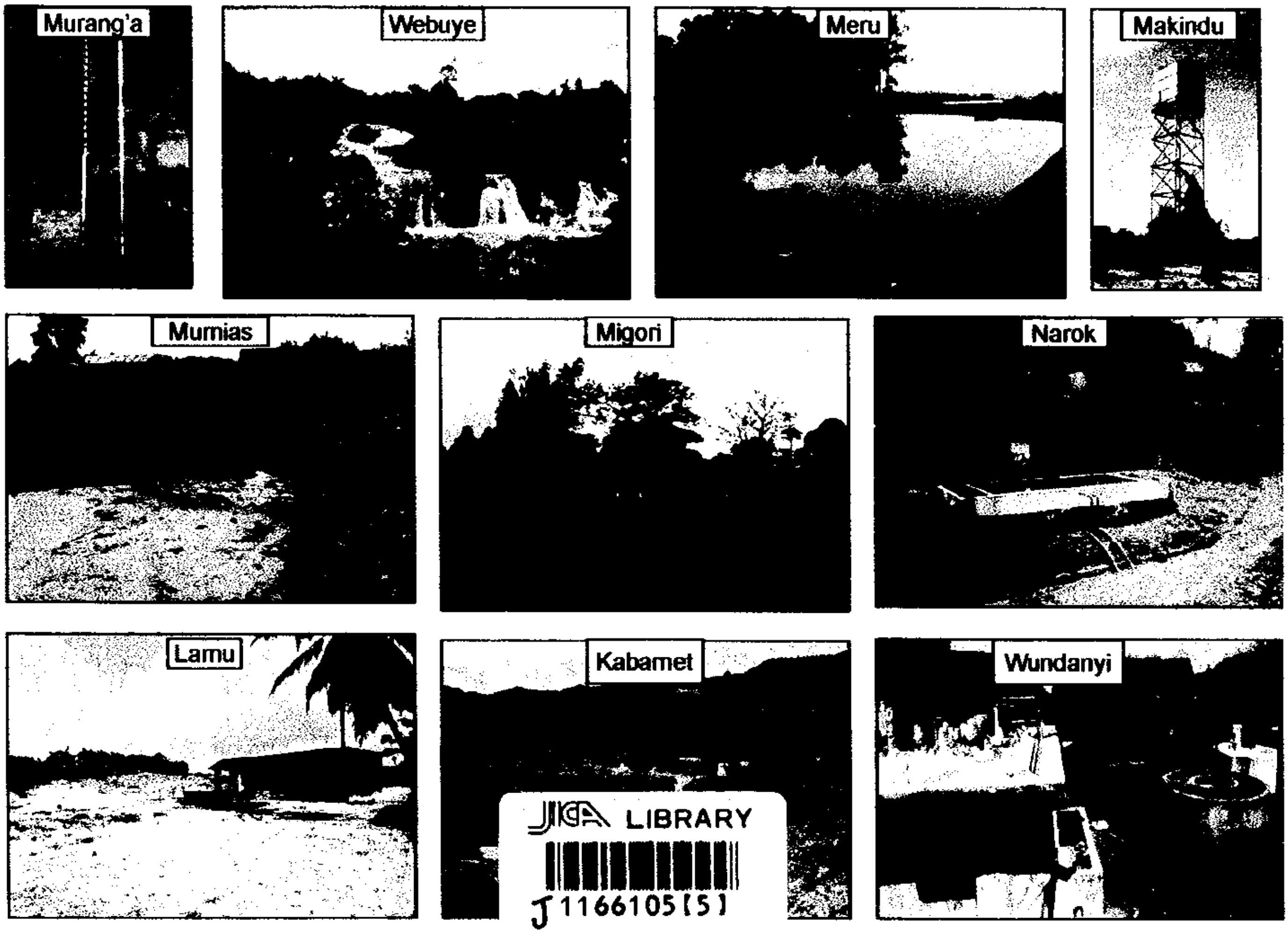
JAPAN INTERNATIONAL COOPERATION AGENCY

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 2G : Main Report (including Appendices) - Migori Town

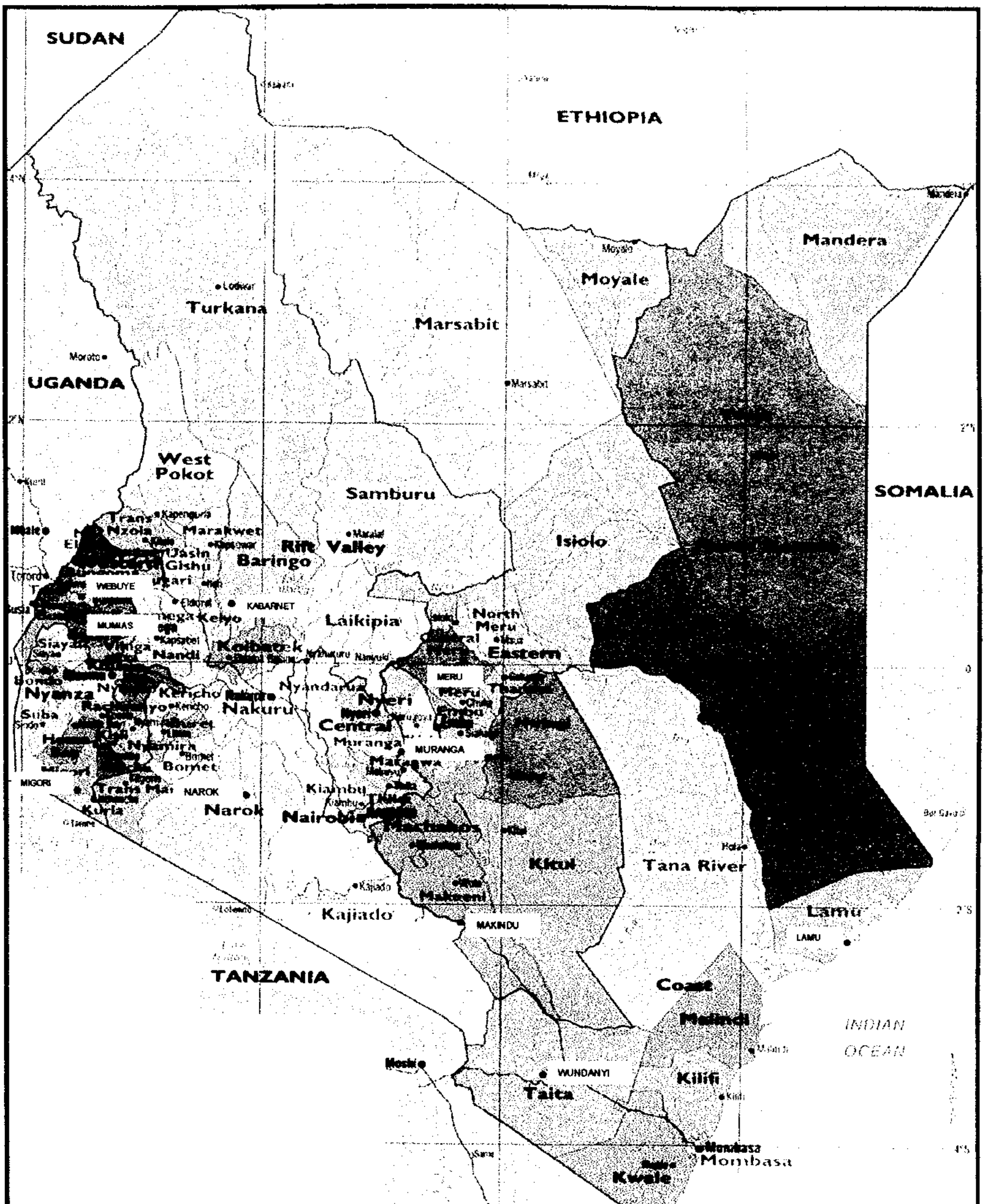
FEBRUARY 2001

Development Impact Consulting

Engineering and Utility Management Ltd.

Gibb Eastern Africa Ltd.

GIBB Eastern Africa
LAWGIBB Group Member



TEN TOWNS WATER & SANITATION STUDY

TOWNS LOCATION MAP

Development Impact Consulting

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MIGORI WATER SUPPLY

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LIST OF ABBREVIATIONS

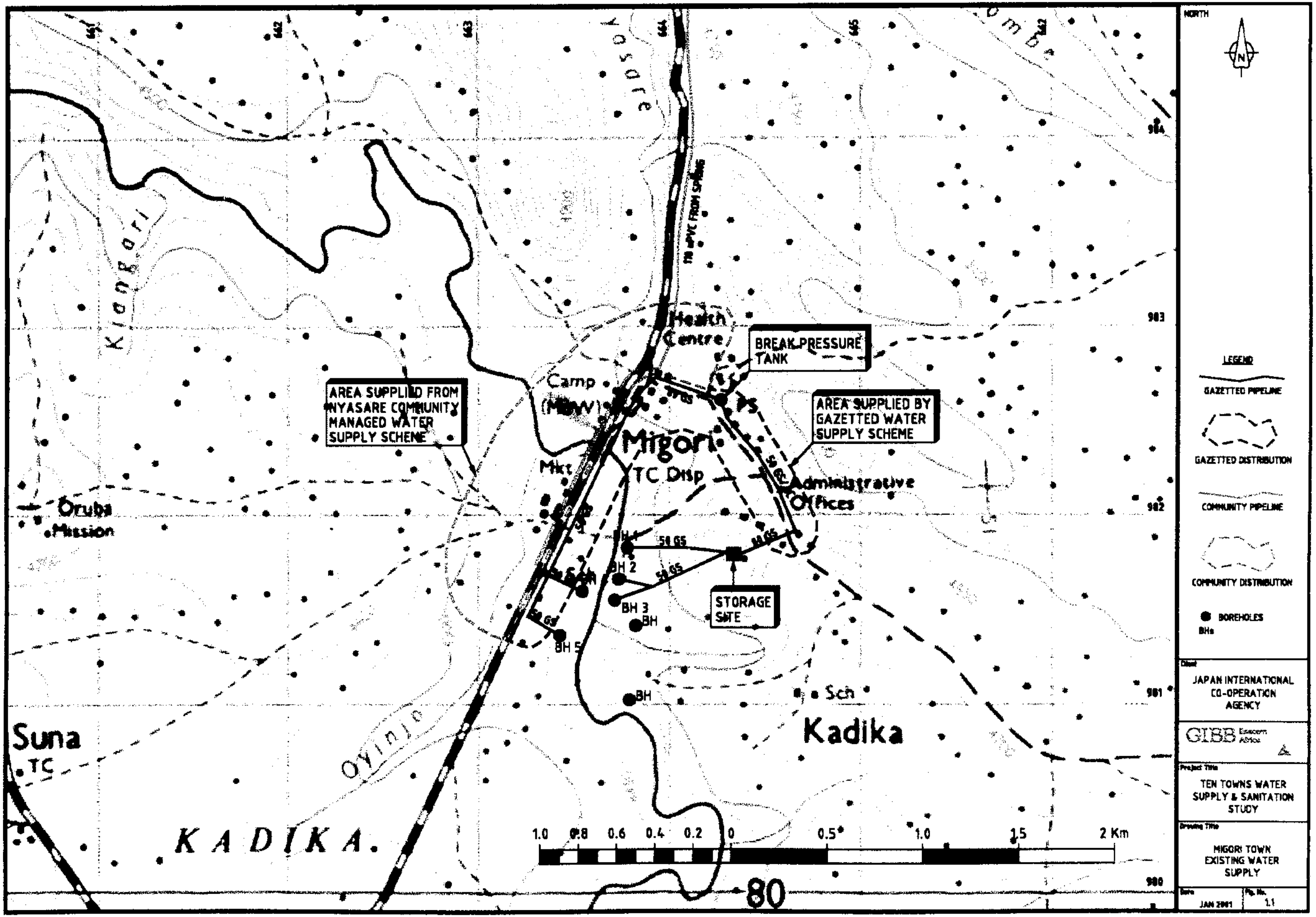
AC	Asbestos Cement (Pipe)
AFW	Accounted for water
AG	Attorney General
AIDS	Acquired Immune Deficiency Syndrome
AIE	Authority to Incur Expenditure
AMREF	African Medical Research Foundation
ASK	Agricultural Society of Kenya
ATP	Ability to Pay
bgl	Below ground level
BH	Borehole
BOT	Board of Trustees
BPT	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



Health Centre
BREAK PRESSURE TANK
Camp (MOW)
AREA SUPPLIED FROM NYASARE COMMUNITY MANAGED WATER SUPPLY SCHEME
AREA SUPPLIED BY GAZETTED WATER SUPPLY SCHEME
PS
Migori
Mkt
TC Disp
Administrative Offices
Oruba Mission
BH 1
BH 2
BH 3
BH 5
BH
STORAGE SITE
Sch
Kadika
Suna TC
KADIKA
Oyinjo
Kiangari
1.0 0.8 0.6 0.4 0.2 0 0.5 1.0 1.5 2 Km
80
NORTH
LEGEND
GAZETTED PIPELINE
GAZETTED DISTRIBUTION
COMMUNITY PIPELINE
COMMUNITY DISTRIBUTION
BOREHOLES BHs
JAPAN INTERNATIONAL CO-OPERATION AGENCY
GIBB
TEN TOWNS WATER SUPPLY & SANITATION STUDY
MIGORI TOWN EXISTING WATER SUPPLY
JAN 2001
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

2.1.1 Location

Migori town is a District Centre in Nyanza Province. It lies on the A1 trunk road from Kisii to the border with Tanzania, some twenty kilometres from the border town of Isebania.

The municipality covers an area of 57 km^2, although only the town centre is provided with piped water.

2.1.2 Topography

The Migori River, which flows from the south east to the north west, passes through the centre of the town. The Nyasare River joins the Migori River from the north and the Oyinjo River joins from the south. To the north and east the town is bounded by hills.

Ground levels within the town range from approximately 1,350 m AMSL near the Migori River to approximately 1,463 m AMSL at the service reservoir site on a hilltop to the east of the town.

2.1.3 Geology

The town lies on a shield comprising Nyanzian system metavolcanics (commonly referred to as 'greenstones'). They comprise basic to acid volcanics; other units of the Nyanzian system include sediments and banded ironstones. Granites also occur in the area, and could be found at depth where they are not exposed on the ground.

2.1.4 Climate

Annual rainfall in Migori averages 1,400 mm.

2.2 PHYSICAL INFRASTRUCTURE

2.2.1 Communications

2.2.1.1 Road links

Migori lies on the trunk road running from Kisii to the border with Tanzania at Isebania. The hinterland is served by an extensive network of classified and unclassified roads.

2.2.1.2 Air transport

There is an airstrip at Nyanchabo to the south west of the town. There are no scheduled flights, but light aircraft may be chartered to reach Migori.

2.2.1.3 Telecommunications

Telephone services and fax facilities are available in the town.

2.2.2 Power supply

Migori 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

The El Niño Emergency Project to improve water supply facilities is in the implementation phase. The government of Austria, through the Institute for International Co-operation is considering funding a second phase of the community-managed Nyasare water supply to improve water supplies in Migori.

2.3 SOCIO-ECONOMIC CONDITIONS

2.3.1 Administration

Migori is a cosmopolitan town located in Migori district, Nyanza province in the southwestern part of Kenya about 450 Kilometres West of Nairobi. As a fast growing town, it was first established as a small trading center in 1931 and gradually attained a municipality status in

1997 which covers approximately 120 Km^2 under two locations, four sub-locations and six wards. It is however important to note that delineation of municipal boundaries used in this study as defined by the Ministry of Local Government includes areas that may not necessarily be urban. The town is the administrative headquarters of Migori district and its Central Business District (CBD) houses offices of the district commissioner, other district departmental heads, municipal, and county council as well as offices of major parastatals. The town is a major business convergence centre for the hinterland especially on market days when urban visitation is at its peak. The presence of the Sony sugar factory has a great influence on the administrative significance of the town.

2.3.2 Population Structure and Distribution

Using the 1999 housing and population census, the population of Migori town was 95,446[1] people as at 1999 against 14,875 persons in the service area. This contrasts with the 1979 and 1989 census figures where the total population was 6,236 and 12,274 respectively representing an inter censal growth rate of 22.77% for 1989-1999 period compared to 6.77% for 1979-1989. The high inter censal growth rate for the 1989 – 1999 period is attributed to expansion of municipality boundaries by an extra 50 km^2. It is however important to note that this does not include special considerations such as population peaks on market days when pressure on existing water utilities is expected to be high. The population from the expansive Awendo sugar belt and traders (normally non-resident population) converge to trade quite often. The number of households increased from 2882 in 1989 to 19812 units in 1999 with a mean household size of 5.3. Urban population density (considering the CBD) was 1,083 persons per km^2 in 1989 compared to 1402 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 2.1 below. See appendix G 1-1 for an in depth exposition of the population structure.

[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 2.1 Population Structure and Distribution (1999)

Sub-Location	Number of Households	Population in urban council	Population in Service area
Wasweta I	4154	17112	14875
Ngege	1034	5292	
Osingo South	553	2574	
Osingo North	793	4181	
Wasio	688	3446	
Manyatta	945	4617	
Sagegi	620	3443	
Ogwedhi	329	1521	
Kwa	997	4726	
Onguo	486	2278	
Marindi	2356	10189	
Special Population	-	1843	
Oruba	3203	13882	
Special population	-	2055	
Otacho	1512	7591	
Kakrao	2142	10696	
Total	**19812**	**95446**	

Source: District Statistical Office Migori, 1999 and Central Bureau of Statistics, 2001

2.3.3 Population Projections to the year 2010

The 1989-1999 inter censal population growth rate for the town was 22.77%. Though this may seem to be high, it was mainly due to expansion of the municipal boundaries by an extra 50 km^2 as well as the rapid establishment of several tobacco leaf processing plants in the hinterland. Once all this factors are considered, the general determinants of population growth in Migori remain confined to social infrastructure, investment potential, fertility rates and rural–urban migration. There was a general decline in fertility levels and the growth in number of industrial investments has been rather slow in the last decade. The total effect of this scenario is therefore a stable population growth rate of 4.5%, which is considered to capture other population growth dynamics such as projected development activities. Table 2.2 below gives an annualized ten year breakdown of population projections for the town to the year 2010.

Table 2.2 Population Projection[2] to the year 2010.

2.2.5 *Year*	2.2.5.1.1 Population under Municipal Council
2000	99700
2001	104200
2002	108900
2003	113800
2004	118900
2005	124300
2006	129900
2007	135700
2008	141800
2009	148200
2010	154900

2.3.4 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. The growth of the town is closely linked to its proximity to the Awendo sugar belt, several tobacco processing plants and fishing activities in lake Victoria. Fishing activities in Lake Victoria positively influence the economic growth of the town. There is a fish processing factory operating in the town especially within the new market. Their combined effect forms a major business and economic convergence bloc whose derived demand for utilities may outweigh the provisions for the town. Also present are a number of small scale processing and fabricating enterprises such as motor vehicle repairs and metal fabricating totaling to 1214. Most of these enterprises are registered as small and medium scale enterprises engaged in manufacturing, import/export and general retailing category. Of these 150 are owned by women. These establishments have a potential to generate considerable income and employment opportunities for the local residents capable of sustaining a cash economy. The distribution of business enterprises in the town is as shown in table 2.3.

[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 2.3: Business enterprises

Type of business	Number
Bars	20
Wholesalers	70
Catering	160
Tourist class hotel	1
Hardwares	12
Garages	13
Regulated trade	1,450
Miscellaneous trade	49
Manufacture	7
Distributors	13
Total	**1,774**

Source: Local Authority Development Plan, Migori 1999

2.3.5 Social Infrastructure

2.3.5.1 Communication

The town lies off an A classification trunk road from Kisii to Kehancha in a north-south direction. Most of the roads in the town are classification C and D of all weather Murram and earth roads. The town is well connected to all the major towns within the region including Tanzania. Some roads are unmotorable and most commuters use bicycles. Other services include subscriber trunk dialing (STD) telephone services, fax facilities, Internet service bureaus as well as an airstrip for chartered light planes.

2.3.5.2 Social Institutions

The growth of Migori town is dependent on the outreach activities of the local sugar factory and a retinue of other tobacco leaf plants. The growth in establishment of such institutions as schools and health facilities has been slow due to lack a political goodwill. However, the main types of institutions and their numbers are summarized in the tables 2.4 and 2.5.

Table 2.4 Educational Institutions

Type of institution	Number
Pre-Primary Schools	41
Primary Schools	19
Secondary Schools	3
Teacher Training College	1
Total	**64**

Source: District Development Office Migori, 1999

Table 2.5 Other Social Institutions

Facility	Number
Mission Hospital	1
Nursing homes	8
GoK Hospital	1
Private Clinics	14
Slaughter house	1
Total	**25**

Source: District Development Office Migori, 1999

2.3.6 Income Levels

The distribution of income in the town is quite uneven and follows the major production lines prevailing that can be broadly defined in terms of household resource endowment. The distribution of household incomes drawn mainly from wages, salaries and profits also varies based on unit of analysis ie urban or peri urban. The presence of the Sony Sugar factory and the British American Tobacco (BAT) through contract farming has considerable impacts on the income levels of the peri-urban population as well as the general development of the town. Fishing and trawling activities on L. Victoria provides raw materials for a number of fish processing industries in the town. The incomes generated from both the formal and informal sectors cumulatively influence the local populations household decision making process and purchasing power. However, according to the findings of the Welfare Monitoring Surveys, II of 1994, the mean monthly income for Migori town including the peri urban population is 6641.2 as shown in table 2.6 below.

2.6 Summary of aggregated mean household income for Migori town

Income source	Mean Income	Percentage share
Wages, salaries, profits	1585.5	26.1
Other non-agricultural income	1540.3	24.6
Agricultural income	2874.4	39.7
Crop income	641.0	9.5
Total	**6641.2**	**100.0**

Source: Welfare Monitoring Survey II, 1994

2.3.7 Willingness and Ability to Pay for Water Services

2.3.7.1 Ability to Pay

Ability to pay for water services is considered to be a function of level of household incomes, the acceptable budget share of water/sewerage services in total expenditures, tariffs and the target consumption levels per household. However, the main consideration in the ability to pay in this study is the household level of income and expenditure. Assuming that households only spend their disposable incomes, then expenditure is a good proxy of estimating income as well as level of utility derived from water consumption since it reflects the true market price and consumer expectations. Under normal circumstances, the ceiling on the proportion of income that may be spent on water/sewerage services is normally taken to be 5% (representing the lower income group) though this figure varies from one income group to another. For instance, households in the lower income bracket spent a higher budget share of their income in real terms on water than households in the middle to high-income groups who spent on average 2.2% and 1.4 % of their incomes respectively.

47% of the population in Migori town live in the low-income bracket and stand pre disposed to contract water born ailments. It is therefore important that a re-evaluation of their income levels as above, W/ATP and W/ATA be the basis for analyzing the expected demand for water.

2.3.7.2 Willingness to pay

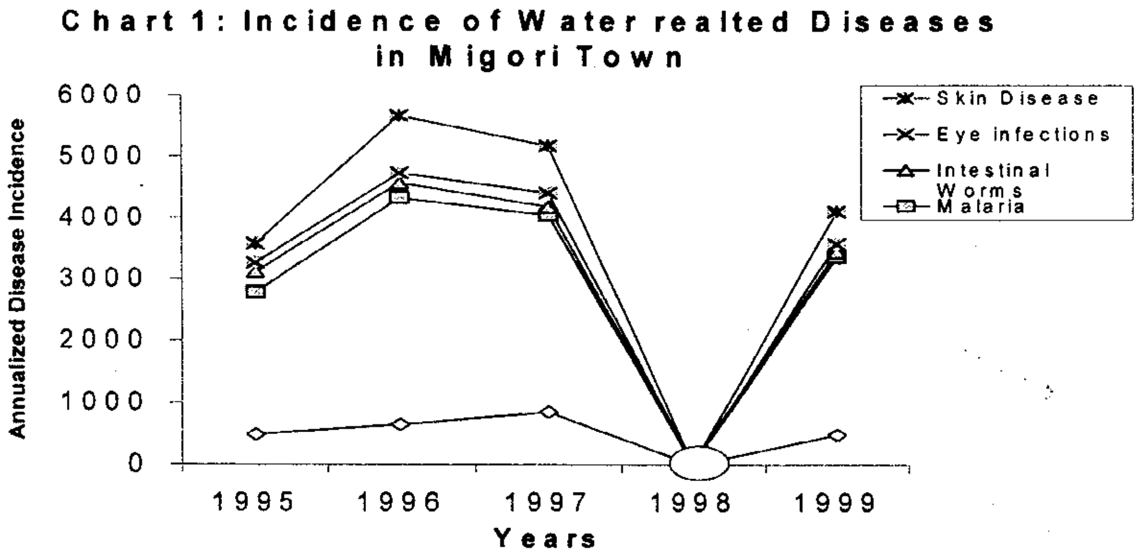
To get information on willingness to pay[3] the study team carried out a random survey on a sample of 80 households mainly within the service area. Three methodologies were adopted. These were focus group discussions with key personnel in water, individual observation and elaborate questionnaires. Through questionnaire based interviews, each household head was asked questions relating to how much they were willing to pay for a cubic meter of water under tow scenarios. One was under existing water supply conditions and the other being under a situation of improved service delivery. Based on the three approaches above, 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. For instance, the

[3] The appropriate methodology in estimating willingness and ability to pay (W/ATP)/ willingness and ability to accept (W/ATA) responsibility for facilitating an improved water supply 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.

average tariff for Migori was taken to be Kshs. 16.57 per m^3. Analysis of willingness to accept contingent partnership for improved water service delivery based on consumer expectations and their perception of the importance of taking water from clean water sources was also considered and found to positively influence water demand. 90% of the households interviewed were willing to pay up to Kshs. 500 for actual water consumption compared to an average monthly bill of Kshs. 400 based on billing estimates. A similar survey in the areas not currently serviced established that majority of the 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

2.3.8 HEALTH AND SANITATION SITUATION

A critical appraisal of the water and sanitation conditions was carried out. Records availed to the team and which were counterchecked from the headquarters of the ministry of health shows that the most common diseases in order of prevalence are malaria, diarrhoea, skin infection, anaemia, pneumonia, pulmonary tuberculosis and typhoid. Most of these diseases are water borne hence the need for better sanitation. The public sewerage system was considered to be of high priority. Pit latrines that are commonly used are a major cause of underground water pollution. Pit latrines are still largely in use even amongst families with water closets due to unreliability of water. This threatens the safety of the many water wells that are also used. Pollution of river water is eminent. The pattern of water borne diseases is as shown in chart one below. Note that there were lapses in data capture for the year 1998



Source: Health Information Systems Unit, Ministry of Health and PHO's Office Migori, 2000

2.3.9 TYPES OF SETTLEMENTS

Most residents of Migori town are poorly housed. High costs involved in purchase of material and hiring of contractors remain the main reason for lack of good owner-occupied houses. Houses built by private companies such as British American Tobacco - BAT for their staff form a very tiny percentage of total housing available. The situation in peri urban areas is one of low income housing mainly grass thatched. The distribution of the population based on income categories is shown in table 2.7 below

Table 2.7 Categorization of households on the basis of income levels

Income category	Number	Percentage
High income	19,174	18
Middle income	29,309	35
Low income	47,963	47
Total	**96,446**	**100**

2.3.10 Situation of Women in Society

Women in Migori 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 primarily depend on the services of the female family members where water collection remains a preserve of women and only forms one of their major social roles among many other economic activities within the household. Just like poverty, collecting water is a circumstance women find themselves in and which does not necessarily define them. Though there exists community water points in Migori, collecting water for the household still has negative repercussions on the length and hardship of an average poor woman's working day. Despite the government pre commitment to provide water in a two kilometre radius by the year 2010, this situation is yet to be realized especially within the peri-urban areas. This therefore means that the rehabilitation exercise planned for the town must meet societal expectations in order to ease the excess burden on the woman and an average woman's workload should be a key monitoring indicator. Other than situations where hand cats, bicycles and donkeys 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 leading 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.

2.4 EXISTING WATER RESOURCES, MANAGEMENT AND UTILISATION

2.4.7 Hydrogeology and the occurrence of groundwater

Hydrogeological conditions in the Migori area can be summarised as follows:

- Depth range to the main aquifer:
- 50 – 100 m for confined aquifers
- 5 – 15 m for unconfined aquifers in connected to surface water sources like the Migori River.

- Depth range of water rest level.
- 5 – 10 m for confined aquifers
- 2.5 – 30 m for free aquifers.

- Discharge range: 0.5 – 20 m^3/hr - best where mixed aquifers occur.

- Water quality: generally fresh, slightly alkaline sodium bicarbonate waters. The ionic concentrations of silica and may be high.

Aquifers are free or confined, and comprise sediments, weathered or fractured rock. Recharge to the aquifers occurs by lateral underflow from recharge catchments and by seepage from surface water bodies. Local infiltration also contributes to recharge.

2.4.8 Boreholes in the project area

There are known to be eight existing boreholes that are owned either by the Ministry of Water Development or institutions in town. These are serialised as follows:

- C 2992 (MENR abandoned Borehole 2).
- C 3920 (MENR production Borehole 3).
- C 4386 (St. Joseph's Mission Hospital production borehole, Diocese of Homa Bay).
- C 4774 (MENR production Borehole 4).
- C 4775 (MENR production Borehole 5).
- C 7387 (Migori Boys Secondary School, Diocese of Homa Bay).
- C 8720 (Rural water development handpump, Diocese of Homa Bay)
- C 8969 (unequipped JICA borehole, yield 4 m^3/hr)
- C 8970 (dry JICA borehole)

There is another abandoned water department borehole (MENR Borehole 1, serial number unknown). Four other boreholes have been drilled during the ongoing El Niño Project.

Boreholes C 2992, C 3920, C 4774, C 4775, C 8969 and C 8970 are all owned by the local water department.

Table 2.8 presents data for the existing water department and institutional boreholes.

Table 2.8
Completion data: Water Dept. & institutional boreholes

SERIAL No.	Total depth (m)	Water strike Levels (m)	*Rest level* (m)	*Tested yield* (m^3/hr)	*Completion date*
C 2992	77.1	11, 61	6.1	3.55*	3-56
C 3920	122	10, 119	5	10 (20.2)	25.05.73
C 4774	125	6, 54	2.5	16.4	20.06.80
C 4775	1706	12, 86, 148	5.85	10.6	6-80
C 7387	110	4, 89	23.76	6.18	12-87
C 8720	60	?	30	0.49	7.10.88
C 8969	120	?	?	4	8-90
C 8970	78	?	?	?	9-90

Data source: NAWARD, MENR, Nairobi.

2.4.9 Groundwater quality

None of the boreholes in Migori are provided with sampling points, so it was not possible to obtain a sample of groundwater during the field visit. The available water quality analyses have been obtained from the Ministry of Environment and Natural Resources. These include four analyses (three partial) for Borehole 3 and one partial analysis for Borehole 4. The most complete analysis for Borehole 3 is presented below.

Table 2.10
Groundwater quality for Borehole 3 (C 3920)

Cations	mg/l	meq/l	Anions	mg/l	Meq/l
NH_4^+	ND	0	Cl^-	34	0.987
Na^+	91	3.958	NO_2^-	0	0.000
K^+	5	0.128	NO_3^-	0	0.000
Ca^{2+}	30	1.497	F^-	1.5	0.079
Mg^{2+}	11	0.905	HCO_3^-	337	5.523
$Fe^{2+,3+}$	0.4	0.018	CO_3^{2-}	0	0.000
Mn^{2+}	0.2	0.007	SO_4^{2-}	27	0.281
			PO_4^{3-}	ND	0.000
Total		6.514	Total		6.870

Data source: MENR database, Nairobi.

Other determinations for the sample include the following:

pH	7.5
Alkalinity	367 mg/l
Hardness	120 mg/l
Free CO_2	10 mg/l

The analytical results are not consistent. At a pH of 7.5, bicarbonate is the only significant type of alkalinity, but the reported bicarbonate concentration of 337 mg/l represents only 276 mg/l of alkalinity expressed as calcium carbonate, not the reported 367 mg/l.

The charts in the 1986 MENR Design Manual show that the water is not aggressive to cement and iron products. This conclusion is supported by calculations that show that the water is over-saturated with respect to calcite.

2.4.10 Potential for groundwater development

The yield of boreholes in the Migori area is strongly linked to the connection of aquifers with sources of recharge like rivers. Thus, where both unconfined and confined aquifers are struck, boreholes tend to return higher yield. This fact limits the areas in which groundwater sources can be developed. The water quality is good and aquifers are recharged regularly by lateral replenishment and direct local infiltration.

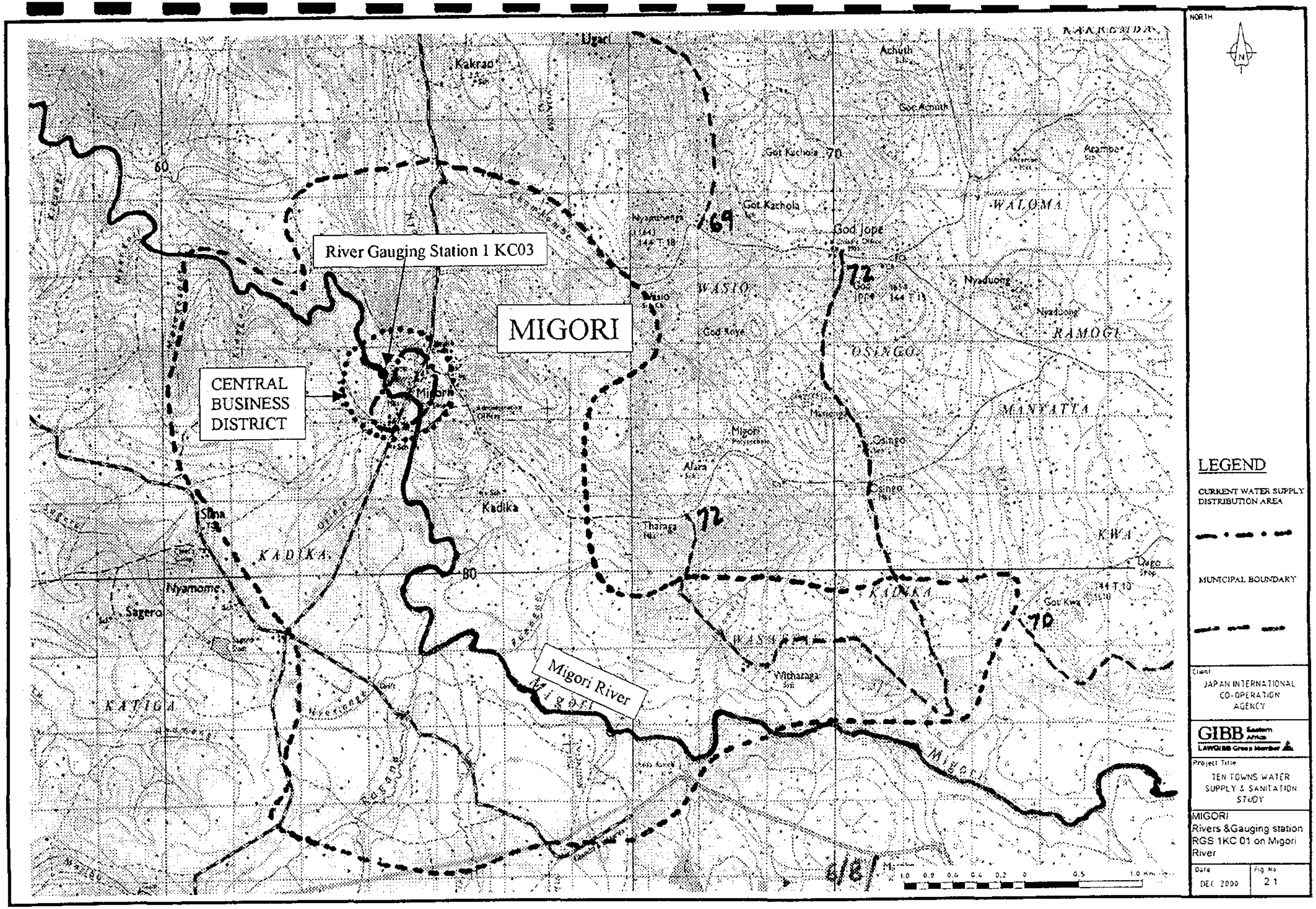
2.4.11 Hydrology and surface water potential

The principal rivers in the vicinity are the Migori River which flows through the centre of the town, and the Osani River which is approximately 8 km from Migori town – see Figure 2.1. The river catchments fall within Sub-Drainage Area 1KB of the Lake Victoria Basin. Only the Migori River is gauged, and details of the gauging station are given in Table 2.11.

Table 2.11
Details of the River Migori gauging station.

Code	River	Latitude	Longitude	Station opened	Station closed	Rated	Catchment area (km^2)	Mean Annual runoff (m^3/s)
1KC03	Migori	00^0 16'50"	$34^0$28'15"	1951	1959	Yes	3,046	17.1

Source: The JICA Aftercare Study on the National Water Master Plan Data Book, 1998.

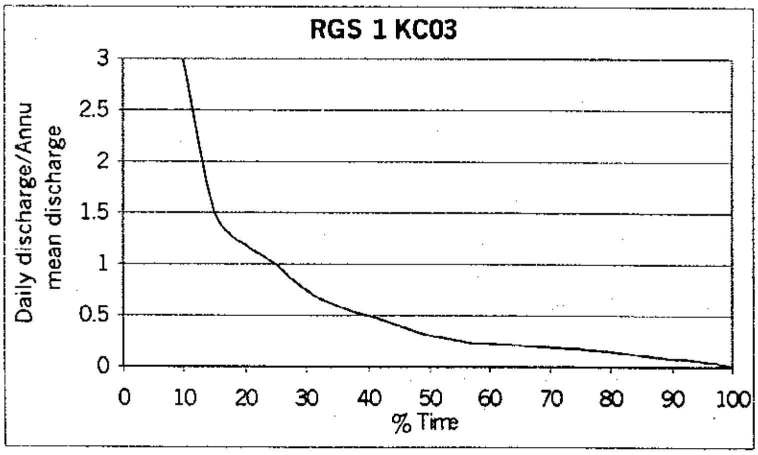


River Gauging Station 1 KC03
MIGORI
CENTRAL BUSINESS DISTRICT
Migori River
WASIO
OSINGO
MANYATTA
WALOMA
RAMOGI
KADIKA
KATIGA
KWA
Kakrao
Ugari
Achuth
Got Achuth
Got Kachola
God Jope
Nyaduong
Osingo
Migori
Kadika
Sagero
Nyamome
Thanga
Got Kwa
Mitharaga
NORTH
LEGEND
CURRENT WATER SUPPLY DISTRIBUTION AREA
MUNICIPAL BOUNDARY
Client
JAPAN INTERNATIONAL CO-OPERATION AGENCY
GIBB Eastern Africa
LAWGIBB Group Member
Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY
MIGORI
Rivers &Gauging station RGS 1KC 01 on Migori River
Date
DEC 2000
Fig No
21

The non-dimensional flow duration curve for the Migori River is presented in Figure 2.2. This curve has been abstracted from the *"Aftercare Study on the National Master Plan" published* by JICA in 1998. As very little additional data has been collected since the time of the JICA study, the curve is applicable today.

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.

Figure 2.2
Flow duration curve for Migori River at RGS 1KC03



The 50% exceedence flow in Figure 2.2 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.

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".*

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.

The runoff characteristics are presented in Table 2.12. The comparison of source yields and demand is presented Table 2.13.

Table 2.12
Flow characteristics – R. Migori at RGS 1KC03.

	Q/Q_{ave}	m^3/sec	m^3/day
Mean annual runoff	-	17.10	1,450,000
50 % flow exceedence ratio Q_{50}/Q_{ave}	0.30	5.13	440,000
90 % flow exceedence ratio Q_{90}/Q_{ave}	0.10	1.71	150,000
95 % flow exceedence ratio Q_{95}/Q_{ave}	0.05	0.85	74,000
100% flow exceedence ratio Q_{100}/Q_{ave}	0.01	0.17	15,000

Table 2.13
Comparison of surface water yield and demand based on data for R. Migori at RGS 1KC03

	m^3/d
Present abstraction capacity	None
2000 water demand (Table 4.3)	13,473
2010 water demand (Table 4.3)	20,933
90 % exceedence flow in R. Migori	150,000
100 % exceedence flow in R. Migori	15,000
Water resource available from R. Migori	135,000

The results in Table 2.13 indicate that there is adequate surface water available from the River Migori to meet future demand. However, the existing water sources are boreholes, and these should be re-equipped in the rehabilitation programme. In the longer term, surface water resources will have to be exploited to meet the growing water demand.

The Osani River has not been considered here. It has been earmarked as a possible source for the future expansion of the Nyasare community-managed water supply project being funded by the Austrian Government. A surface water impoundment of 500,000 m^3 has been proposed (Ref: "*Personal Communication*" from Eng. Winder Markus, IIZ).

3 EXISTING WATER SUPPLY CONDITIONS

3.1 WATER SOURCES

The residents of Migori town obtain water from a variety of sources:

- The gazetted water supply system operated by MENR;
- The community-managed Nyasare water supply scheme;
- A borehole drilled by the Diocese of Homa Bay under their Rural Water Development Programme;
- Shallow wells, and
- Institutions that have private water supply facilities.

These various water supply systems are described in the following sections.

3.2 MIGORI GAZETTED WATER SUPPLY SCHEME

3.2.1 General

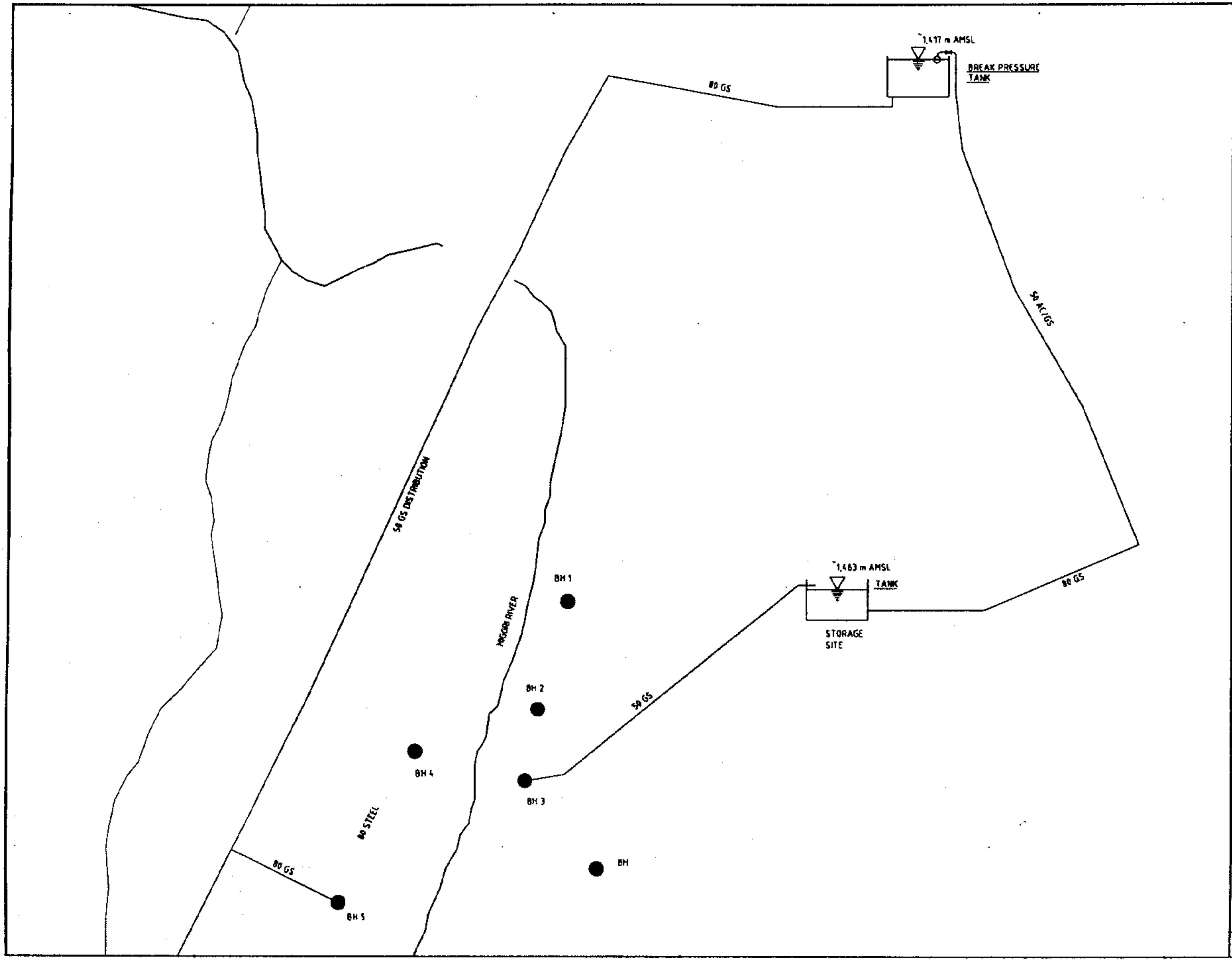
The Ministry of Environment and Natural Resources, through the District Water Office, operates this water supply system. A schematic layout of the scheme is given as Figure 3.1.

The scheme is based on the abstraction of groundwater from a number of boreholes along the banks of the Migori River. The reported abstraction, with two boreholes in operation, is 180 m^3/d.

3.2.2 Boreholes

3.2.2.1 <u>Borehole No.1</u>

This borehole was drilled on the eastern bank of the Migori River in the early 1950s and was abandoned in the 1980s. It was formally equipped with a motorised pump. The borehole is located within a locked building in the old District Water Office compound. The District Water Office has no other details.



Client
JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa
LAWGIBB Group Member

Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title
MIGORI TOWN EXISTING MENR WATER SUPPLY

Date	Fig. No.
DEC 2000	3.1

3.2.2.2 Borehole No.2

This borehole is located some one hundred metres to the south of Borehole No.1 and was drilled in March 1956 to a depth of 77.1 m. The Ministry reference number for this borehole is C-2992. Whilst the yield is reportedly 3.55 m^3/hr, the borehole was formerly equipped with a motorised pump of higher rating (1,500 gallons per hour against 250 feet head, i.e. 6.8 m^3/hr against 76.2 m). The pump-head is still in place, but the motor has been removed. The building surrounding the borehole is derelict, and the borehole is no longer in use.

3.2.2.3 Borehole No. 3

This borehole, Ministry reference C-3920, is located between Borehole Nos 1 and 2. It was drilled in 1973 to a depth of 122 m. It was cased and screened with galvanised steel Class 'B' screwed and socketed 150 mm diameter pipe of 12 m length. The plain casing was set from the surface to 6 m bgl, and the screen was set at 6 m bgl to 12 m bgl. The screen was made of casing with 2 mm by 150 mm long slots. The rest of the hole was left open at 150 mm diameter to total depth.

The casing, which is now 27 years old and nearing the end of its useful life, was inserted to stabilise the overburden and the top aquifer. The casing is only 12 m long and could be replaced if necessary.

The physical log of the borehole mentions no caving or other difficulties. The borehole was cleaned in 1990 to remove silt and test pumped at 20.2 m^3/hr, and was used as a production borehole until mid October 2000 when the submersible pump motor burned out. The District Water Office removed the pump and has requested MENR headquarters to supply a replacement Grundfos pump rated for 16 m^3/hr against 195 m head. The replacement pump is yet to arrive. The headworks pipework has been removed, but a two inch galvanised steel union remains visible above ground. The distance between the borehole and the union is not sufficient for a flow meter.

The switchgear for the borehole pump is located in an adjacent building. It does not include an "hours-run" meter.

3.2.2.4 Borehole No. 4

This borehole, Ministry reference C-4774, is on the opposite bank of the Migori River from Borehole Nos 1, 2 and 3. It was drilled in June 1980 to a depth of 125 m. The borehole was constructed with Class 'B' standard steel socketed 152 mm diameter casing and slotted screen. The construction details are presented in Table 3.1.

Table 3.1
Construction details for Borehole No. 4

Depth of casing joint (m)	Type of casing to joint
8.0	Plain
14.5	Slotted
33.8	Plain
40.3	Slotted
125.0	Open

The hole was left open from 40.3 m to final depth. Slot lengths were 0.3 m and the openings were 1.5 mm. The casing and screen string is now 20 years old and could still last several years. The base of the casing string was not grouted, nor was gravel inserted.

The borehole is currently not operational because it is blocked by a submersible pump that was dropped. This pump can be removed or junk-milled into the hole, depending on the physical conditions.

This uncased borehole has a reported yield of 14.38 m^3/hr but is no longer in use as the hole is blocked.

3.2.2.5 Borehole No.5

This borehole, Ministry reference C-4775, is also located on the opposite bank of the Migori River from Borehole Nos 1, 2 and 3, and to the south of Borehole No. 4. It was drilled in 1980 to a depth of 170 m. The borehole was constructed with 152 mm Class 'B' standard steel socketed casing and slotted screen to 85 mbgl. The screen slots were reported to be 0.3 m long by 1.5 mm wide. The hole was left open at 152 mm from 85 mbgl to total depth. The installation details are presented in Table 3.2.

Table 3.2
Construction details for Borehole No. 5

Depth of casing joint (m bgl)	Type of casing to joint
9	Plain
15	Slotted
73	Plain
79	Slotted
85	Plain
170	Open hole

No gravel pack was installed, nor was the base of the casing string grouted. The borehole galvanised pipe installation is now 20 years old and has served about two-thirds into its life span.

The borehole has a reported yield of 10.6 m^3/hr, but the discharge reduced two years ago and the pump intake was lowered. This is the only borehole operated by the District Water Office that is currently in use.

The borehole headworks pipework includes a two inch threaded gate valve, non-return valve and union for dismantling. There is no flow meter, sampling point or pressure gauge, nor is there any provision for dipping the borehole. Operations staff estimated the pump output from the current drawn by the motor.

The switchgear for the borehole is located in a building between Borehole Nos 4 and 5. The switchgear includes starters, ammeters and voltmeters for both boreholes, but only a single "hours-run" meter.

3.2.2.6 Borehole No.7

This borehole, Ministry reference C-8969, was drilled in August 1990 under the JICA-funded "South Nyanza Water Development Project". It is located to the south of Borehole Nos 1, 2 and 3 on the same side of the Migori River. The borehole is 120 m deep and is cased at six inches. The reported yield is 3.996 m^3/hr, but the borehole has never been equipped. It was originally drilled in open farmland, but is now surrounded by houses.

3.2.2.7 Borehole No. 8

This borehole, Ministry reference C-8970, was drilled in September 1990 under the JICA-funded "South Nyanza Water Development Project". It is to the south of Borehole No. 7, on the opposite bank of an ephemeral stream. It was drilled to a depth of 78 m, but was back-filled with stones and is uncapped.

3.2.3 Disinfection

Borehole No 3 on the eastern bank of the Migori River delivers to a storage site above the town's administrative offices, where DWO staff report that calcium hypochlorite is dosed as a disinfectant. The available records show that 120 kg of tropical chloride of lime is delivered per annum. At the time of our site inspection, the borehole was not in use and no calcium hypochlorite was being dosed. The boreholes on the western bank of the Migori River deliver groundwater directly into the distribution system without disinfection.

3.2.4 Storage

3.2.4.1 Main storage site

The main storage site is on a hilltop above the main government offices. There is a reinforced concrete tank of 136 m^3 capacity, which is being augmented with a new 225 m^3 masonry tank under the El Niño project. The ground level at the storage site is approximately 1,463 m AMSL.

3.2.4.2 Break pressure tank

There is a break pressure tank at a level of approximately 1,417 m AMSL within the distribution system. This is being duplicated with a 65 m^3 tank under the El Niño project.

3.2.4.3 Elevated storage along main road

Two elevated water tanks are to be erected under the El Niño project:

- A 13 m^3 elevated tank to receive water from Borehole 4, and
- A 45 m^3 elevated tank to receive water from Borehole 5.

3.2.4.4 Abandoned tanks at old waterworks

There are two abandoned tanks at the old waterworks near Boreholes Nos 1, 2, and 3: one circular masonry structure and one pressed steel panel tank. It seems that the pump that was installed in Borehole No. 2 was rated to pump to these tanks rather than the hilltop storage site.

3.2.5 Distribution

The distribution system in Migori consists of an 80 mm galvanised steel outlet from the main storage tank, feeding a 50 mm asbestos cement/galvanised steel pipe that runs north along the road past the main government offices. At the northern end of the road is a break pressure tank with an 80 mm galvanised steel outlet that supplies a 50 mm main along the road to the Tanzanian border. The pipework between the service reservoir and the break pressure tank is being reinforced under the El Niño project with a 110 mm uPVC pipe some 1,335 m long.

The gazetted water supply scheme serves the area of town to the east of the road to the Tanzanian border, including the government offices and prison.

3.3 NYASARE WATER SUPPLY SYSTEM

3.3.1 Water source

This is a community-managed water supply scheme constructed in 1994 using funds from the Government of Austria. The water source is a capped spring to the north of Migori, located some eight kilometres from the scheme's main office. When the scheme was constructed in 1994, the spring was surrounded by forest. This has now been cleared and the area is under cultivation with sugar cane and maize. The design capacity of the scheme was 350 m^3/d, but by 2000 the yield had declined to 230 m^3/d. There is a bulk water meter at the spring to measure water production.

3.3.2 Disinfection

Water is disinfected at source using calcium hypochlorite dosed at a rate of one kilogramme per day. For a flow of 230 m^3/d, this represents a dosage rate of 3 mg/l of equivalent chlorine. The 8 km pipeline from the spring is 110 mm Class B uPVC. For a flow of 230 m^3/d, the velocity in the pipe is 0.31 m/s, providing a contact time of 7.2 hours in the eight kilometre main. The dosage rate and contact time are sufficient for effective disinfection.

3.3.3 Storage

The scheme includes two 100 m^3 reinforced concrete tanks.

3.3.4 Distribution

The distribution system comprises the following:

- uPVC distribution pipework outside diameter range 110 - 25 mm;
- 45 five communal drawing points (metered standpipes with single taps) serving rural households;
- 10 metered water kiosks within Migori; and
- 238 metered individual connections within Migori.

All communal drawing points and individual connections are metered.

The scheme serves rural consumers within the Nyasare valley and the area of Migori to the west of the road to the Tanzanian border.

3.4 RURAL WATER DEVELOPMENT PROGRAMME BOREHOLE

Borehole No. C-8720 was drilled in October 1988 to the south east of Ministry Borehole Nos 1, 2, and 3. The drilled depth was 60 m, the water rest level was 30 m and the estimated yield was 0.48 m^3/hr. The borehole is presently equipped with a hand pump and free access is provided to local residents. The water is not disinfected.

3.5 SHALLOW WELLS

Ministry staff report that numerous households within the municipality rely on shallow wells rather than piped water supplies.

3.6 PRIVATE WATER SOURCES

3.6.1 Saint Joseph's Mission Hospital

Borehole No. C-4386 is located some one hundred metres to the east of Ministry Borehole Nos 1, 2 and 3, and was drilled to a depth of 120 m in September 1977. The yield was estimated as 6.24 m^3/hr. The borehole is presently equipped with an electro-submersible pump and is used to supply the hospital and adjacent staff housing. The system is operated by the hospital.

3.6.2 Migori Boys Secondary School

The Diocese of Homa Bay was responsible for drilling Borehole No. C-7387 in December 1987. The borehole depth is 110 m, water was struck at 4 m and 89 m, the rest level was 23.76 m and the estimated yield was 6.18 m^3/hr. The borehole is located in the grounds of Migori Boys Secondary School and is not equipped.

3.7 EXISTING O&M

3.7.1 Migori gazetted water supply scheme

3.7.1.1 Administrative structure

The scheme is operated and maintained by the District Water Engineer's office. The total staff complement for the District Water Office is twenty nine, of whom twelve are solely involved in the operation and maintenance of the Migori gazetted water supply scheme. An organisation chart for the District Water Office is included in Appendix 3.

3.7.1.2 Metering

There are no flow meters to measure water production at any of the boreholes. Examination of the available billing records show that only 34 of the 577 bills raised are for metered water consumption.

3.7.1.3 Water production, sales and unaccounted for water

Operating staff report that water production amounts to 180 m^3/d with Borehole Nos 3 and 5 in use. This can not be verified due to the lack of water meters. Water sales in June 2000 were recorded as 7,553 m^3, or an average of 251.8 m^3/d. Billed water sales exceed estimated production: clearly, there are significant errors in the estimated production, the estimated sales, or both.

3.7.1.4 Facilities and equipment

The original administration buildings and stores were located next to Borehole Nos 1, 2 and 3. The buildings remain, but are now unoccupied. The stores are still in use as the District Water Office is unable to move the container from the site. The District Water Engineer now operates from temporary offices located near the other administration offices in town. The present offices are temporary corrugated iron and prefabricated steel structures, with no power supplies and only one telephone line. The District Water Office has a single four-wheel-drive vehicle to cover the entire district. The District Water Office also has two motor cycles, but only one is serviceable.

3.7.2 Nyasare water supply scheme

3.7.2.1 Administrative structure

The scheme is operated by an association registered under the Societies Act. The association has 989 paid up members, who elect six representatives to the management committee, one for each zone along the Nyasare valley. Members also elect six executive officials, bringing the number of committee members to twelve. The committee runs the project, assisted by nine employed staff headed by a manager.

3.7.2.2 Metering

Water production from the spring is measured using a bulk flow meter. All individual connections are metered, as are the communal drawing points in the Nyasare Valley and the water kiosks within Migori.

3.7.2.3 Tariffs, revenues and costs

The tariffs for the scheme were fixed in 1996. Rural households are charged Ksh 40 per month for drawing water. At the water kiosks within Migori, consumers are charged Ksh 1 per 20 litre jerrycan. For individual connections in Migori, consumers pay a monthly standing charge of Ksh 100 and the following charges for water consumed:

Table 3.3
Tariffs for Nyasare community-managed scheme

Monthly consumption In range:	Tariff Ksh/m^3
First 10 m^3	10
From 11 m^3 to 30 m^3	20
From 31 m^3 to 50 m^3	30
From 51 m^3 to 100 m^3	40
In excess of 100 m^3	50

The acting manager reports that revenues for the scheme average Ksh 80,000 per month, but can range from Ksh 30,000 to over Ksh 100,000 depending on the supply and levels of default. At present, approximately twenty consumers have been disconnected for non-payment of bills.

The scheme has recently made six new connections to the system. Prospective customers pay an initial deposit of Ksh 3,000 and are required to meet the full cost of pipes, fittings and the meter used to make the connection.

The acting manager reports that monthly costs are some Ksh 76,000, including Ksh 3,000 per month for calcium hypochlorite for disinfection.

3.7.2.4 Facilities and equipment

The scheme is administered from a permanent office building adjacent to one of the storage tanks. The office is fully furnished and equipped, but does not have power or telephone. The scheme also owns a motorbike that is used by the line patroller.

3.8 LEVELS OF SERVICE

3.8.1 Gazetted water supply system

3.8.1.1 Major consumers

There are two metered connections in Migori consuming more than 40 m^3 per month, and a further eight unmetered connections with estimated consumptions of over 40 m^3 per month. These ten connections account for a monthly water consumption of 1,194 m^3, in the following charge bands:

Table 3.4
Monthly consumptions for large consumers

Charge band	Consumption (m^3/month)
0-10 m^3/month minimum charge band	100
10-20 m^3/month band	100
20-50 m^3/month band	290
50-100 m^3/month band	284
100-300 m^3/month band	420
Over 300 m^3/month band	0
Total	1,194

3.8.1.2 Population served

The remaining 577 active connections in Migori are assumed to supply domestic consumers. The results of the 1999 census show Migori had a population of 96,446 in 19,812 households. This gives a mean household size of 4.87. Therefore, approximately 2,762 people benefit from piped water supplies, or 2.86% of the total population within the municipality.

3.8.1.3 Per capita supplies

As noted above, there are gross discrepancies between estimated water production and sales. Assuming a production of 180 m^3/d or 5,400 per month, a maximum of 4,206 m^3/month could have been consumed in June 2000 by the 577 minor consumers. This represents an average consumption of 247 l/connection or approximately 50.8 lcd.

3.8.2 Nyasare community-managed water supply system

3.8.2.1 Population served

According to the Acting General Manager, there are 238 connections within Migori Town, of which 218 are active. With a mean household size of 4.87, approximately 1,062 people benefit from individual piped connections to the Nyasare community-managed water supply system. This represents 1.1% of the enumerated population of 95,446. In addition, there are ten water kiosks selling water to unconnected households.

3.8.2.2 Per capita supplies

As noted in Section 3.3 above, the total supply is some 230 m^3/d, of which approximately 170 m^3/d is sold to consumers within the town. This is equivalent to 160 lcd for the connected population of 1,062.

3.8.3 Overall level of service

The combined supply to the urban area from the gazetted scheme and the community-managed scheme is some 350 m^3/d. For a town population of 95,446, this supply is equivalent to 3.67 lcd.

3.9 ON-GOING OR PLANNED EL NIÑO WORKS

3.9.1 Scope of works

The following works are being carried out under the El Niño project to rehabilitate the gazetted water supply system:

- Four new boreholes have been drilled adjacent to existing Ministry boreholes.
- All storage facilities are being duplicated.

- 485 m of 10 mm nominal bore distribution main is being laid from the main storage site to the road running through the town's administrative centre.

- The distribution system along the road running through the town's administrative centre is being reinforced with a 110 mm uPVC pipe some 850 m long to a break pressure tank.

- A 45 m^3 capacity elevated water tank is to be built to receive water from Borehole 5, and

- A 9 m^3 capacity elevated water tank is to be built to receive water from Borehole 4.

Figure 3.2 shows a schematic layout of the works.

3.9.2 El Niño borehole details

3.9.2.1 <u>El Niño Borehole No. 1</u>

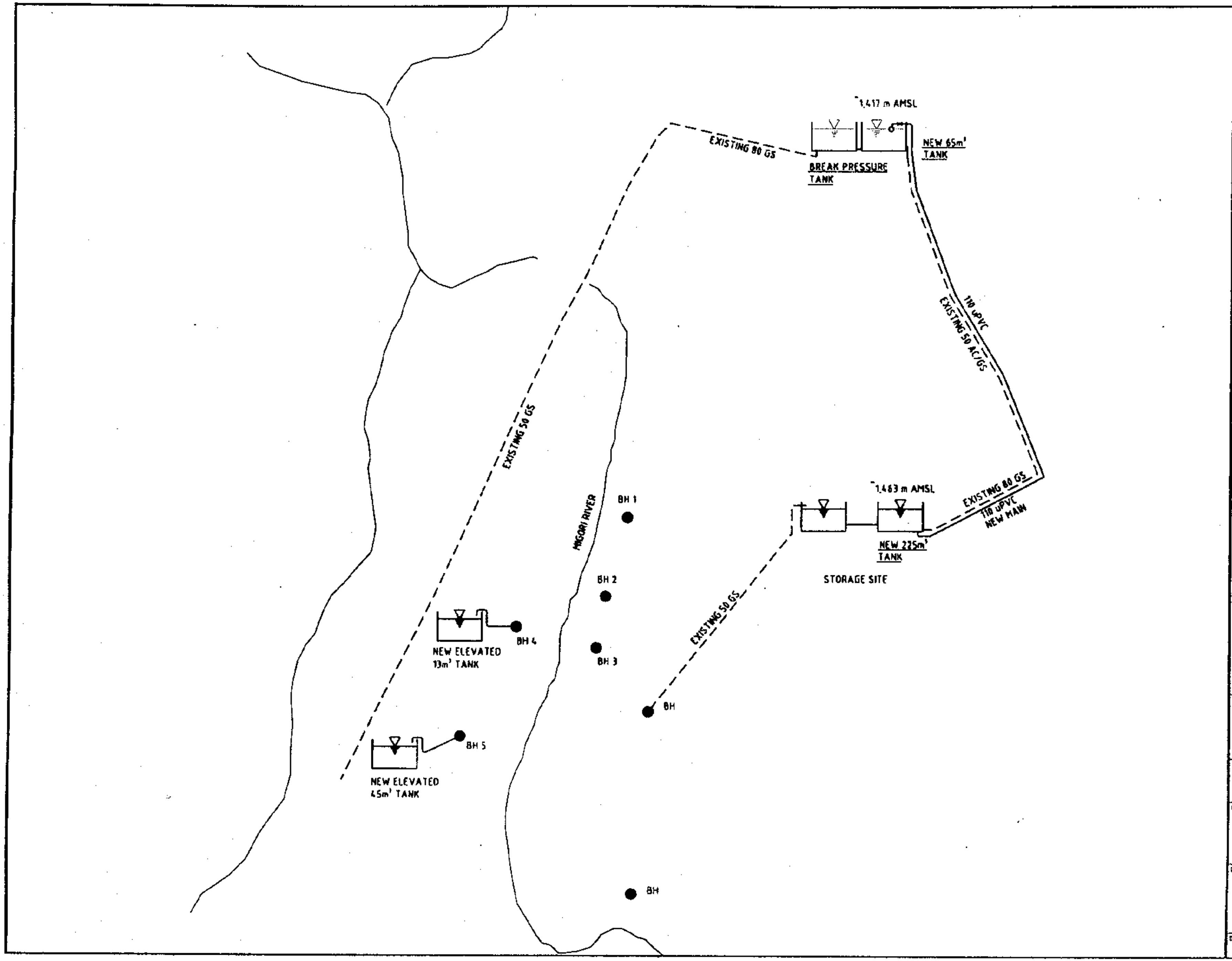
Under the El Niño rehabilitation programme, a new borehole was drilled some five metres to the west of the original Borehole No.1. The borehole was to be drilled to a depth a 120 m and was expected to encounter a fractured andesite aquifer at a depth of 110 m. In the event, the borehole was drilled to only 96 m. It has been left as an open hole to 96 m, with eight inch surface casing to a depth of four metres. The borehole has not been test-pumped or equipped.

3.9.2.2 <u>El Niño Borehole No.2</u>

This borehole, some five metres to the west of the original Borehole No.2, was drilled to a depth of 100 m and struck water between 50 – 53 m, and at 90 m. The water rest level was not recorded. The airlift yield was estimated as 3.5 m^3/hr, but the borehole has not been pump tested. The borehole has 8 inch surface casing to 3 m depth, and is open hole to 100 m depth. The borehole is not equipped, and DWO staff feel that the low yield does not warrant bringing the borehole into production.

3.9.2.3 <u>El Niño Borehole No.3</u>

This borehole, some five metres to the south of the original Borehole No. 3, was drilled to a depth of 112 m in August 2000. The borehole encountered water strikes between 20 m and 22 m, at 84 m and between 102 m and 104 m depth. The water rest level was at depth 9 m. The borehole has 6 inch PVC casing and screen to its full depth,



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Project Title

TEN TOWNS WATER
SUPPLY & SANITATION
STUDY

Drawing Title

MIGORI TOWN
ENEP WORKS TO
EXISTING WATER
SUPPLY

Date	Fig. No.
DEC 2000	3.2

and is provided with a sanitary seal. The borehole has not been test pumped, but the airlift yield was estimated to be 30 m^3/hr. The borehole is yet to be equipped.

3.9.2.4 El Niño Borehole No. 4

This borehole was drilled to a depth of 58 m in August 2000. The borehole struck water at 6 m, 42 m and the main aquifer between 40 and 48 m. The water rest level was not recorded. The borehole has 6 inch PVC casing and screen to its full depth, and is provided with a sanitary seal. The borehole has not been test pumped, but the airlift yield was estimated to be 20 m^3/hr. The borehole is yet to be equipped.

3.10 OTHER WORKS AND PROJECTS

The Austrian Government, through the Institute for International Co-operation (IIZ), is considering funding a second phase of the Nyasare water supply project. In early November 2000, a technical mission visited the scheme to investigate whether the decline in the spring's yield is due to drought or changed land use.

IIZ are considering two options for expanding the scheme:

- Capping additional springs;
- or, if spring catchments cannot be adequately protected, construction of a dam on the Osani River to impound 500,000 m^3, and providing a plant for slow sand filtration.

A donor appraisal mission is due in Kenya in early December 2000, and the phase two project should commence by mid 2001.

4 PROPOSED STRATEGY FOR WATER SUPPLY REHABILITATION

4.1 DEMAND/CONSUMPTION PROJECTIONS TO 2010

4.2 Population projections to 2010

As discussed in Section 2.6, the population of Migori municipality is projected to increase at 4.5% per annum to reach 154,900 in the year 2010. The projected population for the municipality is given in Table 4.1.

Table 4.1
Population projection

Year	Population
1999	95,446
2000	99,700
2001	104,200
2002	108,900
2003	113,800
2004	118.900
2005	124,300
2006	129,900
2007	135,700
2008	141,800
2009	148.200
2010	154,900

4.2.1 Water demand projections

4.2.1.1 Unit water consumption

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

4.2.1.2 Levels of service

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 Migori will reflect the current broad levels of income.

Table 4.2
Projected levels of service

Income level/housing class	Percentage in category
High	18
Medium	35
Low	47

4.2.1.3 Domestic water demand

The domestic water demand projection for Migori is shown in Table 4.4.

4.2.1.4 Institutional and commercial water demands

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

Table 4.3
Institutional and commercial water demands

Activity	Nr	l/unit/d	total
Commercial			
Shops	242	100	24,200
Hotel low class (assume 10 beds each)	40	50	2,000
Garages	13	500	6,500
Total commercial			42,700
Institutional			
District Hospital (assume 200 beds)	200	200	40,000
Mission Hospital (own supply)			0
Schools	11,000	5	55,000
Dispensaries	14	5,000	70,000
Total institutional			165,000
Industrial			
Fish processing plant			20,000
Total commercial, institutional and industrial demand	l/d		227,700
	m^3/d		227.7
	say		**228 m^3/d**

The institutional and commercial water demand is taken as 228 m^3/d, and is projected to increase in line with the town's population.

4.2.1.5 Demand projection

The water demand projection for Migori is summarised in Table 4.4.

Table 4.4
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	Storage capacity m^3
		Status	%								
1999	95,446	High	18	17,180	250	4,295					
		Middle	35	33,406	150	5,011	228	**12,898**	180	180	312
		Low	47	44,860	75	3,364					
2000	99,700	High	18	17,946	250	4,487					
		Middle	35	34,895	150	5,234	238	**13,473**	180	180	312
		Low	47	46,859	75	3,514					
2001	104,200	High	18	18,756	250	4,689					
		Middle	35	36,470	150	5,471	249	**14,082**	180	180	312
		Low	47	48,974	75	3,673					
2002	108,900	High	18	19,602	250	4,901					
		Middle	35	38,115	150	5,717	260	**14,716**	180	180	312
		Low	47	51,183	75	3,839					
2003	113,800	High	18	20,484	250	5,121					
		Middle	35	39,830	150	5,975	272	**15,379**	180	180	312
		Low	47	53,486	75	4,011					
2004	118,900	High	18	21,402	250	5,351					
		Middle	35	41,615	150	6,242	284	**16,068**	180	180	312
		Low	47	55,883	75	4,191					
2005	124,300	High	18	22,374	250	5,594					
		Middle	35	43,505	150	6,526	297	**16,798**	180	160	312
		Low	47	58,421	75	4,382					
2006	129,900	High	18	23,382	250	5,846					
		Middle	35	45,465	150	6,820	310	**17,554**	180	180	312
		Low	47	61,053	75	4,579					
2007	135,700	High	18	24,426	250	6,107					
		Middle	35	47,495	150	7,124	324	**18,338**	180	180	312
		Low	47	63,779	75	4,783					
2008	141,800	High	18	25,524	250	6,381					
		Middle	35	49,630	150	7,445	339	**19,163**	180	180	312
		Low	47	66,646	75	4,998					
2009	148,200	High	18	26,676	250	6,669					
		Middle	35	51,870	150	7,781	354	**20,028**	180	180	312
		Low	47	69,654	75	5,224					
2010	154,900	High	18	27,882	250	6,971					
		Middle	35	54,215	150	8,132	370	**20,933**	180	180	312
		Low	47	72,803	75	5,460					

4.2.2 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.

4.3 PRELIMINARY DESIGN OF RECOMMENDED REHABILITATION OPTION

4.3.1 Boreholes that can be retained or newly equipped

The following boreholes can be equipped to supply Migori:

- Original or El Niño Borehole No. 3 – the two boreholes are only a few metres apart and interference effects will preclude operating both boreholes simultaneously. The original Borehole No. 3 was in production up to November 2000, delivering some 15 m^3/hr. The newly drilled El Niño Borehole No. 3 can be expected to have a similar yield.

- El Niño Borehole No. 4 has been completed as a cased and screened production borehole. It can be equipped to replace the original Borehole No. 4 that is blocked by a dropped pump.

- The original Borehole No. 5 is still in production, and can be retained.

The following boreholes cannot be equipped as production boreholes:

- The original Borehole No. 1 that was drilled in the 1950s and was abandoned in the 1980s. It is past its useful life, and was to be replaced with the El Niño Borehole No. 1. However, the replacement borehole did not penetrate the target aquifer.

- The El Niño Borehole No. 2 has a poor airlift yield and has not been cased and screened.

- Borehole No. 7, drilled under the South Nyanza Water Development Project, had a yield of only 4 m^3/hr. It is now surrounded by residential housing.

- Borehole No. 8, drilled under the South Nyanza Water Development Project, was dry.

4.3.2 Reconfiguration of wellfield to maximise water delivery

4.3.2.1 Number of pressure zones

The levels at various points within the water supply system are:

- River bank near boreholes – 4,450' (1,356 m AMSL);
- Hill top storage site – 4,800' (1,463 m AMSL);
- Break pressure tank – approximately 4,650' (1,417 m AMSL);
- Lowest point within area served – approximately 4,425' (1,349 m AMSL).

If there were no break pressure tank, the maximum head in the system would be some 114 m. This is unacceptably high, so the break pressure tank is required to separate the distribution system into two pressure zones.

4.3.2.2 Wellfield configuration

Under the El Niño project, water from Borehole Nos 4 and 5 will be delivered to elevated storage serving Migori Primary School and Migori Teachers Training College. The remainder of the town would be solely dependent on Borehole No 3 for water supplies. To make the maximum use of water from Borehole Nos 4 and 5, provision must be made for this water to reach the available storage on the hilltop above the town. The break pressure tank within the distribution system precludes pumping to storage through the reticulation system: a dedicated rising main is required. Unfortunately, the boreholes and the storage site are on opposite banks of the perennial Migori River. At this stage of project planning, it is assumed that a dedicated rising main is laid from the boreholes across the river at the existing road bridge.

If groundwater were pumped directly from Borehole Nos 4 and 5 to the hilltop storage site, there would be a pipe running through the town carrying undisinfected water at a pressure of over 10 bar. To minimise the risk of illegal, or inadvertent, connections to a main carrying undisinfected water, it is desirable to reduce the pressure in the main. This can be done by pumping to the old waterworks site rather than the hilltop storage, which would restore the original system configuration. Figure 4.1 shows a schematic layout of the proposed system.

4.3.2.3 Pipe sizing

The combined output of Borehole Nos 4 and 5 is some 26 m^3/hr. The optimal pipe size to convey this flow is 100 mm. The combined output of Borehole Nos 3, 4 and 5 is some 41 m^3/hr, requiring a 150 mm nominal borehole main. The piping requirements can be summarised as:

- 150 mm main from the old waterworks to the hilltop storage site – 700 m
- 100 mm main from borehole 4 to the old waterworks – approximately 1,700 m
- 80 mm main from borehole 5 to borehole 4 – approximately 200 m

4.3.2.4 Pump sizing

The surface-mounted pumps to transfer water from the chlorine contact tank to the service reservoirs are provisionally rated for 41 m^3/hr against 112 m. One duty plus one standby multistage pump running at two-pole speed will have an efficiency of about 66% and absorb about 19 kW.

The original Borehole No. 3 struck water at 10 m and 119 m and had a water rest level of 5 m. Screens were installed from 6 m to 12 m. If the pump inlet is set at the top of the screen, the available drawdown is only one metre. The borehole pump is provisionally rated for 15 m^3/hr against 10 m. The pump will absorb some 1.1 kW.

El Niño Borehole No. 4 struck water at 6 m, 42 m and the main aquifer was recorded as being between 40 and 48 m. The water rest level was not recorded, but the rest level of the original Borehole No. 4, which seems to have struck the same aquifers, was 2.5 m. The borehole has 6" PVC casing and screen to its full depth, but there are no further construction details. Assuming the upper aquifer was cased off and only the main aquifer is screened, the available drawdown is 37.5 m. The borehole pump is provisionally rated for 15 m^3/hr against 55 m, requiring a pump absorbing some 3.7 kW.

For Borehole No. 5, the water rest level is at 5.85 m and the top of the first screen is at 9 m. The available drawdown to the top of the first screen is 3.15 m. The borehole pump is provisionally rated for 11 m^3/hr against 18 m, requiring a pump absorbing some 1.1 kW.

4.3.3 Disinfection

4.3.3.1 Chlorine dosing rate

To achieve a free chlorine residual, sufficient chlorine must be dosed to react with any dissolved ammonia, iron, manganese, etc.

The required doses are:

- 7.6 g of chlorine to react with 1 g of ammonia;
- 0.54 g of chlorine to react with 1 g of ferrous iron, and
- 1.5 g of chlorine to react with 1 g of manganese.

The 1973 analysis for water from Borehole No. 3 shows an iron content of 0.4 mg/l and a manganese content of 0.2 mg/l. A partial analysis for 1978 shows 2.5 mg/l of iron and 0.26 mg/l of manganese. Up to 2.24 mg/l of free chlorine might be required to oxidise the dissolved iron and manganese in Migori groundwater. To achieve a residual of 0.5 mg/l for disinfection, the required dosing rate is 2.74 mg/l.

Tropical chloride of lime (TCL) contains approximately 30% of available chlorine, giving a required dosing rate of 9.13 mg/l. Pure calcium hypochlorite contains 71.57% of available chlorine: commercial grades contain 70%, giving a required dosing rate of 3.91 mg/l.

4.3.3.2 Chlorine contact tank and dosing facilities

The original tanks at the old waterworks site presumably date from the 1950s when Borehole No. 1 was drilled. They are now past their economic lives, so a new chlorine contact tank is required. For a combined inflow of 41 m^3/hr from Borehole Nos 3, 4 and 5, a chlorine contact tank of 80 m^3 capacity would be suitable.

Duty and standby gravity dosers will be required to dose calcium hypochlorite or tropical chloride of lime solution.

4.3.4 Standby diesel generators

4.3.4.1 Borehole Nos 4 and 5

The switchgear for Borehole Nos 4 and 5 is housed in the same building. The two boreholes will be re-equipped with pumps rated for

1.1 kW and 3.7 kW. A single standby generator, provisionally rated for 10 kVA, can be used to power both boreholes pumps.

4.3.4.2 Old waterworks site

Borehole No. 3 will be re-equipped with a pump rated for 1.1 kW. The surface-mounted pump will have a motor rated for 22 kW. A single standby generator, provisionally rated for 50 kVA, can be used to power both boreholes pumps.

4.3.5 Improved borehole headworks

The headworks pipework at production boreholes should be modified to incorporate:

- A flow meter to measure water production;
- A dipper tube to allow groundwater levels to be measured;
- A sampling tap so that samples can be taken for bacteriological and chemical analyses.

A 65 mm Class B meter is accurate to ±2% for flows from 3.75 m^3/hr to 25 m^3/hr. This is suitable for measuring production from the boreholes operated by the Ministry of Environment and Natural Resources.

4.3.6 Distribution pipework

4.3.6.1 General

The proposed reconfiguration of the wellfield so that all groundwater production is pumped to the hilltop storage site will deprive Migori Teachers Training College and the adjacent primary school frorn independent supplies from Borehole Nos 4 and 5. The distribution system should therefore be addressed to ensure these two institutions and adjacent customers receive adequate supplies from the break pressure tank.

4.3.6.2 System between main storage and the break pressure tank

The system comprises two parallel pipes:

- The original 80 mm galvanised steel pipe some 380 m long, laid in series with 50 mm nominal bore asbestos cement/galvanised steel pipe some 850 m long;

- The 110 mm uPVC main some 1,335 m long being laid under the El Niño project.

For a head difference of 150' (45.72 m) between the tanks, the capacity of the system is 58.5 m^3/hr. If the head difference is only 100' (30.48 m), the capacity is reduced to 47.4 m^3/hr.

The capacity of the outlet system is greater than the incoming groundwater supply, but does not allow for a peak flow factor of 2.0. This will suppress peak demands.

4.3.6.3 <u>Pipework below the break pressure tank</u>

The pipework below the break pressure tank comprises an 80 mm galvanised steel main some 400 m long, followed by a 50 mm galvanised steel main some 1,300 m long to Migori Teachers Training College. The level difference between the break pressure tank and the teachers training college is some 200' (60.96 m). Allowing for an elevated tank 2.4 m high on a 10 m high stand, the available head is approximately 48.5 m. The capacity of the pipe system for this head difference is only 7 m^3/hr due to the high friction slope in the 50 mm pipework.

The 80 mm and 50 mm pipes were presumably laid when the system was first constructed in the early 1950s, and are now past there useful lives. They can be replaced with a single 110 mm uPVC pipe, which would have a capacity of 52.3 m^3/hr with an available head of 48.5 m.

4.3.7 Consumer metering

700 ½" (Q_N 1.5 m^3/hr) domestic water meters are required to ensure that all water sales are metered.

4.3.8 Capping Borehole 8

A steel plate should be welded over the casing of the unused Borehole No. 8 to prevent possible contamination of the aquifer.

4.4 COSTING OF RECOMMENDED REHABILITATION PLAN

The proposed works to rehabilitate the gazetted Migori water supply system are given in Table 4.5.

Table 4.5
Costs for rehabilitating Migori gazetted water supply system

Description	Unit	Quantity	Rate (Kshs)	Amount (KShs)
Boreholes and collector pipework				
Equip ENEP borehole 3 to deliver to chlorine contact tank, including pump, riser and headworks pipework and electrical installation	Sum			3,000,000
Equip ENEP borehole 4	Sum			3,000,000
Re-equip existing borehole 5	Sum			3,000,000
80 mm steel collector pipework from borehole 5 to borehole 4	m	200	5,600	1,120,000
100 mm steel collector pipework from borehole 4 to old waterworks site	Sum	1,700	6,000	10,200,000
Cap disused boreholes 3 and 8	nr	2	5,000	10,000
Subtotal				**20,330,000**
Groundwater disinfection and surface mounted pumps				
80 m^3 chlorine contact tank	Sum			1,200,000
Pump house for surface mounted pumps	Sum			1,000,000
One duty plus one standby surface-mounted pumps 41m^3/hr against 112 m, 22 kW	Sum			4,000,000
150 mm steel rising main from old waterworks site to hilltop storage	m	700	6,900	4,830,000
Subtotal				**11,030,000**
Distribution system				
110 mm uPVC pipe from break pressure tank to Migori Teacher's Training College	m	1,700	1,000	1,700,000
Install float operated shutoff valves at elevated tanks	nr	2	80,000	160,000
New consumer meters (replacement and stock)	nr	700	3,000	2,100,000
Subtotal				**3,960,000**
Logistical facilities and equipment				
New office and laboratory facilities	m^2	400	25,000	10,000,000
4WD twin-cab pickups	nr	1	2,500,000	2,500,000
4WD standard vehicles	nr	1	1,500,000	1,500,000
Motorcycles for line patrols, meter readings, etc.	nr	3	250,000	750,000
Multi-geared 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				**18,100,000**
Overall Total				**53,420,000**
Add 20% P&G				10,684,000
Sub-total				64,104,000
Add 15% Contingencies				9,615,600
Sub-total				73,719,600
Add 20% consultancy design fees				14,743,920
GRAND TOTAL				**88,463,820**

4.5 EXPANSION OF WATER SUPPLY FACILITIES

4.5.1 Physical constraints to expansion

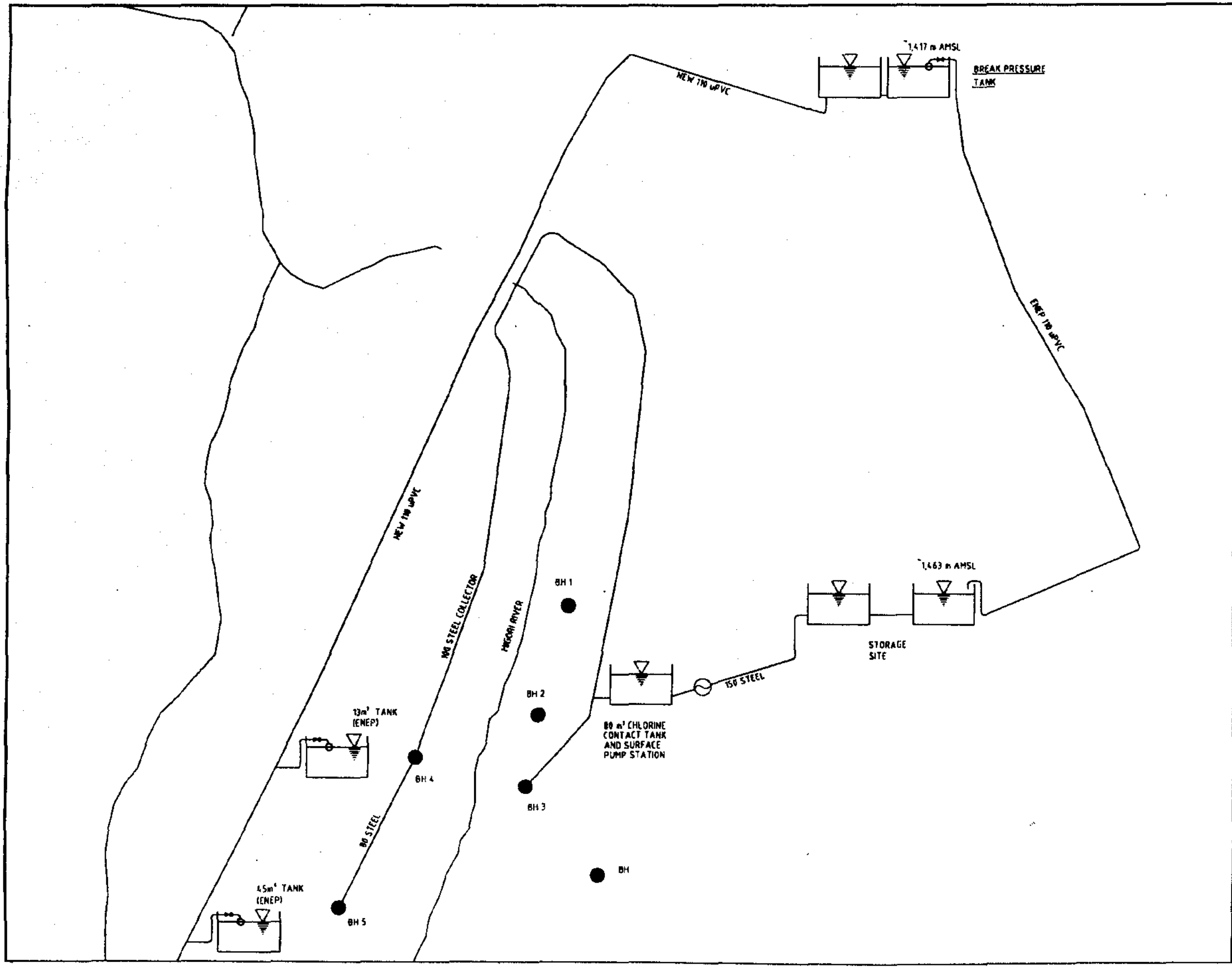
Comparing the available topographic mapping with the census mapping given in Appendix 1, the following conclusions can be drawn:

- The existing storage site at 4,800' (1,463 m AMSL) commands all of Oruba and Marindi sub-locations;
- In Oruba sub-location, Oruba Mission is on a hilltop at 4,750' (1,448 m AMSL), and the lowest point in Oruba Milimani is at 4,350' (1,326 m AMSL), so Oruba sub-location should be divided into two or more pressure zones;
- In Marindi, levels range from 4,450' (1,356 m AMSL) at the market to 4,600' (1,402 m AMSL), so Marindi sub-location should also be divided into two or more pressure zones to avoid excessive pressures;
- In Wasweta sub-location, the higher lying parts of Onyalo A, Midoti and Kolando are above the level of the service reservoirs;
- In Ngege sub-location, the Ngege area is above the level of the service reservoirs, but low lying areas nearer the Migori River may be supplied.

The higher lying areas of Onyalo A, Midoti, Kolando and Ngege cannot be served from the existing service reservoirs. The combined population of these areas from the 1999 census was 4,407, or 9.6% of the town's population. The remaining areas can be readily served.

4.5.2 Storage sites

Figure 4.1 shows the sites of the existing storage and break pressure tank sites, together with the potential storage sites in Oruba and Marindi. Expansion of storage facilities at the existing hilltop storage site is constrained by the two existing reservoirs and radio mast on the top of the hill. There is, however, no difficulty in siting additional storage at the same elevation on the hillside to the north of Kadika. It is assumed that future storage will be provided at all three potential storage sites.



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GIBB Eastern Africa
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Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title
MIGORI TOWN PROPOSED REVISION MENR SUPPLY

Date	Fig. No
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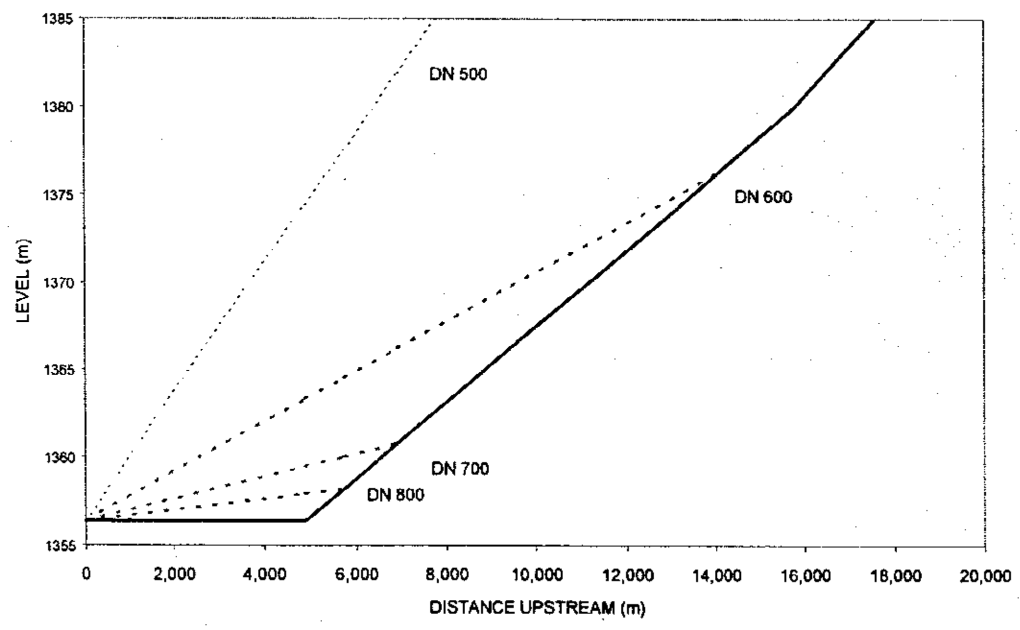
4.5.3 Source works

The projected water demand in 2010 is 20,933 m^3/d. The yield of boreholes along the Migori River is some 350 m^3/d each. Approximately sixty boreholes would be required to meet the projected water demand from groundwater. It is doubtful that the available resource can meet this demand and such a wellfield would be extremely complex to operate. It is therefore assumed that a surface water source will have to be developed.

A gravity supply of raw water to Migori is technically feasible but does not seem to be economically viable. Figure 4.2 below shows the approximate river profile upstream from Migori, together with the hydraulic gradients for various pipe sizes carrying a flow of 20,933 m^3/d.

Figure 4.2
River profile and hydraulic gradients



A 500 mm nominal bore pipe is too small for a gravity supply, as the hydraulic gradient does not intersect the river within a reasonable distance. A 600 mm main would have to be 14.2 km long, reducing to 6.9 km for a 700 mm main and 5.7 km for an 800 mm main.

The approximate costs for these three options are given in Table 4.6.

Table 4.6
Costs for alternative gravity mains

Pipe size (mm)	600	700	800
Length (m)	14,200	6,900	5,700
Cost (Kshs/m)	26,000	35,000	47,000
Cost (Kshs)	369,200,000	241,500,000	267,900,000

At this pre-feasibility stage, allowance is made for a 700 mm main 6.9 km long. The relative economy of gravity supplies versus pumped supplies should be examined further during the feasibility studies and designs.

4.5.4 Treatment

Conventional treatment is assumed, with an installed works capacity of 21,000 m^3/d. To minimise on land take, upward flow clarifiers and rapid gravity filters are assumed.

4.5.5 Transmission and Storage

4.5.5.1 Oruba Sub-Location

Oruba sub-location is commanded by the hill at Oruba Mission. For a demand of approximately 8,000 m^3/d, 18 hours emergency storage and 12 hours balancing storage, the required storage capacity is 10,000 m^3. A small, elevated tank is also provided to serve the Mission and surrounding high lying areas.

Allowance is made for 4.3 km of 350 mm transmission main to transfer disinfected water from the old waterworks site to the proposed storage site at Oruba Mission.

4.5.5.2 Marindi Sub-Location

The area is commanded from a hill to the south west of Migori. As for Oruba, allowance is made for 10,000 m^3 of ground level storage and a 350 mm transmission main some 4.8 km long.

4.5.5.3 Remainder of Migori

Allowance is made for 10,000 m^3 of storage on the hillside above Kadika. An allowance is made for 1,800 m of 350 mm rising main from the old waterworks site to the storage site.

4.5.6 Distribution

The additional area to be served is approximately 52 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 520 km of additional pipelines are required to serve the municipal area.

4.5.7 Costs of expansion works

The cost details are presented in Table 4.7.

The cost of reticulating the municipal area is extremely high. The results of the 1999 census show that large areas of Ngege and Marindi 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.

Table 4.7
Cost of expanding water supplies

Description	Unit	Quantity	Rate	Amount (KShs)
Intake and raw water main				
Intake on Migori River	Sum			25,000,000
700 mm steel raw water main	m	6,900	28,000	193,200,000
subtotal				**218,200,000**
Treatment and transmission				
21,000 m^3/d treatment plant	Sum			260,000,000
Clear water pumps	nr	6	7,000,000	42,000,000
350 mm steel rising main to Oruba	m	4,300	13,000	55,900,000
350 mm steel rising main to Marindi	m	4,800	13,000	62,400,000
350 mm steel rising main to main storage site	m	1,800	13,000	23,400,000
subtotal				**443,700,000**
Storage				
10,000 m^3 storage at Oruba	Sum			50,000,000
Elevated tank and pumps, allow	Sum			6,000,000
10,000 m^3 storage at Marindi	Sum			50,000,000
Elevated tank and pumps, allow	Sum			6,000,000
10,000 m^3 storage at Kadika	Sum			50,000,000
subtotal				**162,000,000**
Distribution system				
Distribution pipework	m	520,000	1,600	832,000,000
Break pressure tanks, allow	Sum			10,000,000
Consumer meters, allow	nr	30,000	3,000	90,000,000
subtotal				**881,000,000**
Overall Total				**1,730,400,000**
Add 20% P&G				346,080,000
Sub-total				2,076,480,000
Add 15% Contingencies				311,472,000
Sub-total				2,387,952,000
Add 20% consultancy design fees				477,590,400
GRAND TOTAL				**2,865,542,400**

4.6 O&M COSTS AFTER REHABILITATION

4.6.1 General

The yield from the proposed wellfield is greater than current production and sales, so the wellfield will not be operating at full capacity after the rehabilitation works. Chemical and power costs are dependent on the quantities of water being produced, so it is necessary to develop water sales and production forecasts to assess these costs.

4.6.2 Water sales and production forecasts

4.6.2.1 Existing connections and unit consumptions

The consumption pattern given in Table 3.2 is applied to the 10 connections consuming more than 40 m^3/month. The 567 domestic connections are assumed to be:

Table 4.8
Assumed domestic connections

Housing category	Number of connections	Household size	Per capita consumption (lcd)	Consumption per household (m^3/month)
High class housing	83	4.87	250	37.03
Medium class housing	125	4.87	150	22.22
Low class housing	359	4.87	75	11.11

4.6.2.2 Future connections

For developing the water sales forecast, it is assumed that sixty new connections are made per annum: forty-two to low class housing and eighteen to medium class housing.

4.6.2.3 Water sales forecasts

The water sales forecast is given in Table 4.9.

4.6.2.4 Allowance for unaccounted for water

It is assumed that the volume of unaccounted for water will be 20% of water production.

4.6.2.5 Water production forecasts

The forecast of water production requirements is also given in Table 4.9.

4.6.3 Power tariffs and costs

4.6.3.1 Tariffs

Power charges are calculated using the tariffs and levies prevailing in December 2000. These are shown in Table 4.10.

Table 4.10
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

4.6.3.2 <u>Running load at Borehole Nos 4 and 5</u>

The total running load at Borehole Nos 4 and 5 will be some 6.4 kVA, made up as follows.

Table 4.11
Running load at Borehole Nos 4 and 5

Item	Borehole 4	Borehole 5	Lighting and small power, say	Total running load
Flow (m^3/hr)	15	11		
Head (m)	55	18		
Efficiency	60%	50%		
Power (kW)	3.7	1.1	1.0	5.8
Power (kVA) at cosF = 0.9	4.1	1.2	1.1	6.4

With both boreholes pumping continuously, the monthly power consumption will be 3,504 kWh, so the applicable charge band is A1. The estimated power consumption is shown in Table 4.12.

4.6.3.3 Power costs at Borehole Nos 4 and 5

Using the above running loads and the A1 tariff band, the standing charge is Kshs 1,800 per annum. Assuming that Borehole Nos 3, 4 and 5 are operated for an equal number of hours per day, the annual power costs for operating Borehole Nos 4 and 5 are summarised in Table 4.12.

Table 4.12
Annual power costs for Borehole Nos 4 and 5

Year	Daily water production (m^3/d)	Hours run per week	Annual power costs				
			Standing charge (Kshs)	Borehole No 4 kWh charge	Borehole No 5 kWh charge	Small power kWh charge	Total
2000	453	77	1,800	186,709	55,508	54,754	296,972
2001	453	77	1,800	186,709	55,508	54,754	296,972
2002	453	77	1,800	186,709	55,508	54,754	296,972
2003	489	83	1,800	201,374	59,868	54,754	315,996
2004	525	90	1,800	216,038	64,228	54,754	335,020
2005	560	96	1,800	230,703	68,587	54,754	354,044
2006	596	102	1,800	245,367	72,947	54,754	373,068
2007	631	108	1,800	260,031	77,307	54,754	392,092
2008	667	114	1,800	274,696	81,666	54,754	411,116
2009	703	120	1,800	289,360	86,026	54,754	430,140
2010	738	126	1,800	304,024	90,386	54,754	449,164

4.6.3.4 Running load at old waterworks

The total running load at the old waterworks site will be some 23.4 kVA, made up as follows.

Table 4.13
Running load at old waterworks site

Item	Borehole 3	High lift pump	Lighting and small power, say	Total running load
Flow (m^3/hr)	15	41		
Head (m)	10	112		
Efficiency	38.0%	66.0%		
Power (kW)	1.1	19.0	1.0	21.1
Power (kVA) at cosF = 0.9	1.2	21.1	1.1	23.4

With both pumps operating continuously, the monthly power consumption will be 15,403 kWh, so the applicable charge band is B1. The estimated power consumption is shown in Table 4.14.

Table 4.14
Annual power costs for Borehole No 3 and the high lift pump

Year	Daily water production (m^3/d)	Hours run per day	Annual power costs					
			Standing charge (Kshs)	Maximum Demand charge (Kshs)	Borehole No 3 kWh charge (Kshs)	High lift pump kWh charge (Kshs)	Small power kWh charge (Kshs)	Total (Kshs)
2000	453	11	7,200	84,240	47,901	827,382	43,546	1,010,270
2001	453	11	7,200	84,240	47,901	827,382	43,546	1,010,270
2002	453	11	7,200	84,240	47,901	827,382	43,546	1,010,270
2003	489	12	7,200	84,240	51,715	893,265	47,014	1,083,434
2004	525	13	7,200	84,240	55,530	959,148	50,481	1,156,599
2005	560	14	7,200	84,240	59,344	1,025,031	53,949	1,229,764
2006	596	15	7,200	84,240	63,158	1,090,914	57,417	1,302,929
2007	631	15	7,200	84,240	66,972	1,156,797	60,884	1,376,094
2008	667	16	7,200	84,240	70,562	1,218,801	64,147	1,444,951
2009	703	17	7,200	84,240	73,656	1,272,247	66,960	1,504,304
2010	738	18	7,200	84,240	76,751	1,325,693	69,773	1,563,657

4.6.4 Chemical costs

The estimated chemical costs for treating one cubic metre of water are shown in Table 4.15.

Table 4.15
Estimated chemical costs

Chemical	Cost Kshs/kg	Dosage (mg/l)	Cost (Kshs/m^3)
Aluminium sulphate	28	0	0.00
Soda ash	7	0	0.00
Calcium hypochlorite	245	4	0.98
Total			0.98

The estimated chemical costs per annum are given in Table 4.16.

Table 4.16
Estimated chemical costs per annum

Year	Daily water production (m^3/d)	Annual chemical costs
2000	453	162,192
2001	453	162,192
2002	453	162,192
2003	489	174,931
2004	525	187,670
2005	560	200,408
2006	596	213,147
2007	631	225,886
2008	667	238,625
2009	703	251,363
2010	738	264,102