UNIVERSITY OF NAIROBI
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WATER SUPPLY IMPROVEMENTS FOR UPGRADING AREAS

with special reference to automatic self-closing taps

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1.0 INTRODUCTION

The present water supply situation for the urban and semi-urban low income population in Kenya is one of great concern. The urban low income population is mostly housed in uncontrolled settlements in low cost sub-standard housing. This population is served by a limited number of water kiosks operated by licensed private intermediaries. The purchasers are paying about five times more for their water than the rest of the population. This has resulted in an unacceptably low level of consumption averaging 11 litres a day per person.

The estimated 14 million population of Kenya will probably double before the end of this century. Only some 12% of this population currently live in towns of more than 2,000 persons, and this group is expected to reach 30% of the total population by the year 2000. In other words in the next twenty years urban centres have to supply water to another 7.5 million people.[1]

To make things worse 63% of the present population living in low income urban areas earn less than K.shs. 300 a month.[2]

The per capita income (measured in constant amounts to discount inflation) will probably decline in the next decade, and with no major income redistribution the future looks bleak.[3]

It is clear, therefore, that the announced National policy that all houses are to be provided with full services, e.g. piped water, shower facilities and water-borne sewerage is not feasible for the majority of the population. A new water policy should be developed for low income urban inhabitants which is capable of implementation.

This paper examines strategies to extend the water supply to the plots of low income families living in urban and semi-urban areas. It will be shown that in those areas where water is supplied by water kiosks or stand pipes, innovative techniques,(such as automatic self closing taps and modern pipe materials) and simplified operating procedures, (such as the establishment of flat rate pricing which simplifies billing and accounting) can make it economically possible to supply every plot with a water tap.

2.0. WATER CONSUMPTION AND PRICE LEVELS IN KENYA

2.1. WATER RATES AND WATER CONSUMPTION.

Where water is supplied by kiosks, it costs on the average K.shs.0.20 per debe (18 litres). This amounts to KShs.11.11 per m^3. These water kiosks are run by licensed private operators. The family who buys water from the water carrier is worse off; they pay about KShs.0.40 per debe or KShs.22.22 per m^3.

This rate can be compared with the lower water rate charged by the Nairobi City Council of KShs.2.64 per m^3 for plot connections. Consequently, the population served by water kiosks pays five to ten times more for their qualitatively and quantitively inferior supply, than other consumers who are often served by multiple tap services. Furthermore, the number of kiosks is generally low, one kiosk per thousand people, in Mathare Valley.

Communal water point in Nairobi (Shauri Moyo Estate) where water is supplied free of charge to the individual consumer.

Recent studies[4] indicate that most households served by water kiosks state that they spend less than KShs.25 per month on water. With an average household size of 5.38 persons/household, this means a monthly per capita expenditure of KShs.4.64. With the cost of water of KShs.0.20 per debe and an average month of 30.5 days this means the use of 4.64 x 1000/11.11/ 30.5 = 13.7 litres per capita per day as an average.

A memorandum of J.F. Linn shows the relationship between household size and water consumption of 60 households in Mathare Valley in 1975. The sample shows an average household size of 6.45 person, with an average consumption of 10-11 litres per person per day[5]. It appears that water consumption per capita per day decreases as the household size increases.

The high cost of water and the low level of services apparently result in the low volume used by people served by water kiosks. For low income families earning less than KShs.300 per month, this would mean that they pay more than 8% of their household income for water. In comparison a high income family with multiple tap services (such as baths, toilets, sinks, etc.) normally pays only 2% of the household income for their plentiful water supply.

2.2. FUTURE WATER RATES

Although the water charges were reduced considerably in Nairobi for people served by water kiosks and raised for the people who are high consumers after 1st July 1978, there will still be a major discrepancy*).

The cost of water under the new new pricing system is as follows:[6]

a. Licensed water kiosk operators are buying it for KShs. 1.32 per m^3 and selling it to the consumer of KShs.0.10 per debe or KShs.5.55 per m^3.

b. Consumption 0-9000 litres, no change in rates KShs.2,64 p.m^3

c. Consumption 9001-18000 litres KShs.3,30 p.m^3

d. Consumption above 18000 litres KShs.3,75 p.m^3

e. Sewer charges KShs.1,40 p.m^3

The cost of 1000 litres water is now KShs.3.75 for the high income family and KShs.5.55 for the population who has to buy it from the water kiosk. Therefore, the low income family still has to spend a disproportionately large part of its earnings for the basic necessity of water.

3.0 WATER AND HEALTH IN KENYA

Numerous epidemiological studies have identified contaminated water and poor sanitary conditions as the principal agents in the transmission of certain diseases. Urban "squatters" suffer from proportionately worse health conditions than the people living in rural areas. High density living causes water-related illnesses to spread more rapidly due mainly to lack of "safe" water*) and a low sanitary awareness.

Bradley makes the following classification of infections in relation to water supplies.[7]

Classification of diseases in relation to water supplies:

CATEGORY	EXAMPLES	WATER IMPROVEMENTS
Water-borne infections	Typhoid Cholera	Improve water quality Prevent use of unimproved sources.
Water-washed infections	Scabies, Trachoma, Diarrhoea	Improve water quantity Improve hygiene
Water-based	Schistosomiasis	Decrease need for water water contact Improve quality
Water-related vectors	Sleeping sickness Filariasis (Malaria)	Piped water from source to user Destroy breeding sites Decrease visits to breeding sites.
Infections based on defective sanitation	Hookworm Amoebiasis	Improve sanitary disposal

3.1. WATER-BORNE DISEASES

In this case water acts as a passive medium for the bacteria. When these bacteria have access to drinking water, they survive for a period, and when the water is drunk, they will make the consumer ill. Cholera is nowadays a major threat in East Africa. The role of a new group of viruses, the rota viruses, as causes of childhood diarrhoea, is beginning to emerge. The mode of transmission is not yet known, but most high intensity outbreaks of diarrhoeal diseases have been associated with defective water supplies. It is estimated that 90% of the cholera cases and 80% of the typhoid cases can be prevented with improved water supplies[9].

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*) "safe" water is defined as treated surface water or untreated but uncontaminated water such as that from springs, protected boreholes or sanitary wells. Other water of doubtful quality is defined as unsafe.

3.2. WATER-WASHED DISEASES

Infections that decrease as a result of increasing the volume of available water are called "water-washed diseases". With these diseases quantity counts more than quality. These diseases are diarrhoea or diseases of the skin and body surface. In general it was found that the incidence of skin diseases in Kenya reflected the pattern of early twentieth century Europe[10]. In Kenya 250,000 children may have tinea capitis, ringworm, (6% of four million children in the suspectible age).[11]

According to Marples, Pityriasis Versicolor, a superficial fungus infection is very common at the Kenya Coast. It is estimated that 40% of young adult males suffer from this disease[12]. Eye diseases are very common in Kenya. Undoubtedly, the most important contributory factor is the lack of adequate water supply. Eye infections are exceedingly common amongst the low income population. When people have sufficient water to wash their faces daily, the incidence of eye infection drops dramatically even when the other environmental conditions remain the same.[13] These diseases and infections are more a nuisance than a major disability, but they cause enough misery so that people frequently seek treatment. For example, 16% of all outpatients in Mombasa town were seeking treatment for eye infections and skin diseases during the period January-June 1977 [14]. In practice it appears that unless water is piped into the house, water use is not sufficient to avoid these illnesses. Up to 50-80% of skin sepsis and ulcers, trachoma, conjunctives, scabies, yaws can be prevented with improved water supplies.[9]

3.3. WATER-BASED DISEASES

Where a necessary part of the life cycle of the infecting agent takes place in a water-based animal, the diseases are called "water-based diseases". These type of diseases are all worm infections. Schistosomiasis or Bilharziasis is caused by the Schistosome flatworm and carried by certain species of freshwater snails. The snails release the flatworm larvae into rivers and ponds. When a human enters the water, the larvae penetrates the skin and develop into mature worms that lay thousands of eggs in the bladder, liver and intestines. The eggs excreted by these victims find their way into water supplies where they start the cycle of infection anew. In Kenya it is estimated that about one million persons have the disease. It is prevalent at the coast (60% of the Malindi school children had the disease) round the shores of Lake Victoria (up to 80%), and it occurs along most rivers and streams in Nairobi [15]. Of the Kikuyu school children in Mathare Valley 85% were found to be infected [16].

Supplying piped water into the household has reduced the rate of water-based diseases. A study in St. Lucia W.I. showed a decrease in Bilharziasis as a result of piped water to the household. After 2 years the incidence, prevalence and intensity of infection with Bilharziasis were significantly lower in the household water supply area, whereas all these indices of infection had increased in the comparison area. The comparison area was served by public standpipes [17].

It is estimated that 60% of Schistosomiasis can be prevented with improved water supplies [9].

3.4 WATER-RELATED VECTORS OF DISEASES

The infections spread by insects that breed in or near water are called "water-related insect diseases". The larvae of many insects are water based, such as filariasis, dengue, yellow fever, sleeping sickness and malaria. These type of diseases, however are very difficult to prevent even with a better water supply service. Stagnant pools around communal waterpoints can become breeding place for these insects.

Urban filariasis is transmitted by a mosquito which breeds mainly in pit latrines and which bites in the middle of the night. Filariasis is quite common in the Coast Province. A survey of the rural areas of the Coast Province showed that 30% of the men had attracted the disease [18].

3.5 DISEASE OF DEFECTIVE SANITATION

Many water-washed and water-based diseases depend on access of human wastes to water. Disease incidence can be reduced by methods aimed at improving waste disposal as well as water supply.
A number of infections like hookworm result from poor waste disposal. Hookworms penetrate the skin from damp infected soil. Round worm, ascaris, lays numerous eggs which escape in the faeces and mature in the ground becoming infections to man if transmitted.

3.6 NATURAL FLUORIDE LEVELS IN WATER

Borehole water in the Nairobi area shows a high content of fluoride. Levels of 8 times [19] the maximum WHO standards [20] have been recorded. A sample group of school children in Nairobi City Council schools demonstrated that the high fluoride content is having serious effects on these children [21].

3.7 DEBILITATION, MORBIDITY AND FATALITY

Unsafe water supply and poor waste disposal can, therefore result in the following main types of health problems.

3.7.1 Debilitation

Some diseases make people ill and may affect their appearance and yet not reduce their working capacity.

3.7.2 Morbidity, sickness

Water carried diseases can cause blindness, diarrhoea, dizziness fatigue and fever. A few days illness can reduce the household income significantly or even result in complete unemployment. For example, health statistics show that 43.6% of the outpatients in Mombasa over the period of January - June 1977 suffered from the following water-related illnesses; diarrhoeal diseases (7.6%), malaria (16.7%) Bilharzia (0.9%), Intestinal worms (2.4%) Eye infections (4.2%) and skin infections (11.8%) [14].

This meant that over this period 280,990 cases were seeking treatment out of a total estimated population of only 375,000 inhabitants. (Some cases may involve the same person) 8.0

Mortality

Mortality is more serios amongst young children suffering from a combination of malnutrition and infectious diseases. Their protein deficiency resulting from general malnutrition makes them more suspectible to diarrhoeal diseases. Enteritus and other diarrhoeal diseases were the second biggest causes of death in Nairobi in the year 1971. [22]

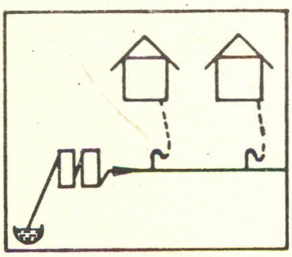
THE AMOUNT OF WATER THAT IS NEEDED TO IMPROVE HEALTH CONDITIONS

Health benefits of increased water use begin to level out somewhere between 30-80 litres per person. This depends on the type of excreta disposal system installed (30 litres of water combined with a dry disposal method as pit latrines or compost toilets, 40 litres of water with aqua privies or pour flush toilets and 80 litres for conventional sewerage systems).

However, very little research has been done on the various effects of water consumption related to health conditions. According to Sharaf N. Bannaga, who carried out a six months long household survey of existing water use, disease mortality and other related factors in El Obeid, Sudan, there were few health benefits from increasing daily water use above 60 litres per person. [23]

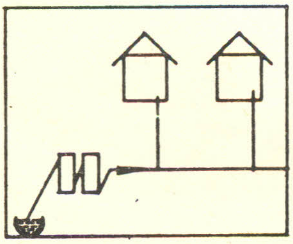
4.0 URBAN WATER SUPPLY LEVELS

Urban water supply in low income areas can be divided into three main levels of services.*



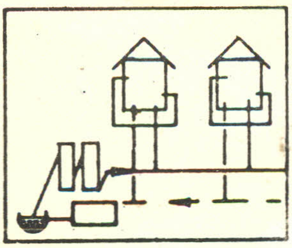
Municipal standpipe services:
Selling for cash payment at the tap.
Water consumption 10-15 litres/cap/day.
Excreta disposal by pit latrines.

Capital cost water supply	per capita Kshs.	20- 80
Monthly consumer charges	per capita Kshs.	2- 5



Single tap services:
Metered or unmetered consumption.
Water consumption 30-60 litres/cap/day.
Excreta disposal by pit latrines.

Capital cost water supply	per capita Kshs.	60- 120
Monthly consumer charges	per capita Kshs.	2- 8



Multiple tap services:
Metered consumption.
Water consumption 60-120 litres/cap/day.
Excreta disposal by waterborne sewerage.

Capital cost water supply	per capita Kshs.	50- 80
Capital cost sewerage	per capita Kshs.	240- 400
Capital cost wet core	per capita Kshs.	820-1360
Monthly consumer charges	per capita Kshs.	8- 15

4.1 STANDPIPE INSTALLATION

A standpipe connection is equivalent to a public hydrant or a water kiosk and normally involves cash payment for use. Standpipe services can be used easily for rapid cheap extensions of water supply systems into low income uncontrolled settlements.

Although standpipes are only a first step towards necessary minimum satisfactory public services, they are often unpopular with local authorities. It has been reported that Nairobi City Council employees are not keen to provide water to so called "squatters" as this would undoubtedly encourage more illegal squatter development.

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* All cost figures are abstracted from, Ministry of Housing and Social Services, "Low -Cost Housing and Squatter Upgrading Study". Final Report, 1978, Vol.2, pages E1-E22 and based on Nairobi water rate structures and recalculated per capita. It is assumed that in the consumer charges the public expenses are recovered.

Water kiosks are handed over to licensed private operators. The necessity for having a collector on duty means that a comparatively large number of people have to be served by each water kiosk. This results in congestion during peak hours and service usually provided only during the day-light hours. In addition, the salary of the standpipe supervisor is recovered from the consumer by increasing 4-5 fold the water price. As shown in Par. 2.1., this results in a low water use of 10-15 litres per capita per day.

Communal water point in Nairobi (Kibera Estate), where water is sold.

Furthermore, there is still the possibility of water contamination during carrying or storage. A Brazilian study showed that the health risk was about the same whether treated water was carried from public taps to private houses or whether water was taken from open unprotected wells. This finding would indicate that the treated water was recontaminated during transport to the houses, and that the quality of water had little effect unless the treated water was piped into the house [25]. A similar result has been recorded in Lesotho. Standpipes did not lead to a reduction in water related diseases because they did not improve hygiene. [26]

Water experts have long maintained that communal facilities are not good enough. As Wolman stated: "The provision of water at a public tap in the street should not be accepted as a major public health asset. Water which must be carried from some central square does not meet essential conditions for the protection of the public health of the community". [38]

Therefore, one of the conclusions and recommendations of a WHO expert committee was: "The aim of a water supply project should be to deliver water to every consumer in his house or on his premises. Any measure less than this, for example the provision of public standpipes, should be regarded as an interim expedient to be improved as early as possible".[39]

As indicated in the "Low Cost Housing and Squatter Upgrading Study"[27], a major complaint of the interviewed inhabitants of the uncontrolled settlements was the lack of water supply in the house. The people found the water kiosk service insufficient. The following percentage of the inhabitants interviewed from these areas mentioned this constraint:

- Pumwani	- Nairobi	12%
- Ngei 1	- Nairobi	18%
- Ruaraka	- Nairobi	62%
- Kawangware	- Nairobi	11%
- Kasauni	- Mombasa	72%
- Chaani	- Mombasa	8%

The study, however, does not indicate the reason why people mentioned this problem.

4.2 HOUSEHOLD SERVICE WITH SINGLE TAPS

The simplest form of water service to individual households is a distribution line of one tap to every house. An individual tap system eliminates water carrying from outside the household, and it facilitates cleanliness in water use. Providing piped water to low income users by means of a single tap service, raises two problems: wasteful use and the collection of water rates.

Generally, the installation of metered water connections leads to decreased use either from leakages of fittings or waste of water. It is, however, uneconomical to install individual water metres since the price of a water meter may be more than the payment for the yearly amount of water.

Metering of individual water connections has the following advantages:-

- Reduction of waste and misuse of water.
- Provision of a "fair" means of payment, the consumer pays only for the water he uses.
- Possibilities of monitoring leakage and losses in distribution mains.

Disadvantages:

- Meters are expensive to install and need maintenance.
- Monthly reading, billing and accounting is expensive.
- It is difficult to collect water charges, because owners in low income areas do not have postal office boxes and may not be able to read bills.
- Disputes can arise over the accuracy of the meters.

Metering houses with single tap services which are not connected to water-borne sewerage has repeatedly shown to be costly and some type of flat rate system may be necessary.

A flat rate is charged without regard to the amount of water actually used by the consumer. Without meters and individual billing, however, the consumer will not normally take any action to prevent waste. With unmetered service there will be no incentive to repair leaking taps that can easily waste 10 litres of water per minute or 14 m^3 of water per day. Excessive run-off can result in stagnant pools, where insects and flies breed. Particularly in the coast zone this can become dangerous because the mosquito transmitting filariasis breeds in these pools.

Local authorities can employ the following different methods to avoid waste of water with unmetered service.

.1 Intermittent supply

Water supply can be limited to certain hours a day. This system is not advisable because intermittent delivery generally results in unsafe water, since periodic drops in water pressure permit entrance of subsoil water through leaking pipes. [30] In addition there may be higher water use than would be obtained by a continuous supply [29].

.2 Water pressure reduction

Water pressure can be reduced, but it is difficult to serve large areas with reduced pressure. People who are living at the end of the piping network will receive hardly any water while people at the beginning will have a considerable pressure and supply.

3 Flow restricting inserts

These inserts will limit the flow in the pipe network to about 4-6 litres a minute. Observations show that people living in those areas where these systems are installed, often leave the tap continuously running with a receptacle under it. People are reluctant to wait for a long period for their bucket to fill. A continuously open tap where the water pressure is reduced or where flow restricted inserts are installed can still mean up to 5000 litres of water wasted per day.

4 Self-closing taps

Ordinary self closing taps are not successful. The push down taps break easily or can be tied or forced permanently open. People will bind wire around them and so convert the self-closing tap into a continuously open tap.

5.0 THE "FORDILLA" VALVE; A SPECIAL SELF-CLOSING TAP[30]*

The "Fordilla" valve is a specially designed automatic self-closing tap. Its purpose is to discourage the waste of water. These types of valves have been installed mostly in Latin America, but also in some African countries such as Ghana and Somalia.

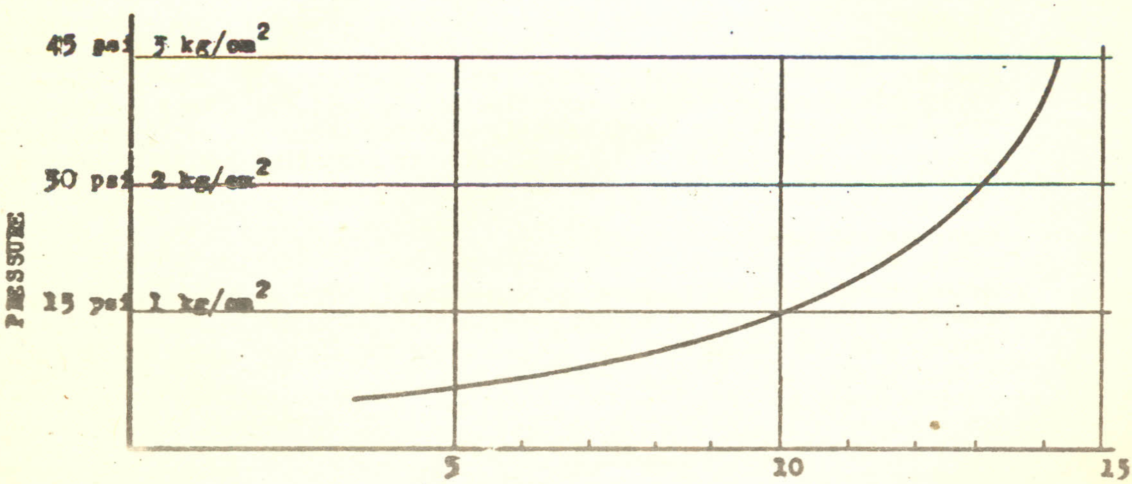
5.1 THE OPERATION OF A "FORDILLA" VALVE

5.1.1 When the top button is pressed and held down, approximately 2 - 3 litres of water are delivered. The manufacturer can, however, provide units that can deliver 7.5 litres of water per cycle. The valve closes itself when the maximum quantity of water for which the tap is calibrated has been discharged. Thus, it cannot be left open, tied open, or propped open.

5.1.2 It the button is pushed down and then released, the valve closes immediately. Thus, water is not wasted when only a limited amount is needed.

5.1.3 After the valve is opened and it has closed itself, the push button may be released and immediately pushed again for more water. Thus, as long as someone is operating it, the "Fordilla" valve will dispense as much water as is needed.

5.1.4 The "Fordilla" valve may be operated on any reasonable water pressure. It delivers about ten litres per minute at .1 Kg/cm^2 water pressure (ca.2 imp. gallons per minute at 15 psi.) Operation is best at pressures from about 0.6 Kg/cm^2 to 6 Kg/cm^2 (9 psi. to 90 psi.), but any difference in water pressure over 4 Kg/cm^2 (60 psi.) will not result in a great increase in flow (see quantity pressure curve).



* The "Fordilla" tap is discussed in depth, because it is probably the fool-proof automatic self-closing tap available on the world market. This tap is designed especially for developing countries and already used extensively.

THE INSTALLATION OF "FORDILLA" VALVE

The "Fordilla" is fixed with a water tight seal to a vertical g.i. pipe, preferably not smaller than ¾". The bottom of the pipe should be encased in concrete or stabilized by attaching it to a fixed post. A concrete tile under the "Fordilla" spout provides a convenient support for the filling of water containers.

The "Fordilla" valve in use.

Because waste is discouraged and water conserved, as many as 40-50 "Fordillas" can be served from one single 1" service line. Ordinarily the lateral from the service line to each individual "Fordilla" can be of ½" pipe unless the lateral is long or the pressure low.

Closing as it does with the pressure, water hammer will occur because of velocity built up in the service line. Such water hammer has not proved injurious to g.i. pipes and certainly not to unplasticised polyvinyl chloride pipes that will absord the water hammer shock by their elasticity.

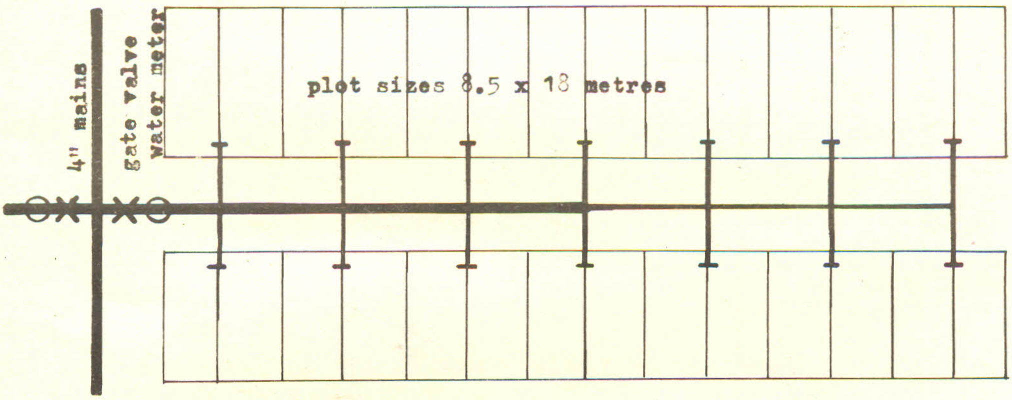
THE CHARACTERISTICS AND ADVANTAGES OF A "FORDILLA" VALVE SYSTEM.

Water use in a "Fordilla" valve system can be more closely calculated than that in a metered system. In a metered system sprinkling and other opened taps are difficult to control.

Also while filling a bucket, the tap will close itself a few times and only as much water is drawn as is needed. Therefore, it is safe for purposes of calculation to assume a peak flow of 2 compared with a peak flow factor of 4 for ordinary taps.[31]

The "Fordilla" valve may be said to furnish unlimited but "unwastable" water.

A single water meter measures the water delivered into a particular portion of the system to check for leakages or unauthorised connections. Together with the water meter, a gate valve is placed at the beginning of the service line. See illustration.



5.4 WATER CONSUMPTION WITH SELF-CLOSING TAPS

Another positive effect of an automatic self-closing tap is that almost every person uses almost the same amount of water. Observations in other countries show that a certain level of water withdrawal is reached with automatic self-closing taps, whether a water meter is used or not.

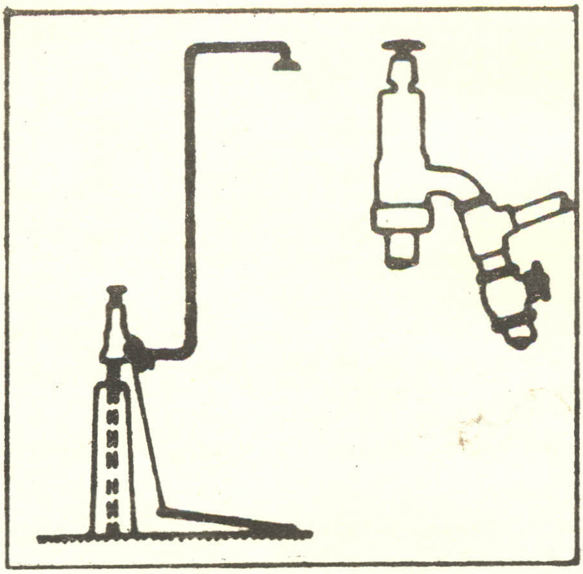
The water consumption will be between 25 - 40 litres per person per day. Therefore, it is easy to establish flat rates for water. With flat rates it is possible to include the water charges in land rents or a general tax revenue. The collection of these combined rates should take place by one central body, for example a Housing Development Department. Preferably the water charges should not be directly connected with the water service since disconnection of the water supply is not a sound way of enforcing payment.

Automatic self-closing taps cost more than regular taps, but result in reduction of the total cost of ordinary taps, meters, meter reading, billing accounting and larger size pipes, as will be shown in chapter 7.

5.5 SHOWER FACILITIES

A possibility of extending the system with shower facilities can be left to the individual plotholder. A simple shower device has been developed in St. Lucia, W.I. [32] by threading the "Fordilla" valve outlet and adding a Tee joint and a simple shut off valve.
A 2 metre length of pipe, 2 elbows and a shower head make up the shower. When the shower is in operation, the lower valve is closed so that the flow is diverted through the shower. When the valve is opened, the tap functions in the usual way. As a simpler alternative, avoiding changes to the tap, a flexible hose can be attached to the outlet of the tap.

A foot control can be made by drilling a small hole through the push button on the tap and attaching a wire to a short board used as a pedal. It is advisable to use taps that are calibrated for at least 6 litres of water per cycle. See illustration.



Possible shower conversion (source G.O. Unrau, reference 32)

5.6 IMPLEMENTATION IN UPGRADING AND SITE ONLY DEVELOPMENT

Another aspect of this type of service deserves a special note. Where the housing density and soil condition permit pit latrines, the house owner as well as the council is saved the cost of sanitary sewers. However, the lower the density the higher the unit cost for water lines.

As the use of automatic self-closing taps limits water use to 25-40 litres per capita per day, the service lines will have minimum dimensions. The main distribution network on the site, however, cannot be reduced below 4" diametre due to fire flow requirements. Furthermore, there is not the introduction of excessive water that cannot be disposed off. Therefore, implementation of this type of water supply service is well suited for site only, "minimum grade", developments [33] or in upgrading schemes as a first step to improve the health situation.

6.0 PIPE MATERIALS

The following pipe materials are currently produced in Kenya. For this paper only the smaller diameters will be reviewed (½" - 4"). *

DIAMETER	GALVANISED IRON	UPVC	POLYTHENE
½"	10	2.6	1.8
¾"	12.2	3.5	3.1
1"	18.3	5.0	3.8
1¼"	22.8	5.7	5.1
1½"	26.7	7.5	6.6
2"	37.5	9.1	10.0
3"	62.5	20.0	na
4"	100	28.3	na

6.1 GALVANISED IRON PIPES [34]

Galvanised iron pipes are made according to BS 1387 from imported raw materials. It is available in three classes.

Class A, with thin walls, banded brown, is used for waste, ventilating and overflow pipes.

Class B, with medium thick walls, banded yellow, and is used for distribution pipes for water.

Class C, thick walls, banded green, usually used for rising mains and for great water pressures.

Jointing is by screwed and socketed joints. Frictional loss and loss by elbows and other sharp fittings can restrict the flow considerably.

Characteristics: strong, both for water pressure and in resisting of external damage- it is not easy to work on and installation needs skilled personnel. Compared with plastic pipe materials it needs larger diameters to transport the same amount of liquid. Furthermore it is fairly expensive compared with other materials.

Uses: In house plumbing and at those places where pipes can be damaged by external forces.

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* Prices of pipe materials in KShs. per metre. Nairobi prices including sales tax on the data of 20-06-1978. Pressure class B, small diameters in plastic are only manufactured for higher working pressures.

6.2 UNPLASTICISED POLYVINYL CHLORIDE PIPES (UPVC)

UPVC pipes are extruded according to B.S. 3505.68 and B.S. 3867 from imported raw materials and are available in four pressure classes.

Class B - working pressure	60 metres,	86 psi.
Class C - working pressure	90 metres,	130 psi.
Class D - working pressure	120 metres,	173 psi.
Class E - working pressure	150 metres,	216 psi.

Jointing: Two main jointing systems are employed.
Solvent welding: Solvent cement is applied to the clean square end of a pipe which is introduced into a fitting of upvc. Solvent joints are cheap and fairly easy to make.
Expansion joints: Rubber ring joints are used for expansion joints. PVC has a high coefficient of thermal expansion and installations should be designed to allow for some movement. Long straight runs of pipes should be equipped with expansion joints.
With adaptors it is possible to join upvc pipes with other pipe materials.

Characteristics: Light weight, simple to join and, therefore, needs less skilled personnel. Neither corrosion nor deposits will build up in the pipe walls resulting in low frictional resistance. UPVC pipes are more susceptible to external pipe damage than gal.iron pipes, but are fairly cheap.

Uses: UPVC has largely replaced gal.iron pipes in water mains service and cold water distribution pipes in Kenya.

6.3 POLYTHENE PIPES [36]

High density polythene pipes are extruded from imported raw materials according to BS 3284. These pipes are available up to 2" diameters and in three pressure classes.

Class B, working pressure	60 metres,	86 psi.
Class C, working pressure	90 metres,	130 psi.
Class D, working pressure	120 metres,	173 psi.

Polythene pipes are flexible and are produced in long lengths, up to 305 metres, making fewer joints necessary.

Jointing brass compression fittings are easy to make and used with adaptors it is possible to join polythene pipes with other pipe materials.

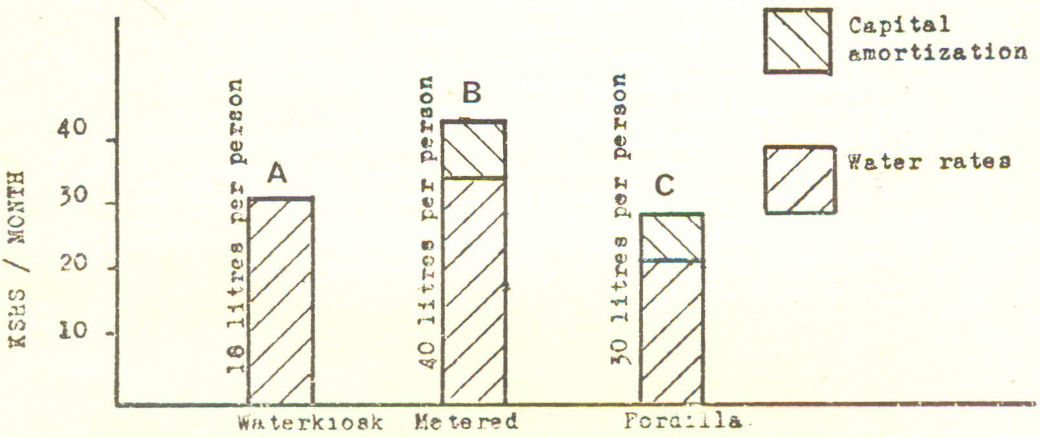
Characteristics: Lightweight (a coil of 153 metres of ½" pipe weighs 14 Kg.), this will mean fewer joints resulting in fewer leaks. Polythene pipe may be bent cold to eight times the outside diameter of the pipe. Polythene has the tendency to reduce water hammer. Low frictional resistance results in high flow. It is easy to install and to work on with no special skills needed. Long straight lengths may be laid without trenching by mole ploughing. Polythene pipe is the cheapest water pipe material available on the Kenya market.

Uses: Considered very good for underground services and is not effected by acids in the soil.

7.0 COST CALCULATIONS

For cost comparison purposes a hypothetical proposal for supplying water to every plot with an individual "Fordilla" valve is compared with two other types of services: service from water kiosks and service with normal taps controlled by an individual water meter. Plot sizes of 8.5 x 18 metres are assumed with the following plot occupancy.

10 persons per plot: represents medium to high density development*



MONTHLY WATER CHARGES PER PLOT (10 pers.).

7.1 SITUATION A. SERVICE WITH WATER KIOSKS

The area is served with a dense network of water kiosks. The maximum walking distance to a water kiosk is assumed to be 125 metres. Water charges are KShs.0.10 per debe for the consumer and KShs.1.32 m^3 for the water kiosk operator. This amounts to KShs. 5.55 per m^3 for the consumer. Water consumption per person is assumed to be 1 debe (18 litres) per day **. This results in 10 x 30.5 x Kshs.0.10 = KShs. 30.50 monthly charges per plot.

7.2 SITUATION B, SERVICE WITH SINGLE HOUSEHOLD TAP (APPENDIX B).

a. Every plot is served with one normal tap (bibcock).
b. Water consumption is individually metered.
c. Water charges are composed of three elements: the progressive rate schedule, (see page 3, par2.2), a fixed monthly water meter rent KShs.2.00 and a deposit of KShs.100.00.
d. Water consumption is assumed to be 40 litres per person per day.

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* This is above the average household size of 5-6.5 pers/household. Practice shows that more than one family often occupies one plot.

** This is above the present recorded figure of 10-12 litres per person per day. It is assumed, however, that with the introduction of the lower water charges this figure will increase. Therefore 18 litres per person is assumed.

e. The peak hourly demand is assumed to be 4 times greater than the average demand over 16 hours.
f. The minimum main distribution dimensions are 4" diameter with 2.75 Kg/ cm^2 (40 psi) minimum pressure, (derived from fire flow requirements).
g. The minimum residual pressure is assumed to be 1.35 Kg/cm^2 (20 psi.).
h. The polythene pipes are limited to three sizes (1¼", 1" and ½" diameters).
i. Surface piping is gal. iron pipes of ½" diameters.
j. Acceptable head losses from friction are assumed to be 50 metres for 1000 metres length of pipe (Appendix A).

.3 SITUATION C. SERVICE WITH AUTOMATIC SELF CLOSING TAPS APPENDIX C.

a. Every plot is served with an automatic self closing tap, ("Fordilla" valve).
b. Only one water meter is installed for 28 plots.
c. Water charges are according to the progressive rate schedule (see page 3 par.2.2).

Rates are recovered as a portion of land rent, and therefore a monthly discount of KShs.3.00 per plot is assumed*.
d. Water consumption is assumed to be 30 litres per person per day.**
e. The peak hourly demand is assumed to be two times greater than the average demand over 16 hours.
f. The minimum main distribution dimensions are 4" diametre with 2.75 Kg/ cm^2 (40 psi) minimum pressure, (derived from flow requirements).
g. The minimum residual pressure is assumed to be 1.35 Kg/cm^2 (20 psi).
h. The polythene pipes are limited to three sizes (1", ¾", and ½" diametres).
i. Surface piping is gal. iron pipes of ½" diametre.
j. Acceptable head losses from friction are assumed to be 50 metres for 1000 metres length of pipe (Appendix A).

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* According to information from Water Department of the Nairobi City Council the monthly operating expenditure for recording meters, billing and accounting is estimated to be KShs.5.00 per connection. This amount is recovered in the water rates. With a simplified billing system a monthly discount of KShs.3.00 per connection is assumed.

** No data is available of water consumption with 'Fordilla' Valves in African Countries. The consumption of 30 litres per capita per day is based on consumption figures from Guatamala.

8.0 COMMUNITY PARTICIPATION

The engineer and designer of water supply networks in low income estates should realise that there is no foolproof way to eliminate abuse.

Every scheme, it does not matter how well designed, can be tampered with by the members of the community. The support of the community and the demonstration of individual responsibility are the greatest safeguards in keeping the system in working operation and minimising vandalism.

Too often new systems are imposed on existing communities without even consulting them. Therefore, the engineer and designer should first get an impression of what the community themselves establishes as their priorities, and how much they would be willing to pay for these improvements. This dialogue can be achieved through sample surveys in the area

It is then the task of the engineer to interprete these opinions and convert them into understandable solutions and alternatives for the community. It should be made clear to the community what they can expect for their investment, and what the consequences are from a certain approach.

In the case of individual household water supply using automatic self-closing taps, the designer should explain the advantages of this system, but he should also explain the need for necessary self-control. The greatest risk in a water supply system with automatic self-closing taps is that the consumer substitutes a cheap ordinary tap for the self-closing tap or makes additional unauthorised connections. This will wreck the system completely. The members of the community should agree beforehand on the type of action that will be undertaken against those who abuse the system.

Every consumer should pay a minimum cash instalment as his contribution for the watertap on his plot. This watertap will become his responsibility and any damages that will result from abuse should be paid for by him. Only the repair of normal wear and tear should be paid out of general expenses.

Any consumer who changes or damages the tap should pay for the full economic cost of a new water tap. Failure to pay would result in disconnection from individual water supply services. Decisions on disconnection and their implementations can often be handled more expeditiously through a local group structure than through direct intervention of the authorities which may incur hostilities of a more general nature. Due to this individual and communal responsibility household water supply should be more abuse proof than communal taps. In addition household water supply will provide more water for a lower cost to the low income consumer.

Health benefits will only be obtained after a proper health education programme. It would be far more effective for the community to institute a procedure that combines the skill of the plumber with that of a community health worker.
A woman community health worker would be preferably well suited to relate to the women in the household charged with water use. The advice of the community health worker would also control misuse of water.

An alternative for individual household water supply is a dense communal standpipe network. However, there are several shortcomings:
unsupervised standpoints break down easily and result in wastage of water. It is difficult to apply pressure on defaulters through cutting off water supply. Supervised standposts would add the salary of the attendant and thereby increase the water tariff substantially with the result that water consumption will be low and little health benefits will be achieved. However, very little planning and community organisation are necessary for this type of development. In case household water supplies are not feasible for a particular community, communal water points are still a valid alternative, but should only be regarded as a second best solution.

9.0 CONCLUSIONS

Adequate urban water supply is a matter of national concern. The population in urban areas is increasing more rapidly than in the rural areas. Consequently, high urban population densities without satisfactory water supply increase the risk of disease and resulting fatality.

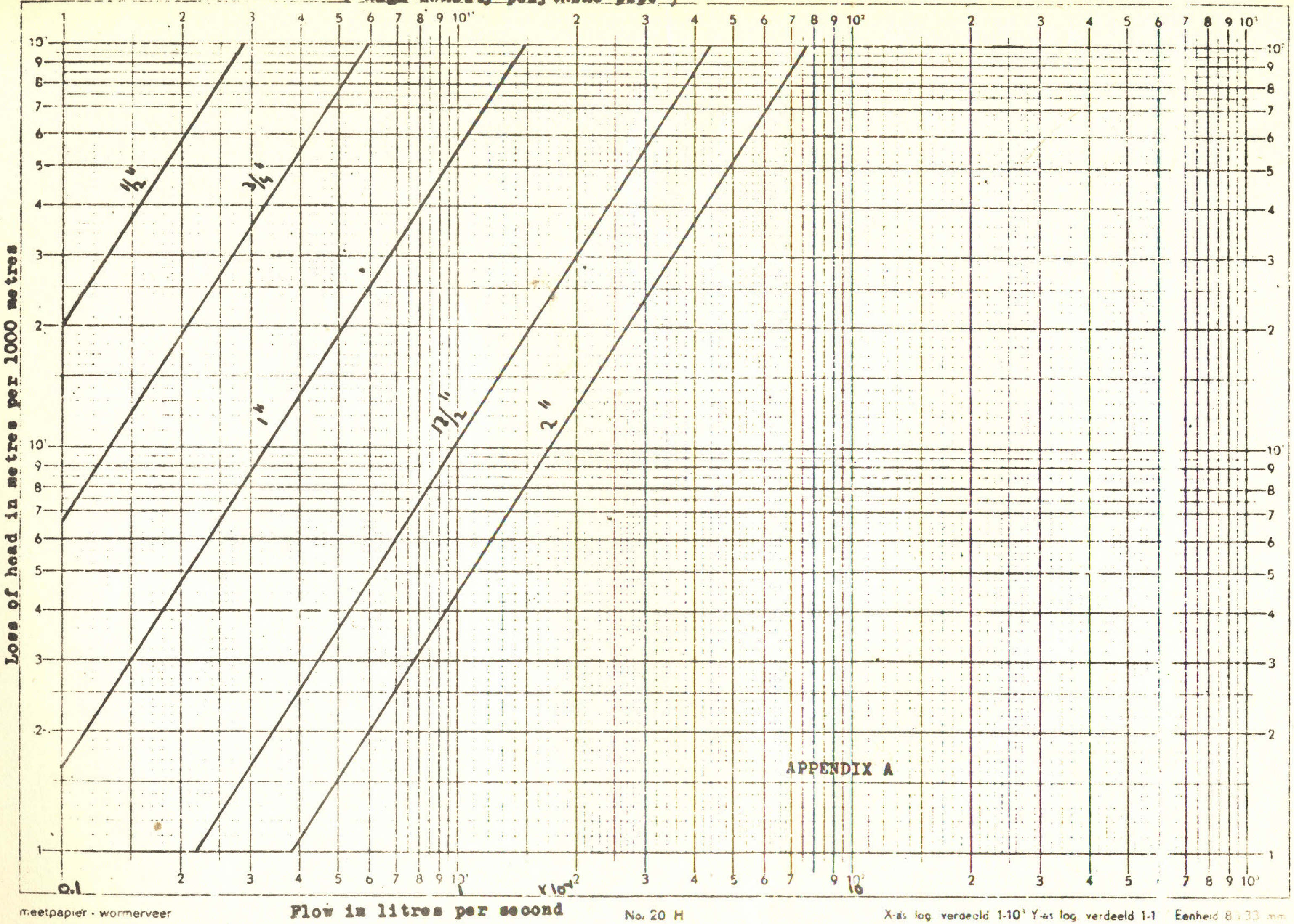
In East Africa there is still no experience with automatic self-closing taps, such as the "Fordilla" valve. In the near future it would be possible with innovative techniques and modern materials to bring piped water into most of the households. It would be well understood that the off-site infrastructure costs should be recovered through the general water charges. The additional expenses for on site distribution should be recovered from the plotholder [37].

Collection of water rates from low income areas raised problems. According to the Water and Sewerage Department of the Nairobi City Council, the low income estates show a bad record of late payments, arrears and disconnections. This results from the fact that people living in these estates are often illiterate, do not understand bills, and do not have mailing addresses. Councils should, therefore, adopt another way of recovering their water charges and should minimize their administrative procedures, such as meter readings, individual billing and accounting. If an area is saturated with these taps, it may be possible to collect water charges along with a general tax revenue, such as land rent, or by some other means.

The importance of local group participation in the initial stages of water supply design should seriously be considered by engineers and designers. It is here that success in involving the community in the initiation and administration of a water supply scheme can have perhaps its clearest reflections. A strong local group involvement can prevent abuse of the system.

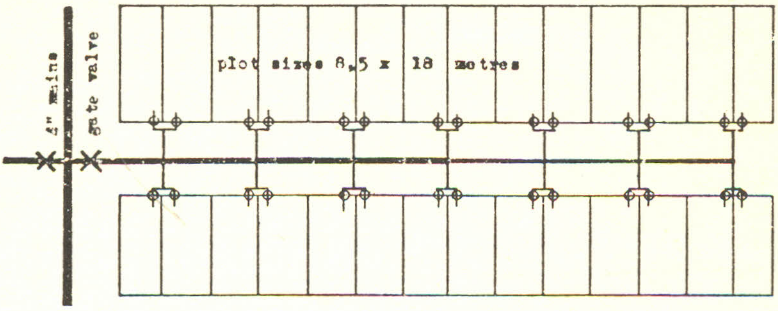
The calculations in this report demonstrate that is is economically feasible to supply low income families with a "Fordilla" watertap on the plot. Even when all extra benefits, such as improved health conditions and time economics are disregarded, it is remarkable that the plotholder can obtain more water with a better supply service for a lower price using automatic self-closing taps. Furthermore, the Council receives more revenue from individual household service than from standpipe connections. It must be considered that with the new water rate structure, standpipe connections are money losers. The only person who really benefits from standpipe service is the middleman, the licensed water kiosk operator.

HEAD LOSS IN PIPELINES (high density polythene pipe)



APPENDIX B

The cost of materials and labour to supply 28 plots of a size of 8,5 x 18 metres with a water tap and a watermeter are the following:



Materials Cost

Connection to distribution mains incl. gate valve	kshs	200	
Polythene piping		790	
Couplings for polythene piping		940	
Gal. iron surface piping		2.655	
Bibcocks ½" @ kshs 35,-		980	
Concrete benching and support		1.120	
Fine aggregate 10 m^3 @ kshs 40,-		400 +	
Total Materials cost			7.085

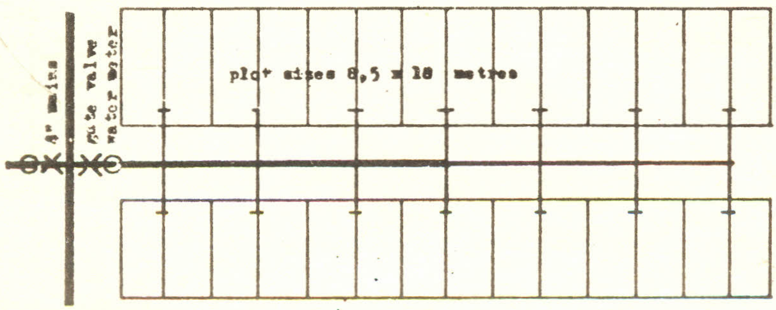
Labour Cost

Connection to mains 2 labour days	kshs	120	
Pipe and plot connections 28 labour days		840	
Excavation for service lines 61 m^3 @ kshs 10,-		610 +	
Total labour cost			1.570 +
			8.655
Contingencies 25%			2.164 +
Total cost			10.819
Total cost per plot			385

Amortization over 10 years with 8,5 % intrest results in a monthly payment per plótconnection of	kshs	4.90
Maintenance cost 2% of total cost per plot		0.64
Meter rent		2.00
Loss of monthly interest on meter deposit of kshs 100,-		0.70 +
Total monthly cost per plot fixed charges		8.24
Monthly water charges per plot, 10 persons 40 litres x 30,5 days according to Nairobi water rates		34.32 +
Total monthly cost per plot connection		42.56

APPENDIX C

The cost of materials and labour to supply 28 plots of 8,5 x 18 metres with automatic self closing taps,type " Fordilla " valve.



Materials Cost

Connection to distribution mains incl. gate valve	kshs	200	
Polythene piping		560	
Couplings for polythene piping		530	
Gal.iron surface piping		1.630	
Fordilla valves 28 @ kshs 180		5.040	
Concrete benching and support		1.120	
Fine aggregate 10 m^3 @ kshs 40,-		400 +	
Total materials cost			9.480

Labour Cost

Connection to mains 2 labour days	kshs	120	
Pipe and plot connections 28 labour days		840	
Excavation for service lines 61 m^3 @ kshs 10,-		610 +	
Total labour cost			1.570 +
			11.050
Contingencies 25 %			2.763 +
Total cost for 28 plots			13.813
Total cost per plot			493

Amortization over 10 years with 8,5 % interest results in a monthly payment per plot connection of	kshs	6.26
Maintenance Cost 2 % of total cost per plOt		0.82 +
Total monthly cost per plot fixed charges		7.08
Monthly water charges per plot ,10 persons @ 30 litres x 30,5 days according to Nairobi water rates		24.26
Discount for collecting water charges in land rent		- 3.00 +
Total monthly cost per plot connection		28,34

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