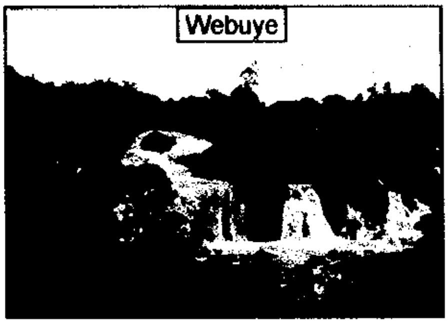
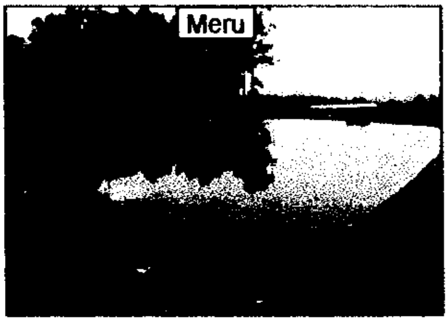
JAPAN INTERNATIONAL COOPERATION AGENCY

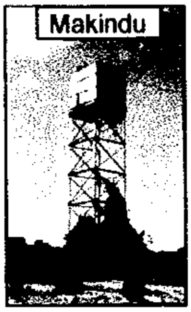
REPUBLIC OF KENYA

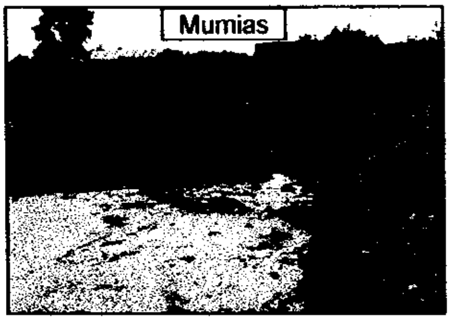
MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES

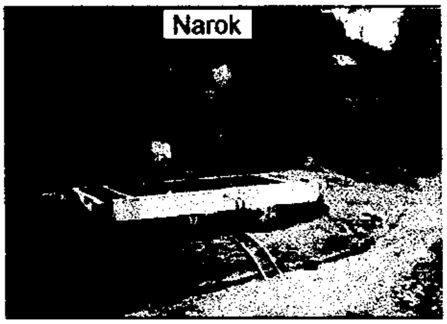
THE STUDY ON INSTITUTIONAL IMPROVEMENT AND REHABILITATION OF WATER SUPPLY SYSTEMS FOR 10 LOCAL TOWNS IN THE REPUBLIC OF KENYA

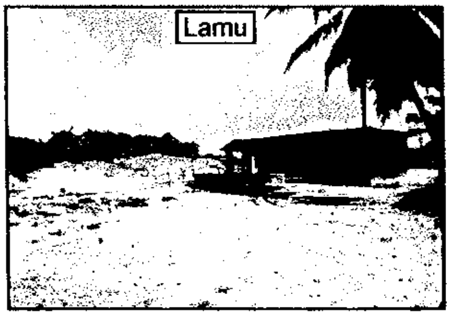


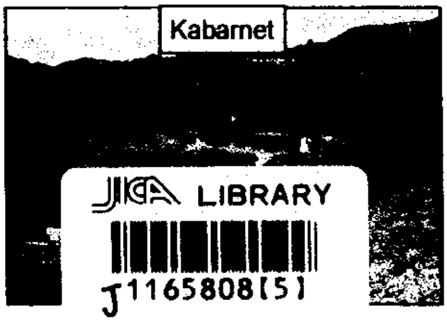












FINAL REPORT

Volume 2F : Main Report (including Appendices) - Wundanyi Town

FEBRUARY 2001

Development Impact Consulting

Engineering and Utility Management Ltd.

Gibb Eastern Africa Ltd.
GIBB Eastern Africa
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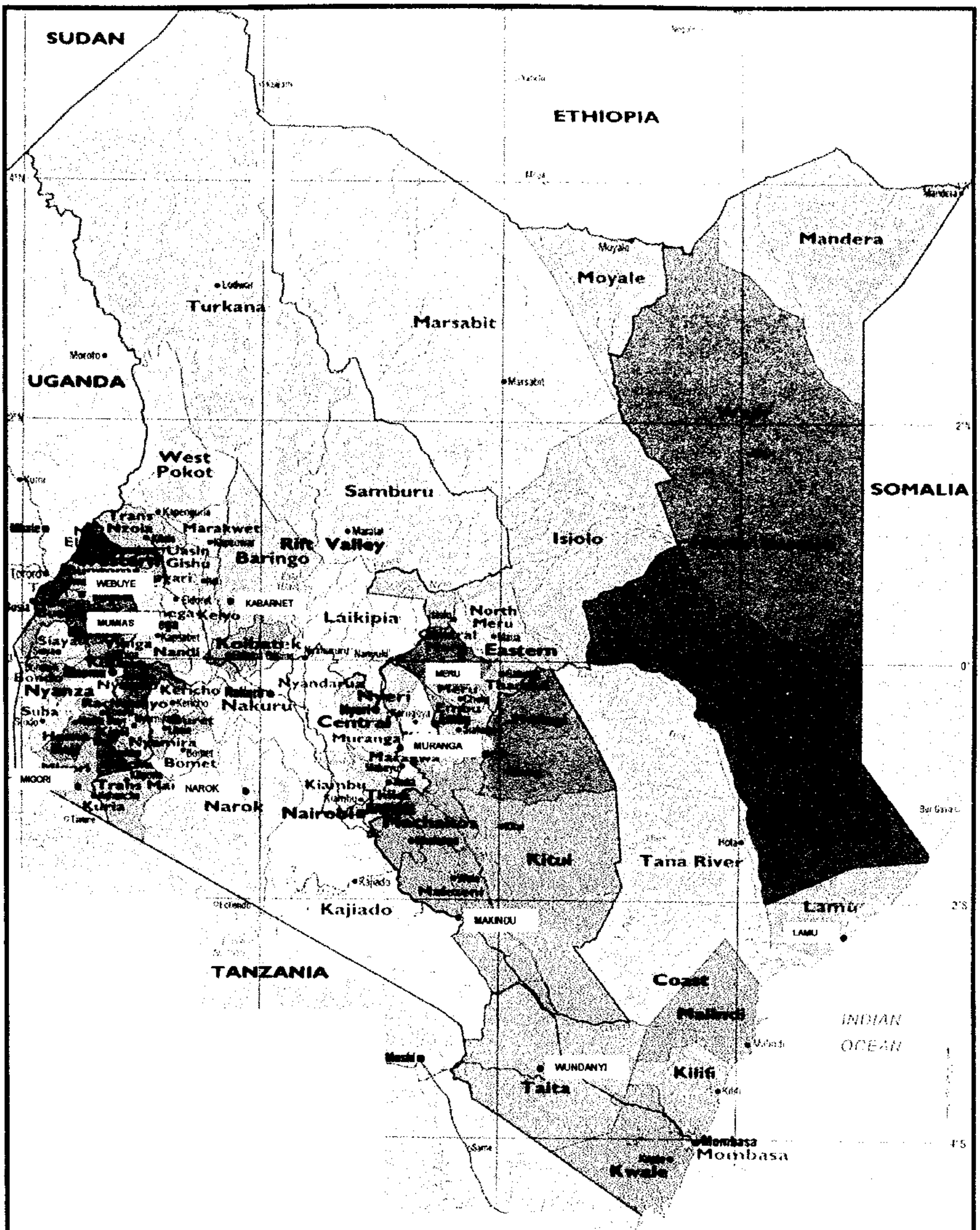

TEN TOWNS WATER & SANITATION STUDY

TOWNS LOCATION MAP

Development Impact Consulting

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WUNDANYI WATER SUPPLY

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LIST OF ABBREVIATIONS

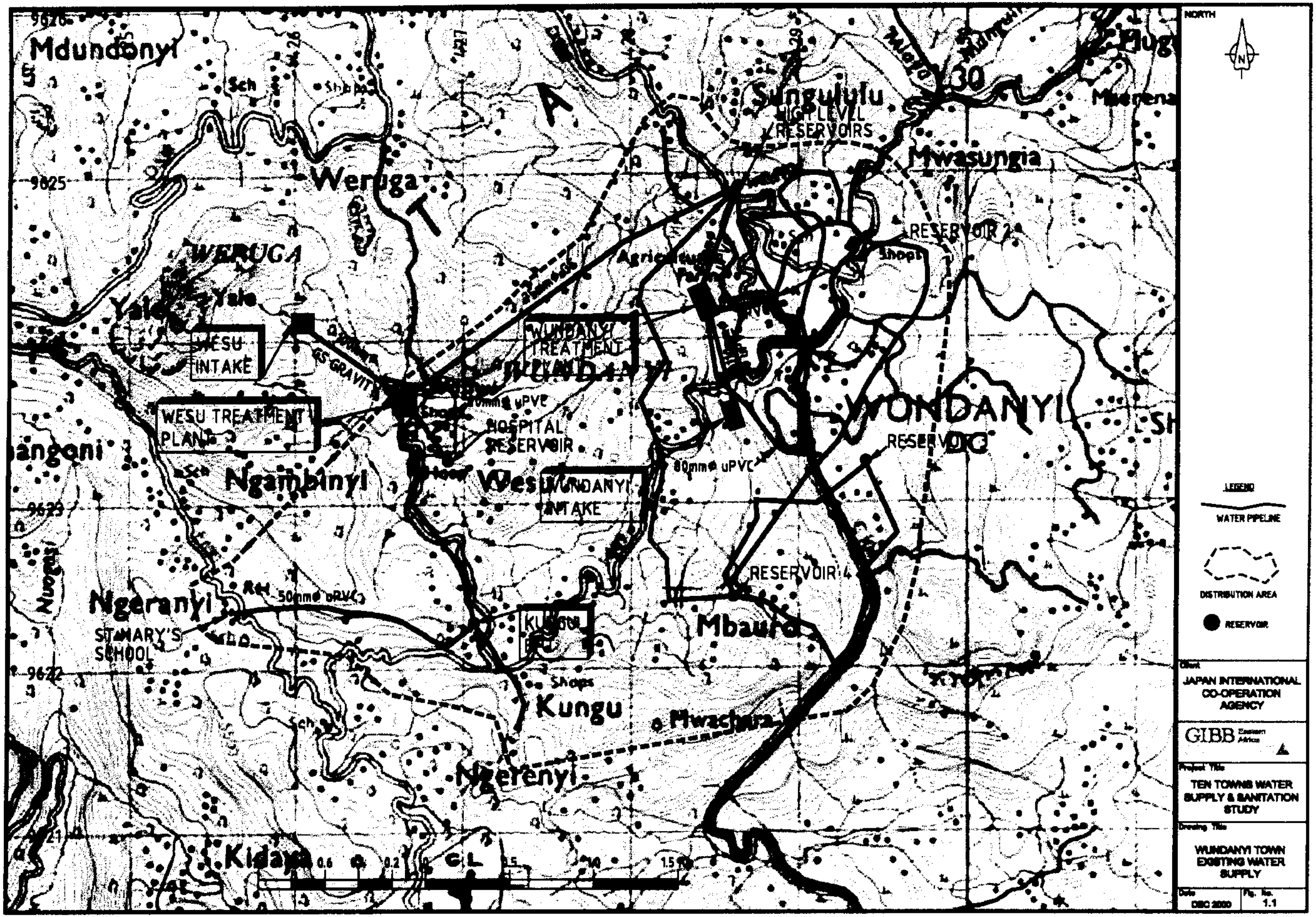
AC	Asbestos Cement (Pipe)
AFW	Accounted for water
AG	Attorney General
AIDS	Acquired Immune Deficiency Syndrome
AIE	Authority to Incur Expenditure
AMREF	African Medical Research Foundation
ASK	Agricultural Society of Kenya
ATP	Ability to Pay
bgl	Below ground level
BH	Borehole
BOT	Board of Trustees
BPT	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
DISTRIBUTION AREA
RESERVOIR
Mdundonyi
Sungululu
HIGH LEVEL RESERVOIRS
Mwasungia
Weruga
WERUGA
Yale
WESU INTAKE
WUNDANYI TREATMENT PLANT
WESU TREATMENT PLANT
HOSPITAL RESERVOIR
RESERVOIR 2
WUNDANYI
RESERVOIR 3
80mm uPVC
Ngambinyi
Wesu
WUNDANYI INTAKE
RESERVOIR 4
Ngeranyi
50mm uPVC
ST MARY'S SCHOOL
Mbauro
Shops
Kungu
Mwachara
Ngerenyi
Kidaya
Sch
JAPAN INTERNATIONAL CO-OPERATION AGENCY
GIBB Eastern Africa
TEN TOWNS WATER SUPPLY & SANITATION STUDY
WUNDANYI TOWN EXISTING WATER SUPPLY
DEC 2000
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

Wundanyi town is located in Wundanyi Division of Taita Taveta District in Coast Province.

Wundanyi lies in the Taita Hills in south west Kenya. Wundanyi is the location of the District headquarters of Taita Taveta District. The headquarters of the Coast Province is Mombasa, which lies some 200km from Wundanyi by road in a south-easterly direction. The town is some 380 km from Nairobi and is reached via the A104 highway to Voi, the A23 road to Mwatate and finally the C104 road to Wundanyi. These are all weather tarmac roads.

2.1.2 Topography

The Taita Hills is a range of Pre-Cambrian rocks that have been upthrust to elevations of 2,207 m (Vuria Hill, west of Wundanyi).

The topography varies dramatically, with steep hills and sharply incised valleys. The town is located on the watershed.

Ground level in Wundanyi varies:

- 1,400 m amsl near the Wundanyi river intake.
- 1,440 m amsl approximately near Storage Reservoir No. 3.
- 1,495 m amsl near Storage Reservoir No. 4.
- 1,680 m amsl at Wesu Treatment Works.

The surrounding plain lies at 900 to 1,200 metres.

2.1.3 Geology

The Taita Hills are made up entirely of Archaean Basement rocks of the Mozambique Belt:

- The northern part of the hills is underlain by the Kasigau Group, comprising quartz-feldspar gneisses and epidote amphibolites.

- To the south lies the Kurase Group that comprises marbles, biotite and sillimanite-kyanite or graphite gneisses. The detailed petrology of these rocks is of little relevance to water resources.

The Basement rocks are overlain by colluvial and residual soils, with alluvial beds present in the lower elevation river valleys (Ref *Austrominerale et al*, 1980).

2.1.4 Climate

The mean annual rainfall is 1,326 mm. Rainfall distribution is bimodal – long rains in September to December and the short rains in March to May.

Temperature and evaporation data are not available. However, annual potential evaporation can be estimated using the Whitehead equation (Ref: *Whitehead,* 1968) which relates elevation and distance from the coast. This gives a value of 1,895 mm/yr.

The aridity ratio for Wundanyi (rainfall divided by evaporation) is 0.7, which makes it a humid area.

The hill mass attracts its own weather system, and is considerably more humid than the surrounding plains. The hills constitute an isolated habitat within which a unique biogeography has evolved.

2.2 PHYSICAL INFRASTRUCTURE

2.2.1 Communications

(a) Road Links

Wundanyi lies off the A104 trunk road running from Nairobi to Mombasa. Access is via the A23 national trunk road turn off at Voi leading to Mwatate from where the C104 primary road leads to Wundanyi. This route to Wundanyi has all weather roads.

(b) Rail Link

The railway from Voi to Taveta on the Kenya Tanzania border passes though Mwatate, which is 18 km from Wundanyi Town. The Voi to Taveta line is a branch off the main Mombasa - Nairobi railway.

(c) Air transport

The closest all weather airstrip is situated in Voi. There are no scheduled flights to Voi. The closest international airport is the Moi International Airport in Mombasa.

(d) Telecommunications

Subscriber trunk dialling (STD) telephone services, fax and email services are available in the town. Currently no cellular phone coverage exists for Wundanyi and surrounding area.

2.2.2 Power supply

Wundanyi town is supplied power from the national power grid.

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 is no central water borne sewerage.

There are currently no known immediate plans for major expansion of the water supply and sanitation services within Wundanyi.

There is no proposed rehabilitation under the on-going El-Nino rehabilitation project.

2.3 SOCIO-ECONOMIC CONDITIONS

2.3.1 Administration

Wundanyi is a cosmopolitan town situated in Taita Taveta district in the Coastal province of Kenya. It has no legal local authority status though it currently serves as the administrative headquarters of Taita Taveta district covering approximately 5.6 km^2 under two sub-locations. The area defined as the Central Business District (CBD) houses offices of the district commissioner, other district departmental heads as well as major offices of parastatals and NGO's. The town is a major business and social infrastructural convergence centre for the hinterland especially on market days when urban visitation is at its peak. The potential for growth of the town as an institutional, commercial and industrial center is enormous especially with the resurgence of tourism activities.

2.3.2 Population Structure and Distribution

Using the 1999 housing and population census, the population of Wundanyi town was placed at 6930[1] people. This contrasts with the 1979 and 1989 censuses that placed the total population at 389 and 2,764 respectively representing an inter-censal growth rate of 9.6% for 1989-1999 period compared to 19.61% for 1979-1989. It is however important to note that this does not include special considerations such as population peaks on market days that exerts pressure on existing water utilities. The number of households more than doubled from 748 in 1989 to a provisional figure of 1698 units in 1999 with an average household size varying from 2.38 to 10.08. In 1989, the population density of the town (CBD) was estimated at 700 persons per km^2

[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.

compared to 1552 in 1999. The distribution of the population and number of households on the basis of sub locations and water service area is shown in table 2.1 below. See appendix F 1-1 for an in depth exposition of the population structure.

Table 2.1 Population Structure and Distribution (1999)

(a) Sub-Location	Number of Households	Population in urban council	Population in Service area
Sungululu	623	3051	3960
Mteni	1075	3879	
Total	**1698**	**6930**	**3960**

Source: District Statistical Office Wundanyi, 1999 and 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 Wundanyi town, it is assumed that the fertility rates declined over the 1989-1999 inter-censal period in accordance with the national trend while the rural-urban migration trend stabilized given that there are no major industrial investments. The total effect is an urban population growth rate of 9.6% for 1989-1999 period compared to 19.61 in 1979-1989 period. Information collected from the district development office however indicates that a rate of 3.4% is used for planning purposes. Since the hinterland of Wundanyi town has many sisal farms, it is expected that the growth in population will remain relatively stable. To capture the other population growth factors and dynamics, such as projected development activities, the 1989-1999 inter censal rate was moderated to 4.0% and used to project the towns' population to the year 2010. Table 2.2 below gives an annualized ten year breakdown of population projections for the town.

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

Year	Population under urban area
2000	7200
2001	7500
2002	7800
2003	8100
2004	8400
2005	8800
2006	9100
2007	9500
2008	9900
2009	10300
2010	10700

[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.

2.3.4 Economic and Commercial Activities

Major economic activities in Wundanyi town and its suburbs remain principally agro based. Commercial activities on the other hand form an important source of income through sale of agricultural and livestock products as well as manufactured goods. In addition to agriculture, a wide range of other auxiliary activities ranging from small-scale jua kali sheds to medium and large-scale enterprises buffer the entrepreneurial potential of the town. This is because the hinterland is endowed with raw materials that favour establishment of small-scale industries. Though this potential has yet to be fully exploited, it covers bananas, vegetables, fruits and oil seed, which form a raw material for fruit processing and oil processing industries. The cumulative effect of these activities is the creation of a favourable environment for the locals to be engaged in waged employment. Milk processing and cooling plants have a potential for growth especially if rearing of dairy cattle can be intensified within the highlands of Wundanyi town. The distribution of the commercial activities is as shown in the table 2.3 below

Table 2.3: Commercial Activities in Wundanyi town

Type of Activity	NUMBER
Retail Shops	37
Hotels	26
Butcheries	25
Wholesale Shops	3
Laundries	3
Bars, Restaurants and Caterers	24
Bookshops	4
Hardware Shops	3
Agro-Chemicals Shops	14
Music Shops	1
Home Utensils & Hire Purchase Shops	1
Garages	2
Total	**143**

Source: District Trade Office, Wundanyi

2.3.5 Social Infrastructure

2.3.5.1 Communication

The road network is an important communication tool for development. Despite the uneven terrain, there exist a number of access roads that are developed to buffer the economic potential of the town. However, some of these roads are poorly maintained and become impassable during the rainy season making transportation of agricultural produce quite difficult. Given its central role as the administrative headquarters, the town has many offices of government, NGO's and other private sector enterprises as well as other institutions and therefore has a greater potential for further development.

Table 2.4 Educational Institutions

Type of institution	Number
Pre-Primary Schools	17
Primary Schools	4
Secondary Schools	2
Farmers Training centre	1
Total	**24**

Source: District Development Office Wundanyi, 1999

Table 2.5 Other Social Institutions

Facility	Number
Mission Hospital	1
Court	1
GoK Hospital	1
Private Clinics	8
Market	3
Stadium	1
Prison	1
Total	**16**

Source: District Development Office Wundanyi, 1999

2.3.6 Income Levels

The distribution of income in the town is quite uneven and reveals major disparities in household resource endowment especially when comparing the CBD and the hinterland. Though urban households may earn more income (through wages, salaries and profits on a monthly basis) compared to their peri urban counterparts, the heavy reliance on the agro-based sector has considerable impacts on the income levels of the peri-urban population as well as the general development of the town. In addition to agriculture, a wide range of other auxiliary activities ranging from small-scale jua kali sheds to medium and large-scale enterprises buffer the entrepreneurial potential of the town. This provides the necessary base income for facilitating a cash economy. Table 2.7 below shows a clear breakdown of income sources for the town, which also includes the peri-urban population. It is important to note that over 55% of the income is from wages, salaries and profits.

Table 2.7 Summary of aggregated mean household income

Income source	Mean Income	Percentage share
Wages, salaries, profits	1895.6	55.0
Other non-agricultural income	1042.73	30.5
Agricultural income	513.9	12.0
Crop income	73.9	2.5
Total	**3526.1**	**100.0**

Source: Welfare Monitoring Survey II, 1994

2.3.7 Willingness and Ability to Pay for Water Services

2.3.7.1 Ability to Pay

Ability to pay is a function of level of household incomes, the acceptable share of water/sewerage services in total expenditures, tariffs and the target consumption levels. However, the main consideration in the ability to pay in this study is the household level of income and expenditure. Particularly, expenditure from a welfare perspective is assumed to be equivalent to the utility derived from the consumption of water and therefore reflects the true market price and peoples expectations on an attitude scale. The ceiling on the proportion of income that may be spent for water/sewerage services is normally taken to be 5% (representing the lower income group) though this varies from one income group to another. Comparatively, households in the lower income bracket spent a higher budget share of their income in real terms on water than households in the middle to high-income group who spent on average 2.2% and 1.4 % of their incomes respectively.

Considering that about 44% of the designated population (for which 33% are women) of the town live in the low income bracket under very poor sanitary conditions and drawing water from untreated sources in times of acute water shortage, a re-evaluation of their income levels as above and W/ATP as well as W/ATA is integral and forms an important component of the perceived water and sanitation improvement plan.

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. Through questionnaire based interviews, each household head was asked questions on how much he was be willing to pay for a cubic meter of water assuming improved service delivery. The general conclusion of the survey was that most households were willing to pay more for improved service delivery commensurate with the level of tariff increase . This also depends on the problem as perceived by the households/major water consumers in the service area.

The preliminary analysis of information collected from the questionnaires indicates that over 90% of the households interviewed are willing to pay up to Kshs. 500 for actual water consumption compared to an average monthly bill of Kshs. 300-400 based on billing estimates. A similar survey in the areas not currently serviced established that majority of the households would be willing to pay for water at the current general water tariff of Kshs. $30/m^3$. Simulations to establish the threshold tariff beyond which people would not be willing to

[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.

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

2.3.8 Health and Sanitation Situation

Sanitation levels and health conditions of the town are generally poor with a high incidence of communicable diseases such as malaria and diarrhoeal diseases. This means that water borne diseases continue to contribute to high mortality in the district, particularly among children and all are directly related to poor personal and environmental hygiene, which is a direct function of lack of adequate clean water. A situational analysis of the major diseases and the morbidity rates are given in the table below:

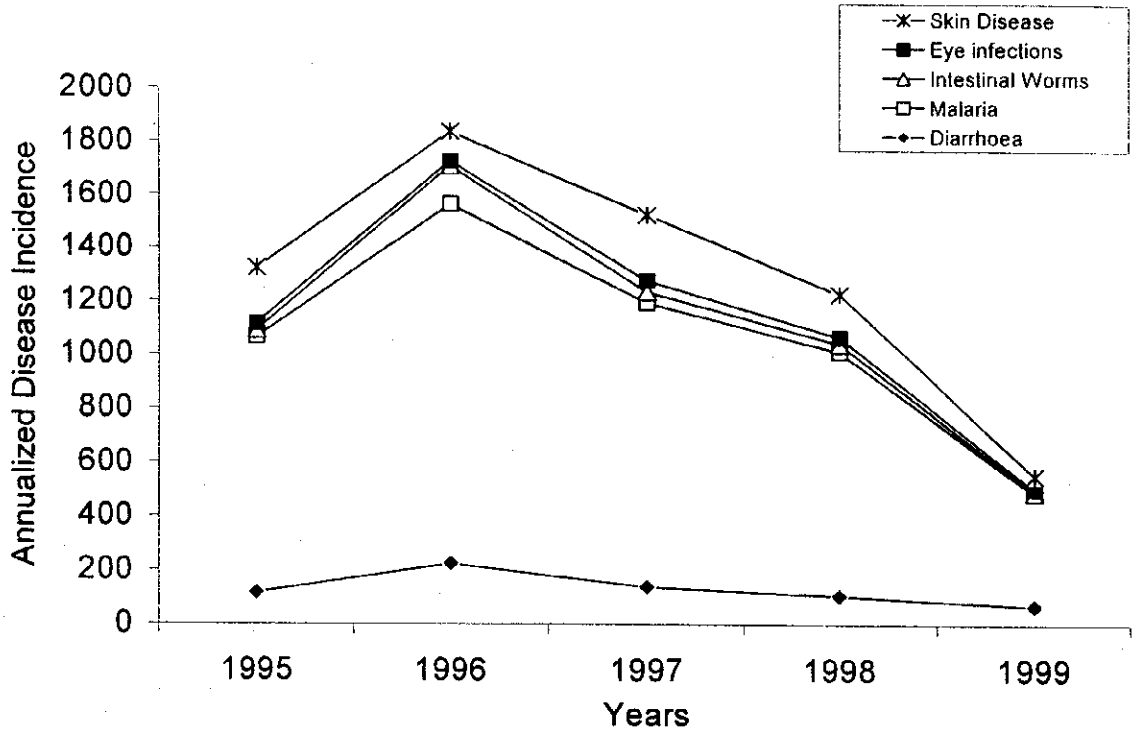
Table 2.8 Major Diseases and Morbidity Rates

Disease	Morbidity Rate (%)
Malaria	37.5
Skin Diseases	8.6
Diarrhoea	2.9
Intestinal Worms	2.1

Source: District Public Health Office, Wundanyi

Although the literacy level is quite high (78%) and people are fairly well sensitized on sanitation matters, pit latrine coverage is still not yet 100% in the town (latrine coverage in 1999 was 94%). Only 46% of the population has access to potable water through the MENR water supply. The remaining bulk of the population draws water mainly from surface streams and springs. This predisposes them to more health problems because of risks of water pollution from on-site sanitation systems. The springs therefore need protection. Inadequate water supply is probably contributing to the high incidence of diarrhoea and worm infections observed from morbidity records. The general disease pattern is shown in chart I below. Due to the problems of data capture most of the ailments are under reported. Two, most patients rarely visit health institutions especially since introduction of cost sharing as they prefer to buy drugs from a local chemist.

Chart 1: Incidence of Water Related Diseases In Wundanyi Town



Source: Ministry of health, Health Information Systems Unit, 2001and PHO Wundanyi

2.3.9 Types of Settlements

The housing conditions within Wundanyi town represent a planned settlement pattern with quarters of district departmental heads forming the affluent residential areas. The trend generally changes as one moves towards the peri urban region that is dominated with semi permanent structures. The table 2.9 below shows the distribution of the population on the basis of broad income categories

Table 2.9 Distribution of households based on income levels

Income category	Number	Percentage
High income	1,110	16
Middle income	2,772	40
Low income	3,048	44
Total	**6,930**	**100**

2.3.10 Situation of Women in Society

Women make up a disproportionately large share of the poor and very poor in urban areas as they are particularly vulnerable to many factors that create and perpetuate poverty. Most families can not survive without the help of female family members. Therefore, women in Wundanyi town like other parts of Kenya are traditionally responsible for collecting water for domestic use in the household. They are conceivably one of the most abused and vulnerable groups in society. Just like poverty, collecting water is a circumstance women find themselves in and which does not necessarily define them. It has been considered that collecting water by women can have negative repercussions on the length and hardship of an average poor woman's working day. For the anticipated rehabilitation exercise to bear fruit, it must meet societal expectations in order to ease the excess burden on the woman and an average woman's workload should be a key monitoring indicator. Other than situations where hand cats, bicycles and donkeys are used, the burden for carrying water requires women to have a substantial amount of energy. This condition is energy sapping and causes considerable stress especially to pregnant women leading to multiple complications at childbirth. Other causes of stress include headaches, backaches, sometimes and deformation of the spine. Accidents do occur and these include slipped discs, paralysis, injury to children carried on the back to extreme cases such as strangulation by the head strap. Improved water supply conditions would change all these and ease the burden on women, releasing time and energy for other development activities necessary in nation building.

2.4 EXISTING WATER RESOURCES, MANAGEMENT AND UTILISATION

2.4.1 Hydrogeology (groundwater resources)

The hydrogeological potential of the Wundanyi area is very limited as no extensive aquifers exist. Aquifers occur in either unconsolidated sediments or weathered or fractured rock. Thus, the hydrogeology is complex.

(a) Basement system hydrogeological units

It appears that in the Wundanyi area there is only one type of aquifer in the Basement rocks: the saprolite (or regolith) aquifer, which occurs in weathered material. Apparently bedrock aquifers that occur where fracturing has occurred are rare. The saprolite itself is very thin, probably extending to 30 m bgl. It is overlain by an overburden of 20 m or so, and thus the saprolite unit is thin, at only about 10 m.

(b) Unconsolidated hydrogeological units

The moderately flat peri-alluvial land adjacent to a river might host a reasonable aquifer, though we believe that this is likely to be limited. In the borehole data in Table 2.10, the main aquifers are unconfined and were struck in alluvial material. One geological log describes a unit of 'well graded sand' as the main aquifer.

(c) Recharge

The localised spring-fed recharge system prevailing in the Wundanyi area makes aquifers here considerably better than elsewhere in Basement areas. This is illustrated by the yields of boreholes C-4602 and C-937 (see Table 2.1). However, Wundanyi is located on a watershed, the potential recharge area is limited, and aquifer yields probably have a wide seasonal variation.

The hydrogeological conditions can be summarised as follows:

- Depth range to the main aquifer: 6 – 30 m for unconfined aquifers.
- Depth range of water rest level: 0.3 – 6 m.
- Discharge range: 2 – 10 m^3/hr.
- Water quality: fresh, neutral waters from unconfined aquifers. The ionic concentrations of iron and manganese may be high because they are at the threshold limit in some spring waters.

Aquifers are mainly unconfined; confined aquifers are rare. The unconfined aquifers comprise alluvium, overburden and *in situ* weathered material. Fractures may produce deeper confined aquifers. Recharge to the aquifers occurs by lateral underflow from recharge catchments on the Taita Hills and local spring-fed circulation systems.

(d) Status of existing groundwater supply facilities

The Water Department in Wundanyi Town does not operate any boreholes. However, a few private boreholes have been drilled in outlying areas. These boreholes were not inspected because they do not constitute sources operated and maintained by the local water department.

Table 2.10 presents data for the existing boreholes. Although the Government drilled Borehole C-937, its current construction and ownership status could not be confirmed. A private company drilled the other two boreholes for use in outlying field camps.

Table 2.10 Completion data for boreholes

SERIAL No.	Total depth (m)	Water strikes (m)	Rest level (m)	Tested yield (m^3/hr)	Owner
C-937	46.6	6.09	6.09	8.2	P. W. D
C-4602	42.5	7	0.73	7.08	Austrominerale
C-4605	36	6, 30	0.4	2.3	Austrominerale

Data source: NAWARD, MENR

(e) Potential for groundwater development

Although moderately high-yielding aquifers may be encountered in alluvial areas of stream valleys, their geometric extent is limited, and their recharge is dependent on spring flows. This occasions large seasonal variation in water level and yield. The potential for deep bedrock aquifers that depend on regional lateral recharge is extremely limited. Under these prevailing conditions, groundwater is not a feasible option for water supply for Wundanyi town.

2.4.2 Hydrology of surface water sources

The drainage network in the Wundanyi area is presented in Figure 2.1.

The regional hydrology comprises four drainage basins:

- Tsavo River Basin. This river is perennial throughout its length and lies to the north of the Taita Hills. Rivers on the northern side of the Taita Hills drain into the Tsavo River.

- Voi River Basin. This is perennial in the headwaters only and drains to the east of the Taita Hills. Rivers on the eastern and south-eastern slopes of the Taita Hills drain into the Voi River basin.

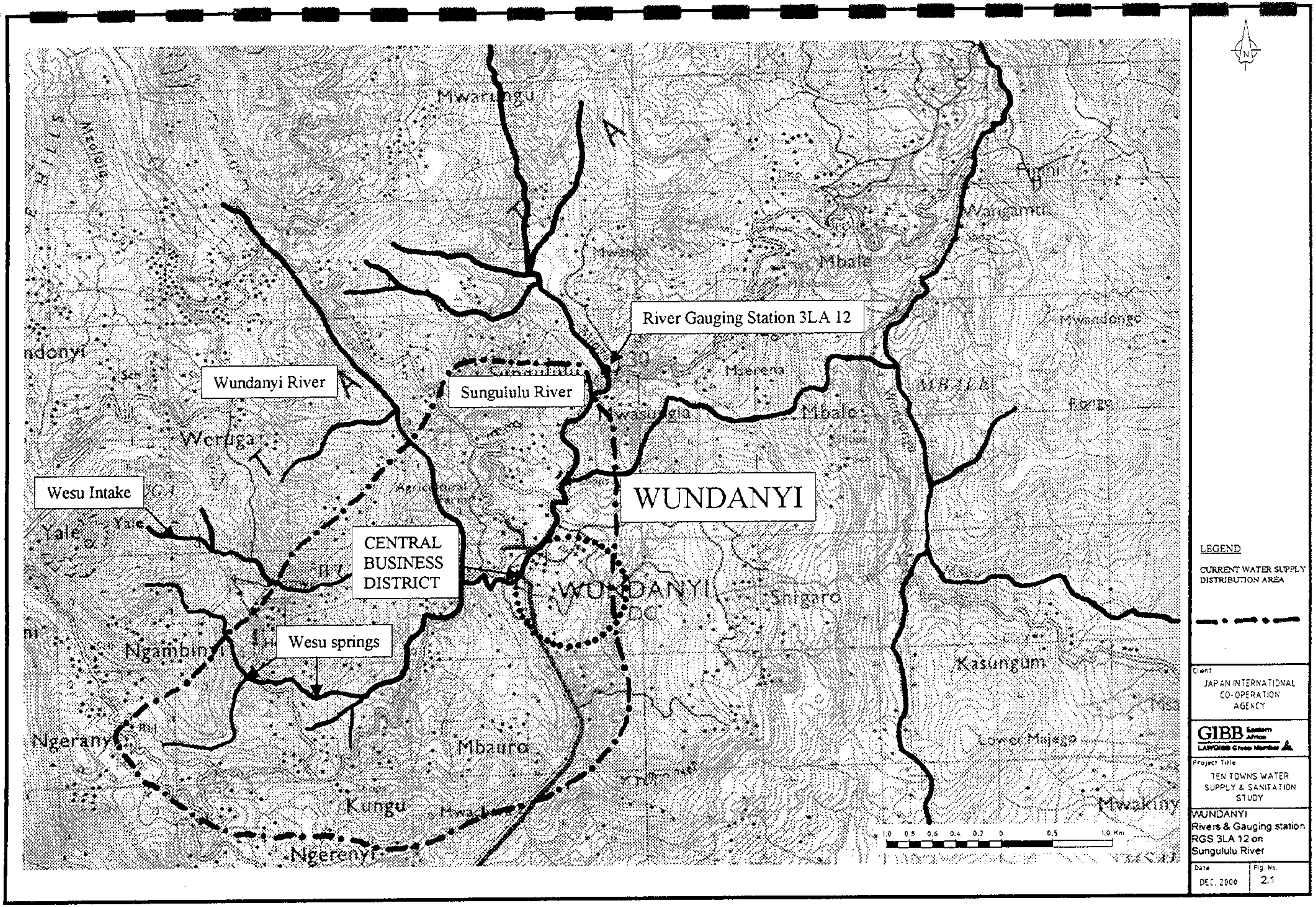
- Mwatate River Basin. This is perennial in the headwaters only and drains to the south of the Taita Hills, and on into Mangeri Swamp and into Kwale District. Rivers on the south-western slopes of the Taita Hills drain into the Mwatate River Basin.

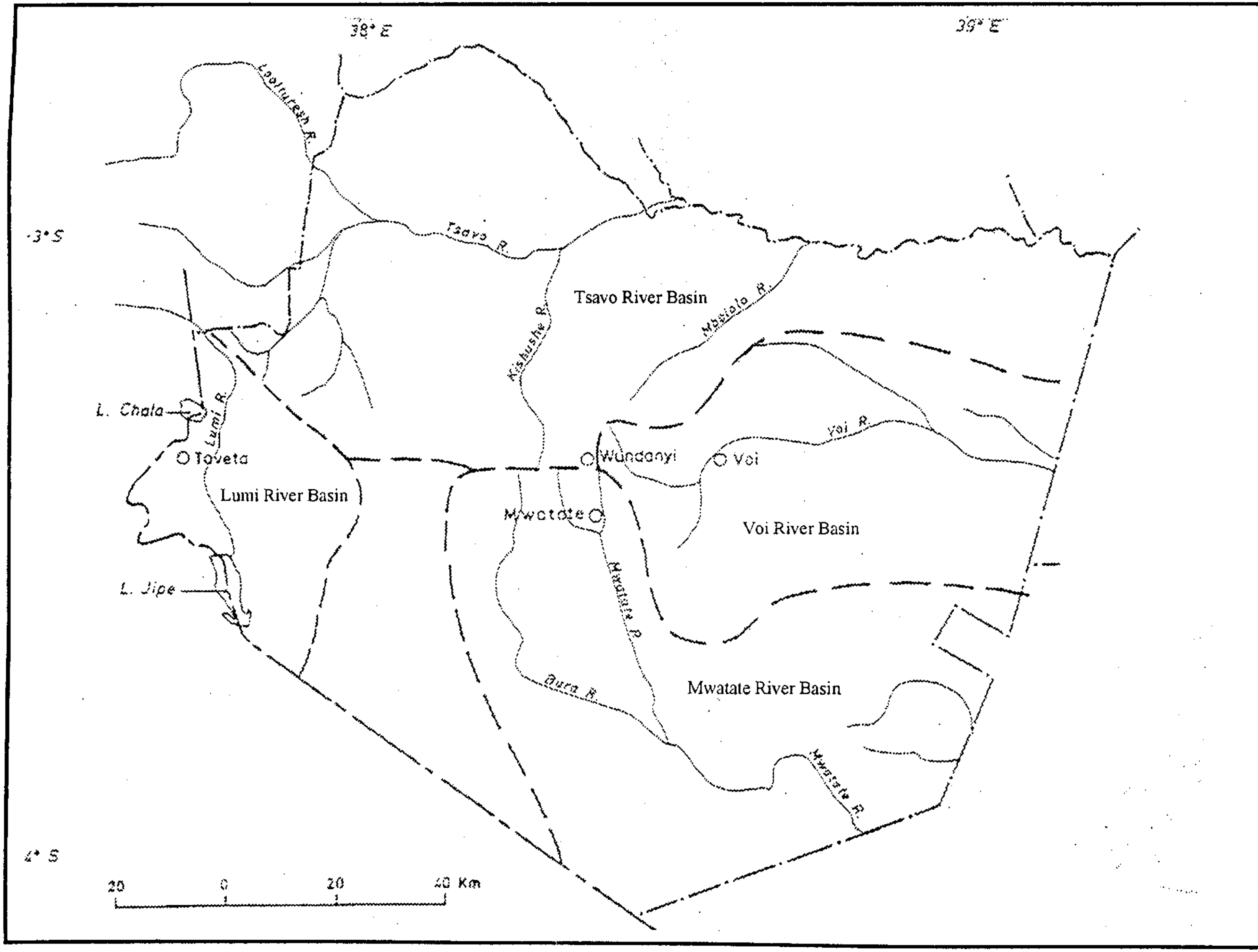
- Lumi River Basin. This is perennial throughout its length and lies west of the Taita Hills and is not linked to the Taita catchments. It is of interest because it includes several large springs and Lakes Chala and Jipe.

Wundanyi is located on a watershed of the Tsavo, Voi and Mwatate River Basins – see Figure 2.2.

The catchments from which Wundanyi derives its water supply are part of the Voi River Basin. The rivers are small. The Voi River Basin is within Drainage Sub-Basin 3LA - the upper Athi Drainage Basin.

The water resources of the area have been presented in the *Water Master Plan Taita Taveta District Phase II, June 1995*. The water balance of the basins is summarised in Table 2.11.


N
Mwarungu
Mbale
Wangamu
Mwandongo
River Gauging Station 3LA 12
Wundanyi River
Sungululu River
Weruga
Wesu Intake
Yale
WUNDANYI
CENTRAL BUSINESS DISTRICT
WUNDANYI
DC
Shigaro
Wesu springs
Ngambinyi
Ngeranyi
Mbaura
Kungu
Ngerenyi
Kasungum
Lower Mijega
Mwakiny
1.0 0.8 0.6 0.4 0.2 0 0.5 1.0 Km
LEGEND
CURRENT WATER SUPPLY DISTRIBUTION AREA
Client
JAPAN INTERNATIONAL CO-OPERATION AGENCY
GIBB Eastern Africa
Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY
WUNDANYI
Rivers & Gauging station RGS 3LA 12 on Sungululu River
Date
DEC. 2000
Fig No.
2.1



LEGEND
BASIN CATCHMENT BOUNDARY
DISTRICT BOUNDARY

Client
JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa
LAWGIBB Group Member

Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY

WUNDANYI
River Basin Catchments

Date	Fig. No.
DEC. 2000	2.2

Table 2.11 Water balance of river basins in Taita Taveta District

River basin	Lowest discharge m^3/day	Normal abstraction m^3/day	Water balance m^3/day	Flood abstraction m^3/day	Water balance m^3/day
Tsavo	52,760	12,080	40,680	55,715	(15,035)
Voi	12,588	8,009	4,579	4,850	(271)
Mwatate	18,590	6,882	11,708	3,002	8,706
Lumi	418,954	77,504	341,450	54,681	286,769

Notes:
1. *Source: Water Master Plan Taita Taveta Distict, Final report, June 1995.*
2. *Lumi River water balance excludes Lakes Chala and Jipe.*
3. *Mzima Springs in Tsavo River Basin is excluded (allocated to Mombasa Water Supply).*

The conclusions from the *Water Master Plan* were:

- There is an absence of continuous flow data.

- When normal flow abstractions are considered, all basins have a surplus of water resources.

- When irrigation abstraction from flood flow is included, the Tsavo and Voi basins show a deficit.

- The water resource is adequate for the project area but the location of sources is not ideal. The resolution of water deficits is the subject of a future study in water supply planning.

The current sources of public water supply for Wundanyi town are the Wundanyi River and the Wesu springs. There is no flow data at the intakes. However, instantaneous flow measurements were made at nearby gauging stations between 1980 and 1985 (Ref: *"Taita Taveta District Water Master Plan Phase I"*, prepared by Groundwater Survey Kenya, March 1991, and "*Water Master Plan Taita Taveta District Final Phase II Report"*, prepared by Norconsult in June 1995). The rivers are within the Voi River Basin, which is gauged as summarised in Tables 2.14 and 2.15.

Table 2.12 summarises minimum discharge data collected in the *District Water Master Plan*.

Table 2.13 summarises the available water resource from each system based on an assessment of existing abstraction permits. The results show that there is inadequate water during low flow periods to meet the current demand.

Table 2.12 River gauging station data near Wundanyi in the Taita Hills

River	RGS number	River basin	Area Km^2	Record period	Minimum discharge l/sec	Minimum discharge m^3/day
Sungululu	3LA12	Voi	10.1	1979-90	3.1	270
Rahai	3LA8	Voi	48.1	1976-90	3.0	260
Msau	3LA9	Voi	67.5	1978-90	2.3	200
Wanganga	3LA10	Voi	61.2	1976-90	9.0	780

Source: Water Master Plan Taita Taveta District Phase II, June 1995.

Table 2.13 Water balance for rivers near Wundanyi

River	RGS number	River basin	Low flows m^3/day	Existing water supplies from normal flow m^3/day	Existing water supplies from flood Flow m^3/day	Surplus water m^3/day
Sungululu	3LA12	Voi	270	170	265	(165)
Rahai	3LA8	Voi	260	190	30	(40)
Msau	3LA9	Voi	200	10	0	190
Wanganga	3LA10	Voi	780	1160	250	(630)

Source: Water Master Plan Taita Taveta District Phase II, June 1995.

Additional sources must be developed to meet the present and the future demand.

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

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

The runoff characteristics in the Voi River Basin are presented in Table 2.15, and the flow duration curve is presented in Figure 2.3.

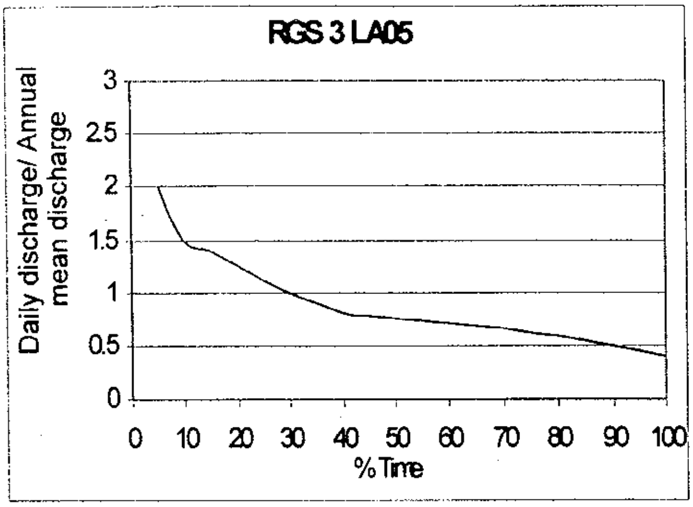


Figure 2.3 - Flow duration curve

Table 2.14 Details of the gauging station on the Voi River.

Code	River	Latitude	Longitude	Station opened	Station closed	Rated	Catchment area (Km²)	Annual mean runoff (m³/s)
3LA05	Voi	00^{0}43'35"	38^{0}35'35"	1969		Yes	496	4.5

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

Table 2.15 Flow characteristics at RGS 3LA05.

	Q/Q_{ave}	m^3/sec	m^3/day
Mean annual runoff Q_{ave} m^3/sec	4.50	4.50	380,000
50% exceedence flow ratio Q_{50}/Q_{ave}	0.75	3.38	290,000
90% exceedence flow ratio Q_{90}/Q_{ave}	0.50	2.25	190,000
95% exceedence flow ratio Q_{95}/Q_{ave}	0.45	2.02	175,000
100% exceedence flow ratio Q_{100}/Q_{ave}	0.40	1.80	155,000

The results in Table 2.15 shows that the water resource in the Voi River in the lower reaches is large. However, the elevation drop is large.

The options for water resources development for Wundanyi are as follows:

- Boreholes: This option is discounted, as groundwater potential is limited.
- Distant surface water and spring sources: Examples are the Tsavo River and Lumi River systems. This option will be costly due to the distances and pumping heads involved.
- Impoundment on nearby streams to store water for release during low flow periods. This option is the most promising.

The existing Wundanyi supply was designed in 1979 (Ref: Ward Ashcroft and Parkman) and constructed in 1985 on the following design basis:

- Expanded abstraction with treatment from Wesu Springs.
- New intake on the Wasiwi river system. This is the Wundanyi Treatment Works and it was designed for future doubling of capacity. The water for the future expanded works was to have been supplied by an impoundment 1.2 km upstream.

The original design of an impoundment upstream of the existing Wundanyi Treatment Works has never been implemented.

Whilst an impoundment scheme looks a promising option, a comprehensive water resources study is needed to quantify the available sources and evaluate the cost of developing these sources. Wundanyi needs to be studied in the context of regional water resources availability.

2.4.3 Raw water quality

A partial raw water quality analysis was obtained from the Provincial Water Office in Mombasa. This shows a pH of 6.8, a calcium content of 12 mg/l and an alkalinity of 44 mg/l measured as calcium carbonate.

2.4.4 Treated water quality

The existing water sources supplying Wundanyi are the Wesu springs and Wundanyi River. Recent microbiological analysis available from the Divisional water office are reproduced below.

Table 2.16 Treated water quality

Sample date	Sampling point	Total coliform organisms/100ml of water
21/2/2000	Wundanyi water supply office	<3
21/2/2000	Wesu Hospital	<3
11/3/2000	Water laboratory tap	240
11/3/2000	DK – Hotel	9
20/10/2000	Mbela Estate	<3
20/10/2000	Wesu Hospital	<3

The results for February and October 2000 are within the maximum permissible value, however the results for March 2000 especially at the water laboratory tap indicates that the treated water quality is very poor. However it is suspected that this may have been caused due to inadequate sterility of equipment or a contaminated tap.

The available records at the water treatment works show that the raw and treated water at both Wesu and Wundanyi treatment works have a pH of between 6.9 and 7.2. There are no records of turbidity analysis.

3 EXISTING WATER SUPPLY CONDITIONS

3.1 BACKGROUND

The water supply to Wundanyi consists of two surface water source supplies namely; Wesu and Wundanyi. Water from each source is treated at its own conventional treatment works.

The Wesu source was developed in the 1950's and is a gravity system. The supply is operational and supplies water to the Wesu District Hospital and parts of the reticulation at higher elevation.

The treatment works capacity was doubled in 1985 to the present total reported capacity of 768m^3/day (32m^3/h).

The Wundanyi source was developed in the 1980s and is a pumped system. The supply is operational with a reported capacity of 768m^3/day (32m^3/h) and supplies water into storage reservoirs within the reticulation.

A map at the beginning of the report (Figure 1.1) shows the key current water supply features for Wundanyi town and the present water supply distribution area. The salient details of the existing water supply systems are shown schematically in figure 3.1 (Wesu) and 3.3 (Wundanyi).

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.

3.4 THE WESU WATER TREATMENT / SUPPLY SYSTEM

3.4.1 Wesu Intake and raw water main

The Wesu intake is located on a small stream that rises from several springs. The intake is a stilling pool created by a weir. The water gravitates to an outlet chamber through a 150 mm diameter GS pipe and from the chamber through a 100 mm diameter GS pipe to the treatment works. The raw water gravity pipe is in good condition. In the last 25 m the pipe has been changed from GS to a 150 mm diameter uPVC pipe.

At present all water in the stream is abstracted and none is released downstream. The treatment works operators reported that this is due to the very low flow in the stream caused by the long dry spell in 1999/2000. From an environmental perspective, this is not acceptable.

3.4.2 Wesu treatment works

(a) <u>General</u>

This is fed from Wesu springs. The conventional treatment works is situated on a steep slope north west of Wesu Hospital at an average elevation of

1675m amsl. The flow through the works is by gravity except for the backwash water, which is pumped from the clear water tanks to the backwash tank. The treatment works capacity was doubled in 1985 and the reported total capacity is 768m^3/day (32m^3/h). There is currently no plan for rehabilitation or expansion of the treatment works.

A layout of the treatment works is given in Figure 3.2.

(b) Raw water quality

Records at the water treatment works show a pH of 6.9 throughout the month of April 2000. There were no records of the turbidity or of alkalinity available.

(c) Coagulant dosing

Aluminium sulphate and lime solution is dosed under gravity from glass reinforced plastic solution tanks using regulating valves on a uPVC pipe as the existing mechanical dosers are not serviceable.

The solutions are designed to be dosed just upstream of an existing V-notch before the flow is split to the two streams.

There is no mixer at the dosing point to distribute the solution through the incoming flow.

The reported dosing rate is 80 ppm of Alum and 64 ppm of lime, and the recorded usage is 34 kg/d and 27kg/d respectively.

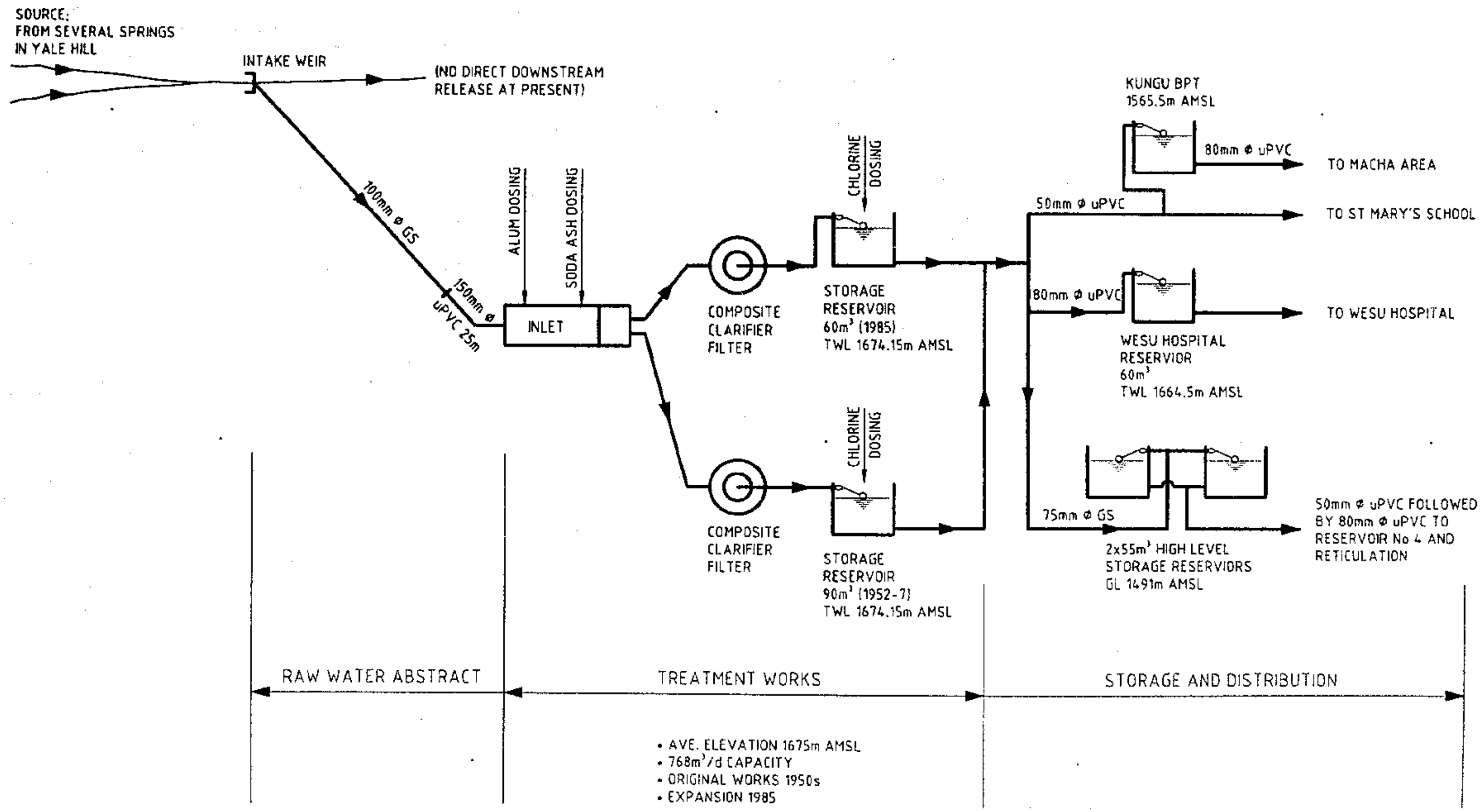
(d) Flow measurement and division

At the time of the site visit, the flow over the V-notch weir had a head of 90mm which gives a flow of approximately 288m^3/day (12m^3/h). Flow division is after the weir, through a 50 mm GS pipe to the old composite clarifier/filter unit and a 80 mm GS pipe to the new unit. The pipe diameter and length therefore control flow as both composite units are at the same level.

(e) The conventional treatment plant

There are two composite filtration units of similar dimensions, of which the more recent one was constructed in 1985. Apart from the loss of filter media and lack of proper back washing facility due to the broken-down wash water pump, the composite filtration units are operational. Backwashing is currently done using raw water, which can be diverted under gravity from the raw water pipe to the backwash tank. The existing backwash tank is a corrugated GI circular tank, which is leaking and is not serviceable in the long term.

The filter is of 1.8 m diameter giving a surface area of 2.545 m^2. The usual surface loading for filters is between 5.0 m/hr and 7.5 m/hr and the Ministry's design manual recommends the lower value. The units therefore have a capacity of between 306m^3/day(12.75m^3/h) and 458m^3/day(19.8m^3/h).



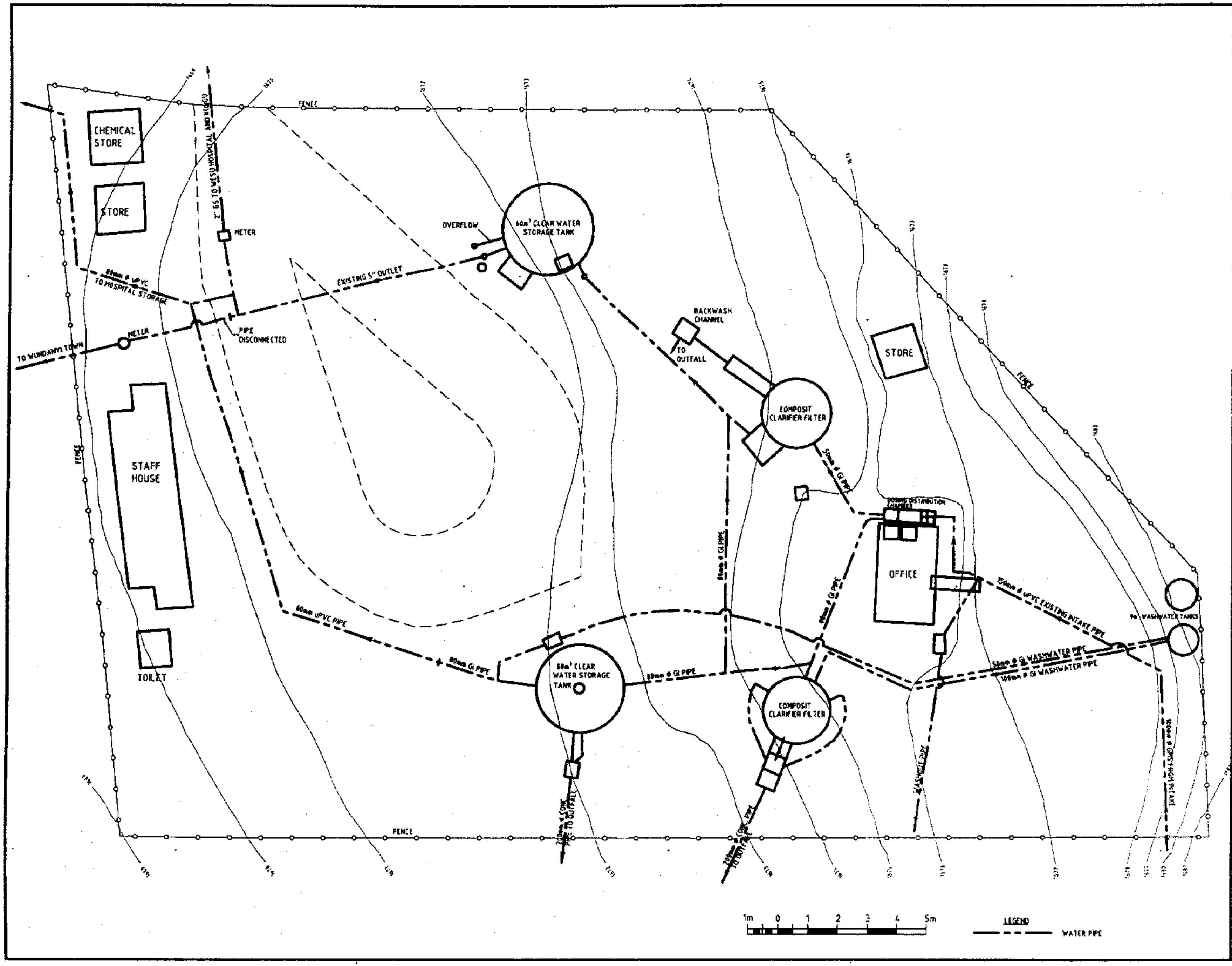
Client
JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa
LAWGIBB Group Member

Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title
WUNDANYI WATER SUPPLY SCHEMATIC LAYOUT OF WESU WATER TREATMENT WORKS SUPPLY

Date	Fig. No.
JAN 2001	3.1



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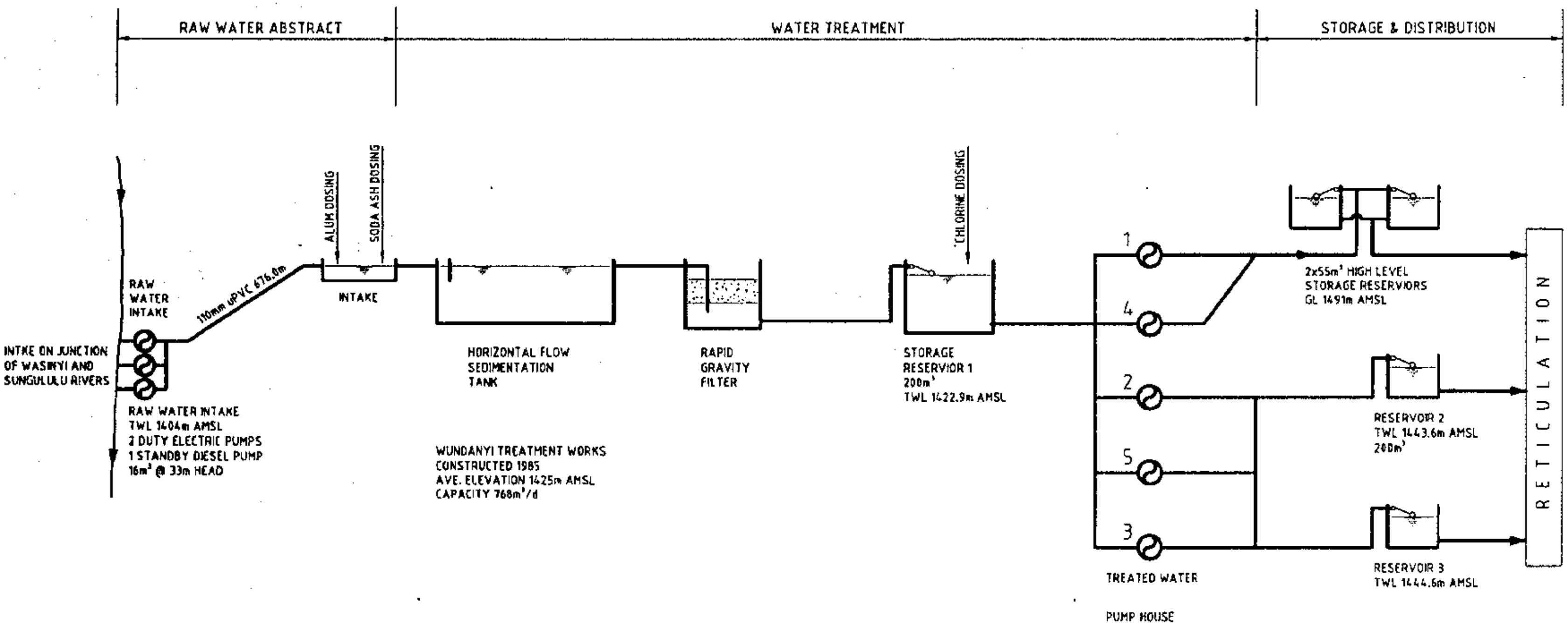
Project Title

TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title

WUNDANYI WATER SUPPLY WESU TREATMENT WORKS LAYOUT

Date	Fig. No.
DEC 2000	3.2



RAW WATER PUMPS

PUMP No	FLOW m³/h	HEAD m	POWER
1	16	33	ELECTRIC
2	16	33	ELECTRIC
3	16	33	DIESEL

TREATED WATER PUMP

PUMP No	FLOW m³/h	HEAD m	POWER	DELIVERY
1	9	64	ELECTRIC	HL STORAGE BACKWASH
2	15	44	ELECTRIC	RESERVOIR 2
3	20	44	ELECTRIC	RESERVOIR 3
4	9	75	DIESEL	HL STORAGE BACKWASH
5	20	44	DIESEL	RESERVOIR 2 & 3

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Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title
WUNDANYI WATER SUPPLY SCHEMATIC LAYOUT OF WUNDANYI TREATMENT SYSTEM

Date JAN 2001
Fig. No. 3.3

Operations staff report that the total capacity of the existing works is 768m^3/day (32m^3/h). This is consistent with the surface areas of the filters, although it represents a filter loading rate of 6.29 m/hr rather than the value of 5 m/hr stipulated in the MENR Design Manual. A value of 768 m^3/day (32m^3/h) has been adopted.

(f) Disinfection and the clear water tank

Tropical chloride of lime is dosed as a disinfectant at a reported rate of 1 2mg/l into both clear water tanks of 60 m^3 capacity each. Both the tanks are serviceable. The top water level in the clear water tank is given as 1674.15m amsl.

(g) Laboratory facilities

There is no laboratory at the treatment works and dosage rates are set based on past experience. There is a laboratory at Wundanyi treatment works.

(h) Transmission mains

There are three gravity mains from Wesu clear water tanks that supply into distribution. These are as follows:

- 50 mm uPVC main to Kungu break pressure tank, which supplies the Kungu area and St. Mary's school.
- 80 mm uPVC main supplying the hospital storage tank
- 75 mm GS pipe supplying into high level storage tanks.

3.5 WUNDANYI TREATMENT WORKS SUPPLY SYSTEM

3.5.1 Wundanyi intake and raw water main

The Wundanyi intake is located at the junction of the Sungululu and Wasinyi Rivers just south of the Wundanyi to Kungu road. The pumping station comprises:

- 2 No. pumps with electric motors
- 1 No. standby pump with a diesel engine

The three pumps are of Ritz make, type 40-315 each with a nominal duty of 16 m^3/h against 33 m head.

From the records the two electric pumps ran for 852 hours in April 2000 giving an output of 13632m^3 in the month or an average of 454m^3/day.

The motor on Pump No. 2 is the original Conrad type DR132-S-4, whereas the original motor for Pump No. 1 has been replaced with a Catco type DY132S-4 dated 1996. The Lister diesel engine is not operational. There is therefore no back-up in the event of power failure.

The raw water is delivered to the treatment works via a 110mm uPVC Class B pumping main of 676.2 m length. The pumping main is reported to be in good condition and does not require any rehabilitation.

The ground level at the intake is at 1404m amsl. The area around the intake is flat and is prone to flooding.

3.5.2 Wundanyi treatment works

(a) General

This conventional treatment works was constructed in 1985 on a slope at an average elevation of 1425 m amsl. Raw water is supplied from the Wundanyi intake.

The flow through the works is by gravity except for the backwash water, which is pumped from the clear water tanks to the backwash tank.

The reported total capacity is 768m^3/day (32m^3/h).

There are no current plans for rehabilitation or expansion of the treatment works. The original design made provision for doubling the capacity of the plant in the future. A layout of the treatment works is given in Figure 3.4.

(b) Raw water quality

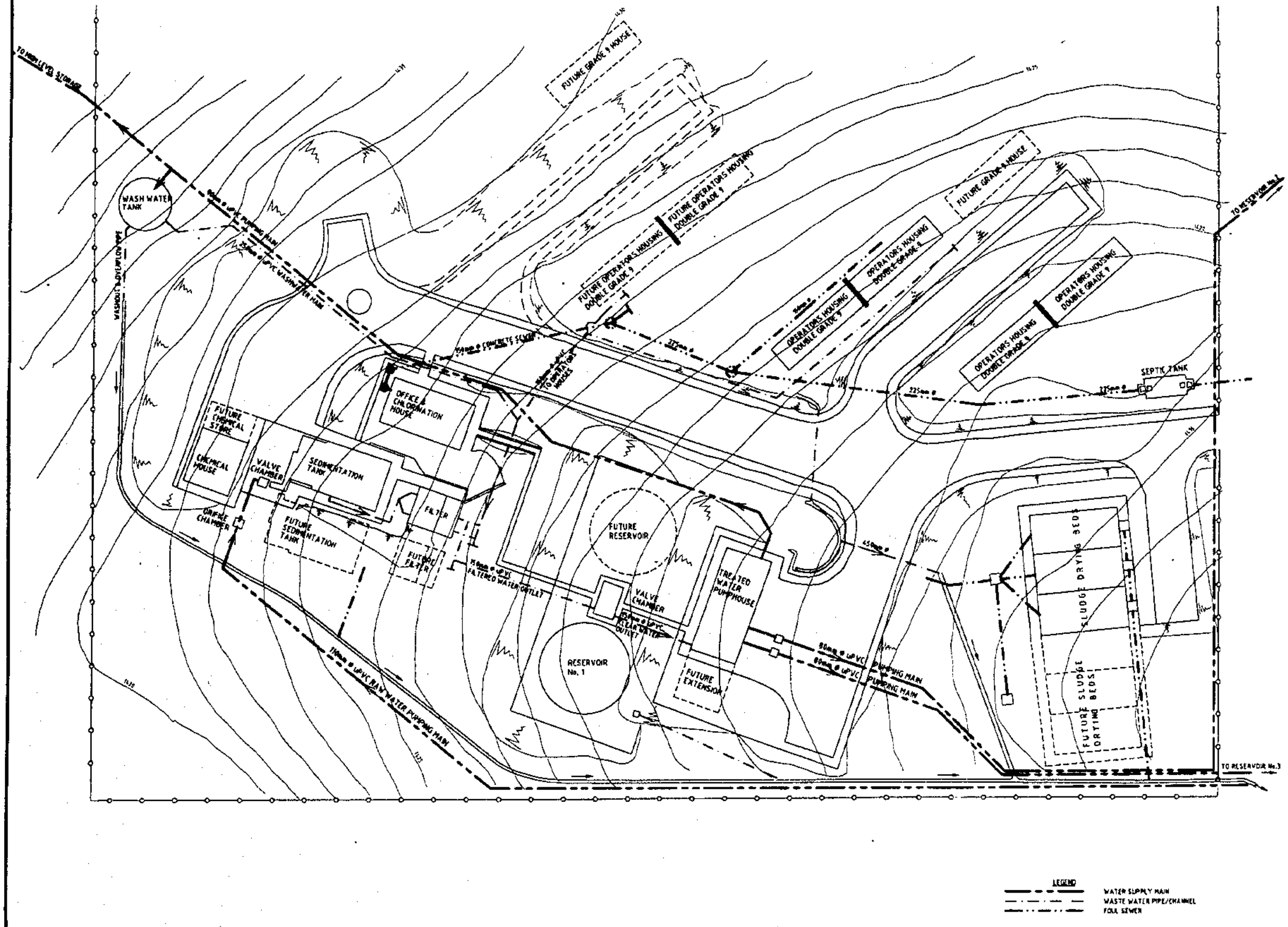
Information from the water supply operation chart shows that the pH was 6.9 throughout the month of April 2000. There were no records of the turbidity or of alkalinity at the water treatment works.

(c) Coagulant dosing

Aluminium sulphate and lime solution is dosed under gravity from glass reinforced plastic solution tanks using a dosing valve on the pipe as the existing mechanical dosers are not serviceable.

The solutions are dosed downstream of a rectangular weir before the flow is split and enters the flocculation chambers of the horizontal flow sedimentation tank. The reported dosing rate is 80 ppm of Alum and 64 ppm of lime, and the recorded usage is 25 kg/d and 20 kg/d respectively.

The regulating valves on the dosing pipes are corroded. The reinforced concrete roof of the chemical store is leaking and is in need of urgent repair. The grano floor in the mixing area is eroded with chemical reactions and also needs to be repaired.



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TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title

WUNDANYI WATER SUPPLY TOWN TREATMENT WORKS LAYOUT

Date	Fig. No.
DEC 2000	3.4

(d) Flow division

At the time of the site visit, the flow over the rectangular weir had a head of 25mm which gives a flow of approximately 168m^3/day (7m^3/h). Flow division is downstream of the weir at the end of the inlet channel, which has two openings, one for each tank.

(e) The conventional treatment plant

Clarifiers

There are two rectangular horizontal flow clarifiers, each 7.5 m by 2.4 m, giving a surface area of 18m^2. The usual surface loading for horizontal flow clarifiers is 1m/hr. The units therefore have a combined capacity of 36m^3/h.

Filters

The conventional treatment plant has two rapid gravity filters, each 2.9 m by 2.0 m, giving a surface area of 5.8 m^2. The usual surface loading for rapid gravity filters is between 5.0 m/hr and 7.5 m/hr: The MENR Design Manual recommends the lower value. The units therefore have a capacity of between 29m^3/h and 43.5 m^3/h, giving an average of 36m^3/h or a surface loading of 6.2m/hr rather than 5m/h as stipulated by the Ministry's design manual.

The filters are washed using water supplied from a header tank above the treatment works.

Plant capacity

Operations staff report that the total capacity of the existing works is 768m^3/day (32 m^3/h). This slightly lower than the calculated capacity of the clarifiers and slightly higher than that given by the filter size and the Ministry's recommended surface loading rate. It is reasonable to adopt the design capacity of the plant as 768 m^3/day (32m^3/hr) as reported by the operations staff.

(f) Disinfection and the clear water tank

Tropical chloride of lime is dosed as a disinfectant at a reported rate of 0.9 mg/l into reservoir No. 1 of 200m^3 capacity. The top water level in reservoir No. 1 is given as 1422.9m amsl.

(g) Laboratory facilities

There is a laboratory at the treatment works, which has the capacity to carry out bacteriological, chemical and physical analysis of water samples. The Laboratory Technician reported that equipment and reagents for bacteriological analysis were available and tests were carried out once a quarter, funds permitting. The autoclave, however, is in need of replacement. The equipment for physical and chemical analysis is not operational and there are no reagents. Physical and chemical analysis has therefore not been carried in the recent past. The concrete roof slab of the laboratory is leaking.

It is recommended that the laboratory be equipped to carry out all basic water testing as the nearest alternative would be for the testing to be carried out in Mombasa, which is 200 km away. The concrete roof should be rehabilitated.

(h) Transmission (pumping) mains

The high lift pumps deliver treated water to service reservoir Nos 2 and 3 and the high level storage tanks through 80mm diameter class B uPVC pipes. A tee from the main supplies the backwash tank on the hillside above the water treatment works. The pumping mains are reported to be in good condition.

(i) High lift pumping

There are 3 No. electric and 2 No. diesel driven pumps in the treated water pumping station. Details of the pumps are given in Table 3.1. All three electric pumps were reported to be operational. The diesel engines are in need of an overhaul so that there is effective backup in the event of power failure.

Table 3.1 Details of treated water pumpsets

Pump	Make	Type	Flow m^3/h	Head m	Power	Hrs run in April 2000	Flow m^3/d
1	Ritz	4504	9	64	Electric	189	1,701
2	Ritz	4504	15	44	Electric	41	615
3	Ritz	4504	20	44	Electric	314	6,280
4	Ritz	4503	9	75	Diesel	0	0
5	Ritz	4504	20	44	Diesel	0	0
					Total	544	8,596
					Average		**287**

3.6 STORAGE

Table 3.2 below shows the schedule of storage reservoirs in Wundanyi.

Table 3.2 Storage reservoirs

Reservoir Ref.	Capacity m^3	Level m amsl	Location	Date built	Condition
1	200	1422.90 TWL	At Wundanyi TW	1985	Good
2	200	1443.60 TWL	Town centre	1985	Good
3	200	1444.60 TWL	Near Livestock office	1985	Good
4	200	1496.40 TWL	Near Mwasombo Pentacostal Church	1985	Good
High level	2 x 55=110	1491.03 GL	Near DC's residence	1952	Requires repairs
Wesu	1 x 60 1 x 90	1674.15 TWL	At Wesu TW	1985	Good
Hospital	60	1664.50 TWL	At Wesu Hospital	1985	Good
Total	1,120				

The two existing high level reservoirs of 45 m^3 capacity each constructed in 1952 are still functional but require repairs to the screeding, which is spalling. The reservoirs are critical in serving the high level areas whilst the supply to reservoir no. 4 is rehabilitated. Although the two high level reservoirs are past their economic life they, in the long term, need to be replaced and the capacity augmented. A detailed network analysis would be necessary at the feasibility stage to assess the capacity and location of the replacement reservoirs.

The high level reservoirs receive water from both treatment works as follows:

- 75 mm diameter GS gravity supply from Wesu treatment works.
- 75 mm diameter uPVC pumped supply from Wundanyi treatment works.

The distribution mains from the reservoirs are:

- 75 mm diameter GS to Wundanyi trading centre.
- 40 mm diameter GS and 50 mm diameter uPVC to Sunguhulu Primary School.
- 50 mm diameter uPVC to government quarters near the reservoirs.

There is a booster pumping station at Reservoir No. 3 which was designed to pump water to Reservoir No. 4. The booster pumping station is not operational as there are no serviceable pumps, motors or switchgear.

The pump station building is in a state of disrepair and the roof is leaking and needs rehabilitation. The surge vessel and pipework is however mostly intact.

Since Reservoir No. 4 does not receive any water, the consumers in that area are served from the high level and Wesu treatment works storage tanks. The pumping main between reservoir no. 3 and 4 is a 110mm diameter uPVC pipe, is reported to have had several leakages. This could have resulted from an incorrect choice of pipe material and pressure rating and a poorly laid pipe in the rocky terrain. The pipe needs to be replaced in order to bring Reservoir no. 4 back into service. The District Water office has been replacing damaged or leaking parts of this uPVC pumping main with a galvanised steel main. It is recommended that the entire length of 1200 metres of the main should be replaced.

3.7 DISTRIBUTION

3.7.1 Reticulation

3.7.1.1 Coverage

The existing water distribution network within the town centre is shown in Figure 3.5.

The reticulation in town and the surrounding area is extensive and a significant portion was laid in 1985. Nearly all the reticulation laid in 1985 was uPVC and the operation and maintenance personnel noted that they were experiencing numerous leakages on the lines. The reticulation consists mainly of 100, 80 and 50 mm pipes and the town is considered to be fairly well covered. A more detailed condition survey, however, would be necessary at the feasibility stage to assess the actual state of the distribution mains.

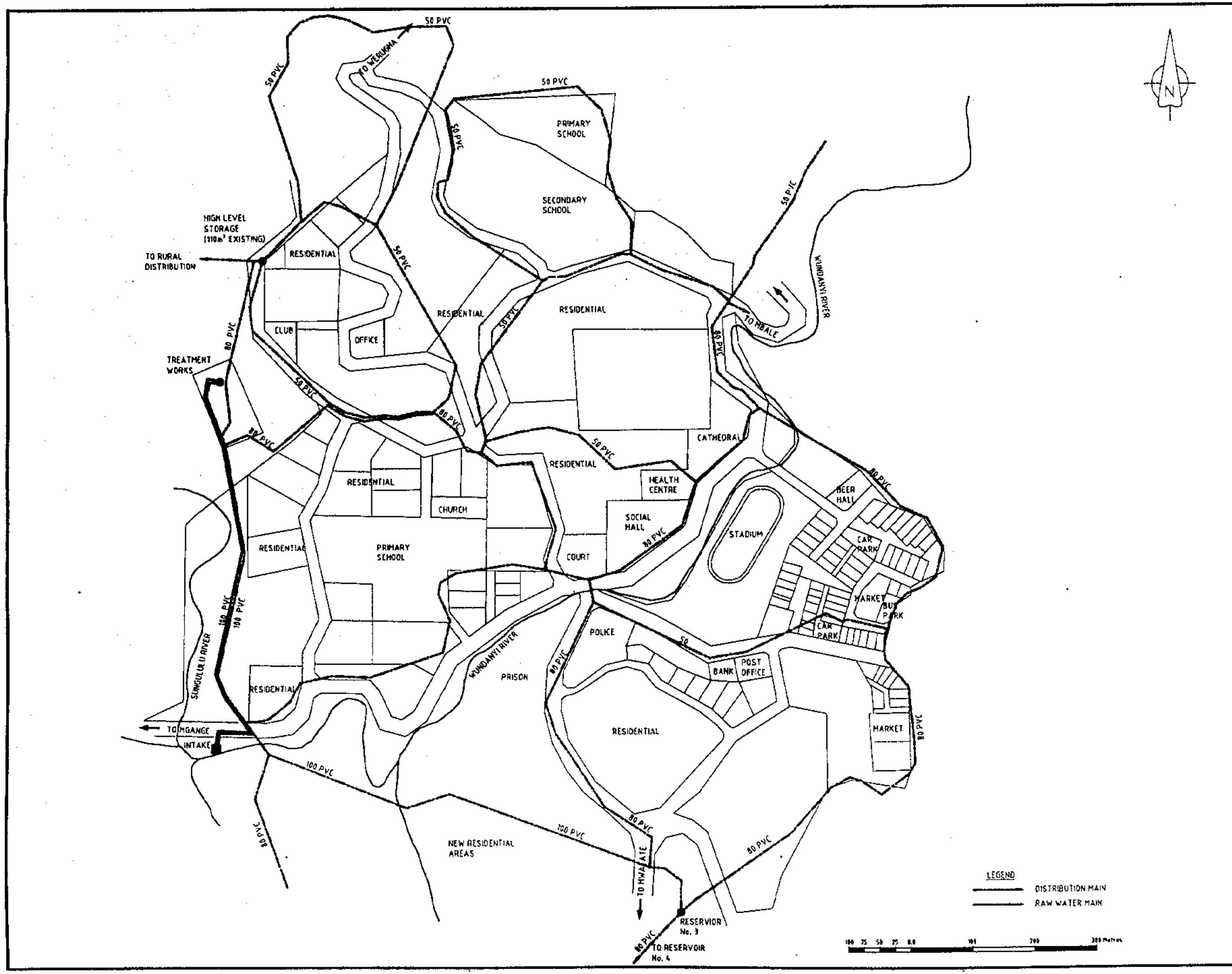
3.7.1.2 Pumping mains

The pumping mains on the reticulation system are discussed in the individual sections under:

- Wundanyi raw water intake for the raw water pumping main.
- Transmission (pumping) mains for pumping mains from the treatment works to reservoirs.
- Storage pumping main between Reservoir 3 and 4 as per report page 3-7.

(c) Consumer connections

Operational staff report that there are 1,003 metered consumers connected to the reticulation system and that approximately 50% of the metres are functional.



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Drawing Title
WANDANYI TOWN EXISTING WATER SUPPLY

Date	Fig. No.
JAN 2001	3.5

(d) Gravity reticulation

The majority of the gravity reticulation was laid in 1985 and consists of 50 mm, 80 mm and 110 mm uPVC pipes. The operators reported that the uPVC pipes have been problematic and are in the process of replacing damaged sections with galvanised steel, uPVC pipes in steep slopes in the hilly terrain in Wundanyi get exposed due to reduction in the cover to pipes as a result of soil erosion and sometimes the pipes are damaged by farmers cultivating the land. In some cases where the erosion is severe, the pipes are exposed to the sun. The following table shows the total pipe length of the three main diameters laid in 1985.

Table 3.3 Lengths of uPVC gravity reticulation mains laid in 1985

Pipe diameter (mm)	Length (Km)
50	7.0
80	11.6
100	6.6

According to the District Water office, a significant portion of the uPVC pipes has been replaced with the preferred galvanised steel (GS) pipes.

The general condition of the older GS mains is reported to be poor, especially due to corrosion. The District Water office has been replacing these pipes as and when the budget allows.

(e) Valves and valve chambers

It is reported that over 90% of the air valves do not function. These have been damaged as a result of vandalism or corrosion. Properly functioning of air valves in the hilly terrain in Wundanyi is essential, as it would reduce damage to pipes due to air locks.

It was also reported that most of the original cast iron valve chamber covers have been vandalised. It is suggested that the replacement chamber covers be constructed of reinforced concrete as these are less prone to vandalism.

3.8 EXISTING O&M

3.8.1 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 35 staff are employed of which 12 (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.

3.8.2 System operation

(a) Chemical dosing regime

The available operational records for April 2000 for both Wesu and Wundanyi water treatment works show the following chemical doses being applied:

Table 3.4 Chemical dosing rates

Aluminium sulphate (mg/l)	Alkalinity consumed (meq/l)	Soda ash (mg/l)	Alkalinity added (meq/l)
80	0.808	64	1.208

The dosing rates are consistently the same for both treatment works for the whole month.

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 the raw water pH as follows:

- PH 7.0 at Wesu Treatment Works
- PH 6.9 at Wundanyi Treatment Works

The available raw water quality analyses of 18/12/2000 shows alkalinity of 44mg/l as calcium carbonate and a pH of 6.8. The calculated inorganic carbon speciation for this alkalinity at a pH of 6.8 is summarised in Table 3.5.

Table 3.5 Inorganic carbon speciation against temperature

Temperature (°C)	10	15	20	25
pH	6.8	6.8	6.8	6.8
Alkalinity (mg/l as $CaCO_3$)	44	44	44	44
$[H^+]$ (mol/l)	1.585E-07	1.585E-07	1.585E-07	1.585E-07
$[OH^-]$ (mol/l)	1.861E-08	2.865E-08	4.319E-08	6.384E-08
$[H_2CO_3^*]$ (mol/l)	4.057E-04	3.660E-04	3.356E-04	3.126E-04
$[HCO_3^-]$ (mol/l)	8.790E-04	8.790E-04	8.789E-04	8.788E-04
$[CO_3^{2-}]$ (mol/l)	1.801E-07	2.062E-07	2.329E-07	2.596E-07
C_T (mol/l)	1.285E-03	1.245E-03	1.215E-03	1.192E-03

Table 3.6 Coagulation conditions for current dosing regime

Temperature (°C)	10	15	20	25
New alkalinity (meq/l)	1.279	1.279	1.279	1.279
New C_T (mol/l)	1.889E-03	1.849E-03	1.819E-03	1.796E-03
Coagulation pH	6.79	6.77	6.76	6.74
$[H^+]$ (mol/l)	1.636E-07	1.696E-07	1.751E-07	1.799E-07
$[OH^-]$ (mol/l)	1.803E-08	2.678E-08	3.911E-08	5.623E-08
$[H_2CO_3^*]$ (mol/l)	6.096E-04	5.698E-04	5.394E-04	5.164E-04
$[HCO_3^-]$ (mol/l)	1.279E-03	1.279E-03	1.279E-03	1.279E-03
$[CO_3^{2-}]$ (mol/l)	2.538E-07	2.805E-07	3.068E-07	3.327E-07
$[Ca^{2+}]$ (mol/l)	2.994E-04	2.994E-04	2.994E-04	2.994E-04
$[Ca][CO_3]$	7.599E-11	8.398E-11	9.187E-11	9.962E-11
Dissociation constant for calcite	6.374E-09	5.821E-09	5.333E-09	4.900E-09
Calcite saturation	1.2%	1.4%	1.7%	2.0%
Dissolved CO_2 (mg/l)	26.8	25.1	23.7	22.7
Hardness (mg/l as $CaCO_3$)	30	30	30	30

The coagulation pH is within the range stipulated in the 1986 Design Manual, but the water is under-saturated with respect to calcite and will be aggressive towards concrete. The charts in the 1986 manual confirm that the product water is extremely aggressive. To achieve stable product water the soda ash dose must be increased substantially to between 117 mg/l and 128 mg/l depending on temperature.

The dosing rate for chlorine is not stated, however the reported residual chlorine of 0.3 - 0.5 mg/l after 10 minutes and 0.2 mg/l after 60 minuets. This is below the recommended residual chlorine concentration of 0.5 mg/l after 30 minutes. The chlorine dosing rate needs to be re-assessed.

(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.

(c) Consumer connections

Operational staff report that there are 1,096 metered consumers connected to the reticulation system and that approximately 50% of the metres are functional.

(d) Bulk flow metering

Only one bulk flow meter at Wundanyi treatment works is operational. The raw water flow to both treatment works is un-metered. None of the flow meters at reservoirs are operational. The two meters on treated water mains at Wesu treatment works are not operational. These meters have been out of order for some time now. It is therefore not possible to verify the flow through the system with any accuracy. This makes effective operation of the system difficult.

3.9 LEVELS OF SERVICE

3.9.1 Population served

According to the District Water Office, there are 1,003 active connections in Wundanyi.

The present population of the service area is 3,690 people. Adding another 200 consumers under the institutional category (see section 4.1.2 of this report) results in a total of some 3,890 people being served by the Wundanyi Water Supply. There are no water kiosks in Wundanyi.

The preliminary results of the 1999 census gave the town's population as 6,930, so approximately 56% of the population is currently provided with piped water. On an area basis, the town centre and environs are covered by potable water supply system.

3.9.2 Per capita supplies

The District Water Office figure for April gave a production of 671 m^3/d. Using the DWO's figure, this is equivalent to 172 lcd for the estimated connected population of 3,890 or 97 lcd for the total population of 6,930. The present total water production capacity is about 1536 m^3/d.

3.10 ON-GOING OR PLANNED EL NIÑO WORKS

There are no on-going or planned El Niño emergency Project (ENEP) works in Wundanyi.

3.11 OTHER WORKS AND PROJECTS

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

4 PROPOSED STRATEGY FOR WATER SUPPLY REHABILITATION

4.1 DEMAND/CONSUMPTION PROJECTIONS TO 2010

4.1.1 Population projections to 2010

The population of Wundanyi according to the 1999 census is 6,930. 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	6,930
2000	7,200
2001	7,500
2002	7,800
2003	8,100
2004	8,400
2005	8,800
2006	9,100
2007	9,500
2008	9,900
2009	10,300
2010	10,700

4.1.2 Water demand projection

Demand rates are taken from the Ministry of Water Development Design Manual (1986) and are included as Table 4.8 of Appendix F2.

Table 4.2 shows the 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	16%	1,110	250	277.5
Middle income	40%	2,772	150	415.8
Low income	44%	3,048	75	228.6
Total	100%	6,930		**921.9**

Table 4.2 Projected Water Demands and Current System Capacities

Year	Population	Income brackets		Population	Demand rate lcd	Demand m^3/d	Institutional demand m^3/d	Total demand m^3/d	Production capacity m^3/d	Transmission capacity m^3/d	Storage capacity m^3
		Status	%								
1999	6,930	High	16	1,109	250	277					
		Middle	40	2,772	150	416	160	**1,082**	1,536	1,536	1,120
		Low	44	3,049	75	229					
2000	7,200	High	16	1,152	250	288					
		Middle	40	2,880	150	432	160	**1,118**	1,536	1,536	1,120
		Low	44	3,168	75	238					
2001	7,500	High	16	1,200	250	300					
		Middle	40	3,000	150	450	160	**1,158**	1,536	1,536	1,120
		Low	44	3,300	75	248					
2002	7,800	High	16	1,248	250	312					
		Middle	40	3,120	150	468	160	**1,197**	1,536	1,536	1,120
		Low	44	3,432	75	257					
2003	8,100	High	16	1,296	250	324					
		Middle	40	3,240	150	486	160	**1,237**	1,536	1,536	1,120
		Low	44	3,564	75	267					
2004	8,400	High	16	1,344	250	336					
		Middle	40	3,360	150	504	160	**1,277**	1,536	1,536	1,120
		Low	44	3,696	75	277					
2005	8,800	High	16	1,408	250	352					
		Middle	40	3,520	150	528	160	**1,330**	1,536	1,536	1,120
		Low	44	3,872	75	290					
2006	9,100	High	16	1,456	250	364					
		Middle	40	3,640	150	546	160	**1,370**	1,536	1,536	1,120
		Low	44	4,004	75	300					
2007	9,500	High	16	1,520	250	380					
		Middle	40	3,800	150	570	160	**1,424**	1,536	1,536	1,120
		Low	44	4,180	75	314					
2008	9,900	High	16	1,584	250	396					
		Middle	40	3,960	150	594	160	**1,477**	1,536	1,536	1,120
		Low	44	4,356	75	327					
2009	10,300	High	16	1,648	250	412					
		Middle	40	4,120	150	618	160	**1,530**	1,536	1,536	1,120
		Low	44	4,532	75	340					
2010	10,700	High	16	1,712	250	428					
		Middle	40	4,280	150	642	160	**1,583**	1,536	1,536	1,120
		Low	44	4,708	75	353					

The following institutional demands have been included in addition:

Activity	Nr	l/unit/d	total
Commercial			
Retail shops	37	100	3700
Hotel low class (assume 20 beds each)	520	50	26000
Butcheries	25	500	12500
Wholesale shops	3	100	300
Laundries	3	5000	15000
Bars restaurants	24	500	12000
Bookshops	4	100	400
Hardware shops	3	100	300
Agro-chemical shops	14	100	1400
Music shops	1	100	100
Home utensils shop	1	100	100
Garages	2	500	1000
Total commercial			72800
Institutional			
Hospital (assume 200 beds at Wesu District Hospital)	200	200	40000
Boarding schools	500	50	25000
Day schools	2000	5	10000
Clinics	2	5000	10000
Total institutional			85000
Industrial			
No known industrial demand			0
Total commercial, institutional and industrial demand	l/d		157800
	m3/d		157.8
	say		**160**

The overall total water demand (1999) is therefore 1,082 m^3/d.

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

4.1.3 Comparison of projected demand with system capacities

Table 4.2 compares the projected water demand with the capacities of the various system components.

The treatment capacity is the total design flow for the two treatment works. The transmission capacity is the sum of the treated water pumps at Wundanyi and the maximum production at Wesu treatment works, which flows by gravity into the reticulation.

The transmission capacity, both treatment and storage capacities will require expansion.

4.2 PRELIMINARY DESIGN OF RECOMMENDED REHABILITATION OPTION

The principal design criteria for water engineering design is presented in Appendix F2.

The following comments summarise the main focus of the proposed rehabilitation plan for Wundanyi water supply.

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

4.2.1 Raw water pumping

The raw water pumping station at Wundanyi does not have any stand-by in the event of a power or pump failure as the existing diesel engine is not serviceable. A diesel engine capable of running a Ritz pump type 40-315 of nominal duty 16 m^3/h at 33 m head and a speed of 1450 rpm. Is required.

4.2.2 Laboratory facilities

The laboratory at Wundanyi water treatment works lacks the necessary laboratory equipment and reagents for routine determinations of basic physical and chemical analysis of raw and treated water.

The laboratory equipment should be provided to facilitate regular monitoring of raw and treated water quality. This will ensure that correct amounts of chemicals are used and safe drinking water is delivered to the consumers.

Laboratory equipment should be available for routine determinations of basic physical, chemical and bacteriological tests.

The leaking roof of the laboratory at Wundanyi treatment works should be repaired to prevent damage to equipment and reagents.

4.2.3 Chemical dosing regime

Wesu TW:
The mechanical dosing units are not operational. These need to be replaced.

Wundanyi TW:
As for Wesu, the mechanical dosing units are not operational. The chemical store roof is leaking and the floor is eroded. The dosing units should be replaced and the roof and floor repaired as a priority.

4.2.4 Chemical dosing for disinfection

The World Health Organisation recommends that water intended for potable use should be disinfected with 0.5 mg/l of free available chlorine for at least thirty minutes at a pH less than 8. This recognises that germicidal efficiency is dependent on both the free chlorine concentration and the time of contact.

Table 4.3 - Schedule of prioritised rehabilitation works - Wundanyi

Item	Unit	Ref	Component	Condition	Repairs needed	Comments	Priority
1.	Wundanyi Raw water Intake	1.1	Trash rack and screens	Good	None	Essential to prevent foreign materials from being drawn into the low lift pumps	NA
		1.2	Structure	Good	None	Prone to flooding due to low elevation Ensure all electric fittings are wall mounted	NA
		1.3	Pumps				
			Duty pumps & motors (2 no.)	operational	routine maintenance	Controls and cabling layout is untidy	Low
			Stand-by diesel pump & engine	out of oder	replace with new	should include switchgear	Very High
	Wesu raw water intake	1.4	Gravity weir intake and pipe to TW's	Good	None	Flows are very low, none realeased downstream	NA
2	Wundanyi Treatment streams	2.1	2 no. 16m³/hour horizontal flow sedimentation tank				
			Alum dosing equipment	Manual dosing	Replace	Gravity dosers are preferred	High
			Soda Ash dosing equipment	Manual dosing	Replace	Gravity dosers are preferred	High
		2.2	2 no. 16m³/hour rapid gravity filter				
			Filter media	Poor	Replace	Affects performance of filter	High
			Underdrains	To be inspected	Inspect & replace as necessary		Medium
	Wesu treatment works	2.3	2 no. composite filteration units				
			Structure	Good			NA
			Filter media	Poor	Replace	Affects performance of filter	High
			Alum dosing equipment	Manual dosing	Replace	Gravity dosers are preferred	High
			Soda Ash dosing equipment	Manual dosing	Replace	Gravity dosers are preferred	High
3	Wundanyi Backwash tank	3.1	60m³ backwash tank				
			Structure	Good	None		NA
	Wesu treatment works	3.2	Backwash system				
			Tank	Poor	Replace	without backwash the filter will not perform well	High
			Backwash pump	not operational	Replace		High
4	Wundanyi Clear water tanks	4.1	200m³ clear water tank				
			Structure (Reservoir no. 1)	Good	None		
			Chlorine dosing equipment	Manual dosing	Replace	Gravity dosers are preferred	High
	Wesu clear water tanks	4.2	1 x 60m3 & 1 x 90m3 tanks				
			Structure	Good	None		
			Chlorine dosing equipment	Manual dosing	Replace	Gravity dosers are preferred	High
5	Wundanyi Treated water pumps	5.1	Pumps				
			Duty pumps & motors (2no.)	operational	routine maintenance		NA
			Stand-by diesel pumps & engine	out of oder	replace with new	should include switchgear	Very High
			Controls & cabling	Untidy	Rehabilitate		Low
6	General	6.1	Pipes & valves	Good	None		Medium
7	Wundanyi treatment works buildings	7.1	Chemical store				
			Alum and soda ash	Poor	Repair leaking roof	Chemicals need dry storage to prevent damage	High
			Chlorine	Poor	Repair leaking roof		High
			Laboratory	Poor	Complete rehabilitation and re-equip	Equip with chemicals and apparatus for carrying out daily tests. Train technicians	High
8	Meters	8.1	Bulk meters				
			Wesu Treatment works	not operational	Replace	Two at treatment works are essential	High
			Reservoirs	not operational	Replace	Three at reservoirs could be installed later	Medium
9	Pumping mains	9.1	Existing DN100 uPVC pipes	In use	Repair as necessary	Routine maintenance to prevent sudden bursts as they are essential links without which there will be no supply	High
10	Wundanyi site works	10.1	Drainage	Good	None		NA
		10.2	Fencing & gates	Good	None		NA
		10.3	Staff housing	Good	None		NA
11	Storage	11.1	Storage reservoirs				
			High level (2 x 45m3)	Deteriorating	Repairs to cracks in walls etc	Essential for supplying high elevation reticulation	High
			Wesu Hospital Reservoir	Good	None		NA
			Reservoirs at Wesu (2x60)	Good	None		NA
			Reservoirs 1,2,3 & 4	Good	None		NA
	Booster station	11.2	Booster station No. 3 at Reservoir No. 3	not operational	Replace pumps & motors	Essential for supplying high elevation reticulation	High
			Pumping main from 3 to 4	not operational	Replace pumping main		High
12	Distribution	12.1	Existing pipes = and > DN50	In use	Rehabilitate, replace as necessary		High
		12.2	Air valves and valve chamber covers	most are not operational	Replace air valves Provide chamber covers	Essential for consistant supply and lower maintenance	High
		12.3	Consumer meters	Approx. 50% are out of order.	Install domestic meters as necessary	Essential for consistant billing and control of leakage and wastage	High

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

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

In the absence of determinations of the above parameters, it is not possible to check the adequacy of the dose applied. The chlorine dosing units should be replaced.

4.2.5 Filter media and underdrains

The MENR standard specification for filter media is sand of 0.5 mm to 1.0 mm (generally 0.6 to 0.8 mm) and a uniformity coefficient not less than 1.5. The filter bed is between 0.7 m and 1.0 m deep. Modern filters use slightly coarser material: Degrémont use silica sand with an effective size close to 1 mm and Paterson Candy use a sand of 0.6 to 1.18 mm. The existing media should be replaced with silica sand with an effective size close to 1 mm and a uniformity coefficient of 1.5 or less. The opportunity should also be taken to inspect the underdrain system and identify any required rehabilitation measures.

The backwash pump of nominal duty 9 m^3/h at 10 m head and the backwash tank at Wesu treatment works are to be replaced.

4.2.6 Clear water pumps

The treated water pumping station at Wundanyi treatment works does not have the required stand-by pumping capacity in the event of power or pump failure. Two pumps of nominal duties 9 m3/h at 75 m head and 20 m3/h at 44 m head with diesel engines have to be replaced.

4.2.7 Metering of treated water production

Wesu:
The existing flow meter on the 2" clear water gravity main has been broken for several years. It should be replaced with a working meter. One additional meter should be fitted on the new 80mm diameter pipe to the hospital reservoir.

Wundanyi:
The existing bulk flow meter is operational.

On reticulation:
There are no operational water meters on any of the storage reservoirs. For information on zonal water demand and better estimate of system losses the existing broken water meters on Reservoirs 2, 3 and 4 should be replaced.

The following new flow meters will be required:

Ref.	Location	Flow range (m^3/h)	Size (mm)	Number required
1	Wesu treatment works	0 - 50	80	1
2	Wesu treatment works	0 - 50	50	1
3	Storage reservoirs 2,3 and 4	0 - 100	150	3

4.2.8 Storage

The high level storage tanks (2 x 55m^3) need to be rehabilitated to extend their life. The work will include repairs to cracks in the masonry walls, cleaning and painting.

Reservoir No. 4 does not receive water as designed from Reservoir No. 3 as the booster station at Reservoir No. 3 is not operational. This booster station needs to be rehabilitated and equipped so that Reservoir No. 4 is fully utilised. This requires the installation of two booster pumps (one electric and one diesel), switch gear and building repairs including leaking roof). The pumps have to overcome a static lift of 51.8 m. Assuming that the reservoir is filled 8 hours, the pumps should be capable of a nominal duty of 25 m3/h at 62 m head.

The pumping main from Reservoir No. 3 to No. 4 was reported as having frequent bursts. These will have to be individually investigated and repaired. A significant portion of the original 110 mm diameter PVC main has been replaced with a GS pipe, however it is recommended that a new main be laid.

The combined capacity of the existing service reservoirs is 1,120 m^3/d. The Ministry's design manual requires a balancing storage volume of twelve hours and an emergency storage volume of eighteen hours for systems supplied by pumping. For a plant output of 1,536 m^3/d, the required storage volume is therefore 1,152 m^3 or 32 m^3 more than the required capacity. Therefore no new storage is required at present.

4.2.9 Distribution

4.2.9.1 <u>Reticulation pipework</u>

The bulk of the reticulation consists of 50 mm, 80 mm and 100 mm diameter uPVC pipes laid in 1985. The uPVC pipes have been problematic and O&M staff have been replacing them with GS pipes. An allowance has been made in the rehabilitation schedule to continue the replacement exercise. Routine maintenance is required to keep the system operational and this can be achieved with a dedicated and well-equipped maintenance team with access to spare parts and transport.

4.2.9.2 Valves and valve chambers

Over 90% of the air valves do not function. These are essential in the hilly terrain in Wundanyi and should be replaced.

Valve chamber covers should be replaced where the original covers have been vandalised to prevent damage to the valves and pipes within the chambers.

4.2.9.3 Consumer meters

Approximately 50% of the 1,003 active consumers do not have functioning water meters. It is recommended that functional consumer meters be installed.

4.3 COSTING OF RECOMMENDED REHABILITATION PLAN

An indicative budget for rehabilitating the existing Wundanyi water supply system is Ksh 145,000,000 as per the breakdown in Table 4.4 overleaf:

4.4 EXPANSION OF WATER SUPPLY FACILITIES

4.4.1 General

Comparing the projected water demand to existing capacities it is found that there will be:

- A small shortfall in treatment capacity of $47m^3/d$ by 2010 as the current treatment capacity is $1,536m^3/d$ while the 2010 projected demand is $1,583m^3/d$.
- A small shortfall in storage capacity of $68m^3$ as the required storage capacity in 2010 will be $1,188m^3$ while the existing storage capacity is $1,120m^3$.
- A need to expand the reticulation to the areas surrounding the immediate town centre.

4.4.2 Source

The two existing raw water sources are unable to satisfy the two treatment works capacities. Therefore for the additional supply required, a new source needs to be identified.

It is evident that groundwater potential is low and not a long term permanent supply option. A surface source will have to be identified to meet the current shortfall and demand.

Table 4.4 : Cost estimates of rehabilitation works for Wundanyi water supply

Ref	Description	Unit	Quantity	Rate (Kshs)	Amount (Kshs)
Wundanyi raw water intake and treatment works					
1	**Pumphouse & raw water pumps**				
1.1	Rehabilitate structure (doors, windows, electrical wiring etc)	sum	1	1,000,000	1,000,000
1.2	Stand-by diesel pump and engine 16m3 @ 33m (5.5kW)	nr	1	1,500,000	1,500,000
2	**Treatment works**				
2.1	**Sedimentation tanks**				
2.1.1	Gravity chemical dosers for alum and soda ash	no.	2	600,000	1,200,000
2.2	**Filters**				
2.2.1	Filter media	m^3	12	15,000	180,000
2.2.2	Underdrainage system	sum	1	500,000	500,000
2.3	**Clear water tanks**				
2.3.1	Gravity chemical dosers	no.	4	600,000	2,400,000
2.4	**Treated water transmission**				
2.4.1	Stand-by diesel pump and engine 9m3 @ 75m and 20m3 @ 44m	nr	2	1,500,000	3,000,000
2.5	**Buildings**				
2.5.1	Rehabilitate offices, chemical store and laboratory	sum	1	2,000,000	2,000,000
2.5.2	Laboratory equipment	sum	1	3,000,000	3,000,000
2.5.3	Reagents	sum	1	1,000,000	1,000,000
Wesu raw water intake and treatment works					
3.1	**Inlet works**				
3.1.1	Gravity chemical dosers for alum and soda ash	no.	2	600,000	1,200,000
3.2	**Composit filteration units**				
3.2.1	Filter media	m^3	12	15,000	180,000
3.2.2	Underdrainage system	sum	2	500,000	1,000,000
3.3	**Backwash system**				
3.3.1	Pump 9m3 @ 10m (1.1kW)	nr	1	850,000	850,000
3.3.2	5m3 capacity tank including support structure	nr	1	100,000	100,000
3.4	**Clear water tanks**				
3.4.1	Gravity chemical dosers	no.	2	600,000	1,200,000
3.5	**Water meters**				
3.5.1	Bulk meters (various diameters)	no.	3	250,000	750,000
Reticulation					
4.1	**Pumping mains**				
4.1.1	New pumping main between reservior 3 and 4, 100mm dia GS	m	1,200	4,000	4,800,000
4.2	**Water meters**				
4.2.1	Domestic meters	nr	500	4,000	2,000,000
4.2.2	Meter test bench	nr	1	3,500,000	3,500,000
4.3	**Gravity reticulation (including air valves and chamber covers)**				
4.3.1	50mm diameter GS	m	3,000	3,000	9,000,000
4.3.2	80mm diameter GS	m	3,500	3,500	12,250,000
4.3.3	100mm diameter GS	m	4,000	4,000	16,000,000
4.3.4	Toolkits	nr	3	250,000	750,000
Storage					
5.1	Re-equip booster pump station no. 3 with 2 nr pumps 25m3 @ 62	nr	2	1,500,000	3,000,000
5.2	Rehabilitate booster pump station no. 3	sum	1	1,000,000	1,000,000
5.3	Bulk meters (various diameters)	no.	3	250,000	750,000
5.4	Rehabilitate high level tanks 2 x 55m3 each	sum	1	500,000	500,000
Logistical facilities and equipment					
6.1	4WD twin-cab pick-ups	no.	2	2,500,000	5,000,000
6.2	Saloon cars	no.	2	1,500,000	3,000,000
6.3	Motorcycles	no.	4	250,000	1,000,000
6.4	Computers	no.	5	200,000	1,000,000
6.5	Printers	no.	2	100,000	200,000
6.6	Computer software	sum	1	1,000,000	1,000,000
6.7	Office equipment & furniture	sum	1	2,000,000	2,000,000
		Total of works			**87,810,000**
Add	20% preliminaries and general items				17,562,000
		Sub-total			105,372,000
	15% contingencies				15,805,800
		Sub-total			121,177,800
	20% consultancy fee				24,235,560
		GRAND TOTAL			**145,413,360**
				say	**145 million**

4.4.3 Treatment capacity

There is provision at Wundanyi treatment works for adding a second parallel stream to the existing. This would increase the treatment capacity by $768m^3/d$. However this may not be necessary as the shortfall in treatment capacity is only $47m^3/d$. However, from chapters 2 and 3 it is evident that an additional raw water source would have to be sited so as to satisfy the current and projected demands. In developing a cost estimate, it has been assumed that a treatment works will not be expanded.

4.4.4 Storage

Existing effective storage is $1,120m^3$.

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 $1,583m^3$/day and therefore storage is of the order of $1,188m^3$. An additional $68m^3$, say $100m^3$ is required.

4.4.5 Distribution

The existing Wundanyi and Wesu supplies cover an area of approximately $8km^2$ at present and contain some 35 km of mainly 50, 80 and 100 mm diameter pipes. The population will increase by 54% between 1999 (6,930) and 2010 (10,700). Assuming that the population density will remain the same, the additional land area developed will be 4.3 km^2, which would require an additional 19 km of reticulation of mainly 80-100 mm diameter for the purpose of initial planning estimates for expansion of the reticulation.

4.4.6 Cost of expansion works

The initial planning cost estimates are presented in Table 4.5.

4.5 O&M COSTS AFTER REHABILITATION

4.5.1 Power tariffs and costs

(a) Tariffs

Power charges are calculated using the tariffs and levies prevailing in December 2000. These are shown in Table 4.6.

Table 4.5 : Initial planning cost estimates for expansion works for Wundanyi water supply

Ref	Description	Unit	Quantity	Rate (Kshs)	Amount (Kshs)
Source works					
1	Dam storage	sum	1	*	*
2	Pumphouse, raw water pumps and transmission mains	sum	1	*	*
Storage					
3	Additional storage of 100 m3	nr	1	2,500,000	2,500,000
Distribution pipework					
4	uPVC and steel pipes of 80-100 mm diameter (inclusive of valves, chambers etc.)	m	19,000	4,000	76,000,000
		Total of works			**78,500,000**
Add	20% preliminaries and general items				15,700,000
		Sub-total			94,200,000
	15% contingencies				14,130,000
		Sub-total			108,330,000
	20% consultancy fee				21,666,000
		GRAND TOTAL			**129,996,000**
				say	**130 million**

* The estimate for source works and transmission can only be prepared after a source has been identified

Table 4.6 KPLC power tariffs

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

(b) Running load at Wundanyi raw water pump station

The total running load at the Wundanyi raw water pump station is calculated with two pumps in operation and lighting and small power at site. This is estimated to be 7.1 kVA, made up as follows.

Table 4.7 Running load at raw water pump station

Item	Two raw water pumps	Lighting and small power, say	Total running load
Flow (m^3/hr)	32		
Head (m)	33		
Efficiency	65.0%		
Power (kW)	4.4	2.0	6.4
Power (kVA) at cosF = 0.9	4.9	2.2	7.1

The monthly power consumption with two pumps in continuous operation is 4,672 kWh, so charge band A1 applies.

(c) Running load at Wundanyi clear water pump station

The total running load at the Wundanyi clear water pump station is calculated with pumps 1, 2 and 3 in operation and lighting and small power at site. This is estimated to be 7.1 kVA, made up as follows.

Table 4.8 Running load at clear water pump station

Item	Pump 1	Pump 2	Pump 3	Lighting and small power, say	Total running load
Flow (m^3/hr)	9	15	20		
Head (m)	64	44	44		
Efficiency	60.0%	60.0%	60.0%		
Power (kW)	2.6	3.0	4.0	2.0	11.6
Power (kVA) at cosF = 0.9	2.9	3.3	4.4	2.2	15.2

The monthly power consumption with three pumps in continuous operation is 8,468 kWh, so charge band B1 applies.

(d) <u>Power costs</u>

To develop power cost estimates, it is assumed that the pumps are started at 8:00 am each day and run until the service reservoirs have been replenished.

Table 4.9 Annual power costs at Wundanyi

Year	Demand (m^3/d)	Total power cost (Kshs p.a.)
2001	1,158	401,649
2002	1,197	435,618
2003	1,237	470,458
2004	1,277	505,298
2005	1,330	551,460
2006	1,370	586,300
2007	1,424	626,757
2008	1,477	664,205
2009	1,530	701,654
2010	1,583	739,102

4.5.2 Chemical costs

Chemical costs are estimated for the current aluminium sulphate dose of 80 mg/l and a soda ash dose of 120 mg/l. the estimated chemical costs are shown in Table 4.10.

Table 4.10 Estimated chemical costs

Chemical	Cost Kshs/kg	Dosage (mg/l)	Cost (Kshs/m^3)
Aluminium sulphate	28	80	2.24
Soda ash	7	120	0.84
Calcium hypochlorite	245	3.2	0.78
Total		39	3.86

The annual chemical costs are given below for the forecast water production.

Table 4.11 Annual chemical costs

Year	Daily water production (m^3/d)	Annual chemical costs (Kshs per annum)
2001	1,158	1,631,506
2002	1,197	1,686,453
2003	1,237	1,742,809
2004	1,277	1,799,165
2005	1,330	1,873,837
2006	1,370	1,930,193
2007	1,424	2,006,274
2008	1,477	2,080,945
2009	1,530	2,155,617
2010	1,583	2,230,289