# CHAPTER V ESTABLISHMENT OF MASTER PLAN

## 5.1 Basic Strategy

### 5.1.1 Fundamental Concepts

The Study Schemes are based on existing piped water supply systems which, for one reason or another, do not provide an adequate supply of water to consumers. The objective of this Study is therefore to improve, rehabilitate and extend these schemes, as necessary, to provide an adequate supply for a Planning horizon year of 2010.

In the context of this report, an adequate supply is defined as one that provides water 24 hours a day, in sufficient quantity to satisfy the consumption rates established in Section 4.1, with a minimum pressure of 10m, and to MLRRWD water quality guidelines which are similar to the international WHO guidelines. Disinfection is therefore required as a basic minimum level for all schemes.

To improve sustainability, it is required to increase cost recovery through a number of initiatives including reduction of unaccounted water and the universal application of metering. It is to be then stressed that metering is critical for successful operation of the schemes. The consumer survey showed that without the constraint that metering applies on consumption, rates of up to 5 times the design rates can be expected, with the result that the systems will fail to operate as designed. This is one of the principal reasons for poor performance of existing schemes.

To assist operation and maintenance of the schemes and to reduce recurrent costs, the maximum use of gravity supplies will be made, pumping being limited to areas where it is essential. For the same reason, good quality raw water sources, requiring low levels of treatment, will be used wherever feasible.

It is also to be stressed, that the proposed designs in themselves will not provide a reliable and safe water supply. Improvements are also required in many aspects of management, operations and maintenance.

### 5.1.2 Summarised Scheme Requirements

The population and water demand projections determined from the previous chapter are summarised in below. Requirements for new water production capacity are rounded, after deducting existing usable capacity, taken from Chapter III above. The required raw water capacity allows for 10% losses in the treatment plant.

**Table 5.1-1 Required Production Capacities For Individual Schemes**

| Scheme | 2010 Population | 2010 Demand (m3/day) | Supply Area (km2) | Existing Production Capacity (m3/day) | Required Production Capacity (m3/day) | Required Raw Water Capacity (m3/day) |
|---|---|---|---|---|---|---|
| Meru | 251,668 | 22,725 | 185 | 3,172 | 20,000 | 22,000 |
| Nkubu | 15,611 | 1,915 | 3.5 | (400) | 2,000 | 2,200 |
| Isiolo (1) | 65,471 | 10,671 | 45 | 2,800 | 8,000 | 8,000 (2) |
| Chuka (Whole Area) | 116,577 | 7,255 | 150 | 3,260 | 4,000 | 4,400 |
| Chuka (Supply Area) | 64,433 | 4,403 | 88 | 0 | 4,000 | 4,400 |
| Chogoria | 44,376 | 2,886 | 58 | 0 | 3,000 | 3,300 |
| Maua | 13,344 | 1,493 | 5 | (200) | 1,500 | 1,650 |
| Tigania (Whole Area) | 168,929 | 6,871 | 300 | 3,500 | 3,500 | 3,850 |
| Tigania (Supply Area) | 83,121 | 3,778 | 92 | 0 | 4,000 | 4,400 |

*Notes: ( ) Denotes production capacity beyond service life, to be abandoned*
*Shaded lines include areas outside the study areas.*
*(1) Includes allowance for seasonal migration*
*(2) Additional 10% treatment losses are not required in the event of grandwater source.*

Storage reservoirs are needed to balance peak flows and, in the case of urban areas, for providing emergency storage. As discussed in Section 4, balancing storage is taken as 12 hours at average water demand and, for urban areas supplied by gravity, an additional 12 hours storage will be provided for emergencies. The resultant storage capacities required, after allowing for existing facilities, are shown below:

**Table 5.1-2 Storage Capacity Requirements**

| Scheme | 2010 Demand (m3/day) | Urban demand as % of total | Required Storage (m3) | Existing Storage Capacity (m3) | New Storage Required (m) |
|---|---|---|---|---|---|
| Meru | 22,725 | 61% | 18,260 | 1,008 | 17,250 |
| Nkubu | 1,915 | 68% | 1,605 | 50 | 1,550 |
| Isiolo | 10,671 | 53% | 8,144 | 2,150 | 6,000 |
| Chuka (Supply Area) | 4,403 | 30% | 2,860 | 0 | 2,900 |
| Chogoria | 2,886 | 12% | 1,610 | 0 | 1,650 |
| Maua | 1,493 | 64% | 1,223 | 45 | 1,300 |
| Tigania (Supply Area) | 3,778 | 0% | 1,840 | 0 | 1,900 |

### 5.1.3 Phasing and Logistics

Phasing the construction of schemes is desirable for many reasons. Investments can keep pace with demand, local construction capacity can be maximised and, risks attached to uncertain future projections can be minimised by rescheduling construction either forwards or backwards. Nevertheless, the high initial water demand requirements given in Chapter IV suggest that, in many of the schemes, more than 50% of the ultimate demand capacity is required by the year 2000, or closely thereafter, making phasing appear unattractive.

However this is the theoretical demand calculated by assuming 100% completion of the distribution system in the first year of operation. There are a number of reasons why this is an unrealistic assumption: The demand for individual connections will take a number of years to develop; the capacity for their construction will also limit initial connection rates and, except for small schemes, it is rarely possible to obtain funding for the construction of the entire distribution system during the initial phase of a project.

In practice therefore, the construction of distribution systems is usually phased according to priorities and availability of funds. Spatial water supply coverage therefore increases gradually as the distribution system is extended. The initial supply will therefore be less than the initial demand calculated by direct application of the service levels given in Chapter IV.

For the purposes of phasing construction and for estimating operational expenditure and income for this Study, it has been assumed that 50% of the population will be reached by the initial construction phase, and the remaining 50% will be served as the distribution system is built gradually over the design horizon. Exceptions to this rule are Isiolo and Maua, where their small supply areas are already substantially covered by existing distribution systems. The resultant water supply curves on which the proposed phasing for the individual schemes had been based are shown on ***Figure 5.1-1***.

Logistically the improvement of each scheme will start by providing adequate raw water and treatment capacity, and sufficient transmission lines to enable water to reach the main population centres. The spatial extension of the distribution systems can be gradually increased by phased extensions of the trunk transmission system and annual extensions of the smaller diameter distribution pipelines.

### 5.1.4 Scheme Strategies

(1) Meru

The projected demand for Meru's supply area of 185 km2 by the year 2010 is 22,725 m3/day, compared to the existing capacity of 3,172 m3/day. The supply area ranges in elevation from 2,060 m at the forest edge, in the west of the area to 1,200 m in the east. The existing treatment plant is located close to Meru Town, and therefore close to the centre of demand but is at an elevation of 1,690 m and can only supply the lower half of the supply area by gravity. The northern parts of the existing supply area are supplied by pumping, and it is this area that suffers the most acute water shortages and is in urgent need for augmentation. It is required therefore to provide additional capacity at a sufficiently high elevation to supply this area by gravity.

Approximately 50% of the demand is located in the area around Meru Town, where the consequences of an inadequate water supply on public health is seen to be greatest. The improvement and expansion of supplies to these urban areas is therefore seen as being of the highest priority.

An intake located within the forest to the west of the supply is proposed. A number of advantages can be gained including: good quality raw water; the ability to supply the whole area by gravity and, if the treatment plant is located within the forest boundary, little disruption to human settlement.

In addition to any improvement in water supply infrastructure, the high level of unaccounted for water in Meru makes it essential that improvement in the institutional arrangements for the operation, maintenance and management of the system are effected in parallel.

(2) Nkubu

The existing treatment plant providing a pumped supply of 400 m3/day to Nkubu was built in 1952. It is now beyond its service life and its capacity is inadequate to serve the projected water demand for the town of almost 2,000 m3/day.

The District Water Office has proposed that a new intake be built on the Kiguandegwa River, 4 km upstream of the existing intake, at a sufficiently high elevation to enable gravity supply to the town. There are good arguments for moving the intake a further 8 km or more upstream so that it is located within Mount Kenya Forest where better raw water quality can be expected. However it would be difficult to do this without also supplying the intervening rural areas with water, which would considerably increase the costs and scope of work. The smaller catchment area would also result in a lower safe yield.

The treatment plant can be constructed in two phases each providing a 1,000 $m^3$/day capacity. ***Figure 5.1-1*** suggests that the second phase should be operational by the year 2003. The smaller secondary pipes can be added on a continuous basis annually in accordance with demand and priorities. However, the intake, raw water pipeline and transmission mains can not be phased, and will need to be included with the first construction phase.

(3) Isiolo

The original pumped scheme built in the 1950s was replaced in 1980 by the current gravity system taking water from Isiolo River, with a design capacity of 2,800 m3/day. It is still generally in good condition, but is insufficient to supply existing demands, and requires an additional 8,000 m3/day capacity to meet the projected 2010 demand.

However, water from the Isiolo River is extensively used for irrigation upstream of the intake site. As a result, during period of low flow, there is already insufficient water available at the intake site. Any further development of this source would then have to be in relation to the construction of an impounding dam on the River.

A survey of one potential dam site selected by the District Water Office indicated a retention capacity of 400,000 m3. This is insufficient for the projected water requirements, and would also require a severe reduction of the existing irrigation practices in the area which could prove problematical. Further investigations of potential sources and dam sites, hydrological studies, site investigations etc. are required to establish the viability of alternative surface water sources. All surface water alternatives however will involve considerable investment and operational costs for the necessary civil works, treatment and transmission mains.

In comparison to the high cost of further development of surface water, the development of groundwater sources in the area, represents a cheaper option.

During the initial stages of this study it was found that there had been a number of successful boreholes in the area, and there appeared to be a potential for further groundwater development. In order to gain a better understanding of the groundwater potential an electrical resistivity survey was conducted in the area, which suggested reasonable potential in the area to the south of the town and located positions for three exploratory boreholes.

The position of the proposed well field to the south of Isiolo, is such that the water, after being pumped to the surface, will gravitate to Isiolo. Reservoir storage can be provided at strategic locations at the outskirts of the town, feeding the distribution system.

Development of the well field, and reservoir storage can be phased in accordance with demand. The main distribution pipe network however will need to be installed during the first phase.

(4) Chuka

Chuka's existing water supply is from the Karingani water supply scheme, built in 1976, with a capacity of 3,260 m3/day. The system was designed as a rural water supply system to supply Karingani, Mthanbe and Magumoni Locations, with a supply area totalling some 150 km2, but was provided with a system of small diameter distribution pipes which have proved insufficient for the area.

The proposed supply area for Chuka is primarily the new Chuka Municipal area, which covers approximately 50% of the original Karingani scheme, and has a 2010 projected demand of 4,403 m3/day.

The remainder of the Karingani supply area has an estimated 2010 water demand of 2,852 m3/day, which is close to the capacity of the existing intake and treatment works. It would therefore appear logical that the existing Karingani system should continue to supply the areas outside the municipal area, and that the new system should be specifically designed to supply the Chuka supply area.

An intake in Mount Kenya Forest will combine the advantages of good raw water quality and sufficient elevation to supply the area by gravity, although access to the intake will require a 9 km long access road.

The treatment plant can be built in two phases, with the second phase operational by the year 2003. Approximately 10 km of transmission mains are required to augment the existing distribution system. A detailed survey of the existing system will be required however to record all connections, locate leaks and to report on its condition and expected life.

(5) Chogoria

Chogoria's existing water supply is based on the Mwimbe Water Supply scheme, built in 1975, with a capacity of only 500 m3/day. The capacity is insufficient for the supply area, and Chogoria, with a 2010 estimated demand of 3,000 m3/d, lies in the south of the Mwimbe scheme, connected by a single 150 mm dia pipeline and receives very little water. Complicating meters further, Chogoria is located in the newly formed Tharaka-Nithi District, whereas the remainder of the Mwimbe scheme, including the intake and treatment plant lies in Meru District. A number of factors therefore combine to make it logical for Chogoria to have its own independent scheme.

Chogoria's situation is very similar to Chuka and Meru: An intake in Mount Kenya Forest will combine the advantages of good raw water quality and will provide sufficient elevation to supply most of the area by gravity. In this case the access to the intake will require a somewhat shorter 3 km long access road. However, due to adverse terrain, it will not be possible to supply the entire area by gravity from a single intake. The higher parts of Murugi sub-location are too high to be supplied by gravity, and moving the intake higher into the forest will reduce its yield. This relatively small area will therefore either have to be served by pumping or, by a separate intake.

The treatment plant can be built in two phases, with the second phase operational by the year 2004. The existence of existing distribution lines will reduce the requirements for secondary pipes, however a new transmission main will be required to supply Chogoria Town itself. A detailed survey of the existing system will be required however to record all connections, locate leaks and to report on its condition and expected life.

(6) Maua

The existing system, built in 1956, takes water from the Mboone River 1 km north west of the town. It provides full treatment and a gravity supply of 200 m3/day to only the centre of Maua. It is now beyond its service life and its capacity is inadequate to serve the growing demands of the town.

Water resources in the area are scarce. Mboone River is the main source in the area with the ability to supply Maua by gravity. The supply area is therefore limited by the available yield of this river after allowing for compensation water and supplies to surrounding community water supply systems which also take water from this source. The remaining yield has been estimated to be limited to 1,650 m3/d, which is sufficient to supply the projected demand of the urban areas only.

The Ura River to the south of the supply area is the only other significant source in the area. This could supply the area to the south of Maua through a separate pumped system. A new intake on the Mboone River therefore is the most feasible alternative to improve water supplies to the town itself. The town will be able to be supplied by gravity from the proposed intake, but the catchment contains significant areas of agricultural land, and treatment will be required. The yield of the river decreases at higher elevations, and it is not therefore feasible to go high enough to locate an intake within the Nyambene Forest where better raw water quality could be expected.

The presence of the existing distribution system and the fact that the supply area is small means that, in this case, it will be relatively easy to supply the full projected water demand as soon as the production capacity exists. It is therefore proposed not to phase construction of the treatment plant.

(7) Tigania

Tigania is a large rural water supply scheme, phase 1 of which was designed and constructed in the 1970s. This obtains water from the Mikurwe spring and the Nchoro intake both of which are on the West side of the Nyambene Hills. Water is distributed from a single transmission main which follows the main Meru road for some 15 kms as far as Kunene.

The Nchoro intake has since dried up causing severe water constraints to the existing system. An additional intake at Michimikuru has been constructed, but water shortages continue to be experienced.

The strategy established for this study is to concentrate on the area to the south east of the existing service area, where available water sources are more plentiful, and from where water can be transferred to augment the supplies to the existing areas. This area was included in the original Tigania Project Area, but has not yet been covered.

The obvious choice of source for this area is the Thangatha River, which is the main river running southwards from the Nyambene Forest, and which has adequate water to supply the proposed additional area, and to reinforce the existing system.

For Master Planning purposes therefore, it has been assumed that the new system will supply water to the area immediately to the south of the Nyambene Hills. The existing system based on the Mikurwe Springs and the Michimikuru Intake will supply a reduced area to the west, thus relieving the present shortfall of supply.

### 5.1.5 Operations

For the proposed improvements and expansion of existing systems to be effective, corresponding improvements and expansion of the management, operation and maintenance of the systems is essential.

An overall strategy is needed for improving accountability, cost recovery, monitoring and reporting. Performance targets need to be established and staff provided with appropriate training to meet these targets.

## 5.2 Proposed Works

### 5.2.1 Selection of Water Sources

The capacity of intakes, raw water pipelines and water sources have to allow for treatment plant losses due to backwashing etc., normally taken as 10% of plant capacity. As a contingency against possible future raw water quality deterioration, this allowance has been applied to all raw water sources regardless of treatment requirements, except for groundwater, where no additional allowance has been made.

The resultant raw water requirements and the 95% daily low flows for alternative sites for the different schemes are given below:

**Table 5.2-1 Source Requirements and Minimum Flows**

| Scheme | Raw Water Requirement $m^3/d$ | Source | Minimum Safe Yield $m^3/day$ |
|---|---|---|---|
| Meru | 22,000 | Kathita River (proposed)<br>Kathita River (existing)<br>Gatabora spring (existing) | 55,300<br>80,500<br>605 |
| Nkubu | 2,200 | Kiguandequa (proposed)<br>Thinghthu (existing) | 22,000<br>26,000 |
| Isiolo | 4,000 | Kithima Spring (proposed)<br>Rugusu Spring<br>Isiolo River (existing)<br>Typical borehole | 3,000<br>3,900<br>2,000 (1)<br>480 |
| Chuka | 4,400 | Ruguti River (proposed)<br>Tungu River (existing) | 12,800<br>25,800 |
| Chogoria | 3,300 | Mara Manyi stream (proposed)<br>Mutunga River (existing) | 13,300<br>62,000 |
| Maua | 1,650 | Mboone Stream (proposed)<br>Mboone Stream (existing)<br>Ura River | 1,900<br>2,700<br>1,900 |
| Tigania | 4,400 | Thangatha Stream<br>Mikrowe Spring (existing)<br>Michi Mikuru Spring (existing) | 4,500<br>1,800<br>1,750 |

*Notes: (1) Minimum safe yield is lower than the existing water production capacity of 2,800 m3/d*

(1) Meru

The Kathita River is the largest river in the area and the proposed intake is located approximately 8 km inside Mount Kenya Forest. The raw water quality is good and the elevation is sufficiently high to gravitate to a treatment plant located within the forest boundary thereby causing little disruption to human settlement. The proposed location is close to the Kiirua Intake, which is under construction, and to the Kimori and Kiamiogo Community Water Supply intakes, which share a common weir but which requires reconstruction. The uPVC raw water pipelines for the Kimori and Kiamiogo schemes have also been broken in many places and also require reconstruction. The raw water requirement for the proposed Meru scheme amounts to 22,000 m3/day. The Water Permit for the Kiirua Scheme is 4,100 m3/d, Kimori 63 m3/d and Kiamiogo 472 m3/d. In addition, there is a preliminary proposal for abstraction of 9,000 m3/d further upstream, for the Mwaa scheme. The proposed total abstraction amounts to approximately the safe yield of 35,300 m3/day at the intake site. This suggests that any future allocation of water resources in this area should be carefully assessed.

There appear to be a number of mutual advantages by having the intakes in close proximity, including access (which needs improvement) and co-ordination of operational activities. Nevertheless, careful liaison between the scheme management committees will be required.

(2) Nkubu

As seen from the table above, the proposed intake location for Nkubu has ample capacity to supply the estimated raw water requirements.

(3) Isiolo

The results of the exploratory drilling and test pumping indicate that there is potential to meet the immediate needs of the town of Isiolo, by the development of a well field to the south of Isiolo, where groundwater quality and yields appear to be favourable. Although further drilling and testing is required to determine the ultimate potential for this well field, the Master Plan for Isiolo has been developed on the basis of this alternative.

(4) Chuka

The Rugati River is the largest river in the area and the proposed Rugati River intake has ample capacity to provide the estimate raw water requirements. The main disadvantage being the difficult access for construction and maintenance.

(5) Chogoria

The raw water requirements for Chogoria represent about 25% of the yield measured for the Mara Manyi intake site during the dry season of 1996, which should therefore prove adequate.

(6) Maua

The yield of the Mboone Spring, measured during the dry season of 1996 came to only 1,900 m3/day, which is below the requirements of the originally identified supply area of 2,000 m3/day. It has therefore been necessary to reduce the supply area from this source in order to supply a maximum of 1,500 m3/day.

There are no other sources of comparable size in the area except for the Ura River to the south of Maua. It is therefore suggested that these southern areas are supplied from this river under a separate project, but the use of pumping will be required.

(7) Tigania

The Thangatha River is the largest river in the region, flow measurements at the forest edge, taken during February 1997 indicate a minimum flow of 4,500 m3/day. This however was taken at the end of one of the driest periods known in the area, and may therefore be taken as an extreme low flow. The capacity of the stream increases significantly downstream, but the quality of the water deteriorates as increasing areas of farm land drain into the river. The advantage of good water quality, but relatively low yield of a higher intake site has to be balanced against the higher yield, but poorer quality at a lower intake site. For the first phase development the flow is adequate at the forest edge.

### 5.2.2 Intakes and Raw Water Pipelines

A typical intake structure is shown on ***Figure 5.2-1***, which incorporates the features proposed in ***Section 4.1***, which are designed to reduce maintenance cost and limit the intake of sediment, floating material and submerged objects. This conceptual design, however, will need to be adapted to suit the particular circumstances of each location. Raw water pipeline profiles for the different schemes are shown on ***Figure 5.2-2***. Details are given in ***Table*** 5.2-2, although these need to be confirmed for Meru and Tigania

**Table 5.2-2 Raw Water Pipeline Details**

| Scheme | Flow (m3/day) | Pipe diameter (mm) | Pipe Length (m) | Velocity (m/s) | Head Loss (m) |
|---|---|---|---|---|---|
| Meru | 22,000 | 500 | 6,000 | 1.30 | 20 |
| Nkubu | 2,200 | 200 | 600 | 0.81 | 3 |
| | | 150 | 1,013 | 1.44 | 24 |
| Isiolo (boreholes) (1) | 480 | 100 | 2000 | 0.71 | 20 |
| (4) | 1,920 | 200 | 2000 | 0.71 | 8 |
| (5) | 2,400 | 200 | 2000 | 0.57 | 4 |
| (6) | 2,880 | 250 | 500 | 0.68 | 1.4 |
| (8) | 3,840 | 250 | 1450 | 0.91 | 7 |
| (9) | 4,320 | 250 | 2000 | 1.02 | 12 |
| Chuka | 4,400 | 250 | 3,100 | 1.04 | 20 |
| | | 200 | 5,633 | 1.62 | 116 |
| Chogoria | 3,300 | 200 | 4,654 | 1.22 | 54 |
| Maua | 1,650 | 150 | 400 | 1.08 | 5 |
| Tigania | 4,400 | 250 | 2,000 | 1.04 | 13 |

In the case of Isiolo, the raw water main acts as a collector from a number of boreholes, the flows, and therefore size of pipeline, increasing in a downstream direction. The raw water, in this case, will also be of good quality. Therefore, the low velocities required to limit head losses along the rather flat terrain, will not result in sedimentation along the pipeline.

Intake and Treatment plant location for different schemes are shown on ***Figures** 5.2-3 – 5.2-9.*

### 5.2.3 Treatment Works

Preliminary proposals for treatment processes for each scheme are shown in ***Table** 5.2-3.* They have been based on raw water quality, potential for future sources of pollution, existing technologies and staff familiarity with the processes and, availability of materials and chemicals. Finalisation of these proposals will however depend on the results of further sampling to be taken during the forthcoming rainy season.

**Table 5.2-3 Treatment Processes And Number Of Units Per Scheme**

| | Meru | Nkubu | Isiolo | Chuka | Chogoria | Maua | Tigania |
|---|---|---|---|---|---|---|---|
| 2010 demand (m3/d) | 22,725 | 1,915 | 10.671 | 7,256 | 2,886 | 1,493 | 3,778 |
| Existing capacity (m3/d) | 3,172 | 0 | 2,800 | 3,260 | 0 | 0 | 0 |
| Required capacity (m3/d) | 20,000 | 2,000 | 8,000 | 4,000 | 3,000 | 1,500 | 4,000 |
| **Phase I units** | | | | | | | |
| Chlorine dosers | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Flocculation tanks | | 1 | | | | | |
| Sedimentation basins | 4 | 1 | | 2 | 2 | 1 | 2 |
| Roughing filters | | | | | | 3 | |
| Rapid sand filters | | 3 | | | | | |
| Sludge concentrators | | 2 | | | | | |
| Sludge drying beds | | 3 | | | | | |
| **Phase II units** | | | | | | | |
| Chlorine dosers | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Flocculation tanks | | 2 | | | | | |
| Sedimentation basins | 8 | 2 | | 4 | 4 | 2 | 4 |
| Roughing filters | | | | | | 4 | |
| Rapid sand filters | | 4 | | | | | |
| Sludge concentrators | | 3 | | | | | |
| Sludge drying beds | | 5 | | | | | |

At this stage, since a river intake is not being recommended for Isiolo, full treatment is proposed only at Nkubu. However, although the initial water quality analyses indicated that roughing filtration should be adequate for Maua, it is likely that the results of the wet season sampling program will indicate that Maua will require a higher level of treatment and, by locating the Meru intake further upstream, it will be possible to use plain sedimentation only. However, regardless of the water quality of all surface sources, the layout design of each treatment plant will allow for the addition of higher levels of treatment, as indicated on ***Figure 5.2-10***.

### 5.2.4 Transmission and Distribution Facilities

(1) General

For planning purposes, pipe diameters of 63 mm and larger have been classified as transmission and distribution mains, and other small diameter pipes have been defined as service mains. Unplasticised polyvinyl chloride (uPVC) pipes are proposed for the majority of transmission and distribution mains with diameters less than 350 mm. Steel pipes are proposed for pipes of diameters 350 mm and more, and pipes for some sectors such as road and river crossings. Transmission and distribution mains have been planned for each scheme based on the projected water demand in 2010 described in ***Section 4.3 "Water Demand Projection"*** and existing supply conditions. Existing transmission and distribution facilities have been incorporated into the proposed water supply systems as appropriate.

The water demand and required storage volume for the seven schemes are summarized in the following table.

**Table 5.2-4 Water Demand and Required Storage Volume**

| Scheme | Study Area (Original) | Supply Area (Actual) | Demand in 2010 | Supply Demand | Demand for Urban Area | Required Storage Volume * |
|---|---|---|---|---|---|---|
| | ($km^2$) | ($km^2$) | ($m^3$/day) | ($m^3$/day) | ($m^3$/day) | ($m^3$) |
| | A | B | C | D | E | F |
| Meru | 185.3 | 185.3 | 22,725 | 22,725 | 13,794 | 18,260 |
| Nkubu | 3.5 | 3.5 | 1,915 | 1,915 | 1,295 | 1,605 |
| Isiolo | 44.9 | 44.9 | 10,671 | 10,671 | 5,617 | 8,144 |
| Chuka | 88.0 | 88.0 | 4,403 | 4,403 | 1,315 | 2,859 |
| Chogoria | 57.5 | 57.5 | 2,886 | 2,886 | 335 | 1,611 |
| Maua | 15.0 | 11.2 | 2,011 | 1,500 | 945 | 1,223 |
| Tigania | 99.1 | 92.5 | 3,778 | 3,674 | 0 | 1,837 |
| Total | 493.3 | 482.9 | 48,389 | 47,774 | 23,301 | 35,537 |

*: Required storage volume amounts to 12 hours demand for Items D and E.

The difference between totals of the Study Area (Column A) and the Supply Area (Column B) is due to part of the Study Areas in Maua and Tigania being unable to receive water supplies for the following reasons;

1) Because of limited raw water yield and the topography of the Study Area for Maua, the west part of approximately 3.8 km$^2$ will not be covered by the proposed water supply system.

2) In Tigania, because of high ground in the north part of Kitheo sub-location, of approximately 6.6 km$^2$, it will not be covered by the proposed water supply system.

(2) Transmission and Distribution Facilities

1) Meru

The projected water demand for Meru in 2010 is estimated at 22,725 m$^3$/day. Existing water production capacity is 3,172 m$^3$/day, so that an additional capacity of 19,558 m$^3$/day is needed to be treated and distributed to the supply area. All water produced in the existing treatment plant will be used for Upper Igoki sub-location in which the urban center of Meru Town is located. The supply area covered by the existing plant is estimated at 3.1 km$^2$ of Upper Igoki. The balance of demand in Upper Igoki, and demands in other sub-locations, will be supplied from the proposed treatment plant. The following table shows details of the projected water demand and required storage capacity for each sub-location.

**Table 5.2-5 Projected Water Demand and Required Storage Capacities**

| Sub-Location | Study Area (km$^2$) | Demand in 2010 (m$^3$/day) | Demand for Urban Area (m$^3$/day) | Required Storage Volume (m$^3$) |
|---|---|---|---|---|
| | A | C | E | F |
| U.Igoki | 12.2 | 11,811 | 11,566 | 11,689 |
| Ntakira | 10.2 | 1,271 | 581 | 926 |
| L.Igoki | 6.0 | 645 | 261 | 453 |
| Nthimbiri | 6.8 | 500 | - | 250 |
| Mpuri | 5.1 | 417 | - | 209 |
| Ngonyi | 8.1 | 480 | - | 240 |
| Mulathankare | 4.0 | 1,442 | 1,386 | 1,414 |
| Thura | 29.5 | 852 | - | 426 |
| Chungu | 19.4 | 1,224 | - | 612 |
| Munithu | 14.0 | 807 | - | 404 |
| Nkabune | 7.2 | 352 | - | 176 |
| Katheri | 29.2 | 1,364 | - | 682 |
| Githongo | 13.8 | 712 | - | 356 |
| Kithrune | 19.8 | 850 | - | 425 |
| Total | 185.3 | 22,727 | 13,794 | 18,261 |

Proposed routes for transmission and distribution mains and locations of storage tanks for the target year of 2010 are shown in ***Figure 5.2.-11. Figure 5.2.-12*** shows the proposed plan for transmission and distribution facilities schematically. The supply area is divided into two major distribution zones by two main pipelines discharging from the proposed treatment plant. One zone covers the north part of the area , and the other zone covers the south part of the area.

Total proposed storage volume is 17,850 $m^3$, and the total length of proposed transmission and distribution mains is 139.9 km. The resultant total storage tank capacity in 2010 will be 19,061 $m^3$, including the existing storage capacity of 1,211 $m^3$. Breakdowns of these figures for proposed storage tanks and pipelines are listed in the following tables.

**Table 5.2-6 Proposed Storage Tanks**

| Tank No. | Capacity (m3) | Tank No. | Capacity(m3) |
|---|---|---|---|
| ST-WTP | 800 | ST-9 | 100 |
| ST-1 | 9,000 | ST-10 | 600 |
| ST-2 | 300 | ST-11 | 500 |
| ST-3 | 500 | ST-12 | 800 |
| ST-4 | 150 | ST-13 | 200 |
| ST-5 | 1,500 | ST-14 | 200 |
| ST-6 | 100 | ST-15 | 250 |
| ST-7 | 400 | ST-EX1 | 2,250 |
| ST-8 | 250 | | |

**Table 5.2-7 Proposed Pipeline**

| Diameter (mm) | Length (km) |
|---|---|
| 400 SP | 3.8 |
| 350 SP | 6.8 |
| 315 PVC | 8.5 |
| 280 PVC | 5.8 |
| 225 PVC | 19.0 |
| 160 PVC | 37.8 |
| 110 PVC | 34.7 |
| 90 PVC | 23.5 |

2) Nkubu

The projected water demand for Nkubu in 2010 is estimated at 1,915 $m^3$/day. The existing 400 $m^3$/day water treatment plant, built in 1952, will be abandoned. All water will be, therefore, treated and distributed to the supply area, which consists of one sub-location, with an area of 3.5 $km^2$.

The following table shows the required storage capacity for Nkubu Water Supply System.

**Table 5.2-8 Storage Capacity for Nkubu Water Supply System**

| Supply Area ($km^2$) | Demand in 2010 ($m^3$/day) | Demand for Urban Area ($m^3$/day) | Required Storage Volume* ($m^3$) |
|---|---|---|---|
| 3.5 | 1,915 | 1,295 | 1,605 |

Proposed routes for transmission and distribution mains and, locations of storage tanks for the target year of 2010, are shown in ***Figure 5.2.-13***. ***Figure 5.2.-14*** shows the proposed plan for transmission and distribution facilities schematically.

Total proposed storage volume is 1,550 $m^3$, and total length of proposed transmission and distribution mains is 5.9 km. Consequently, the total storage capacity in 2010 will be 1,625 $m^3$, including the existing storage capacity of 75 $m^3$. This provides the required storage capacity of 1,605 $m^3$. A breakdown of these figures is listed in the following table.

**Table 5.2-9 Breakdown of Storage Capacity and Distribution Main**

| Storage Tanks | Capacity ($m^3$) | Unit | Total ($m^3$) |
|---|---|---|---|
| | 500 | 2 | 1,000 |
| | 300 | 1 | 300 |
| | 250 | 1 | 250 |
| Distribution Main | diameter | length | |
| | dia.225 | 1.3 km | |
| | dia.160 | 2.3 km | |
| | dia.90 | 2.0 km | |
| | dia.63 | 0.3 km | |

3) Isiolo

The projected water demand for Isiolo in 2010 is estimated at 10,671 $m^3$/day. Existing water production capacity is 2,800 $m^3$/day, so that an additional 7,871 $m^3$/day will be required for distribution to the supply area. The proposed raw water source and storage tank are planned to be located in the south of the Study Area. It has been assumed that all the production from the existing treatment plant will be used for the urban area of Isiolo. The balance of urban demand and the rural demand will be supplied by the proposed system. The following table shows details of projected water demand for urban and rural areas.

**Table 5.2-10 Projected Water Demand and Required Capacity in Isiolo**

| | Area | Demand | | | Required Storage |
|---|---|---|---|---|---|
| | (km$^2$) | in 2010 (m$^3$/day) | Existing (m$^3$/day) | Balance (m$^3$/day) | Capacity (m$^3$) |
| Urban | 14.9 | 5,617 | 2,800 | 2,817 | 5,617 |
| Rural | 30.0 | 1,405 | 0 | 1,405 | 703 |
| Institutional | - | 3,649 | - | 3,649 | 1,824 |
| Total | 49.0 | 10,671 | 2,800 | 7,871 | 8,144 |

Proposed routes for distribution mains and locations of storage tanks for the target year of 2010 are shown in ***Figure 5.2.-15***. ***Figure 5.2.-16*** shows the proposed plan for the distribution facilities schematically. The supply area is divided into two distribution zones by the Isiolo River.

The total length of proposed distribution mains is 30.7km. The proposed storage volume has been planned to be 6,000 m$^3$, consisting of two 3,000m$^3$ tanks. Consequently, the total storage capacity in 2010 will be 8,150 m$^3$, including the existing storage capacity of 2,150 m$^3$, and which provides the required storage capacity of 8,144 m$^3$. A breakdown of distribution mains is listed in the following table.

**Table 5.2-11 Breakdown of Distribution Main**

| diameter | length |
|---|---|
| dia.280 | 6.7 km |
| dia.225 | 9.4 km |
| dia.160 | 2.9 km |
| dia.110 | 2.7 km |
| dia.63 | 9.0 km |

4) Chuka

The projected water demand for Chuka in 2010 is estimated at 4,403 m$^3$/day. As discussed in **Section 5.1.4**, water from the existing 3,260 m$^3$/day water treatment plant will be diverted to supply other areas outside the Study Area. Therefore, all water from the proposed new 4,000 m$^3$/day treatment plant will be supplied to the Study Area, even those areas which have been covered by the existing system. The transmission and distribution system in Chuka has been quite extensively developed by the existing water supply system. Therefore, the current requirements is only for strengthening the existing system and replacement of the existing main pipelines where necessary. The following table shows details of the projected water demand and required storage capacity for each sub-location.

**Table 5.2-12 Required Storage Capacity for each Sub-location**

| | Study Area (km²) | Demand in 2010 (m³/day) | Demand for Urban Area (m³/day) | Required Storage Volume (m³) |
|---|---|---|---|---|
| Mugiriwa | 13.5 | 902 | - | 451 |
| Muiru | 8.5 | 724 | - | 362 |
| Mariani | 28.7 | 63 | - | 32 |
| Ndagani | 13.3 | 565 | - | 283 |
| Chuka T | 5.5 | 1,668 | 1,315 | 1,492 |
| Kinangondu | 8.7 | 441 | - | 221 |
| Kithangani | 9.8 | 40 | - | 20 |
| Total | 88.0 | 4,403 | 1,315 | 2,859 |

Proposed routes for the transmission and distribution mains and the locations of storage tanks for the target year of 2010, including existing mains, are shown in ***Figure 5.2.-17***. ***Figure 5.2.-18*** shows the proposed plan for the transmission and distribution facilities schematically.

Total proposed storage volume is 2,850 m³, and total length of proposed transmission and distribution mains is 8.3 km. Consequently, the total storage capacity in 2010 will be 2,940 m³, including the existing storage capacity of 90 m³, which provides the required storage capacity of 2,859 m³. A breakdown of these figures is listed in the following table.

**Table 5.2-13 Breakdown of Storage Tanks and Distribution Main**

| Storage Tanks | Capacity (m³) | Unit | Total (m³) |
|---|---|---|---|
| | 750 | 1 | 750 |
| | 500 | 1 | 500 |
| | 400 | 1 | 400 |
| | 300 | 1 | 300 |
| | 200 | 3 | 600 |
| | 150 | 2 | 300 |
| **Distribution Main** | **diameter** | **length** | |
| | dia.280 | 2.9 km | |
| | dia.225 | 2.8 km | |
| | dia.160 | 2.6 km | |

5) Chogoria

Chogoria's existing water supply system depends on the Mwimbi Water Supply System which is located in neighboring Meru District and which has insufficient capacity to supply water to its own District. It is, therefore, necessary for Chogoria to develop its own independent water supply system in order to secure a reliable water supply.

The projected water demand for Chogoria in 2010 is estimated at 2,886 $m^3$/day. Chogoria Town has three sub-locations i.e. Chogoria, Kiraro and Murugi. The following table show details of the projected water demand and required storage capacity for each sub-location.

**Table 5.2-14 Projected Water Demand and Storage Capacities**

| | Study Area ($km^2$) | Demand in 2010 ($m^3$/day) | Demand for Urban Area ($m^3$/day) | Required Volume ($m^3$) |
|---|---|---|---|---|
| Chogoria | 25.2 | 1,246 | 335 | 791 |
| Kiraro | 6.4 | 334 | - | 167 |
| Murugi | 25.9 | 1,306 | - | 653 |
| Total | 57.5 | 2,886 | 335 | 1,611 |

Proposed routes for transmission and distribution mains, and locations of storage tanks for the target year of 2010, are shown in ***Figure 5.2.-19***. ***Figure 5.2.-20*** shows the proposed plan for the transmission and distribution facilities schematically. The supply area is divided into two major distribution zones. One zone covers the north part of the Area including Chogoria and Kiraro sub-locations, and the other covers the south part of the Area including Murugi sub-location. It is, however, noted that it might not be able to supply some parts of the west side of the supply area by gravity, due to topographic features.

Total proposed storage volume is 1,500 $m^3$, and total length of proposed transmission and distribution mains is 39.1 km. Consequently, the total storage capacity in 2010 will be 1,735 $m^3$, including the existing storage capacity of 235 $m^3$, which provides the required storage capacity of 1,611 $m^3$. A breakdown of these figures is listed in the following table.

**Table 5.2-15 Breakdown of Storage Tanks and Distribution Main**

| Storage Tanks | Capacity ($m^3$) | Unit | Total ($m^3$) |
|---|---|---|---|
| | 300 | 2 | 600 |
| | 250 | 2 | 500 |
| | 200 | 2 | 400 |
| Distribution Main | diameter | length | |
| | dia.225 | 5.0 km | |
| | dia.160 | 11.6 km | |
| | dia.110 | 2.8 km | |
| | dia.63 | 15.2 km | |

6) Maua

The projected water demand for Maua in 2010 is estimated at 2,011 m³/day. The existing 200 m³/day water treatment plant, built in 1956, will not be expected to be used for the proposed water supply system. All the demand in 2010 will therefore be treated and distributed from the proposed water treatment plant to the supply area. Because of source constraints and topography of the Study Area for Maua, however, the west part, estimated at approximately 3.8 km², can not be covered by the proposed water supply system. The proposed system will, therefore, be limited to supply only the urban areas around Maua to a maximum demand of 1,500 m³/day, which is less than the originally estimated total demand of 2,011 m³/day. The following table shows details of the projected water demand and required storage capacity for supply area and the area not to be supplied.

**Table 5.2-16 Projected Water Demand and Storage Capacities**

| | Study Area (km²) | Demand in 2010 (m³/day) | Demand for Urban Area (m³/day) | Required Volume (m³) |
|---|---|---|---|---|
| Supply | 11.2 | 1,500 | 945 | 1,223 |
| Non-supply | 3.8 | 511 | - | 256 |
| Total | 15.0 | 2,011 | 945 | 1,478 |

Proposed routes for transmission and distribution mains and locations of storage tanks for the target year of 2010 are shown in ***Figure 5.2.-21***. ***Figure 5.2.-22*** shows the proposed plan for the transmission and distribution facilities schematically.

Total proposed storage volume is 1,300 m³, and total length of proposed transmission and distribution mains is 8.4 km. Consequently, the total storage capacity in 2010 will be 1,345 m³, including the existing storage capacity of 45 m³, which provides the required storage capacity of 1,233 m³. A breakdown of these figures is listed in the following table.

**Table 5.2-17 Breakdown of Storage Tanks and Distribution Main**

| Storage Tanks | Capacity ($m^3$) | Unit | Total ($m^3$) |
|---|---|---|---|
| | 500 | 2 | 1,000 |
| | 150 | 2 | 300 |
| Distribution Main | diameter | length | |
| | dia.225 | 1.5 km | |
| | dia.160 | 4.2 km | |
| | dia.110 | 1.7 km | |
| | dia.63 | 1.0 km | |

7) Tigania

The projected water demand for Tigania in 2010, excluding the existing supply area called Old Tigania, is estimated at 3,778 $m^3$/day. Because of the topography of the Study Area, however, the north part of Kitheo sub-location, estimated at approximately 6.6 $km^2$, can not be covered by gravity from the proposed water supply system. The following table shows details of the projected water demand and required storage tank capacity for each sub-location.

**Table 5.2-18 Projected Water Demand and Required Storage Capacities**

| | Study Area | | Supply Area | | |
|---|---|---|---|---|---|
| | Area ($km^2$) | Demand ($m^3$/day) | Area ($km^2$) | Demand ($m^3$/day) | Required Storage Volume ($m^3$/day) |
| Nkomo | 27.6 | 719 | 27.6 | 719 | 360 |
| Miathene | 17.2 | 948 | 17.2 | 948 | 474 |
| Kiguchwa | 18.1 | 1,230 | 18.1 | 1,230 | 615 |
| Athwana | 5.3 | 236 | 5.3 | 236 | 118 |
| Antwamburi | 11.0 | 332 | 11.0 | 332 | 166 |
| Kitheo | 19.9 | 313 | 13.3 | 209 | 105 |
| Total | 99.1 | 3,778 | 92.5 | 3,674 | 1,837 |

Proposed routes for transmission and distribution mains and locations of storage tanks for the target year of 2010 are shown in ***Figure 5.2.-23***. ***Figure 5.2.-24*** shows the proposed plan for the transmission and distribution facilities schematically. The west end of the proposed main will be connected to the existing pipeline at Nkomo sub-location in order to cover its area by the proposed scheme.

Total proposed storage volume is 1,900 $m^3$, and total length of proposed transmission and distribution mains is 51.4 km. Consequently, the total storage capacity in 2010 will be 1,950 $m^3$, including the existing storage capacity of 50 $m^3$, which provides the required storage capacity of 1,837 $m^3$. A breakdown of these figures is listed in the following table.

**Table 5.2-19 Breakdown of Storage Tanks and Distribution Main**

| Storage Tanks | Capacity ($m^3$) | Unit | Total ($m^3$) |
|---|---|---|---|
| | 500 | 1 | 500 |
| | 400 | 1 | 400 |
| | 200 | 2 | 400 |
| | 150 | 4 | 600 |
| Distribution Main | diameter | length | |
| | dia.280 | 11.8 km | |
| | dia.225 | 8.9 km | |
| | dia.160 | 7.1 km | |
| | dia.110 | 10.6 km | |
| | dia.63 | 13.0 km | |

(3) Service Pipelines

Service pipeline requirements have been estimated after consideration of the existing conditions of service pipelines in each scheme. Existing lengths of service pipelines and the number of house connections for each scheme are mentioned previously in ***Chapter III "Existing Water Supply in the Study Area"***. Service pipelines are tentatively defined as pipe diameters less than 63 mm in this Study. Existing lengths of service pipelines and numbers of house connection are summarized in the following table.

**Table 5.2-20 Existing Service Pipeline and House Connection**

| | Pipe Length (m) | Number of Connection | Unit Length (m/conn.) |
|---|---|---|---|
| Meru | 61,500 | 2,519 | 24.4 |
| Nkubu | - | 325 | - |
| Isiolo | 15,600 | 2,771 | 5.6 |
| Chuka | - | 590 | - |
| Chogoria | 4,500 | 270 | 16.7 |
| Maua | 2,700 | 465 | 5.8 |
| Tigania | 39,000 | 1,686 | 23.1 |
| Total* | 123,300 | 7,711 | 16.0 |

*: excluding figures of Nkubu and Chuka, because of no data for pipe length

There is no available data on pipe length for Nkubu and Chuka. In case of Isiolo and Maua, the existing service areas are limited mainly to cover the center of the towns. Other schemes i.e. Meru, Chogoria and Chuka include both urban and rural areas. Whereas Tigania is predominantly rural in character. Therefore, the unit length of service pipeline per connection has been estimated from data of the following representative schemes. The table below shows the estimation of unit length of service pipeline per connection for these existing schemes.

**Table 5.2-21 Unit Length of Service Pipeline**

| | Pipe Length (m) | Number of Connection | Unit Length (m/conn.) |
|---|---|---|---|
| Meru | 61,500 | 2,519 | 24.4 |
| Chogoria | 4,500 | 270 | 16.7 |
| Tigania | 39,000 | 1,686 | 23.1 |
| Total | 105,000 | 4,475 | 23.5 |

Service pipeline lengths in the low population density areas is usually longer than that in high density areas, if all connections are individual house connection. Actually, public taps (Kiosks) are often the more appropriate water supply service facility in rural areas or with low population density. It is, however, impossible to plan all necessary public taps at the Master Plan Stage, since there is not sufficient and detailed data for distribution and location of houses. And all public water points should only be located after discussion and approved with local communities. For the purpose of the Master Plan, therefore, 23.5 m per connection as the average length has been applied to the unit length of the service pipeline.

### 5.2.5 Rehabilitation

(1) Meru Town

The major facilities in Meru town were augmented in 1995. In this sense, a full-scale rehabilitation is considered premature and unpractical. As identified in the inventory survey carried out under the present study, however, some old facilities and pipelines need repair. Leakage was found from the storage reservoir constructed in the treatment works. Some bulk meters and gate valves installed in 1970s and 1980s were not functioning, including the inlet and outlet valves of filtration units and storage tanks and sluice valves installed on the distribution mains.

(2) Other Towns

Most of the treatment facilities in other towns are operational despite some institutional problems. In Nkubu, Chogoria and Maua, new treatment facilities are planned for construction under phase 1, while the existing facilities will be abandoned after that. In Chuka Water Supply, sedimentation basins were added in May 1996. Treatment facilities in Isiolo are working normally. Tigania water supply depends on spring water and does not have any treatment facilities.

Accordingly, the main focus will be placed on the establishment of a metering system under phase 1 which is discussed in the succeeding sections. To this end, bulk meters will be installed at the outlet of treatment works/intake facilities.

**Table 5.2-22 Bulk Meters**

| Town | Bulk Meters | | |
|---|---|---|---|
| | Diameter (mm) | Type | Quantity |
| Nkubu | 75 | Mechanical | 1 |
| | 40 | ditto | 1 |
| Isiolo | 200 | ditto | 1 |
| Chuka | 150 | ditto | 1 |
| Chogoria | 100 | ditto | 1 |
| Maua | 75 | ditto | 1 |
| Tigania | 200 | ditto | 1 |
| | 75 | ditto | 1 |

*Source: JICA Study Team*

### 5.2.6 Operation and Maintenance Program

Most of the DWOs in the Study Area are facing many operational problems: inappropriate chemical dosing, obsolete equipment left without maintenance, a lack of human resources and leakage abatement activities. Further, chemicals, pipe materials, vehicles and tools generally required for normal water supply system operation are all in a serious and chronic shortage. DWEs are of the opinion that financial constraints are the main reason for improper maintenance and operation.

The UFW ratio is high in most water supplies in the Study Area. In the case of the surveyed area of Meru water supply, approximately 70% of the water production were unaccounted-for. This is due to the fact that most individual connections are not metered and a surprisingly large number of the non-registered customers exists, consuming water for agriculture and animals. The costs in lost revenue to the DWO are large. To tackle these issues and establish financially sound water supplies in the area, the introduction of metering is urgently needed. In the long run, the DWO's should undertake appropriate leakage control programs for the distribution pipe networks.

The following is a draft conceptual program, giving procedures and schedules for meter installation and leakage control.

(1) Meter Installation and Replacement

1) Procedures

Preparatory works shall be focused on obtaining support and understanding from the public and relevant administrative bodies for the introduction of a metering system. Careful attention shall be paid to motivation of the non-registered customers and customers with unmetered connections, who are usually reluctant to obtain a meter installation. A probation period for registration and incentives for connection fees may encourage people to obtain meter installations.

The financial and organizational set up by the DWO at an early stage will play a decisive role for the meter replacement program. Zoning of the supply area for metering and billing purposes and prioritization of the zones shall be carefully designed.

At the commencement of the meter installation for the prioirty zone, an engineer (a team leader) shall explain to every household the reasons and need for the metering system to obtain their understanding and cooperation. Meters with boxes shall be installed according to a standard design. All information on serial number, type, year of manufacturing, an outline sketch of the meter installation and households' particulars shall be recorded on an appropriate form for developing a database.

These activities shall be continued to cover all supply zones. To initiate meter reading and billing in the supply area, an adequate number of meter readers and bill collectors shall be mobilized through training inhouse staff. When considered appropriate, zonal shifting of meter readers and bill collectors shall be periodically undertaken.

2) Proposed Schedule for Meter Installation

Meter installation requires huge resources over a long period. Hence, the schedule largely depends on the magnitude and quality of the inputs for the work. ***Figure 5.2-25*** demonstrates recommended procedures and work schedules, which will be subject to review in the course of the field work.

3) Numbers of Meters and Pipeline Length

All the works for meter installation shall be completed within the period of Phase 1. The pipeline lengths and number of customer meters to be installed are given in a table below:

**Table 5.2-23 Meter Installation (Phase 1)**

| Town | 2000 Population | Nos. of 1996 | Nos. of 2000 | Diameter mm | Nos. of Meters | Service Pipelines uPVC, km |
|---|---|---|---|---|---|---|
| Meru | 183,257 | 2,519 | 17,857 | 13 | 14,185 | 306.8 |
| | | | | 16 | 3,571 | 76.7 |
| Nkubu | 10,648 | 2,771 | 2,824 | 13 | 1,036 | 17.8 |
| Isiolo | 29,029 | 2,771 | 2,824 | 13 | 2,260 | 56.5 |
| | | | 1,477 | 16 | 565 | 14.1 |
| Chuka (Whole Area) | 88,861 | 590 | 8,646 | 13 | 8,646 | 216.1 |
| Chogoria | 34,920 | 270 | 3,398 | 13 | 3,398 | 84.9 |
| Maua | 24,827 | 465 | 2,416 | 13 | 2,416 | 60.4 |
| Tigania (Whole Area) | 168,929 | 1,686 | 16,436 | 13 | 16,436 | 410.9 |

Note ; 1) Nos. of customers suppose 60% service coverage at 2000
2) 20% provision for number of meters and pipeline length is considered
3) 80% of customer meters in Meru and Isiolo will have a diameter of 13 mm and the remaining 16mm
4) Service pipelines are supposed to have a length assume to be 25 m per connections.

(2) Leakage Control

1) Procedures

In establishing a district metering system, zoning of the supply area is essential. This zoning should preferably be consistent with the metering and billing zones. At each district, district meters shall be installed for flow rate measurement.

An analysis of these zone flow rates will provide the basis for determining priority areas for leakage control.

On-the-job training to mobilize staff and technicians for leakage control is desirable to be carried out at national level. Overseas trainings of these staff, may in addition, be desirable to enable early mobilization.

Financial and organizational set-up at the district level is necessary to procure equipment and materials for leakage control. The most appropriate methodology shall be applied based on the analysis of preliminary leakage survey results, conducted in the pilot area. The time required for leakage control will be determined on a basis of these surveys. One unit of the leakage control team to be organized under the DWE may consist of three (3) leakage detection sub-teams, six (6) leakage repair sub-teams, one (1) design and recording sub-team and one (1) equipment control sub-team. This team will be headed by a leakage control manager. Leakage control will be initiated immediately after establishment of the metering systems.

2) Work Schedule

In preparing a draft work schedule for leakage control in each area, a period required for mobilization of staff and delivery of materials and equipment needs to be taken into consideration together with the pipe network length, and work volume. Leakge control activities should be carried out on a routine basis. ***Figure 5.2-25*** also shows draft work schedules for leakage control.

3) Materials and Equipment

Phase 1 is a preparatory stage for leakage control. Major activities will be carried out under Phase 2. The following materials and equipment are required;

**Table 5.2-24 Equipment for Leakage Control**

| District | Township | Nos. of Metering Districts | Phase 1 District meters Dia. (mm) | Phase 2 Equipment |
|---|---|---|---|---|
| Meru | Meru | 10 | 100 | One set |
| | Nkubu | 1 | 100 | |
| Isiolo | Isiolo | 2 | 100 | One set |
| Tharaka Nithi | Chuka | 4 | 100 | One set |
| | Chogoria | 2 | 100 | |
| Nyambene | Maua | 2 | 100 | One set |
| | Tigania | 8 | 100 | |

Note; 1) Leakage control equipment includes leak detectors, flow meters, pressure gauges, sounding bars, pipe locators, etc.
2) District flow meters are of mechanical vane wheel type.

## 5.3 Preliminary Cost Estimate

### 5.3.1 Unit Construction Prices

A review of current construction prices in Kenya has been conducted, based on a combination of recent tender rates for the construction of similar works, and suppliers quotations for materials.

The unit rates derived from this review are given in ***Table 5.3-1***. These rates have been used to make a preliminary estimate of construction costs for the works identified under this Master Plan phase of the study. The table also provides "all in" costs for concrete, pipeline construction using different materials and estimates for the costs of standard reservoir sizes.

Preliminary and general items have not been included in the unit rates, as these will generally differ between different locations, and for different types of construction contracts. These have therefore been estimated separately for each scheme.

The base date for the costs is October 96, with an exchange rate of 1 US$ = 56 Kshs.

### 5.3.2 Construction Cost Estimates

Quantities have been taken off for each of the proposed schemes, and bills of quantities priced using the above unit construction prices, to prepare preliminary cost estimates of the proposals to meet the 2010 water demand requirements.

The resultant estimates are summarised on ***Table 5.3-2***. This indicates that the cost averages at about US $ 62 per capita, with 70% of the costs incurred during the initial phase, 20% during the second phase and 10% spread evenly over the design horizon for the construction of annual extensions to the distribution system.

The main costs are related to the transmission and distribution systems, followed by treatment, the costs of raw water pipelines and storage.

The electrical and mechanical components of the schemes represent less than 5% of the total, due to the conceptual basis of the designs to reduce operation and maintenance costs to a minimum.

### 5.3.3 Recurrent Costs

(1) Operation and maintenance

Historic levels of operation and maintenance costs have generally been low. However, to safeguard investments so that they continue to provide a reliable service for their expected lifetimes, it is advisable to budget for higher levels of maintenance costs. The 1986 Design Manual suggests guidelines for annual maintenance budgets which are in reasonable agreement with figures used in other developing countries. These are based on a percentage of the investment costs, which can be simplified to the following categories:

**Table 5.3-3 Investment Cost Breakdown**

| Asset | Annual maintenance cost as % of investment costs |
|---|---|
| Civil works | 1% |
| Pipelines | 1% |
| Electrical & Mechanical works | 5% |

The actual maintenance costs will tend to increase as the assets become older. However, the above rates represent a reasonable average to be expected over the asset lifetime, and have therefore been applied to the investment costs to arrive at the annual maintenance cost of assets.

(2) Economic Life

All assets have an economic lifetime, after which it is no longer considered economic to maintain them. The 1986 Design Manual provides the following guidance:

**Table 5.3-4 Economic Life**

| Asset | Economic Lifetime Years |
|---|---|
| Civil works | 30 |
| Pipelines | 30 |
| Electrical & Mechanical works (assuming electrical power) | 10 |

These economic lifetimes are again similar to those used in other developing countries, although they are much lower than those currently used in most developed countries. This is probably due to the harsher conditions in developing countries, and the higher levels of training and commercialisation in developed countries.

(3) Power costs

Power costs are not generally very significant for the proposed schemes, due to the fact that they are all designed for gravity flow. Power however will be required for treatment plant site lighting and for backwashing. The annual costs have been calculated using the Kenya Power and Lighting Tariff Method B1, (Oct 1996) for supplies metered at a pressure of 240 volts single phase, or 415 volts three phase as follows:

1) a fixed charge of Ksh. 500 per month
2) unit consumption charge of Ksh. 4.40 per unit
3) Ksh. 250 per month per KVA of demand.

(4) Staffing costs

Staffing requirements have been estimated for each treatment plant and distribution system. Staffing includes for local management, meter reading, billing and collection for each individual scheme, but does not include Ministry overheads at District and National headquarters. The annual projections are shown, using similar salary scales as currently applicable for Government staff, in the individual scheme cost estimate sheets given in ***Appendix L***.

(5) Chemical costs

Chemical costs have been estimated using current unit costs for supply of chemicals, as quoted by suppliers, and using dosage rates appropriate to the raw water quality for each scheme. The cost per m3 of treated water range from Ksh. 0.7 per m3 for chlorination alone, to Ksh. 1.3 per m3 when Aluminium sulphate (Alum) is added at a dosage rate of 20 mg/l. The annual cost of chemicals for each scheme is given in the cost estimate sheets for the individual schemes.

(6) Transport

The cost of some basic transport has also been included in the annual projections. Replacement of vehicles has been assumed to be every 5 years, and an operation and maintenance budget amounting to 20% of vehicle costs per annum has been allowed.

## 5.4 Comparative Assessment

Cost estimates for each scheme, broken down into their major components of expenditure are indicated on ***Table 5.3-2.***

To compare the relative merits and costs of the different schemes, it is necessary to examine the incremental costs and benefits. A convenient way of doing this is to discount the stream of investments and operational costs over the project period to obtain its Net Present Value, and divide this by the discounted increase in water supplied. The result is termed the Average Incremental Cost (AIC) of water expressed as US$/m$^3$. This is a very useful figure, as it immediately gives an indication of the level of tariff required, after allowing for losses etc., in order to obtain full cost recovery.

All investment and recurrent costs as well as incremental benefits were therefore projected to the year 2010, and discounted to arrive at the average incremental costs for each scheme, as shown in ***Table 5.3-2.*** The choice of discount rate depends upon loan conditions, current market interest rates, and Government and Donor policies. Therefore, although the results shown on ***Table 5.3-2*** are only for a 9% interest rate, the average incremental costs have been calculated for a range of interest rates, as indicated on the individual scheme cost estimate sheets in ***Appendix L.***

The average AIC for all the schemes came to Ksh. 38/m$^3$. This is well above existing tariff levels, the current basic rate being only Ksh. 9/m$^3$, which should recover the annual operation and maintenance costs but not much more. This underlines the urgency to improve performance in terms of unaccounted for water, and for increasing tariff levels.

It can be seen that Meru is at the cheapest scheme in terms of cost per m$^3$ of water supplied, and Chogoria the most expensive.

Meru is by far the largest of the schemes and therefore benefits from economies of scale. This is constrained however due to the difficult raw water route, and the extensive nature of much of its rural service area.

The raw water source problems at Isiolo result in a rather piece meal development of its supplies which results in a comparatively high cost/benefit level considering its size.

Nkubu and Maua, being the smallest schemes would have been expected to be the most costly. They were not, because, in both instances, the sources are located close to the center of demand and, the supply areas are predominantly urban, requiring only short lengths of distribution pipework.

Chuka was also one of the second cheapest schemes due to the fairly extensive existing distribution network, despite having the most difficult raw water intake route.

Chogoria was relatively expensive due to the combination of a number of factors including the difficult raw water pipeline route, and the relatively difficult terrain for the distribution system.

Tigania was fairly expensive, due to the extensive nature of the supply area and the relatively low population density.

(1) Affordability and related issues

The fact that the cost of the proposed schemes can not be recovered using the current MLRRWD tariff rates raises the questions:

1) To what level can the tariff be raised without adversely affecting affordability?

2) Will the schemes require continued Government subsidy?

3) In order to determine a level that may be appropriate for Government funding, and the economic viability of the schemes: What are the economic benefits of the schemes to the Government in terms of improved health and reduced hardship?

4) What is the most appropriate form of funding?

The following text presents an assessment of the first two questions. The remaining questions are addressed in subsequent chapters, but will be more fully covered during the feasibility study.

(2) Affordability

1) Basis of Analysis

A household's willingness to pay for water is linked to many factors such as water quality, reliability of supply, knowledge of disease transmission, culture, social, previous price rises, etc. All of these factors however can be improved by appropriate action, and will change with time.

If it can be assumed that a new water supply scheme will provide reliable and good quality water and, that it will be initiated together with a propaganda campaign to ensure that the population have a sound understanding of the need for good quality water, then it can be assumed that the willingness to pay for water will be high, and that the limiting factor will be the household's ability to pay.

A household's ability to pay for water is closely linked to its income, and is therefore more readily measured. A frequently used criteria, sanctioned by international developing agencies, is that poor households should not have to pay more than about 5% of their income for water, and that households would be expected to reduce their consumption not to exceed this level of expenditure.

This criteria has been used to assess the ability of households in the study areas to pay for water.

The ability of households to pay for water has therefore been assessed by studying the impact of steadily increasing the tariff, to see what proportion of the population will be able to pay, assuming 4%, 5% and 6% of their income is available.

2) Household Income

In order to commence such an affordability analysis, it is first necessary to have an income profile for the target communities. Fortunately, the household survey contains sufficient information on household income to be able to generate a household income profile from its results. The resultant profile, averaged over all scheme areas is as shown on Graph A on ***Figure 5.4-1***. The actual incomes were found to be highest in Nkubu, (11% higher than the average), and lowest in Tigania (23% lower). The assessment of household income was based on a conservative assessment of the agricultural and livestock production of households, cross checked by individual interviews.

3) Tariff Structure

The current tariff, and its band increments have been taken as the baseline for the analysis. Increased tariff rates have been obtained by simple multiplication of the existing rates, as indicated below:

**Table 5.4-1 Tariff Structure**

| Tariff multiplier | 1 (current) | 2 | 3 |
|---|---|---|---|
| Consumption to 10m3/month | 90 Shs | 180 Shs | 270 Shs |
| from 10m3 to 30 m3/month | 15 Shs/m3 | 30 Shs/m3 | 45 Shs/m3 |
| from 30 m3 to 60 m3/month | 20 Shs/m3 | 40 Shs/m3 | 60 Shs/m3 |
| from 60 to 100 m3/month | 30 Shs/m3 | 60 Shs/m3 | 90 Shs/m3 |

It should be noted however that increased affordability levels should be explored by appropriate adjustment of the increments to allow for a higher level of cross-subsidy for a basic human needs supply, but such an exercise is beyond the current study requirements.

4) Demand Limits

The analysis makes two further assumptions:

a) Households which cannot afford to pay for 45 litres per head per day will obtain water from communal water points, kiosks or other sources.

b) For revenue calculations, a maximum demand of 200 litres per capita per day was taken for high income households.

(3) Results

1) Affordability

Graph B on ***Figure 5.4-1*** illustrates how the percentage of households affording 45 litres/capita/day will decrease as the tariff increases, and suggests the following affordability levels:

**Table 5.4-2 Affordability vs. Tariff Level**

| | % of households affording connections | | |
|---|---|---|---|
| % of income available for water | 4% | 5% | 6% |
| Tariff multiplier: 1 | 86% | 86% | 100% |
| Tariff multiplier: 2 | 68% | 68% | 86% |
| Tariff multiplier: 3 | 55% | 55% | 68% |
| Tariff multiplier: 4 | 42% | 55% | 55% |
| Tariff multiplier: 5 | 23% | 42% | 42% |

The resultant affordability levels decrease in steps which relate to the income categories given by the survey results. This has resulted in the apparent anomaly of having the same affordability for more than one level of available income. A more detailed income profile however would result in a smoothing of the curve.

The connection rates assumed in the design of the schemes depend upon the urban/rural characteristics of the supply areas, but they generally range from about 40% in the year 2000, rising to 80% by the year 2010. It would therefore appear that there would be some scope in increasing the tariff by a modest amount without affecting the affordability appreciably. Increases however should be made in small increments to avoid dissatisfaction. Ultimately they should be index linked.

Graph C on ***Figure 5.4-1*** indicates the reduction in the average per capita consumption of those households who remain connected to the supply. This suggests that at the current tariff, the per capita consumption could be greater than assumed in the designs, particularly in rural areas, and that an increase in tariff might eventually be beneficial to reduce consumption.

2) Revenue

The average revenue from all households who remain connected is indicated on Graph D. This suggests that a doubling of the tariff would not decrease consumption to the extent that it would impact on revenue. A purely commercial operation would, on a basis of this graph, look towards increasing the tariff by at least double, and by probably as much as three times.

(4) Conclusions

1) It is likely that the current tariff levels could be increased significantly without unduly reducing the level of affordability. A target of doubling current tariff levels (at present day prices) over a period of 5 years is suggested.

2) It is unlikely however that full costs will be able to be recovered from consumers without raising the costs to levels that will deter most consumers from obtaining connections. Operation and maintenance costs should be recovered by an efficiently run utility using the current tariff. It is suggested that utilities should aim to recover the full costs of the schemes based on low interest loans. It has been estimated that by doubling the current tariff, the Meru scheme, assuming an acceptable level of unaccounted for water, should be able to recover full costs, if investments are based on a 4% interest rate.

## 5.5 Institutional and Organizational Development Plan

Most of the Ministry water supplies in the study area are facing serious problems of water source limitation, a shortage of chemicals and materials, frequent water rationing, high percentage of UFW, weak organisation for metering and accounting, insufficient number of experienced staff and engineers, etc. Further, the overwhelming number of community self-help schemes are giving adverse effects on development of Ministry water supplies. The coverage ratio in the area by the Ministry water supply stays constant, around 15 - 20% in the last decade. Instead, the community self-help schemes, mostly depending on river water, are increasingly providing unsanitary and untreated water to the public.

The long-term water supply development plan described in the previous sections, therefore, are based on a prerequisite that institutional and organizational development plans both at national and local levels will be implemented successfully. Unless these key issues are handled properly by the agencies concerned, the current trend of decreasing service coverage by the Ministry W/S will not be curbed and furthermore, the water supply conditions in the study area will deteriorate. Infectious water borne diseases can be transmitted by poorly maintained water supply systems. The resultant systems will therefore increase the chances of outbreak of such diseases.

Our draft concept for development of national water supply schemes and recommendations for operation and management at national and district levels are described in the subsections.

### 5.5.1 National Water Development Strategy

The proposed strategic development will be outlined seeking for development and coexistence of the Ministry and Community W/S schemes in harmony. The present status of the community water supply schemes and their view of future development are first discussed on the basis of questionnaire surveys and interviews conducted under the current study.

(1) Present

As described in Section 3.2.2 of the present report, a number of community water supply schemes exist within the study area. They are generally simple gravity schemes, built with contributions mainly from members, supplying raw water for animal watering and for irrigation (60%) as well as for household use (40%). Population served by these schemes is larger than those of the Ministry water supply. Apart from the initial cost and occasional repair costs, there are no regular charges.

Our survey results indicated that they are facing many operational and managerial problems as listed below;

1) Technical and Operational

-a shortage of conveyance capacity of the intake and trunk mains

-a lack of storge facilities, resulting in low water pressure

-frequent water rationing

-inadequate site for raw water intake

-overlapped supply areas, creating complicated pipeworks

-no technical staff engaged for operation and maintenance

2) Financial and Management

-a lack of finance and frequent failure in fund raising

-facilities that ignored technical design, resulting in low water pressure

-leadership wrangles between the members

(2) Opinion by Community Water Supply Committees

All representatives of the water user groups organized under the schemes, without exception, stated their wish not to be interfered by the Government. They fear metering and tariff policy set up by the government. Some of them, however, expressed their willingness to accept financial and technical assistance from the Government, which are helpful to solve the problems they are currently facing.

(3) Development Strategy

The ultimate goal of water supply systems, is to provide safe and clean water to the whole population. This will be beneficial to the living environment and to public health. The Ministries concerned should exert concerted efforts to achieve this target.

The best method of providing treated water to these communities will vary with the particular circumstances of each scheme, the existing water usage, and the community's attitudes to institutionalised water supply schemes. Nevertheless, in general terms, there would appear to be a number of development options. ***Figure 5.5-1*** schematically portrays typical patterns of these options.

1) O-1 Full Integration:

Community schemes to be integrated fully into MLRRWD schemes. The MLRRWD will become fully responsible for operation, maintenance, revenue collection etc. Each connection being provided with a meter, and billed on a monthly basis using a standard MLRRWD tariff.

2) O-2 Bulk Supply:

The community scheme is provided by a bulk metered connection from the MLRRWD supply. Responsibilities for operation and maintenance being separated at the meter. The community management being responsible for collecting charges from its members and paying bulk water charges to the MLRRWD.

3) O-3 Parallel Systems:

Two schemes will coexist; one supplying treated water to households, the other being the community supply providing untreated water for other purposes. The community supply area, or the MLRRWD can provide treated water as a bulk supply for the community to be responsible for the distribution system.

4) O-4 Separate Supply Areas:

Community and MLRRWD schemes to supply completely separate areas.

From the present status and the leading opinions of the members of Community W/Ss, however, it is considered premature for the Ministry W/S to apply the above options immediately. As a long term target, however, the use of parallel systems is considered most likely option that will gain widest acceptance within the existing community supply systems and which will, at the same time, comply with Government Policy to provide people with "safe" water supplies.

(4) Formulation

Keeping in mind this target is a long term solution, a draft concept for development of water supply in the country should be formulated as follows:

1) Phase I (up to 2005)

(National Level)

* To grasp whole picture of the existing water supply systems developed in the country to date, including community self-help schemes, schemes operated by NGO, factories and other institutions, by conducting surveys at a national scale.

* To strengthen a legal framework for water quality control and management. In about coming three years, the MLRRWD should conduct water sampling and testing at all community water supplies. It is desirable that all costs will be shouldered by the Government. In parallel with this work, the MLRRWD shall explain the needs and importance of this task. The community water supplies, thereafter, will take over this duty.

* To provide the organizations with professional advice in producing clear water, based on the review of the water testing.

* To provide assistance in the field of technical and managerial aspects. If required, the Government's officials and engineers will visit the sites and provide appropriate advice in solving the problems.

* To take over if the community is willing.

(District Level)

- To supply clean and safe water to the people by dosing chlorine on a continuous basis. This will be a base for obtaining public understanding.

- To establish metering systems throughout the country to avoid water wastage.

- To intensively conduct campaigns for obtaining public support and understanding for water supply services.

- To hold seminars and meetings periodically to have a dialogue with the public and to provide information on health and sanitation aspects.

2) Phase II (up to 2010)

- To continue supplying safe and clean water to the public.

- To conduct public campaigns for applying separate systems; Ministry water supply mainly for domestic consumption and community water supply schemes for irrigation and watering animals.

- To have frequent contacts with consumers of the community WS schemes, who are using unsanitary water for drinking so as to change to clean and potable water.

### 5.5.2 Recommendations for Operation and Management at National Level

(1) Government's Support for Establishment of Metering System

Metering is a basis for operation and management of water supply. Despite the government's stated need for meter installation at all connections, only a few customers have meters that function normally. Per capita consumption of these metered customers is in a standard level of 80 - 100 lpcd in average. The remaining customers have no meters in most cases or defective meters which are left without repair. They are enjoying abundant water with relatively low flat rate tariff.

It is an urgent requirement to establish a metering system throughout the country. Without government's strong support, however, all efforts will be in vain. The government shall take the following measures to facilitate early establishment of the metering system and to obtain public understanding and support.

1) to mobilize meter readers through inhouse/on-the job trainings,

2) to mobilize accountants for normal bookkeeping and accounting generally accepted worldwide,

3) to mobilize technicians for meter-calibration and repair through training,

4) to assist DWOs in establishing meter repair shops with necessary equipment at district level,

5) to assist DWOs in installing bulk meters at the outlet of each treatment works and storage reservoir, and

6) to carry out public campaigns for introduction of the metering system, explaining its need and pointing out present uneven water rate charged to the consumers, preferably on daily papers, radio, TV and other media

(2) Provision of Irrigation Water

Farmers in the supply area are using large quantities of piped water for irrigation. Without provision of irrigation water, they will easily vandalize the meters installed. Under the circumstances, alternative water sources for irrigation might be a number of community self-help schemes developed within the supply area of the Ministry W/S. In this respect, the Government shall play a leading role to obtain public consensus.

(3) Water Quality Control and Management

The MLRRWD, in view of the present situation, should take regulatory measures to place all water supply schemes under an obligation to periodically conduct water quality testing and report back to the Ministry for monitoring. The MLRRWD, based on review of the report, shall provide them with proper technical advice for improving the water quality. These activities may create increasing opportunities of communication between the MLRRWD and the water supply schemes.

(4) Water Tariff Structure

The Water Act regulates standard water tariff; Ksh 0.5 per 20litre for water kiosk and Ksh 90.0 for the first 10m3 for individual connection. Unit price is estimated at Ksh 25 per m3 for kiosks and Ksh 9 per m3 for individual connections. Furthermore, in some water kiosks, piped water are being sold at Ksh 1 or Ksh 2 per 20 litre (double - four times higher than the standard tariff). This implies that the poor who normally obtain water from communal water points or kiosks suffer from a high rate water tariff, while the rich who have individual connections enjoy water with relatively lower prices. This is a contradiction to the government policy to encourage even distribution of wealth among the population. The Government should take proper measures to normalize the water tariff, particulaly for kiosks.

(5) Water Rights

Water Apportionment Board (WAB) organized under the Ministry is responsible for issuance of water right permission, registration, water shed management and control in the country. According to the questionnaire survey, most community W/S schemes and schemes operated by NGOs in the study area have been legally registered. The critical problem found in relation to water rights is that the flow measurement devices are not provided at intakes. Therefore, actual intake rates are not known. It is also observed that the design intake rates applied for obtaining water rights differ significantly from the actual situation observed at the sites. Increase/decrease in the intake rates are frequently taking place after application. This situation makes proper coordination of water users by the WAB difficult. From these observation, the following are considered important.

1) to install flow measurement devices at the existing intakes (particularly at large and middle scale intake facilities) for periodical measurement,

2) to monitor and keep records of intake rates based on reports to be submitted periodically by the schemes,

3) to conduct periodical checking of the flow measurement devices, and

4) to give order to repair and replace if necessary.

(6) Financing

Flow measurement and UFW surveys carried out under the study indicate the possibility of significantly inaccurate data being compiled at DWOs. The survey also indicates high ratios of UFW or water losses which are not billed.

Annual budget appropriated for DWOs are always below that required for normal operation and maintenance of the water supply systems. This is attributable to the fact that revenues from water sales are not sufficient to cover O&M costs due to high UFW ratios and a substantial amount of delinquent bills. From these facts, the following are considered important;

1) to install meters at all connections and record all information in an uniform format, including number of family members, customer's address, date of meter installation, types, brand, size, sketches where meters are installed,
2) to conduct a field survey for updating customer registration,
3) to charge water tariff based on a comsumption basis,
4) to upgrade customer services for public support and understanding, and
5) to mobilize qualified accountants for a review and renewal of all accounting procedures currently practiced.

(7) Training and Staffing

KEWI in Nairobi is an organization responsible for training staff, artisans, craftsmen and technicians assigned in the water sector. In view of the increasing tasks resulting from establishment of metering systems, it is of vital importance to strengthen fuctions of the KEWI training center. The areas to be reinforced will cover the followings;

1) meter repair and calibration,
2) leakage repair and detection,
3) computer operation for spread sheet and date base,
4) metering and billing, and
5) accounting and bookkeeping.

(8) Expatriate Staff Assignment at District level

In order to advise and assist DWOs in overall areas of operation and management, it is suggested that expatriate engineers be assigned at national/district levels. This arrangement may be possibly carried out under the JICA Technical Cooperation Program. The objective being to improve capacity and motivation of operation and maintenance staff. It is most desirable if they could be assigned continuously throughout the project period, including the preparatory stage.

### 5.5.3 Recommendations at District Level

(1) Data Recording

Data on water production and distribution kept in the DWOs are not necessarily accurate. Maps of the existing distribution pipe network also lack accuracy for hourly control of water distribution and transmission. Under the Phase 1 project, it is planned to install bulk meters on all distribution mains. Various data on customers will be available in the course of meter installation and customer registration. This data, it recorded properly, will provide useful information both for routine operation and for future expansion.

(2) Chemical Dosage

Chemicals shall be dosed when required, particularly continuous cholorine dosage, which is minimum requirement to supply safe and clean water for domestic consumption. In view of the general objective of improving public health through adequate water supply, reasons for non-dosage are not acceptable.

(3) Customer Registration

The customer survey indicates that many non-registered connections exist in the supply area (approximately 20% of the customers in Meru pilot area). They are utilizing abundant piped water without paying. Unless proper measures to register these customers are taken immediately, they will continue to waste water, which result in significant losses to the DWO revenue. These activities by DWO will also be a base for obtaining public support and understanding.

(4) Bookkeeping and Accounting

Trained accountant/s will be mobilized at the national level. They will periodically supervise all procedures taken for bookkeeping and accounting at DWO. They will advise inhouse staff in preparing budgetary plans and financial statements including balance sheet, cash flow and income statements based on generally accepted accounting principles. They will also provide general information on water supply business, assets and inventory control, metering and billing.

(5) Recruitment of Meter Readers

Following the training at KEWI, a chief for meter reading will organize meter readers at the district level, selecting candidates from the inhouse staff and giving explanation of the need and importance of their duties.

(6) Recruitment of Experts and Staff for Leakage Control

Similar procedures as above will be taken. Following the training at KEWI, a chief engineer for leakage control will organize a team at the district level, explaining methodology, procedures and schedules to the selected staff. The leakage control team will utilize equipment and tools to be purchased at the national level.

(7) Public Campaign

It is preferable to organize a "Public Relation (PR) Section" at the district level, otherwise it will be impossible to conduct a public campaign to obtain support for the water supply services. To this end, the PR Section will make every effort to give information on the needs of water supply and hygiene education, an outline of the existing water supply system, future water supply planning, etc., to the public through various types of media, including local papers, radio, TV, movies, pamphlets, handouts, leaflets, etc.

(8) Branch Office

Meru and Tigania water supplies will expand the supply area accompanied with completion of the project facilities. To facilitate customers for payment and to facilitate the staff for routine inspection of the distribution pipe network, one or two branch offices will be established at strategic points of the supply area. Possible sites may be at the storage reservoirs to be constructed. In the branch office, a store house for meters, pipes and fittings will be constructed for routine maintenance. For the purpose of meter repair and calibration, the district water office will have a workshop equipped with tools, fittings and calibrators on its premises.

## 5.6 Community Education

Community participation requires users to be well informed when making realistic choices on what facilities they will use, how they will maintain, operate and pay for services. Therefore intended users must be given opportunities to communicate their views, needs and objections, through community education.

Community education is a partnership approach, it involves sharing of information, consultation, discussion and negotiation. The education empowers the user communities to make informed decisions concerning improved water and sanitation systems.

In the study area, there is not adequate communication between the water users and the authorities concerned, therefore the break down in communication causes some constraint in the delivery of water services. There is need for authorities to establish mechanisms for dialogue and for responding to express community needs, which can be achieved through community education.

It is proposed that community education be part and parcel of the implementation strategy, so that the communities shall be well informed to play an effective role as water consumers.

The following aspects will constitute community education program.

(1) Hygiene Education

The public awareness survey and monitoring of communal water point indicated that people in the study area had poor knowledge of the requirements of safe water, and most of them used rivers and community water supplies. Only 22% used ministry water supplies. This means that safe water in adequate quantity, and sanitary waste disposal, while important, are not enough to ensure better health, unless these are used properly. This low usage of improved water facilities is caused by lack of consumer acceptance of the facilities and awareness of health implications.

Improvement in Public Health care therefore depends on better knowledge of interrelations among water, sanitation and health and of cultural and religious beliefs and personal hygiene habits.

The objectives of hygiene education campaigns are:

a) To help users adopt better hygiene practices such as safe collection of water, safe storage and hand washing.

b) To assist communities in identifying their health problems and priorities, this will ensure that the program is relevant to them.

c) To make use of people's own capabilities and help them to set and attain their own goals.

d) To improve sanitary practices in the study area.

The target group will be:

1) Schools

Local schools provide challenging opportunities for hygiene improvement. This will be done through practical lessons in class and on site, through improvement of school sanitary and hygiene conditions. Schools will also take part in community programs such as clean up campaigns at home and in public places.

2) Water Consumers

Mainly consumers using communal water points will be targeted. Results obtained from monitoring of communal water points indicate that water consumption is very low, health and sanitation facilities inadequate and waste water disposal facilities non existence.

3) Women Groups

Women are the users of water and sanitation facilities. As users they decide on whether they will use the improved water facility (tap), kiosks or latrine, and they are responsible for educating children on their use. Women have sound ideas on water use and hygiene and have networks of cooperation with other women. In planning, they are the best source of information on the appropriateness of the new facilities.

(2) Community Education Campaign

Community Education campaigns will aim at educating the consumers on the importance of using safe clean water. The major goal will be to improve the relationships between the MLRRWD and the consumers. From the interviews conducted, and public awareness survey, there is no proper flow of information between the ministry and the consumers. Therefore, this lack of information causes dissatisfaction between the two groups. Community education campaigns will aim at educating the consumers on the services offered such as:

1) Metering System:

Consumers are highly suspicious when one talks about water meters. Most of the consumers prefer flat rates, because they feel metering will make them pay more. However, introducing meters, the aim is to provide equitable services, so that the interests of the poor will be guarded. Flat rates usually favor the rich, who usually have larger areas to irrigate, more items to wash, and yet pay the same amount as the poor. Through community campaigns, people will discuss the advantages and disadvantages of meters and decide for themselves the system which is better.

2) Legal Framework for Water Quality Control

The campaigns will explain the importance of using good quality water and the consequences which communities face using untreated water. This will involve distinction between water for irrigation and for drinking.

Other aspects will include billing, cost recovery, preventive maintenance community participation, illegal connections etc.

The target group for community education campaigns will be:

3) District/divisional Water Staff

The campaigns will target the district/divisional staff, because they are the ones who deal with the consumers. They will be taught how to deal with consumers during the course of their work.

4) Water Consumers

The programme will target registered consumers who are already using Ministry water supplies. The campaigns will also be done at water points provided by the project and target water committee and caretakers.

5) Community Leaders

These will include chiefs, teachers and religious leaders. The aim will be to pass messages further to the rest of the population through meetings, seminars, workshops.

(3) Development of Training Materials

Participatory materials similar to those developed for monitoring of communal water points will be developed. These will include posters, pamphlets, flip charts, photographs slides, guidelines. The materials will be culture specific ready to give specific messages on:

1) Personal Hygiene

Messages on washing hands, bathing, use of latrines, washing clothes and using clean vessels for drinking water.

2) Household Hygiene

Will involve safe excreta disposal, covering water storage vessels, disposal of household and solid waste.

3) Community Hygiene

Cleanliness at the water source, provision of communal latrines at public places, keeping roads free from rubbish and human waste, provision of safe means of disposing waste and solid waste from public places.

(4) Implementation of Community Education.

The program will be implemented by the government ministries, MLRRWD, MOH and MOCSS. The Ministry of Health will handle all aspects of health education, MOCSS will mobilize the user groups while MLRRWD will provide information on the water related aspects.

The main strategy will be to identify animators/educators who come from within the communities in order for them to participate in the training and to use that training on a long term basis.

(5) Training Messages

Proper messages modified to local conditions will be developed, and be made participatory. The following activities will be carried out.

1) Role play and story telling
2) Posters and Pamphlets
3) Slides, Films and Videos
4) Discussion
5) Demonstrations
6) Mapping
7) Home visits
8) Health Games
9) Drama and Puppets.

## 5.7 Preliminary Financial and Economic Evaluation

At the stage of establishing a master plan, preliminary project evaluation of the proposed water supply schemes in the Study Area was undertaken in compliance with the financial and economic viability of the project. The overall results of the financial and economic evaluation by water supply scheme are summarized in ***Table 5.7-1.***

**Table 5.7-1 Overall Financial and Economic Evaluation by Water Supply Scheme**

| Scheme | Financial Evaluation | | | Economic Evaluation | | | Social Concerns | | Overall |
|---|---|---|---|---|---|---|---|---|---|
| | FIRR | NPV | RER | EIRR | NPV | CBR | Health Needs | Water Needs | Evaluation |
| Meru | - | - | ● | ● | ● | ● | ● | ● | ◎ |
| Nkubu | - | - | ▲ | - | - | - | ▲ | ● | △ |
| Isiolo | - | - | - | - | - | - | ● | ● | △ |
| Chuka | - | - | ● | ● | ● | ● | ● | ▲ | ◎ |
| Chogoria | - | - | ▲ | - | - | - | ● | ▲ | △ |
| Maua | - | - | ▲ | - | - | - | ▲ | ● | △ |
| Tigania | - | - | ▲ | ▲ | - | - | ● | ● | △ |

*Symbols for financial/economic evaluation*
● = *Viable*
▲ = *Justifiable*
\- = *Not viable*
*Symbols for social concerns*
● = *Highly concerned for improvement*
▲ = *Improvement recommended*
*Symbols for Overall evaluation*
◎ = *Socio-economically investment justifiable*
△ = *Socio-economically investment considerable*

### 5.7.1 Financial Aspects

The results of the financial evaluation given in ***Table 5.7-2*** indicate that none of the schemes of the project can become financially viable at the present tariff on the basis of the full-cost recovery. Although resulting in either negative or marginal values of FIRR and NPV, two schemes, Meru and Chuka, can generate revenue to cover O&M costs. All the other schemes except Isiolo would be in deficit for some years at the beginning. It is therefore necessary for these schemes that the initial deficits be subsidized by the central government (MLRRWD). Financial cash flow prepared on an annual basis is then presented in ***Table 5.7-5***.

**Table 5.7-2 Financial Evaluation by Water Supply Scheme**

| Scheme | FIRR | | NPV | | RER | |
|---|---|---|---|---|---|---|
| | Rate | Viability | Rate | Viability | Rate | Viability |
| Maru | 1.7% | - | -6,336 | - | **1.13** | ● |
| Nkubu | -2.6% | - | -1,119 | - | 0.87 | ▲ |
| Isiolo | n.a. | - | -9,821 | - | 0.22 | - |
| Chuka | 0.3% | - | -2,002 | - | **1.02** | ● |
| Chogoria | -2.8% | - | -1,993 | - | 0.84 | ▲ |
| Maua | -2.3% | - | -850 | - | 0.89 | ▲ |
| Tigania | n.a. | - | -2.799 | - | 0.66 | ▲ |

***Symbols***

● = *Financially viable*

▲ = *Financially justifiable with condition*

\- = *Not financially viable*

### 5.7.2 Economic Aspects

The results of the economic evaluation are summarized in ***Table 5.7-3***, showing that two schemes, Meru and Chuka are found to be economically viable, and Tigania is considered justifiable with a fairly acceptable economic return. The four other schemes are, however, found to be not economically viable. The undesirable outcome of the EIRR rates in some schemes is attributed to the fact that the economic benefits calculated are confined to the quantifiable benefit of the time saved by the reduction of water carrying. Economic cash flow prepared on annual basis is presented in ***Table 5.7-6.***

**Table 5.7-3 Economic Evaluation by Water Supply Scheme**

| Scheme | EIRR | | NPV | | CBR | |
|---|---|---|---|---|---|---|
| | Rate | Viability | Rate | Viability | Rate | Viability |
| Maru | **11.6%** | ● | **855** | ● | **1.06** | ● |
| Nkubu | n.a. | - | -1,890 | - | 0.12 | - |
| Isiolo | n.a. | - | -8,129 | - | 0.20 | - |
| Chuka | **14.9%** | ● | **885** | ● | **1.21** | ● |
| Chogoria | n.a. | - | -1,705 | - | 0.51 | - |
| Maua | n.a. | - | -1,181 | - | 0.33 | - |
| Tigania | **7.2%** | ▲ | -398 | - | 0.91 | - |

***Symbol***

● = *Economically viable*

▲ = *Economically justifiable*

\- = *Not economically viable*

### 5.7.3 Social Aspects

Aside from both financial and economic aspects, social concerns were also evaluated to determine the needs for water by the local residents, as given in ***Table 5.7-4.*** This clearly shows that all schemes should be eligible for the provision of water supplies in terms of public health and water shortage, to improve public welfare as a part of the government mandate.

**Table 5.7-4 Social Evaluation by Water Supply Scheme**

| Scheme | Public Health | | Water Shortage | |
|---|---|---|---|---|
| | Rate | Severity | Rate | Severity |
| Meru | 1.73 | ● | 2.09 | ● |
| Nkubu | 1.56 | ▲ | 1.94 | ● |
| Isiolo | 1.69 | ● | 1.98 | ● |
| Chuka | 1.85 | ● | 1.50 | ▲ |
| Chogoria | 2.04 | ● | 1.10 | ▲ |
| Maua | 1.04 | ▲ | 1.84 | ● |
| Tigania | 1.72 | ● | 1.80 | ● |
| Average | 1.66 | - | 1.75 | - |

***Symbols***

● = *Highly concerned for improvement*

▲ = *Improvement recommended*

### 5.7.4 Overall Financial and Economic Evaluation

According to all the above aspects, the overall financial and economic evaluation identified Meru and Chuka as being the most socio-economically justified, and that lending arrangement will be required to cover investment costs.

Furthermore, due to the severe situation of public health and water shortage found in the Study Area, investment for the other five schemes of Nkubu, Isiolo, Chogoria, Maua and Tigania is also justified, also requiring financing in the same manner as Meru and Chuka.

Regarding the selection of a priority project, it should be noted at the end of overall financial and economic evaluation that the financial return can only determine the relative investments for development projects by the government. The financial return alone should not become the criterion of selecting the project, as long as the project is considered to be socio-economically viable and to be a priority project by the government for the sake of the public welfare. This notion is particularly appropriate with respect to water supply projects, since the provision of water is one of the basic human needs of people.

## 5.8 Implementation Schedule

(1) Phasing of Schemes

As described in the previous section, the implementation of each scheme by the target year shall be made in two phases as follows:

Phase 1

1) Construction of intake and raw water pipeline

2) Establishment of 50% of treatment works capacity, or as appropriate

3) Installation of main transmission pipelines sufficient to serve the main concentrations of population within the service area

4) Construction of storage reservoir, or as appropriate

Phase 2

1) Construction of remaining treatment works

2) Construction of remaining storage reservoir

3) Construction of any remaining major extensions of the trunk main system to feed the entire service area

In addition to the above, the smaller distribution pipework will be built through annual extensions of the system, either by small contracts or by direct labor.

(2) Improvement of Water Supply Organization and Institutions

In the course of implementing the schemes, improvement of the existing water supply organizations and relevant institutions shall be made.

## 5.9 Overall Evaluation

### 5.9.1 Evaluation on Technical Aspects

The surface water sources in and around the Study Area were confirmed to be sufficient in quantity and quality for the development of future water supply systems except in the case of Isiolo. Consequently, the future water supply systems for the other six schemes shall be based upon surface water sources using river intakes.

Based on the data at the downstream gauging station, it was found that the minimum safe yield of the Isiolo River is even far less than that required for the existing water demand. Hence, it can be inferred that the surface water potential in the case of Isiolo is rather limited, especially during dry season. Groundwater development is therefore proposed to supplement the surface water sources.

On the basis of these factors, and in order to find out the potentiality of groundwater development, geological investigation including geophysical electric sounding tests was carried out in Isiolo. Further, test boring was conducted in three locations, which also featured pumping rests. It was found out that these wells are suitable for groundwater development. However, it has to be noted that the tests were conducted only in three locations, which were unevenly distributed over the study area. Moreover, quantities of hydrological tests per borehole were limited. Hence, further investigation is needed to confirm the sufficiency of groundwater required to meet future water demand.

Intakes, raw water transmission lines, treatment plants and subsequent distribution facilities have been planned in outline for each supply area. The construction works for these facilities will be carried out by phasing, as shown in the implementation schedule, namely Phase 1 and Phase 2 targeting the years 2005 and 2010 respectively. The phasing will optimize the scale of the facilities and investment cost recovery. Environmental impacts of the proposed works have been duly considered.

The existence of community water supply systems, is a significant factor for establishing future water supply systems, especially in its extension programs.

### 5.9.2 Evaluation on Economic and Financial Aspects

The financial viability of the projects are shown to be fairly low and the current average water tariff does not bring about viability to any of the schemes. If the current water tariff is doubled, only Meru becomes financially viable, indicating that Meru has the largest potential for return of investment.

According to the financial analysis, the Isiolo scheme resulted in the third highest viability following Chuka.

According to the results of the financial cashflow analysis, none of the schemes resulted in a financially viable operation if all costs are to be recovered (O&M and capital costs). Whereas only Meru was found to be viable if only Operation and Maintenance costs, (without capital costs), were to be recovered. Isiolo, Chuka and Chogoria were conditionally financially viable if only O&M costs are to be recovered. These three schemes however will operate under a deficit for several years initially, resulting in the requirement of government subsidy or donor assistance.

## 5.10 Selection of Schemes for Feasibility Study

In compliance with the overall evaluation, Meru scheme will be preliminarily and conditionally selected as the prioritized projects from the view point of financial viability.

# TABLES

# Table 2.1-1 Summary of Lithostratigraphy

**Mount Kenya**

| Period | Epoch | Formation | | Lithology | Maximum Thickness (meters) |
|---|---|---|---|---|---|
| Quaternary | Recent | Superficial Deposit | | Loam, Silt, Clay, Laterites, Gravel, Ashes, Moraines | |
| | Recent | Mont Kenya Volcanic Series | Upper : Parasitic Vents | Basaltic Pumice, Scoriaceous Lavas | 200 - 300 |
| | Pleistocene | | Middle : Parasitic Fissure Eruptions | Trachytes, Olivine Basalts, Mugurites, Olivine Trachytes | > 500 |
| | | | Lower : Main Eruptive Episode | Nepheline Syenite of the Plug | |
| | | | | Kenytes, Phonolites | 600 |
| Tertiary | Pliocene | | | Phonolites and Trachytes | > 500 |
| | | | | Unexposed Volcanics | 3000 |
| | | (End-Tertiary Peneplain) | | | |
| Pre-Cambrian | | Basement System | | Pelitic to Semi-Pelitic Gneisses, Granitoid Gneisses, Pegmatites, Schists<br>Mt. Kenya Charnokitic Rock (Dioritic) interbedded with Semi-Pelitic Gnesses | |
| | | Intrusives | | Gabbros, Olivie Doierites, Perknites | |

**Nyambene Hills**

| Period | Epoch | Formation | | Lithology | Maximum Thickness (meters) |
|---|---|---|---|---|---|
| Quaternary | Recent | Superficial Deposit | | Loam, Silt, Clay, Laterites, Gravel, Ashes, Calcretes | |
| | Recent | Nyambene Volcanic Series | Parasitic Vents | Basaltic Pumice, Scoriaceous Lavas | 60 - 100 |
| | Pleistocene | | Upper : | Basalts, Phonolites, Tephrites, Scoriaceous Lavas, Tuffs | 1070 |
| | | | Lower : | Porphiric Olivine Basalts | 30 - 300 |
| | | | Lakebeds | Friable Limestone | |
| | | (End-Tertiary Peneplain) | | | |
| Pre-Cambrian | | Basement System | | Pelitic to Semi-Pelitic Gneisses, Granitoid Gneisses, Pegmatites, Schists | |
| | | Intrusives | | Perknites | |

Source : WRAP

**Table 2.2-2 Summary of Runoff Data at Existing River Gauging Stations**

| Sub-basin | No. of RGS | River | Period Recorded (year) | Catchment Area (km2) | Mean Monthly Flow (m3/sec) | 95 % Daily Flow (m3/sec) | Minimum Monthly Flow (m3/sec) | Minimum Daily Flow (m3/sec) |
|---|---|---|---|---|---|---|---|---|
| 4EA | 4EA01 | Mutonga | 1953-1988 | 124 | 5.22 | 1.72 | 1.55 | 1.26 |
| | 4EA03 | Kithenu | 1952-1969<br>1975-1989 | 44 | 1.98 | 0.58 | 0.41 | 0.26 |
| | 4EA06 | Mutonga | 1964-1988 | 613 | 11.73 | 3.20 | 2.49 | 1.39 |
| 4EB | 4EB01 | Nithi | 1953-1988 | 120 | 3.17 | 0.94 | 0.80 | 0.52 |
| | 4EB02 | South Mara | 1953-1962<br>1966-1971 | 83 | 2.49 | 0.58 | 0.41 | 0.12 |
| | 4EB03 | North Mara | 1952-1969 | 44 | 1.73 | 0.34 | 0.23 | 0.17 |
| | 4EB04 | Thuchi | 1956-1988 | 111 | 4.34 | 0.68 | 0.45 | 0.44 |
| | 4EB06A | Ruguti | 1962-1988 | 368 | 4.84 | 0.79 | 0.52 | 0.26 |
| | 4EB07 | Thuchi | 1960-1988 | 495 | 5.13 | 0.76 | 0.51 | 0.35 |
| | 4EB09 | Tungu | 1959-1988 | 80 | 1.61 | 0.15 | 0.04 | 0.03 |
| | 4EB11 | Mara | 1967-1988 | 534 | 10.41 | 2.51 | 2.33 | 1.85 |
| | 4EB12 | South Mara | 1981-1988 | 84 | 2.30 | 0.63 | 0.43 | 0.38 |
| | 4EB16 | North Mara | 1985-1989 | 44 | 1.98 | 0.42 | 0.41 | 0.28 |
| 4FA | 4F03 | Kathita | 1952-1961 | 246 | 2.45 | 1.25 | 1.09 | 1.04 |
| | 4F04 | Thingithu | 1953-1988 | 91 | 2.32 | 0.96 | 0.89 | 0.79 |
| | 4F05 | Mariara | 1956-1974<br>1980-1988 | 42 | 1.44 | 0.56 | 0.38 | 0.36 |
| | 4F10 | Kathita | 1960-1987 | 878 | 13.43 | 2.63 | 1.78 | 1.28 |
| | 4F17 | Thingithu | 1965-1987 | 303 | 4.16 | 0.57 | 0.55 | 0.14 |
| 4FB | 4F08 | Thangatha | 1958-1988 | 210 | 5.07 | 0.33 | 0.32 | 0.06 |
| | 4F09 | Ura | 1958-1988 | 198 | 5.36 | 0.48 | 0.45 | 0.07 |
| 5DA | 5D08 | Isiolo | 1976-1988 | 230 | 0.18 | 0.025 | 0.014 | - |

Source : WRAP, NWMP

## Table 2.2-3 Summary of Hydrogeological Zones

| Zone | | Area (km2) | Lithology | Aquifers | Springs No. | Springs Average Yield (L/sec) | Boreholes No. | Boreholes Rate Successful | Depth Average | Depth Range | Struck Level Average | Struck Level Range | Rest Level Average | Rest Level Range | Yield Average (m3/hr) | Yield Max. (m3/hr) | Water Quality | Groundwater Potential |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | (meters below ground surface) | | | | | | | | | |
| Mount Kenya | Upper and Middle Slopes | 1,248 | Phonolites, Trachytes, Kenyte Lavas, Agglomerates | Regional : Cinder Layers Old Land Surfaces | ( Many ) | ( high ) | ( No Boreholes ) | | - | - | - | - | - | - | - | - | Very Good | (Inaccessible) |
| Mount Kenya | Widnward Lower Slopes | 987 | Phonolites, Kenyte Lavas, Tuffs, Agglomerates | Regional : Cinder Layers Old Land Surfaces | 307 | 7.4 | 11 | 100% | 129 | 21 - 201 | 53 | 12 - 170 | 53 | 8.5 - 150 | 9.6 | 70 | Very Good | High |
| Mount Kenya | Leeward Lower Slopes | 651 | Trachytes, Tuffs, Agglomerates | Regional : Cinder Layers Old Land Surfaces | 24 | 5.6 | 12 | 92% | 93 | 50 - 157 | 76 | 34 - 157 | 60 | 16 - 151 | 4.6 | 13.7 | Very Good | Medium |
| Mount Kenya | Deep Aquifer Zone | 200 | Coarse Pyroclasts | Very Good Extensive Aquifers at Greater Depth | 6 | 0.19 | 4 | 25% | 190 | 136 - 239 | 82 | - | - | - | 0.13 | - | Probably Good (No Data) | Uncertain |
| Mount Kenya | Compact Tuff Area | 137 | Compact Tuffs | Very Poor | 0 | 0 | ( No Boreholes ) | | - | - | - | - | - | - | - | - | (No Data) | Low |
| Nyambene Hills | | 457 | Phonolites Tephrites | Regional : Cinder Layers Old Land Surfaces | 125 | 11.3 | 13 | 69% | 55 | 18 - 120 | 40 | 4.5 - 116 | 30 | 1.6 - 101 | 5.1 | 10.3 | Probably Good (No Data) | High |
| Nyambene Deep Aquifer Zone | | 394 | Coarse Pyroclasts, Basaltic Lavas, Phonolites, Tuffs | Very Good Extensive Aquifers at Greater Depth | 2 | 5 | 13 | 15% | 78 | 49 - 104 | 45 | 28 - 76 | 61 | 39 - 84 | 2.7 | - | Very Good | High |
| Volcanic Plains | | 2,565 | Basalts, Pyroclasts | Regional : Cinder Layers Old Land Surfaces | 45 | 9.4 | 75 | 85% | 66 | 11 - 213 | 40 | 5 -115 | 30 | 0 - 100 | 10.5 | 100 | Good | Uncertain |
| Basement Area | | 2,546 | Metamorphic Rocks, Alluvium, Colluvium | Local : Weathered Zones, Faults, Fractures, Alluvium | 0 | 0 | 33 | 55% | 29.1 | 9 - 57 | 13.8 | 2 - 40 | 6.1 | 1.5 -24 | 3.1 | 10 | Poor to Fair | Low |

Source : WRAP

## Table 2.2-8 Water Sources

Unit : m3/day

| Town | Water Sources | Flow rate given by DWO | Estimated 95% daily low flow | Flow rate measured | Flow rate applied as safe yield 1) | Remarks |
|---|---|---|---|---|---|---|
| 1 Meru | (1) Kathita River (existing) | 97,600 | 80,520 | | 57,100 | |
| | (2) Gatabora Spring (existing) | 1,500 | | | 1,500 | |
| | (3) Kathita River (proposed by MLRRWD) | | 60,900 | (105,300) | 43,200 | |
| | (4) Kathita River (alternative) | | 49,700 | (78,200) | 35,300 | Selected |
| 2 Nkubu | (1) Thinghthu River (existing) | | 82,900 | | 53,200 | |
| | (2) Kiguandegwa River (proposed by MLRRWD) | | 21,900 | (18,600) | 14,100 | Selected |
| | (3) Kiguandegwa River (alternative) | | 8,400 | | 5,400 | |
| 3 Chuka | (1) Tungu River (existing) | | 23,400 | | 11,700 | |
| | (2) Ruguti River (proposed by MLRRWD) | | 25,800 | | 12,900 | Selected |
| 4 Chogoria | (1) Mutonga River (existing) | | 62,000 | | 31,000 | |
| | (2) Mara Manyi Stream (proposed by MLRRWD) | | | (13,200) | (13,200) 2) | Selected |
| 5 Maua | (1) Mboone Stream (existing) | 2,700 | | | 2,700 | |
| | (2) Mboone Stream (proposed by MLRRWD) | | | (1,900) | (1,900) 2) | Selected |
| | (3) Ura River (alternative) | | 7,800 | | 6,700 | |
| 6 Tigania | (1) Mikrowe Spring (existing) | 2,100 | | | 2,100 | |
| | (2) Michi Mikuru Spring (existing) | 1,800 | | | 1,800 | |
| | (3) Thangatha Stream (proposed by MLRRWD) | | | (1,400) | (1,400) 2) | |
| | (4) Thangatha Stream (alternative) | | | (4,500) | (4,500) 2) | Selected |
| 7 Isiolo | (1) Isiolo River (existing) | 2,800 | 2,000 | 4,500 | 2,000 | |
| | (2) Isolo River (proposed Dam by MLRRWD) | | | 4,500 | 5,500 3) | |
| | (3) Kithima Spring (proposed by MLRRWD) | | | 3,000 | 3,000 | |
| | (4) Rugusu Spring (alternative) | | | 3,800 | 3,800 | |
| | (5) Groundwater (alternative) | | | | 8,800 | Selected |

Note : 1) River maintenance flow is taken into account for intakes on major rivers.
2) ( ) denotes flow measurements only available during the dry seasons in 1996 and 1997.
3) Requirements for downstream water rights can not be satisfied.

## Table 2.2-10 Results of Preliminary Water Balance Study

Unit : m3/day

| Water Requirement / Flow Rate | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| (1) Isiolo Dam Site Upstream (Domestic) | 417 | 417 | 417 | 417 |
| (2) Isiolo Dam Site Upstream (Irrigation) | 3,772 | 2,829 | 1,886 | 943 |
| (3) Development Flow Rate by Dam | 5,616 | 6,566 | 7,517 | 8,467 |
| (4) Isiolo Dam Site Downstream (Domestic) | 242 | 242 | 242 | 242 |
| (5) Isiolo Dam Site Downstream (Irrigation) | 4,557 | 3,418 | 2,779 | 1,139 |
| (6) Isiolo Town Water Demand | 10,671 | 10,671 | 10,671 | 10,671 |
| (7) Total Water Requirements Downstream (5)+(6)+(7) | 15,470 | 14,331 | 13,639 | 12,052 |
| Water Balance (3) -(7) | -9,854 | -7,765 | -6,122 | -3,585 |

## Table 2.2-12 Water Quality at Intake Sites

| Parameters | Unit | Meru | Nkubu | Chuka | Chogoria | Maua | Tigania | Isiolo | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kathita River | Kiguandegwa River | Ruguti River | Mara Manyi Stream | Mboone Steam | Thangatha Stream | Isiolo River | Kithima Spring |
| pH | | 7.89 | 7.69 | 7.97 | 7.57 | 7.5 | 7.52 | 8.04 | 7.7 |
| Apparent Color | oH | < 5 | 10 | 10 | 5 | 5 | < 5 | 10 | 15 |
| True Color | oH | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 |
| Conductivity | us/cm | 104 | 93 | 103 | 70 | 65 | 92 | 558 | 219 |
| Turbidity | F.T.U. | 0.3 | 1.4 | 1.2 | 0.5 | 0.6 | 0.2 | 1.3 | 1.2 |
| Calcium Hardness as CaCo3 | mg/l | 2 | 4 | 10 | 12 | 12 | 4 | 20 | 40 |
| Total Hardness as CaCo3 | mg/l | 6 | 12 | 38 | 36 | 42 | 12 | 70 | 114 |
| Total Alkalinity as CaCo3 | mg/l | 50 | 47 | 46 | 32 | 32 | 46 | 262 | 96 |
| Carbonate Alkalinity | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iron | mg/l | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.06 | 0.02 | 0.02 |
| Fluorides | mg/l | 0.45 | 0.3 | 0.42 | 0.26 | 0.27 | 0.43 | 0.48 | 0.34 |
| Sulfates | mg/l | 44 | 25 | 29 | 36 | 33 | 60 | 33 | 46 |
| Phosphates | mg/l | 0.05 | 0.03 | 0.03 | 0.02 | 0.01 | 0.06 | 0.01 | 0.01 |
| Silica | mg/l | 47 | 22 | 55 | 47 | 45 | 85 | 30 | 60 |
| Dissolved Oxygen | p.p.m. | 6 | 5.9 | 6 | 5.8 | 5.7 | 5.9 | 5.7 | 5.6 |
| Nitrates | mg/l | 0.06 | 0.02 | 0.02 | 0.01 | 0.04 | 0.04 | 0.04 | 0.01 |
| Manganese | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chlorides | mg/l | 25 | 10 | 12 | 8 | 10 | 27 | 64 | 22 |
| Chromium | mg/l | 0.02 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 |
| Copper | mg/l | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Coliform | /100ml | 60 | 300 | 20 | 10 | 25 | 270 | 50 | 20 |
| Total Faecal Coliform | /100ml | 5 | 55 | 10 | 0 | 4 | 20 | 11 | 0 |
| Dissolved Solids | mg/l | 182 | 45 | 40 | 35 | 45 | 191 | 325 | 90 |
| Suspended Solids | mg/l | 0 | 15 | 10 | 5 | 0 | 0 | 15 | 30 |
| Total Solids | mg/l | 182 | 60 | 50 | 40 | 45 | 191 | 340 | 120 |
| Biochemical Oxygen Demand | mg/l | 2 | 5 | 2 | 10 | 6 | 2 | 3 | 130 |
| Chemical Oxygen Demand | mg/l | 8 | 8 | 4 | 12 | 8 | 6 | 4 | 160 |

## Table 2.2-14 Borehole Data around Isiolo Town

| Borehole No | Location | Coordinates X | Coordinates Y | Ground Elevation (m) | Total Depth (m) | Completion Date | Water Struck Level Depth (m) | Water Struck Level Elevation (m) | Water Rest Level Depth (m) | Water Rest Level Elevation (m) | Yield (m3/hour) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C2114 | Isiolo | | | | 136.8 | 08/12/53 | 54.8 | | 64.0 | | 0.60 |
| C2212 | Isiolo | | | | 97.5 | 07/06/54 | 47.2 | | 36.0 | | 10.90 |
| C2502 | Isiolo | | | | 213.4 | 30/04/56 | 65.5 | | 52.0 | | 18.20 |
| C3129 | Mlango | | | | 83.8 | 08/07/61 | 68.0 | | 62.5 | | 5.18 |
| C6877 | (no data) | | | | | | | | | | |
| C7344 | (no data) | | | | | | | | | | |
| C7406 | (no data) | | | | | | | | | | |
| C7409 | Maliala | 0 23' 16" N | 37 47' 20" E | 1143.0 | 127.0 | 11/07/87 | 112.0 | 1031.0 | 79.0 | 1064.0 | 8.00 |
| C7631 | (no data) | | | | | | | | | | |
| C7734 | (no data) | | | | | | | | | | |
| C7924 | Isiolo Air Strip | 0 20' 18" N | 37 35' 49" E | 1040.0 | 184.0 | 31/07/89 | 112.0 | 928.0 | 18.0 | 1022.0 | |
| C7925 | Ngare Mara River | 0 23' 35" N | 37 40 '06" E | 1025.0 | 48.0 | 26/10/89 | 28.0 | 997.0 | 19.0 | 1006.0 | 25.00 |
| C7926 | Near Buie Shime Rive | 0 25' 57" N | 37 45' 55" E | 1057.0 | 138.0 | 25/08/89 | 52.0 | 1005.0 | 41.0 | 1016.0 | 100.00 |
| C7927 | Near 78 Barracks | 0 21 '42" N | 37 36' 39" E | 1080.0 | 78.0 | 25/09/89 | 22.0 | 1058.0 | 15.0 | 1065.0 | 30.00 |
| C7969 | (no data) | | | | | | | | | | |
| C87 | Isiolo | | | | 64.0 | 10/02/40 | 26.2 | | 13.4 | | 4.60 |
| C8976 | Ngare Mara Village | 0 29' 34" N | 37 38' 20" E | 950.0 | 45.7 | 10/01/90 | 31.0 | 919.0 | 21.0 | 929.0 | 30.00 |
| C90 | Isiolo | | | | 54.8 | 08/04/40 | 37.5 | | 29.0 | | 4.80 |
| C9385 | (no data) | | | | | | | | | | |
| C97 | Isiolo | | | | 36.6 | 25/04/40 | 24.4 | | 14.6 | | 14.00 |
| C98 | Isiolo | | | | 62.0 | 01/06/40 | 30.5 | | 24.4 | | 15.90 |
| SA6 | Isiolo | 0 20' 15" N | 37 48' 15" E | 1082.0 | 39.3 | 29/09/40 | 28.0 | 1054.0 | 12.2 | 1069.8 | 4.53 |

Source : WRAP

## Table 2.2-15 Chemical Data for Boreholes around Isiolo Town

| Borehole No. | Date | pH | EC | Fe | Mn | Ca | Mg | Na | K | Total Hardness | Total Alkatinity | Cl | F | HCO3 | NO2 | SO4 | Free CO2 | TDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (microS/cm) | (mg/l) | | | | | | | | | | | | | | |
| C7344 | 30/09/88 | 7.8 | 1560 | < 0.1 | < 0.1 | 9.6 | 122 | 91 | 12 | 524 | - | 44 | 0.6 | 186 | - | 7 | - | 936 |
| C7409 | 16/06/88 | 7.3 | 910 | 2.6 | < 0.1 | 27 | 20 | 92 | 25 | 148 | 360 | 21 | 1.5 | 438.8 | < 0.01 | 30 | 22 | 546 |
| C7631 | 05/01/88 | 8.6 | 1100 | 0.8 | 0.15 | 86 | 53 | 137 | 11.5 | 440 | - | 26 | - | 652 | - | 6 | - | 800 |
| C7924 | 28/07/89 | 7.4 | 7278 | 0.2 | < 0.1 | - | - | 1323 | 82 | 468 | 442 | 176 | 0.1 | 538.8 | < 0.01 | 288 | 460 | 4367 |
| C7926 | 30/08/89 | 7.6 | 855 | < 0.1 | < 0.1 | 25 | 80 | 116 | 27 | 392 | 352 | 22 | 1.2 | 429.1 | < 0.01 | 11 | 22 | 513 |
| C7927 | 07/11/89 | 7.1 | 1696 | 0.7 | < 0.1 | 90 | 81 | 168 | 13 | 558 | 860 | 22 | 0.4 | 1048 | < 0.01 | 17 | 398 | 1017 |
| C8976 | 19/01/90 | 7.1 | 1700 | < 0.1 | < 0.1 | 205 | 33 | 126 | 15 | 650 | - | 38 | 0.8 | 834 | - | 15 | - | 650 |
| C90 | | 6.9 | - | 0.3 | - | - | - | - | - | 100 | - | 1.2 | 0.3 | 453 | - | - | - | 585 |
| C10557 | 27/11/96 | 6.9 | 1660 | 0.1 | < 0.1 | 62 | 90 | 125 | 13 | 526 | 698 | 47 | 0.2 | - | < 0.01 | 37 | 232 | 1225 |
| C11340 | 15/05/96 | 6.8 | 1500 | < 0.1 | < 0.1 | 80 | 87 | 125 | 13 | 560 | 800 | 61 | 0.8 | - | < 0.01 | 27 | 100 | 1370 |

Source : WRAP, NWMP, Isiolo District Water Office

## Table 2.2-18 Summary of the Pumping Test

| Well No. | TestType | Statistic Water Level | Discharge (Q) | Drawdown(Sw) | Specific Capacity | Sw/Q | Aquifer Loss Coeffient | Well Loss Coeffient | Aquifer Loss (BxQ) | Well Loss (CxQ2) | Total Drawdown(BQ+CQ2) | Ratio of Well Loss (CQ2)/(BQ+CQ2) | Transmissivity <Jacob/TimeDrawdown> | Transmissivity <RecoveryTest> |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (m) | (l/sec) | (m) | (l/sec/m) | (m/l/s) | B | C | (m) | (m) | (m) | (%) | (m2/day) | (m2/day) |
| TW1 | C. | 24.71 | 5.28 | 13.46 | 0.39 | 2.55 | 1.67 | 0.17 | 8.82 | 4.71 | 13.53 | 34.8 | 55.6 | 52.5 |
| | ST-1 | 23.72 | 1.94 | 3.85 | 0.50 | 1.98 | 1.67 | 0.17 | 3.24 | 0.64 | 3.88 | 16.4 | | |
| | ST-2 | | 3.33 | 9.55 | 0.35 | 2.87 | 1.67 | 0.17 | 5.56 | 1.87 | 7.44 | 25.2 | | |
| | ST-3 | | 4.44 | 11.05 | 0.40 | 2.49 | 1.67 | 0.17 | 7.42 | 3.33 | 10.75 | 31.0 | | |
| | ST-4 | | 5.13 | 12.85 | 0.40 | 2.50 | 1.67 | 0.17 | 8.57 | 4.45 | 13.02 | 34.2 | | |
| TW2 | C. | 0.90 | 4.90 | 12.43 | 0.39 | 2.54 | 2.70 | 0.11 | 13.25 | 2.54 | 15.79 | 16.1 | 129 | 129 |
| | ST-1 | 0.00 | 3.19 | 9.70 | 0.33 | 3.04 | 2.70 | 0.11 | 8.63 | 1.07 | 9.70 | 11.1 | | |
| | ST-2 | | 3.70 | 11.45 | 0.32 | 3.09 | 2.70 | 0.11 | 10.00 | 1.45 | 11.45 | 12.6 | | |
| | ST-3 | | 4.10 | 11.78 | 0.35 | 2.87 | 2.70 | 0.11 | 11.09 | 1.78 | 12.86 | 13.8 | | |
| | ST-4 | | 4.90 | 12.12 | 0.40 | 2.47 | 2.70 | 0.11 | 13.25 | 2.54 | 15.79 | 16.1 | | |

## Table 3.2-12 Community Water Supply Schemes - Meru

| Name of Project | Water Source | Production (m3/day) | Supply area (km2) | Water Consumption % | | | Households Served | Assistance from MLRRWD | | | Capital Investment | Year of Construction | Remarks (problems) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (1) | (2) | (3) | | Design | O & M | Others | | | |
| 1 Runogone | Gachiuma river | 168 | 6.0 | 30 | 10 | 60 | 126 | Yes | No | None | 1.8 million | 1973 | -extension in 1995<br>-need to improve intake and tanks |
| 2 Lower Chungu | Karumanthi stream | 500 | 24.0 | 60 | 30 | 10 | 750 | Yes | No | None | 460,000 | 1979 | -extension in 1995 but new source required<br>-leadership problems |
| 3 Gaitune Rutuntune | Gieto spring | 250 | 5.0 | 40 | 0 | 60 | 250 | Yes | No | None | 200,000 | 1985 | -frequent pipe burst<br>-improper intake |
| 4 Gaitune Mwimanyi | Gieto spring | 34 | 2.5 | 70 | 0 | 30 | 60 | Yes | No | None | 114,000 | 1987 | -constructed tanks in 1989<br>-dried up intake and low water pressure |
| 5 Nkirote-Gieto Women Project | Gieto spring | 28 | 2.0 | 100 | 0 | 0 | 70 | Yes | No | None | 100,000 | 1988 | -over exploited intake<br>-weak management |
| 6 Koiru - Ciomburu | Kioru Spring | 24 | 1.0 | 100 | 0 | 0 | 60 | No | No | None | 40,000 | 1992 | -inadequate system<br>-no fund source to expand |
| 7 Nkugua | Kathita river | 667 | 5.0 | 30 | 10 | 60 | 500 | Yes | No | None | 518,000 | 1974 | -need of new intake and tanks<br>-water wastage |
| 8 Magundu | Kathita river | 400 | 10.0 | 30 | 20 | 50 | 300 | Yes | Yes | None | 250,000 | 1976 | -lack of management<br>-weak pipelines and frequent water shortage |
| 9 Gaitune Kithima | M'mkindia spring | 160 | 2.5 | 30 | 0 | 70 | 120 | Yes | No | None | 410,000 | 1996 | -overlapped supply area and double membership<br>-lack of storage facilities |
| 10 Ngithirai | Tributary Kathita | 93 | 2.0 | 30 | 10 | 60 | 70 | Yes | No | None | 70,000 | 1980 | -improper pipe reticulation<br>-lack of storage due to fail in fund raising |
| 11 Mulanthankari Women Project | M'mkindia spring | 46 | 8.0 | 70 | 10 | 20 | 80 | Yes | Yes | None | 267,000 | 1965 | -handed over to women group in 1991<br>-interference by men<br>-facilities ignored design |
| 12 Thura Giaki | Kathita river | 302 | 20.0 | 100 | 0 | 0 | 756 | Yes | No | None | 400,000 | 1980 | -wrangled leadership<br>-poor implementation |
| 13 Nkurene | Muirane stream | 53 | 2.0 | 30 | 0 | 70 | 40 | Yes | No | None | 150,000 | 1972 | -insufficient intake and pipes<br>-weak leadership and double membership |
| 14 Vijana | Nkurune stream | 32 | 0.5 | 10 | 0 | 90 | 8 | No | No | None | 30,000 | 1992 | -no design<br>-shortage of fund |
| 15 Matigari | Kathita Munyui | 54 | 2.0 | 20 | 0 | 80 | 27 | Yes | No | None | 30,000 | 1987 | -limited intake capacity<br>-lack of fund and proper management |
| 16 Karimainga | Koiga spring | 137 | 6.0 | 70 | 0 | 30 | 240 | Yes | No | None | 300,000 | 1992 | -works not consistent with design<br>-doubtful management |
| 17 Mukera | Mukera spring | 40 | 3.0 | 80 | 0 | 20 | 80 | Yes | No | None | 140,000 | 1987 | -low spring yield<br>-facilities ignored design<br>-doubtful committee ability |
| 18 Memeo | Ngachiuna river | 160 | 12.0 | 90 | 10 | 0 | 360 | Yes | Yes | None | 100,000 | 1964 | -weak management<br>-works not consistent with design |
| 19 Ngachiuma Kathima | Ngachiuna river | - | 3.0 | Under implementation | | | 120 | Yes | N/A | None | 1.04 million | 1995 | -under implementation |
| 20 Mwanika Kanja | tributary Nyachima | - | 4.0 | Under implementation | | | 200 | Yes | N/A | None | 257,000 | 1996 | -under implementation |
| **Total** | | 3,149 | 120.5 | | | | 4,217 | | | | 6,676,000 | | |

Note:
*.....(1) Domestic, (2) Institutional and (3) agricultural water consumption
**...Water production are estimated under assumption that average size of a famiily is 8 persons and percapita consumption, 50 litres.

## Table 3.2-13 Nkubu Community Water Schemes

| Name of Project | Location | Source | Year Started | rea Covera (km2) | Present Pop. Served | Water Consumption (%) | | | Water Tariff | Problems Identified |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Domestic | Irrigation | Institution, others | | |
| 1. Taita Muguru | Nkuene | Kiuga Ndegwa river | 1976 | 10 | 3400 | 30 | 50 | 20 | free | poor construction, insufficient spring yield, a lack of fund, no drawings |
| 2. Mwirangara | Mikumbone | Mwirangara springs & Kiuga Ndegwa river | 1972 | 8 | 4000 | 30 | 50 | 20 | free | poor construction, insufficient storage, low pressure, poor management due to illeteracy |
| 3. Munani Factory | Kigane | Mwirangara river | 1978 | - | - | 0 | 0 | 100 | free | not surveyed |
| 4. Ntimekiga | Kigane | Kagwandungu river | 1989 | 4 | 300 | | Not known | | not surveyed | not surveyed |
| 5. Consolata Mission | Nkubu town | Mwirangara spring | - | - | - | 0 | 0 | 100 | free | not surveyed |

## Table 3.2-15 Chogoria Community Water Schemes

| Name of Project | Location | Source | Year Started | Area Coverage (km2) | Present Pop. Served | Water Consumption (%) | | | Water Tariff | Problems Identified |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Domestic | Irrigation | Institution, others | | |
| 1. Kithiu Water Project | 1km west from town | Kamaara river | 1975 | 2 | 688 | 50 | 30 | 20 | free | poor design, poor management |
| 2. Makuri Water Project | Makuri | Tributary of Kamaara river | 1978 | 6 | 2000 | 30 | 50 | 20 | free | insufficient yield |
| 3. Giachagura Water Project | West Makuri | Kamaara river | 1979 | 0.5 | 128 | 85 | 15 | 0 | free | poor design, insufficient capacity, no training |
| 4. Chogoria Mission Water Supply | 1km from town | Kamaara river | - | - | - | 0 | 0 | 100 | free | - |

## Table 3.2-16 Maua Community Water Schemes

| Name of Project | Location | Source | Year Started | Area Coverage (km2) | Present Pop. Served | Water Consumption (%) | | | Water Tariff | Problems Identified |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Domestic | Irrigation | Institution, others | | |
| 1. Rwaene Water Project | Northwest of town | Kamurani springs | 1988 | 3 | 2200 | 65 | 25 | 15 | free | a lack of leakage control, insufficient capacity |
| 2. Kithelu-Miori Water Project | Kithelu, Luluma, Miori | Kanyoni spring | 1990 | 18 | 1200 | 80 | 0 | 20 | 1Ksh/day | insufficient capacity, poor water charge collection, leakage, poor technical and managerial skills |
| 3. Antu Buchiu Water Supply | Antu Buchie | Kathambi spring | 1992 | 10 | 3000 | 60 | 20 | 20 | flat rate | insufficient capacity, poor operation, many leakage |
| 4. Muhorone Water Project | Ituni | Mwaamba springs | 1984 | 4 | 1300 | 60 | 10 | 30 | flat rate | poor technical and management skills, many leakage, poor maintenance |
| 5. Ntingiral Water Project | Mboone | Mwambaa stream | 1987 | 3.5 | 2000 | 85 | 0 | 15 | flat rate | poor management, many waste water, insufficient capacity |
| 6. Maua Methodist Water Project | Town center | Mboone stream | 1940s | - | - | 10 | 0 | 90 | free | no significant problem |
| 7. Kibilaku Water Project | Kiegoi | Mwaamba stream | 1978 | 4 | 1000 | 65 | 10 | 25 | flat rate | a lack of storage, poor management, insufficient capacity |
| 8. Mboone Water Project | Kiegoi | Mboone stream | 1977 | 2 | 400 | 40 | 40 | 20 | free | limited fund, poor management, insufficient capacity |

## Table 3.2-17 Tigania Community Water Schemes

| Name of Project | Location | Source | Year Started | Area Coverage (km2) | Present Pop. Served | Water Consumption (%) | | | Water Tariff | Problems Identified |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Domestic | Irrigation | Institution, others | | |
| 1. Kamberai Catholic Water Project | 1km from Muriri market | Kamberia springs | 1990 | 40 | 30000(design) | 55 | 0 | 45 | flat rate | not surveyed |
| 2. Laiiuba-Lachathuriu Water Project | 2km west from Muthara | Gatwamwari springs | 1983 | 12 | 4800(design) | 60 | 10 | 30 | flat rate | delayed payment |
| 3. Mbaranga-Nduluma Water Project | Karama and Muthara | Kalinkoro stream | 1990 | 12 | 8000(design) | 60 | 5 | 35 | flat rate | delayed payment |
| 4. Chararu Women Water Project | Athing'a and Kitharene | Liutu stream | 1987 | 6 | 900 | 70 | 0 | 30 | free | inadequate storage, limited fund for O&M |
| 5. Nduluma Factory Water Supply | Southeast of Muthara market | Kalimucico spring | 1979 | 4 | 400 | 45 | 0 | 40 | free | low pressure, clogged inlet, insufficient capacity |
| 6. K.K Mwethe Project | Kiguchwa | Liutu river | 1978 | 24 | 8000 | 50 | 30 | 20 | flat rate | no funds for expansion, many leakage, poor management |
| 7. Kiabaibate-Nchura water Project | Nkomero | Karindi springs | 1993 | 5 | 1000 | 80 | 0 | 20 | free | many leakage, poor maintenance |
| 8. Antu Anuu Water Project | Athinga and Athanje | Kaimucico stream | 1990 | 3 | 300 | 75 | 10 | 15 | free | poor implementation, insufficient storage |
| 9. Kanoo-Mula Water Project | Karama and Muthara | Kanoo spring | 1996 | 10 | not surveyed | 60 | 0 | 40 | not surveyed | not surveyed |
| 10. Kiriene Water Project | Athanje | MLRRWD main | 1996 | 1 | 50 | 65 | 0 | 15 | flat rate | Lack of funds, poor staff and operation |
| 11. Ndiine Water Project | Kitharene | MLRRWD main | 1995 | 2 | 600 | 80 | 0 | 20 | flat rate | Lack of funds, insufficient intake rate, poor design |

# Table 3.4-1 Water Quality Survey Results (Dry Season)

| PARAMETERS | UNIT | MERU | | | | NKUBU | | | ISIOLO | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | UP-STREAM | PROPOSED INTAKE | DOWN STERAM | MERU TOWN | UP STREAM | PROPOSED INTAKE | DOWN STERAM | ISIOLO RIVER UPSTREAM | ISIOLO RIVER INTAKE | GITHIMA SPRING UPSTREAM | GITHIMA SPRING INTAKE | DOWN-STREAM |
| | | 13th Sep | 13th Sep | 22nd Sep | 19th Sep | 11th Sep | 11th Sep | 22nd Sep | 12th Sep | 12th Sep | 12th Sep | 12th Sep | 19th Sep |
| pH | | 7.62 | 7.93 | 7.42 | 6.11 | 7.58 | 7.69 | 7.86 | 8.02 | 8.04 | 7.72 | 7.7 | 8.12 |
| Apparent Colour | °H | 10 | 10 | 15 | 5 | 10 | 10 | 15 | 10 | 10 | 10 | 15 | 100 |
| True Colour | °H | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | 10 | < 5 | < 5 | < 5 | < 5 | 80 |
| Conductivity | µs/cm | 67 | 90 | 121 | 169 | 79 | 93 | 92 | 554 | 558 | 215 | 219 | 1099 |
| Turbidity | F.T.U | 1.4 | 0.4 | 1.6 | 0.3 | 1 | 1.4 | 2.5 | 1.7 | 1.3 | 1 | 1.2 | 46 |
| Calcium Hardness as CaCo3 | mg/l | 4 | 8 | 26 | 12 | 12 | 4 | 18 | 16 | 20 | 20 | 40 | 18 |
| Total Hardness asCaCo3 | mg/l | 24 | 36 | 76 | 46 | 36 | 12 | 58 | 52 | 70 | 72 | 114 | 62 |
| Total Alkalinity as CaCo3 | mg/l | 38 | 45 | 53 | 58 | 33 | 47 | 42 | 260 | 262 | 92 | 96 | 555 |
| Carbonate Alkalinity | mg3/l | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iron | mg/l | 0.02 | 0.01 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |
| Fluorides | mg/l | 0.28 | 0.5 | 0.38 | 0.24 | 0.31 | 0.3 | 3.3 | 0.48 | 0.48 | 0.34 | 0.34 | 0.62 |
| Sulphates | mg/l | 35 | 38 | 33 | 37 | 27 | 25 | 38 | 40 | 33 | 39 | 46 | 26 |
| Phosphates | mg/l | 0.03 | 0.01 | 0.02 | 0.03 | 0.02 | 0.03 | 0.04 | 0.02 | 0.01 | 0.02 | 0.01 | 0.04 |
| Silica | mg/l | 55 | 56 | 66 | 44 | 20 | 22 | 30 | 32 | 30 | 55 | 60 | 38 |
| Dissolved Oxygen | p.p.m | 5.8 | 6 | 5.9 | 5.4 | 6.1 | 5.9 | 6 | 5.8 | 5.7 | 5.8 | 5.6 | 5.4 |
| Nitrates | mg/l | 0.03 | 0.02 | 0.01 | 0.03 | 0.02 | 0.02 | 0.03 | 0.01 | 0.04 | 0.01 | 0.01 | 0.02 |
| Manganese | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chlorides | mg/l | 16 | 10 | 16 | 24 | 8 | 10 | 12 | 60 | 64 | 22 | 22 | 86 |
| Chromium | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Copper | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Coliform | /ml | 0 | 0 | 350 | 660 | 20 | 300 | 450 | 10 | 50 | 30 | 20 | 500 |
| Total Feacal Coliform | /ml | 0 | 0 | 9 | 140 | 4 | 55 | 80 | 3 | 11 | 6 | 0 | 150 |
| Dissolved Solids | mg/l | 50 | 50 | 65 | 80 | 35 | 45 | 50 | 305 | 325 | 100 | 90 | 660 |
| Suspended Solids | mg/l | 5 | 5 | 5 | 0 | 15 | 15 | 5 | 25 | 15 | 10 | 30 | 60 |
| Total Solids | mg/l | 55 | 55 | 70 | 80 | 50 | 60 | 55 | 330 | 340 | 110 | 120 | 720 |
| Biochemical Oxygen Demand | mg/l | 5 | 5 | 10 | 5 | 5 | 5 | 10 | 50 | 3 | 2 | 130 | 10 |
| Chemical Oxygen Demand | mg/l | 8 | 6 | 12 | 8 | 8 | 8 | 12 | 68 | 4 | 4 | 160 | 12 |

| PARAMETERS | UNIT | CHUKA | | | CHOGORIA | | | MAUA | | | TIGANIA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | UP-STREAM | PROPOSED INTAKE | DOWN-STERAM | UP STREAM | PROPOSED INTAKE | DOWN-STERAM | UP-STREAM | PROPOSED INTAKE | DOWN STERAM | UP-STREAM | PROPOSED INTAKE | DOWN-STERAM |
| | | 19th Sep | 19th Sep | 20th Sep | 20th Sep | 20th Sep | 20th Sep | | 16th Sep | 16th Sep | | 16th Sep | 17th Sep |
| pH | | 7.64 | 7.97 | 7.17 | 7.84 | 7.57 | 7.51 | - | 7.5 | 7.65 | - | 7.66 | 7.79 |
| Apparent Colour | °H | 10 | 10 | 150 | 5 | 5 | 30 | - | 5 | 10 | - | 5 | 20 |
| True Colour | °H | < 5 | < 5 | 100 | < 5 | < 5 | 20 | - | < 5 | < 5 | - | < 5 | 10 |
| Conductivity | µs/cm | 28 | 103 | 44 | 70 | 70 | 30 | - | 65 | 102 | - | 96 | 79 |
| Turbidity | F.T.U | 1 | 1.2 | 75 | 0.6 | 0.5 | 6 | - | 0.6 | 1.3 | - | 0.2 | 3.1 |
| Calcium Hardness as CaCo3 | mg/l | 12 | 10 | 9 | 18 | 12 | 12 | - | 12 | 10 | - | 18 | 22 |
| Total Hardness asCaCo3 | mg/l | 36 | 38 | 26 | 44 | 36 | 34 | - | 42 | 30 | - | 52 | 90 |
| Total Alkalinity as CaCo3 | mg/l | 14 | 46 | 21 | 36 | 32 | 24 | - | 32 | 43 | - | 47 | 40 |
| Carbonate Alkalinity | mg3/l | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | - | 0 | 0 |
| Iron | mg/l | 0.05 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | - | 0.02 | 0.03 | - | 0.01 | 0.02 |
| Fluorides | mg/l | 0.28 | 0.42 | 0.25 | 0.26 | 0.26 | 0.23 | - | 0.27 | 0.28 | - | 0.23 | 0.23 |
| Sulphates | mg/l | 22 | 29 | 22 | 25 | 36 | 30 | - | 33 | 35 | - | 39 | 41 |
| Phosphates | mg/l | 0.02 | 0.03 | 0.03 | 0.01 | 0.02 | 0.04 | - | 0.01 | 0.02 | - | 0.01 | 0.04 |
| Silica | mg/l | 36 | 55 | 32 | 38 | 47 | 55 | - | 45 | 44 | - | 56 | 60 |
| Dissolved Oxygen | p.p.m | 5.9 | 6 | 5.9 | 5.7 | 5.8 | 5.8 | - | 5.7 | 5.7 | - | 5.8 | 5.9 |
| Nitrates | mg/l | 0.05 | 0.02 | 0.02 | 0.04 | 0.01 | 0.01 | - | 0.04 | 0.04 | - | 0.03 | 0.02 |
| Manganese | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | - | 0 | 0 |
| Chlorides | mg/l | 8 | 12 | 14 | 12 | 8 | 14 | - | 10 | 14 | - | 8 | 10 |
| Chromium | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | - | 0 | 0 |
| Copper | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | - | 0 | 0 |
| Total Coliform | /ml | 30 | 20 | 60 | 100 | 10 | 130 | - | 25 | 25 | - | 10 | 225 |
| Total Feacal Coliform | /ml | 10 | 10 | 18 | 20 | 0 | 28 | - | 4 | 0 | - | 0 | 65 |
| Dissolved Solids | mg/l | 25 | 40 | 20 | 45 | 35 | 40 | - | 45 | 45 | - | 55 | 45 |
| Suspended Solids | mg/l | 5 | 10 | 15 | 5 | 5 | 0 | - | 0 | 0 | - | 0 | 5 |
| Total Solids | mg/l | 25 | 50 | 35 | 50 | 40 | 40 | - | 45 | 45 | - | 55 | 50 |
| Biochemical Oxygen Demand | mg/l | 20 | 2 | 5 | 2 | 10 | 5 | - | 6 | 12 | - | 5 | 5 |
| Chemical Oxygen Demand | mg/l | 28 | 4 | 8 | 4 | 12 | 6 | - | 8 | 16 | - | 8 | 8 |

# Table 3.4-2 Water Quality Survey Results (Wet Season)

| PARAMETERS | UNIT | MERU | | | NKUBU | | ISIOLO | | CHUKA | | CHOGORIA | | MAUA | | TIGANIA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Kathita Munyi River | Kathita Munyi River | Kathita Munyi River | Kigwandegwa River | Kigwandegwa River | Kathima Springs | Kathima Springs | Manyaga (Rugudi) River | Manyaga (Rugudi) River | Mara Manyi River | Mara Manyi River | Mbuone River | Mbuone River | Thangatha River | Thangatha River | Thangatha River |
| | | 20th Feb | 27th Mar | 30th Mar | 28th Mar | 31st Mar | 29th Mar | 31st Mar | 24th Mar | 30th Mar | 27th Mar | 30th Mar | 29th Mar | 31st Mar | 15th Feb | 29th Mar | 31st Mar |
| pH | | 7.89 | 8.28 | 8.30 | 8.08 | 8.09 | 8.14 | 8.18 | 7.78 | 7.87 | 8.04 | 8.05 | 7.91 | 7.8 | 7.52 | 8.05 | 8.06 |
| Apparent Colour | P H | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 |
| True Colour | P H | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 |
| Conductivity | µs/cm | 104 | 98 | 95 | 98 | 76 | 207 | 206 | 75 | 71 | 65 | 59 | 60 | 83 | 92 | 60 | 60 |
| Turbidity | F.T.U. | 0.3 | 0.4 | 1.1 | 1.9 | 1.4 | 1.2 | 1.1 | 0.9 | 1.7 | 0.5 | 1.5 | 0.5 | 2.5 | 0.2 | 0.4 | 1.2 |
| Calcium Hardness as CaCo3 | mg/l | 2 | 2 | 2 | 4 | 8 | 22 | 22 | 2 | 2 | 2 | 2 | 8 | 8 | 4 | 12 | 8 |
| Total Hardness asCaCo3 | mg/l | 5 | 18 | 18 | 32 | 66 | 176 | 174 | 18 | 18 | 18 | 18 | 62 | 60 | 12 | 76 | 68 |
| Total Alkalinity as CaCo3 | mg/l | 50 | 94 | 90 | 70 | 28 | 72 | 74 | 70 | 70 | 72 | 72 | 22 | 22 | 46 | 32 | 30 |
| Carbonate Alkalinity | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iron | mg/l | 0.04 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.06 | 0.02 | 0.02 |
| Fluorides | mg/l | 0.45 | 0.31 | 0.32 | 0.38 | 0.38 | 0.28 | 0.26 | 0.32 | 0.32 | 0.30 | 0.30 | 0.40 | 0.41 | 0.43 | 0.43 | 0.44 |
| Sulphates | mg/l | 44 | 38 | 37 | 38 | 38 | 48 | 50 | 40 | 42 | 38 | 40 | 38 | 40 | 60 | 56 | 56 |
| Phosphates | mg/l | 0.05 | 0.01 | 0.01 | 0.02 | 0.02 | 0 | 0 | 0.03 | 0.03 | 0 | 0 | 0.03 | 0.02 | 0.06 | 0.02 | 0.01 |
| Silica | mg/l | 47 | 54 | 56 | 44 | 44 | 64 | 63 | 58 | 60 | 48 | 50 | 52 | 52 | 85 | 82 | 82 |
| Dissolved Oxygen | p.p.m. | 6.0 | 5.8 | 5.8 | 5.9 | 5.9 | 5.4 | 5.4 | 6.0 | 6 | 5.8 | 5.9 | 5.6 | 5.6 | 5.9 | 5.9 | 5.9 |
| Nitrates | mg/l | 0.06 | 0 | 0 | 0 | 0.01 | 0.01 | 0.01 | 0.01 | 0 | 0.01 | 0.01 | 0.02 | 0.01 | 0.04 | 0.03 | 0.02 |
| Manganese | mg/l | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chlorides | mg/l | 25 | 10 | 17 | 23 | 12 | 32 | 30 | 24 | 24 | 16 | 21 | 42 | 23 | 27 | 25 | 33 |
| Chromium | mg/l | 0.02 | 0 | 0 | 0.01 | 0.01 | 0 | 0 | 0.01 | 0.01 | 0 | 0 | 0.01 | 0.01 | 0.01 | 0.01 | 0 |
| Copper | mg/l | 0.02 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.01 | 0 | 0.01 | 0 |
| Total Coliform | /ml | 60 | 10 | 410 | 90 | 320 | 550 | 500 | 220 | 15 | 0 | 90 | 200 | 170 | 270 | 100 | 20 |
| Total Feacal Coliform | /ml | 5 | 0 | 70 | 0 | 50 | 100 | 100 | 30 | 0 | 0 | 0 | 30 | 0 | 20 | 0 | 0 |
| Dissolved Solids | mg/l | 182 | 150 | 130 | 160 | 140 | 280 | 260 | 65 | 65 | 150 | 135 | 160 | 130 | 191 | 150 | 155 |
| Suspended Solids | mg/l | 0 | 10 | 25 | 15 | 15 | 30 | 20 | 25 | 25 | 20 | 5 | 15 | 25 | 0 | 20 | 25 |
| Total Solids | mg/l | 2 | 160 | 155 | 175 | 155 | 310 | 280 | 90 | 90 | 170 | 140 | 175 | 155 | 191 | 170 | 180 |
| Biochemical Oxygen Demand | mg/l | 8 | 4 | 4 | 2 | 0 | 6 | 4 | 0 | 8 | 6 | 6 | 2 | 0 | 2 | 0 | 2 |
| Chemical Oxygen Demand | mg/l | 8 | 8 | 8 | 4 | 4 | 8 | 8 | 12 | 12 | 10 | 12 | 8 | 8 | 5 | 4 | 4 |

## Table 4.1-3 Surface Water Sources

**1 Meru**

| Water Sources | Safe Yield | Remarks |
|---|---|---|
| (1) Kathita River (Existing) | 57,100 m3/day | |
| (2) Gatabora Spring (Existing) | 1,500 m3/day | |
| (3) Kathita River (Proposed) | 43,200 m3/day | |
| (4) Kathita River (Alternative) | 35,300 m3/day | |

**2 Nkubu**

| Alternatives | Safe Yield | Remarks |
|---|---|---|
| (1) Thinghthu River (Existing) | 53,200 m3/day | |
| (2) Kiguandegua River (Proposed) | 14,100 m3/day | |
| (3) Kiguandegua River (Alternative) | 5,400 m3/day | |

**3 Chuka**

| Alternatives | Safe Yield | Remarks |
|---|---|---|
| (1) Tungu River (Existing) | 11,700 m3/day | |
| (2) Ruguti River (Proposed) | 12,800 m3/day | |

**4 Chogoria**

| Alternatives | Safe Yield | Remarks |
|---|---|---|
| (1) Mutonga River (Existing) | 31,000 m3/day | |
| (2) Mara Manyi Stream (Proposed) | 13,200 m3/day | Yield in Dry Season in 1996 |

**5 Maua**

| Alternatives | Safe Yield | Remarks |
|---|---|---|
| (1) Mboone Stream (Existing) | 2,700 m3/day | |
| (2) Mboone Stream (Proposed) | 1,900 m3/day | Yield in Dry Season in 1996 |

**6 Tigania**

| Alternatives | Safe Yield | Remarks |
|---|---|---|
| (1) Mikrowe Spring (Existing) | 1,800 m3/day | |
| (2) Michi Mikuru Spring (Existing) | 1,750 m3/day | |
| (3) Thangatha Stream | 1,400 m3/day | Yield in Dry Season in 1996 |

**7 Isiolo**

| Alternatives | Safe Yield | Remarks |
|---|---|---|
| (1) Isiolo River (Existing) | 2,800 m3/day | |
| (2) Isiolo River Dam | - m3/day | Feasibility not expected |
| (3) Kithima Spring (Proposed) | 3,000 m3/day | Minimum Measured |
| (4) Rugusu Spring (Alternative) | 3,800 m3/day | Minimum Measured |

# Table 5.3-1 Unit Construction Prices

Exchange rate........ Oct-96 ........ 1US $ = 56 Shs

Preliminaries and General Items are NOT included within the following rates

***General Items***

| | Unit | Rate Shs |
|---|---|---|
| General excavation in normal material not exceeding 3.0m depth | m3 | 350 |
| EO for rock | m3 | 1,500 |
| Earthworks for dams - Soft | m3 | 175 |
| Earthworks for dams - Rock | m3 | 1,000 |
| Earthfill for dams | m3 | 310 |
| Filter/drainage material for dams | m3 | 1,550 |
| Rip rap material for dams | m3 | 1,630 |
| Concrete Class 25 | m3 | 8,000 |
| Concrete Class 30 | m3 | 12,000 |
| Mass concrete for dams | m3 | 6,000 |
| Reinforcement | tonne | 65,000 |
| Formwork F1 | m2 | 475 |
| Formwork F2 | m2 | 750 |
| Blockwork walling | m2 | 1,200 |
| "All in" cost for reinforced concrete | m3 | 20,175 |

***Pipework***

| Assumptions — Type of pipe | uPVC | Steel | DI |
|---|---|---|---|
| Manufacturers discount | 10% | 0% | 0% |
| Tax and duties | 15% | 15% | 15% |
| Transport and handling | 15% | 15% | 20% |
| Wastage | 5% | 1% | 1% |
| Pipe trench width | 700 mm + nominal dia. | | |
| Average trench depth | 1200 mm + nominal dia. | | |
| Average rock excavation | 10% | | |
| Valves & specials - Add to "All in" pipe costs | 15% | | |

***uPVC Pipelines***

| | | | Materials delivered to site | | | | "All in" pipe costs | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dia mm | Trench Excav'n Shs/m | Lay, joint etc Shs/m | uPVC 6 bar Shs/m | uPVC 9 bar Shs/m | uPVC 12 bar Shs/m | uPVC 15 bar Shs/m | uPVC 6 bar Shs/m | uPVC 9 bar Shs/m | uPVC 12 bar Shs/m | uPVC 15 bar Shs/m |
| 63 | 482 | 40 | 75 | 125 | 155 | 200 | 597 | 647 | 677 | 722 |
| 90 | 510 | 60 | 187 | 242 | 298 | 365 | 757 | 812 | 868 | 935 |
| 110 | 531 | 60 | 252 | 362 | 442 | 562 | 843 | 953 | 1033 | 1153 |
| 160 | 585 | 100 | 506 | 747 | 943 | 1155 | 1191 | 1432 | 1628 | 1840 |
| 225 | 659 | 140 | 1000 | 1380 | 1825 | 2104 | 1799 | 2179 | 2624 | 2903 |
| 280 | 725 | 180 | 1450 | 2125 | 2504 | 3262 | 2355 | 3030 | 3409 | 4167 |
| 315 | 769 | 200 | 1837 | 2660 | 3374 | 4124 | 2806 | 3629 | 4343 | 5093 |
| 400 | 880 | 280 | 3074 | 4374 | | | 4234 | 5534 | | |

***Steel and DI Pipelines***

| | | | Materials delivered to site | | "All in" pipe costs | |
|---|---|---|---|---|---|---|
| dia | Trench Excav'n Shs/m | Lay, joint etc Shs/m | Steel Shs/m | DI Shs/m | Steel Shs/m | DI Shs/m |
| 80 | 499 | 70 | | 1235 | | 1804 |
| 100 | 520 | 90 | 1115 | 1518 | 1725 | 2128 |
| 150 | 574 | 140 | 2049 | 2285 | 2763 | 2999 |
| 200 | 630 | 200 | 3154 | 3080 | 3984 | 3910 |
| 250 | 689 | 260 | 4408 | 4073 | 5357 | 5022 |
| 300 | 750 | 320 | 5794 | 5166 | 6864 | 6236 |
| 350 | 814 | 380 | 7301 | 6386 | 8495 | 7580 |
| 400 | 880 | 450 | 8921 | 7663 | 10251 | 8993 |
| 450 | 949 | 510 | 10036 | 9097 | 11495 | 10556 |
| 500 | 1020 | 580 | 11152 | | 12752 | |

***Reservoirs***

| Capacity (m3) | 50 | 100 | 150 | 200 | 250 | 300 | 400 | 500 | 750 |
|---|---|---|---|---|---|---|---|---|---|
| "All in" costs | 550,000 | 780,000 | 940,000 | 1,070,000 | 1,290,000 | 1,520,000 | 1,940,000 | 2,350,000 | 3,360,000 |
| Cost/m3 | 11,000 | 7,800 | 6,267 | 5,350 | 5,160 | 5,067 | 4,850 | 4,700 | 4,480 |

| ***Boreholes*** | Unit | rate | quantity | Amount |
|---|---|---|---|---|
| Basic costs for 50 m deep borehole | Lump sum | 87,500 | 1 | 87,500 |
| Additional costs for deeper boreholes | m | 875 | 50 | 43,750 |
| Pump test | LS | 37340 | 1 | 37,340 |
| | Total costs | | | 168,590 |

***Land costs***

Varies depending upon location, but without additional information take ........ 200000 Shs/ha

| ***Pumps*** | Flow(l/s) | Head (m) | Efficiency | kW | Estimated costs Shs x 1,000 |
|---|---|---|---|---|---|
| Civil costs | (l/s) | (m) | (eff'y) | (l/s) x (m)/(102 x (eff'y) | 400 x KW^.675 |
| E&M costs | (l/s) | (m) | (eff'y) | (l/s) x (m)/(102 x (eff'y) | 360 x KW^.6 |

## Table 5.3.2 Summary of investment and operational costs

| Scheme | Investment costs US $ x 1,000 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Meru | Nkubu | Isiolo | Chuka | Chogoria | Maua | Tigania | Totals |
| **Phase 1** | | | | | | | | |
| Rehabilitation | 179 | 18 | 61 | 22 | 49 | 16 | - | 345 |
| Intake/Boreholes | 175 | 37 | 1,404 | 318 | 184 | 4 | 135 | 2,257 |
| Raw water pipeline | 1,139 | 93 | 1,245 | 697 | 331 | 20 | 191 | 3,716 |
| Treatment plant | 847 | 551 | - | 337 | 284 | 552 | 294 | 2,867 |
| Storage | 518 | 92 | 249 | 200 | 96 | 59 | 95 | 1,308 |
| Transmission | 2,318 | 128 | 665 | 383 | 701 | 149 | 1,260 | 5,602 |
| Ancillaries | 1,294 | 230 | 906 | 489 | 411 | 200 | 494 | 4,024 |
| Preliminaries | 970 | 172 | 679 | 367 | 309 | 150 | 370 | 3,018 |
| **Total Phase 1** | 7,438 | 1,321 | 5,209 | 2,814 | 2,365 | 1,150 | 2,839 | 23,137 |
| **Phase 1(a) - distribution** | 492 | 22 | 80 | 196 | 80 | 22 | 154 | 1,045 |
| **Phase 2** | | | | | | | | |
| Intake/Boreholes | | | 1,354 | | | | | 1,354 |
| Raw water pipeline | | | 1,375 | | | | | |
| Treatment plant | 986 | 273 | - | 237 | 197 | - | 207 | 1,901 |
| Storage | 979 | 42 | 240 | 55 | 42 | 59 | 87 | 1,504 |
| Transmission | 1,589 | - | 268 | 76 | 105 | 44 | 81 | 2,163 |
| Ancillaries | 888 | 79 | 809 | 92 | 86 | 26 | 94 | 2,074 |
| Preliminaries | 666 | 59 | 607 | 69 | 65 | 19 | 70 | 1,555 |
| **Total Phase 2** | 5,108 | 453 | 4,653 | 529 | 495 | 147 | 540 | 11,925 |
| **Phase 2(a) - distribution** | 666 | 33 | 119 | 293 | 120 | 33 | 230 | 1,495 |
| **TOTAL** | 13,705 | 1,829 | 10,061 | 3,832 | 3,060 | 1,352 | 3,763 | 37,602 |

**Supply area details**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Design population | 251,668 | 15,611 | 65,471 | 64,433 | 44,376 | 13,344 | 83,121 | 538,024 |
| Design demand (m3/day) | 22,725 | 1,915 | 8,537 | 4,403 | 2,886 | 1,493 | 3,778 | 45,737 |
| Incremental demand | 19,551 | 1,915 | 5,737 | 4,403 | 2,886 | 1,493 | 3,778 | 39,763 |
| Supply area (km2) | 185 | 4 | 45 | 88 | 58 | 5 | 92 | 477 |
| Cost/capita (US$/capita) | 54 | 117 | 154 | 59 | 69 | 101 | 45 | 70 |
| Cost/m3/day (US $/m3/day) | 701 | 955 | 1,754 | 870 | 1,060 | 906 | 996 | 946 |

**Average incremental costs at 9%**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Investment costs (US $/m3) | 0.46 | 0.46 | 0.67 | 0.44 | 0.54 | 0.41 | 0.49 | 0.50 |
| Annual costs (US $/m3) | 0.12 | 0.20 | 0.29 | 0.14 | 0.17 | 0.21 | 0.16 | 0.18 |
| Total costs (US $/m3) | 0.58 | 0.66 | 0.96 | 0.58 | 0.71 | 0.61 | 0.65 | 0.68 |
| Total costs (Shs/m3) | 32 | 37 | 54 | 32 | 40 | 34 | 36 | 38 |
| *(1 US $= 56 Shs)* | | | | | | | | |

# Table 5.7-5 Financial Evaluation by Water Supply Scheme

(Unit 1,000US$)

| Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MERU** | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 7,776.0 | 123.0 | 123.0 | 123.0 | 123.0 | 5,468.0 | 111.0 | 111.0 | 111.0 | 111.0 | 678.0 | 111.0 | 111.0 | 111.0 | 111.0 | 682.0 | 111.0 | 111.0 | 111.0 | 0.0 | 16,317.0 |
| O&M Costs | 0.0 | 221.0 | 227.0 | 233.0 | 240.0 | 322.0 | 340.0 | 350.0 | 361.0 | 373.0 | 395.0 | 408.0 | 423.0 | 432.0 | 441.0 | 458.0 | 459.0 | 460.0 | 461.0 | 411.0 | 7,015.0 |
| Total Costs (A) | 7,776.0 | 344.0 | 350.0 | 356.0 | 363.0 | 5,790.0 | 451.0 | 461.0 | 472.0 | 484.0 | 1,073.0 | 519.0 | 534.0 | 543.0 | 552.0 | 1,140.0 | 570.0 | 571.0 | 572.0 | 411.0 | 23,332.0 |
| Water Revenue (B) | 0.0 | 57.6 | 172.5 | 288.7 | 416.3 | 555.7 | 707.8 | 873.2 | 1,052.8 | 1,247.2 | 1,457.3 | 1,684.2 | 1,928.5 | 2,064.2 | 2,200.0 | 2,335.7 | 2,335.7 | 2,335.7 | 2,335.7 | 2,335.7 | 26,384.4 |
| Net Revenue (B-A) | -7,776.0 | -286.4 | -177.5 | -67.3 | 53.3 | -5,234.3 | 256.8 | 412.2 | 580.8 | 763.2 | 384.3 | 1,165.2 | 1,394.5 | 1,521.2 | 1,648.0 | 1,195.7 | 1,765.7 | 1,764.7 | 1,763.7 | 1,924.7 | 3,052.4 |
| Revenue - O&M Costs | 0.0 | -163.4 | -54.5 | 55.7 | 176.3 | 233.7 | 367.8 | 523.2 | 691.8 | 874.2 | 1,062.3 | 1,276.2 | 1,505.5 | 1,632.2 | 1,759.0 | 1,877.7 | 1,876.7 | 1,875.7 | 1,874.7 | 1,924.7 | 19,369.4 |
| FIRR = | 1.7% | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -6,336 | | | | | | | | | | | | | | | | | | | | |
| RER = | 1.13 | | | | | | | | | | | | | | | | | | | | |
| **NKUBU** | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 1,342.0 | 5.5 | 5.5 | 5.5 | 5.5 | 474.9 | 5.5 | 5.5 | 5.5 | 5.5 | 148.4 | 5.5 | 5.5 | 5.5 | 5.5 | 85.9 | 5.5 | 5.5 | 5.5 | 0.0 | 2,133.7 |
| O&M Costs | 0.0 | 63.0 | 63.7 | 64.5 | 65.3 | 77.5 | 82.4 | 83.9 | 85.5 | 87.2 | 93.9 | 95.4 | 97.0 | 97.1 | 97.1 | 99.5 | 99.6 | 99.6 | 99.7 | 95.0 | 1,646.2 |
| Total Costs (A) | 1,342.0 | 68.5 | 69.2 | 70.0 | 70.8 | 552.4 | 87.9 | 89.4 | 91.0 | 92.7 | 242.3 | 100.9 | 102.5 | 102.6 | 102.6 | 185.4 | 105.1 | 105.1 | 105.2 | 95.0 | 3,780.6 |
| Water Revenue (B) | 0.0 | 63.9 | 75.0 | 86.2 | 98.6 | 111.9 | 126.3 | 141.9 | 158.8 | 176.9 | 196.5 | 212.2 | 228.8 | 228.8 | 228.8 | 228.8 | 228.8 | 228.8 | 228.8 | 228.8 | 3,278.2 |
| Net Revenue (B-A) | -1,342.0 | -4.6 | 5.8 | 16.2 | 27.8 | -440.5 | 38.4 | 52.5 | 67.8 | 84.2 | -45.8 | 111.3 | 126.3 | 126.2 | 126.2 | 43.4 | 123.7 | 123.7 | 123.6 | 133.8 | -502.4 |
| Revenue - O&M Costs | 0.0 | 0.9 | 11.3 | 21.7 | 33.3 | 34.4 | 43.9 | 58.0 | 73.3 | 89.7 | 102.6 | 116.8 | 131.8 | 131.7 | 131.7 | 129.3 | 129.2 | 129.2 | 129.1 | 133.8 | 1,631.3 |
| FIRR = | -2.6% | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -1,119 | | | | | | | | | | | | | | | | | | | | |
| RER = | 0.87 | | | | | | | | | | | | | | | | | | | | |
| **ISIOLO** | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 5,292.7 | 19.9 | 19.9 | 19.9 | 19.9 | 4,736.5 | 19.9 | 19.9 | 19.9 | 19.9 | 1,123.8 | 19.9 | 19.9 | 19.9 | 19.9 | 1,105.7 | 19.9 | 19.9 | 19.9 | 0.0 | 12,557.2 |
| O&M Costs | 0.0 | 221.1 | 234.3 | 238.7 | 243.3 | 432.6 | 441.1 | 450.1 | 459.5 | 469.3 | 520.4 | 531.2 | 542.5 | 553.6 | 565.2 | 617.4 | 630.0 | 643.2 | 657.1 | 611.3 | 9,061.9 |
| Total Costs (A) | 5,292.7 | 241.0 | 254.2 | 258.6 | 263.2 | 5,169.1 | 461.0 | 470.0 | 479.4 | 489.2 | 1,644.2 | 551.1 | 562.4 | 573.5 | 585.1 | 1,723.1 | 649.9 | 663.1 | 677.0 | 611.3 | 21,619.1 |
| Water Revenue (B) | 0.0 | 84.5 | 122.0 | 134.2 | 147.0 | 160.4 | 174.5 | 189.2 | 204.6 | 220.8 | 237.7 | 255.5 | 274.1 | 292.4 | 311.4 | 331.4 | 352.3 | 374.2 | 397.1 | 421.1 | 4,681.5 |
| Net Revenue (B-A) | -5,292.7 | -156.5 | -132.2 | -124.4 | -116.2 | -5,008.7 | -286.5 | -280.8 | -274.8 | -268.4 | -1,406.5 | -295.6 | -288.3 | -281.1 | -273.7 | -1,391.7 | -297.6 | -288.9 | -279.9 | -190.2 | -16,931.6 |
| Revenue - O&M Costs | 0.0 | -136.6 | -112.3 | -104.5 | -96.3 | -272.2 | -266.6 | -260.9 | -254.9 | -248.5 | -282.7 | -275.7 | -268.4 | -261.2 | -253.8 | -286.0 | -277.7 | -269.0 | -260.0 | -190.2 | -4,377.4 |
| FIRR = | n.a. | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -9,821 | | | | | | | | | | | | | | | | | | | | |
| RER = | 0.22 | | | | | | | | | | | | | | | | | | | | |
| **CHUKA** | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 2,919.6 | 48.9 | 48.9 | 48.9 | 48.9 | 634.5 | 48.9 | 48.9 | 48.9 | 48.9 | 226.9 | 48.9 | 48.9 | 48.9 | 48.9 | 205.4 | 48.9 | 48.9 | 48.9 | 0.0 | 4,719.9 |
| O&M Costs | 0.0 | 97.0 | 98.8 | 100.6 | 102.5 | 120.2 | 122.3 | 124.7 | 127.2 | 129.9 | 135.7 | 138.1 | 140.6 | 141.1 | 141.6 | 144.1 | 144.6 | 145.1 | 145.6 | 141.1 | 2,440.8 |
| Total Costs (A) | 2,919.6 | 145.9 | 147.7 | 149.5 | 151.4 | 754.7 | 171.2 | 173.6 | 176.1 | 178.8 | 362.6 | 187.0 | 189.5 | 190.0 | 190.5 | 349.5 | 193.5 | 194.0 | 194.5 | 141.1 | 7,160.7 |
| Water Revenue (B) | 0.0 | 117.1 | 143.9 | 170.2 | 199.4 | 231.6 | 267.0 | 305.7 | 347.9 | 393.6 | 442.8 | 483.3 | 526.0 | 526.0 | 526.0 | 526.0 | 526.0 | 526.0 | 526.0 | 526.0 | 7,310.1 |
| Net Revenue (B-A) | -2,919.6 | -28.8 | -3.8 | 20.7 | 48.0 | -523.1 | 95.8 | 132.1 | 171.8 | 214.8 | 80.2 | 296.3 | 336.5 | 336.0 | 335.5 | 176.5 | 332.5 | 332.0 | 331.5 | 384.9 | 149.4 |
| Revenue - O&M Costs | 0.0 | 20.1 | 45.1 | 69.6 | 96.9 | 111.4 | 144.7 | 181.0 | 220.7 | 263.7 | 307.1 | 345.2 | 385.4 | 384.9 | 384.4 | 381.9 | 381.4 | 380.9 | 380.4 | 384.9 | 4,869.3 |
| FIRR = | 0.3% | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -2,002 | | | | | | | | | | | | | | | | | | | | |
| RER = | 1.02 | | | | | | | | | | | | | | | | | | | | |
| **CHOGORIA** | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 2,449.0 | 20.0 | 20.0 | 20.0 | 20.0 | 600.0 | 20.0 | 20.0 | 20.0 | 20.0 | 186.0 | 20.0 | 20.0 | 20.0 | 20.0 | 168.0 | 20.0 | 20.0 | 20.0 | 0.0 | 3,701.0 |
| O&M Costs | 0.0 | 85.0 | 87.0 | 88.0 | 89.0 | 106.0 | 107.0 | 109.0 | 110.0 | 112.0 | 116.0 | 118.0 | 119.0 | 120.0 | 120.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 2,096.0 |
| Total Costs (A) | 2,449.0 | 105.0 | 107.0 | 108.0 | 109.0 | 706.0 | 127.0 | 129.0 | 130.0 | 132.0 | 302.0 | 138.0 | 139.0 | 140.0 | 140.0 | 290.0 | 142.0 | 142.0 | 142.0 | 122.0 | 5,799.0 |
| Water Revenue (B) | 0.0 | 84.9 | 103.6 | 121.0 | 140.1 | 161.0 | 183.6 | 208.1 | 234.6 | 263.2 | 293.7 | 318.3 | 344.4 | 344.4 | 344.4 | 344.4 | 344.4 | 344.4 | 344.4 | 344.4 | 4,867.3 |
| Net Revenue (B-A) | -2,449.0 | -20.1 | -3.4 | 13.0 | 31.1 | -545.0 | 56.6 | 79.1 | 104.6 | 131.2 | -8.3 | 180.3 | 205.4 | 204.4 | 204.4 | 54.4 | 202.4 | 202.4 | 202.4 | 222.4 | 931.7 |
| Revenue - O&M Costs | 0.0 | -0.1 | 16.6 | 33.0 | 51.1 | 55.0 | 76.6 | 99.1 | 124.6 | 151.2 | 177.7 | 200.3 | 225.4 | 224.4 | 224.4 | 222.4 | 222.4 | 222.4 | 222.4 | 222.4 | 2,771.3 |
| FIRR = | -2.8% | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -1,993 | | | | | | | | | | | | | | | | | | | | |
| RER = | 0.84 | | | | | | | | | | | | | | | | | | | | |
| **MAUA** | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 1,170.9 | 5.5 | 5.5 | 5.5 | 5.5 | 168.4 | 5.5 | 5.5 | 5.5 | 5.5 | 146.0 | 5.5 | 5.5 | 5.5 | 5.5 | 26.9 | 5.5 | 5.5 | 5.5 | 0.0 | 1,594.7 |
| O&M Costs | 0.0 | 60.8 | 61.6 | 62.2 | 63.0 | 72.7 | 73.5 | 74.5 | 75.4 | 76.5 | 82.4 | 83.6 | 84.9 | 84.9 | 85.0 | 85.0 | 85.1 | 85.1 | 85.2 | 79.6 | 1,461.0 |
| Total Costs (A) | 1,170.9 | 66.3 | 67.1 | 67.7 | 68.5 | 241.1 | 79.0 | 80.0 | 80.9 | 82.0 | 228.4 | 89.1 | 90.4 | 90.4 | 90.5 | 111.9 | 90.6 | 90.6 | 90.7 | 79.6 | 3,055.7 |
| Water Revenue (B) | 0.0 | 78.7 | 85.9 | 92.5 | 99.4 | 107.0 | 115.0 | 123.8 | 133.2 | 143.2 | 154.1 | 165.8 | 178.3 | 178.3 | 178.3 | 178.3 | 178.3 | 178.3 | 178.3 | 175.3 | 2,725.4 |
| Net Revenue (B-A) | -1,170.9 | 12.4 | 18.8 | 24.8 | 30.9 | -134.1 | 36.0 | 43.8 | 52.3 | 61.2 | -74.3 | 76.7 | 87.9 | 87.9 | 87.8 | 66.4 | 87.7 | 87.7 | 87.6 | 95.7 | -330.3 |
| Revenue - O&M Costs | 0.0 | 17.9 | 24.3 | 30.3 | 36.4 | 34.3 | 41.5 | 49.3 | 57.8 | 66.7 | 71.7 | 82.2 | 93.4 | 93.4 | 93.3 | 93.3 | 93.2 | 93.2 | 93.1 | 95.7 | 1,264.4 |
| FIRR = | -2.3% | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -850 | | | | | | | | | | | | | | | | | | | | |
| RER = | 0.89 | | | | | | | | | | | | | | | | | | | | |
| **TIGANIA** | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 2,911.5 | 38.3 | 38.3 | 38.3 | 38.3 | 645.1 | 38.3 | 38.3 | 38.3 | 38.3 | 207.1 | 38.3 | 38.3 | 38.3 | 38.3 | 188.3 | 38.3 | 38.3 | 38.3 | 0.0 | 4,559.5 |
| O&M Costs | 0.0 | 99.8 | 101.4 | 102.9 | 104.6 | 125.0 | 126.8 | 128.8 | 130.9 | 133.1 | 135.0 | 139.9 | 141.9 | 142.3 | 142.7 | 141.8 | 145.2 | 145.6 | 146.0 | 129.7 | 2,469.4 |
| Total Costs (A) | 2,911.5 | 138.1 | 139.7 | 141.2 | 142.9 | 770.1 | 165.1 | 167.1 | 169.2 | 171.4 | 345.1 | 178.2 | 180.2 | 180.6 | 181.0 | 333.1 | 183.5 | 183.9 | 184.3 | 129.7 | 7,028.9 |
| Water Revenue (B) | 0.0 | 83.3 | 101.4 | 118.2 | 136.5 | 156.4 | 178.0 | 201.1 | 226.1 | 252.8 | 281.3 | 301.0 | 327.7 | 327.7 | 327.7 | 327.7 | 327.7 | 327.7 | 327.7 | 327.7 | 4,669.3 |
| Net Revenue (B-A) | -2,911.5 | -54.8 | -38.3 | -23.0 | 6.4 | -613.7 | 12.9 | 34.0 | 56.9 | 81.4 | 63.8 | 122.8 | 147.5 | 147.1 | 146.7 | -5.4 | 144.2 | 143.8 | 143.4 | 198.0 | -2,368.6 |
| Revenue - O&M Costs | 0.0 | -16.5 | 0.0 | 15.3 | 31.9 | 31.4 | 51.2 | 72.3 | 95.2 | 119.7 | 143.3 | 164.1 | 185.8 | 185.4 | 185.0 | 182.9 | 182.5 | 182.1 | 181.7 | 198.0 | 2,199.9 |
| FIRR = | n.a. | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -2,799 | | | | | | | | | | | | | | | | | | | | |
| RER = | 0.66 | | | | | | | | | | | | | | | | | | | | |

# Table 5.7-6 Economic Evaluation by Water Supply Scheme

(Unit 1,000US$)

| Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MERU | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 7,465.0 | 118.1 | 118.1 | 118.1 | 118.1 | 5,249.3 | 106.6 | 106.6 | 106.6 | 106.6 | 650.9 | 106.6 | 106.6 | 106.6 | 106.6 | 654.7 | 106.6 | 106.6 | 106.6 | 0.0 | 15,664.3 |
| O&M Costs | 0.0 | 221.0 | 227.0 | 233.0 | 240.0 | 322.0 | 340.0 | 350.0 | 361.0 | 373.0 | 395.0 | 408.0 | 423.0 | 432.0 | 441.0 | 458.0 | 459.0 | 460.0 | 461.0 | 411.0 | 7,015.0 |
| Total Costs | 7,465.0 | 339.1 | 345.1 | 351.1 | 358.1 | 5,571.3 | 446.6 | 456.6 | 467.6 | 479.6 | 1,045.9 | 514.6 | 529.6 | 538.6 | 547.6 | 1,112.7 | 565.6 | 566.6 | 567.6 | 411.0 | 22,679.3 |
| Estimated Benefits | 0.0 | 1,460.5 | 1,538.8 | 1,630.2 | 1,725.2 | 1,823.9 | 1,926.5 | 2,033.1 | 2,144.0 | 2,259.3 | 2,379.2 | 2,504.1 | 2,633.9 | 1,766.0 | 1,766.0 | 1,766.0 | 1,766.0 | 1,766.0 | 1,766.0 | 1,766.0 | 36,420.4 |
| Net Benefits | -7,465.0 | 1,121.5 | 1,193.7 | 1,279.1 | 1,367.1 | -3,747.4 | 1,479.9 | 1,576.6 | 1,676.4 | 1,779.7 | 1,333.3 | 1,989.6 | 2,104.3 | 1,227.4 | 1,218.4 | 653.2 | 1,200.4 | 1,199.4 | 1,198.4 | 1,355.0 | 13,741.1 |
| EIRR = | 11.6% | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | 855 | | | | | | | | | | | | | | | | | | | | |
| CBR (10%) = | 1.06 | | | | | | | | | | | | | | | | | | | | |
| NKUBU | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 1,288.3 | 5.3 | 5.3 | 5.3 | 5.3 | 455.9 | 5.3 | 5.3 | 5.3 | 5.3 | 142.5 | 5.3 | 5.3 | 5.3 | 5.3 | 82.5 | 5.3 | 5.3 | 5.3 | 0.0 | 2,018.4 |
| O&M Costs | 0.0 | 63.0 | 63.7 | 64.5 | 65.3 | 77.5 | 82.4 | 83.9 | 85.5 | 87.2 | 93.9 | 95.4 | 97.0 | 97.1 | 97.1 | 99.5 | 99.6 | 99.6 | 99.7 | 95.0 | 1,616.9 |
| Total Costs | 1,288.3 | 68.3 | 69.0 | 69.8 | 70.6 | 533.4 | 87.7 | 89.2 | 90.8 | 92.5 | 236.4 | 100.7 | 102.3 | 102.4 | 102.4 | 182.0 | 104.9 | 104.9 | 105.0 | 95.0 | 3,695.3 |
| Estimated Benefits | 0.0 | 25.5 | 27.0 | 28.8 | 30.7 | 32.7 | 34.8 | 37.1 | 39.4 | 41.9 | 44.5 | 36.3 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 32.6 | 639.6 |
| Net Benefits | -1,288.3 | -42.8 | -42.0 | -41.0 | -39.9 | -500.7 | -52.8 | -52.1 | -51.4 | -50.6 | -191.8 | -64.4 | -69.7 | -69.8 | -69.8 | -149.4 | -72.3 | -72.3 | -72.4 | -62.4 | -3,055.6 |
| EIRR = | n.a. | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -1,690 | | | | | | | | | | | | | | | | | | | | |
| CBR (10%) = | 0.12 | | | | | | | | | | | | | | | | | | | | |
| ISIOLO | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 5,081.0 | 19.1 | 19.1 | 19.1 | 19.1 | 4,547.0 | 19.1 | 19.1 | 19.1 | 19.1 | 1,078.8 | 19.1 | 19.1 | 19.1 | 19.1 | 1,061.5 | 19.1 | 19.1 | 19.1 | 0.0 | 12,054.9 |
| O&M Costs | 0.0 | 221.1 | 234.3 | 238.7 | 243.3 | 432.6 | 441.1 | 450.1 | 459.5 | 469.3 | 520.4 | 531.2 | 542.5 | 553.6 | 565.2 | 617.4 | 630.0 | 643.2 | 657.1 | 611.3 | 9,061.9 |
| Total Costs | 5,081.0 | 240.2 | 253.4 | 257.8 | 262.4 | 4,979.6 | 460.2 | 469.2 | 478.6 | 488.4 | 1,599.2 | 550.3 | 561.6 | 572.7 | 584.3 | 1,678.9 | 619.1 | 662.3 | 676.2 | 611.3 | 21,116.8 |
| Estimated Benefits | 0.0 | 499.4 | 555.3 | 170.4 | 177.2 | 184.4 | 191.9 | 199.5 | 207.9 | 216.4 | 225.5 | 235.0 | 244.9 | 256.7 | 269.1 | 282.0 | 295.6 | 309.8 | 324.9 | 340.5 | 5,186.5 |
| Net Benefits | -5,081.0 | 259.2 | 301.9 | -87.4 | -85.2 | -4,795.3 | -268.4 | -269.7 | -270.7 | -272.0 | -1,373.8 | -315.3 | -316.7 | -316.0 | -315.2 | -1,396.8 | -353.5 | -352.5 | -351.3 | -270.8 | -15,930.3 |
| EIRR = | n.a. | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -8,129 | | | | | | | | | | | | | | | | | | | | |
| CBR (10%) = | 0.20 | | | | | | | | | | | | | | | | | | | | |
| CHUKA | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 2,802.8 | 46.9 | 46.9 | 46.9 | 46.9 | 609.1 | 46.9 | 46.9 | 46.9 | 46.9 | 217.8 | 46.9 | 46.9 | 46.9 | 46.9 | 197.2 | 46.9 | 46.9 | 46.9 | 0.0 | 4,531.1 |
| O&M Costs | 0.0 | 97.0 | 98.8 | 100.6 | 102.5 | 120.2 | 122.3 | 124.7 | 127.2 | 129.9 | 135.7 | 138.1 | 140.6 | 141.1 | 141.6 | 144.1 | 144.6 | 145.1 | 145.6 | 141.1 | 2,440.8 |
| Total Costs | 2,802.8 | 143.9 | 145.7 | 147.5 | 149.4 | 729.3 | 169.2 | 171.6 | 174.1 | 176.8 | 353.5 | 185.0 | 187.5 | 188.0 | 188.5 | 341.3 | 191.5 | 192.0 | 192.5 | 141.1 | 6,971.9 |
| Estimated Benefits | 0.0 | 559.5 | 589.6 | 625.8 | 662.9 | 701.2 | 739.9 | 779.3 | 818.4 | 857.3 | 895.2 | 695.6 | 594.5 | 594.5 | 594.5 | 594.5 | 594.5 | 594.5 | 594.5 | 594.5 | 12,680.7 |
| Net Benefits | -2,802.8 | 415.6 | 443.8 | 478.2 | 513.5 | -28.1 | 570.7 | 607.7 | 644.3 | 680.5 | 541.7 | 510.6 | 406.9 | 406.4 | 405.9 | 253.2 | 402.9 | 402.4 | 401.9 | 453.4 | 5,708.8 |
| EIRR = | 14.9% | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | 885 | | | | | | | | | | | | | | | | | | | | |
| CBR (10%) = | 1.21 | | | | | | | | | | | | | | | | | | | | |
| CHOGORIA | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 2,351.0 | 19.2 | 19.2 | 19.2 | 19.2 | 576.0 | 19.2 | 19.2 | 19.2 | 19.2 | 178.6 | 19.2 | 19.2 | 19.2 | 19.2 | 161.3 | 19.2 | 19.2 | 19.2 | 0.0 | 3,554.9 |
| O&M Costs | 0.0 | 85.0 | 87.0 | 88.0 | 89.0 | 106.0 | 107.0 | 109.0 | 110.0 | 112.0 | 116.0 | 118.0 | 119.0 | 120.0 | 120.0 | 122.0 | 122.0 | 122.0 | 122.0 | 122.0 | 2,096.0 |
| Total Costs | 2,351.0 | 104.2 | 106.2 | 107.2 | 108.2 | 682.0 | 126.2 | 128.2 | 129.2 | 131.2 | 294.6 | 137.2 | 138.2 | 139.2 | 139.2 | 283.3 | 141.2 | 141.2 | 141.2 | 122.0 | 5,650.9 |
| Estimated Benefits | 0.0 | 209.5 | 220.7 | 230.4 | 240.0 | 249.9 | 259.8 | 269.8 | 279.8 | 289.9 | 300.0 | 223.1 | 184.9 | 184.9 | 184.9 | 184.9 | 184.9 | 184.9 | 184.9 | 184.9 | 4,252.1 |
| Net Benefits | -2,351.0 | 105.3 | 114.5 | 123.2 | 131.8 | -432.1 | 133.6 | 141.6 | 150.6 | 158.7 | 5.5 | 85.9 | 46.7 | 45.7 | 45.7 | -98.4 | 43.7 | 43.7 | 43.7 | 62.9 | -1,398.8 |
| EIRR = | n.a. | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -1,705 | | | | | | | | | | | | | | | | | | | | |
| CBR (10%) = | 0.51 | | | | | | | | | | | | | | | | | | | | |
| MAUA | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 1,124.1 | 5.3 | 5.3 | 5.3 | 5.3 | 161.7 | 5.3 | 5.3 | 5.3 | 5.3 | 140.2 | 5.3 | 5.3 | 5.3 | 5.3 | 25.8 | 5.3 | 5.3 | 5.3 | 0.0 | 1,530.9 |
| O&M Costs | 0.0 | 60.8 | 61.6 | 62.2 | 63.0 | 72.7 | 73.5 | 74.5 | 75.4 | 76.5 | 82.4 | 83.6 | 84.9 | 84.9 | 85.0 | 85.0 | 85.1 | 85.1 | 85.2 | 79.6 | 1,461.0 |
| Total Costs | 1,124.1 | 66.1 | 66.9 | 67.5 | 68.3 | 234.4 | 78.8 | 79.8 | 80.7 | 81.8 | 222.6 | 88.9 | 90.2 | 90.2 | 90.3 | 110.8 | 90.4 | 90.4 | 90.5 | 79.6 | 2,991.9 |
| Estimated Benefits | 0.0 | 49.5 | 53.0 | 56.9 | 60.8 | 65.1 | 69.7 | 74.5 | 79.8 | 85.4 | 91.2 | 97.7 | 104.5 | 104.5 | 104.5 | 104.5 | 104.5 | 104.5 | 104.5 | 104.5 | 1,620.0 |
| Net Benefits | -1,124.1 | -16.6 | -13.8 | -10.6 | -7.4 | -169.2 | -9.1 | -5.3 | -0.9 | 3.6 | -131.3 | 8.8 | 14.4 | 14.4 | 14.3 | -6.3 | 14.2 | 14.2 | 14.1 | 24.9 | -1,371.9 |
| EIRR = | n.a. | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -1,161 | | | | | | | | | | | | | | | | | | | | |
| CBR (10%) = | 0.33 | | | | | | | | | | | | | | | | | | | | |
| TIGANIA | | | | | | | | | | | | | | | | | | | | | |
| Investment Costs | 2,826.7 | 36.8 | 36.8 | 36.8 | 36.8 | 619.3 | 36.8 | 36.8 | 36.8 | 36.8 | 195.8 | 36.8 | 36.8 | 36.8 | 36.8 | 180.8 | 36.8 | 36.8 | 36.5 | 0.0 | 4,377.1 |
| O&M Costs | 0.0 | 99.8 | 101.4 | 102.9 | 104.6 | 125.0 | 126.8 | 128.8 | 130.9 | 133.1 | 138.0 | 139.9 | 141.9 | 142.3 | 142.7 | 144.8 | 145.2 | 145.6 | 146.0 | 129.7 | 2,469.4 |
| Total Costs | 2,826.7 | 136.6 | 138.2 | 139.7 | 141.4 | 744.3 | 163.6 | 165.6 | 167.7 | 169.9 | 336.8 | 176.7 | 178.7 | 179.1 | 179.5 | 325.6 | 182.0 | 182.4 | 182.5 | 129.7 | 6,846.5 |
| Estimated Benefits | 0.0 | 476.2 | 502.0 | 519.6 | 536.9 | 553.7 | 570.1 | 585.8 | 601.0 | 615.6 | 629.4 | 447.5 | 354.2 | 354.2 | 354.2 | 354.2 | 354.2 | 354.2 | 354.2 | 354.2 | 8,871.2 |
| Net Benefits | -2,826.7 | 339.6 | 363.8 | 380.0 | 395.5 | -190.6 | 406.5 | 420.2 | 433.3 | 445.8 | 292.6 | 270.8 | 175.5 | 175.1 | 174.7 | 28.6 | 172.2 | 171.8 | 171.4 | 224.5 | 2,024.7 |
| EIRR = | 7.2% | | | | | | | | | | | | | | | | | | | | |
| NPV (10%) = | -398 | | | | | | | | | | | | | | | | | | | | |
| CBR (10%) = | 0.91 | | | | | | | | | | | | | | | | | | | | |