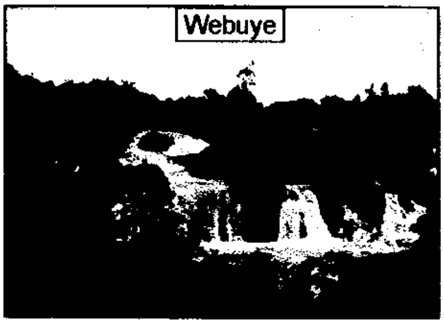
JAPAN INTERNATIONAL COOPERATION AGENCY

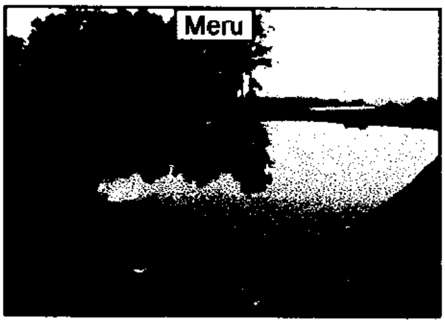
REPUBLIC OF KENYA

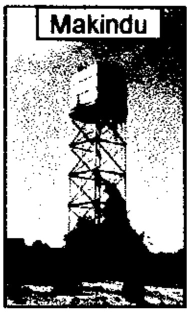
MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES

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

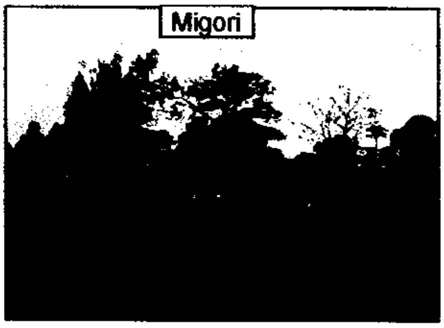


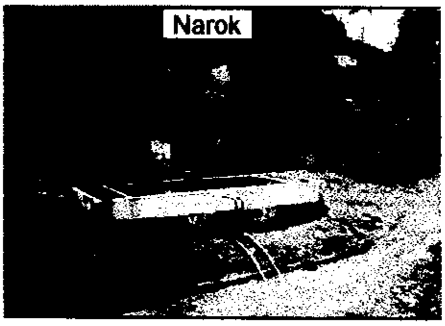



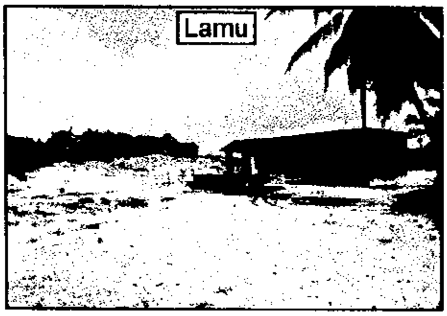



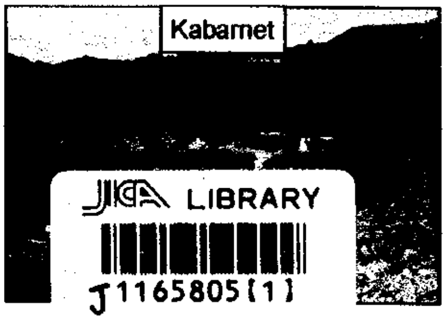



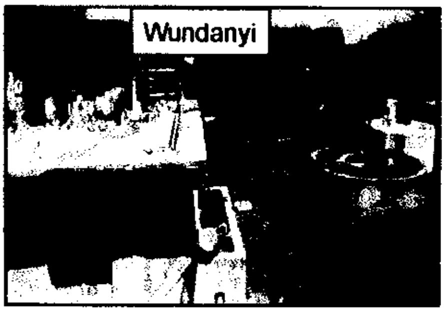







## FINAL REPORT

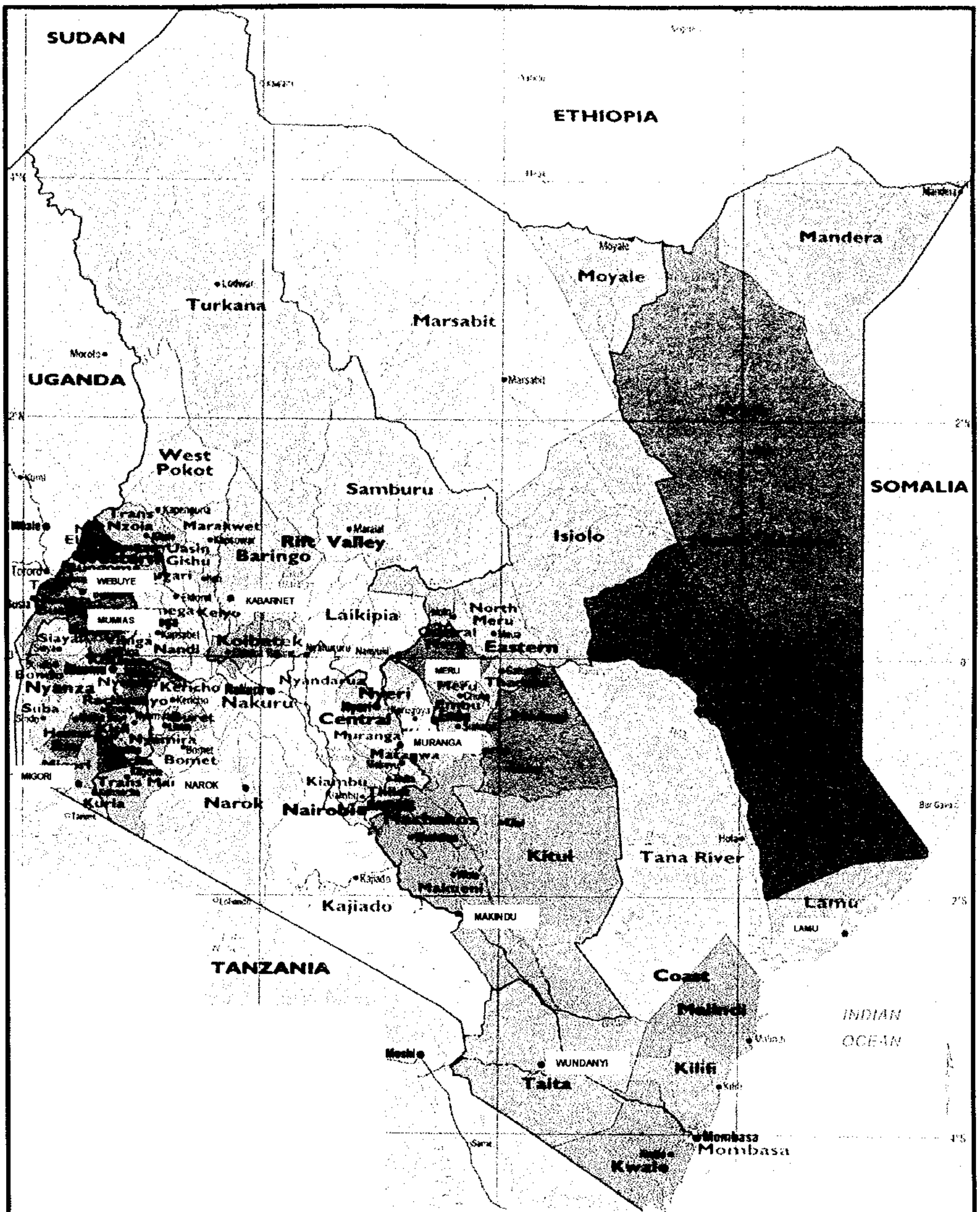
**Volume 2C : Main Report (including Appendices) - Murang'a Town**

**FEBRUARY 2001**

Development Impact Consulting

Engineering and Utility Management Ltd.

Gibb Eastern Africa Ltd.




# TEN TOWNS WATER & SANITATION STUDY

## TOWNS LOCATION MAP

Development Impact Consulting

GIBB Eastern Africa

LAWGIBB Group Member

# MURANG'A WATER SUPPLY

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## LIST OF ABBREVIATIONS

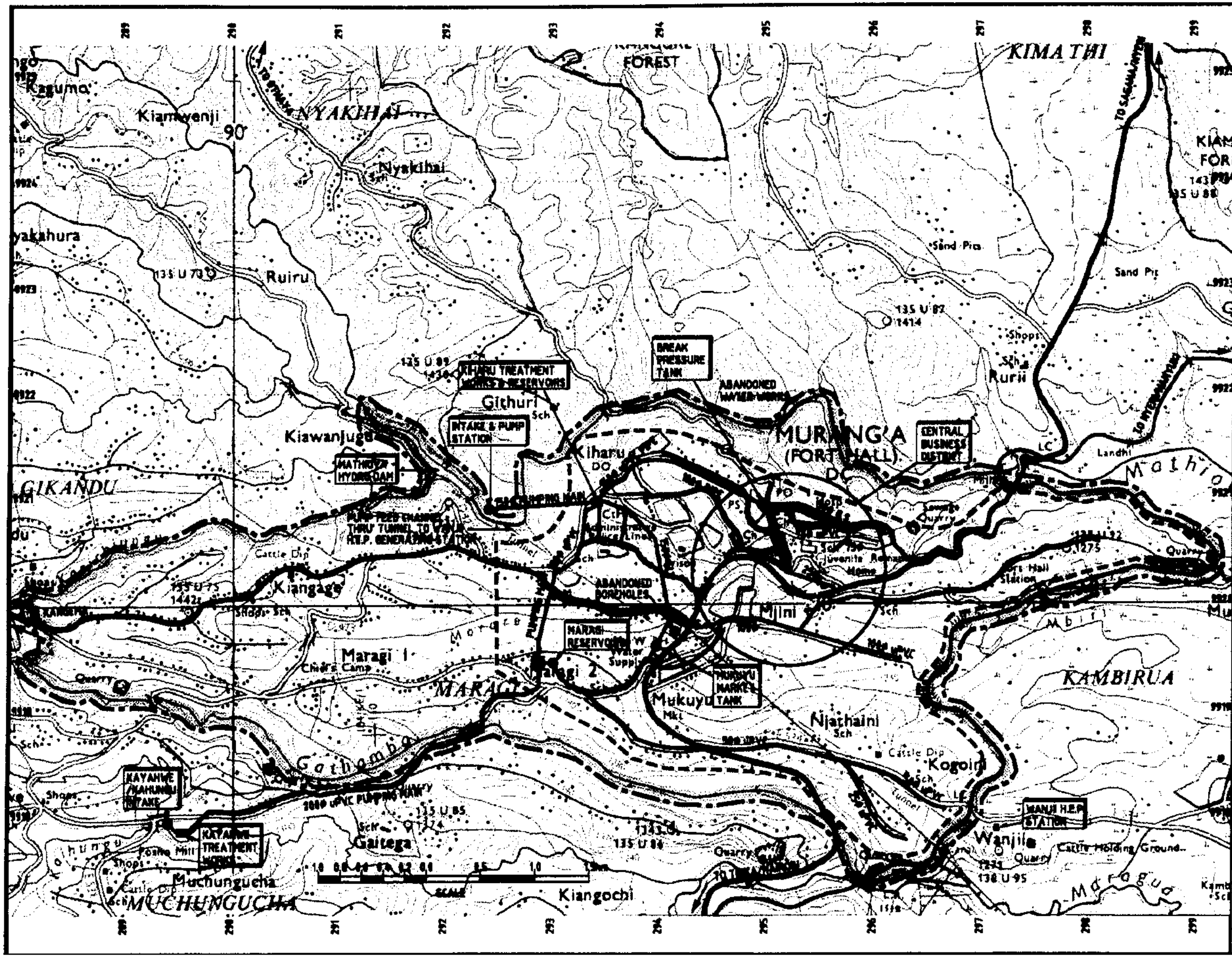
| | |
|---|---|
| AC | Asbestos Cement (Pipe) |
| AFW | Accounted for water |
| AG | Attorney General |
| AIDS | Acquired Immune Deficiency Syndrome |
| AIE | Authority to Incur Expenditure |
| AMREF | African Medical Research Foundation |
| ASK | Agricultural Society of Kenya |
| ATP | Ability to Pay |
| 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 |




NORTH

LEGEND

WATER PIPELINE

CURRENT WATER DISTRIBUTION AREA

MUNICIPAL BOUNDARY

Client: JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa

Project Title: TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title: MURANG'A MUNICIPALITY EXISTING WATER SUPPLY

Date: DEC 2000

Fig. No. 1.1

# 1 INTRODUCTION

## 1.1 BACKGROUND OF THE STUDY

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

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

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

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

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

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

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

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

## 1.2 OBJECTIVES OF THE STUDY

The objectives of the study are:

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

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

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

## 1.3 SCOPE OF THE STUDY

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

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

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

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

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

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

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

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

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

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

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

## 1.4 COMPOSITION OF THE FINAL REPORT

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

Volume 1: Executive Summary
Volume 2: Main Report

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

# 2 EXISTING PHYSICAL AND SOCIO-ECONOMIC CONDITIONS

## 2.1 GEOGRAPHY OF THE STUDY AREA

### 2.1.1 Location

Murang'a Municipality is located in Kiharu Division of Murang'a District in Central Province. The town is about 87 km (through Maragua) or 115km (through Sagana) from Nairobi and lies off the A2 Nairobi to Nanyuki trunk road. The A2 road is part of the Trans African Highway and runs north to Ethiopia through the Kenyan border town of Moyale.

Murang'a Municipality is the location of the Murang'a district headquarters. The headquarters of Central Province is in Nyeri which lies some 62 km from Murang'a by road in a north westerly direction.

The municipal boundary covers an area of just over 25 $km^2$ and has expanded over the years from its beginnings as the small colonial township of Fort Hall. The Nairobi – Nanyuki railway line defines the eastern boundary of the Municipality.

### 2.1.2 Topography

Ground levels within the municipality slope at an average of about 1:40:

- from approximately 1,150 mAMSL at the eastern most end,
- to 1,460 mAMSL at the western most end towards the Aberdare range.

A series of ridges run from west to east in the region and these are separated by a number of valleys with rivers that rise in the Aberdare Mountains.

### 2.1.3 Geology

The town lies on Miocene volcanic rocks equivalent to the Simbara Basalts of the Middle Athi Series. Other volcanic rocks in the general area include tuffs, trachytes and lava. The volcanic units overlie metamorphic rocks of the Basement System. The latter are mainly gneisses.

### 2.1.4 Climate

Murang'a town receives a mean rainfall of 1,195 mm per annum. The rainfall is bimodal, occurring as 'long' rains from March to June and 'short' rains from October to December.

## 2.2 PHYSICAL INFRASTRUCTURE

### 2.2.1 Communications

#### (a) Road links

Murang'a lies off the A2 trunk road running from Nairobi to Nanyuki. The A2 continues northward to Moyale and into Ethiopia. The A2 road is part of the Trans African Highway.

The hinterland is served by an extensive network of classified and unclassified roads.

#### (b) Rail links

The railway line from Nairobi to Nanyuki passes along the eastern municipal boundary. The Fort Hall (Murang'a) railway station serves the municipality and its environs.

#### (c) Air transport

There has been no major airport development in the area. However, a small airstrip is located to the east of the Municipality and this is supposed to serve Murang'a and its surroundings. However, this airstrip is reported to be not in use at present.

#### (d) Telecommunications

Subscriber trunk dialling (STD) telephone services and fax facilities are available in the town as are Internet service bureaux. Currently, no cellular phone coverage exists for Murang'a and surrounding area but plans are underway to expand coverage to Murang'a from the current limit at Thika.

### 2.2.2 Power supply

Murang'a is a major town in the region and is connected to the national power grid. The Mathioya hydro dam is located within the municipal boundaries and provides water, through a tunnel, to the Wanjii power station which generates 7MW of power.

### 2.2.3 Water supply and sanitation infrastructure

Water and sanitation is the subject of the present study and a detailed evaluation of this infrastructure is included in the chapters that follow.

### 2.2.4 Existing and planned services

There are currently no known immediate plans for major expansion of the water supply and sanitation services within Murang'a municipality.

The on-going El Nino rehabilitation program for town roads and water supply facilities is in the implementation phase.

## 2.3 SOCIO-ECONOMIC CONDITIONS

### 2.3.1 Administration

Murang'a is a cosmopolitan town situated in the Central province of Kenya. It was established as an urban council in 1960's and gradually attained a town council status in 1973. It became a municipal council in 1982 when its boundaries were expanded to cover more areas within the hinterland. The town currently serves as the administrative headquarters of Murang'a District and its Central Business District (CBD) houses offices of the district commissioner, other district departmental heads, municipal and county council offices. The town is a major business convergence centre for the hinterland especially on market days when urban visitation is at its peak. The town covers 20.2 $km^2$ with only 8 $km^2$ being considered urban especially the CBD and Mukuyu area. The potential for growth of the town as an institutional, commercial and industrial center is enormous despite its peripheral positioning at the tail end of the district map

Murang'a district is a high potential agricultural area with a high rainfall regime and good soils especially the upper zones of the district. However, some of the lower parts of the district normally remain dry throughout the year and are therefore of low agricultural potential.

### 2.3.2 Population Structure and Distribution

Using the 1999 housing and population census, the population of Murang'a town was 58,007[1] people. This contrasts with the 1979 and 1989 censuses where the population was 15,290 and 21,650 respectively representing an inter-censal growth rate of 3.48%and 10.36% per annum for the 1979-1989 and 1989-1999 periods. For instance, the urban population normally peaks on market. The number of households almost doubled from 5843 in 1989 to a provisional figure of 9,519 units in 1999 with a mean household size of 5.9. In 1989, the population density of the town (CBD) was 1,228 persons per $km^2$ and 1271 in 1999. The distribution of the population and number of households on the basis of sub locations is shown in table 2.1 below. See appendix C 1-1 for a map of the study area.

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

**Table 2.1 Population Structure and Distribution (1999)**

| Population in Municipal council | Population in Service area |
|---|---|
| 58007 | **24460** |

*Source: Central Bureau of statistics, 2001*

### 2.3.3 Population Projections to the year 2010

The main determinants of urban population growth rates are mainly existence of social infrastructure, potential for industrial growth and fertility rates. For Murang'a it is assumed that the fertility rates in the area declined over the 1989-1999 inter-censal period in accordance with the national trend while the rural-urban migration trend increased especially in the absence of any major industry. The total effect is therefore a population growth rate that is more or less similar to the 1979-1989 inter-censal growth rate of 3.4%. To capture the other population growth factors and dynamics, such as projected development activities, this figure was adjusted to 3.5% and used to project the towns' population to the year 2010. This rate is also the official rate adopted by the DDC and the physical development planning department for their planning purposes. Table 2.2 below gives the annualized population projections for the town to the year 2010.

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

| Year | Population under Municipal Council |
|---|---|
| 2000 | 60000 |
| 2001 | 62100 |
| 2002 | 64300 |
| 2003 | 66600 |
| 2004 | 68900 |
| 2005 | 71300 |
| 2006 | 73800 |
| 2007 | 76400 |
| 2008 | 79100 |
| 2009 | 81800 |
| 2010 | 84700 |

### 2.3.4 Economic and Commercial Activities

The main land-use patterns within the CBD are limited to residential, business/economic activities, institutions and social infrastructure. For along time, there has been a slow down in establishment of medium to large-scale enterprises. There are no major industries to support such investments though the town is well established as a trading center within the district, which gives room for development of light industries. This means development of any water master plan for the town needs to consider such potential for growth.

Table 2.3 below summarizes the pattern and distribution of business and commercial establishments in Murang'a town.

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

**Table 2.3 Pattern and distribution of Business and Commercial Activities**

| Type of Activity | Number of enterprises |
|---|---|
| Retail Shops | 759 |
| Hotels and Butchers | 231 |
| Barbers and Salons | 23 |
| Hardware | 20 |
| Carpentry/Workshops | 6 |
| Metal Fabrication | 15 |
| Wholesale | 34 |
| Manufacturing (Light industry and Agro-processing) | 9 |
| Financial institutions | 7 |
| Tailoring | 115 |
| Saw millers | 29 |
| Animal Feed | 6 |
| Petrol Stations | 6 |
| **Total** | **1,262** |

*Source: District Trade Office Murang'a, 1999*

Other commercial activities include four commercial banks, three financial institutions, head offices for farmers' organizations, credit co-operative societies, ACK and catholic churches, Kenya chamber of commerce and industry, Wanjengi youth advisory association and the Kenya small traders and entrepreneur's society.

### 2.3.5 Social Infrastructure

2.3.5.1 Communication

The town lies off an A classification trunk road from Nairobi to Nanyuki. The inconsistency in road maintenance is a major cause of the slowed growth in development activities and delivery of perishable goods to town from the hinterland. A railway line from Nairobi towards Karatina passes along the municipal boundary. Other services include subscriber trunk dialing (STD) telephone services, fax facilities, Internet service bureaus as well as an airstrip.

2.3.5.2 Social Institutions

The town remains a major institutional center for Murang'a district. The number of institutions hosted within the town is as shown in tables 2.4 and 2.5 below.

**Table 2.4 Educational Institutions**

| Type of institution | Number |
|---|---|
| Pre-Primary Schools | 40 |
| Primary Schools | 24 |
| Secondary Schools | 8 |
| Murang'a College of Technology | 1 |
| Youth Polytechnics | 3 |
| **Total** | **76** |

*Source: District Development Office Murang'a, 1999*

**Table 2.5 Other Social Institutions**

| Facility | Number |
|---|---|
| District Hospital (GoK) | 1 |
| Health Centre | 1 |
| Dispensaries (GoK) | 14 |
| Juvenile Remand home | 1 |
| GK Prison (with an estimated number of households and population of 129 and 228 people respectively) | 1 |
| Church | 8 |
| Private Clinics | 24 |
| Mosques | 3 |
| **Total** | **33** |

*Source: District Development Office Murang'a, 1999*

### 2.3.6 Income Levels

The distribution of income in Murang'a town is quite uneven and reveals major disparities in household resource endowment. The main sources of income for the urban population are confined to wages, salaries and profits and this varies as one moves away from the CBD towards the hinterland. According results obtained form the Welfare Monitoring Survey (WMS) II, the mean monthly household income for the town was Kshs. 11,513 while the annual per capita income was estimated at Kshs. 27,012 as shown in table 2.6 below. On the other hand the mean monthly household expenditure and per capita expenditures were estimated at Kshs. 6,796.8 and 15,332 respectively. This means that about 74% of the urban households mean monthly income is drawn from wages, salaries and profits.

It then follows that, except for the residents of slum areas such as Mjini, St Mary and parts of Konguini, most urban water consumers are able to pay for water. But even for the slum areas, a random sample survey of 80 households carried out by the study team revealed that more than half of the households interviewed earn an average income of over Ksh 5,000 per month. According to the DWO the problem at the moment is not the level of the tariff but the level of service. In fact, currently most of the households pay as high as Kshs 10 for a 20L jerricane of untreated water drawn from vendors.

**Table 2.6 Mean Monthly Household Incomes (Kshs).**

| Income Source | Mean |
|---|---|
| Wages/salaries/profits | 7450.8 |
| Other Non-agriculture income | 1844.3 |
| Agriculture income | 1566.9 |
| Crop income | 650.9 |
| **Total household income** | **11512.9** |

*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 is a function of level of household incomes, the acceptable share of water/sewerage services in total expenditures, tariffs and the target consumption levels as well as peoples awareness of existing safe water sources. The main consideration in the ability to pay in this study is the threshold household level of income. It is important recognize that the ceiling on the budget share of income that a household can spent on water/sewerage services is usually taken to be 5% though this varies from one income group to another. The budget share of income spent by the middle to high-income groups in real terms on water is approximately 2.2% and 1.4 % of their incomes respectively.

43% of the urban population live in the low-income bracket and stand predisposed to contract diseases related to water and sanitation conditions. In times of water shortage, a majority of this population especially residents of Mukuyu draw water from the same sources (nearby stream). It is therefore important to give a critical evaluation of the income levels, W/ATA and W/ATP for improved water services in the town as a basis for analyzing the water demand partnerships in the town.

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 and this were mainly focus group discussions especially with key personal dealing with water in the town, individual observations as well as use of elaborate questionnaires. Through questionnaire based interviews, each household head was asked questions on how much they would be willing and able to pay for a cubic meter of water under two scenarios. Questions asked in scenario one were based on the household's willingness to pay for water under existing circumstances where as in scenario two, households were asked questions relating to how much they would be willing top pay if the existing water supply conditions were improved. In both cases, the general conclusion of the survey was that most households were willing to pay more for an improved water service delivery system commensurate with the level of tariff. This was also found to be in tandem with consumer expectations and perception of the problem in a particular service area since not all consumers faced similar service delivery problems.

The preliminary analysis of information collected indicated that over 80% of the households interviewed were willing to pay up to Kshs. 500 for actual water consumption compared to an average monthly bill of Kshs. 300. 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

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

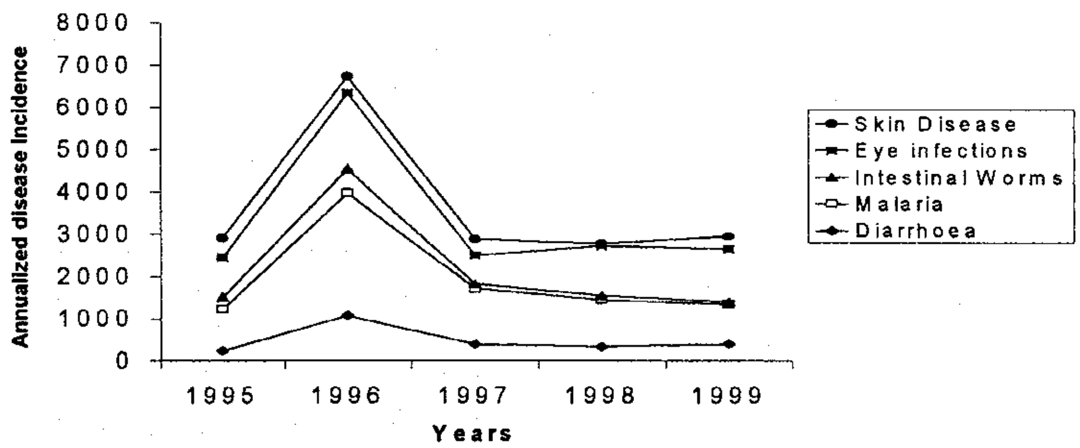
revealed that even with increment of up to 30% in the tariff, people would still be willing to pay

### 2.3.8 Health and Sanitation Situation

A critical analysis of the public health and sanitation situation in the town shows an appalling condition. From a casual survey of the town, the team established that residents of Mjini, Konguini suburb, Gaitega, St. Mary and Station Road source water from Murari stream which is considered serious health hazard to the local population as the council often disposes raw sewage to the stream due do inadequate treatment works. Such a situation in the absence of water kiosks may predispose the population to more dilapidating cases of water related diseases

For instance, there is only one functional public toilet, less than 50% of business premises not connected to the min sewer line as wastewater from these premises go into open drains. For instance water contamination is prevalent around Mukuyu estate. Absence of water kiosks forces consumers to revert to more traditional sources such as streams and wells. Efforts by the public health office through establishment of community policing units for waste removal and disposal has over time proved infeasible due to lack of a comprehensive community sensitization and mobilization agenda. Consequently, there is lack of a general commitment of interest and goodwill especially from the literate public. However it is expected that through proper targeting under a situation of political will, communication on issues of hygiene can be enhanced through a social marketing approach in order enhance the social demand for health and sanitation facilities. The chart below show the general pattern of water related diseases over a retrogressive period of five years. It can be noted that skin diseases affecting mainly children is a major problem. The low prevalence of diarrhoeal diseases is related to the poor health seeking behaviour among the urban households as well as poor data capture techniques.

**Chart 1: Incidence of water related Diseases in Murang'a District**




*Source: Health Information Systems Unit, MOH and PHO's, Murang,a*

### 2.3.9 Types of Settlements

The major housing estates in Murang'a are broadly classified in terms of income levels. However, housing standards for the low-income areas is very poor. No physical planning is done in this area.

**Table. 2.7 Settlement patterns**

| High Income | Middle Income | Low Income. |
|---|---|---|
| Milimani A and B | Maragi A and B | Konguini Suburb |
| Town A and B | Mukuyu mashambani | Gaitega |
| Kiharu A and B | Kangema Road | Mjini (slum) |
| Mukuyu Market | Mumbi General | St. Mary |
| MumbiT.P (Tenant purchase houses) | | Station Road |

*Source: District Development Office Murang'a, 1999*

Table 2. 8 below shows the distribution of the population based on the three major income categories.

**Table 2.8 Settlement patterns based on income categories**

| Income category | Number | Percentage |
|---|---|---|
| High income | 7,540 | 13 |
| Middle income | 25523 | 44 |
| Low income | 24944 | 43 |
| **Total** | **58007** | **100** |

### 2.3.10 Situation of Women in Society

Traditionally, women are responsible for collecting water for domestic use in the household. 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. Other than situations where donkeys are used, the burden for carrying water requires women to have a substantial amount of energy irrespective of whether one's focus is on urban or peri-urban focus. 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.

### 2.3.11 Public Health Awareness and Mobilisation

Analysis of the health and sanitation conditions observed in Murang'a town shows that the sewerage system serves a paltry population of less than 15%. Only the CBD and particularly areas around Milimani are well served. Problems relating to urban environmental sanitation such as excreta disposal (there is no functional public toilet), water supply, solid waste management, liquid waste and drainage and sewerage treatment were enumerated. Residents living around the sewage treatment works consider the council to be disposing raw sewage into the river and this has often caused a major outcry from the local residents. The epidemiology of water borne diseases is found to cut across existing socio economic strata such that in situations where lapses in surveillance by the public health office are eminent, the situation may degenerate into an epidemic in future especially in the low income areas such as Mukuyu and Konguini areas.

Given the health and sanitation concerns enumerated in section 2.3.8, the study team considered the need for public health awareness and mobilization campaigns as an important component of the water rehabilitation programme. The approach to this important exercise should be based on participatory methods that emphasize making use of all the stakeholders such as businessmen, private sector organizations, government agencies and individual households. These groups are indeed the actual beneficiaries of health and sanitation improvement programmes and must therefore be sensitized on ways of preventing or reducing water and sanitation related diseases. Essentially, the major areas of focus need to be on use of safe water, safe excreta disposal, personal and domestic hygiene, safe handling of food both in public eating points and at home and safe waste disposal/drainage of excess water.

In this regard, it is important that the public health office (PHO) in collaboration with the office of the district social development officer (DSDO) be assisted and empowered in conducting rapid needs assessment surveys of the existing health and sanitary conditions. This should pave the way for a situational analysis of sanitation conditions with the needs and aspirations of all the affected parties forming a major design consideration of the logical framework through community groups. Formation of community level groups should be demand driven, based on sound economic principles, appropriate technology and an acceptable management structure to all before a social mobilization and sensitization agenda can be initiated.

In view of the above, the study proposes that there will be need to develop a basis and framework for mobilization and training of the community. This training should be in the form of a manual entailing among other things;

a) Training of facilitators
b) Training of trainers
c) Preparation of training aid materials to be used in community training

## 2.4 EXISTING WATER RESOURCES, MANAGEMENT AND UTILISATION

### 2.4.1 Hydrogeology (groundwater resources)

The main water-bearing units are the sediments intercalated between volcanic flows, weathered or fractured lava and basalt, and the old land surface at the contact between the basal volcanic flow and basement gneisses. The old land surface and fractured basalt are potentially the most important aquifers.

The following is a summary of the groundwater conditions in Murang'a district:

- Average depth is 102.53 m (104 boreholes).
- Average water struck level is 67.15 m (103 boreholes).
- Average water rest level is 20.78 m (96 boreholes).

For the immediate study area where the three water supply boreholes are situated, the following apply:

- Depth range to the main aquifer: 50 – 100 m.
- Depth range of water rest level: 15 – 25 m.
- Discharge range: 2 – 50 $m^3$/hr.
- Water quality: generally fresh, neutral sodium bicarbonate water. The silica concentration is often high.

Aquifers within the area of interest are confined and recharge occurs by lateral replenishment, mainly from the ridges to the north and north-west of Murang'a' municipality. Seepage from rivers as baseflow and local infiltration also contributes to recharge.

The data above confirms that there is groundwater potential in the Murang'a municipal area. However, for this potential to be realised, boreholes must be suitably sited because the range of discharge is wide.

#### (a) Status of existing groundwater supply facilities

5 No. boreholes have been drilled in the Murang'a municipality for town water supply. Only 2 of these have yielded water in the past for municipal water supply and none are currently operational.

Summary details of the boreholes are presented in Table 2.11.

**Table 2.11**
**Summary details of Murang'a municipality boreholes**

| Borehole No. | Yield ($m^3/hr$) | Current Status | | Comments |
|---|---|---|---|---|
| | | Pump | Gantry | |
| C2868 * | 21 | installed | original | operated until 1980 |
| C3034 | --- | none | original | operated until 1980 |
| C3921 | low ** | none | original | never operated due to low yield |
| C3876 | low ** | --- | --- | never traced by current authority |
| 600m SW of C2868 | --- | --- | --- | no data available, but known to be dry |

* *This borehole is reported by the district geologist to be BH-3, from which the yield data is obtained.*

** *Diminishing yield is reported by Howard Humphreys (1973) to be the reason why these boreholes were taken out of operation in the 1970s.*

Borehole Nos C 2868 and C 3034 were operated until production/operations were stopped some time around 1980. The boreholes were equipped with Beresford submersible pumps rated at discharge (Q) of 9500 gallons per hour (gph) at a total head (H) of 300 ft (Q=43.2 m3/hr, H= 91.5 m).

Discharge data for one of the boreholes is presented below, taken from operational charts:

- 1970 – 1972 24 $m^3$/hr.
- 1973 – 1974 20 $m^3$/hr.
- 1974 – 1975 20 $m^3$/hr.

It was not possible to establish the specific borehole to which this data applies, because the boreholes are only identified as BH –1, BH – 2 and BH – 3 on the operational charts. The district geologist, however, believes that the above data is for Borehole C 2868. Data from NAWARD also indicates this as BH – 3.

Borehole C 2868 still has the pump installation in place, but the pump in C 3034 was removed. All the boreholes have the original maintenance gantries, except C 3876 for which the borehole installation could not be traced. The three identified boreholes are located in a single wellfield, so that they share the same aquifer and interference must occur when the boreholes are pumped simultaneously.

It cannot be established at this stage whether the combined abstraction from the aquifer by the two boreholes led to the observed discharge reduction with time reported by Howard Humphreys in 1973. There may have been factors related to construction or pump efficiency as well. The geologist reported that when the pump was removed from Borehole C 3034, all the pipes were retrieved with minimum difficulty. It can therefore be assumed that the borehole had not collapsed. This, however, does not exclude the possibility that any caving or excessive silting had occurred below the level of the pump intake. The boreholes were nonetheless operational up to the time production was stopped.

Because of declining yield, operations at the borehole sites were stopped after a new river intake near to Mathioya Dam (also known as Murang'a I) was commissioned in 1980. Data at the time of construction of the boreholes currently known to the Murang'a water department are presented in Table 2.12.

**Table 2.12**
**"As-completed" borehole data for existing Water Department boreholes**

| Serial No. | Total depth<br>m | Water strike levels<br>m | Rest level<br>m | Tested yield<br>$m^3/hr$ | Completion date |
|---|---|---|---|---|---|
| C 2868 | 122 | 19.2<br>6.0<br>6.5<br>97.6 | 15.9 | 50 | 17.01.59 |
| C 3034 | 134 | 18.3<br>106.9<br>122.0 | 18.3 | 28.8 | 16.06.60 |
| C 3921 | 165.2 | 160.0 | 21 | 1.8 | 13.05.73 |

*Data source: NAWARD, MENR, Nairobi.*

### (i) Construction condition of Borehole C-2868

This borehole was completed in 1959 as an 'open hole' construction. The top 24 metres of the hole was cased with 254 mm diameter steel casing, secured with cement grout that also acted as the borehole sanitary seal. The rest of the hole was left open at 254 mm diameter. The borehole physical log describes the rock from 21 m below ground level (bgl) to total depth as 'hard lava'.

The casing is now 40 years old and is past its useful life.

### (ii) Construction condition of Borehole C 3034

This borehole was completed in 1960, constructed with 254 mm diameter steel casing of length 30 metres, then left open hole (305 mm diameter) to the bottom. This borehole is 40 years old and is past its useful life.

The hole was left open in semi-consolidated units comprising volcanic and quartzitic sands. It is likely that some silting has occurred since completion of the borehole. It is instructive to note that during the initial test pumping, two disparate pumping water levels were recorded as outlined below:

**Table 2.13**
**Pumping test data for Borehole C 3034**

| Test ref. | Static water level (m bgl) | Pumping water level (m bgl) | Pump intake (m bgl) | Yield ($m^3/hr$) | No. of hours tested |
|---|---|---|---|---|---|
| No. 1 | 18.3 | 74.4 | 109.8 | 13.6 | 18 |
| No. 2 | 18.3 | 54.3 | 104.3 | 28.8 | 22 |

*Data source: NAWARD, MENR, Nairobi*

It can be seen that the discharge in the first test was only 47% of the second test, but the pumping water level was 19.9 m lower (ie. 37% more drawdown) than the second test. Two events could have occurred either separately or in combination:

- The borehole was either better developed in the second test due to pumping during the first test, thus able to yield more water; and/or

- The lower section of the borehole may have backfilled due to collapse of loose material.

However, the discharge water was reported as 'clear' (free of sand or sediment) after the second test, making the second option a less likely conclusion and some flow development would seem to have taken place.

**(iii) Construction status of Borehole C 3921**

Borehole C 3921 was completed in May 1973. It was installed with 18.3 m of 152 mm diameter Class 'B' screwed and socketed galvanised piping. The rest of the borehole was left open at 200 mm diameter.

The log does indicate that the open length was drilled in alternate layers of 'soft' and 'hard rock. These are likely to be tuff and basalt horizons. They are generally stable, but weathered or fractured aquifer zones may experience scouring under turbulent flow conditions, leading to collapse of fragments and fine material.

The borehole galvanised pipe installation is now 27 years old and is approaching the end of its useful life.

**(b) Groundwater quality**

The MENR database contains an analysis of groundwater from Borehole C 3921 dated 4 May 1973. The calculated ionic balance for this sample is shown in Table 2.14.

**Table 2.14**
**Groundwater quality analysis**

| Parameter | mg/l | meq/l | Parameter | mg/l | meq/l |
|---|---|---|---|---|---|
| $NH_4^+$ | ND | 0.000 | $Cl^-$ | 5 | 0.145 |
| $Na^+$ | 8 | 0.348 | $NO_2^-$ | ND | 0.000 |
| $K^+$ | 2 | 0.051 | $NO_3^-$ | ND | 0.000 |
| $Ca^{2+}$ | 17 | 0.848 | $F^-$ | 0.4 | 0.021 |
| $Mg^{2+}$ | 7 | 0.576 | $HCO_3^-$ | 114.7 | 1.880 |
| $Fe^{2+,3+}$ | 0.2 | 0.009 | $CO_3^{2-}$ | ND | 0.000 |
| $Mn^{2+}$ | 0.1 | 0.004 | $SO_4^{2-}$ | 0.7 | 0.015 |
| | | | $PO_4^{3-}$ | ND | 0.000 |
| Total | | 1.836 | Total | | 2.061 |

The reported pH for the sample was 7, the reported alkalinity was 114.7 mg/l as calcium carbonate and the reported dissolved carbon dioxide was 15 mg/l. The reported alkalinity and bicarbonate are inconsistent: the bicarbonate alkalinity (which will be the only significant form of alkalinity at a pH of 7) is 1.88 meq/l or 94.1 mg/l as calcium carbonate.

Assuming the reported bicarbonate and dissolved carbon dioxide concentrations are correct, the calculated inorganic carbon specification is given below.

**Table 2.15**
**Calculated inorganic carbon specification and pH**

| Temperature (°C) | 10 | 15 | 20 | 25 |
|---|---|---|---|---|
| $[H_2CO_3^*]$ (mol/l) | 3.41E-04 | 3.41E-04 | 3.41E-04 | 3.41E-04 |
| $[HCO_3^-]$ (mol/l) | 1.88E-03 | 1.88E-03 | 1.88E-03 | 1.88E-03 |
| PH | 7.21 | 7.16 | 7.12 | 7.09 |
| $[OH^-]$ (mol/l) | 4.74E-08 | 6.58E-08 | 9.10E-08 | 1.25E-07 |
| $[CO_3^{2-}]$ (mol/l) | 9.8E-07 | 1.01E-06 | 1.05E-06 | 1.09E-06 |
| Alkalinity (mg/l as $CaCO_3$) | 94.2 | 94.2 | 94.2 | 94.2 |
| $[Ca^{2+}]$ (mol/l) | 4.24E-04 | 4.24E-04 | 4.24E-04 | 4.24E-04 |
| $IAP_{calcite}$ | 4.16E-10 | 4.30E-10 | 4.45E-10 | 4.62E-10 |
| Dissociation constant for calcite | 6.37E-09 | 5.82E-09 | 5.33E-09 | 4.9E-09 |
| Saturation | 6.5% | 7.4% | 8.3% | 9.4% |

The calculated results give a plausible pH at the higher temperatures. They also show that the water is undersaturated with respect to calcite and will be aggressive towards concrete and asbestos cement pipes.

### (c) Potential for groundwater development

The operation of the boreholes that have previously been used to supply water to Murang'a town was stopped in 1980 when a new river intake was constructed near Mathioya Dam. This dam is a hydro-dam and is not specifically used for storage of water for supply to the town.

The intake near Mathioya Dam (known as Murang'a I) was decommisioned when the Kayahwe Intake (known as Murang'a II) was commissioned. The Murang'a I intake was later rehabilitated in 1998 and re-commissioned when Murang'a II intake works/bulk water pumping system could not meet the demand. Due to further increase in demand, over and above the capacity of the existing treatment works and bulk distribution system, the water office is now considering rehabilitating the old borehole system.

The rehabilitated boreholes would therefore function as a fast track measure to ensure sustained water supply, especially while the treatment works undergo rehabilitation. Once the treatment works are fully operational, the borehole supply would act as a backup and later a supplementary supply to augment the surface water system.

Water quality is such that minimal treatment (only chlorination) will be required to bring it to acceptable standards.

There is potential for high-yielding (defined as more than 10 $m^3$/hr) aquifers in old land surfaces or riverbeds in the vicinity of Murang'a. The catchment receives adequate rainfall for recharge of the aquifers. These factors combine to present groundwater as a viable option for public water supply.

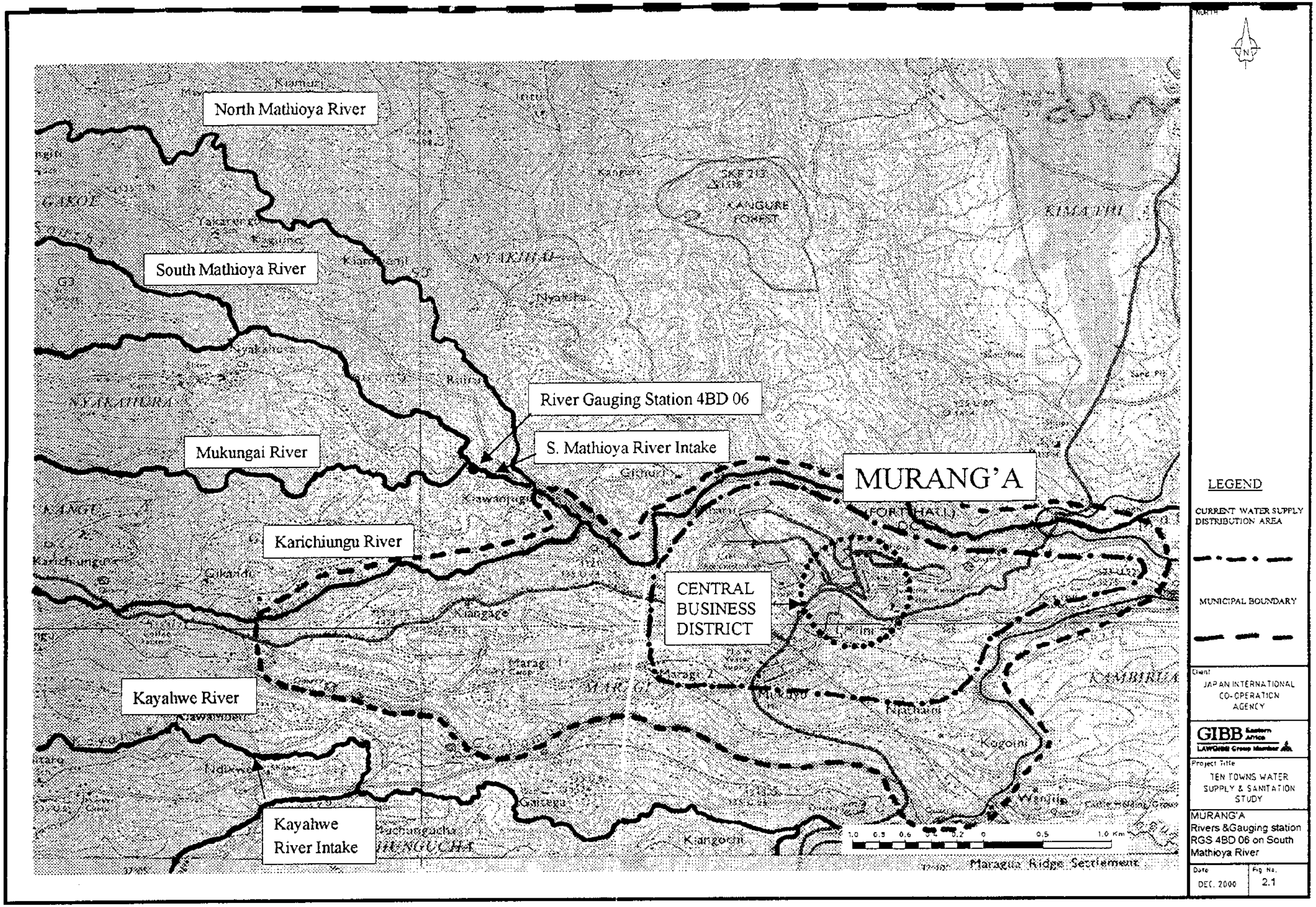
The quantity of water from the present boreholes, however, is definitely not sufficient to supply the estimated 2010 demand of 12,358 $m^3$/day. Additional water is required from surface water sources and the borehole supply can be considered as an immediate remedial measure that is supplementary only.

Details of the proposed reconstruction works and estimated cost for the rehabilitation of Boreholes C2868 and C3034 is given in Appendix C2-1.

## 2.4.2 Hydrology (surface water resources)

### (a) Catchment characteristics

The town lies approximately 4.5 kilometres north of the Tana River. Rivers generally drain west to east. The general layout of the key geographic features in and around Murang'a, including the key geographic features, are shown in Figure 2.1.


North Mathioya River
South Mathioya River
River Gauging Station 4BD 06
Mukungai River
S. Mathioya River Intake
MURANG'A
Karichiungu River
CENTRAL
BUSINESS
DISTRICT
Kayahwe River
Kayahwe
River Intake
KANGURE FOREST
NYAKIHAI
NYAKAHURA
KIMATHI
KAMBIRUA
MARAGI
Maragua Ridge Settlement
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
MURANG'A
Rivers &Gauging station RGS 4BD 06 on South Mathioya River
Date
DEC. 2000
Fig No.
2.1

The two rivers supplying Murang'a town are the Mathioya and Kayahwe Rivers which rise in the Aberdare mountain range about 50 km west of the town. The catchments fall in Sub-Drainage Area 4B within Drainage Area 4 of the Upper Tana Drainage Area.

Rainfall records show an average 1,195 mm per year for the town rising to over 1,400mm in the upper parts of the catchment.

**(b) Assessment of water potential**

The principal sources of public water supply in Murang'a town are the Mathioya and Kayahwe rivers. Data on the flow characteristics of the Mathioya River is available from the *Aftercare Study on the National Master Plan*, conducted by JICA in 1998. The river gauging station for which records are available, RGS 4BD06, is situated some 500 m upstream of the confluence of the North and South Mathioya rivers. The waterworks intake is located sufficiently close to the gauging weir that the recorded flow figures from the gauging station are directly applicable to this intake. The relative positions of the gauging station and Mathioya intake works are shown in Figure 2.1.

In the absence of readily available or reported data, flow characteristics for the adjacent Kayahwe River can be estimated by adjusting the South Mathioya River flows proportionally according to the catchment areas. This is justified, given the close proximity and similarity of the two catchments in shape, topography and land use. The data for the two rivers, used in this evaluation, is presented in Table 2.16

**Table 2.16**
**River flow data for Mathioya and Kayahwe river intakes**

| River | Gauging station | Station opened | Station closed | Rated | Catchment Area ($km^2$) | Mean annual runoff ($m^3/s$) |
|---|---|---|---|---|---|---|
| Mathioya | 4BD06 | 1972 | 1991 | Yes | 227 | 3.1 |
| Kayahwe | --- | --- | --- | --- | 93 | 1.3 |

The data from the South Mathioya River extends over a period of 19 years. This data was used in the 1998 JICA funded *Aftercare Study* to generate a non-dimensional flow duration curve for the South Mathioya River, presented in Figure 2.2.

The flow duration curve represents the ranked daily flow data. The 50% exceedence flow 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. This 100% exceedence value represents the lowest daily discharge on record.

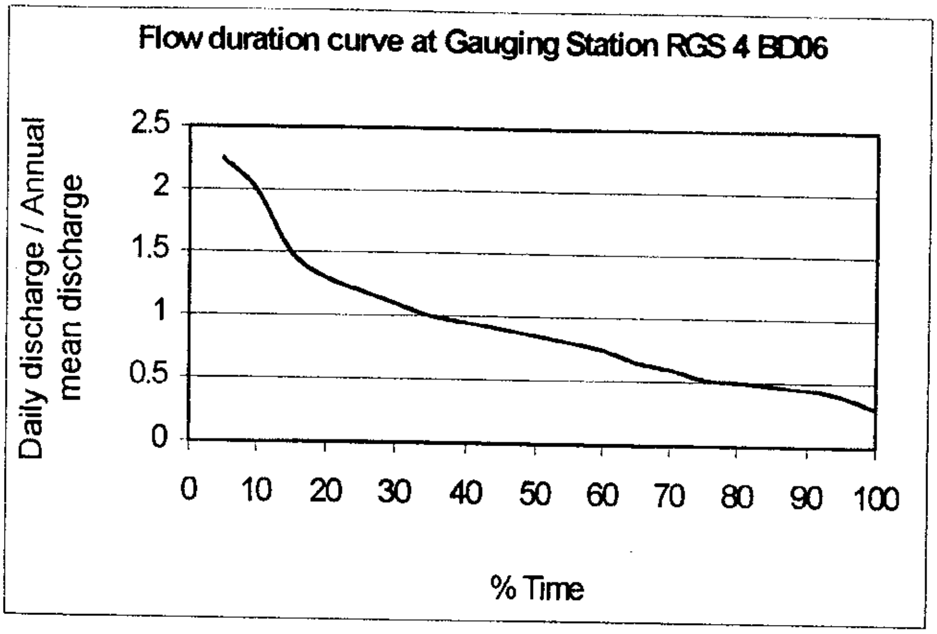



**Figure 2.2 Flow duration curve for South Mathioya River**

The low flow statistics derived from the above flow duration curve are summarised in Table 2.17. It should be noted that due to the proximity of the river gauging station and the Mathioya intake works, these figures are representative of the Mathioya intake works flows as well.

Similarly, due to the proximity and similarity of the Mathioya and Kayahwe rivers, the characteristics in Table 2.17 can be applied to the adjacent Kayahwe river.

**Table 2.17. Flow duration characteristics at RGS 4BD06**

| **Exceedence value (%)** | **$Q/Q_{ave}$** |
|---|---|
| 50% exceedence flow ratio $Q_{50}/Q_{ave}$ | 0.85 |
| 90% exceedence flow ratio $Q_{90}/Q_{ave}$ | 0.45 |
| 95% exceedence flow ratio $Q_{95}/Q_{ave}$ | 0.40 |
| 100% exceedence flow ratio $Q_{100}/Q_{ave}$ | 0.30 |
| Mean annual runoff ($m^3/s$) | 3.10 |

The JICA funded 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 ...".*

The same study also goes on to say that:

- *"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, according to the *Aftercare Study*, 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 here.

The 90% and 100% exceedence flows and available water resource for both rivers using the above methodology are presented in Table 2.18 below. Also presented, for purposes of comparison are the present and future abstraction requirements.

**Table 2.18**
**Comparison of river yields and demands for Murang'a municipal water supply**

| **Description** | **Flow** | **($m^3$/day)** | **Flow** | **($m^3$/sec)** |
|---|---|---|---|---|
| | Mathioya River | Kayahwe River | Mathioya River | Kayahwe River |
| 90 % flow exceedence | 120,528 | 49,380 | 1.395 | 0.572 |
| 100 % flow exceedence | 80,352 | 32,920 | 0.930 | 0.381 |
| Available water resource | 40,176 | 16,460 | 0.465 | 0.191 |
| Present abstraction capacity | 3,240 | | 0.038 | |
| 2000 demand (Table 4.2) | 8,345 | | 0.097 | |
| 2010 demand (Table 4.2) | 11,575 | | 0.134 | |

*Note: Murang'a I intake is sited near to Mathioya hydro dam, but does not use the available reservoir storage. Murang'a II intake is sited on the confluence of the Kayahwe/Kaihungu rivers.*

On inspection of Table 2.18, it can be seen that there is sufficient water, on the basis of the analysis, to reliably supply Murang'a town from either source at all times now and in the foreseeable future (even beyond the design horizon of 2010), without any difficulty.

### 2.4.3 Raw water quality

#### (a) Mathioya River

The 1973 design report for Murang'a water supply contains a single analysis of water from the Mathioya River dated 17 April 1973. The water had a reported colour of 175 Hazen units and a reported turbidity of 232 JTU. The reported pH for the sample was 7.5, the reported alkalinity was 36 mg/l as calcium carbonate and the reported dissolved carbon dioxide was 6 mg/l. The calculated ionic balance for this sample, assuming all alkalinity is bicarbonate, is shown in Table 2.19.

**Table 2.19**
**Mathioya river raw water quality analysis**

| Parameter | mg/l | meq/l | Parameter | mg/l | meq/l |
|---|---|---|---|---|---|
| $NH_4^+$ | 0.57 | 0.032 | $Cl^-$ | 4 | 0.116 |
| $Na^+$ | 3 | 0.130 | $NO_2^-$ | 0 | 0.000 |
| $K^+$ | 2 | 0.051 | $NO_3^-$ | 1.77 | 0.029 |
| $Ca^{2+}$ | 4 | 0.200 | $F^-$ | 0.2 | 0.011 |
| $Mg^{2+}$ | 3 | 0.247 | $HCO_3^-$ | 43.9 | 0.719 |
| $Fe^{2+,3+}$ | 14 | 0.627 | $CO_3^{2-}$ | ND | 0.000 |
| $Mn^{2+}$ | 0.2 | 0.007 | $SO_4^{2-}$ | 21 | 0.219 |
| | | | $PO_4^{3-}$ | ND | 0.000 |
| Total | | 1.294 | Total | | 1.093 |

The reported dissolved iron content of 14 mg/l is abnormally high. The reported total hardness for the sample was 24 mg/l as calcium carbonate, or 0.639 meq/l. Assuming this value and the calcium, magnesium and manganese determinations are correct, the iron content becomes 0.58 mg/l, but the error in the ionic balance becomes greater. Despite the analytical errors, the water can be classified as soft with high iron and manganese concentrations.

### (b) Maragua River (downstream of Kayahwe/Kaihungu rivers)

The Howard Humphreys design report contains three analyses for the Maragua River. This river is just downstream of the confluence of the Kayahwe and the Kaihungu rivers. A sample taken on 5 April 1973 showed colour of less than 5 Hazen units and no turbidity. The reported pH for the sample was 7.5, the reported alkalinity was 70 mg/l as calcium carbonate and the reported dissolved carbon dioxide was 11 mg/l. The calculated ionic balance for this sample, assuming all alkalinity is bicarbonate, is shown in Table 2.20.

**Table 2.20**
**Maragua river raw water quality analysis, 05/04/73**

| Parameter | mg/l | meq/l | Parameter | mg/l | meq/l |
|---|---|---|---|---|---|
| $NH_4^+$ | 0 | 0.000 | $Cl^-$ | 4 | 0.116 |
| $Na^+$ | 7 | 0.304 | $NO_2^-$ | 0 | 0.000 |
| $K^+$ | 1 | 0.026 | $NO_3^-$ | 2.21 | 0.036 |
| $Ca^{2+}$ | 12 | 0.599 | $F^-$ | 0.2 | 0.011 |
| $Mg^{2+}$ | 6 | 0.494 | $HCO_3^-$ | 85.4 | 1.400 |
| $Fe^{2+,3+}$ | 0.6 | 0.027 | $CO_3^{2-}$ | ND | 0.000 |
| $Mn^{2+}$ | 0.2 | 0.007 | $SO_4^{2-}$ | 8 | 0.083 |
| | | | $PO_4^{3-}$ | ND | 0.000 |
| Total | | 1.457 | Total | | 1.645 |

The water is moderately soft, calcium-magnesium bicarbonate type. Unlike the sample for the Mathioya River, the calculated and reported hardnesses are in agreement.

A second sample from the Maragua River was taken on 30 April 1973. This showed a colour of 200 Hazen units and a turbidity of 90 JTU. The reported pH was 7.2, the reported alkalinity was 40 mg/l as calcium carbonate and the reported dissolved carbon dioxide was 5 mg/l. The calculated ionic balance for this sample is given in Table 2.21 below.

**Table 2.21**
**Maragua river raw water quality analysis, 30/04/73**

| Parameter | mg/l | meq/l | Parameter | mg/l | meq/l |
|---|---|---|---|---|---|
| $NH_4^+$ | 0.03 | 0.002 | $Cl^-$ | 2 | 0.058 |
| $Na^+$ | 4 | 0.174 | $NO_2^-$ | 0 | 0.000 |
| $K^+$ | 1 | 0.026 | $NO_3^-$ | 1.77 | 0.029 |
| $Ca^{2+}$ | 8 | 0.399 | $F^-$ | 0.2 | 0.011 |
| $Mg^{2+}$ | 2 | 0.165 | $HCO_3^-$ | 48.8 | 0.800 |
| $Fe^{2+,3+}$ | 6 | 0.269 | $CO_3^{2-}$ | ND | 0.000 |
| $Mn^{2+}$ | 0.4 | 0.015 | $SO_4^{2-}$ | 9 | 0.094 |
| | | | $PO_4^{3-}$ | ND | 0.000 |
| Total | | 1.048 | Total | | 0.991 |

The calculated hardness from the above determinations is 51 mg/l as calcium carbonate, not the reported 28 mg/l. The water is soft with a significant iron content.

The third determination for the Maragua River is for a sample taken on 29 May 1973. This showed a colour of 175 Hazen units and a turbidity of 232 JTU. The reported pH was 7.5, the reported alkalinity was 36 mg/l as calcium carbonate and the reported dissolved carbon dioxide was 6 mg/l. The calculated ionic balance for this sample is given in Table 2.22 below.

**Table 2.22**
**Maragua river raw water quality analysis, 29/05/73**

| Parameter | mg/l | meq/l | Parameter | mg/l | meq/l |
|---|---|---|---|---|---|
| $NH_4^+$ | 0.51 | 0.028 | $Cl^-$ | 3 | 0.087 |
| $Na^+$ | 3.2 | 0.139 | $NO_2^-$ | 0 | 0.000 |
| $K^+$ | 1 | 0.026 | $NO_3^-$ | 1.68 | 0.027 |
| $Ca^{2+}$ | 6.4 | 0.319 | $F^-$ | 0.2 | 0.011 |
| $Mg^{2+}$ | 4 | 0.329 | $HCO_3^-$ | 43.9 | 0.719 |
| $Fe^{2+,3+}$ | 3.5 | 0.157 | $CO_3^{2-}$ | ND | 0.000 |
| $Mn^{2+}$ | 0.2 | 0.007 | $SO_4^{2-}$ | 15 | 0.156 |
| | | | $PO_4^{3-}$ | ND | 0.000 |
| Total | | 1.048 | Total | | 1.000 |

The ionic balance for the sample is excellent, but the calculated hardness is 40.7 mg/l as calcium carbonate, not 32 mg/l as reported. The water is soft, of low alkalinity and with a significant iron content.

### (c) Summary of raw water quality

Raw water in the Murang'a area is soft of low alkalinity and with a significant iron content. The pH is in the order of 7.2 to 7.5 mg/l and the alkalinity is some 40 mg/l to 70 mg/l as calcium carbonate.

In order to provide long term data for future planning, it is necessary to properly record the raw water quality. It is recommended that a routine testing programme should be immediately put in place by MENR and it is recommended that full chemical and bacteriological tests be done on a regular basis.

## 2.4.4 Treated water quality

No treated water quality data was available for analysis at the time of the site visits to Murang'a. The consultant and DWO have independently abstracted treated water samples from the distribution network which were sent to laboratories in Nairobi for analysis.

The analytical results are incomplete as neither laboratory determined the alkalinity or the individual carbon species, but the results show anions far in excess of cations. The pH of the treated water is 6.65 and the calculated hardness is 18.8 mg/l as calcium carbonate. The water is likely to be aggressive. The detailed results are included as Appendix C2-4

## 2.4.5 Water resource conclusions

In summary, it was found that there is potential for groundwater abstraction from the aquifer underlying Murang'a, but not sufficient to supply the 2010 demand. Three of the five known boreholes have effectively reached the end of their useful life, while the remaining two were decommisioned due to low performance or lack of water. The boreholes to be selected for rehabilitation are Borehole Nos C2868 and C3034, which have the highest probable yields and can be rehabilitated without costly re-drilling. As the expected yields from the aquifer are not sufficient to meet the demand, borehole supply can only be seen as supplementary to surface water supply.

The surface water from the South Mathioya and the Kayahwe rivers is available in quantities that are orders of magnitude greater than the required demand. The raw water quality is reported to be acceptable after measures for removal of sediment prevalent in the wet season. It can be concluded that either the South Mathioya or the Kayahwe river can easily supply the required quantity of water to meet the estimated demand.

# 3 EXISTING WATER SUPPLY CONDITIONS

## 3.1 HISTORY

Originally, water supply for the township was abstracted from the Mathioya river to the north of the town. In order to supply the township, treated water had to be pumped over high static heads.

The Mathioya works was abandoned in the 1950s when a borehole source was implemented. Four boreholes were sunk, but by 1975 one borehole ran dry while another produced negligible yield. At that time the two operational boreholes were producing about 450 $m^3$/day. A fifth borehole was drilled but was a failure as well, due to unknown reasons.

Around 1975 an emergency scheme was implemented using water pumped from the tunnel feed channel at the Mathioya Hydro dam to a treatment works constructed at Kiharu and initially producing 455 $m^3$/day.

In 1980 a new intake was constructed that tapped water from the confluence of the Kayahwe and Kaihungu rivers. Raw water was transmitted over a distance of 135m to a new conventional treatment works with a maximum output of 2,400 $m^3$/day. Treated water is pumped to the Maragi and Kiharu reservoirs.

Once this source was operational the borehole sources were de-commissioned due to the high pumping costs per unit volume of water. It was reported that later even the Mathioya source was not utilised for a while until the rehabilitation of the Hydro dam and source works in 1997 when this source was re-commissioned.

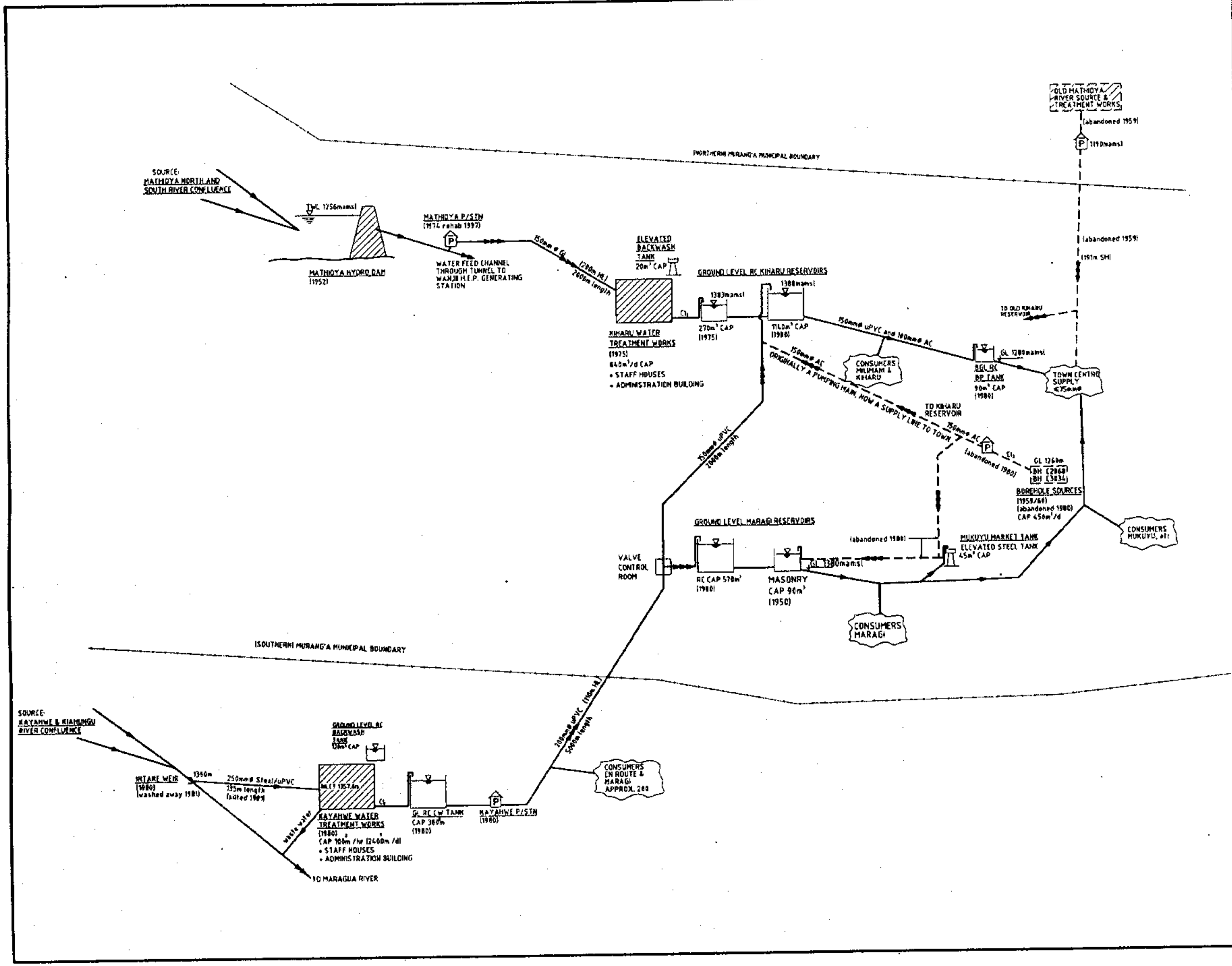
The sources of the current water supply to Murang'a municipality are therefore the Mathioya river and the confluence of the Kayahwe and Kaihungu rivers.

All the water supply and distribution facilities are owned and operated by the Ministry of Environment and Natural Resources (MENR).

A map at the beginning of the report (Figure 1.1 ) shows the key current water supply features within the municipal boundary and the present water supply distribution area.

The salient details of the existing water supply system are shown schematically in Figure 3.1.

The following is a detailed assessment and diagnostic evaluation of the existing water supply system. Chapter 4 recommends a rehabilitation plan in accordance with the terms of reference of this study.




ABBREVIATIONS

- GL = GROUND LEVEL
- BGL = BELOW GROUND LEVEL
- RC = REINFORCED CONCRETE
- BP = BREAK PRESSURE
- CW = CLEAR WATER
- P/STN = PUMPING STATION
- TWL = TOP WATER LEVEL
- CAP = CAPACITY
- GI = GALVANISED IRON
- uPVC = UNPLASTICISED POLYVINYL CHLORIDE
- mm = MILIMETRES
- m = METRES
- m³ = CUBIC METRES
- HL = HEAD LOSS
- SH = STATIC HEAD
- Cl₂ = CHLORINATION FACILITIES
- BH = BOREHOLE
- (1975) = YEAR OF CONSTRUCTION
- mamsl = METRES ABOVE MEAN SEA LEVEL

LEGEND

- GRAVITY FLOW CONDUIT
- PUMPING MAIN
- ABANDONED PIPELINES

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Drawing Title
MURANG'A URBAN WATER SUPPLY
SCHEMATIC LAYOUT OF EXISTING (2000) SITUATION

| Date | Fig. No. |
|---|---|
| DEC 2000 | 3.1 |

## 3.2 THE MATHIOYA / KIHARU WATER SUPPLY SYSTEM

### 3.2.1 Intake from Mathioya hydro-electric power supply dam

Water from the Mathioya hydro-electric power supply dam is passed via a concrete channel 3m deep and 4m wide, through a 5.5km tunnel beneath Murang'a town to the Wanjii Hydropower station which produces and feeds about 7MW into the national power grid. Kengen owns and operates all these facilities.

In agreement with Kengen, a pumping station located along the open concrete transmission channel is operated by the MENR to supply raw water through a 150mm diameter, 2km long GI pipeline to the Kiharu water treatment works. The reported capacity of the pumps (one duty and one standby) is about 840 $m^3$/day with 24hr pumping.

The District Water Office has plans to augment the pumping station capacity by adding a third pump capable of delivering 75 $m^3$/hr at a total head of 175m. They currently lack the funds to implement this plan.

The source works were rehabilitated in 1997 and are in good condition.

### 3.2.2 Kiharu treatment works and treated water transmission
(see Figures 3.2 & 3.3)

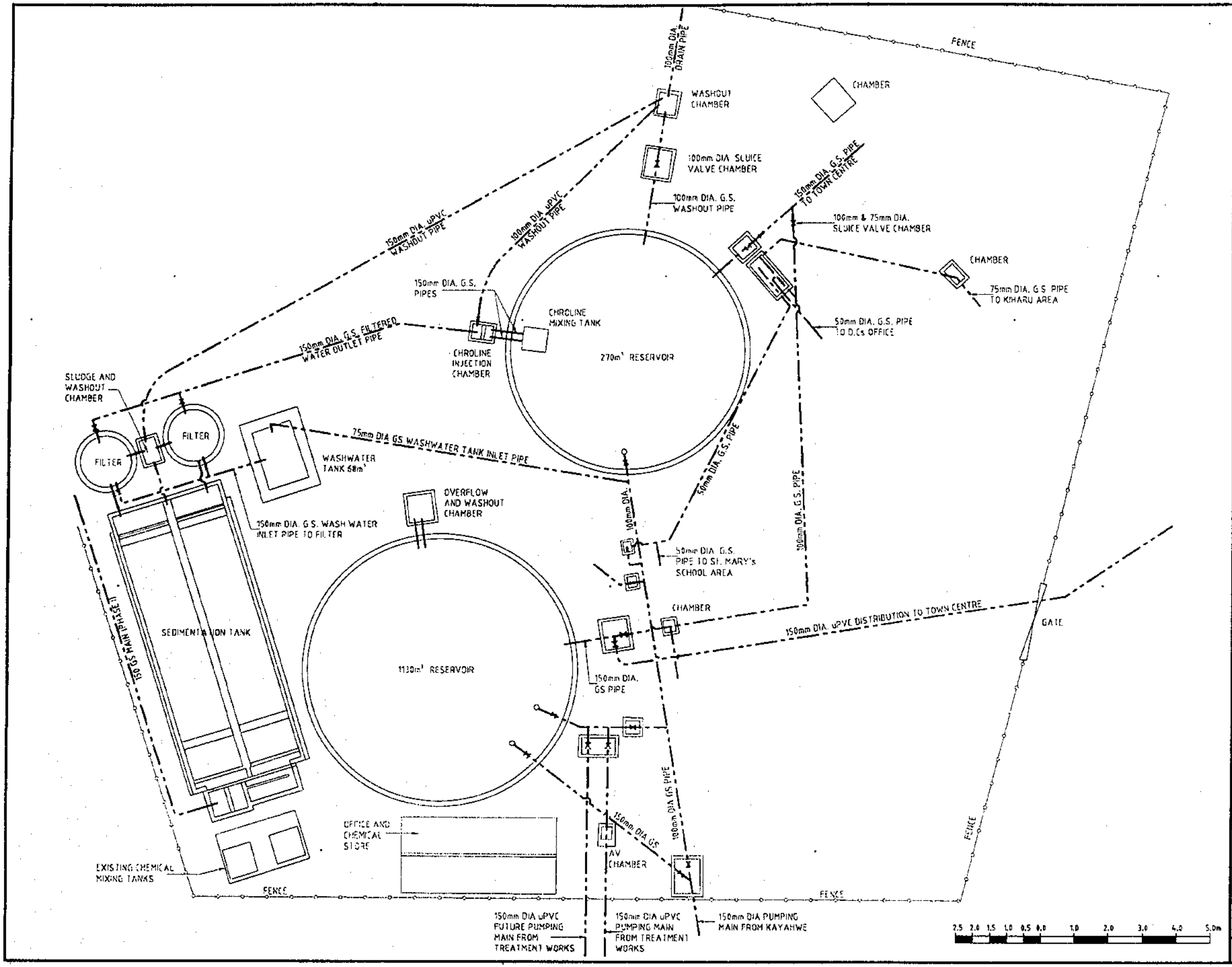
This treatment works receives raw water pumped from Mathioya dam. The, 150mm diameter GI raw water rising main, laid in 1975 from Mathioya dam to Kiharu treatment works, is in good condition. It has a capacity to transmit up to 1,530 $m^3$/d per day at an average velocity of 1m/s

The treatment works is conventional, with reinforced concrete horizontal flow clarifiers and rapid gravity filters. Aluminium sulphate, soda ash and calcium hypochlorite/tropical chloride of lime (chlorine) are used for the treatment.

There are 2 no. horizontal flow clarifiers, each approximately 15.4 m long by 2.8 m wide. At the design surface loading of 1.0 m/hr given in the 1986 MENR Design Manual, the two units have a combined capacity of 2,070 $m^3$/d.

There are 2 no. rapid gravity filters, each 2.7 m in diameter. At the design surface loading of 5.0 m/hr given in the 1986 MENR Design Manual, the two units have a combined capacity of 1,374 $m^3$/d. The filters are washed from an elevated steel backwash tank that requires rehabilitation.

There are 2 no. reinforced concrete clear water tanks at the works, both of which are in an acceptable condition requiring only basic maintenance work: one with a capacity of 1,140 $m^3$ and the other with a capacity of 270 $m^3$. From these, water is transmitted by gravity through parallel 150 mm diameter uPVC and 100 mm diameter AC pipes to the town centre, via a 90 $m^3$ capacity underground reinforced concrete break pressure tank.

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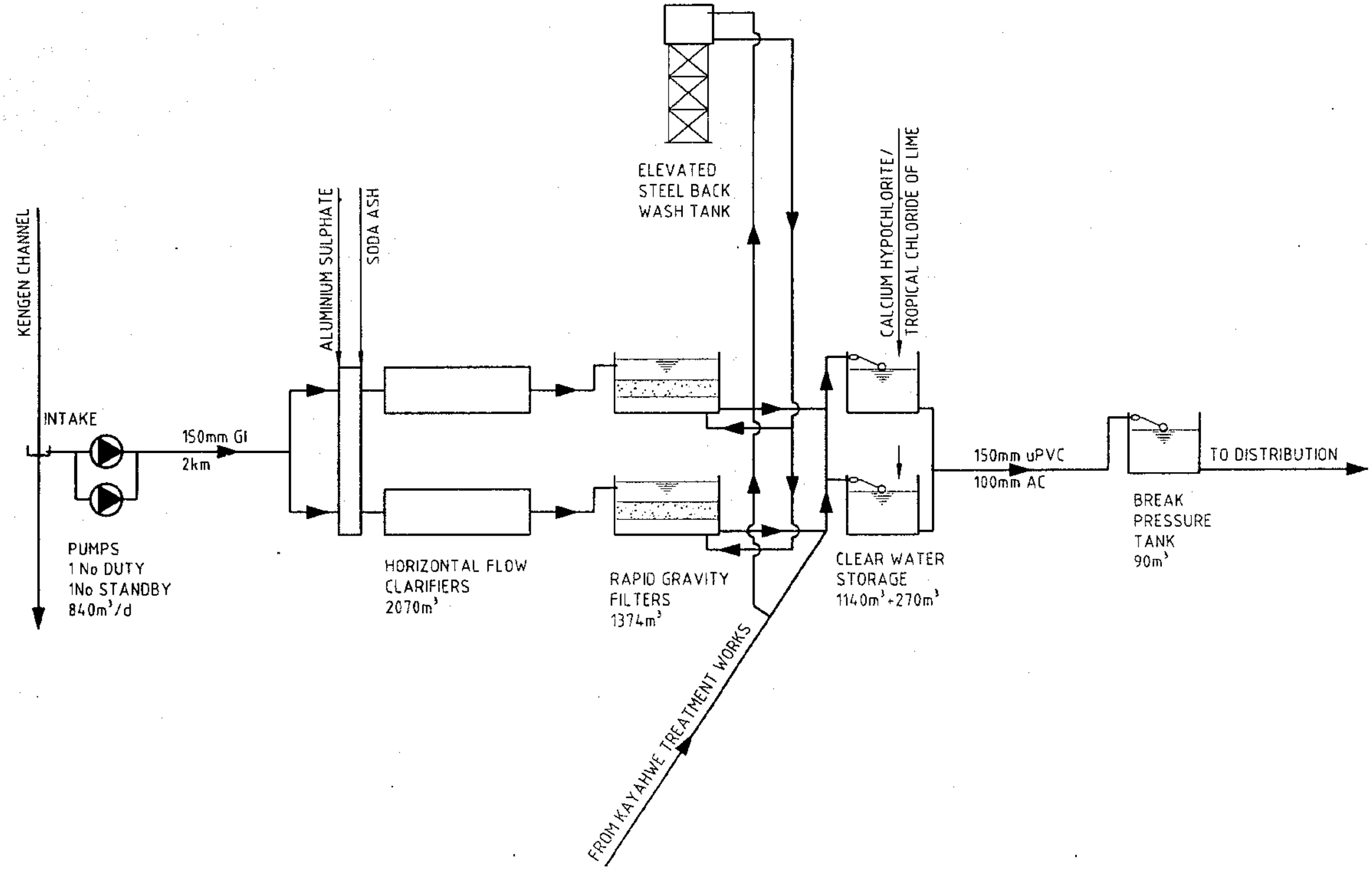
Drawing Title: MURANG'A TOWN WATER SUPPLY KIHARU TREATMENT WORKS & RESERVOIRS

Date: JAN 2001

Fig. No. 3.2

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Drawing Title
MURANGA WATER SUPPLY
KIHARU WATER TREATMENT WORKS PROCESS (SCHEMATIC)

| Date | Fig. No. |
|---|---|
| JAN 2001 | 3.3 |

The capacity of Kiharu water treatment plant is limited by the size of the filters to 1,374 $m^3/d$. However, operations staff report that the capacity of the plant is only 840 $m^3/d$. No bulk water meters are installed and this latter figure is based on the estimated capacity of the raw water pumps.

The works are 25 years old and require rehabilitation of the structural components and a review of the operational functions to enhance the treated water output.

### 3.2.3 Laboratory facilities

Only very basic laboratory tests (jar tests, residual chlorine and pH measurements) can be carried out at the treatment works site. There is therefore an urgent need for laboratory equipment and materials. The treatment works has no laboratory technicians and the duty water operators are in need of training and refresher courses.

## 3.3 THE KAYAHWE WATER SUPPLY SYSTEM

### 3.3.1 Intake from the confluence of Kayahwe and Kaihungu rivers

The intake weir was washed away during the heavy rains experienced in 1981 and the intake works and raw water main were further damaged during the El Niño floods. Currently raw water is led through a 135m long temporary earth channel to the Kayahwe treatment works which has a present production capacity of about 2,400 $m^3$ of treated water per day.

A new intake and raw water main are proposed to be constructed under the El Niño Emergency Project.

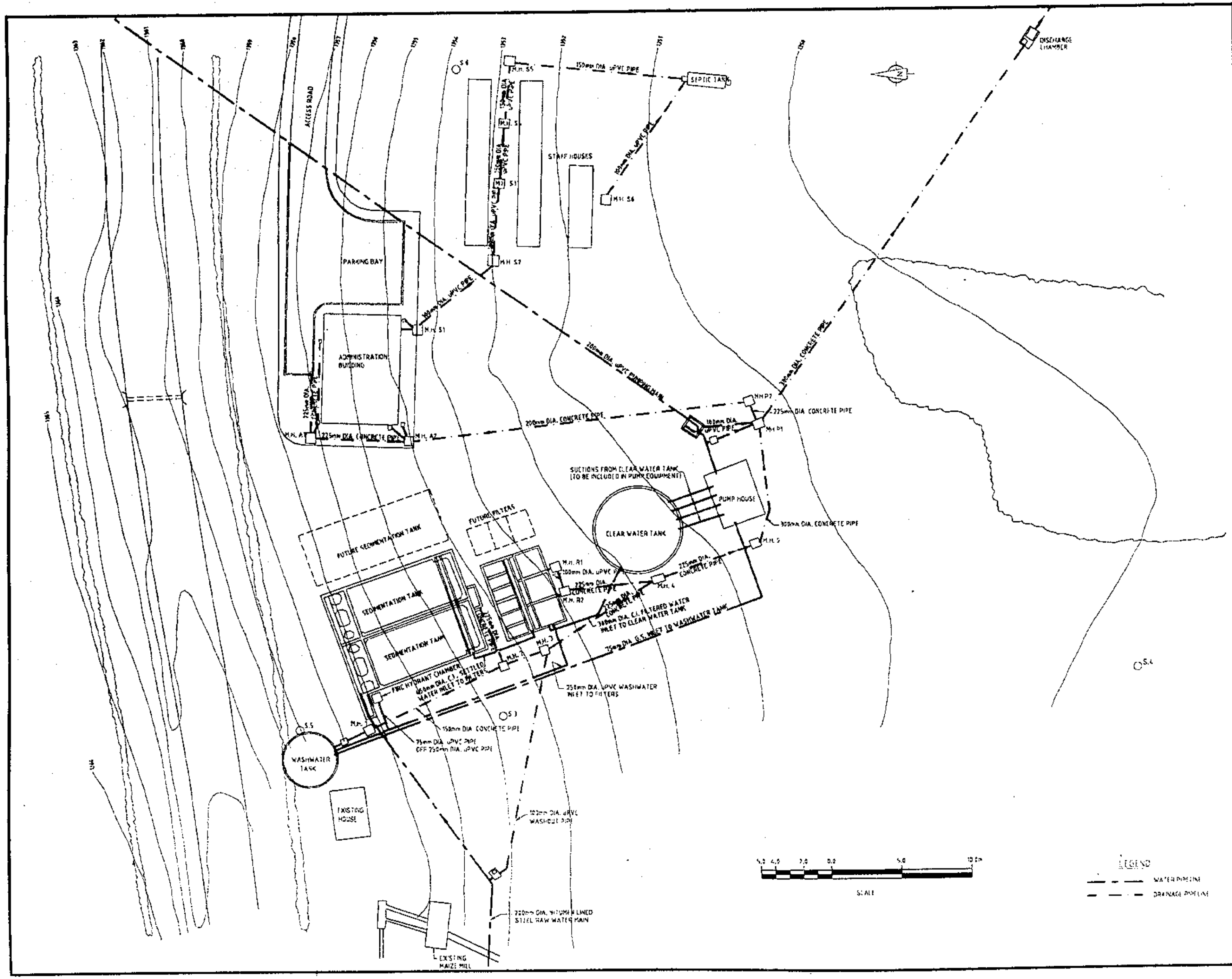
Also under the El Niño Emergency Project, two new treated water pumps rated for 132$m^3/hr$ against a head of 110 m are to be installed.

### 3.3.2 Kayahwe treatment works (see Figures 3.4 & 3.5)

This treatment plant receives raw water under gravity from the Kayahwe and Kaihungu Rivers. The plant is conventional, with horizontal flow clarifiers and rapid gravity filters. The treatment works is about 20 years old and the treatment units require some basic structural rehabilitation.

There are 2 no. reinforced concrete horizontal flow clarifiers, each 16.0 m long by 7.2 m wide. At the design surface loading of 1.0 m/hr given in the 1986 MENR Design Manual, the two units have a combined capacity of 5,530 $m^3/d$.

There are 3 no. reinforced concrete rapid gravity filters, each 3.5 m square. At the design surface loading of 5.0 m/hr given in the 1986 MENR Design Manual, the three units have a combined capacity of 4,410 $m^3/d$.

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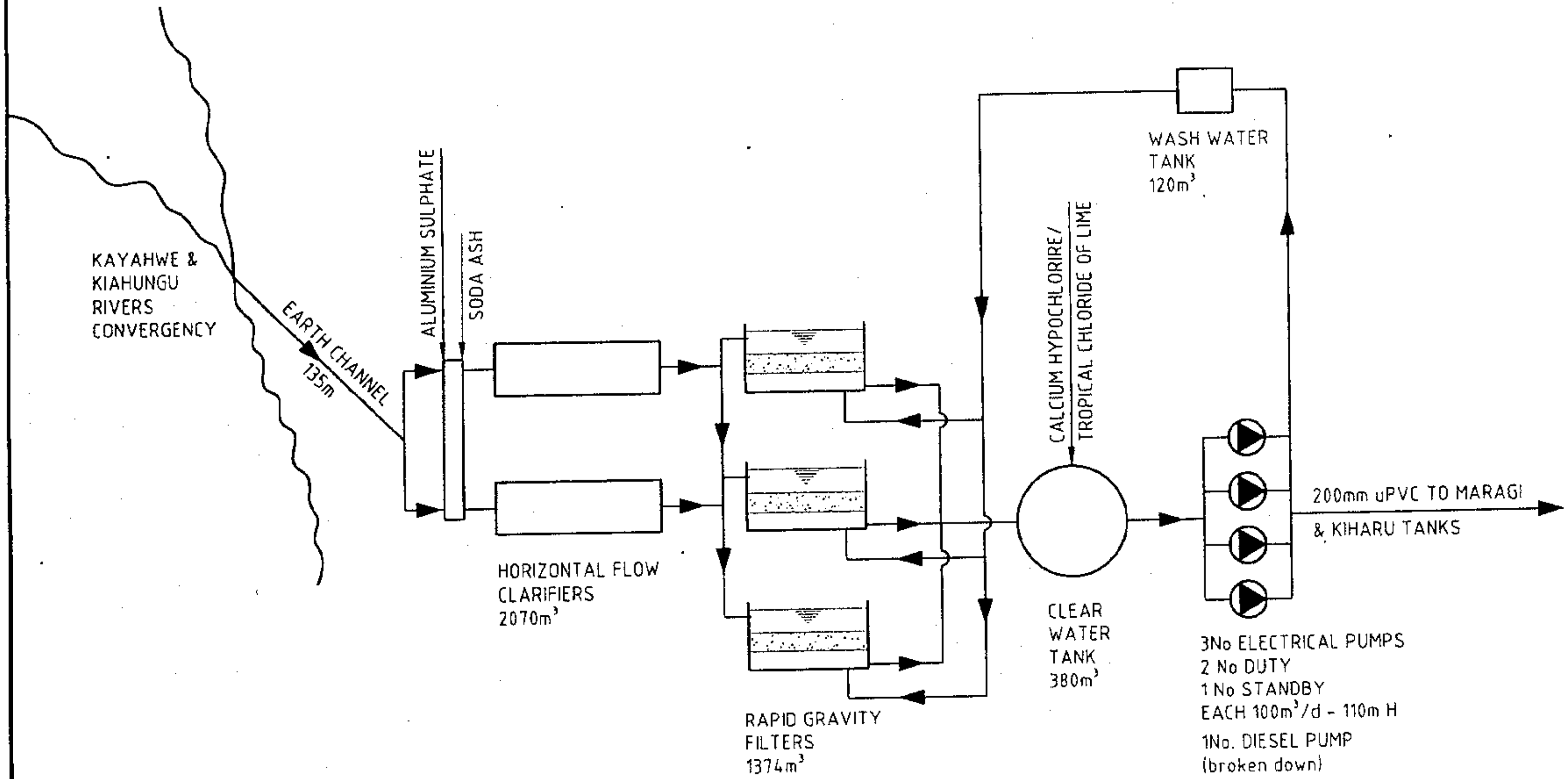
Drawing Title
MURANG'A TOWN WATER SUPPLY KAYAHWE TREATMENT WORKS LAYOUT

| Date | Fig. No. |
| --- | --- |
| JAN. 2001 | 3.4 |

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| Client | JAPAN INTERNATIONAL CO-OPERATION AGENCY |
| | GIBB Eastern Africa — LAWGIBB Group Member |
| Project Title | TEN TOWNS WATER SUPPLY & SANITATION STUDY |
| Drawing Title | MURANGA WATER SUPPLY<br>KAYAHWE WATER TREATMENT WORKS PROCESS (SCHEMATIC) |
| Date: JAN 2001 | Fig. No. 3.5 |

The clear water tank at the treatment works site, into which chlorine solution is fed, is a circular reinforced concrete structure with a top water level of 1,354.78 mAMSL and a capacity of 380 $m^3$. The structure is in an acceptable physical condition.

There is a wash water tank of capacity 120 $m^3$ and a pumping station that transmits the treated water to the Maragi and Kiharu tanks (200mm followed by 150mm diameter uPVC rising mains respectively).

5 no. type F staff house units are provided for the water operators at the site. An administration building also houses the chemical store, the offices and the laboratory. The building works are in a poor state and require urgent rehabilitation.

Stormwater drainage at the site is poor, and in particular at the lower end near the treated water pumpstation.

### 3.3.3 Laboratory facilities

Only very basic laboratory tests (jar tests, residual chlorine and pH measurements) can be carried out at the treatment works site. There is therefore an urgent need for laboratory equipment and materials. The treatment works has no laboratory technicians and the duty water operators are in need of training and refresher courses.

### 3.3.4 Kayahwe clear water pumps and rising main

There are three electrically driven pumps installed in the pump station, each rated for 100 $m^3$/hr against a head of 110 m. There is also a broken diesel driven pump and a diesel generator that can only light the treatment works.

It would appear that the pumps were designed as a two duty plus one standby configuration, with the diesel driven pump to give fifty per cent of supply during periods of power failure. However, the electrically powered pumps are being operated singly, each running for eight hours per day. With this current mode of operation, the pumps can only deliver some 2,400 $m^3$/d. The existing 200mm diameter bulk water meter along the treated water delivery main is out of order and needs to be replaced.

The clear water rising main from the treatment works delivers to two storage sites: one at Maragi and the other the reservoirs at the Kiharu water treatment works. From the clear water pump station to Maragi, the rising main is 4,327 m long, comprising:

- 200 mm uPVC Class C 449 m
- 200 mm uPVC Class D 1930 m
- 200 mm uPVC Class E 1431 m
- 200 mm ductile iron 517 m

At a flow of 100 $m^3$/hr, the calculated friction loss is 17.98 m, giving a mean friction slope of 4.155 m/km. If two pumps were operated in parallel to deliver 200 $m^3$/hr, the friction loss would increase to 68.09 m, or a mean friction slope of 15.74 m/km. The pipeline is clearly designed for a flow of some 100 $m^3$/hr, although the capacities of the treatment units and installed pumps are much higher.

If the reservoirs at Maragi are ever filled, the full pump output will be delivered to the Kiharu storage site through a 150 mm nominal bore uPVC pipe. At present, the Maragi tanks cannot be filled and flows are apportioned between the two storage sites by throttling valves.

The 200 mm diameter uPVC treated water rising main from Kayahwe treatment works follows the E535 road generally to the Maragi tanks (570m3 and 90m3). Recent rehabilitation of the road has left sections of the main exposed or with very little cover, and therefore more prone to pipe bursts. About 8 to 10 bursts occur along this main every month causing major disruptions in service to consumers.

### 3.3.5 Capacities of Kayahwe water treatment plant and transmission system

The capacity of this system is limited to 2,700 $m^3$/d by the size of the rising main and to 2,400 $m^3$/d by the current mode of operating the clear water pumps.

## 3.4 STORAGE

The total water storage capacity of 2,700 $m^3$ is made up of:

- 1,140 $m^3$ and 270 $m^3$ ground level RC tanks at Kiharu.
- 570 $m^3$ RC and 90 $m^3$ masonry ground level tanks at Maragi.
- 380 $m^3$ and 120 $m^3$ ground level RC tanks at Kayahwe treatment works.
- 90 $m^3$ underground reinforced RC break pressure tank in town.
- 45 $m^3$ elevated steel tank at Mukuyu market.

With the exception of the last tank which requires rehabilitation, the other tanks require only basic maintenance and are in an acceptable condition.

Of the total storage capacity of 2,700 $m^3$, only the 1,410 $m^3$ storage at Kiharu and 660 $m^3$ at Maragi can be used for balancing diurnal variations in demand with steady state supply.

Some consumers within Murang'a have their own ground level and elevated storage tanks.

## 3.5 DISTRIBUTION SYSTEM

### 3.5.1 Distribution mains

The existing water distribution network is shown in Figures 3.6 and 3.7. The details of the current reticulation mains are summarised in the table below.

**Table 3.1**
**Details of reticulation mains**

| Type of pipe | *Pipe diameter* *mm* | *Approx. Pipe length Km* |
|---|---|---|
| AC | 150 | 2 |
| uPVC | 150 | 3 |
| AC | 100 | 3 |
| uPVC | 100 | 1 |
| AC | 75 | 3 |
| uPVC | 75 | 2 |
| GI | 75 | 2 |
| GI | 50 | 8 |
| uPVC | 50 | 5 |
| **TOTAL PIPES** | | **29** |

The general condition of the older mains, especially the AC pipes, is reported to be poor and need to be replaced. A more detailed condition survey, however, would be necessary at the feasibility stage to assess the actual state of the distribution mains.

### 3.5.2 Consumer connections

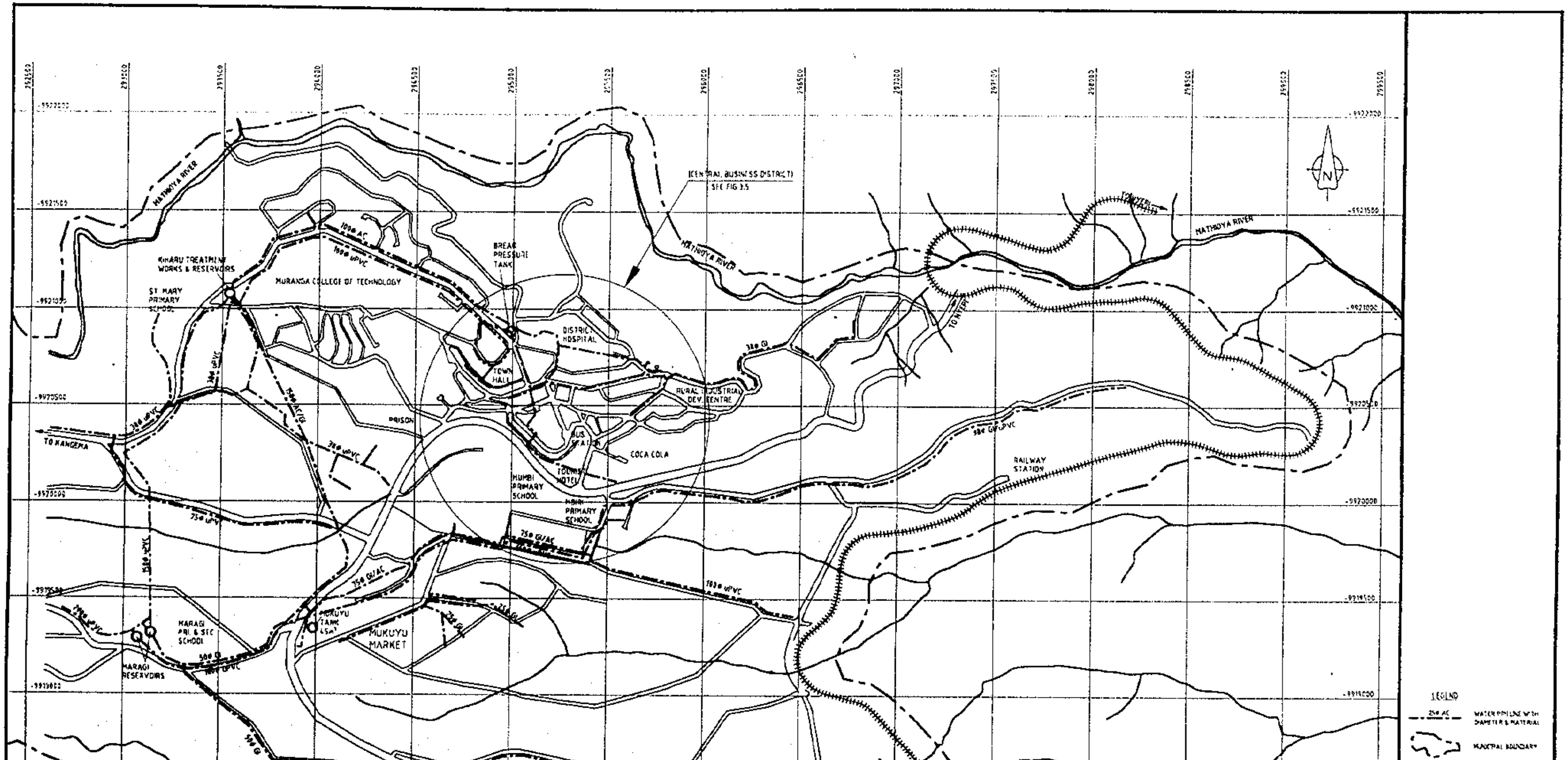
There are currently 2,850 individual connections, all of which are metered. About 1,500 of the meters are not functional according to the operations personnel and the water bills for these are based on estimates and average consumption. The reliability of the 'functioning' meters are not known as there are currently no facilities for meter calibration.

## 3.6 EXISTING O&M

### 3.6.1 Organisation

The MENR staff, headed by the District Water Officer (DWO), are responsible for the operation and maintenance of water supplies in the entire District. A total of 187 staff are employed of which 67 are 'allocated' to Murang'a urban water supply. Of these 18 staff (including the DWO) share their time between their district and the municipal water supply duties.

The organisation chart and details of staffing and organisation are given in Section 8.1.3 of this report.

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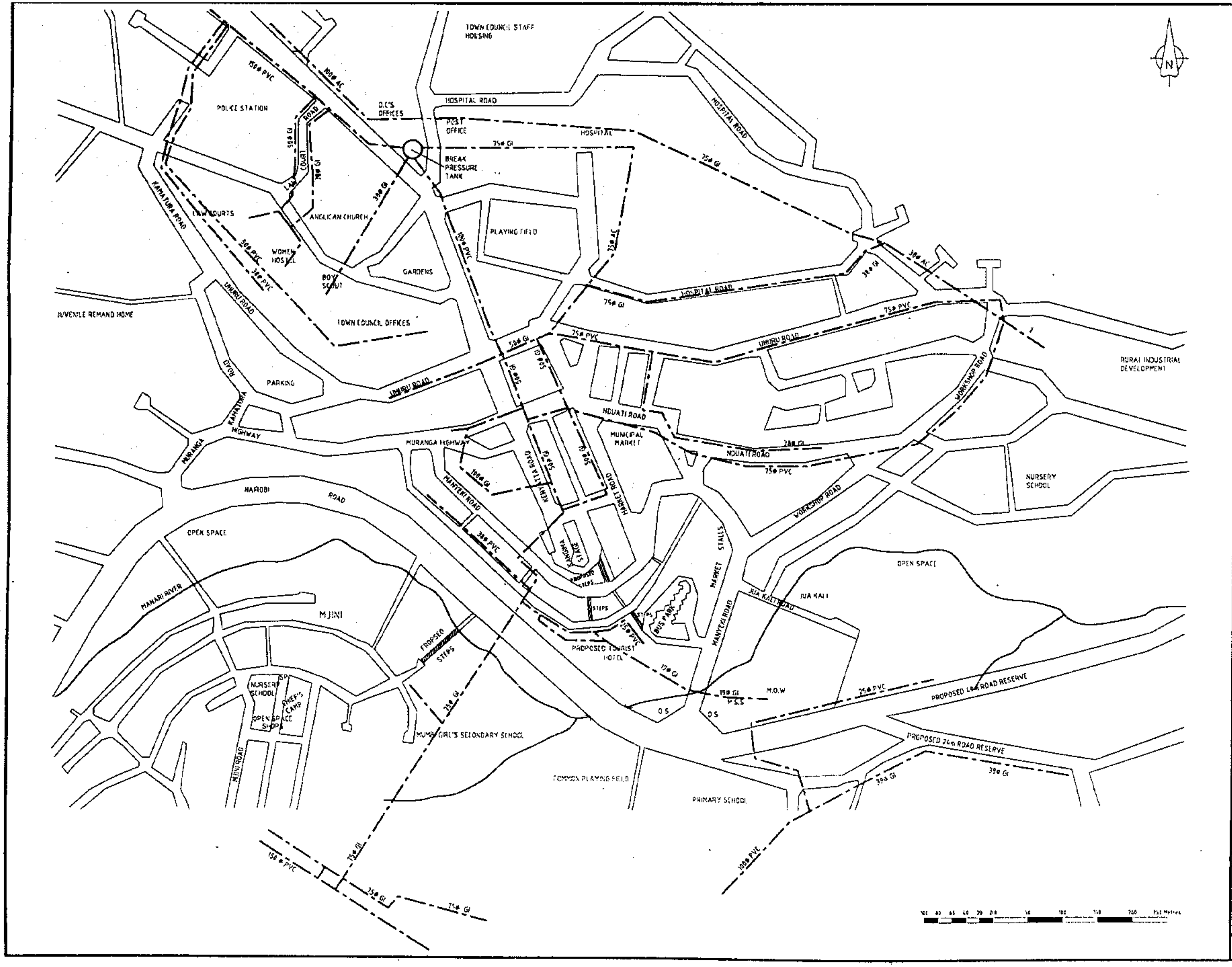
MURANG'A MUNCIPALITY EXISTING WATER DISTRIBUTION NETWORK

| Date | Fig. No. |
|---|---|
| DEC 2000 | 3.6 |

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TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title

MURANG'A CENTRAL BUSINESS DISTRICT EXISTING WATER DISTRIBUTION

| Date | Fig. No. |
|---|---|
| DEC 2000 | 3.7 |

### 3.6.2 System operation

#### (a) Chemical dosing regime

The available operational records for November and December 2000 at the Kayahwe water treatment works show the following chemical doses being applied:

**Table 3.2 Chemical dosing rates**

| Aluminium sulphate (mg/l) | Alkalinity consumed (meq/l) | Soda ash (mg/l) | Alkalinity added (meq/l) |
|---|---|---|---|
| 96 | 0.969 | 24 | 0.453 |
| 168 | 1.696 | 32 | 0.604 |
| 168 | 1.696 | 48 | 0.906 |
| 96 | 0.969 | 48 | 0.906 |
| 80 | 0.808 | 24 | 0.453 |
| 80 | 0.808 | 16 | 0.302 |
| 48 | 0.485 | 24 | 0.453 |
| 112 | 1.131 | 24 | 0.453 |
| 112 | 1.131 | 32 | 0.604 |

Each mole of aluminium sulphate dosed consumes six moles of bicarbonate alkalinity. The reductions in alkalinity due to dosing aluminium sulphate, expressed in milli-equivalents per litre, are given in the second column of the above table. Each mole of soda ash dosed increases alkalinity and total inorganic carbon by one mole. The fourth column of the above table gives the alkalinity, expressed in milli-equivalents per litre, corresponding to the various soda ash doses. For each dosing regime, the alkalinity of the raw water is reduced.

The available operational records show a raw water pH of between 7.0 and 7.2. The available raw water quality analyses show alkalinity of between 40 mg/l and 70 mg/l as calcium carbonate. The calculated inorganic carbon speciation for these two alkalinities at a pH of 7.2 are summarised in Table 3.3 below.

**Table 3.3**
**Inorganic carbon speciation against alkalinity**

| pH | 7.2 | 7.2 |
|---|---|---|
| Alkalinity (mg/l as $CaCO_3$) | 40 | 70 |
| [$H_2CO_3$*] (mol/l) | 1.130E-04 | 1.978E-04 |
| [$HCO_3^-$] (mol/l) | 7.980E-04 | 1.397E-03 |
| [$CO_3^{2-}$] (mol/l) | 5.921E-07 | 1.036E-06 |
| $C_T$ (mol/l) | 9.116E-04 | 1.595E-03 |

The available operational records show that the most frequent dosing regimes during November and December 2000 were either 96 mg/l or 112 mg/l of aluminium sulphate with 24 mg/l of soda ash. The calculated coagulation pH and inorganic carbon speciation for these dosing rates are summarised below for alkalinities of 40 mg/l and 70 mg/l.

**Table 3.4**
**Coagulation pH and inorganic carbon speciation against alkalinity**

| | | | | |
|---|---|---|---|---|
| Raw water pH | 7.2 | 7.2 | 7.2 | 7.2 |
| Raw water alkalinity (mg/l as $CaCO_3$) | 40 | 70 | 40 | 70 |
| Raw water alkalinity (meq/l) | 0.799 | 1.399 | 0.799 | 1.399 |
| Raw water inorganic carbon (mol/l) | 9.116E-04 | 1.595E-03 | 9.116E-04 | 1.595E-03 |
| Aluminium sulphate dose (mg/l) | 96 | 96 | 112 | 112 |
| Soda ash dose (mg/l) | 24 | 24 | 24 | 24 |
| Final alkalinity (meq/l) | 0.283 | 0.883 | 0.122 | 0.721 |
| Final inorganic carbon (mol/l) | 1.138E-03 | 1.822E-03 | 1.138E-03 | 1.822E-03 |
| Coagulation pH | 5.87 | 6.32 | 5.44 | 6.17 |
| Dissolved carbon dioxide (mg/l) | 37.6 | 41.3 | 44.6 | 48.4 |

The coagulation pH is lower than the permitted value of 6.5 given in the 1986 Design Manual. At a hardness of approximately 50 mg/l, the treated water is also aggressive towards concrete and steel. The water should be stabilised by dosing lime or increased quantities of soda ash.

The reported dosing rate for chlorine varies between 1.5 mg/l and 2.0 mg/l, with a reported residual greater than 0.5 mg/l after sixty minutes. This is sufficient for effective disinfection.

**(b) Distribution system**

Operations staff maintain a daily regimen of water rationing to the different service areas in order to ensure that their customers have an equitable share of the limited supply. This is carried out by operating sectional valves within the distribution system. The lack of sufficient sectional valves and bulk zonal meters make the exercise of monitoring physical losses in the distribution network very difficult.

## 3.7 LEVELS OF SERVICE

### 3.7.1 Population served

According to the District Water Officer, there are currently about 2,850 active connections in Murang'a,. The 1999 population and housing census gave the average household size as 5.9, so, in theory only about 16,815 people benefit from the 2,850 piped water connections in the domestic consumer category. Adding another 3,000 consumers under the institutional category (see section 4.1.2 of this report) results in a total of some 19,815 people being directly served by the Murang'a urban water supply. There are no registered water kiosks in Murang'a. The current service area population has been estimated at 24,460, thus indicating that over 80% of the service area population is served.

The results of the 1999 census gave the town's population as 58,007 (projected to 60,000 in 2000), so approximately 33% of the total municipal population is currently provided with piped water.

On an area basis almost 40% of the municipal area is covered by a potable water supply system.

### 3.7.2 Per capita supplies

The current total water production capacity is about 3,240 $m^3/d$. Assuming that actual water supplied averages 85% of production capacity (i.e. 2,754 $m^3/d$), the per capita consumption for the estimated 'connected' population of 19,815 is equivalent to 139 lcd for or a global average of 47 lcd for the total Murang'a population of 58,007 (1999 population). These figures suppose no unaccounted-for water.

Assuming that about half the production volume comprises unaccounted-for water in Murang'a then the per capita figures above work out to 70 and 24 lcd respectively.

## 3.8 ON-GOING OR PLANNED EL NIÑO WORKS

Some works are planned to be carried out in Murang'a under the ongoing El Niño Emergency Project (ENEP) funded by AfD. These include:

at **KAYAHWE**:

- New intake and chamber,
- 240 m of raw water main.
- Mechanical flocculators.
- GRP mixing tank linings.
- Filter media and under drains.
- Compressors for air blowing.
- New pumps: 132m3/hr at 110m head.
- 90 HP diesel engine.
- Surge vessel for water hammer protection.

at **MATHIOYA:**

- New pump: 70m3/hr at 140m head.

**Others:**

- 12.5 km of reticulation pipework.
- 15 no. valve chambers.

Details of these works with their estimated costs are given in Appendix C2-2.

The results of the 1999 census gave the town's population as 58,007 (projected to 60,000 in 2000), so approximately 33% of the total municipal population is currently provided with piped water. On an area basis almost 40% of the municipal area is covered by a potable water supply system.

### 3.7.2 Per capita supplies

The current total water production capacity is about 3,240 $m^3/d$. Assuming that actual water supplied averages 85% of production capacity (i.e. 2,754 $m^3/d$), the per capita consumption for the estimated 'connected' population of 19,815 is equivalent to 139 lcd for or a global average of 47 lcd for the total Murang'a population of 58,007 (1999 population). These figures suppose no unaccounted-for water.

Assuming that about half the production volume comprises unaccounted-for water in Murang'a then the per capita figures above work out to 70 and 24 lcd respectively.

## 3.8 ON-GOING OR PLANNED EL NIÑO WORKS

Some works are planned to be carried out in Murang'a under the ongoing El Niño Emergency Project (ENEP) funded by AfD. These include:

at **KAYAHWE**:

- New intake and chamber,
- 240 m of raw water main.
- Mechanical flocculators.
- GRP mixing tank linings.
- Filter media and under drains.
- Compressors for air blowing.
- New pumps: 132m3/hr at 110m head.
- 90 HP diesel engine.
- Surge vessel for water hammer protection.

at **MATHIOYA:**

- New pump: 70m3/hr at 140m head.

**Others:**

- 12.5 km of reticulation pipework.
- 15 no. valve chambers.

Details of these works with their estimated costs are given in Appendix C2-2.

## 3.9 OTHER WORKS AND PROJECTS

Apart from the proposed El Nino project, there are currently no other known major water supply projects planned for Murang'a .

# 4 PROPOSED STRATEGY FOR WATER SUPPLY REHABILITATION

## 4.1 DEMAND/CONSUMPTION PROJECTIONS TO 2010

### 4.1.1 Population Projections to 2010

The population of Murang'a municipality according to the 1999 census is 58,007.

Yearly population projections to 2010 (rounded to the nearest '00) are shown in Table 4.1.

**Table 4.1**
**Population projections to 2010**

| Year | Population |
|---|---|
| 1999 | 58,007 |
| 2000 | 60,000 |
| 2001 | 62,100 |
| 2002 | 64,300 |
| 2003 | 66,600 |
| 2004 | 68,900 |
| 2005 | 71,300 |
| 2006 | 73,800 |
| 2007 | 76,400 |
| 2008 | 79,100 |
| 2009 | 81,800 |
| 2010 | 84,700 |

### 4.1.2 Water Demand Projection

Demand rates are taken from the 1986 MENR Design Manual.

Table 4.2 shows estimated daily demand from 2000 to 2010 compared with the current capacities of the various system components.

Demand has been calculated using the following percentages for different level income brackets of consumers, ascertained from data collected in the field. Reference is made to Table 2.8 of this report which shows the categorisation of the population by income.

| **Category** | **Proportion** | **Population (1999)** | **rate (lcd)** | **Demand ($m^3/d$)** |
|---|---|---|---|---|
| High income | 13% | 7,541 | 250 | 1,885 |
| Middle income | 44% | 25,523 | 150 | 3,828 |
| Low income | 43% | 24,943 | 75 | 1,871 |
| **Total domestic water demand** | | | | **7,584** |

**Table 4.2 Murang'a - Projected Water Demands and Current System Capacities**

| Year | Population | Income brackets | | Population | Demand rate | Domestic water demand | Institutional demand | Total demand | Production capacity | Transmission capacity | Storage capacity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Status | % | | lcd | $m^3$/day | m3/d | $m^3$/day | $m^3$/day | m3/d | m3 |
| 1999 | 58,007 | High | 13 | 7,541 | 250 | 1,885 | | | | | |
| | | Middle | 44 | 25,523 | 150 | 3,826 | 500 | **8,084** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 24,943 | 75 | 1,871 | | | | | |
| 2000 | 60,000 | High | 13 | 7,800 | 250 | 1,950 | | | | | |
| | | Middle | 44 | 26,400 | 150 | 3,960 | 500 | **8,345** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 25,800 | 75 | 1,935 | | | | | |
| 2001 | 62,100 | High | 13 | 8,073 | 250 | 2,018 | | | | | |
| | | Middle | 44 | 27,324 | 150 | 4,099 | 500 | **8,620** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 26,703 | 75 | 2,003 | | | | | |
| 2002 | 64,300 | High | 13 | 8,359 | 250 | 2,090 | | | | | |
| | | Middle | 44 | 28,292 | 150 | 4,244 | 500 | **8,907** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 27,649 | 75 | 2,074 | | | | | |
| 2003 | 66,600 | High | 13 | 8,658 | 250 | 2,165 | | | | | |
| | | Middle | 44 | 29,304 | 150 | 4,396 | 500 | **9,208** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 28,638 | 75 | 2,148 | | | | | |
| 2004 | 68,900 | High | 13 | 8,957 | 250 | 2,239 | | | | | |
| | | Middle | 44 | 30,316 | 150 | 4,547 | 500 | **9,509** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 29,627 | 75 | 2,222 | | | | | |
| 2005 | 71,300 | High | 13 | 9,269 | 250 | 2,317 | | | | | |
| | | Middle | 44 | 31,372 | 150 | 4,706 | 500 | **9,822** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 30,659 | 75 | 2,299 | | | | | |
| 2006 | 73,800 | High | 13 | 9,594 | 250 | 2,399 | | | | | |
| | | Middle | 44 | 32,472 | 150 | 4,871 | 500 | **10,149** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 31,734 | 75 | 2,380 | | | | | |
| 2007 | 76,400 | High | 13 | 9,932 | 250 | 2,483 | | | | | |
| | | Middle | 44 | 33,616 | 150 | 5,042 | 500 | **10,489** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 32,852 | 75 | 2,464 | | | | | |
| 2008 | 79,100 | High | 13 | 10,283 | 250 | 2,571 | | | | | |
| | | Middle | 44 | 34,804 | 150 | 5,221 | 500 | **10,842** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 34,013 | 75 | 2,551 | | | | | |
| 2009 | 81,800 | High | 13 | 10,634 | 250 | 2,659 | | | | | |
| | | Middle | 44 | 35,992 | 150 | 5,399 | 500 | **11,195** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 35,174 | 75 | 2,638 | | | | | |
| 2010 | 84,700 | High | 13 | 11,011 | 250 | 2,753 | | | | | |
| | | Middle | 44 | 37,268 | 150 | 5,590 | 500 | **11,575** | 3,240 | 4,910 | 2,700 |
| | | Low | 43 | 36,421 | 75 | 2,732 | | | | | |

The following institutional demands have been included in addition:

| | | |
|---|---|---|
| Hospital (500 beds) | 500l/500 beds | 250 $m^3/d$ |
| Prison | 50l/300 | 15 $m^3/d$ |
| Juvenile remand home | 50l/300 | 15 $m^3/d$ |
| College of Technology | 50l/1,000 | 50 $m^3/d$ |
| Teacher's College | 50l/500 | 25 $m^3/d$ |
| Boarding school | 50l/400 | 20 $m^3/d$ |
| Private clinics | 5,000l/25 | 125 $m^3/d$ |
| **Total Institutional water demand** | | **500 $m^3/d$** |
| ***Overall total water demand (1999)*** | | ***8,084 $m^3/d$*** |

There are no major industries in Murang'a, and commercial activity is of a level such that domestic water usage rates can be applied.

## 4.2 PRELIMINARY DESIGN OF RECOMMENDED REHABILITATION OPTION

The principal design criteria for water engineering design is presented in Appendix C2-3.

The following comments summarise the main focus of the proposed rehabilitation plan for Murang'a water supply.

Table 4.3 gives the summary schedule of the proposed rehabilitation works.

### 4.2.1 Rehabilitation of existing boreholes

The two boreholes within the district water office compound (Nos C2868 and C3034) are to be rehabilitated in order to augment water production and to provide a standby source in the future.

### 4.2.2 Laboratory facilities

Murang'a water supply lacks the necessary laboratory equipment for determinations of water quality parameters. Procurement of the necessary laboratory equipment and facilities should be arranged to ensure proper monitoring of water quality.

### 4.2.3 Matching capacities of the treatment works & clear water transmission system

The current abstraction, treatment and transmission rates of flow are about 39% of the theoretical unrestricted water demand. Storage capacity is only about 32% of the unrestricted water demand.

The capacity of the filters at Kayahwe treatment plant is 4,410 $m^3/d$ and the installed pump capacity is some 4,800 $m^3/d$ with two pumps operating in parallel. The capacity of the transmission main from Kayahwe is only some

**Table 4.3**
**MURANG'A WATER SUPPLY**
**SUMMARY SCHEDULE OF PROPOSED REHABILITATION WORKS**

| Item | Unit | Ref | Component | Condition ** | Proposed action | Comments | Implementation |
|---|---|---|---|---|---|---|---|
| 1. | Intake works and raw water pumping | 1.1 | Intake and chambers | washed away by floods | New | Washed away | under ENEP |
| | | 1.2 | Raw water main | washed away by floods | New | 240m of 250mm diameter | under ENEP |
| | | 1.3 | Raw water pump | undersized | Augment | Pump at 70m³/hr at 140m head at Mathioya | under ENEP |
| | | 1.4 | Pumphouse | undersized | construct extension to pumphouse | The pumpstation is undersized for the additional pump | Current project |
| 2. | Treatment works and boreholes | 2.1 | Mechanical flocculators | not operational | New | | under ENEP |
| | | 2.2 | Mixing tank | not operational | New | Includes tank linings and dosers | under ENEP |
| | | 2.3 | Filters | operational problems | New | Includes filter media and underdrains | under ENEP |
| | | 2.4 | Boreholes C2868 & C3034 | not in use since 1980 | Rehabilitate boreholes | Boreholes are old but can be rehabilitated | Current project |
| | | 2.5 | Lab | delapidated | Procure and equip | Equipment and materials | Current project |
| | | 2.6 | Buildings | poorly maintained | Rehabilitate | | Current project |
| | | 2.7 | Staff houses and facilities | poorly maintained | Rehabilitate | | Current project |
| | | 2.8 | Treatment works structures | poorly maintained | Rehabilitate | | Current project |
| | | 2.9 | Backwash tank | old | Rehabilitate | | Current project |
| 3. | Water pumps and mains | 3.1 | Compressors | not operational | New | Compressors for air blowing | under ENEP |
| | | 3.2 | Pump | old | New | Pumps at 132m³/hr at 110m head | under ENEP |
| | | 3.3 | Diesel engine | not operational | New | 90HP standby engine | under ENEP |
| | | 3.4 | Surge vessel | not operational | New | For water hammer protection | under ENEP |
| | | 3.5 | Pump house siteworks | inadequate design | re design | Provide flood control & earthworks | Current project |
| | | 3.6 | Rising main | frequent bursts & undersized | New | 4.8km of 250mm diameter | Current project |
| | | 3.7 | Generator set | below capacity | Replace & refurbish existing | | Current project |
| | | 3.8 | Bulk water meters | not operational | Replace | 3 nr bulk water meters | Current project |
| 4. | Distribution system | 4.1 | Valve chambers | damaged | New | 15 nr valve chambers | under ENEP |
| | | 4.2 | Reticulation pipework | old | Replace | 7km of 75mm diameter | under ENEP |
| | | 4.3 | Reticulation pipework | old | Replace and augment | 14.5km pipework | Current project |
| | | 4.4 | Reservoirs | old<br>under capacity | Rehabilitate<br>New | Elevated tank at Makuyu market<br>1,500 m3 reservoir at Maragi site | Current project<br>Current project |
| | | 4.5 | Zonal bulk meters | do not exist | New | 12 nr 150 & 100mm diameter meters proposed | Current project |
| | | 4.6 | Consumer meters | not operational | New | 1,500 new meters | Current project |
| | | 4.7 | Meter test bench | not available | New | For consumer meter calibration | Current project |
| | | 4.8 | Toolkits | not available | New | For distribution network and pump station maintenance | Current project |
| 5 | Logistical facilities & equipment | 5.1 | New office and laboratory | n/a | New | For operation and maintanance | Current project |
| | | 5.2 | Transportation incl. Vehicles motor cycles, bicycles | n/a | New | Existing transport is inadequate and in poor condition | Current project |
| | | 5.3 | Computer hardware and software | n/a | New | To enable timely billing and record keeping | Current project |
| | | 5.4 | Office equipment & furniture | n/a | New | For operation and maintanance | Current project |

[shaded box] = UNDER EL NINO EMERGENCY PROJECT (ENEP)

** = for further details see text

2,700 $m^3$/d, and the main is reportedly subject to frequent bursts. The main should be replaced preferably with a 250mm diameter steel pipe.

### 4.2.4 Water pumps

At the Kayahwe water treatment works (despite the reliability of power supply so far in Murang'a) provision should be made to purchase a new diesel pump and to rehabilitate the existing diesel pump and motor lying unused and put them into service as standby sets for the pumping system. In addition a new generator set should be procured for backup power generation at the Kayahwe water treatment works.

### 4.2.5 Metering of treated water production and bulk meters

New bulk water meters are proposed at the two treatment works and at the Maragi reservoir site in order to monitor flow rates effectively. The current 200mm diameter bulk treated water meter at Kayahwe treatment works is not working and needs to be replaced. Further zonal bulk water meters are proposed within the reticulation system in order to monitor losses.

### 4.2.6 Water storage

In order to cater for security of water supply, it is proposed that a 1,500 $m^3$ capacity ground level RC reservoir be constructed at the Maragi site. This will give a total of 4,210 $m^3$ of storage within the system (almost 75% of the current treatment works design capacity).

### 4.2.7 Distribution pipework

The network has been laid over several decades and is in various states of disrepair. It is recommended that certain stock sizes of pipe mains (38mm to 150mm) be maintained for repair work. It would be advisable to replace sections of mains that are more prone to bursts and leaks with uPVC class D pipes or GI pipes for the smaller diameter mains.

### 4.2.8 Consumer meters

About 1,500 individual consumer meters are out of order and need replacement. The ministry staff maintain a stock of consumer meters and monitor the quality and serviceability of the consumer's meter. A meter test bench facility is to be established in order to calibrate consumer meters.

## 4.3 COSTING OF RECOMMENDED REHABILITATION PLAN

An indicative budget for rehabilitating the existing Murang'a water supply system is Kshs 290,296,800 (exclusive of works planned under the on-going El Nino Emergency Project (ENEP) as per the following breakdown in Table 4.4.

## Table 4.4
## Cost estimate of rehabilitation works for Murang'a water supply

| Description | Unit | Quantity | Rate | Current Study Amount (KShs) | ENEP Rehab Amount (KShs) |
|---|---|---|---|---|---|
| **Intake works, raw water pumping and mains** | | | | | |
| Kiharu pumpstation: supply and install a new electric raw water pump set ( 75cu.m/hr at 175m head) with associated fittings | nr | 1 | 1,200,000 | 1,200,000 | |
| Allow for addition and modification to the existing control panel | Sum | | | 400,000 | |
| Allow for extensions to the existing pump house | Sum | | | 500,000 | |
| ***subtotal*** | | | | *2,100,000* | |
| ENEP Construction of intake works and raw water main | | | | | 5,308,250 |
| | | | | | |
| **Water treatment works, treated water pumping and mains** | | | | | |
| Rehabilitate boreholes C2868 and C3034 at District water office | Sum | | | 3,000,000 | |
| Kayahwe: flood control and earth works outside pump house | Sum | | | 1,000,000 | |
| Replacement and realignment of rising main with 250 mm nominal diameter steel pipe | m | 4,800 | 15,000 | 72,000,000 | |
| Kayahwe: generator set replacement and refurbish existing set | Sum | | | 3,000,000 | |
| Bulk water meters, 200mm diameter | nr | 3 | 500,000 | 1,500,000 | |
| Kayahwe and Kiharu: laboratory equipment and materials | Sum | | | 4,500,000 | |
| Kayahwe: buildings rehabilitation | Sum | | | 1,000,000 | |
| Kayahwe: staff houses, water & sanitation facilities rehabilitation | Sum | | | 500,000 | |
| Kiharu: treatment works rehabilitation | Sum | | | 4,000,000 | |
| Kiharu: rehabilitation of elevated backwash tank | Sum | | | 1,000,000 | |
| ***subtotal*** | | | | *91,500,000* | |
| ENEP Rehabilitation of tanks, M&E for pump sets, civil works and part rising main | | | | | 10,435,000 |
| | | | | | |
| **Distribution system** | | | | | |
| New 1,500 m3 reservoir at Maragi, including ancillaries | Sum | | | 8,000,000 | |
| Rehabilitate Mukuyu market elevated tank | Sum | | | 2,000,000 | |
| 150 mm nominal diameter uPVC pipes | m | 3,000 | 3,000 | 9,000,000 | |
| 100 mm nominal diameter uPVC pipes | m | 11,500 | 2,000 | 23,000,000 | |
| New zonal bulk meters (100/150mm diameter) | nr | 12 | 250,000 | 3,000,000 | |
| New consumer meters (replacement and stock) | nr | 1,500 | 6,000 | 9,000,000 | |
| Meter test bench | nr | 1 | 3,500,000 | 3,500,000 | |
| O & M tool kits and equipment | nr | 3 | 250,000 | 750,000 | |
| ***subtotal*** | | | | *58,250,000* | |
| ENEP Rising and distribution mains | | | | | 35,421,000 |
| | | | | | |
| **Logistical facilities and equipment** | | | | | |
| New office and laboratory facilities at MENR District water office and treatment works sites | $m^2$ | 400 | 25,000 | 10,000,000 | |
| 4WD twin-cab pickups | nr | 2 | 2,500,000 | 5,000,000 | |
| 4WD standard vehicles | nr | 2 | 1,500,000 | 3,000,000 | |
| Motorcycles for line patrols, disconnections, meter readings, etc. | nr | 6 | 250,000 | 1,500,000 | |
| Multi-geared mountain bikes | nr | 2 | 25,000 | 50,000 | |
| Desk top computer setups | nr | 6 | 200,000 | 1,200,000 | |
| 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*** | | | | *23,450,000* | |
| | | | | | |
| **Overall Total** | | | | **175,300,000** | **51,164,250** |
| Add 20% P&G | | | | 35,060,000 | |
| Sub-total | | | | 210,360,000 | |
| Add 15% Contingencies | | | | 31,554,000 | |
| Sub-total | | | | 241,914,000 | |
| Add 20% consultancy design fees | | | | 48,382,800 | |
| **GRAND TOTAL** | | | | **290,296,800** | |

## 4.4 EXPANSION OF WATER SUPPLY FACILITIES

### 4.4.1 General

The tentative proposed expansion plan includes expansion of the existing water treatment works, provision of additional storage and expansion of the distribution network all to a design planning horizon of 2010.

### 4.4.2 Water treatment works

Kiharu treatment works has a potential treatment capacity of 2,070m$^3$/day based on the treatment capacity of the existing horizontal flow sedimentation tanks. The works can realise its maximum effectiveness by increasing filtration and high lift pumping capacities.

Similarly, Kayahwe treatment works has a potential treatment capacity of 5,530m$^3$/day, again based on the treatment capacity of the horizontal flow sedimentation tanks. Expansion of filtration and high lift pumping facilities will maximise output.

The theoretical maximum production of the two expanded works is 7,600m$^3$/day, which is less than the calculated water demand for 2010 of 11,575m$^3$/day.

### 4.4.3 Storage

Existing effective storage is 2,700m$^3$.

To satisfy the conditions of Section 11.3.2 of the 1986 MENR Design Manual for a pumped water supply, 18 hours storage is required.

The 2010 demand is 11,575m$^3$/day and therefore storage is of the order of 8,680m$^3$.

An additional 4,470m$^3$, say 4,500m$^3$ is required.

### 4.4.4 Distribution

The existing Murang'a municipal area for which MENR has responsibility for water supply is approximately 25 km$^2$.

The existing water supply service area is approximately 10km$^2$ and contains 29km of various diameter pipes (DN50 and larger). On a pro-rata basis, a further 45km is required to service the entire municipal area.

However, the existing reticulation network does not cover 100% of the service area.

If an assumption is made that each $km^2$ of the service area contains 10km of distribution pipes > or = DN50, then 150km of additional pipelines are required to completely service the municipal area.

The projected population in 2010 is 84,700, which, if spread uniformly in the $25km^2$ municipal area results in an average population density of approximately 34c/ha.

It is assumed that the length of new distribution pipes lies between 45km and 150km, and for the purpose of initial planning estimates is taken to be 75km.

### 4.4.5 Costs of expansion works

The cost details are presented in Table 4.5.

## 4.5 O&M COSTS AFTER REHABILITATION

### 4.5.1 Capital costs

| | | |
|---|---|---|
| Management consultancy, 2 years | 25,000,000 | |
| Purchase of vehicles, office equipment | 10,000,000 | **35,000,000** |

### 4.5.2 Recurrent costs (monthly)

| | | |
|---|---|---|
| Monthly salaries | 1,500,000 | |
| Electricity charges | 500,000 | |
| Chemicals costs | 250,000 | |
| Vehicle running costs and maintenance | 150,000 | |
| Office running costs | 80,000 | |
| Housing maintenance | 80,000 | **2,560,000** |

### 4.5.3 Spare parts (for 1 year)

| | | | |
|---|---|---|---|
| Pipes | | 1,000,000 | |
| Fittings | | 200,000 | |
| Valves | | 250,000 | |
| Meters | bulk | 250,000 | |
| | domestic | 2,000,000 | |
| Pumps | impellers | 200,000 | |
| | seals | 100,000 | |
| | packing | 50,000 | |
| Motors | re-winding | 150,000 | |
| Controls | relays | 150,000 | |
| | MCBs , etc | incl. | |
| Dosers | parts | 100,000 | **4,450,000** |

**Table 4.5**
**Cost estimate for expansion works for Murang'a water supply (2010 planning horizon)**

| Description | Unit | Quantity | Rate (Kshs) | Amount (Kshs) |
|---|---|---|---|---|
| **Treatment works (Kiharu and Kayahwe)** | | | | |
| Expansion of raw water pumping, filtration, high lift pumping and ancillaries | sum | | | 75,000,000 |
| **Storage** | | | | |
| Reinforced concrete ground level tanks, capacity 1,500$m^3$ | nr | 3 | 8,000,000 | 24,000,000 |
| **Distribution pipework** | | | | |
| uPVC, steel pipes DN 300 - 50 | km | 75 | 3,000 | 225,000,000 |
| Fittings | sum | | | 25,000,000 |
| Domestic meters | nr | 8,000 | 5,000 | 40,000,000 |
| **Sub-total** | | | | **389,000,000** |
| Add | | | | |
| 20% preliminary and general items | | | | 77,800,000 |
| 15% contingencies | | | | 70,020,000 |
| 20% consultancy fees | | | | 107,364,000 |
| **TOTAL** | | | | **644,184,000** |
| | | | **say** | **650,000,000** |