	265	267	271	271	272	267 ～290 (275)	262 ～330 (280)
Turbidity	(mg/ℓ)	—	—	—	—	—	—	—	—	—	—	—	—
SS	(mg/ℓ)	12	14	8	7	18	8	10	8	8	9	8 ～ 18 (11)	8 ～ 14 (9)
DO	(mg/ℓ)	7.6	7.2	—	—	—	—	—	—	—	—	—	—
COD	(mg/ℓ)	43	45	31	35	39	40	57	85	47	43	31 ～ 57 (43)	35 ～ 85 (50)
T-N	(mg/ℓ)	—	—	—	—	—	—	—	—	—	—	—	—
K-N	(mg/ℓ)	—	—	—	—	—	—	—	—	—	—	—	—
NH_4-N	(mg/ℓ)	—	—	0.05	0.22	0.09	0.20	0.16	0.22	0.29	0.18	0.05～ 0.29 (0.15)	0.18～ 0.22 (0.21)
NO_3-N	(mg/ℓ)	0.80	0.90	0.90	1.10	0.50	0.50	0.70	0.30	—	—	0.50～ 0.90 (0.70)	0.30～ 1.10 (0.70)
NO_2-N	(mg/ℓ)	0.009	0.009	0.009	0.007	ND	ND	0.009	0.009	0.004	0.003	0.004～ 0.009 (0.008)	0.003～ 0.009 (0.007)
T-P	(mg/ℓ)	—	—	0.52	0.64	0.22	0.32	0.08	0.11	0.60	0.56	0.08～ 0.60 (0.36)	0.11～ 0.64 (0.41)
PO_4-P	(mg/ℓ)	0.05	0.06	0.11	0.05	0.10	0.08	0.24	0.18	0.13	0.05	0.09～ 0.24 (0.13)	0.05～ 0.18 (0.08)

Legend S : Surface, B : Bottom

Table G.2.12 Water Quality Monitored in Lake Naivasha (3/3)

Testing Items	St. No. / S·B	7										Total	
		S	B	S	B	S	B	S	B	S	B	S	B
Month.Day		Jun.21		July. 4		July.11		July.17		July.24		Min ~ Max (Ave)	Min ~ Max (Ave)
Time		12 : 40		10 : 26		16 : 40		11 : 10		13 : 10		—	—
Depth	(m)	6.7		6.9		6.8		6.9		6.8		6.7 ~ 6.9 (6.8)	—
Transpency	(m)	0.8		0.9		0.9		1.0		1.1		0.8 ~ 1.1 (0.9)	—
Color of Water		16		16		17		15		16		15 ~ 17 (16)	—
Temperature	(·)	20.2	19.5	—	—	—	—	—	—	—	—	—	—
pH		8.73	8.68	—	—	8.53	8.49	8.35	8.34	8.60	8.55	8.35~ 8.73 (8.55)	8.34~ 8.68 (8.52)
Conductivity	(μs/cm)	280	280	267	268	264	261	268	268	267	269	264 ~280 (269)	261 ~280 (269)
Turbidity	(mg/ℓ)	—	—	—	—	—	—	—	—	—	—	—	—
SS	(mg/ℓ)	11	12	7	7	7	8	8	7	10	8	7 ~ 11 (9)	7 ~ 12 (9)
DO	(mg/ℓ)	—	—	—	—	—	—	—	—	—	—	—	—
COD	(mg/ℓ)	41	37	54	39	35	37	68	57	32	40	32 ~ 68 (46)	37 ~ 57 (42)
T-N	(mg/ℓ)	—	—	—	—	—	—	—	—	—	—	—	—
K-N	(mg/ℓ)	—	—	—	—	—	—	—	—	—	—	—	—
NH_4-N	(mg/ℓ)	—	—	0.04	0.10	0.13	0.16	0.24	0.27	0.24	0.26	0.04~ 0.24 (0.16)	0.10~ 0.27 (0.20)
NO_3-N	(mg/ℓ)	1.10	0.80	1.10	1.00	0.50	0.60	0.50	0.30	—	—	0.50~ 1.10 (0.80)	0.30~ 1.00 (0.68)
NO_2-N	(mg/ℓ)	0.009	0.010	0.007	0.007	0.007	0.007	0.007	0.006	0.002	0.004	0.002~ 0.009 (0.006)	0.004~ 0.010 (0.007)
T-P	(mg/ℓ)	—	—	0.64	0.06	0.05	ND	0.08	0.14	0.51	0.46	0.05~ 0.64 (0.32)	0.06~ 0.46 (0.22)
PO_4-P	(mg/ℓ)	0.05	0.04	0.05	0.06	0.07	0.06	0.27	0.07	0.07	0.15	0.05~ 0.27 (0.10)	0.04~ 0.15 (0.08)

Legend S : Surface, B : Bottom

Table G.2.13 Phytoplankton Communities in Lake Naivasha

Date:4,5,June,1990
Method:Van don water bottle(500mℓ)
Unit:cells/mℓ

No.	Division	Class	Species / Station / Layer	No. 2 Upper	No. 2 Bottom	No. 7 Upper	No. 7 Bottom
1	Cyanophyta	Cyanophyceae	Aphanocapusa sp.A	(428)	(402)	(449)	(333)
2			Aphanocapusa sp.B	(441)	(454)	(445)	(294)
3			Chroococcus sp.	73	181	151	125
4			Cylindrospermopsis raciborskii	(720)	(82)	(720)	(39)
5			Lyngbya contorta	(13)	(22)	(13)	(9)
6			Ly. limnetica	(39)	(60)	(48)	(39)
7			Merismopedia sp.	(56)	(78)	(9)	(17)
8			Microcystis aeruginosa	3,000	1,080	7,600	233
9			Mic. wesenbergii	190	648	280	441
10			Oscillatoria sp.	(4)			
11			Phormidium sp.	(26)	(9)	(22)	(22)
12	Pyrophyta	Dinophyceae	Peridinium sp.	4	4	4	
13	Chrysophyta	Xanthophyceae	Ophiocytium sp.	4	9	9	4
14		Bacillariophyceae	Aulacosira ambigua	43	69	17	17
15			Aul. granulata	134	156	22	52
16			Cyclotella stelligera	26	35	52	35
17			Fragilaria sp.	39	52	52	60
18			Nitzschia acicularis	48	65	60	30
19			Nitzschia sp.A	9	35	13	17
20			Nitzschia spp.	95	112	108	91
21			Rhizosolenia eriensis	4	30	26	65
22			Synedra acus	4	4	9	4
23			Synedra sp.A	1,690	1,370	2,030	1,880
24			Synedra sp.B	104	69	177	147
25	Chlorophyta	Chlorophyceae	Actinastrum sp.	35	35	17	
26			Ankistrodemus spp.	69	104	82	108
27			Chodatella sp.	17	26	4	9
28			Closterium spp.	13	9	13	22
29			Coelastrum spp.	69	69	346	346
30			Cosmarium spp.	99	91	233	156
31			Crucigenia tetrapedia	17		69	
32			Dictyosphaerium pulchellum	337	268	432	251
33			Elakatothrix sp.	108	86	156	151
34			Kirchneriella sp.	9		35	
35			Micractinium pusillum	22	17	17	17
36			Mougeotia sp.	78	9	69	9
37			Oocystis sp.	95	99	298	108
38			Pediastrum duplex	60	35	69	69
39			Ped. simplex	17	69	17	104
40			Ped. tetras	17	52		
41			Scenedesmus spp.	691	596	544	456
42			Schroederia sp.	17	26	35	26
43			Staurastrum sp.	181	143	346	298
44			Tetradesmus sp.	17		35	17
45			Tetraedron caudatum	9	4	4	4
46			Tet. minimum	30	78	82	48
47			Tetraedron spp.	112	147	147	151
48			Treubaria spp.	13	9	13	4
49	Euglenophyta	Euglenophyceae	Euglena sp.	9	9		
50			Phacus spp.	4	4	17	4
51			Trachelomonas spp.	4	9	4	
52			Unknown micro-flagilletes	9	13	9	9
			Total (cells/mℓ)	9,352	7,033	15,409	6,321

※( )=colony number

Table G.2.14 Zooplankton Communities in Lake Naivasha

Date:4, 5, June, 1990

Method:ventrical haul with planktonnet

Unit:individuals/ℓ

No.	Phylum	Class	Speices Station / Layer(m)	No. 2 0~4.3	No. 7 0~6.0
1	Protozoa	Rhizopoda	Centrophyxis acureata	1.3	
2			Difflugia sp.	0.6	0.5
3		Ciliata	Epistylidae		6.9
4			Ciliata	2.6	2.9
5	Aschelminthes	Rotatoria	Asplancha sp.	0.6	
6			Brachionus angularis	3.2	1.5
7			Br. calyciflorus	11.6	7.8
8			Br. caudatus	34.3	14.2
9			Br. farficula	0.3	1.0
10			Brachionus sp.	3.9	1.0
11			Collotheca sp.	0.6	13.2
12			Conochiloides sp.	5.8	2.0
13			Filinia spp.	11.0	5.4
14			Hexarthra sp.	2.6	1.5
15			Keratella valga	4.5	1.0
16			Platyias patulus	4.5	2.0
17			Polyarthra sp.	0.3	2.0
18			Synchaeta sp.	3.2	3.9
19			Trichocerca sp.	1.3	
20			Rotatoria	1.9	
21	Arthropoda	Crustacea	Alona sp.	1.3	1.0
22			Ceriodaphnia rigaudi	0.6	1.0
23			Chydorus sp.	0.3	
24			Diaphanosoma sp.	15.5	24.0
25			Macrothrix sp.	0.3	
26			Simocephalus sp.	1.9	4.4
27			Cyclopoida	48.5	32.8
28			Nauplius of Copepoda	123.0	140.0
			Total (individuals/ℓ)	285.5	270.0

Table G.2.15 Fish Introduction in Lake Naivasha

Scientific Name	Common name	Purpose of Introduction	Year of First Introduction	Existence or Not
Micropterms salmoides lacepede	Black-Bass	Commercial, Sports	1927	Yes
Oreocgromis spilurus niger	Tilapia	Commercial	1925	No
Tilapia zillii	Tilapia	Commercial	1956	Yes
Oreochromis leucostictus	Tilapia	Commercial	1956	No
Barbus amphigramma	Barbus	-	*(1982)	Yes
Salmo gairnerz	-	Sports	--	No
Gambusia sp	-	Control Mosquitos	--	No
Poelica sp	-	Control Mosquitos	--	No
Lebistes reticulata	-	Control Mosquitos	--	No
Oreochromis hiloticus	-	-	1965	No
Lates niloticus	-	-	1970	No
Procamburus clakii	Craytish	Commercial	1970	Yes

* Migrate from Malewa river

Table G.2.16 LIST OF EXISTING BOREHOLES (1/5)

No.	Borehole No. C -	Complete Mon./Year	Location	Elevation m	Total Depth m	Struck Level Depth, Eleva. m	Rest Level Depth, Eleva. m	Discharge lit./min.	Difference be. W.L. m	Remarks
1	54	7 /39	NP	1,905	46	31 (1874)	15 (1890)	203	6	-
2	57	10	EL	2,088	76	13 (2075)	-	-	-	Ab (No Water)
3	92	12	EL	2,118	156	-	-	-	-	Ab (No Water)
4	137	-	WM	1,890	-	-	-	31	-	-
5	210	2 /43	SM	1,905	67	37 (1868)	15 (1890)	273	7	-
6	231	7	EM	1,905	46	9 (1896)	9 (1896)	355	14	Ab (-)
7	295	7	EM	1,996	86	-	37 (1959)	20	77	Ab (-)
8	457	8 /46	EM	(1,940)	76	76 (1905)	27 (1954)	128	32	Nw (-) Checked Rest Level : 8m
9	458	8	EM	(1,940)	102	101 (1880)	27 (1954)	158	32	Nw (-)
10	465	9	EM	1,966	99	97 (1869)	41 (1925)	91	44	Nw (To Repair)
11	467	10	EM	(1,950)	95	87 (1863)	83 (1867)	152	-14	Wk (Livestock)
12	468	10	NP	1,906	46	18 (1888)	17 (1889)	144	8	-
13	531	5 /47	EM	1,920	61	16 (1904)	16 (1904)	303	22	Ab (-)
14	562	6	SP	1,896	56	43 (1853)	23 (1873)	151	-9	Wk (Irrigation)
15	563	7	WM	1,890	31	21 (1869)	7 (1883)	104	0	Wk (Domestic)
16	567	6	SM	1,950	102	81 (1869)	56 (1894)	102	12	Nw (-)
17	578	9	WM	1,890	33	20 (1870)	20 (1870)	134	-13	-
18	579	9	WM	1,890	43	27 (1863)	22 (1868)	114	-15	Wk (Irrigation), Saline Water
19	580	9	SP	1,920	67	52 (1868)	46 (1874)	114	-9	-
20	581	7	WM	1,890	31	27 (1863)	23 (1867)	120	-16	-
21	582	7	SP	1,897	56	40 (1857)	14 (1883)	136	0	-
22	594	9	SP	1,893	34	18 (1879)	16 (1881)	133	-2	-
23	628	10	SP	(1,911)	46	34 (1877)	34 (1887)	135	-6	Wk (Domestic)
24	629	10	SP	1,891	61	58 (1833)	14 (1877)	36	-6	-
25	630	10	WM	(1,970)	114	119 (1851)	100 (1870)	60	-13	-
26	631	11	WM	1,905	46	33 (1872)	27 (1878)	135	-5	Wk (Irrigation)
27	632	9	SP	1,890	33	31 (1859)	11 (1879)	132	-4	-
28	667	10	SP	1,890	37	23 (1867)	22 (1868)	135	-15	-

Table G.2.17 LIST OF EXISTING BOREHOLES (2/5)

No.	Borehole No. C -	Complete Mon./Year	Location	Elevation m	Total Depth m	Struck Level Depth, Eleva. m	Rest Level Depth, Eleva. m	Discharge lit./min.	Difference be. W.L. m	Remarks
29	729	9 /48	SM	2,051	183	164 (1887)	160 (1891)	65	9	Nw (-)
30	733	6	NP	(1,955)	241	223 (1732)	193 (1762)	61	-33	-
31	910	5 /49	SM	(1,940)	33	27 (1913)	13 (1927)	99	45	Wk (Livestock)
32	939	9	EL	2,126	150	128 (1998)	126 (2000)	91	118	-
33	947	5	SP	1,900	49	24 (1876)	24 (1876)	76	-8	-
34	1,062	3 /50	WM	(1,890)	32	26 (1864)	11 (1879)	227	-3	-
35	1,063	3	WM	(1,890)	41	19 (1871)	11 (1979)	227	-3	-
36	1,068	4	SP	1,923	76	70 (1853)	45 (1888)	197	7	-
37	1,265	12	EL	2,240	256	-	-	-	-	Ab (No Water)
38	1,279	10	SM	2,002	183	139 (1863)	122 (1880)	117	-1	Nw (-)
39	1,281	11	SP	1,890	32	30 (1860)	24 (1866)	129	5	-
40	1,356	3 /51	SP	1,905	31	30 (1875)	12 (1893)	182	12	-
41	1,359	3	SP	1,905	34	32 (1873)	12 (1893)	153	12	-
42	1,464	3 /50	WM	1,935	31	11 (1924)	8 (1927)	212	46	Wk (Irrigation)
43	1,481	6 /51	SP	1,897	30	26 (1871)	17 (1880)	114	-2	-
44	1,482	6	SP	1,890	36	35 (1855)	11 (1879)	35	-3	-
45	1,483	6	EM	1,974	46	40 (1934)	32 (1942)	30	60	Ab (-)
46	1,486	7	EM	1,973	152	122 (1851)	101 (1872)	341	-10	Wk (Domestic)
47	1,487	7	EM	1,975	155	119 (1856)	91 (1884)	491	2	Nw (To Repair)
48	1,488	7	EL	(2,080)	91	82 (1998)	76 (2004)	38	122	Wk (Livestock)
49	1,652	1 /52	SP	1,892	61	-	-	151	-	-
50	1,843	9	SM	2,073	256	-	-	-	-	Nw (Saline Water)
51	1,898	1 /53	EM	2,019	102	92 (1927)	59 (1960)	190	78	Ab (-)
52	1,926	2	SM	1,981	125	104 (1877)	91 (1890)	113	8	Nw (Saline Water)
53	1,927	3	SM	1,900	42	35 (1865)	18 (1882)	75	1	-
54	1,947	4	EM	1,920	67	52 (1868)	16 (1904)	75	23	Ab (-)
55	2,015	4	WM	1,890	32	18 (1872)	12 (1878)	151	-3	-
56	2,017	3	SP	1,892	23	21 (1871)	16 (1876)	52	-5	-
57	2,058	11	SP	1,895	47	44 (1851)	15 (1880)	105	-1	-
58	2,069	9	WM	(1,920)	78	76 (1844)	46 (1874)	67	-7	-

Table G.2.18 LIST OF EXISTING BOREHOLES (3/5)

No.	Borehole No. C -	Complete Mon./Year	Location	Elevation m	Total Depth m	Struck Level Depth, Eleva. m	Rest Level Depth, Eleva. m	Discharge lit./min.	Difference be. W.L. m	Remarks
59	2,071	10 /53	WM	1,897	18	12 (1885)	12 (1885)	67	4	-
60	2,117	11	SP	(1,890)	26	22 (1868)	12 (1878)	53	-3	-
61	2,119	11	SP	1,892	28	24 (1868)	11 (1881)	75	0	-
62	2,220	6 /54	SP	(1,915)	58	38 (1877)	30 (1885)	151	4	-
63	2,221	6	SP	1,890	37	24 (1866)	12 (1878)	151	-3	-
64	2,222	7	SP	1,890	49	46 (1844)	15 (1875)	151	-6	-
65	2,223	6	SP	1,890	30	18 (1872)	12 (1878)	151	-3	-
66	2,224	6	SP	1,890	46	43 (1847)	15 (1875)	151	-6	-
67	2,246	7	NP	1,903	38	17 (1886)	14 (1889)	83	8	Nw (To Repair)
68	2,304	12	WM	1,935	42	8 (1927)	5 (1930)	833	48	Wk (Irrigation)
69	2,347	2 /55	EL	2,073	186	172 (1901)	119 (1954)	68	73	Ab (To Repair)
70	2,430	10	NP	1,890	32	32 (1858)	6 (1884)	379	3	-
71	2,522	4 /56	WM	1,943	52	51 (1892)	46 (1897)	112	16	-
72	2,523	5	WM	1,903	57	53 (1850)	30 (1973)	151	-9	Nw (-)
73	2,534	6	SP	1,897	22	15 (1882)	17 (1880)	220	-2	-
74	2,535	6	WM	1,896	13	7 (1889)	7 (1889)	227	7	Nw (-)
75	2,536	6	WM	1,905	10	5 (1900)	5 (1900)	190	8	Nw (-)
76	2,537	6	WM	1,890	16	8 (1882)	3 (1887)	227	5	Nw (-)
77	2,538	6	WM	1,902	14	12 (1890)	10 (1892)	227	10	Wk (Irrigation)
78	2,539	7	WM	1,905	12	-	5 (1900)	151	8	Nw (-)
79	2,536	2 /57	SP	1,887	30	6 (1881)	5 (1882)	485	0	Wk (Irrigation)
80	2,657	4	WM	(1,900)	33	3 (1887)	23 (1877)	228	-5	-
81	2,659	3	WM	(1,900)	24	9 (1881)	8 (1882)	0	10	Wk (Irrigation) Drought in dry season
82	2,660	3	WM	1,890	25	20 (1870)	20 (1870)	484	-2	Wk (Irrigation)
83	2,661	4	WM	(1,900)	33	20 (1880)	21 (1879)	531	-3	-
84	2,701	10 /59	WM	1,890	48	48 (1842)	7 (1883)	0	-1	-
85	2,703	5 /57	WM	1,890	31	3 (1887)	3 (1887)	471	5	Nw (-)
86	2,705	7	WM	(1,920)	31	19 (1901)	17 (1903)	1,710	20	-
87	2,706	8	WM	1,920	62	39 (1881)	39 (1881)	4,710	-2	Nk (Irrigation)
88	2,813	7 /58	WM	1,905	63	63 (1842)	41 (1864)	225	-20	-
89	2,823	9	SM	2,143	306	265 (1878)	260 (1883)	112	-1	Ab (Saline Water)

Table G.2.19 LIST OF EXISTING BOREHOLES (4/5)

No.	Borehole No. C -	Complete Mon./Year	Location	Elevation m	Total Depth m	Struck Level Depth, Eleva. m	Rest Level Depth, Eleva. m	Discharge lit./min.	Difference be. W.L. m	Remarks
90	2,863	-	SP	1,890	153	-	-	-	-	-
91	2,883	1 /60	EM	(1,950)	107	107 (1813)	53 (1867)	120	13	Wk (Domestic)
92	2,885	-	WM	2012	377	-	-	-	-	Ab (Geothermal)
93	2,886	-	WM	2,012	939	-	-	-	-	Ab (Geothermal)
94	2,997	1 /60	SM	2,164	320	284 (1880)	28 (2136)	129	253	Nw (Saline Water)
95	3,064	8	WM	1,897	18	15 (1882)	15 (1882)	-	-1	-
96	3,216	-	NP	1,890	43	6 (1884)	5 (1885)	75	0	Ab (Under Lake Water)
97	3,217	-	NP	1,890	43	6 (1884)	5 (1885)	75	0	Ab (Under Lake Water)
98	3,289	4 /64	NP	1,897	79	-	-	150	-	Wk (Irrigation)
99	3,292	5	NP	1,897	76	76 (1821)	8 (1889)	242	2	-
100	3,298	5	NP	1,903	40	40 (1863)	5 (1898)	300	11	Ab (Saline Water)
101	3,299	6	NP	1,897	40	3 (1894)	2 (1895)	300	8	Ab (Saline Water)
102	3,365	11 /65	NP	1,899	82	15 (1884)	11 (1888)	-	2	Wk (Irrigation)
103	3,366	10	NP	1,899	77	14 (1885)	10 (1889)	-	3	Wk (Irrigation)
104	3,417	12 /66	NP	1,903	92	46 (1887)	11 (1892)	76	6	-
105	3,459	9 /67	NP	1,905	62	39 (1860)	17 (1888)	303	2	-
106	3,472	1 /68	NP	1,900	76	14 (1886)	11 (1889)	288	3	Wk (Domestic)
107	3,551	2 /69	NP	1,897	77	6 (1891)	5 (1892)	273	5	Nw (Saline Water)
108	3,616	9 /67	WM	(1,920)	57	24 (1896)	22 (1898)	-	12	-
109	3,674	4 /70	WM	1,890	31	6 (1884)	6 (1884)	376	-2	-
110	3,675	3	NP	1,897	61	9 (1888)	-	-	-2	Wk (Irrigation)
111	3,676	2 /68	NP	1,900	92	92 (1808)	14 (1886)	-	0	Wk (Irrigation)
112	3,677	2	NP	1,902	91	18 (1884)	15 (1887)	-	1	Wk (Irrigation)
113	3,678	4 /70	NP	1,905	73	21 (1884)	17 (1888)	-	0	Wk (Irrigation)
114	3,740	1 /71	SP	1,900	36	21 (1879)	17 (1883)	83	-3	-
115	3,767	5	WM	(1,900)	72	37 (1863)	27 (1873)	3,011	-13	-
116	3,924	6 /73	SP	1,888	38	11 (1877)	7 (1881)	6	-4	-
117	3,929	7	NP	1,896	61	17 (1879)	16 (1880)	533	-5	-
118	4,057	9 /74	SP	(1,905)	61	6 (1899)	3 (1902)	283	17	Wk (Irrigation)
119	4,155	8 /75	EM	1,929	183	143 (1786)	34 (1895)	545	11	Wk (Irrigation)

Table G.2.20 LIST OF EXISTING BOREHOLES (5/5)

No.	Borehole No. C -	Complete Mon./Year	Location	Elevation m	Total Depth m	Struck Level Depth, Eleva. m	Rest Level Depth, Eleva. m	Discharge lit./min.	Difference be. W.L. m	Remarks
120	4,157	6 /75	NP	1,900	78	18 (1882)	11 (1889)	1,833	5	-
121	4,161	8	NP	1,900	52	31 (1869)	16 (1884)	600	0	Nw (Little Water)
122	4,168	9	NP	(1900)	52	48 (1852)	17 (1883)	600	-2	-
123	4,177	9	NP	1,920	52	42 (1878)	16 (1904)	908	19	-
124	4,178	11	NP	1,905	52	25 (1880)	16 (1889)	600	4	Nw (Little Water)
125	4,208	2 /76	NP	1,889	61	61 (1828)	6 (1883)	650	-1	-
126	4,209	2	NP	1,889	62	62 (1827)	4 (1885)	650	1	-
127	4,301	3 /77	NP	1,920	110	55 (1865)	33 (1887)	524	3	-
128	4,397	9	SP	-	25	17 (-)	7 (-)	0	-	Wk (Domestic)
129	4,420	- /77	SP	-	25	17 (-)	7 (-)	-	-	-
130	4,500	-	WM	(1,900)	213	42 (1858)	15 (1885)	325	1	Wk (Irrigation)
131	4,501	4 /77	WM	1,905	61	42 (1863)	15 (1890)	0	6	Wk (Irrigation)
132	4,555	8 /78	NP	(1,945)	128	80 (1865)	28 (1917)	270	31	-
133	4,591	- /79	WM	(1,900)	45	23 (1877)	21 (1879)	227	-8	-
134	4,986	6 /81	SP	(1,900)	54	5 (1895)	5 (1895)	690	9	-
135	4,989	7	SP	(1,890)	25	2 (1888)	1 (1889)	675	3	-
136	5,002	9	EL	2,230	186	160 (2070)	-	152	183	Wk (Irrigation)
137	6,379	9 /85	EM	1,951	80	70 (1881)	60 (1891)	97	6	-

Note:
1) This list is made up based on the Borehole Record and Location Map of MOWD.
2) "Location" is indicated with the classification of the Team.

NP : North Plain　EM : East Piedmor　SP : South Plain
WM : West Piedmont　EL : East Plateau　SM : South Piedmont

3) "Elevation" indicated in parenthesis is corrected one when it is very different from that confirmed at the site or that on the Location Map.
4) "Struck Level" is the deepest one if there are many.
5) "Discharge" means 60% of the yield (maximum discharge), according as MOWD.
6) "Difference be W.L." means that the difference between Rest Level and Lake Water Level which is as of completion date of that borehole.
7) In "Remarks"

– : Unknown, Ab : Abandoned and its reason in parenthesis, Nw : Not working and its reason in parenthesis,
Wk : Working and its main purpose in parenthesis

8) As far as confirmed, there are more 17 working and eight not working boreholes within those being not identified Borehole Number. These probably are included in the unkown in this list.

Table G.2.21 Characteristics of Boreholes in Each Classified Location (1/2)

Location	Borehole Number nos	Elevation m	Total Depth m	Struck Level (Depth) m	Rest Level (Depth) m	Discharge lit./min.	Difference be. W.L. m	Area
NP (North Plain)	31	1,889 to 1,955 (1,903.4)	32 to 241 (71.5)	3 to 223 (38.8)	2 to 193 (18.8)	61 to 1,833 (404.8)	-33 to 48 (4.4)	1 to 78 (21.1)
SP (South Plain)	35	1,887 to 1,923 (1,896.7)	22 to 153 (44.3)	2 to 70 (27.4)	1 to 46 (15.4)	0 to 690 (161.5)	-9 to 17 (-1.0)	0 to 44 (14.1)
EL (East Plateau)	7	2,073 to 2,240 (2,136.4)	76 to 256 (157.3)	13 to 172 (111.0)	76 to 126 (107.0)	38 to 152 (87.3)	73 to 183 (124.0)	2 to 53 (20.3)
WM (West Piedmont)	39	1,890 to 2,012 (1,910.0)	10 to 939 (76.6)	3 to 119 (27.6)	3 to 100 (19.7)	0 to 4,710 (459.0)	-20 to 46 (2.0)	-20 to 41 (7.2)
EM (East Piedmont)	15	1,905 to 2,019 (1,953.9)	46 to 183 (97.1)	9 to 143 (80.8)	9 to 101 (45.7)	20 to 545 (206.4)	-14 to 77 (22.3)	0 to 109 (34.4)
SM (South Piedmont)	10	1,900 to 2,164 (2,010.9)	33 to 320 (161.7)	27 to 284 (126.2)	13 to 260 (84.8)	65 to 273 (120.6)	-1 to 253 (37.0)	5 to 256 (41.4)
Area	137	1,887 to 2,240 (1,968.6)	10 to 939 (101.4)	2 to 284 (68.6)	1 to 260 (48.6)	0 to 4,710 (239.9)	-33 to 253 (31.5)	-20 to 256 (23.1)

Note : "Difference be. Sl & RL" means "Rest Level minus Struck Level"

Table G.2.22 Characteristics of Boreholes in Each Classified Location (2/2)

	Description
NP	Elevation is low Total depth and Rest level (depth) are shallow Discharge is highly Differences between Struck and Rest level (Degree of confined pressure) is moderately Rest level is almost the same to Lake level
SP	Elevation is the lowest Total depth and Rest level are the shallowest Discharge is slightly Degree of confined pressure is slightly Rest level is almost the same to Lake level
EL	Elevation is the highest Total depth is deep and Rest level is the deepest Discharge is the least Degree of confined pressure is moderately Rest level is the highest from Lake level
WM	Elevation, Total depth and Rest level are almost the same to those of "NP" Discharge is the most plenty Degree of confined pressure is the least Rest level is almost the same to the Lake level
EM	Elevation is moderately Total depth, Rest level and Discharge are also moderately Degree of confined pressure is high Rest level is higher than Lake level
SM	Elevation is high Total depth is the deepest Rest level is deep Confined pressure is the highest Rest level is higher than Lake level

Table G.2.23 Number of Farms by Land Holding Size

Land holding size (acre) / Location of the lake	Number of farms East	West	South	North	Total
Less than 100	11	2	4	4	21
101 - 300	5	3	1	1	10
301 - 500	1	1	-	1	3
501 - 1,000	2	-	-	2	4
1,001 - 5,000	-	-	3	3	6
5,001 - 10,000	1	1	-	-	2
More than 1,000	-	1	-	-	1
Total	20	8	8	11	47

Table G.2.24 Cultivated Area by Crops

Unit : acre

Kind of crops	East	West	South	North	Total
Meadow	362	825	87	2,269	3,543
Vegetable	475	152	20	836	1,483
Fruit	156	60	-	35	251
Flower	25	220	1,182	204	1,631
Total	1,018	1,257	1,289	3,344	6,908

Table G.2.25 Farm Land in East Side of Lake Naivasha (Acres)

Code	Farms	Farm Land				Fodder Crops			Horiculture Crops									Enterprise
		Holding size	Cultivated area	Irrigated area	Non Irrigated	Lucern	Pasture	Maize	Aspara carrots	French beans	Cabbegs	Grapes	Oranges	Straw-berries	Apples	Flower Bulbs	Cutflowers	
2	ABERDARE	145	90	80	10				30	25	25							Vegetables
3	INDU FARM	400	400	130	270				10	80	40							Vegetables
7	LONGONOT HORTICULTURE	1,000	23	23						10				13				Mixed
9	MASAKA FARM	30	20	20		2	15						3					Livestock
10	S.N. MWAURA	36	23	23				11	8	3	1							Begetables
11	CHEDIRELWE	130	84	84		30			10			30			14			Mixed
13	FRAMINGO	200	100	100					48					30		12	10	Flower
14	PEPPINO	40	30	26	4	6		4		12	4							Mixed
15	CLAUSE	20	7	7		1		5					1					Livestock
18	OSOTUA	20	10	10		2	3	2					3					Livestock
20	J.T. ARMITAGE		(Lake)															Fishery
21	KEDONG FARM	96000	(Natural grass)															
22	O. BARTON	52	35	35		35	30						5					Livestock
24	OS/RUA	200	160	160					30	80	50							Begetables
25	LAKE MAIVASHA	50	35	35								35						Fruits
29	LAKE CROP	20	7	7					5						2			Mixed
31	SANCTVARY	566	150	150		15	120	15										Livestock
39	BOFFAR	175	100	100		10	17	73										Livestock
45	KIJARE HILL	29	20	20									20					Fruits
46	HORTITEC	10	9	8	1			1	1	2	1						3	Mixed
	TOTAL	3,123	1,303	1,018	285	101	185	111	142	212	121	65	32	43	16	12	13	

Table G.2.26 Farm Land in West Side of Lake Naivasha (Acres)

Code	Farms	Farm Land				Fodder Crops			Horiculture Crops									Enterprise
		Holding size	Cultivated area	Irrigated area	Non Irrigated	Lucern	Pasture	Maize	Aspara carrots	French beans	Cabbegs	Grapes	Oranges	Straw-berries	Apples	Flower Bulbs	Cut-flowers	
1	KOGONI FARM	13,500	80	80			30	50										Livestock
16	KINJA NURSERY	160	25	17	8				5		2		10					Mixed
17	OLOLORAI	500																No-farming
26	NINI FARM	100	85	85		5		25	15	39	1							Vagetables
32	LENTOLIA	109	15	15		15												Livestock
41	SHALIMAR-1	30	30	30					30									Begetables
42	SHALIMAR-2	460	300	300					60					50			190	Mixed
43	LOLDIA LTD	6,000	700	700		100	200	400										Livestock
44	NDERIT	70	30	30													30	Flower
48	MUNDUI	1,145																No-farming
	TOTAL	22,074	1,265	1,257	8	120	230	475	110	39	3	0	10	50	0	0	220	

Table G.2.27 Farm Land in South Side of Lake Naivasha (Acres)

Code	Farms	Farm Land				Fodder Crops			Horiculture Crops									Enterprise
		Holding size	Cultivated area	Irrigated area	Non Irrigated	Lucern	Pasture	Maize	Aspara carrots	French beans	Cabbegs	Grapes	Oranges	Straw-berries	Apples	Flower Bulbs	Cut-flowers	
4	LAKE SIDE	1,500	94	94			77		17									Mixed
5	SHER AGENCY	132	132	132													132	Flowers
6	GOLDSMITH	32	4	4												4		Flowers
27	DSERIAN	5,000	500	500													500	Flowers
28	SULMAC	4,455	500	500													500	Flowers
30	LONGONOT FARI	89	29	29			10		3								16	Flowers
40	SHANGARI	30	30	30													30	Flowers
47	ALBIDA PARK	20																Villa
	TOTAL	11,258	1,289	1,289	0	0	87	0	20	0	0	0	0	0	0	4	1,178	

Table G.2.28 Farm Land in North Side of Lake Naibasha (Acres)

Code	Farms	Farm Land				Fodder Crops			Horiculture Crops									Enterprise
		Holding size	Cultivated area	Irrigated area	Non Irrigated	Lucern	Pasture	Maize	Aspara. Carrots	French beans	Cabbegs	Grapes	Oranges	Straw-berries	Apples	Flower Bulbs	Cut-flowers	
8	BRIXIA LTD.	1,400	401	401					100	100	200					1		Vegetables
12	PAN VEGETABLE	400	300	300			30		220	50								Vegetables
19	MANERA FARM	2,440	1,500	1,500		600	375	525										Livestock
23	FRNCIS FARM	20	20	20		8		3	9									Mixed
33	NORTH LAKE	200	93	93		17		73				1	2					Liverstock
34	MALEWA BAY	750	200	200			148			20			17		15			Livestock
35	MARI LAND	18	18	18					8		10							Vegetables
36	KIHOTO FARM	18	8	8					2	3	3							Vegetables
37	MATUYA ESTATE	2,700	700	470	230	30	40	100		100							200	Mixed
38	JASHO FARM	18	14	14						9	2						3	Vegetables
49	GOV. FARM	800	320	320		30	270	20										Livestock
	TOTAL	8,764	3,574	3,344	230	685	863	721	339	282	215	1	19		15	1	203	

Table G.2.29 Total Survey Area Aroun Lake Naibasha (Acres)

Compass direction	Farm Land				Fodder Crops			Horiculture Crops								
	Holding area	Cultivated area	Irrigated area	Non Irrigated	Lucern	Pasture	Maize	Aspara carrots	French beans	Cabbegs	Grapes	Oranges	Straw-berries	Apples	Flower Bulbs	Cut-flowers
Eastern	3,123	1,303	1,018	285	66	185	111	142	212	121	65	32	43	16	12	13
Western	22,074	1,265	1,257	8	120	230	475	110	39	3		10	50			220
Southern	11,258	1,289	1,289			87		20							4	1,178
Northern	8,764	3,574	3,344	230	685	863	721	339	282	215	1	19		15	1	203
	45,219	7,431	6,908	523	871	1,365	1,307	611	533	339	66	61	93	31	17	1,614

Table G.2.30 Fish Production of Lake Naivasha

Year	Tilapia		Black bass		Cray Fish		Total	
	Weight value		Weight value		Weight value		Weight value	
	(kg)	(Kshs)	(kg)	Kshs)	(kg)	(Kshs)	(kg)	(Kshs)
1974	34,216	n.a.	4,573	n.a	n.a	n.a	38,789	n.a
1975	n.a.	n.a	n.a	n.a	n.a	n.a	44,000	n.a
1976	67,167	356,034	10,353	62,090	n.a	n.a	77,520	418,124
1977	48,429	268,054	22,996	148,930	n.a	n.a	71,425	416,984
1978	255,381	1,131,510	29,526	252,885	n.a	n.a	284,907	1,384,395
1979	459,338	2,421,826	32,545	198,783	n.a	n.a	482,883	2,620,609
1980	452,839	3,234,728	18,082	145,173	n.a	n.a	470,921	3,379,901
1981	265,069	2,492,006	3,819	38,964	n.a	n.a	268,888	2,530,970
1982	339,069	4,290,500	13,008	156,681	58,525	1,287,550	410,602	5,734,731
1983	534,608	6,084,698	41,001	563,724	116,165	2,929,879	691,774	9,578,301
1984	212,733	2,366,529	64,162	874,112	43,340	1,083,560	320,235	4,324,201
1985	146,000	1,609,000	60,000	846,000	39,000	1,007,000	245,000	3,462,000
1986	384,173	3,724,623	83,607	961,054	45,372	254,110	513,152	4,939,787
1987	204,130	2,550,129	19,881	274,007	92,008	472,110	316,019	3,296,246
1988	22,969	465,395	15,063	366,469	n.a	n.a	-	-

Source: Fisheries Dept., Min. of Regional Development

Table G.2.31 Phytoplankton Communities in Lake Nakuru

Date:15, June, 1990

Method:Van don water bottle(500mℓ)

Unit:cells/mℓ

No.	Division	Class	Species / Station / Layer	No. 1 Upper	No. 1 Bottom	No. 8 Upper	No. 8 Bottom
1	Cyanophyta	Cyanophyceae	Anabaena sp. A	(91)	(52)	(4)	(4)
2			Anabaena sp. B	(108)	(60)	(40)	(13)
3			Lyngbya contorta	(4)		(4)	(4)
4			Spirulina platensis	(9)	(9)	(17)	(22)
5			Spirulina sp.	(9)	(4)	(26)	(4)
6	Pyrophyta	Cryptophyceae	Cryptomonadales	208,000	186,000	179,000	147,000
7	Chrysophyta	Bacillariophyceae	Nitzschia spp.	17	13	17	39
8			Synedra sp. A	91	4	69	86
9	Euglenophyta	Euglenophyceae	Euglenaceae	255	190	52	26
			Total (cells/mℓ)	208,584	186,332	179,229	147,198

※( )=colony number

Table G.2.32 Zooplankton Communities in Lake Nakuru

Date:18, 19, June, 1990

Method:ventrical haul with planktonnet

Unit:individuals/ℓ

No.	Phylum	Class	Speices / Station / Layer(m)	No. 1 0~1.0	No. 8 0~1.2
1	Protozoa	Ciliata	Ciliata	0.5	4.0
2	Aschelminthes	Rotatoria	Brachionus calyciflorus	163.0	22.9
3			Br. caudatus		0.1
4			Brachionus sp.	113.0	40.5
5			Hexarthra sp.	2.9	11.6
6			Synchaeta spp.		0.8
7	Arthropoda	Crustacea	Bosmina sp.	0.2	
			Total (individuals/ℓ)	279.6	79.9