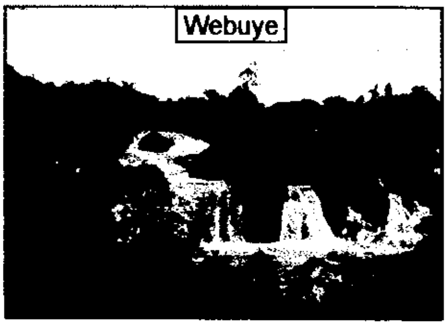
JAPAN INTERNATIONAL COOPERATION AGENCY

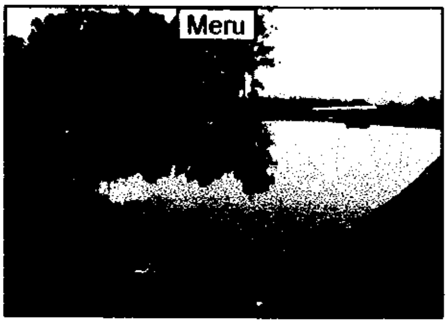
REPUBLIC OF KENYA

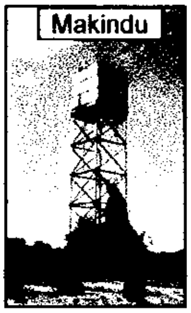
MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES

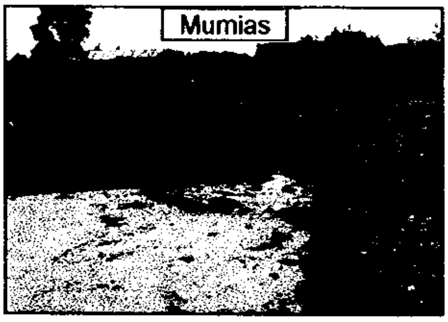
THE STUDY ON INSTITUTIONAL IMPROVEMENT AND REHABILITATION OF WATER SUPPLY SYSTEMS FOR 10 LOCAL TOWNS IN THE REPUBLIC OF KENYA

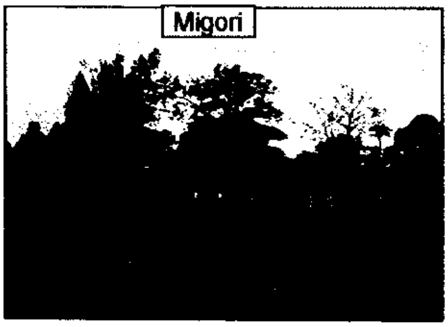
No.1

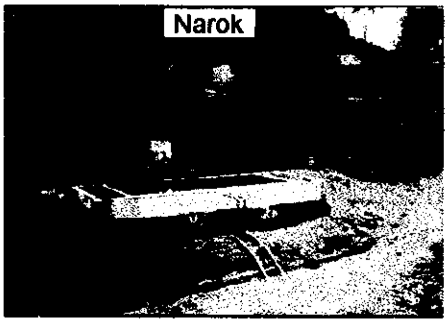


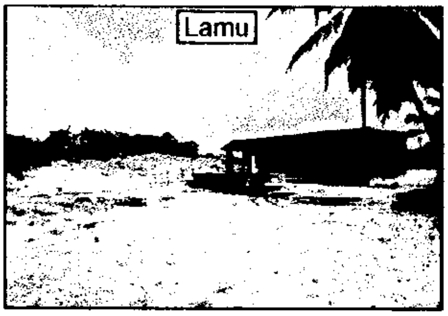


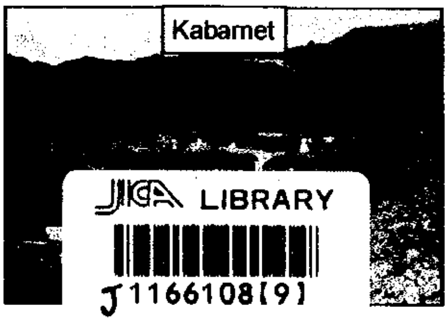


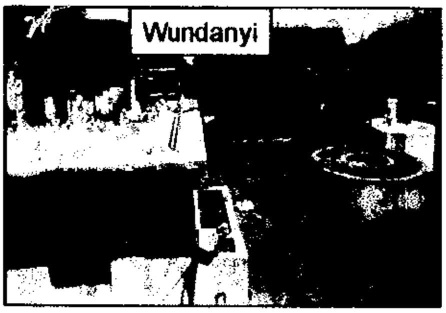












FINAL REPORT

Volume 2J : Main Report (including Appendices) - Mumias Town

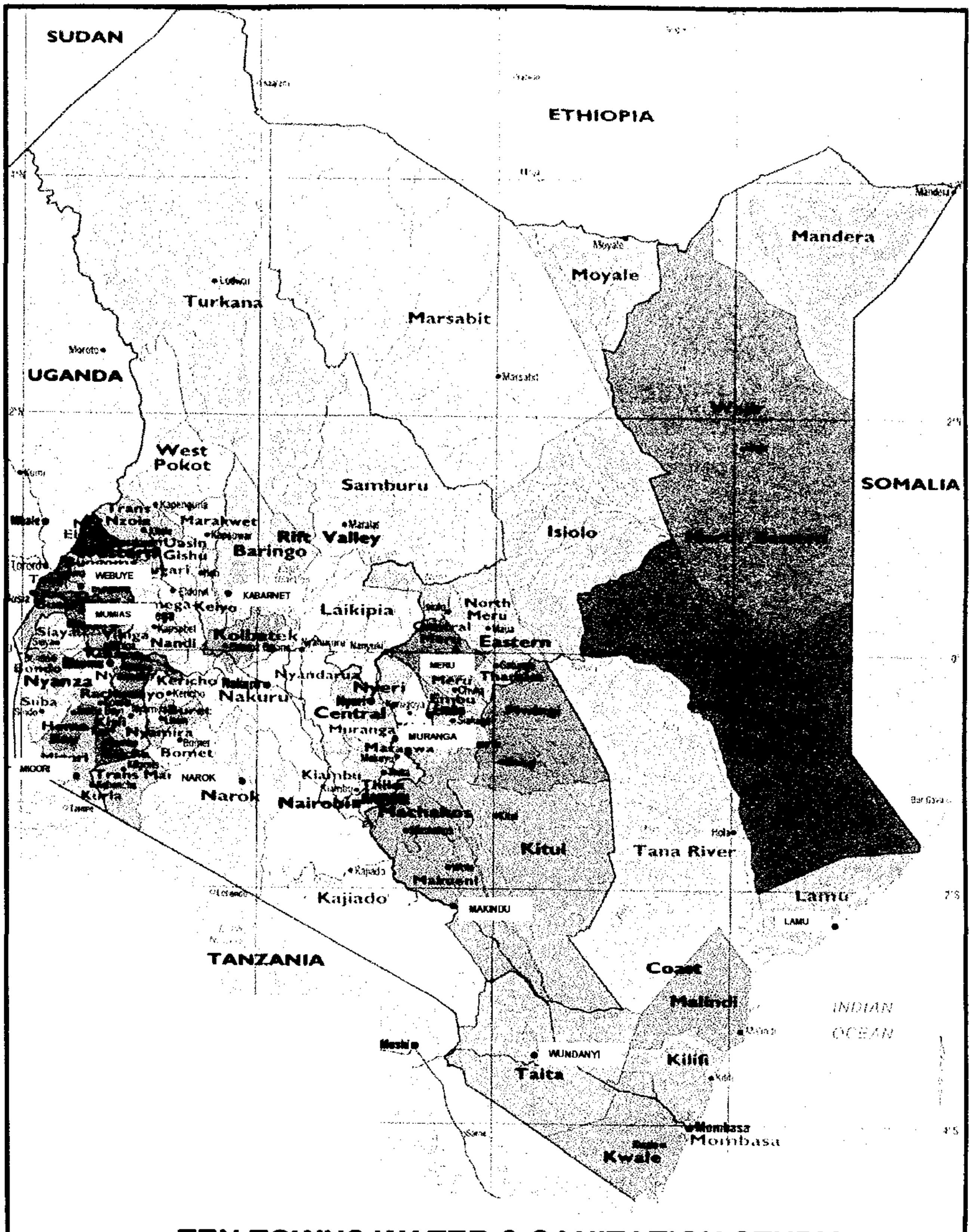
FEBRUARY 2001

DIC Development Impact Consulting

Engineering and Utility Management Ltd.

GIBB Eastern Africa
LAWGIBB Group Member

Gibb Eastern Africa Ltd.



TEN TOWNS WATER & SANITATION STUDY

TOWNS LOCATION MAP

DIC Development Impact Consulting

EAU

GIBB Eastern Africa
LAWGIBB Group Member

MUMIAS WATER SUPPLY

TABLE OF CONTENTS

LIST OF TABLES

Chapter 2

Chapter 3

Chapter 4

1.1 Chapter 5

1.2 Chapter 6

Chapter 7

LIST OF FIGURES

LIST OF ABBREVIATIONS

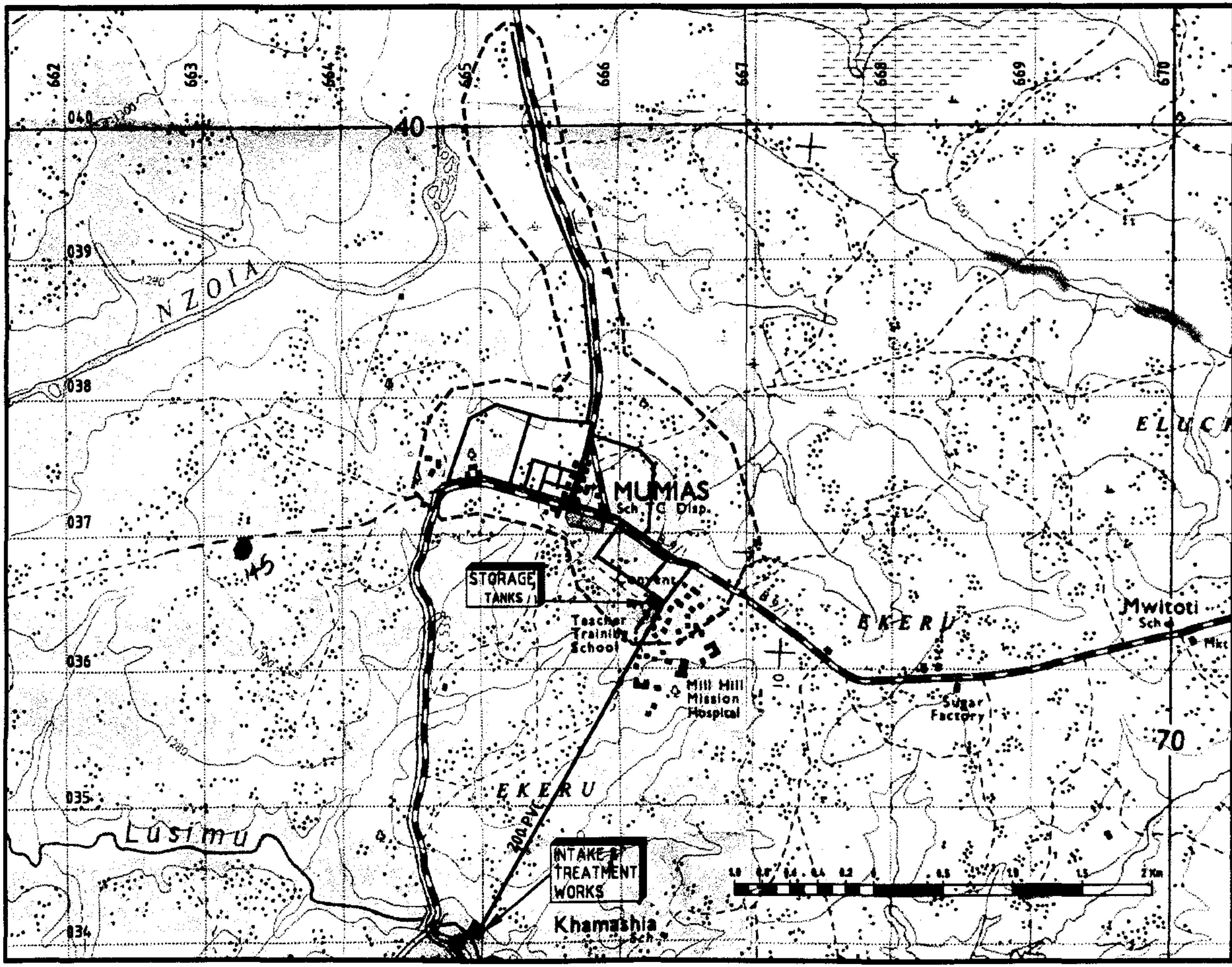
AC	Asbestos Cement (Pipe)
AFW	Accounted for water
AG	Attorney General
AIDS	Acquired Immune Deficiency Syndrome
AIE	Authority to Incur Expenditure
AMREF	African Medical Research Foundation
ASK	Agricultural Society of Kenya
ATP	Ability to Pay
bgl	Below ground level
BH	Borehole
BOT	Board of Trustees
BPT	Break Pressure Tank
CBD	Central Business District
CBR	Cost Benefit Ratio
CIM	Centre for International Migration
CMT	Core Management Team
CTB	Central Tender Board
CV	Contingent Valuation
CWS	Community Water Supplies
DAF	Daily Average Flow
DCO	District Commissioner's Office
DDC	District Development Committee

DWD	Department of Water Development
Dia	Diameter
DTO	District Treasury Office
DWE	District Water Engineer
DWF	Dry Weather Flow
DWO	District Water Office(r)
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
ENEP	El-Nino Emergency Project
FIRR	Financial Internal Rate of Return
FY	Financial Year
GAA	German Agro Action
GI	Galvanized Iron
GoK	Government of Kenya
Gph	Gallons per hour
GPS	Global Positioning System
GTZ	German Technical Assistance
H	Head
Ha	Hectares
HO	Head Office
HQ	Headquarters
IEE	Initial Environmental Examination
ITCZ	Inter-tropical Convergence Zone

JICA	Japan International Cooperation Agency
KEFINCO	Kenya-Finland Co-operation
KEWI	Kenya Water Institute
Km	Kilometer
Km^2	Square Kilometers
KP&LC	Kenya Power and Lighting Company
KR	Kenya Railways
Kshs	Kenya Shillings
L	litre
LA's	Local Authorities
L/c/d	Litres per capita per day
LPO	Local Purchasing Order
L/sec	Litres per second
M^3/day	Cubic meters per day
M^3/hr	Cubic meters per hour
MENR	Ministry of Environment and Natural Resources
MoLG	Ministry of Local Government
MTB	Ministerial Tender Board
MW	Mega-watts
NAWARD	National Water Resources Database
NEAP	National Environment Action Plan
NEMA	National Environmental Management Authority
NGO	Non-Governmental Organisation

NPV	Net Present Value
NTU	Nephelometric Turbidity Units
NWC&PC	National Water Conservation and Pipeline Corporation
NWMP	National Water Master Plan
ODA	Official Development Assistance
O&M	Operation and Maintenance
PE	Polyethylene Pipe
PSP	Private Sector Participation
PVC	Polyvinyl Chloride
PWO	Provincial Water Office(r)
Q	Discharge
RDF	Rural Development Fund
RER	Revenue Expenditure Ratio
RGS	River Gauging Station
RHS	Random Households Survey
SIDA	Swedish International Development Agency
SS	Subordinate Staff
STD	Subscriber Trunk Dialing
STW	Sewage Treatment Works
TDS	Total Dissolved Solids
ToT	Training of Trainers
T-Works	Treatment Works
UFW	Unaccounted for water

UNICEF	United Nations Children's Fund
WHO	World Health Organization
WMS	Welfare Monitoring Survey
WRAP	Water Resources Assessment Project
WS	Water System
WSS	Water Supply System
WTP	Water Treatment Plant



NORTH

LEGEND

WATER PIPELINE

DISTRIBUTION AREA

Client: JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa

Project Title: TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title: MUMIAS TOWN EXISTING WATER SUPPLY

Date: JAN 2001 | Fig. No. 1.1

1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Kenya's water and sanitation sector is in critically poor condition. Like in many developing countries, the sector is plagued by a series of problems. These problems have arisen because of lack of technically sound operation and maintenance practices resulting in a backlog in rehabilitation, and above all, poor utility management. The existing institutional framework and organizational procedures result in bottlenecks and failure to create required authority and responsibility capacity at the most beneficial levels. Lack of autonomy for the managers of water utilities at all levels is one of the key causes for sustained inferior performance.

The tremendous pressure occasioned by population increase, rural-urban migration and unplanned settlements have strained the water and sewerage schemes beyond the original design capacities.

Periodic technical and financial reviews of water services in Kenya and the Aftercare Study on Kenya's National Water Master Plan have revealed that there is need for serious re-evaluation of management of water and sanitation utilities to meet the targets of effective service delivery in support of the integrated development plans. Decentralization of decision making and management to the local levels and transferring to the private sector activities that can be carried out without compromising social, health or vital economic requirements of the population are of cardinal importance.

Against this background, the Government of Kenya recently approved the National Water Policy paving the way for legislative changes in the Laws of Kenya that touch on water activities. The changes aim at rationalizing management, decentralizing operations to the local level, creating the necessary regulatory framework and activating private sector participation in the sector, in order to obtain a more responsive management system that ensures efficient service delivery and project sustainability at the most economical cost.

JICA, one of Kenya's leading development partners, would like to help create a sustainable environment for water and sanitation service delivery systems, by supporting formulation and development of workable management arrangements in the water sector.

The Study on Institutional Improvement and Rehabilitation of Water Supply Systems for Ten Local Towns is being undertaken in order to provide Kenya with feasible, viable and implementable options that are sensitive to local conditions, especially social, environmental, economic and political.

The findings, recommendations and work plans derived from this study may then be used to develop a more comprehensive framework for rehabilitation and extension of water services to meet development objectives as enshrined in the National Poverty Eradication Plan for the rest of the nation.

The use of local initiatives such as Kitale and Nakuru to investigate the potential and/or constraints for commercialization of water services within local authority setting will be a useful barometer for the future of the National Water Policy, which envisions decentralization of water activities to local authorities in urban areas. Malindi, which is under a partnership between the National Water Conservation and Pipeline Corporation and Gauff Utility Services, will provide another alternative for comparison of performance and benchmarking.

1.2 OBJECTIVES OF THE STUDY

The objectives of the study are:

(1) To obtain the baseline information regarding the water supply systems for the ten local towns;

(2) To recommend the institutional arrangement for effective water service delivery and rehabilitation plan of the relevant facilities in the project areas;

(3) To give advice on the application of the recommendation to the other areas in the Republic of Kenya.

1.3 SCOPE OF THE STUDY

The fundamental philosophy of this study hinges on the fact that without appropriate intervention in the water supply and sanitation sector, no major improvements in service delivery will be realized. This study focuses on ten (10) towns in the Republic of Kenya namely: Meru, Lamu, Kabarnet, Webuye, Mumias, Migori, Narok, Muranga, Makindu, and Wundanyi as a pilot programme of implementing the desirable interventions which will serve as a show case for replication in the rest of the country.

The interventions entail three main components, which must go hand in hand:

(1) To restore the water supply and sanitation facility to its original technical and functional capacity by undertaking the necessary physical rehabilitation.

(2) To put in place an appropriate institution to run the water supply and sanitation facility. This institution should be more responsive to the needs of, and directly answerable to the consumers. The institution should have the legal backing and formed in line with the current National Water Policy, which advocates active private sector participation in the water sector for more efficient service delivery.

(3) To put in place an appropriate technical team of operators, with the necessary skills and equipment and tools to take over the day to day operation and maintenance of the rehabilitated facility. It is envisaged that a team starting with an efficiently functioning facility free of major repairs and replacements, and with a good management backing,

stands a better chance of achieving a self-sustaining facility within a reasonable time span.

In order to achieve the foregoing intervention goals and the overall project objectives, the study entails a two-phase strategy for collecting the relevant data and information: a Preliminary and a Pre-feasibility phase.

The preliminary study covers review of relevant data and information, diagnostic survey of existing water supply and sanitation facilities, water demand projection, revision of water supply facility plan, cost estimation and evaluation, identification of the laws and regulations of environmental impact assessment, legal and regulatory framework on facility performance. It entails basic data collection, field reconnaissance and field inspection of the utilities to assess the current condition and situation of the water supply and sanitation schemes.

The pre-feasibility study phase covers establishing the socio-economic characteristics of the study area, assessment of surface water and groundwater potential, identification of institutional and legal constrains that affect improvement in operations of water facilities and determination of viable financial and commercial plans that ensure long-term sustainability of the facilities.

The pre-feasibility phase includes review of existing data, evaluation of the technical, socio-economic, institutional and financial aspects, formulation of water supply and sanitation facility rehabilitation plans, and formulation of preliminary technical and institutional development plans on which recommendations will be based.

In addition to the ten towns that constitute the pilot programme, operational experiences have been obtained from the towns which have been undergoing the commercialization approach, promoted by GTZ, i.e. Malindi, Kitale and Nakuru, for comparison purposes. The year 2010 has been chosen as a planning horizon.

1.4 COMPOSITION OF THE FINAL REPORT

The final report comprises of a total of two volumes as follows:

Volume 1: Executive Summary
Volume 2: Main Report

As indicated by their titles, Volume 1 is a summary of the study while Volume 2 is a presentation of the full town report including supporting and back-up data.

2 EXISTING PHYSICAL AND SOCIO-ECONOMIC CONDITIONS

2.1 GEOGRAPHY OF THE STUDY AREA (CLIMATE, TOPOGRAPHY, GEOLOGY ETC.)

2.1.1 Location

Mumias Municipality is located in the Mumias Division of Mumias-Butere District in the Western Province of Kenya. The municipal boundary encloses an area of over 200 km^2.

2.1.2 Topography

Mumias lies on the watershed between the Nzoia and Lusumu rivers, which converge some 10 km to the west of the town centre. The ground slopes gently down towards the Nzoia River in the north and the Lusumu River to the south. Levels range from 1,260 m AMSL near the water intake on the Lusumu River to 1,330 m AMSL at the town's storage site.

2.1.3 Geology

The are of Mumias is underlain by ubiquitous granite. Weathering of the rock has produced a brownish sandy clay loam soil that is often leached into laterite. The overburden depth is generally less than fifteen metres.

2.1.4 Climate

Annual rainfall in Mumias averages 1,900 mm. The annual rainfall increases to almost 2,000 mm towards Kakamega.

2.2 PHYSICAL INFRASTRUCTURE

2.2.1 Communications

2.2.1.1 Road links

Mumias lies on the C33 tarred road south of Bungoma. The town can also be reached using the C40 tarred road from Kakamega.

2.2.1.2 Air links

There is an airstrip at Ebutunga Estate in the sugar plantation.

2.2.1.3 Telecommunications

Telephone services and fax facilities are available in the town.

2.2.2 Power supply

Mumias is connected to the national power grid.

2.2.3 Water supply and sanitation infrastructure

This is the subject of the present study and a detailed evaluation of the water supply and sanitation infrastructure is included in the chapters that follow.

2.2.4 Existing and planned services

There are existing water, sewerage, electricity and telephone services in Mumias. The sewerage system is confined to serving a single estate of 170 houses.

2.2.5 Major industries

The major industry in the area is the Mumias Sugar Company that reportedly has 8,000 employees. The sugar factory operates its own water supply system and is not dependent on municipal supplies. The factory also operates its own waste stabilisation ponds.

2.3 EXISTING WATER RESOURCES, MANAGEMENT AND UTILISATION

2.3.1 Hydrogeology and occurrence of groundwater

The occurrence of groundwater in granite terrain depends on the extent to which the rocks have been weathered, jointed or fractured. Granite weathering through sheet jointing and exfoliation does not result in a thick regolith that can allow groundwater accumulation. Thus, most of the aquifers in the area are confined to fractures and joints.

The hydrogeological conditions in the Mumias area can be summarised as follows:

- Depth range to the main aquifer: 20 – 70 m.
- Depth range of water rest level: 2.5 – 10 m.
- Discharge range: 0 – 8 m^3/hr (best where mixed aquifers occur).
- Water quality: Generally fresh to brackish, neutral to slightly alkaline sodium bicarbonate waters. The ionic concentrations of iron may be high.

Aquifer recharge occurs by lateral underflow from recharge catchments and by local direct infiltration. Aquifers are likely to be limited.

2.3.2 Hydrology and surface water resources

The town is located on a watershed between the Nzoia and Lusumu rivers. The Nzoia River rises in the Cherangani Hills and the Lusumu River rises in the Nandi Hills. The catchments fall within Sub-Drainage Area 1ED of the Lake Victoria basin.

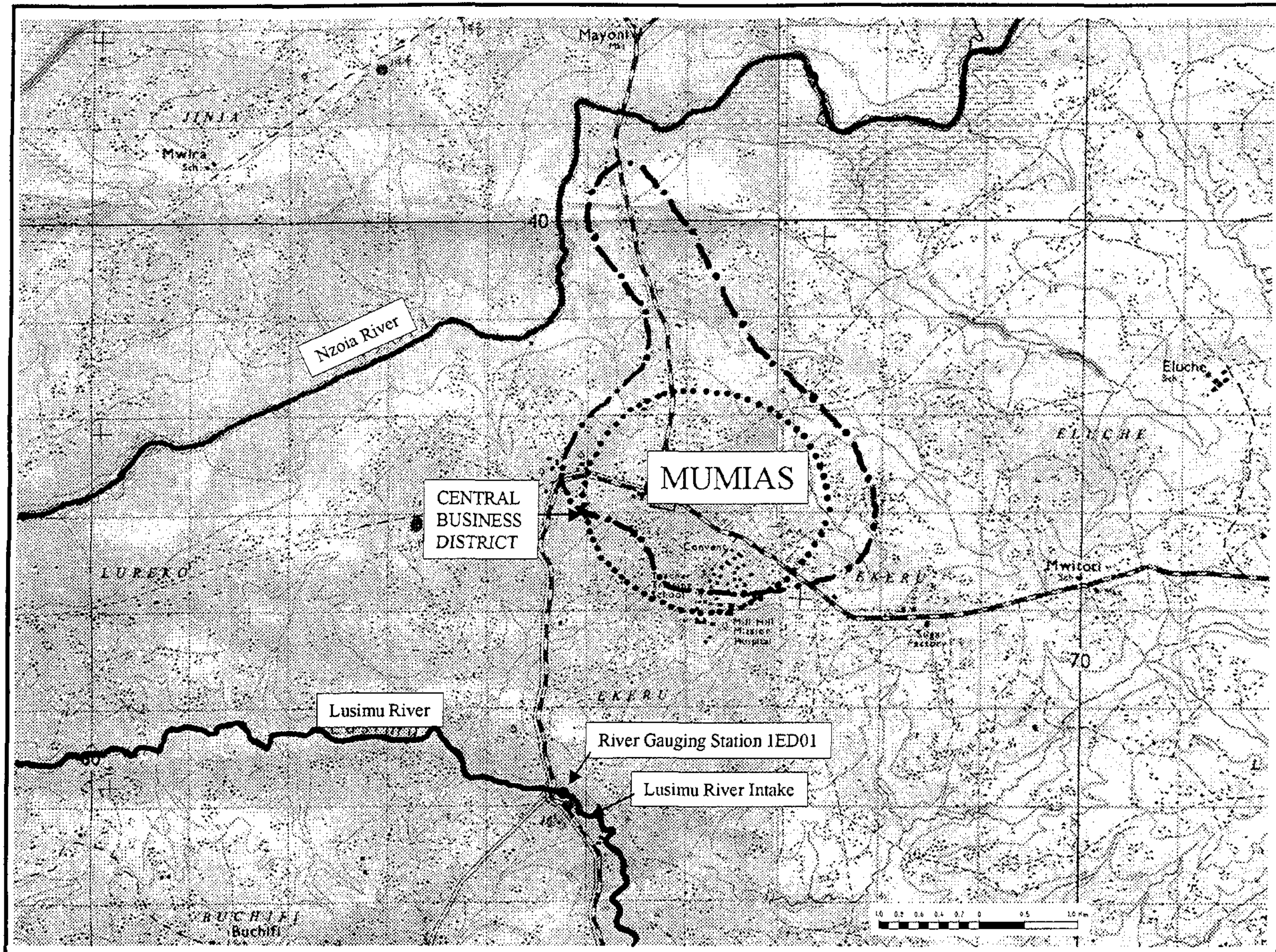
The rivers near Mumias are shown in Figure 2.1, and details of river gauging stations are presented in Table 2.1.

Table 2.1 Details of gauging stations

RGS No,	River	Latitude ***	Longitude ***	Station opened	Station closed	Rated	Catchment area (km^2)	Mean Annual Runoff (m^3/s)
1BD02	Nzoia	00°45' 40"	34°50' 40"	1946	1972		3,950	14.9
1EB02	Isukhu	00°15' 15"	34°45 '00"	1963	1985	Yes	359	9.0
1ED01	Lusumu	00°18' 33"	34°28' 50"	1951	1985	Yes	1,207	20.8

Source; JICA funded Aftercare Study National Water Master Plan Supporting Report, 1998.
****: The co-ordinates are incorrect and need to be corrected.*

The major source of water for public water supply in Mumias town is the Lusumu River. Non-dimensional flow duration curves for the Nzoia, Isukhu, and Lusumu rivers are presented in Figure 2.2. These curves have been abstracted from the *"Aftercare Study on the National Master Plan conducted by Japan International Cooperation Agency (JICA), 1998"*. As very little additional data has been collected since the time of the JICA study, the curves are applicable today.



NORTH

LEGEND

CURRENT WATER SUPPLY DISRIBUTION AREA

Client: JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa — LAWGIBB Group Member

Project Title: TEN TOWNS WATER SUPPLY & SANITATION STUDY

MUMIAS
Rivers &Gauging station RGS 1ED01 on Lusimu River

Date: DEC. 2000

Fig. No. 2.1

The flow duration curve shows the relationship between any given discharge and the percentage of time that the discharge is exceeded. The flow duration curve is derived from daily flow data by assigning daily discharges to class interval and counting the number of days within each interval. The proportion of the number of days above the lower limit of any given class interval is then calculated and plotted against the lower limit of the interval.

The 50% exceedence flow in Figures 2.2(a) to (c) is the daily discharge that was exceeded 50% of the time. The 100% exceedence flow is the flow that was exceeded 100% of the time during the flow sequence. Thus, the 100% exceedence value represents the lowest daily discharge on record.

Thus, the difference between the 90% and 100% exceedence flows corresponds to the available water resource. For consistency of approach, the same definition of reliable flow is adopted for this project.

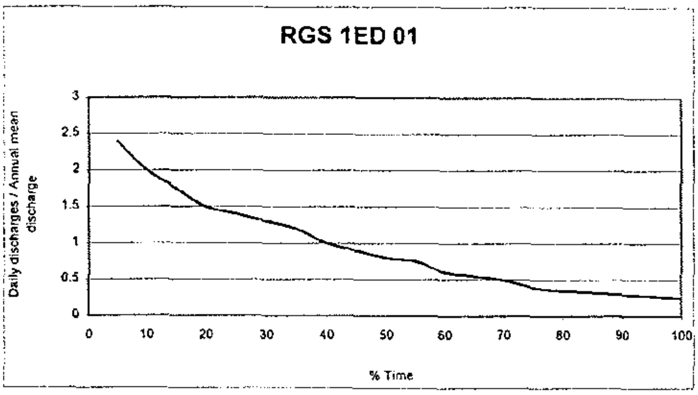


Figure 2.2(a) Flow duration curve for the Lusumu

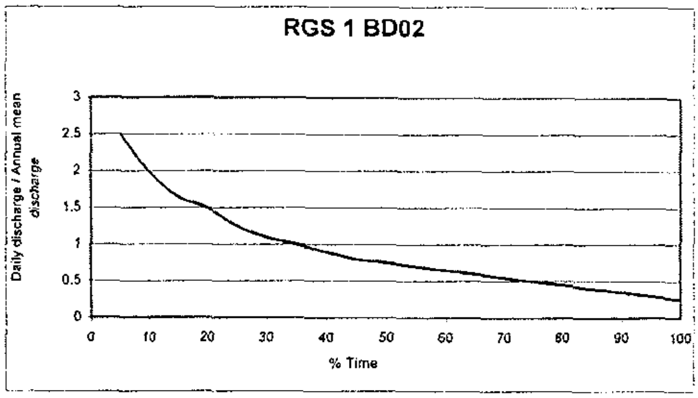


Figure 2.2(b) Flow duration curve for the Nzoia

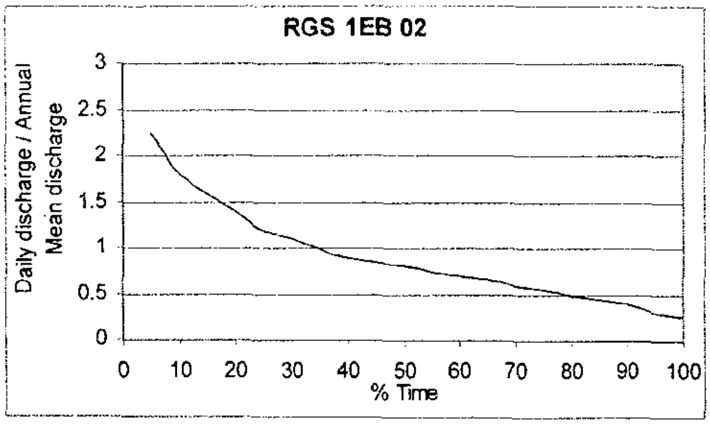


Figure 2.2(c) Flow Duration Curve for Isukhu

The JICA "*Aftercare Study*" defined the yield of an unregulated river source as follows:

- *"The reliable flow at a given site of a given river is defined to be a 90% dependable flow deducted by river maintenance flow ...", and*
- *"The 90% dependable flow is obtainable from the flow duration curve of the nearest gauging station ...".*
- The maintenance flow is defined as "*... the recorded daily minimum runoff of the river concerned".*

The flow characteristics for the rivers are presented in Table 2.2.

Table 2.2
Flow characteristics

Station reference number	**RGS 1BD02**	**RGS 1EB02**	**RGS 1ED01**
Mean annual runoff Q_{ave} m^3/sec	14.90	9.00	20.80
50% flow exceedence ratio Q_{50}/Q_{ave}	0.75	0.80	0.80
90% flow exceedence ratio Q_{90}/Q_{ave}	0.35	0.40	0.30
95% flow exceedence ratio Q_{95}/Q_{ave}	0.30	0.30	0.27
100%flow exceedence ratio Q_{100}/Q_{ave}	0.25	0.25	0.25

The comparison of source yields and water demand is presented **Table 2.3** for the Lusumu River RGS 1ED01.

Table 2.3
Comparison of surface water yield at RGS 1ED01 and water demand

	m^3/d
Present abstraction capacity	1,430
2000 water demand	14,895
2010 water demand	23,514
90 % exceedence flow	540,000
100 % exceedence flow	450,000
Water resource available	90,000

The available surface water resource is substantial. The current and future abstraction requirements are small in comparison.

2.3.3 Raw water quality

An analysis of raw water from the Lusumu River in 1972 shows colour of 60, a turbidity of 30 JTU, a pH of 7.3 and an alkalinity of 40 mg/l. The calculated ionic balance for this sample is shown in Table 2.4.

Table 2.4
Raw water quality analysis

Cations	mg/l	meq/l	Anions	mg/l	meq/l
NH_4^+	0.24	0.014	Cl^-	3	0.087
Na^+	8	0.348	NO_2^-	0.33	0.007
K^+	2	0.051	NO_3^-	0.04	0.001
Ca^{2+}	7	0.349	F^-	0.3	0.016
Mg^{2+}	2	0.165	HCO_3^-	48.8	0.800
$Fe^{2+,3+}$	0.8	0.036	CO_3^{2-}	0	0.000
Mn^{2+}	0.03	0.001	SO_4^{2-}	8	0.166
			PO_4^{3-}	ND	0.000
	Total	0.964		Total	1.077

The analytical error is only 0.113 meq/l. The principal concern with the raw water quality is the iron concentration of 0.8 mg/l, but this will reduce somewhat during clarification and will eventually precipitate after chlorination.

The JICA funded *National Water Master Plan* reports the sediment load of the Lusumu River as 142 mg/l.

2.4 SOCIO-ECONOMIC CONDITIONS

2.4.1 Administration

Mumias is a cosmopolitan town located in Mumias-Butere district in Western province approximately 400 kilometres west of Nairobi along the Kakamega-Bungoma road. The town was established as a market centre in 1956 and gradually attaining municipality status in 1997. It covers two locations, six sub-locations and seven wards with an area of 122 Km^2. The town is the administrative headquarters of Mumias division and its Central Business District (CBD) houses offices of the district officer, other divisional departmental heads, municipal, county council, Mumias Out-growers Company (MOCO) offices and offices of a few non governmental organisations operating in the locality. The town is a major business convergence centre for the hinterland as well as the expansive Mumias Sugar Factory especially on market days when urban visitation is at its peak.

2.4.2 *Population Structure and Distribution*

Using the 1999 housing and population census, the population of Mumias town was 105,446[1] people as at 1999. This contrasts with the 1979 and 1989 censuses where the total population was 5,690 and 23,335 respectively representing an inter censal growth rate of 7.4% for 1989-1999 period. 32% of this population lies within the service area. The high population growth is linked in migration of businessmen and job seekers from rural areas and other neighbouring districts due to the presence of Mumias sugar factory. However, a further analysis of the 1999 population results shows a general decline in inter censal growth rate in line with national expectations. The number of households increased from 6,675 in 1989 to 26,296 units in 1999 with a mean household size of 5.5. Urban population density (considering the CBD) was 569 people per km^2 in 1989 compared to 1924 in 1999. The distribution of the population and number of households on the basis of sub locations and water service area is shown in **Table 2.5** (See appendix J 1-1 for a map of the study area)

[1] This excludes non-residential population but includes the special population. Special population in this regard based on the 1999 census enumeration procedures considered to include though not restricted to people in hotels/lodgings, bus stops, police cells, on transit, idlers and street urchins found within the town as at mid-night of the census enumeration day.

Table 2.5
Population Structure and Distribution (1999)

Sub-Location	Number of Households	Population under Municipal council	Population in Service area
Mayoni	3269	14463	
Matungu	1745	7621	
Musamba	1420	6721	
Matawa	1542	7032	
Lureko	728	3433	
Township Special Population	5,294 -	18473 530	33440
Nucleus Special Population	4,640 -	16740 825	
Ekero	1828	7900	
Lusheya	2465	12365	
Eluche	2044	9343	
Total	**24975**	**105446**	**33,440**

Source: District Statistical Office Butere-Mumias, 1999 and central Bureau of Statistics, 2001

2.4.3 Population Projections to the year 2010

The 1989-1999 inter censal growth rate for the town was 7.4%. This rate is at variance with the declining national trend mainly due to a reduction in fertility rates and a fall back in urban job opportunities. It is however expected that the population growth will remain relatively stable over the next ten years similar to the 1979-1989 inter censal rate as there are no major investments expected in the next years which might alter the water demand situation. The inter censal rate was therefore moderated based on planning projections of the district development office as well as the physical development plan of the local authority to 4.7%. Table 2.6 below gives a comparative trend of the population growth for the next ten years based on the water service area and overall population in the urban council using a growth rate of 4.7%.

Table 2.6
Population Projection[2] to the year 2010

Year	Population under Municipal Council
2000	110400
2001	115600
2002	121000
2003	126700
2004	132700
2005	138900
2006	145400
2007	152300
2008	159400
2009	166900
2010	174800

2.4.4 Economic and Commercial Activities

The main land-use patterns within the CBD are limited to business/economic activities, schools, hospitals and other health facilities, institutional offices and other essential social infrastructure. There have been no major investments other than the existing Mumias sugar factory. There are efforts to establish small and medium scale enterprises (SME's) as an alternative source of informal sector employment mainly targeting the youth from medium level technical institutions. The town lies within a rich agricultural hinterland that mainly grows sugarcane. There are diverse. The use of *boda boda* transport business generates approximately Kshs 200-300 per day for each operator. Table 2.7 below shows the structure of commercial activities in the town

[2] Projections based on the following formula [$P_{projected} = P_{actual} (1+r)^t$] where r=rate of pop growth and t= year and the base year is the 1999 estimated population rounded off to the nearest 100.

Table 2.7
Commercial Activities in Mumias Town

Activity	Number in 1999
General Retailers	185
Wholesalers	23
Bars, Restaurant	36
Hardware Shops	13
Carpentry Workshops And Timber Traders	22
Motor Spares	4
Posho Mill	30
Photo Studio	4
Foot Wear	9
Bookshops	5
Manufacturing	3
Hotels	17
Tailoring	41
Kiosks	61
Butchery	25
Boutique	3
Saloon	5
Chemist	5
Private Hospitals And Clinics	14
Petrol Stations	3
Hides And Skins	6
Jua Kali Activities	58
Garages	6
Total	**518**

Source: finance department – Mumias town council

2.4.5 Social Infrastructure

2.4.5.1 Communication

The town lies off a C classification trunk road from Kakamega to Bungoma. It is well connected to all the major towns within the region. The feeder roads are all weather motorable murram roads that are regularly maintained by the local sugar factory. There are plans to extend a railway line from Bungoma to Mumias. Other services include subscriber trunk dialling (STD) telephone services, fax facilities, Internet service bureaux as well as an airstrip owned by MSC.

2.4.5.2 Social Institutions

Many institutions have been set up as a result of the presence of Mumias sugar factory. The growth in establishment of such institutions as schools and health facilities has been phenomenal. The main types of institutions and their numbers are summarised in the tables 2.8 and 2.9.

Table 2.8
Educational Institutions

Type of institution	Number
Pre-Primary Schools	35
Primary Schools	18
Secondary Schools	12
Medical Training College	1
Youth Polytechnics	3
School for the deaf	1
Total	**70**

Source: District Development Office Butere-Mumias, 1999

Table 2.9
Other Social Institutions

Facility	Number
Mission Hospital	1
Nursing homes	2
Health Centres	2
Dispensaries (GoK)	1
Churches	12
Private Clinics	30
Mosques	11
Social hall	1
Fire plants and accessories	5
Mumias Complex Stadium	1
Total	**66**

Source: District Development Office Butere-Mumias, 1999

2.4.6 Income Levels

The distribution of income in the town is quite uneven and reveals major disparities in household resource endowment especially within the central business district. Wages, salaries and profits form a major income source for a majority of the residents in this local town. The local sugar factory provides additional income through direct employment and contract farming. This enables the local population to engage in highly monetarised transactions such as direct purchase of consumables and other basic necessities. According to findings of the Welfare Monitoring Survey (WMS) II, the mean monthly household income from sugar cane sales accounted for 35% of the total mean household crop income. In total, the income share from non-agricultural sources was 52% of the household income estimated to be Kshs. 7270.2 as shown in Table 2.10 below

Table 2.10
Summary of Aggregated Mean Monthly Household Income

Income source	Mean Income	Percentage share
Wages, salaries, profits	3753.4	51.7
Other non-agricultural income	1086.2	14.9
Agricultural income	1867.0	25.8
Crop income	563.6	7.6
Total	**7270.2**	**100.0**

Source: Welfare Monitoring Survey II, 1994

A random household survey focusing on 80 consumers of water carried out by the study team revealed that more than half of the households interviewed earn an average monthly income of between Kshs 5,000 to Kshs 15,000. According to information obtained from the local divisional DWO's office, households pay on average Kshs 15 to buy one 20 litre jerrican of water using the *boda boda*. The prevailing situation where water consumers have no incentive to pay for water is linked to poor management, poor water quality and infrequent water. Over 96% of the respondents felt that the current level of service was unsatisfactory.

2.4.7 Willingness and Ability to Pay for Water Services

2.4.7.1 <u>Ability to Pay</u>

Ability to pay is taken to be a function of the level of household incomes, the acceptable share of water/sewerage services in total expenditures, tariffs and the target consumption levels. The main consideration in the analysis of the consumers' ability to pay for water in this study is the household level of income and expenditure. For instance, household expenditure is from a welfare perspective presumed to be equivalent to the sum total of utility derived from water consumption. Under normal circumstances, the ceiling on the budget share of income that can be spent by a household on water/sewerage services is roughly taken to be 5%. However, this figure tends to vary from one income group to another. Households in the lower income bracket do spent a higher budget share of their income in real terms on water than households in the middle to high income group who spent on average 2.2% and 1.4 % of their incomes respectively.

Considering that about 49% of the designated population (for which over 52% are women) of the town live in the low income bracket under very poor sanitary conditions, an evaluation of their income levels, W/ATP and W/ATA is integral and forms an important entry point in the analysis of water demand based on consumer perceptions of the water situation in the town.

2.4.7.2 Willingness to pay

To get information on willingness to pay,[3] the study team carried out a random survey on a sample of 80 households mainly within the service area. The team adopted three methodologies though questionnaire based interviews were instructively more elaborate. Other approaches used were personal observation as well as focus group discussions especially with key players in the water sector in Mumias town. For the questionnaire-based survey, each household head was asked questions relating to how much he was willing to pay for a cubic meter of water under two scenarios. One was under existing water service delivery and the other on the expected service on completion of the rehabilitation exercise. The general conclusion of the survey was that most households were willing to pay more for improved service delivery commensurate with the level of tariff increase depending on the perceived problem specific to a particular area or household.

Analysis of information collected from the questionnaires indicates that 90% of the households interviewed are willing to pay on average up to Kshs. 500 for actual water consumption. This is in comparison to their current average monthly bills of Kshs. 300-400 based on billing estimates. A similar survey in the areas not currently serviced established that many households would be willing to pay for water at the current general water tariff of Kshs. 30/m^3. Simulations to establish the threshold tariff beyond which people would not be willing to pay revealed that even with increment of up to 30% in the tariff, people would still be willing to pay

2.4.8 Health and Sanitation Situation

The team carried out an elaborate analysis of the health and sanitation situation in the town and information on disease prevalence collected.

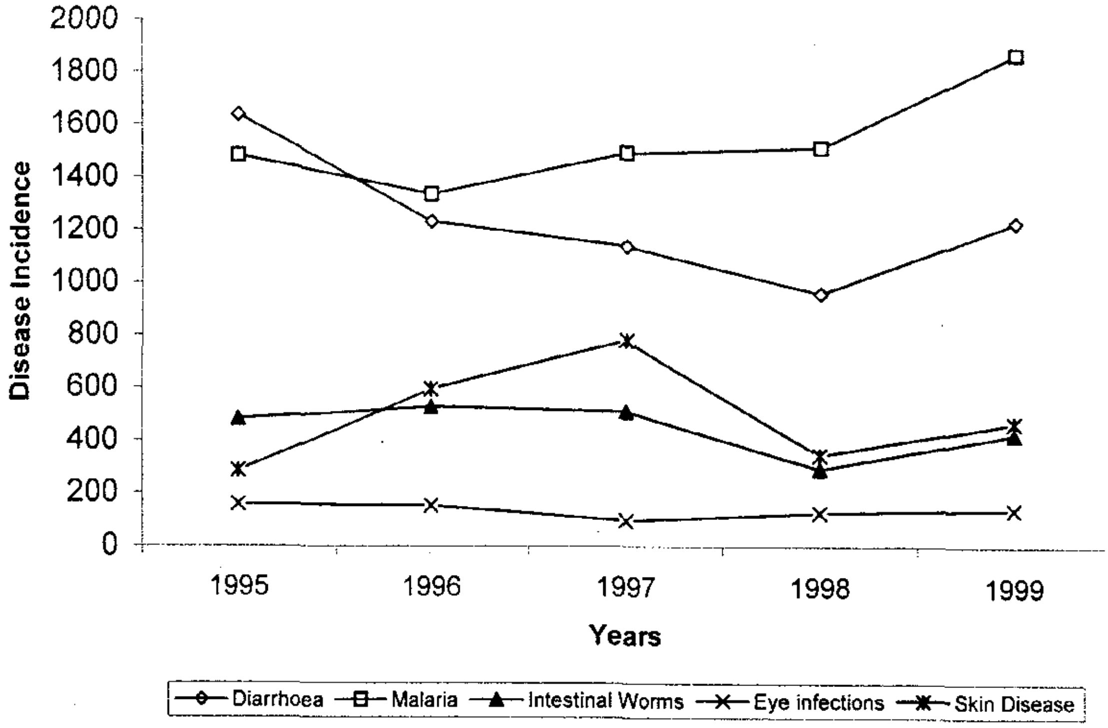
[3] The appropriate methodology in estimating willingness and ability to pay (W/ATP)/ willingness and ability to accept (W/ATA) is to use the contingent valuation (CV) approach. This approach is validated through asking water consumers at the household level hypothetical questions (which are a true reflection of actual water consumption levels) how much they are paying for water as compared to how much they would be WTP if existing water supply externalities are internalized.

Discussions were held with the local public health officer where common problems experienced in the fight against the spread of water borne diseases were enumerated. It may be generally accepted that the existing health and sanitation conditions are appalling especially in the low-income areas such as Angola, Shibale and lukoye.

The local population is more predisposed to contract water related diseases than their counter parts in the hinterland due to poor sanitary and living conditions. Cases of raw sewage flowing through residential areas were observed for instance at Shibale. However, 11.6% of the urban households surveyed had no access to a pit latrine. Given that Mumias town lies within a high water table area, there are high chances of contamination of ground water sources from pit latrines. Diarrhoeal diseases accounted for over 50% of all water related diseases though only 46% of the respondents had suffered from water related disease.

The disease pattern like in many other towns is dominated by high incidences of malaria, which is attributed to poor environmental management. Diarrhoea and skin diseases that are associated with poor hygienic conditions and untreated water are also prevalent. The pattern of refuse disposal and sanitary facilities on the other hand follows settlement patterns though such responsibility is vested with the local municipality. The situation dramatically changes as one moves away from the CBD towards the hinterland where only pit latrines are used and residents mainly connected to rural water supply schemes. See chart one below for a graphic presentation of the disease situation in Mumias over a retrogressive five year period.

Chart 1: Incidence of water related diseases in Mumias town



Source: Health Information Systems Unit, Ministry of Health and PHO's Office Butere-Mumias 2001

2.4.9 Types of Settlement

Other than designated staff houses for government employees and staff of the local sugar factory, which accounts for over 70% of total housing developments, the housing structures within town are characterised by mud walls and rusty roofs. Generally housing standards are particularly low with 31% of the population living in mud walled houses. Note that based on table 2.5 below, the high number of people classified as low income is mainly due to expansion of municipality boundaries to include areas that are not strictly urban by definition. Based on the above analysis, the distribution of the population on the basis of broad income categories is shown in table 2.11 below.

Table 2.11
Settlement patterns based on broad income categories

Income category	Number	Percentage
High income	20.173	19.1
Middle income	33.405	31.7
Low income	51.868	49.2
Total	**105.446**	**100.0**

2.4.10 Situation of Women in Society

Women make up a disproportionately large share of the poor and very poor in urban areas. They are particularly vulnerable to many factors that create and perpetuate poverty. Most families whether poor or not may not be able to survive without the help of female family members. However, for Mumias town, water collection remains a preserve of women and only forms one of their major social roles among many other economic activities within the household. Other than situations where *boda boda's* are used, the burden for carrying water requires women to have a substantial amount of energy. This condition is energy sapping and causes considerable stress especially to pregnant women, which might lead to multiple complications at childbirth. Other causes of stress include headaches, backaches, sometimes and deformation of the spine. Accidents do occur and these include slipped discs, paralysis, injury to children carried on the back to extreme cases such as strangulation by the head strap. Improved water supply conditions would change all these and ease the burden on women, releasing time and energy for other development activities necessary in nation building. With such evidence, women stand to automatically benefit from an improved water and sanitation programme, especially from a social and economic point of view as this will remove the constraints on gainful female employment. This will open up the status of a woman in society to participate more actively in other economic activities.

3 EXISTING WATER SUPPLY CONDITIONS

3.1 LISUMU WATER TREATMENT WORKS

3.1.1 Intake and raw water main

The raw water intake was constructed in 1973 on the Lusumu River some 5 km from the town. Water flows from the intake to the treatment works site through a gravity main some 1,000 m long.

3.1.2 Treatment

3.1.2.1 General

The water treatment plant at Mumias also dates from 1973. It was refurbished in 1990 under a Finnish-funded project. The plant is conventional, comprising upward flow clarifiers and rapid gravity filters.

3.1.2.2 Chemical preparation

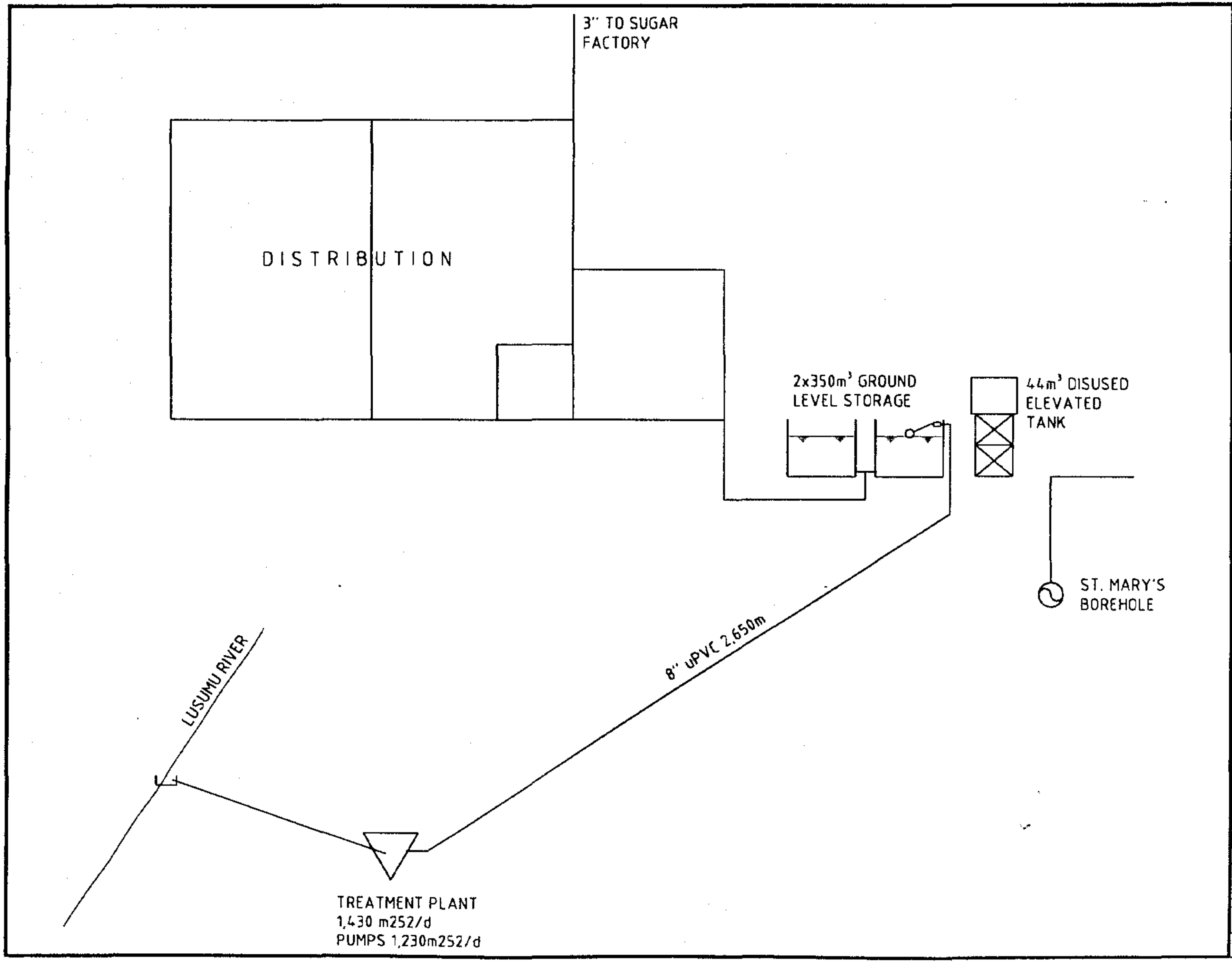
A chemical preparation room containing four solution tanks is located adjacent to the high lift pump station. Solutions are prepared manually: there are no mechanical mixers.

3.1.2.3 Coagulant dosing

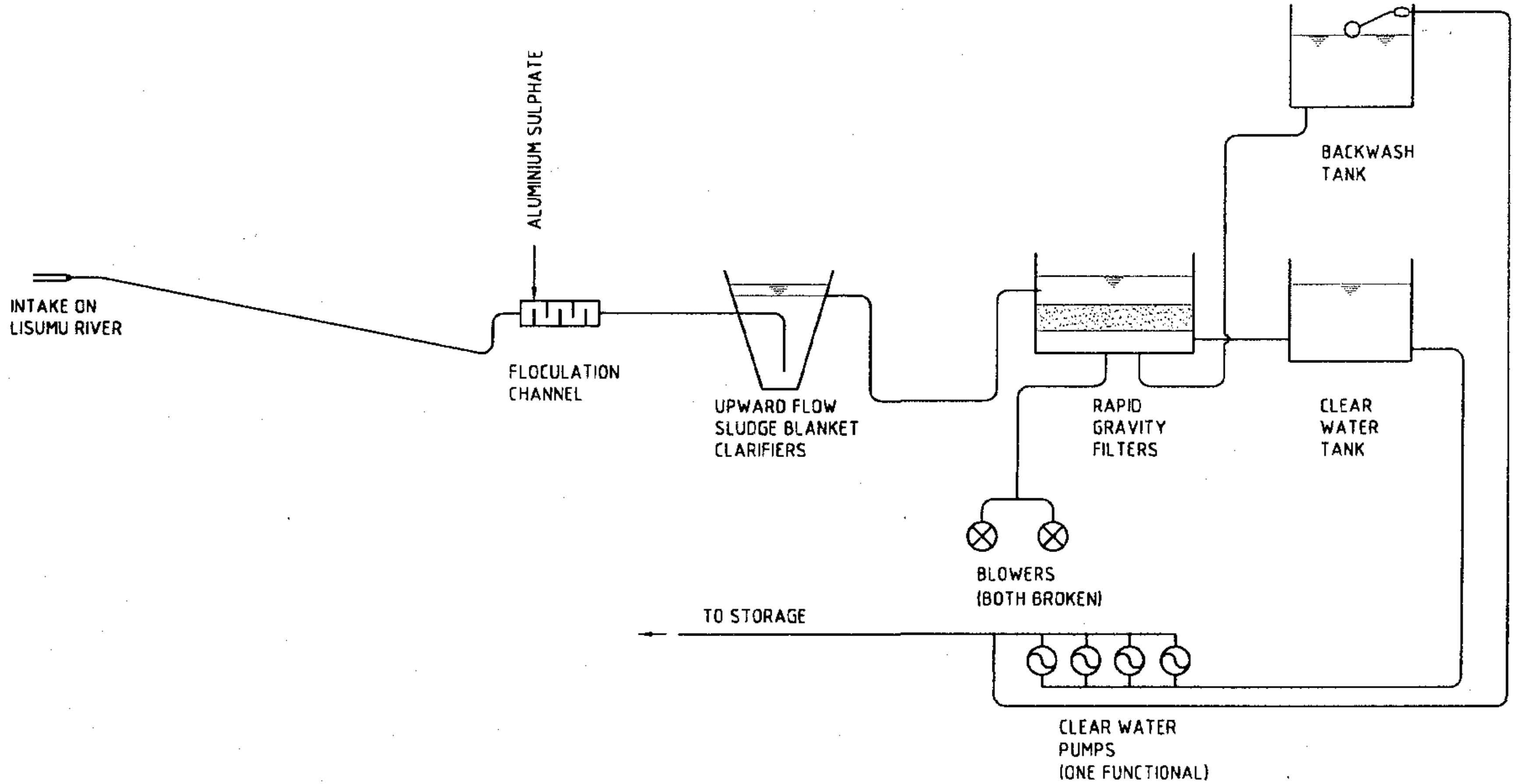
Aluminium sulphate solution is dosed at the head of the works using dosing pumps, as the clarifiers are above the chemical preparation room.

3.1.2.4 Clarifiers

There are two hopper-bottomed, upward-flow clarifiers, each 4.27 m square, giving a surface area of 18.21 m^2. The 1986 design manual does not give design surface loadings for upward flow, sludge blanket clarifiers. In modern design practice, the design surface loading for upward flow clarifiers is between 1.5 m/hr and 2.5 m/hr, although the 1978 design manual stipulated a loading of between 1.2 m/hr and 1.5 m/hr. Adopting a loading of 1.5 m/hr, the units have a combined capacity of 1,310 m^3/d.



Client	JAPAN INTERNATIONAL CO-OPERATION AGENCY
	GIBB Eastern Africa — LAWGIBB Group Member
Project Title	TEN TOWNS WATER SUPPLY & SANITATION STUDY
Drawing Title	MUMIAS TOWN WATER DISTRIBUTIN SCHEMATIC LAYOUT
Date: DEC 2000	Fig. No. 3.1



Client: JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa — LAWGIBB Group Member

Project Title: TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title: MUMIAS TREATMENT PROCESS 1,430m³/d

Date: DEC 2000 | Fig. No. 3.2

3.1.2.5 Filters

The plant has two rapid gravity filters. The access walkway overhangs the filter boxes, so the plan dimensions of the filters could not be measured.

3.1.2.6 Filter washing

The filters are washed using water from a 35 m^3 elevated backwash tank. The main plant room includes two Dresser 45 U-RA1 air blowers for scouring the filters with air, but both blowers are broken.

3.1.2.7 Plant capacity

The plant operator reports that the capacity of the plant is 1,430 m^3/d. This is consistent with the size of the clarifiers and represents a surface loading of 1.64 m/hr.

3.1.2.8 Disinfection and the clear water tanks

Tropical chloride of lime is dosed as a disinfectant at a rate of 1 mg/l into two clear water tanks, each with a reported capacity of 350 m^3.

3.1.2.9 Laboratory facilities

There is a laboratory adjacent to the clear water pumping station. There is no laboratory equipment, and dosage rates are set based on past experience. The laboratory is equipped with a clarity bowl to monitor raw, clarified and filtered water clarity, but this is not being used for its intended purpose.

3.1.3 High lift pumping system

3.1.3.1 Installed pumps

Three Stork HCM 20AX3-3 pumps were installed during the 1990 rehabilitation, each driven by a 30 kW two-pole motor. Of the three pumps, one had been removed at the time of our visit and one was out of commission with a burned out motor, leaving only one serviceable pump.

The sole serviceable pump was running at the time of our visit: the pressure gauge on the delivery manifold showed a pressure of 10 bar. There is a flow meter on the rising main outside the pump house, but this has not worked since 1997 so the flow rate could not be measured. However, the plant operator reports that the capacity of the pump is 1,230 m^3/d.

3.1.3.2 Transmission main

The high lift pumps deliver to the service reservoir site through an 8" nominal bore Class C uPVC pipeline some 2,650 m long. The pipeline is equipped with eight air release valves.

Before the 1990 rehabilitation, a 150 mm nominal bore rising main was being used, but this has now been incorporated into the distribution system.

3.2 ST. MARY'S BOREHOLE

A borehole was drilled at St. Mary's hospital in 1992 under a Finnish-funded project. The flow meter at the borehole head is broken, but the Divisional Water Engineer reports that it yields 10 m^3/hr and the motor driving the pump is rated for 4 kW.

3.3 STORAGE

The storage site at Mumias is opposite St. Mary's Girls Secondary School. There are two reinforced concrete ground level tanks, each of 350 m^3 capacity. There is also an unused elevated steel tank of 44 m^3 capacity.

The Divisional Water Office located adjacent to the storage tanks has two 50 mm nominal bore galvanised steel pipes passing through the wall. Presumably, these were once the suction and delivery pipework for a booster pump to supply the elevated tank, but the room no longer houses a pump.

3.4 DISTRIBUTION

3.4.1 Distribution pipework

The distribution pipework in Mumias is mainly uPVC, ranging in size from 6" to 3". The outlet from the storage site is 6" diameter, and the pipeline running along the Bungoma road towards the sugar factory is 3" diameter.

The original design for the Mumias water supply system comprised two pressure zones:

- A high level zone to be supplied from an elevated water tower.

- A low level zone supplied from ground level storage. The low level zone was to have an 8" outlet from the reservoirs, feeding 6"/4"/3" ring mains.

The distribution system within the town is not that which was designed. The elevated water tank exists, but there is no means to fill it. The entire town is currently supplied from ground level storage through a 6" main rather than the 8" main given in the original design report.

3.4.2 Consumer connections

The available records reproduced in Appendix 3 show that there are 1,567 active connections to the Mumias distribution system, only seven of which have functional water meters. Bills for the remaining 1,560 connections are based on estimated consumptions.

3.5 EXISTING O&M

3.5.1 Administrative structure

The scheme is operated and maintained by the Divisional Water Office. The total staff complement is fourteen, all of whom are involved in the operation and maintenance of the Mumias gazetted water supply scheme. An organisational chart for the Mumias Divisional Water Office is given in Appendix 3.

3.5.2 Procurement of chemicals

Aluminium sulphate and tropical chloride of lime are obtained from the District Water Office in Butere. Deliveries are not reliable: at the time of our visit, there was no tropical chloride of lime for disinfection. The Divisional Water Engineer was planning to visit Butere to collect some.

3.5.3 Treatment process

The available water quality analysis for the Lusumu River shows a pH of 7.3 and an alkalinity of 40 mg/l. The calculated coagulation pH and dissolved carbon dioxide (in mg/l as CO_2) for various doses of aluminium sulphate to the raw water are shown in Table 3.1.

Table 3.1
Coagulation pH and dissolved CO_2 for various aluminium sulphate doses and temperatures

Temperature (°C)	**10**		**15**		**20**		**25**	
Alum dose	pH	CO_2	pH	CO_2	pH	CO_2	pH	CO_2
10 mg/l	6.97	9.6	6.95	9.0	6.93	8.7	6.92	8.4
20 mg/l	6.74	14.0	6.71	13.5	6.68	13.1	6.66	12.8
30 mg/l	6.54	18.4	6.51	17.9	6.48	17.5	6.45	17.2
40 mg/l	6.35	22.9	6.31	22.3	6.28	22.0	6.26	21.7
50 mg/l	6.14	27.3	6.11	26.8	6.07	26.4	6.05	26.1

At only the lower dosage rates does the coagulation pH remain above the MENR lower limit of acceptability of pH 6.5.

The water has a hardness of 28 mg/l. Even at the lowest dosing rate considered, the water has a calculated free CO_2 content of between 9.6 mg/l and 8.4 mg/l, depending on temperature. According to the MENR Design Manual, the water will be very aggressive towards concrete and iron products. Fortunately, most of the pipes used in the Mumias water supply system are uPVC, which are not susceptible to corrosion. However, the reservoirs are concrete and the service connections are steel and are thus susceptible.

3.5.4 *Water production*

The raw water flow to the water treatment works is unmetered. There is a broken bulk flow meter on the rising main from the water treatment works to the service reservoirs. There is a broken flow meter on the delivery pipework from the borehole at St. Mary's Hospital. Water production therefore cannot be measured.

Operational staff report that the treatment works capacity is 1,430 m^3/d and clear water pump capacity is 1,230 m^3/d, but these figures cannot be verified. Operational staff also report that the borehole at St. Mary's Hospital yields 240 m^3/d, bringing the total reported water production to 1,470 m^3/d.

3.5.5 Facilities and equipment

The Mumias Water Office is a small blockwork building located at the service reservoir site. The office has no power supply and no telephone. At the water treatment works site, there is a laboratory next to the clear water pump room, but this has only basic furniture and no laboratory equipment. There is no telephone at the treatment works site.

The office has a motor cycle that was provided under the KEFINCO project to cover community water supplies in the Division. This is used for all transport requirements, including the collection of tropical chloride of lime from Butere.

3.6 LEVELS OF SERVICE

3.6.1 *Major consumers*

There is one metered connection in Mumias consuming more than 40 m^3 per month, and a further thirty-one unmetered connections with estimated consumptions of over 40 m^3 per month. These thirty-two connections account for a monthly water consumption of 2,489 m^3, in the following charge bands:

Table 3.2
Monthly consumptions for large consumers

Charge band	Consumption (m^3/month)
0-10 m^3/month minimum charge band	320
10-20 m^3/month band	320
20-50 m^3/month band	953
50-100 m^3/month band	446
100-300 m^3/month band	450
Over 300 m^3/month band	0
Total	2,489

3.6.2 Population served

The remaining 1,535 connections in Mumias are assumed to supply domestic consumers. The results of the 1999 census show Mumias has a population of 105,466 in 26,296 households. This gives a mean household size of 4.01. Therefore, approximately 6,155 people benefit from piped water supplies, or 5.84% of the total population within the municipality.

3.6.3 Per capita supplies

The 1,535 domestic connections in Mumias consumed an estimated 1,082 m^3/d in June 2000. This represents an average consumption of 705 l/connection or approximately 176 lcd.

3.7 ON-GOING OR PLANNED EL NIÑO WORKS

There are no works planned in Mumias under the El Niño Emergency Project.

3.8 OTHER WORKS AND PROJECTS

There are no other works or projects affecting the Mumias water supply system.

4 PROPOSED STRATEGY FOR WATER SUPPLY REHABILITATION

4.1 DEMAND/CONSUMPTION PROJECTIONS TO 2010

4.1.1 Population projections

As discussed in Section 2.6, the population of Mumias is projected to increase at 4.7% per annum to reach 174,800 in the year 2010. The projected population for the municipality is given in Table 4.1.

Table 4.1
Population projection

Year	Population
1999	105,466
2000	110,400
2001	115,600
2002	121,000
2003	126,700
2004	132,700
2005	138,900
2006	145,500
2007	152,300
2008	159,500
2009	166,900
2010	174,800

4.1.2 Water demand projections

4.1.2.1 <u>Unit water consumption</u>

Unit consumptions are taken from the then Ministry of Water Development Design Manual (1986).

4.1.2.2 <u>Levels of service</u>

It is assumed that the Government of Kenya achieves its goal of providing piped water to one hundred per cent of the urban population by the year 2010. It is further assumed that the classes of housing within Mumias will reflect the current broad levels of income.

Table 4.2
Projected levels of service

Income level/housing class	Percentage in category
High	19
Medium	32
Low	49

4.1.2.3 Domestic water demand

The domestic water demand projection for Mumias is shown in Table 4.3.

4.1.2.4 Institutional and commercial water demands

The estimated current institutional and commercial water demand is summarised below.

Table 4.4
Institutional and commercial water demands

Activity	Nr	l/unit/d	total
Commercial			
Shops	392	100	39,200
Hotel low class (assume 10 beds each)	170	50	8,500
Butcheries	25	500	12,500
Bars and restaurants	36	500	18,000
Garages	6	500	3,000
Total commercial			81,200
Institutional			
Hospital (assume 400 beds)	400	200	80000
Boarding schools	500	50	25000
Day schools	20000	5	100000
Total institutional			205000
Industrial			
Separate supply to sugar factory			0
Total commercial, institutional and industrial demand	l/d		286200
	m^3/d		286.2
	say		**290 m^3/d**

The institutional and commercial water demand is taken as 290 m^3/d, and is projected to increase in line with the town's population.

Table 4.3
Mumias Projected Water Demands and Current System Capacities

Year	Population	Income brackets		Population	Demand rate lcd	Demand m^3/d	Institutional demand m^3/d	Total demand m^3/d	Production capacity m^3/d	Transmission capacity m^3/d	Equivalent storage capacity m^3/d
		Status	%								
1999	105,466	High	19	20,039	250	5,010					
		Middle	32	33,749	150	5,062	286	**14,234**	1,670	1,470	560
		Low	49	51,678	75	3,876					
2000	110,400	High	19	20,976	250	5,244					
		Middle	32	35,328	150	5,299	295	**14,895**	1,670	1,470	560
		Low	49	54,096	75	4,057					
2001	115,600	High	19	21,964	250	5,491					
		Middle	32	36,992	150	5,549	304	**15,592**	1,670	1,470	560
		Low	49	56,644	75	4,248					
2002	121,000	High	19	22,990	250	5,748					
		Middle	32	38,720	150	5,808	313	**16,315**	1,670	1,470	560
		Low	49	59,290	75	4,447					
2003	126,700	High	19	24,073	250	6,018					
		Middle	32	40,544	150	6,082	322	**17,078**	1,670	1,470	560
		Low	49	62,083	75	4,656					
2004	132,700	High	19	25,213	250	6,303					
		Middle	32	42,464	150	6,370	332	**17,882**	1,670	1,470	560
		Low	49	65,023	75	4,877					
2005	138,900	High	19	26,391	250	6,598					
		Middle	32	44,448	150	6,667	342	**18,712**	1,670	1,470	560
		Low	49	68,061	75	5,105					
2006	145,500	High	19	27,645	250	6,911					
		Middle	32	46,560	150	6,984	352	**19,594**	1,670	1,470	560
		Low	49	71,295	75	5,347					
2007	152,300	High	19	28,937	250	7,234					
		Middle	32	48,736	150	7,310	363	**20,505**	1,670	1,470	560
		Low	49	74,627	75	5,597					
2008	159,500	High	19	30,305	250	7,576					
		Middle	32	51,040	150	7,656	374	**21,468**	1,670	1,470	560
		Low	49	78,155	75	5,862					
2009	166,900	High	19	31,711	250	7,928					
		Middle	32	53,408	150	8,011	385	**22,458**	1,670	1,470	560
		Low	49	81,781	75	6,134					
2010	174,800	High	19	33,212	250	8,303					
		Middle	32	55,936	150	8,390	397	**23,514**	1,670	1,470	560
		Low	49	85,652	75	6,424					

4.1.2.5 Demand projection

The water demand projection for Mumias is summarised in Table 4.3.

4.1.3 Comparison of projected demand with system capacities

Table 4.3 compares the projected water demand with the capacities of the various system components. The projected water demand far exceeds the capacity of the existing water supply system.

4.2 PRELIMINARY DESIGN OF RECOMMENDED REHABILITATION OPTION

4.2.1 Raw water delivery

At the request of the District Water Officer, a budgetary allowance is made for repairing the weir on the Lusumu River and the raw water main to the treatment works.

4.2.2 Chemical dosing

4.2.2.1 Coagulation and pH correction

The pH and alkalinity of treated water can be raised by dosing soda ash. This will increase both the alkalinity and total inorganic carbon, but will not affect the hardness. The MENR Design Manual shows that water with a hardness of 28 mg/l and dissolved carbon dioxide of 4 mg/l will be only slightly aggressive to concrete and steel. The calculated soda ash dosage (in mg/l) to achieve this value are shown below, together with the final pH.

Table 4.5
Required soda ash dose for stable product water

Temperature (°C)	10		15		20		25	
Alum dose	Na_2CO_3	pH	Na_2CO_3	pH	Na_2CO_3	pH	Na_2CO_3	pH
10 mg/l	13.4	7.48	12.3	7.43	11.2	7.38	10.6	7.35
20 mg/l	24.3	7.53	23.0	7.48	22.0	7.43	21.4	7.40
30 mg/l	35.0	7.57	33.6	7.51	32.8	7.47	32.0	7.43
40 mg/l	45.6	7.60	44.5	7.56	43.5	7.51	42.7	7.47
50 mg/l	56.3	7.63	55.2	7.59	54.2	7.54	53.4	7.50

The required soda ash dose is slightly greater than the aluminium sulphate dose for coagulation. The final pH remains below 8: the upper limit for disinfection with chlorine.

In some countries, lime is used instead of for pH correction. Dosing lime increases both the alkalinity and the hardness, while leaving the total inorganic carbon unaltered. The use of lime as an alternative to soda ash should be examined.

4.2.2.2 Chemical dosing for disinfection

The raw water contains 0.24 mg/l of ammonia, 0.8 mg/l of dissolved iron and 0.03 mg/l of dissolved manganese. To attain a free chlorine residual of 0.5 mg/l, the required dosing rate is 2.8 mg/l. Tropical chloride of lime (TCL) contains approximately 30% of available chlorine, giving a required dosing rate of 7.7 mg/l. Pure calcium hypochlorite contains 71.57% of available chlorine: commercial grades contain 70%, giving a required dosing rate of 3.29 mg/l.

4.2.3 Chemical dosing pumps

Duty and standby dosing pumps should be provided for dosing aluminium sulphate and soda ash solutions, which can be prepared in the four existing solution tanks. Additional preparation and dosing facilities will be required for disinfection.

4.2.4 Replacement blowers

The air scour rate when washing filters ranges from 25 m/hr to 70 m/hr. Adopting a rate of 50 m/hr, the required volume flow rate is 300 m^3/hr for a 6 m^2 filter. The required pressure will be some 40 kPa and the power required some 7.5 kW.

4.2.5 *Clear water pumps*

For a system output of 1,430 m^3/d and an 8" Class C uPVC rising main, the required pump duty becomes 59.6 m^3/hr against a head of 79 m. Allowing for station losses of 2 m, the design head becomes 81 m. The duty can be met using any of the following pump installations:

- Two duty plus one standby 40-250 DIN 24255 end-suction pumps running at two-pole speed at an efficiency of about 55%.
- One duty plus one standby 65-250 DIN 24255 end-suction pumps running at two-pole speed at an efficiency of about 61%.
- Two duty plus one standby three-stage, multistage pumps running at two-pole speed at an efficiency of about 66%.

- One duty plus one standby two-stage, multistage pumps running at two-pole speed at an efficiency of about 70%.

- Two duty plus one standby eight-stage, multistage pumps running at four-pole speed at an efficiency of about 69%.

- One duty plus one standby six-stage, multistage pumps running at four-pole speed at an efficiency of about 70%.

Small end-suction pumps running at two-pole speed are inefficient for this duty. The efficiencies of multistage pumps are similar at two-pole and four-pole speeds, but the slower pumps are much larger and will be difficult to mate to the existing suction pipework. We recommend one duty plus one standby multistage pumps running at two-pole speed as they can be installed with minimal disruption to operations.

4.2.6 Metering of treated water production

The pumped flow from the treatment works will be some 60 m^3/hr. A 150 mm meter is accurate to ±2% from 22.5 m^3/hr to 150 m^3/hr, and so is suitably sized for the design flow.

The flow meter at the borehole at St. Mary's Mission Hospital should also be replaced.

4.2.7 Clear water rising main

The eight air release valves on the main should be replaced and the chambers rebuilt.

4.2.8 Ground level storage

The two existing ground level tanks have a combined capacity of only 700 m^3. Four a system output of 1,430 m^3/d, eighteen hours of emergency storage and twelve hours of balancing storage, the required capacity is 1,788 m^3. An addition 1,100 m^3 of storage is required.

4.2.9 Distribution system

4.2.9.1 Network analysis

The ground level at the Mumias storage site is approximately 4,370 feet or 1,332 m AMSL. Ground levels within the area covered by the distribution system range from 4,340 feet (1,323 m AMSL) to 4,200 feet (1,280 m AMSL) at Shibale. The maximum head under zero flow conditions is therefore less than 60 m.

The distribution system (as originally designed with an 8" outlet from the reservoirs) has been reanalysed for a system output of 1,430 m^3/d and a peak flow factor of 2.0. With the ground level reservoirs at bottom water level, the minimum head in the system is only 5.8 m. The outlet from the reservoirs is reportedly only 6", reducing the minimum head 3.1 m. The lowest head occurs in an area where the ground level is 1,323 m AMSL, or only 9 m below the level of the storage site. The minimum required head of 10 m therefore cannot be provided from ground level storage.

4.2.9.2 Increasing the available heads

The available heads within the distribution system can be raised by some 10 m by supplying the system from the elevated storage tank rather than ground level storage.

4.2.9.3 Pumping to elevated storage

The easiest way of supplying the system from the elevated storage tank is to allow the tank to "float" with a bottom inlet/outlet. The pumps supplying the system should be rated for the peak hourly flow, or 120 m^3/hr against a head of about 12 m. This duty can be met with the following end-suction pumps to DIN 24255:

- Two duty plus one standby 80-200 pumps running at four-pole speed at an efficiency of about 76%.

- One duty plus one standby 100-200 pumps running at four-pole speed at an efficiency of about 82%.

- Two duty plus one standby 50-125 pumps running at two-pole speed at an efficiency of about 74%.

- One duty plus one standby 65-125 pumps running at two-pole speed at an efficiency of about 71%.

The slower pumps are obviously more efficient. The total running load for two duty pumps is 5.2 kW, compared to 4.8 kW for a single duty pump. Allowance is made for the installation of one duty plus one standby pump.

4.2.10 Consumer meters

Approximately 1,560 consumer meters are required to ensure all bills are based on metered water consumptions.

4.3 COSTING OF RECOMMENDED REHABILITATION PLAN

An indicative budget for rehabilitating the existing Mumias water supply system is given in Table 4.6.

Table 4.6
Rehabilitation costs

Description	Unit	Quantity	Rate	Amount (KShs)
Intake weir and raw water main				
Allow for works at weir and raw water main	Sum			2,500,000
Access to intake site	m	1,000	3,000	3,000,000
Subtotal				5,500,000
Treatment plant				
Refurbish sludge bleed pipes and valves at clarifiers	Sum			500,000
Replace air scour blowers	Sum			1,600,000
Install duty and standby dosing pumps for aluminium sulphate	nr	2	125,000	250,000
Install duty and standby dosing pumps for soda ash	nr	2	125,000	250,000
Install duty and standby gravity dosers for hypochlorite	nr	2	100,000	200,000
Provide laboratory equipment and consumables	Sum			4,500,000
Subtotal				7,300,000
Transmission				
New clear water pumps	nr	2	3,750,000	7,500,000
Replace air valves on rising main	Sum			350,000
Replace flow meter on rising main	Sum			100,000
Subtotal				7,950,000
Storage				
1,100 m^3 additional storage	Sum			5,250,000
Repair leaking valves	Sum			50,000
Refurbish elevated tank	Sum			5,000,000
Construct new pump house	Sum			5,000,000
New transfer pumps	nr	2	1,500,000	3,000,000
Subtotal				13,050,000
Distribution system				
New consumer meters (replacement and stock)	nr	1,560	3,000	4,680,000
Subtotal				4,680,000
Logistical facilities and equipment				
New office and laboratory facilities	m2	400	25,000	10,000,000
4WD twin-cab pickups	nr	1	2,500,000	2,500,000
Motorcycles for line patrols, meter readings, etc.	nr	3	250,000	750,000
Multi-geared mountain bikes	nr	2	25,000	50,000
Desk top computer setups	nr	3	200,000	600,000
Printers	nr	2	100,000	200,000
Licensed standard computer software	Sum			1,000,000
Standard office equipment, furniture and fittings	Sum			1,500,000
Subtotal				16,600,000
Overall Total				57,705,000
Add 20% P&G				11,541,000
Sub-total				69,246,000
Add 15% Contingencies				10,386,900
Sub-total				79,632,900
Add 20% consultancy design fees				15,926,580
GRAND TOTAL				95,559,480

4.4 FUTURE EXPANSION OF WATER SUPPLIES

4.4.1 General

The design horizon for expansion works is the year 2010.

4.4.2 Adequacy of source

Table 2.3 of this report shows that the available yield from the Lusumu River is some 90,000 m^3/d. Table 4.3 shows a projected water demand of 23,514 m^3/d in the year 2000. The existing water source is sufficient to meet projected demands for the foreseeable future.

4.4.3 Intake and raw water main

The existing intake and raw water main has a capacity of only 1,430 m^3/d. A new intake structure and raw water main will be required to meet the projected demands. The main is provisionally sized at 500 mm, giving a flow velocity of 1.3 m/s when conveying 22,000 m^3/d. The preferred pipe material for engineering and economic reasons is steel.

4.4.4 Water treatment plant

New treatment units will be required with a total capacity of some 22,000 m^3/d. The land requirement for horizontal flow clarifiers of such a capacity is some 917 m^2. This presents obvious difficulties at the existing treatment site. It is assumed that the additional clarifiers will be upward flow units and filters will be rapid gravity.

Sludge generation rates in a works with a capacity of 22,000 m^3/d will become a significant environmental issue.

4.4.5 Transmission

A 500 mm main is also proposed for pumping treated water to the town storage site. Steel is again the preferred pipe material for engineering and economic reasons.

4.4.6 Storage

4.4.6.1 Ground level storage

For an average daily demand of 23,514 m^3/d, the required storage volume to balance supply and demand is 11,757 m^3, with a further 17,635 m^3 required as emergency storage. Constructing such large tanks at the existing storage site presents obvious difficulties. It is assumed that a 10,000 m^3 tank is constructed, and that the emergency storage requirement can be relaxed if a standby generator is installed at the water treatment plant.

4.4.6.2 Transfer pump capacity

For an average daily demand of 23,514 m^3/d and a peak hour factor of 2.0, the peak hourly flow becomes 1,959.5 m^3/hr. This duty will be divided between two duty pumps.

4.4.6.3 Elevated storage

The existing pressed steel elevated tank has a volume of 44 m^3. For one automatically controlled transfer pump delivering 980 m^3/hr, a control volume of 49 m^3 is required to limit pump starts to five per hour. Additional elevated storage will be required. This should be optimised during the modelling of the distribution system to determine the best elevation to minimise the total cost of the scheme. The vertical inlet/outlet to the tank is provisionally sized at 500 mm. The pipe from the elevated water tower towards the road to Kakamega is provisionally sized at 700 mm.

4.4.7 Distribution

A network analysis of the entire service area will be required using topographical survey information, population density and settlement data and the physical development plan for the town. The results of the analysis will identify the optimum elevation for elevated storage and sizes of primary, secondary and tertiary distribution pipelines.

In order to provide indicative budgetary estimates for expanding the distribution system, allowance is made for reticulating an additional area of 100 km^2. Assuming that each square kilometre of the service area contains 10 km of distribution pipes with a size greater than 50 mm, then 1,000 km of additional pipelines are required to serve the municipal area.

4.5 COST OF EXPANSION WORKS

An indicative cost estimate for expanding water supplies in Mumias is given in Table 4.7.

Table 4.7
Estimated cost of expanding water supplies

Description	Unit	Quantity	Rate	Amount (KShs)
Intake, treatment and transmission				
500 mm raw water main	m	1,000	20,000	20,000,000
22,000 m^3/d treatment plant	Sum			260,000,000
Clear water pumps	nr	3	7,000,000	21,000,000
500 mm clear water main	m	2,650	20,000	53,000,000
Subtotal				354,000,000
Storage				
11,000 m^3 reservoir	Sum			55,000,000
New transfer pumps	nr	3	4,000,000	12,000,000
New elevated storage	Sum			10,000,000
Subtotal				77,000,000
Distribution				
700 mm spine main	m	4,300	40,000	172,000,000
uPVC distribution pipework n.e. 150 mm	m	1,000,000	1,600	1,600,000,000
Consumer meters	nr	42,000	3,000	126,000,000
Subtotal				1,898,000,000
Overall Total				2,329,000,000
Add 20% P&G				465,800,000
Sub-total				2,794,800,000
Add 15% Contingencies				419,220,000
Sub-total				3,214,020,000
Add 20% consultancy design fees				642,804,000
GRAND TOTAL				3,856,824,000

The cost of reticulating the municipal area is extremely high. The results of the 1999 census show that large areas of the municipality have population densities less than five hundred people per square kilometre. This is equivalent to five people (or approximately one family) per hectare. At current tariffs, it is not economically viable for a water undertaker to provide such sparsely settled areas with piped water. The expansion of the distribution system should instead target the more densely settled areas. The importance of planned urban development to the economic provision of services cannot be over emphasised.

4.6 O&M COSTS AFTER REHABILITATION

4.6.1 Power tariffs and costs

Power charges are calculated using the tariffs and levies prevailing in December 2000. These are shown in Table 4.8.

Table 4.8
KPLC power tariffs

Charge band	A1	B1	B2
Monthly consumption not exceeding (kWh)	7,000	100,000	100,000
Supply voltage (V)	415	415	11,000
Monthly standing charge	150.00	600.00	2,000.00
Monthly maximum demand charge per kVA	0.00	300.00	200.00
High rate tariff per kWh	6.70	6.10	5.50
Low rate tariff per kWh	6.70	3.75	3.25
Fuel cost adjustment per kWh	4.07	4.07	4.07
Forex adjustment per kWh	0.16	0.16	0.16
ERB levy per kWh	0.03	0.03	0.03
REP levy at 5% on high rate tariff per kWh	0.3350	0.3050	0.2750
REP levy at 5% on low rate tariff per kWh	0.3350	0.1875	0.1625
VAT at 18% on high rate tariff per kWh	1.2060	1.0980	0.9900
VAT at 18% on low rate tariff per kWh	1.2060	0.6750	0.5850
Total high rate tariff per kWh	12.5010	11.763	11.025
Total low rate tariff per kWh	12.5010	8.8725	8.2575

The total running load at the rehabilitated Mumias water treatment plant will be some 31.5 kVA, made up as follows.

Table 4.9
Running load at treatment plant

Item	One clear water pump	One air scour blower	Lighting and small power, say	Total running load
Flow (m^3/hr)	60			
Head (m)	81			
Efficiency	70%			
Power (kW)	18.9	7.5	2.0	28.4
Power (kVA) at cosF = 0.9	21.0	8.3	2.2	31.5

With the clear water pump running continuously, the monthly power consumption will be 13,608 kWh, so the applicable charge band is B1. The estimated power consumption is shown in Table 4.10.

Table 4.10
Annual power consumption at Mumias treatment plant

Item	One clear water pump	One air scour blower	Lighting and small power, say	Total
Power (kW)	18.9	7.5	2.0	28.4
High rate hours used p.a.	3,,963.0	182.5	2,190.0	
Low rate hours used p.a.	4,797.0	0.0	2,190.0	
High rate power (kWh p.a.)	74,900.7	1,368.8	4,380.0	80,649.5
Low rate power (kWh p.a.)	90,663.3	0.0	4,380.0	95,043.3

Using the B1 tariff given in Table 4.6 above, the annual power bill for the Mumias water treatment plant is KShs 1,912,551.

The transfer pump at the reservoir site has a running load of 5 kW. Allowing 2 kW for lighting and small power, the monthly power consumption is 2,520 kWh. Charge band A1 will be applicable for this site, and the annual power cost is KShs 385,081.

The total annual power cost for the two sites is therefore KShs 2,297,632.

4.6.2 Chemical costs

Estimated chemical costs are shown in Table 4.11.

Table 4.11
Estimated chemical costs

Chemical	Cost Kshs/kg	Dosage (mg/l)	Cost (Kshs/m^3)
Aluminium sulphate	28	40	1.12
Soda ash	7	44	0.31
Calcium hypochlorite	245	3.3	0.81
Total			2.24

At a plant throughput of 1,430 m^3/d, the estimated annual chemical cost is Kshs 1,169,168 per annum.

4.6.3 Capital costs

Management consultancy, 2 years (EAU)

4.6.4 Spare parts (for 1 year)

5 EXISTING WASTE WATER DISPOSAL & SANITATION CONDITIONS

5.1 SANITATION SYSTEM

5.1.1 Municipal Sewerage system

5.1.1.1 Inventory of the existing sewerage system

The municipal sewerage system in Mumias serves 170 site and service plots through 170 sewer connections. The sewer network comprises some 1.5 km of sewers. These cover about 0.08 km^2 of the municipal area and serves about 1% of the current municipal population. The location of the existing sewered area is shown in *Figure* 5.1.

5.1.1.2 Conditions of the existing sewers

The existing sewers within the housing estate are in a good structural condition, and no incidence of collapse has been reported.

The system, constructed in 1972, was intended to discharge to a set of waste stabilisation ponds. The outfall sewer was defective from the outset (municipal authorities suspect an error in the levels) and the *outfall sewer and waste stabilisation ponds were abandoned soon after* construction. Raw sewage is therefore conveyed from the housing estate to the "temporary" ponds through an open, unlined drain.

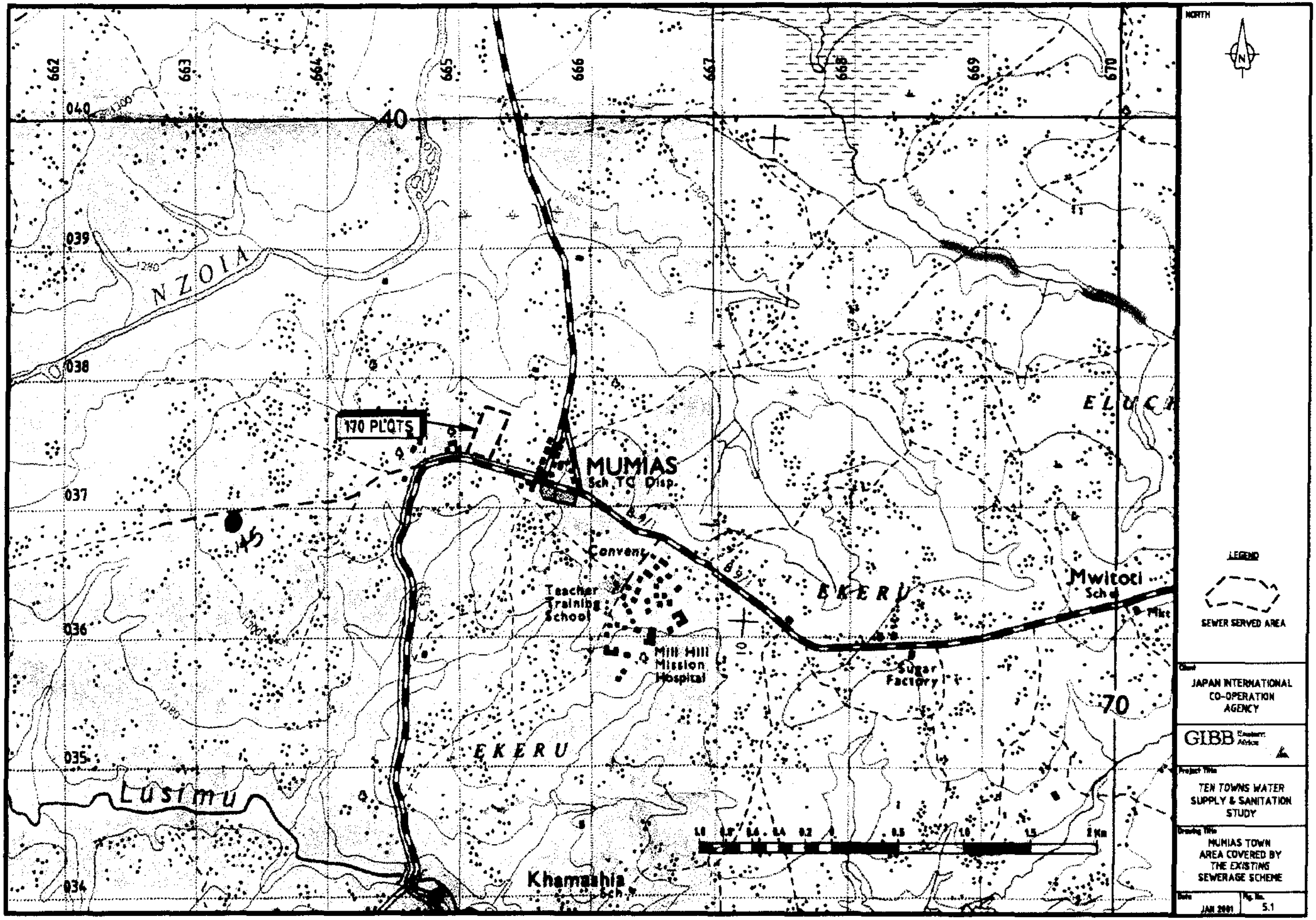
5.1.2 Municipal sewage treatment plant

5.1.2.1 Inventory of existing sewage treatment plant

A set of "temporary" ponds was dug four years ago immediately to the north of the sewered housing estate. These comprise three ponds in series, each approximately 10 m x 5m in plan. The level of treatment achieved is negligible before sewage is discharged to a stream leading to the Nzoia River.

5.1.2.2 Conditions of the temporary ponds

The temporary ponds were not designed and they are in bad state. During the site visit, it was noted that the overflow from the last pond was being diverted to farmland. The following are the key problems of the existing facility:


NORTH
LEGEND
SEWER SERVED AREA
NZOIA
Lusimu
MUMIAS
Sch TC Disp
170 PLOTS
Convent
Teacher Training School
Mill Hill Mission Hospital
EKERU
ELUCH
Mwitoti Sch
Sugar Factory
Khamashia Sch
40
70
662
663
664
665
666
667
668
669
670
040
039
038
037
036
035
034
2 Km
Client
JAPAN INTERNATIONAL CO-OPERATION AGENCY
GIBB
Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY
Drawing Title
MUMIAS TOWN AREA COVERED BY THE EXISTING SEWERAGE SCHEME
Date
JAN 2001
Fig. No.
5.1

- Nuisance from mosquitoes, flies and rodents.
- Odour.
- Spread of diseases through flies, rodents, food crops, air and direct contact with sewage.
- Spread of diseases through drinking water contaminated with sewage.

5.2 SEWERAGE SYSTEM (O&M)

Operation and maintenance of the sewerage system is the responsibility of Mumias Municipal Council. The Council is able to unblock the sewers and maintain the flow to the "temporary" ponds.

5.3 SEWAGE TREATMENT WORKS (O&M)

The original waste stabilisation ponds were abandoned soon after construction. The Council therefore does not have a sewage treatment works to maintain and the temporary ponds are neglected. Wastewater sampling is not carried out.

5.4 OTHER DISPOSAL FACILITIES

Most premises in Mumias are not connected to the municipal sewerage system and rely on septic tanks or pit latrines for sanitation. The council owns a tractor-drawn vacuum tanker of 3 m^3 capacity. Septic tank contents are discharged into the "temporary" holding ponds to the north of the sewered site and service housing.

5.5 ON-GOING OR PLANNED EL NINO WORKS

No improvements are being carried out under the ongoing El Niño project.

5.6 OTHER WORKS AND PROJECTS

Mumias Municipal Council commissioned African Consulting Engineers in 1993 to prepare a master plan for extending the municipal sewerage system. This was updated in 1998, and the cost estimate revised to Ksh 365,295,718 without contingencies, P&G and consultancy. The plan has not been implemented due to lack of funds.

5.7 SUMMARY OF SHORTCOMINGS AND PRELIMINARY RECOMMENDATIONS FOR REHABILITATION

The main shortcoming with the present sanitation system is the total lack of facilities for wastewater treatment and disposal. These should be provided.

The raw sewage from the sewered section of the town should be directed into a properly designed sewage treatment plant to ensure that the final effluent will meet the required quality for discharge to the receiving environment and also to safeguard public health. The existing system is not acceptable and the council should immediately construct a sewage treatment plant to ensure that the following requirements are met:

- The effluent from the treatment plant should meet the required national standard for discharge to watercourses.
- Public nuisance due to odour, mosquitoes, flies and rodents are minimised.
- Public health requirements are met.

If the effluent is to be used for irrigating food crops, additional treatment will be required to meet the applicable international standards.

Details of the rehabilitation works are given in Chapter 6 and summarised in Table 5.1 below.

Table 5.1
Schedule of rehabilitation works

Unit	Component	Repairs needed	Comments /recommendations
Sewerage system	Outfall sewer	New	To convey the sewage from the site and service scheme estate to a new sewage treatment plant. Existing sewer not properly implemented.
Sewage treatment plant	Screenings facility	New	To remove debris prior to discharge to first pond.
	Main treatment plant	New	To treat wastewater to acceptable standards.
	Sludge drying beds	New	To take care of septage from on plot sanitation facilities as well as sludge from anaerobic ponds in future.

6 PROPOSED STRATEGY FOR WASTEWATER DISPOSAL AND SANITATION REHABILITATION

6.1 DEMAND FOR SANITATION SERVICES

On plot sanitation facilities are the main type of sewage disposal facilities in the town. Only one site and service scheme estate with 170 households has a sewerage system.

The moderate permeability of the sandy clay soil, deep overburden soil layer and the low population densities in the town makes the use of on plot sanitation facilities suitable. However, the high annual rainfall may cause high maintenance cost of the facilities.

In the central part of the town where densities are high, it will be necessary to implement a waterborne sewerage system in order to safeguard public health.

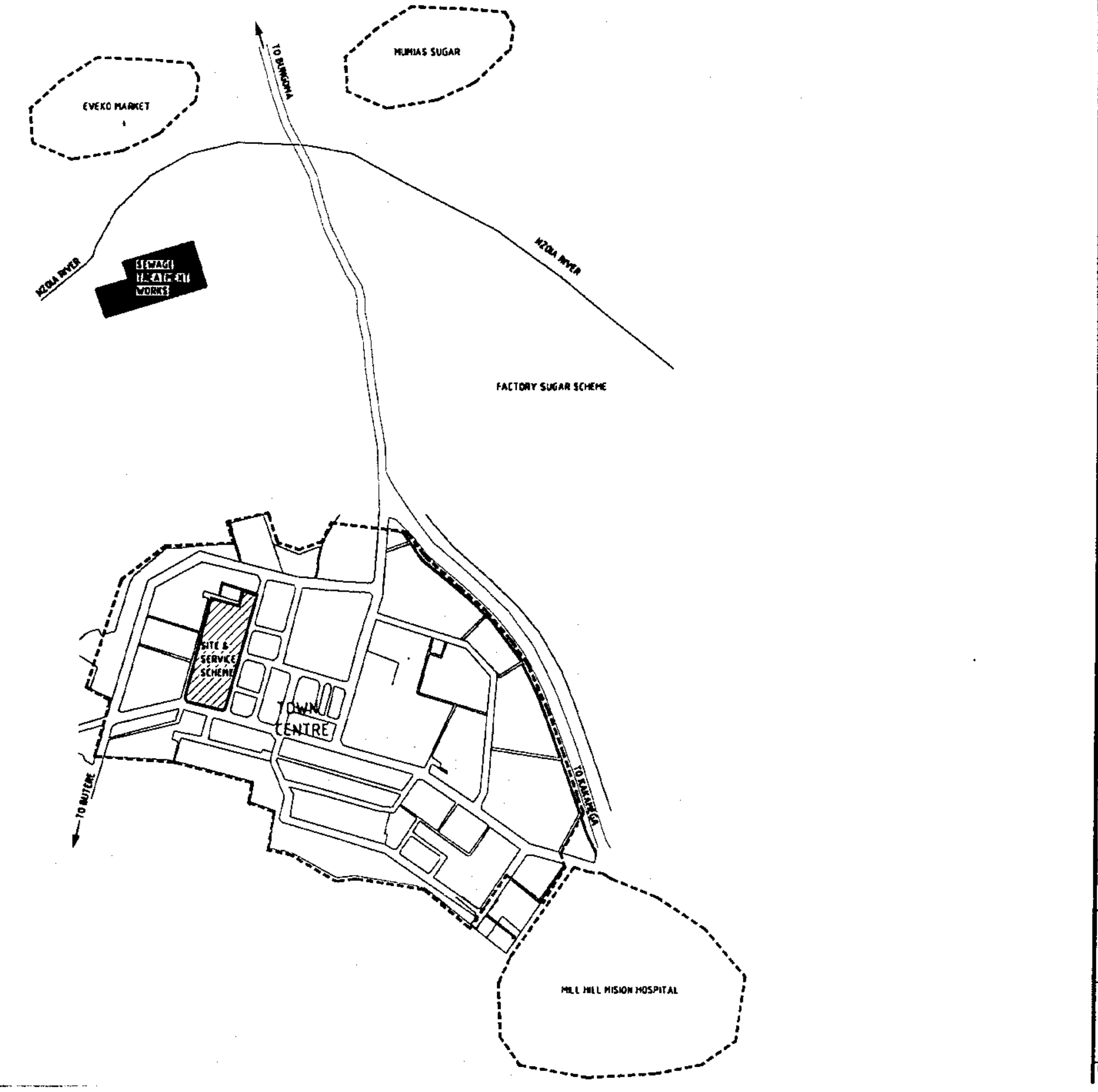
6.2 DEMAND FOR WASTEWATER DISPOSAL SERVICES

The designed sewage treatment plant is not in use and it is necessary for the council to implement a properly designed sewage treatment plant that will ensure compliance with the national effluent discharge standards as well as safeguard public health.

6.3 REHABILITATION REQUIREMENTS

A new sewage treatment plant is needed at the proposed masterplan site to take care of the sewage from the sewered area as well as the septage from the on plot sanitation facilities. The following rehabilitation works are proposed:

- Construction of a gravity sewer to convey the sewage from the site and service scheme to the proposed masterplan sewage treatment plant site.
- Construction of sewage treatment plant system. The plant should be planned in consideration of future needs of the municipality.
- Construction of sludge drying beds to take care of the large quantities of septage from the on-plot sanitation facilities.
- Divert the wastewater from the temporary ponds to the proposed plant and subsequent backfilling of the temporary ponds.



Client

JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa
LAWGIBB Group Member

Project Title

TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title

MUMIAS TOWN
EXISTING AND PRPOSED SEWERAGE COVERAGE

Date: JAN 2002 | Fig. No. 6.1

6.4 PRELIMINARY DESIGN OF RECOMMENDED OPTION

The population in the sewered area is estimated to be 680 persons at an average household size of four persons. On the basis of the per capita water demand rates recommended by the Ministry of Environment and Natural Resources the average per capita water demand will be 125 l/d. The estimated sewage generation from this population at a reduction factor of 0.8 will be 68 m^3/d.

It is recommended that a new sewage treatment plant to cater for the above sewage flows be implemented. The design of the waste stabilisation pond system will be based on the *Manual for Waste Stabilisation Ponds in Eastern Africa by D Mara et al* with a raw BOD concentration of 48g/ca/d.

The system will be designed in consideration with the town sewerage masterplan to ensure ease of expansion when the sewerage system is expanded in future.

The proposed treatment process will comprise of a manually raked screening facility and one stream of the following ponds:

- One anaerobic pond.
- One facultative pond.
- Two maturation ponds.

The screening facility will be replaced with a large inlet works when the sewerage network for the town is expanded and additional ponds will be required.

In order to ensure that the sludge from the on plot sanitation facilities is catered for, it is recommended that some sludge drying beds be implemented under the rehabilitation works.

6.5 COSTING OF RECOMMENDED REHABILITATION PLAN

An indicative cost estimate for the immediate rehabilitation works for Mumias sewage treatment plant is given in Table 6.1 below.

Table 6.1
Cost estimate for the rehabilitation works

Item No.	Item description	Unit	Quantity	Rate KShs	Cost of item KShs
1	225 mm gravity sewer 1 km long	m	1,000	8,000	8,000,000
2	Screen chamber with one screen	nr	1	150,000	150,000
3	Anaerobic pond	Item			1,000,000
4	Facultative and maturation ponds	Item			10,000,000
5	Interpond connection conduits	nr	3	150,000	450,000
6	Inlet/outlet structures for ponds	nr	2	150,000	300,000
7	Sludge drying beds to serve the whole town	m^2	400	5,000	2,000,000
8	Access road to site	m	1,000	3,000	3,000,000
	Subtotal				**24,900,000**
	Add 20% P&G				**4,980,000**
	Subtotal				**29,880,000**
	Add 15% contingencies				**4,482,000**
	Total				**34,362,000**
	Add 20% consultancy				**6,872,400**
	Grand total				**41,234,400**

6.6 FUTURE EXPANSION NEEDS OF THE MUNICIPALITY

A sewerage masterplan for the municipality has been prepared by African Engineering Consultants. The extent of the proposed sewerage coverage is given in Figure 5.1 and covers the following areas:

- Town area.
- Mill Hill Mission Hospital.
- Ereko Market.
- Mumias Sugar Factory.
- Mayoni Market.

It is proposed that the sewage from all these areas be treated at a central sewage treatment plant prior to discharge of effluent to Nzoia River.

We recommend that the future expansion of the sewerage system and the treatment plant be in conformity with this masterplan.

6.7 COST ESTIMATES FOR FUTURE EXPANSION

The cost estimate of carrying out the proposed sewerage and sewage treatment plant as per the above masterplan was estimated to be KShs 365,295,718 in 1998 without P&G, Contingencies and consultancy. The average cost of constructing the 23.4 km of sewers proposed in this estimate was KShs 12,431 per m. Most of the sewers are 225 mm in diameter and therefore this reflects a realistic rate for adoption in this study.

The detailed cost breakdown according to the masterplan proposal is given in Table 6.2 below.

Table 6.2
Cost estimate for future extensions of the sewerage system

Item No.	Item description	Unit	Quantity	Rate KShs	Cost KShs
1	Construction of sewers in the town centre	m	13,000	8,000	161,606,900
2	Construction of sewer extension in Mill Hill Mission Hospital, Ereko Market, Mumias Sugar Factory, Mayoni Market	m	10,352	12,431	128,688,800
4	Construction of a new sewage treatment plant	Item			75,000,000
	Subtotal				**365,295,718**
	Add 20% P&G				**73,059,144**
	Subtotal				**438,354,862**
	Add 15% contingencies				**65,753,229**
	Total				**504,108,090**
	Add 20% consultancy				**100,821,618**
	Grand total				**539,176,648**

6.8 OPERATION AND MAINTENANCE COST FOR THE REHABILITATED SYSTEM

It will be necessary to assign adequate staffing in order to ensure effective performance of the sewers and sewage treatment plant. Table 6.2 below shows the estimated operation and maintenance cost of the proposed staff for both the sewerage and the sewage treatment plant as well as the necessary operation and maintenance facilities.

Table 6.3
Estimated operation and maintenance cost

Item description	Proposed staffing	Annual cost per person (KShs)	Total annual cost (KShs)
Labourers for sewer maintenance	3	144,000	432,000
Labourers for sewage treatment plant	3	144,000	432,000
Foremen for both sewerage and sewage treatment plant	1	180,000	180,000
Total staff cost			**1,044,000**
Add 15% for protective garments and maintenance equipment			**156,600**
Grand total			**1,200,600**