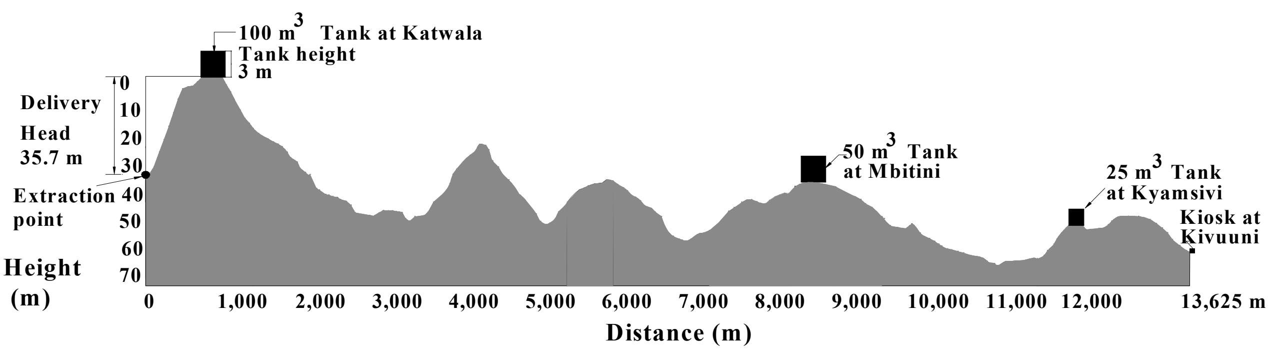
Water Surveys and Designs

Explains survey techniques and gives standard designs with average costs on water supply structures

By sighting along the two water levels in a circular transparent hosepipe filled halfway with water, horizontal lines and gradients can be measured.

A surveyor sights through a dumpy levelling instrument to get horizontal readings, or gradients for setting out ranging rods to mark a pipeline.



A profile of the ground level of the Mbitini Water Project is described in this hand book. The rising main pipeline, which starts from the extraction point at Mwiwe riverbed to the tank situated at Katwala, which is shown to the left. The farthest water kiosk, 13.6 km away from the extraction point is shown to the right of the profile.

Erik Nissen-Petersen and Catherine W. Wanjihia

for

Danish International Development Assistance (Danida)

2006

Technical handbooks in this series :

Titles	**Contents**
1 Water for rural communities	Lessons learnt from Kitui pilot projects
2 Water supply by rural builders	Procedures for being rural contractors
3 Water surveys and designs	Survey, design and cost of water projects
4 Water from rock outcrops	Rock catchment tanks, masonry and earth dams
5 Water from dry riverbeds	Wells, subsurface dams, weirs and sand dams
6 Water from roads	Rainwater harvesting from roads
7 Water from small dams	Ponds and small earth dams built manually
8 Water from roofs	Various types of roof catchments for domestic use

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Text by
Erik Nissen-Petersen and Catherine W. Wanjihia

Photos and sketches by
Erik Nissen-Petersen

Computer drawings and tracing by
Catherine W. Wanjihia

Editing by
Prof. Elijah K. Biamah

Proofs by
Prof. Elijah K. Biamah, Amin Verjee and Steen S. Larsen

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ASAL Consultants Ltd. P.O. Box 739, Sarit 00606, Nairobi, Kenya
asal@wananchi.com asalconsultants@yahoo.com
Fax/Tel : 254 020 2710296 and 4766144 Mobiles: 0733 619 066 and 0722 599 165
Website : www.waterforaridland.com

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Also many thanks are due to the hundreds of builders and thousands of community members we worked together with on building reliable water supplies based mainly on rainwater harvesting in the arid and semi-arid (ASAL) regions of Africa.

Special thanks are due to the team that assisted me in producing this series of handbooks. The team consisted of Catherine W. Wanjihia, who computerised the technical drawings and compiled bills of quantities. To Mr Amin Verjee and Steen Larsen who proof-read the text several times and to Prof. Elijah K. Biamah and Mr. Gabriel Mukolwe who edited the handbooks. Thanks are also due to Mr Oliver who supervised the printing and Mr Edwin Ondako who loaded the handbooks onto the internet.

Erik Nissen-Petersen
Managing Director
ASAL Consultants Ltd.
P.O. Box 739, 00606, Nairobi, Kenya
Tel/fax 254 (0)20 2710296 / 4766144
Mobile 0733 619066 / 0722 599144

Acronyms and Abbreviations

ASAL	-	Arid and Semi-arid Land
BQ	-	Bill of Quantities
BS	-	British Standard
cm	-	Centimetres
g	-	gauge
GS	-	Galvanized steel
GI	-	Galvanized iron
GL	-	Ground level
Hardcore	-	Crushed stones
HGL	-	Hydraulic Grade line
km	-	Kilometre
KVA	-	Kilo Volts Ampere
kW	-	Kilo Watt
KWSP	-	Kenya Water and Sanitation Programme
m	-	Metre
mm	-	Millimetre
m^2	-	Square metre
m^3	-	Cubic metre
MoWI	-	Ministry of Water and Irrigation
PVC	-	Poly Vinyl Conduits
RWSS	-	Rural Water Supply and Sanitation
uPVC	-	Ultra Poly Vinyl Conduits
Y8	-	8 mm twisted iron bar
Y10	-	10 mm twisted iron bar
WL	-	Water level
WSBs	-	Water Service Boards
WSP	-	Water Service Provider

Measurements and Conversions

Length 1 metre = 3.28 feet
1 km = 0.62 miles

Area	1 acre	= 4,047 m^2	= 0.4047 hectares (ha)
	1 ha	= 10,000 m^2	= 2.471 acres
	1km^2	= 100 ha	= 247.1 acres

Volume	1 litre	= 1.75 pints	= 0.22 Imp gallons (or 0.26 US galls)
	1 m^3	= 1,000 litres (l)= 220 Imp gallons (or 260 US gallons)	
	1 Imperial gallon		= 4.550 l
	1 US gallon		= 3.785 l

Weight	1 tonne	= 1,000 kg
	1 British ton	= 1,016 kg
	1 US ton	= 907 kg

Volumes and weight of materials

1 m^3 water	= 1,000 kg
1 m^3 dry soil	= 1,230 to 2,000 kg
1 m^3 compacted soil	= 2,180 kg, approximately
1 m^3 loose gravel	= 1,745 kg, approximately
1 m^3 stones	= 2,400 kg to 2,900 kg

Foreword

The concept of water availability is very crucial especially in arid and semi arid lands. It is therefore inevitable to explore sustainable water sources like shallow wells/boreholes, runoff water harvesting, sand storage dams, earth dams and pumping of water from permanent rivers. The exploitation of these water sources has cost implications, which must be considered at the design stage. That is the reason for having to choose a reasonably affordable option. When doing so, it is obvious that the water demand is high and the beneficiaries are low-income earners.

It is with these prevailing environmental conditions that many communities living in these areas of water scarcity opt for community based water projects to collectively achieve this goal of sustainable water availability. Donor funded projects usually simplify this endeavour through their support in terms of provision of cheap labour, available local materials and cost sharing.

This booklet contains some fundamental applications of water surveys and designs of piped water. The techniques and procedures of surveying and implementation of a water project including the equipment used are well discussed. Cost is revealed in bills of quantities, purchase of pipes, choice of pump, water tanks and other accessories. Economic viability and legal aspects of personnel involved are laid out for the project in this booklet while the stakeholders who are mainly the beneficiaries are also articulated. The main aim of this booklet is to raise awareness to have an overview of what it entails to have clean water at a water kiosk facility for instance and the cost implications of labour, material and equipment. The procedural techniques of surveys of the pipeline are elaborated in detail including the standard designs of the structures and recommendations of ideal scenarios.

A case study of the Mbitini Water Project has been used to explain the procedural requirements when surveying and designing a community water project. A stretch of over 12 km was surveyed, implemented and a longitudinal profile developed in which water was pumped from a river with a head of over 71 m to the highest point in the project area and stored in water tanks such that it could serve the downstream beneficiaries by gravity. Other storage tanks were strategically placed for storage and distribution to over ten water kiosks. The efforts of planning and implementing this project, if well taken into account can transform the entire arid lands from water scarcity to water security areas in Kenya.

Eng. F.K. Kyengo
Programme Coordinator
Kenya Water and Sanitation Programme (KWSP)
Ministry of Water and Irrigation
P.O. Box 49720
Nairobi, Kenya

Chapter 1. Surveys, designs and proposals

1.1 Purpose of surveys

Surveys of proposed water projects are required for several purposes, such as establishing whether a proposed water project can supply the required volume of water for its intended users (water demand), if a proposed water project is financially viable, and for writing a proposal to the Water Services Boards for financial and technical assistance.

In the past, many water projects were built without considering their financial viability and without training the project committees in financial management. The result of that policy is the many abandoned water projects all over Africa.

Surveys of proposed water projects should provide the following data:

1) The capacity of the water source, i.e. the number of people it can serve. It is important to know the volume of water that can be extracted from a water source throughout the year. Otherwise water may not reach people living towards the end of a pipeline. Also, if the construction cost is too high per unit volume of water supplied from the project, nobody may have an interest in funding the project.

2) Data for designing the structures required for constructing the water project. It is equally important to install the correct size and type of pump, pipes and tanks for the water source. If a water project is over-designed, it may not be financed because it is too expensive per unit of water it can deliver. On the other hand, if the pump, pipes and tanks are under-designed, the cost ratio will look good, but water will be wasted at the source, instead of benefiting the maximum number of people.

3) A bill of quantities (BQ) - a list of required labour and materials with their costs, for the construction of the designed structures. It is preferable to use the standard designs and their BQs presented in this handbook to avoid miscalculations.

4) The costs of operation and maintenance, also called ***recurrent costs***. These costs include fuel, spare-parts and maintenance of pumps and generators, salaries for pump/generator operators, line patrollers/repair teams, kiosk attendants, fee collectors, accountants, committee members, bank charges, etc.

   In addition to these costs, an amount of about Ksh 30,000 should be deposited in the bank account every month to cover unforeseen expenditures, such as repair or replacement of a pump or generator that the warranty does not cover.

   Also funds should be set-aside in the bank account to finance possible extensions of the pipelines. At Kisasi Water Project they say; "*Selling water is a good business and the business gets better when there are more customers*". They have therefore extended their 16 km long pipeline by an additional 6 km.

5) Cost analysis of the expenditures versus the income from sale of water that show whether the project is financially viable. Providing water is like any other business. There must be more money coming in than going out, otherwise the enterprise will go bankrupt and people will not get any water. If a cost analysis shows that a project is not economically viable, it may be difficult to obtain funding.

6) Technical and financial data for writing a proposal that can be presented to the WSB or a donor.

The cost of carrying out such a professional survey is about Ksh 2,000 per working day in addition to about Ksh 2,000 per day for hiring of equipment and allowances for transport, food and accommodation. An experienced surveyor is expected to survey 3 km of pipeline in the field in a day, including transport and meetings with the community. The approximate survey cost per km of pipeline is therefore Ksh 4,000/3 = Ksh 1,333.

The Mbitini Water Project, which is described on the next pages, has 23 km of pipeline. The working days in the field should therefore have taken 8 working days (23 km / 3 km) @ Ksh 4,000 = Ksh 32,000. The office work of transferring the field data into a Survey Report is estimated to take twice as many days as the field work, which is 16 working days costing Ksh 4,000 per day = Ksh 64,000. The total cost of the survey of Mbitini Water Project would therefore be about Ksh 96,000, say Ksh 100,000.

The cost for an engineer to work out the sizes and type of pipes, pump, generator, water tanks, water kiosks, air-valves and wash-outs using standard designs, as well as compiling all this data into a Project Document will cost about double the price of the survey, thus Ksh 200,000. A final Project Document that can be presented as a proposal to the WSB for a water project with 23 km of pipelines could therefore be about Ksh 300,000.

1.2 Brief surveys for draft proposals

It is therefore costly for a community to hire a surveyor and an engineer to carry out a complete survey with designs, BQs and costs as well as presenting and getting a proposal approved by the WSB or a donor. In fact, some proposals may never be approved and the investment in such proposals will be lost.

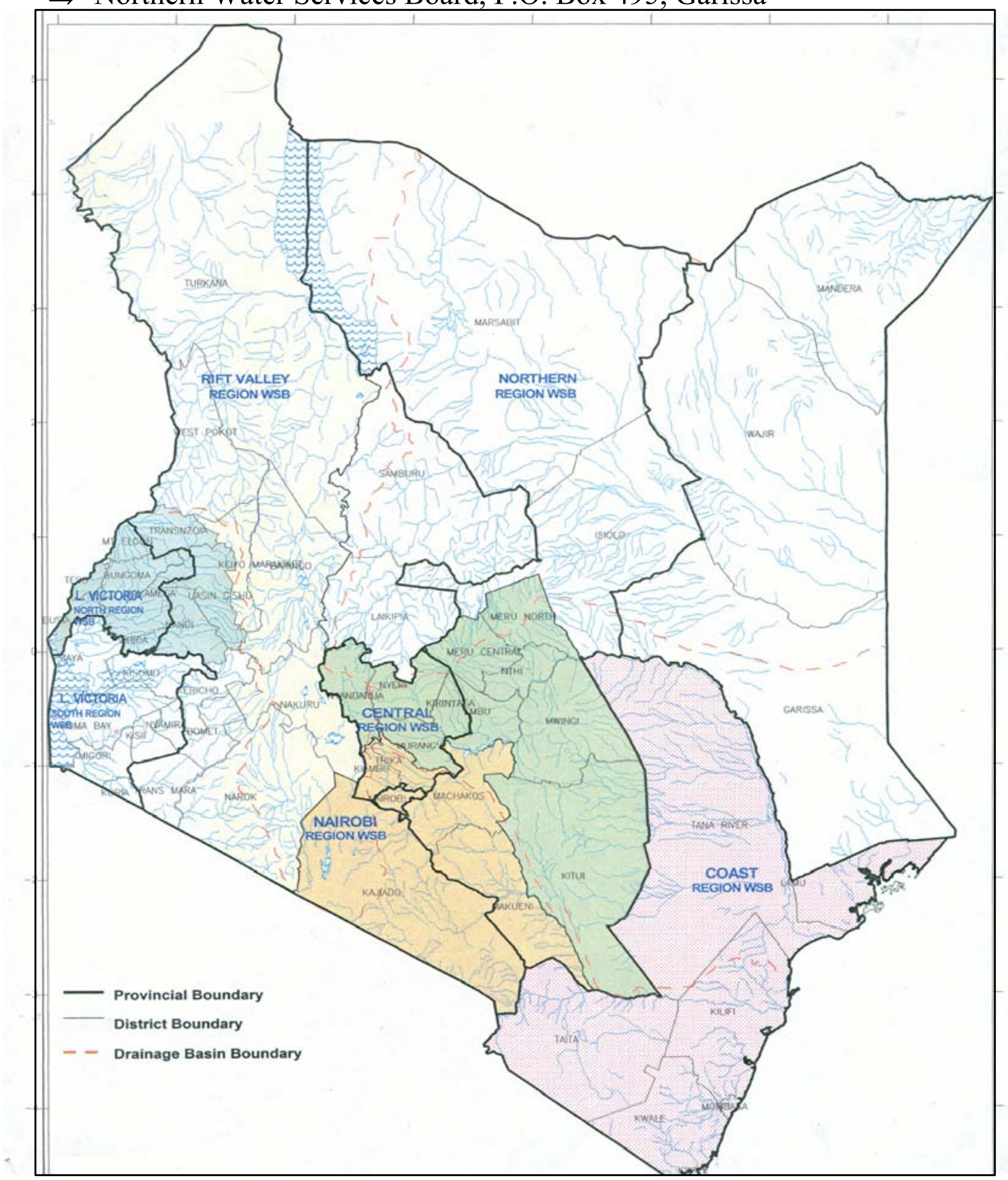
It is therefore more economical to make a brief survey and forward a draft proposal to the WSB. If the WSB is willing to finance the proposed project, they may, most likely, finance a professional survey and a Project Document as a final proposal.

A brief survey and a draft proposal can be carried out by a surveyor or an engineer who has retired or who would like to work during their vacation. Such a task would only take about ten days and cost about Ksh 40,000 in total, at Ksh 4,000 per day, or possibly less if transport, food and accommodation are provided free of charge.

1.3 Water Services Boards

There are 7 Water Services Boards (WSBs) in Kenya. Project proposals should be presented to the WSB covering the relevant project area. The WSBs addresses are:

⇒ Athi Water Services Board, P.O. Box 45283, 00100 Nairobi
⇒ Tana Water Services Board, P.O. Box 1343, Nyeri
⇒ Coast Water Services Board, P.O. Box 90417, Mombasa
⇒ Rift Valley Water Services Board, P.O. Box 220, Nakuru
⇒ Lake Victoria South Water Services Board, P.O. Box 3325, Kisumu
⇒ Lake Victoria North Water Services Board, P.O. Box 673, Kakamega
⇒ Northern Water Services Board, P.O. Box 495, Garissa

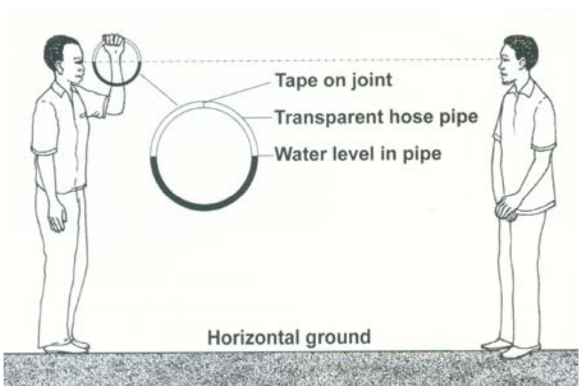


A map showing the regional WSBs in Kenya

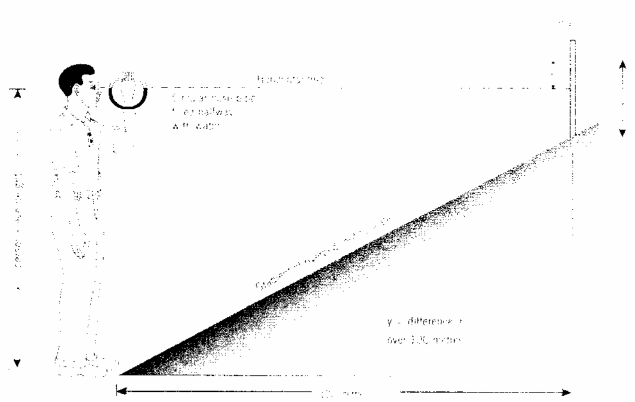
1.4 Simple equipment for brief surveys

The expensive levelling instrument shown in the next chapter can be replaced with a 1 metre length of transparent hosepipe that is bent in a circle and filled halfway with water.

When sighting along the two water levels in the hosepipe an exact horizontal line is projected forward.

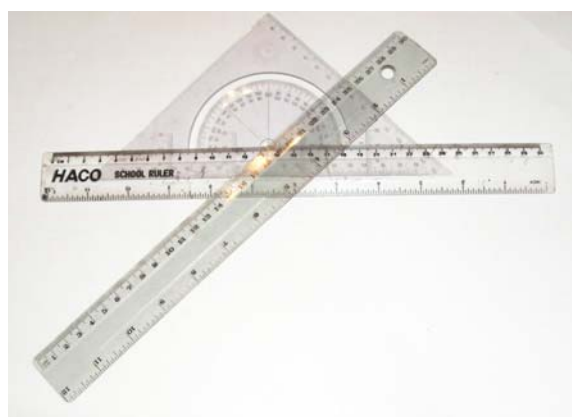


Horizontal contour lines are found by 2 persons having same eye height. Source:*Water from Ponds ,Pans and Dams* Erik Nissen-Petersen for RELMA/Sida.



Gradients are found by sighting onto a stick marked with measurements, and measuring the distance between the sticks and the person. Source: *Water from Sand Rivers* by Erik Nissen-Petersen for RELMA.

The expensive Theodolite for measuring angles can be replaced by either reading the grades on a compass, or sighting along two rulers laid onto a protractor as shown.



1.5 Guidelines for writing draft proposals

⇒ Start with the name, postal address, telephone number, sub-location, location and district of the community organisation that should be registered with the Ministry of Social Services. The proposal should be signed by the project committee that has been elected by the community.

⇒ Thereafter explain the exact location of the proposed water project with the name and distance to the three nearest villages so that the project can be plotted on a map.

⇒ Now describe the type of water project in general terms. Is it a new project, or rehabilitation or extension of an old one? Is it an earth dam, a hand-dug well, a subsurface dam, a weir, a sand dam, a rock catchment, a borehole, or gravitated water from a spring, or what is it?

⇒ Then state what the water will be used for, e.g. domestic, livestock or irrigation? Also state how much water will be required per day all year round. Can the yield of the water source supply sufficient water in demand every day of the year?

⇒ How much money will the construction work and the community training cost? Some actual construction costs of various types of structures for water projects are given on the next page.

⇒ How much of the construction and training costs can be raised by the local community for cost-sharing, in the form of local skills, local labour, locally available materials, accommodation and transport?

⇒ How is the financial viability of the proposed project?

⇒ Who has surveyed and designed the project?

⇒ Which contractor or organisation would the community prefer to assist them with the construction work and community training?

⇒ Attach the surveyor's report with sketches and the engineer's project document with designs and BQs.

1.6 Construction cost of structures built to MoWI design in Kitui in 2005 (in Ksh).

Type of structures of MoWI design of high quality and with an expected lifespan of 20 years	**Survey, designs, builders, material and transport**	**Community contribution by selling labour and materials for 50% below market price**	**Total cost of construction works, including community contribution**	**MoWI cost estimates in 2004**
A 6" x 9" x 18" concrete block	50	24	74	
A 9" x 9" x 18" concrete block	77	36	113	
A latrine slab, 122 x 122 cm	569	89	658	
A fence concrete post	478	67	545	850
A 25 cubic metre tank	214,210	76,600	290,810	337,180
A 50 cubic metre tank	331,205	99,620	430,925	444,525
A 100 cubic metre tank	627,720	190,800	818,520	719,560
An elevated 50 cubic metre steel tank	1,236,019	41,602	1,277,621	2,800,000
An elevated pump house	596,810	177,250	773,060	1,017,800
A water kiosk	93,165	25,200	118,365	99,610
A chamber for air-valve and wash-out	7,427	3,160	10,587	11,794
A rectangular trough	33,091	18,524	51,615	62,600
A circular trough	9,046	3,213	12,259	
A washing stand	18,389	8,019	26,408	
Subsurface dam of soil	68,600	35,250	103,850	1,027,000
River extraction point	159,040	53,120	212,160	993,086
Sand dam of masonry	377,200	170,850	548,050	1,027,000
Fence 150 m long	84,508	25,258	109,766	123,225
Excavating trenches, laying 6 m of UPVC pipes and back-fill	From 219 to 7,155 for 6 m	From 108 to 180 for 6 m	From 327 to 7,335 for 6 m	
Excavating trenches, laying 6 m of GI pipes and back-fill	From 813 to 12,718 for 6 m	From 132 to 204 for 6 m	From 945 to 12,922 for 6 m	
65 KVA Atlas Copco generator			1,198,220	2,170,000
Submersible Grundfoss pump, 260 m			1,009,760	550,000
100 m borehole with casing & gantry			678,100	1,753,150

1.7 Surveyor's information to communities

The first activity of a surveyor when he arrives in a proposed project area, is to have a meeting with the elders of the proposed project, who shall show him where they propose to have the extraction point of water, lines of water pipes and the required water kiosks and tapping points.

On the basis of the first field visit, the surveyor will draft a sketch showing his/her proposed plan for carrying out a detailed survey. The surveyor shall also present a quotation for his/her work on carrying out the survey and produce a Survey Report.

Public use of private land

Another advantage of carrying out surveys is that the surveyor will explain to the landowners that all those parts of their land which will be used for the pipelines, tanks and kiosks must be declared public land, so that it can be used legally by their neighbours during the construction work and, later, for drawing water.

This is a very sensitive issue for the landowners who may not be paid compensation by the community. However, the land issues must be solved, agreed upon and verified in writing by the legal authorities, before any detailed survey and construction work can be initiated.

Cost-sharing

The surveyor will also explain to the community that according to the donor or the Water Service Board, they must produce a certain percentage, usually around 15%, of the cost for survey, design and construction works as part of their cost-sharing. This contribution may be in the form of locally available skills, labour and materials. As explained in *Water for Rural Communities,* the main contractor bought skilled and unskilled labour, sand, crushed stones, hardcore and water from the community for 50% of the normal cost. The other 50% was recorded, but not paid, as their contribution to cost-sharing.

Simplified and cost-efficient designs

When a surveyor has produced his/her report on a completed survey, it must be presented and discussed during several meetings with the community that will draw water from the project. During such discussions, the community may present some good ideas on how to simplify the design, thereby reducing costs, or finance their proposals for extra extensions from the main pipeline.

1.8 Categories of surveyors

There are several categories of surveyors. The ones recommended in this handbook are experienced surveyors who are registered with the Institute of Surveyors and licensed by the Ministry of Water.

Other surveyors, who survey roads, land and plots may not be experienced in surveying water projects. Quantity Surveyors calculate Bills of Quantities (BQs), which are lists of the required man power and materials required for construction works.
Hydrogeologists and drilling firms often advertise that the drilling of a borehole will solve all water problems. The fact is that nearly all deep boreholes, except shallow ones near riverbeds, in arid and semi-arid lands (ASALs) are either dry or contain saline water unusable for domestic use and irrigation.

1.9 Satellite surveys (øget fra font 12 til font 14, som de andre)

A modern type of survey technique is being implemented by the Danish Refugee Council in Somaliland. Instead of the cumbersome fieldwork of clearing many kilometres of sighting lines through the bush and farmers' fields, they carry out surveys comfortably from their offices.

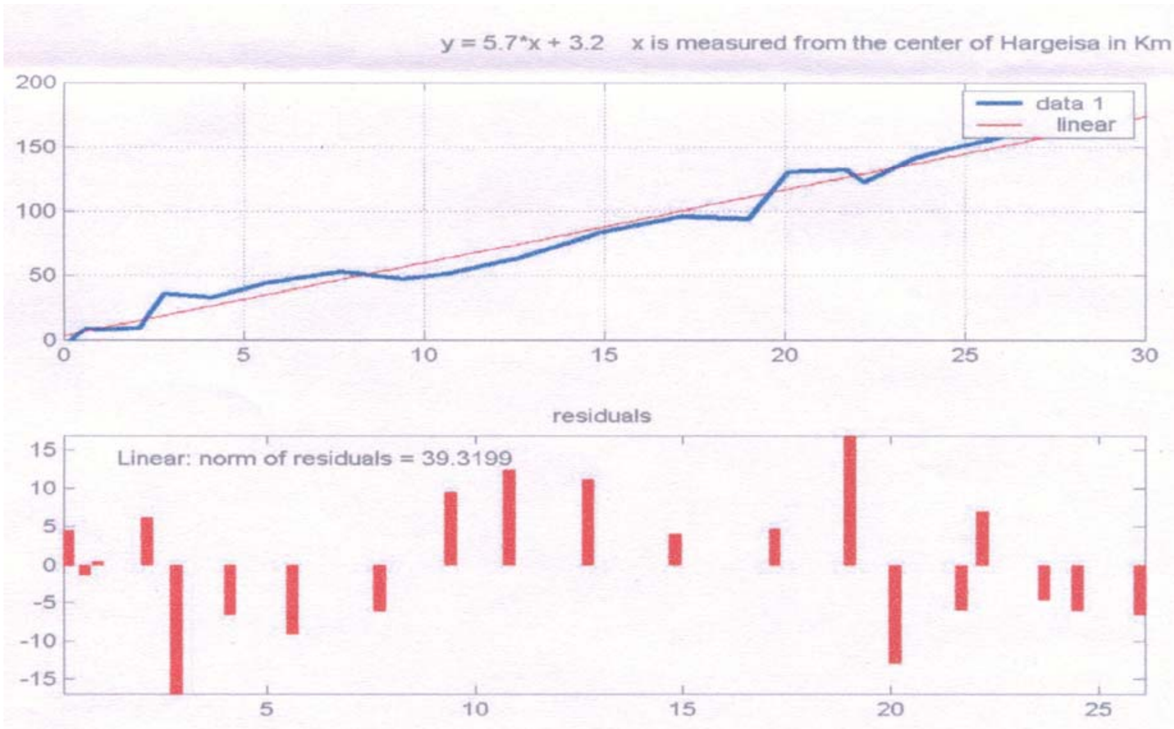
Satellite surveys are implemented by using a NASA-developed computer programme that utilises locations obtained from the Global Position System (GPS). The surveyor enters the exact GPS position of the extraction point of the proposed water project and the various points along the proposed pipeline in the computer programme (see figure below).

Data from the Digital Elevation Model

From the center of Hargeisa											
0 Km	0.6	0.9	2.1	2.8	4.1	5.6	7.7	9.4	10.8	12.7	26
1250	1258	1258	1259	1286	1283	1294	1303	1297	1302	1346	1407

GPS map and data of water project in Hargeysa, Somaliland

A few minutes later, the profile of the ground level and its linear line of the proposed pipeline can be printed out as shown below.



In the above example, the linear was found to have the norm of residuals = 39.4199.

The negative residuals head indicates that there is not enough gravitational energy to move the desired quantity of water. Hence the quantity of water will not flow.

The positive residuals head indicates that there is an excess of gravitational energy that is enough to move an even greater flow of water through the stream. If allowed to discharge freely, a positive residual head means that the gravity will try to increase the flow through the stream. As flow increases, the friction head-losses will decrease the residual head. The flow will increase until the residual head is reduced to zero.

Source: Chief Engineer - Rashed I. Guleed, Danish Refugee Council, Somaliland.

Chapter 2. Survey and design of a rising main pipeline

2.1 The project area to be surveyed

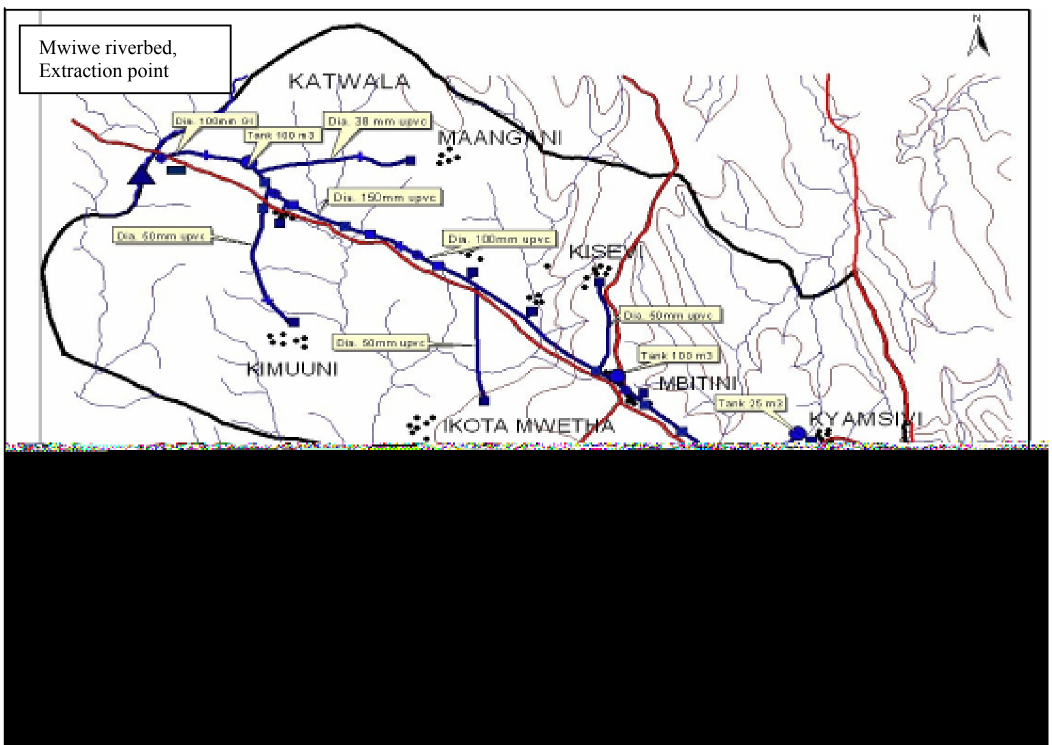
The data presented in the following chapters originates from the actual survey and implementation of the Mbitini Water Project in Kitui that was implemented by ASAL Consultants Ltd. for the Royal Danish Embassy and the Kenya Water and Sanitation Programme (KWSP) from 2004 to 2005.

First the rising main was surveyed from its starting point at Mwiwe riverbed (shown in the upper left side of the map). A100 m^3 water tank is situated at Katwala from where water is gravity-fed by a main distribution pipe to two other water tanks and 11 water kiosks.

The procedure for surveying the rising main and the calculations for determining the sizes of pipes is explained on the following pages in this chapter. Included also in this chapter is how the capacity of the pump and its power requirement was calculated.

The procedures for surveying the main gravity distribution line from the Katwala tank to the farthest water kiosk at Kivunee (shown on the lower right corner of the map) is explained in Chapter 3.

Survey and calculations for the four branches of distribution pipelines to Maangani, Kisevi, Kimuuni and Ikota Mwetha, is explained in Chapter 4.



Map showing Katwala Mbitini Water Project

2.2 A Surveyor's equipment

1) A tripod onto which a levelling instrument with telescope and a theodolite can be mounted.

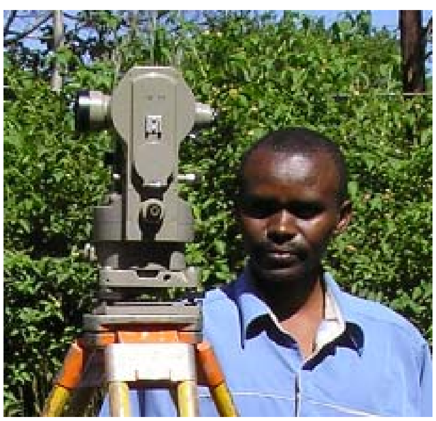
2) Ranging rods for setting out lines.

3) A Surveyor's chain or a long tape measure for measuring distances.

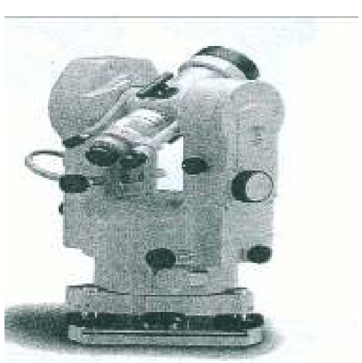
4) Chain arrows for marking distances.

5) Short iron rods for benchmarks.

6) A dumpy level with various levels and telescope (cost Ksh 61,500 including tripod).

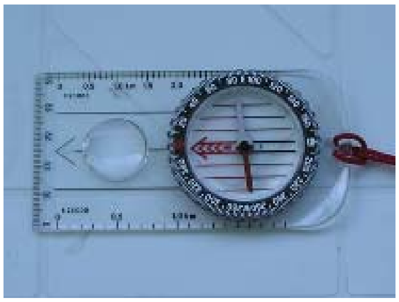


7) Theodolite for measuring angles (cost Ksh 388,500 including tripod).



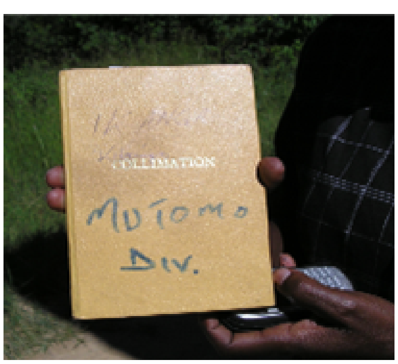
8) Alternatively, a "TM1A one second reading optical theodolite" can be used instead of the two instruments described above. This instrument costs Ksh 767,500 inclusive of a tripod.

9) An altimeter for measuring altitudes above sea level.



10) A compass for indicating the direction to North, South, East and West.

11) A collapsible levelling staff being 4 metres long for vertical measurements.



12) A notebook, called a ***level book.***

2.3 Description of survey procedures for rising mains

In this example, a short iron rod was hammered into the ground, as the bench mark, at the exact extraction point at Mwiwe riverbed, which had proved to have a sufficient supply of water to meet the water demand of 15,000 people.

The latitude (distance from equator measured in degrees) and longitude (distance east of the prime meridian measured in degrees or time) was found for the benchmark using a contour map 1:50,000. A Global Position System (GPS) instrument could also have been used to find the latitude and the longitude.

The altitude (height over the sea level measured in metres or feet) was found using the contour map. A GPS could also have been used, although they are not precise in measuring altitudes.

The exact position of the ***rising main*** pipeline, through which water would be pumped from the extraction point to the ***main storage tank*** at Katwala Village, was marked by setting out white and red coloured ranging rods according to the work plan for Mbitini Water Project. This is to define a straight line with minimal errors. A straight line is necessary to minimize friction losses that occur when water negotiates bends in a pipeline.

The community's approval of the position of the rising main pipeline was obtained once more to avoid any land disputes at a later stage.

The length and the gradient of the rising main was thereafter measured, so that the ***delivery head*** (difference in height measured in metres between the extraction point and top of the main tank) could be calculated.

The delivery head was found using a levelling instrument mounted horizontally on a tripod stand, a 30 metre long tape measure and a collapsible levelling staff well calibrated on its entire 4 metres height. Alternating red and white colours for every 10 centimetres make the figures on the levelling staff clearly visible when sighting through the instrument. This makes the figures read to have three decimals for precision.

Vertical and horizontal measurements were then taken all the way from the extraction point to the top of the proposed tank to be constructed at Katwala Village.

The usual technique for surveys is as follows:

⇒ The surveyor sets up the levelling instrument on a tripod on the line marked for the rising main at a distance of 60 metres from the bench mark. Thereafter the staff-man holds his staff vertically at the benchmark.

⇒ The surveyor turns his instrument to face the staff-man, sights through the eye piece and reads the figures on the levelling staff and notes the relevant figures in his level book. This is called a ***back-sight*** reading.

⇒ Thereafter, the staff-man moves 60 metres uphill from the surveyor on the line marked for the rising main. There he holds the staff vertically and facing the surveyor.

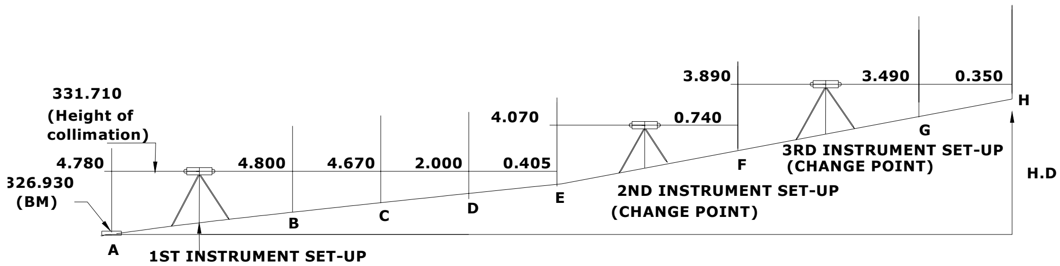
⇒ The surveyor turns his instrument towards the levelling staff and reads the relevant figures on the staff, which he notes down. This is called a ***fore- sight*** reading.

⇒ Readings of the difference in heights between a back-sight and a fore-sight reading is called an ***intermediate sight*** reading.

⇒ This procedure is repeated at some more points with intervals of 60 metres. When the staff is too far for clear reading, the surveyor decides to shift to another point along the marked line. The last reading before shifting is a fore-sight.

The surveyor sets up his instrument 60 metres from the last fore-sight, where the staff-man holds the staff vertically. The surveyor then takes a back-sight reading down the staff. Thereafter the staff-man moves 60 metres uphill from the surveyor on the marked line so that a fore-sight reading can be taken. This procedure is repeated until the whole marked line is surveyed and recorded.

This procedure is shown graphically below.



A graphical illustration of surveying with levelling instrument

From the above diagram, once a machine is set for the first reading, it is called a ***back -sight*** A.E.F. The subsequent readings until the surveyor decides to change station are called intermediates B.C.D.G. The levels are then reduced using the method described in the two booking tables shown below.

Heights of Collimation Method (Reducing levels)

B.S	I.S	F.S	H.C	R.L	REMARKS
4.780			331.710	326.930	BM (A)
	4.800			326.910	B
	4.670			327.040	C
	2.000			329.710	D
4.070		0.405	335.375	331.305	E (C.P)
3.890		0.740	338.525	334.635	F (C.P)
	3.490			335.035	G
		0.350		338.175	H

The above procedure is called the reducing method, because of the continuous subtracting of the intermediate staff readings from the height of collimation.

The height of collimation is the horizontal view/line through the machine's eyepiece. All the levels on the ground before change of the machine station are related to the collimation to get the ground level at any given point.

i) Height of collimation = Staff reading + level of point of reference.
ii) Reduced level = Collimation – Staff reading.
iii) Reduced level at change point = Reduced level of the last instrument set up plus back-sight of the new instrument set up.

Another method, called ***Rise and Fall Method***, shown below can also be used.

The Rise and Fall Method

B.S	I.S	F.S	RISE	FALL	R.L	REMARKS
4.780					326.930	BM (A)
	4.800			0.020	326.910	B
	4.670		0.130		327.040	C
	2.000		2.670		329.710	D
4.070		0.405	1.595		331.305	E (C.P)
3.890		0.740	3.330		334.635	F (C.P)
	3.490		0.400		335.035	G
		0.350	3.140		338.175	H

Reduced level = Reduced level at any particular point minus Fall or plus Rise
Rise or fall = Previous staff reading minus the next staff reading.

2.4 Technical description of surveying rising mains

Surveys described in this chapter are engineering surveys for construction of pipelines. The measurements taken are drawn to suitable scales of maps and plans that are compiled in a ***Survey Report*** that will form the basis for producing designs, bills of quantities and costs for constructing the surveyed water project.

The first inspection of the area, called a ***reconnaissance,*** is carried out some time before the actual survey to be implemented. The purposes of the reconnaissance are to:

1. Draw a sketch of the project area showing the extraction point, buildings, hedges, roads, etc.

2. Ensure that the project committee and the community have agreed and solved all land disputes on the location of the extraction point and proposed pipelines, water tanks and water kiosk sites.

3. Ensure that the committee is willing to clear paths and fields free of charge, where the surveyor and his/her chain-man will work.

4. Estimate the scope of work and type of equipment required for carrying out the survey.

After the reconnaissance has been completed, the ***preliminary work*** can be carried out. It consists of:

5. Selection of the ***main line***, which is the base line running across the area to be surveyed.

6. ***Running the survey lines***, which involve measuring the lengths of all survey lines. This is established by making straight lines between the survey stations, whereby intermediate ranging rods are placed in line with terminal points. This process will ensure that the chain lines are measured along definite paths by which unnecessary lengths and costs of water pipes will be avoided. The procedure is as follows:

   a. Place vertically, a line of ***ranging rods*** from the beginning to the end of a survey line.

   b. A ranging rod is placed between each ***chain length,*** or length of measuring tape, by sighting between the first and last ranging rods.

7. ***Chaining*** is the term for measuring lengths using either a ***surveyor's chain*** or a long tape measure. ***Chain arrows*** are short lengths of iron rods with handles that are pressed into the ground at each full length of surveyor's chain, or tape measurements.

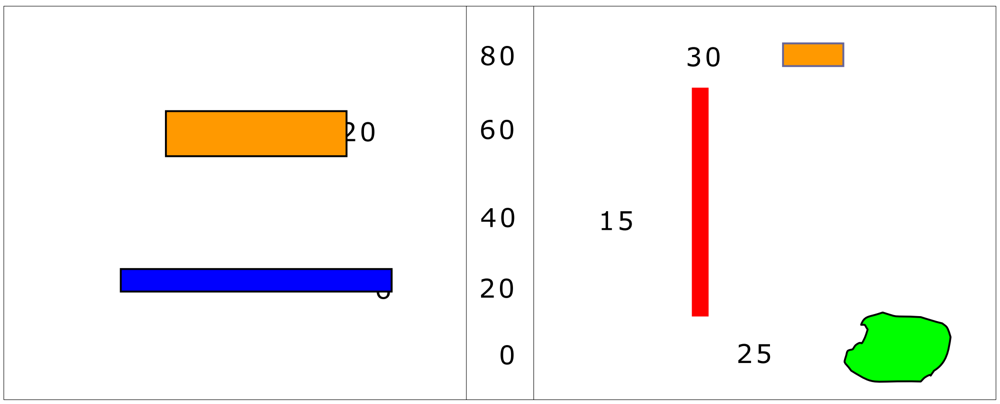
8. ***Booking a chain survey*** is the term for recording chain surveys in ***field books***. Surveys are recorded as follows:

a) Chain lines are drawn as two parallel lines in the middle of a page.

b) The start of a chain line is drawn as starting from the bottom of the page.

c) The distances between the chain lengths are marked with the distances in metres between the two parallel lines. Symbols are placed outside the parallel lines with the distance marked in metres.

An example of booking a chain survey is as follows:



The symbols above stand for the following:

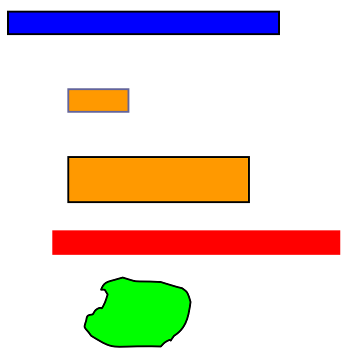
Riverbed

House

School

Road

Tree



Levelling is a process whereby the difference in height between two or more points can be determined. The purposes of levelling a project area are:

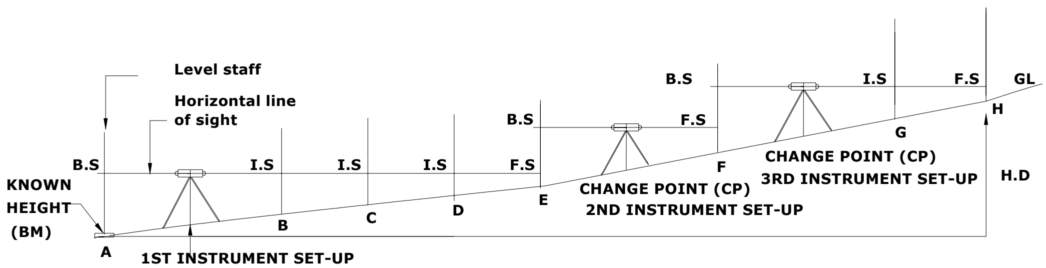
a) Assess the nature and topography of the landscape.
b) Determine the elevations of points along desired lines.
c) Determine the actual distances between points.

The equipment for levelling is:

a) Levelling instrument with telescope and dumpy, tilting and automatic levels
b) Digital or optical theodolites
c) Tripod for mounting levelling instrument and theodolite
d) Levelling staff 4 metres high
e) Level book for recording readings and calculations

Levelling procedure start with setting and temporary adjustment at an arbitrary point near the benchmark with a known height.

A ***back-sight*** reading is taken from the levelling staff, which is placed vertically on the benchmark. Thereafter the levelling staff is moved up along the line and an ***intermediate*** and ***fore-sight*** reading is taken from it with the levelling instrument. The measurements taken consist of distance and elevation between the readings as shown in the sketch below.



Key words:

Bench Mark (BM) is the enduring point for starting surveys. Surveying authorities protect benchmarks.

Temporary Bench Mark (TBM) is a temporary benchmark established to avoid continuous reference to the BM.

Reduced Level (RL) is the height of a point above or depth below a BM or a TBM that is adopted as BM.

Back-sight (BS) is the first reading made to the staff at every instrument set-up.

Fore-sight (FS) is the last reading made to the staff at every instrument set-up.

Intermediate Sights (ISs) are all other staff readings from an instrument set-up that are neither back-sight nor fore-sight.

Change Point (CP) is shifting the levelling instrument to a new station. The first reading from the new station is a fore-sight of the previous instrument station. Two readings are therefore recorded for the same staff station i.e. back-sight and fore-sight.

Height Difference (H.D) is difference in height.

Datum surface is the horizontal surface from which heights are referred.

Horizontal and level lines are at right angles with the pull of gravity. The difference between the two types of lines is that horizontal lines are at right angles with the pull of gravity at one point.

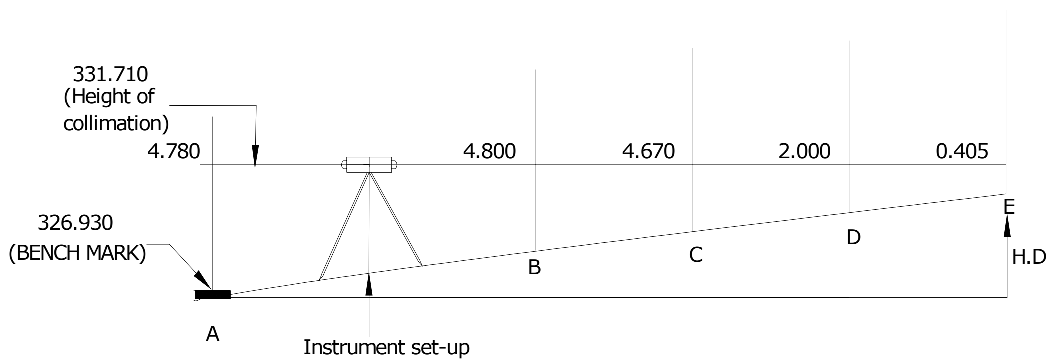
Reading, recording and reducing the levels

The surveyor reads the relevant figures on the staff through the cross hairs of the eye piece of the levelling instrument. The readings are recorded in the ***level book***. The staff readings are later reduced using the ***Height of collimation method*** that consists of:

a) Height of collimation is determined by adding the reduced level on the bench mark to the staff reading on the bench mark.

b) Height of collimation remains constant for an instrument station but changes when the instrument is moved to another station.

c) Reduced levels are obtained by height of collimation (subtract) staff readings at that instrument station. An example is shown below.



There are two methods of recording and reducing the levels, namely:

a) Height of Collimation Method

B.S	I.S	F.S	H.C	R.L	Remarks
4.780			331.710	326.930	BM (A)
	4.800			326.910	B
	4.670			327.040	C
	2.000			329.710	D
		0.405		331.305	E

Height of collimation = the reduced level at the Bench Mark plus staff reading at the Bench Mark.

Reduced level = Height of collimation minus intermediate or back-sight or fore-sight

b) Rise and fall method

B.S	I.S	F.S	Rise	Fall	R.L	Remark
4.780					326.930	BM (A)
	4.800			0.020	326.910	B
	4.670		0.130		327.040	C
	2.000		2.670		329.710	D
		0.405	1.595		331.305	E

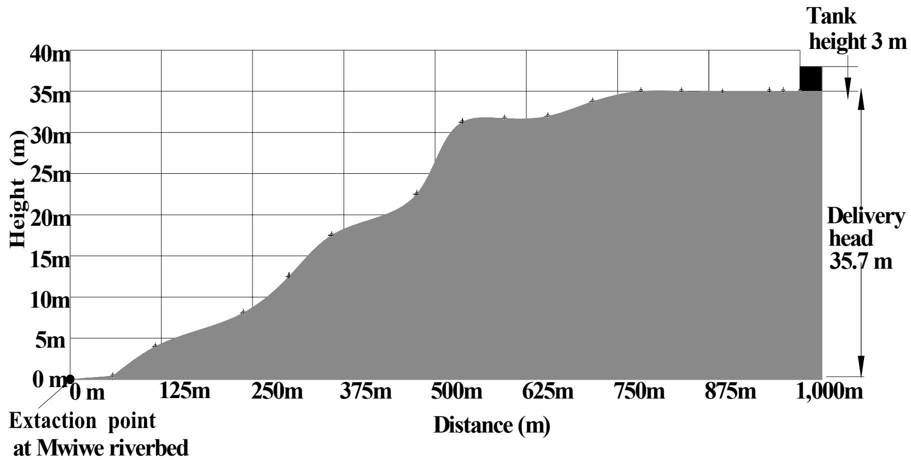
Reduced level = Reduced level at benchmark minus fall or plus rise

Rise or fall = Previous staff reading minus the next staff reading.

The actual readings taken from the extraction point at Mwiwe riverbed to the main storage tank at Katwala Village are listed below.

Date:	16th Sept. 2004			Levels for Mbitini Water Project		
From extraction point at Mwiwe river to tank at Katwala						
B.S	**I.S**	**F.S**	**H.C**	**R.L**	**Distance**	**Remarks**
4.780			331.71	326.301	0	Peg in concrete
	4.800			326.910	0	Peg in concrete
	4.670			327.040	57	
	2.000			329.710	117	
4.070		0.405	335.375	331.305		CP
3.890		0.740	338.525	334.635		CP
	3.490			335.035	237	
4.580		0.350	342.755	338.175		CP
	3.325			339.430	297	
4.420		0.240	346.935	342.515		CP
	2.68			344.255	357	
4.650		0.160	351.405	346.755		CP
	2.310			349.095	417	
4.805		0.410	355.8	350.995		CP
	1.760			354.040	477	
4.080		0.365	359.515	355.435		CP
	1.765			357.750	537	
	1.110			358.405	597	
2.450		1.160	360.805	358.355		CP Sandy
	2.315			358.490	657	soil
3.400		0.720	363.485	360.085		CP
	3.260			360.225	717	
	1.655			361.830	777	
	1.560			361.925	837	
	1.595			361.890	897	
1.660		1.530	363.615	361.955		CP
	1.555			362.060	957	
	1.600			362.015	916	Tank at Katwala
	1.710			361.905	1008	

2.5 Rising main



A graph of the rising main

The result of the survey is drawn in this graph that shows the ground profile of the rising main, that starts from the extraction point at Mwiwe riverbed (lower left corner of the graph) and rises to the proposed tank (upper right corner).

The vertical distance, called ***delivery head***, is **35.7 metres** above the extraction point. The horizontal distance, called ***length*** is **916 metres.**

Based on the survey data, the following can now be estimated:

2.6 Required size and type of pipe for the rising main.

The frictional losses in straight water pipes can be read from Cole Broke's White Charts that are contained in the Ministry of Water and Irrigation Manual – 1986 edition.

It can also be calculated using the following formula:

(i) Q = $\frac{22xD^2V}{7X4}$ **: Where V = Velocity in m/s.** This is usually assumed to be 0.8 m/s

D = Pipe size in m.

Q = Flow in m^3/s.

While **V** is assumed and **Q** is known (i.e. derived from daily water demand) then it is easy to calculate the diameter/size of the required pipe, as shown below.

After getting the pipe size, it is necessary to apply the same formula **(i)** above again, to confirm/get the actual velocity for the size of pipe selected.

Determination of pipe size

$Q = 44.3775 m^3 / day$ = Daily water demand for the Mbitini Water Project.

Assume 16 hours of pumping in the ultimate (extreme) year.

$$q = \frac{443.775}{16x3600} = 7.704x10 m^3 / s$$

$$D = \sqrt{\frac{7.704x10^{-3} x4}{3.14x0.8}} = 0.110m$$

Actual velocity of flow in m/s

$$V_{actual} = \frac{QX7X4}{22XD^2}$$

$Q = 7.704x10^{-3} m^3 / s$

D = 0.1m (100mm dia. GS pipe medium grade for the pumped rising main)

$$= \frac{7.704x10^{-3} m^3 / sx7x4}{22x0.1^2}$$

V_{actual} = 1m/s

Frictional losses for pumping line

The following formula **(ii)** is applied with reference to Cole Broke's White Charts which give the frictional loss for any particular length of pipe.

(ii) $H_{fs} = \frac{4xfxLxv^2}{2xDx9.81}$

Where:
- L - Length in m
- V - Velocity of flow in m/s
- D - Internal pipe diameter in m
- L - Distance from extraction point to the main tank 916m
- f - Frictional Coefficient
- f_{GI} - 0.011 (1 + 25/D) D = internal diameter in mm
  0.011 (1 + 25/100) = 0.01375

$$= \frac{4x0.01375x916x1^2}{2x0.1x9.81} = 25.7m$$

2.7 Required capacity of pump and generator (Genset)

Available data from the survey:

Ground level at Katwala Market	362.0 m
Ground level at intake	326.3 m
Delivery head	**35.7 m**, which is the difference in height
Residual head	**35.7+25.7+3 = 64.4 m**

Frictional losses can be found in Cole Broke's White Charts or as explained above under Section 2.6.

Delivery head	35.7 m
Frictional losses	25.7 m
Height of water tank	3.0 m
10% ***residual head***	6.4 m, which means extra height
Pumping head	**70.8 m,** the required capacity of the pump

Total pumping head, say **71.0 m**, which gives a surplus capacity of 0.2 m.

For the case of Mbitini Water Project, the amount of water to be pumped was 28 m^3/hr and the total pumping head is 71 m. The pump must therefore be capable of delivering 28 m^3/hr at a total head of 71m.

$$P = \frac{q \times Q \times H \times 2.72 \times 10^{-3}}{\eta_p \times \eta_m}.$$

Where ,

P = Pump power in kW
q = Density of water (Unity)
Q = Discharge /Flow rate in m^3/s
H = Total system head in m
$2.7x10^{-3}$ = Conversion factor
η_p = Pump efficiency
η_m = Motor efficiency

Pump power requirement

η_p = Pump efficiency and η_m = Motor efficiency is usually assumed as 30% for small pumps and 60% for big pumps. For this case we take 0.6 because it's a big pump.

In this case the calculation is:

$$P = \frac{1x28x71x2.72x10^{-3}}{0.6x0.6} = 15.05 \quad kW \quad (18.8 \quad KVA)$$

Genset should supply 30% more power to cater for losses and also avoid overloading it (i.e. 130%)

Therefore, the required power is: 18.8 x 130% = 24.4 KVA, **(≈ 25 KVA)**

The pump seen in the photo is a Grundfoss CR32-6, 11.0 kW, 3 Phase electric booster pump with a capacity of 32m^3/hr at 71 m head that was installed at the extraction point. Together with accessories and installation, the cost was Ksh 558,200 in December, 2004.

The diesel generator set that powers the Grundfoss pump is an Atlas Copco 41, KVA, QUB41. Its cost was Ksh 876,550 in December, 2004.

Chapter 3. Design, bill of quantities and cost of the rising main for Mbitini Water Project

According to the evaluation report, the extraction point in Mwiwe riverbed is required to supply 309,460 litres (309.5 m^3) of water daily at present. It is estimated that in 20 years, the demand will be 443,775 litres (443.8 m^3). The extraction point consists of three components (structures), namely a hand-dug well in the riverbank, infiltration pipes (gallery) to drain water from the riverbed into the hand-dug well, and a sand dam that will raise the level of sand and water in the riverbed.

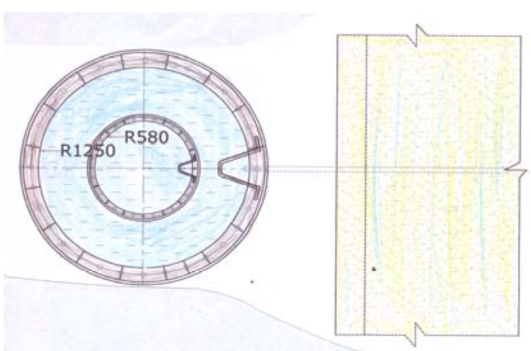
3.1 A hand-dug well

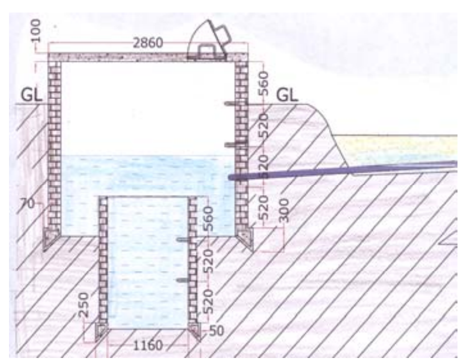
This is made of curved concrete blocks on a foundation ring with an internal diameter of 300 cm. Short lengths of insulated electric wires were bent into a "U" shape and inserted in each course of the concrete blocks for every 30 cm with the U facing inwards.

The well shaft was sunk as deep as a petrol-powered suction pump could remove the inflowing water. When the capacity of the pump was reached at about 4 metres depth, the internal diameter of the shaft was reduced to 110 cm. The well-diggers then sunk the well shaft to an additional 3 metres before the inflow of water became too much for the diggers and the pump. When the shaft had reached its final depth, the insulated bent wires were pulled out of the shaft, each wire leaving two small infiltration holes in the shafts for replenishing of the well.

The small well shaft being sunk inside the wide diameter well shaft in the riverbank

The completed well head with the pipe from the well to the pump.





Plan and section of extraction point in the riverbank of Mwiwe riverbed (mm)

Bill of quantities and cost of the hand-dug well at Mwiwe extraction point

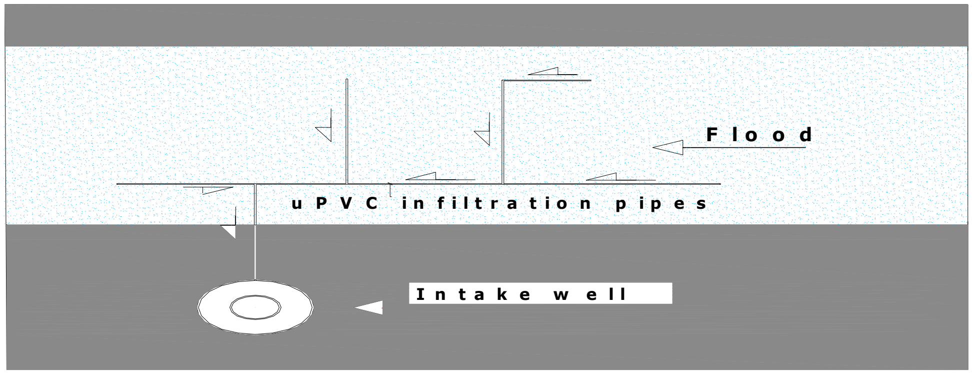
Description 8 m deep intake well	Unit	Quantity / Days	Unit cost Ksh	Total cost Ksh	Community Contribution (Ksh)
Labour cost					
1 Surveyor	Surveyor	2 days	1,200/day	2,400	
1 Supervisor	Supervisor	10 days	1,200/day	12,000	
1 Contractor	Contractor	1 x 20 days	800/day	16,000	
2 Artisans	Artisans	2 x 20 days	200/day	8,000	8,000
2 Trainees	Trainees	2 x 20 days	100/day	4,000	4,000
10 Community labourers	Labourers	10 x 20 days	100/day	Free	20,000
Cost of labour				**42,400**	**32,000**
Materials					
Cement	50 kg bags	10	600	6,000	
River sand	Tonnes	3	200	Free	600
Crushed stones	Tonnes	3	600	1,800	1,800
Curved well blocks	Blocks	700	50	35,000	14,000
Galvanised wire, 4mm	Kg	50	150	7,500	
Iron bar, Y8	40 m length	10	500	5,000	
Dewatering pump	Days	10	800	8,000	
Cost of materials				**63,300**	**16,400**
Transport of materials					
Tractor trailer loads	3 tonnes	1 load	900	900	900
Cost of transport				**900**	**900**
Cost and value				**106,600**	**49,300**
Total cost				**155,900**	

3.1 Infiltration pipes

This is to increase the recharge even further by laying 72 metres of perforated 160 mm uPVC pipes. The infiltration pipes were laid in crushed stones as deep as possible in the sand of the riverbed and with a gradient towards the intake well to enable the water to drain from the sand into the intake.

Infiltration pipe connecting to the intake.

A flooded trench for infiltration pipes.



Plan of infiltration pipes and the extraction point

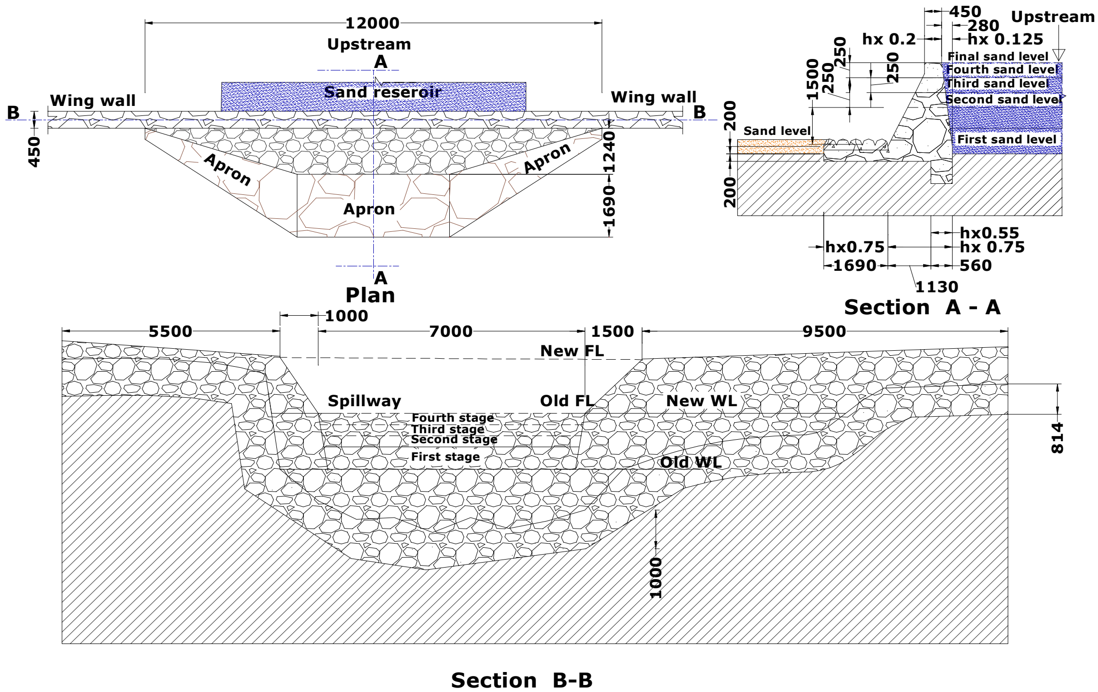
Bill of quantities and cost of 72 metres of infiltration pipe

Description	Unit	Quantity / Days	Unit cost (Ksh)	Total cost (Ksh)	Community contribution (Ksh)
Perforating and laying 72 meters of 160 mm uPVC pipe deep in a riverbed and sloping towards a well in the riverbank					
Labour					
1 Surveyor	Surveyor	4 days	1,200/day	4,800	
1 Supervisor	Supervisor	6 days	1,200/day	7,200	
1 Contractor	Contractor	1 x 15 days	800/day	12,000	
2 Artisans	Artisans	2 x 15 days	200/day	6,000	6,000
4 Trainees	Trainees	4 x 15 days	100/day	6,000	6,000
10 Community labourers	Labourers	10 x 15 days	100/day	Free	15,000
Total cost of labour				**36,000**	**27,000**
Materials					
Dewatering suction pump	8 days		800	6,400	
Perforated PVC pipes,160 mm	6 m length	14 pipes	3,048	42,672	
Cost of materials				**49,072**	
Transport of materials					
Tractor trailer loads	3 tonnes	1 load	900	900	450
Cost of transport				**900**	**450**
Cost and value				**85,972**	**27,450**
Total cost and value				**113,422**	

3.3 Sand dam

A sand dam built across the riverbed on an underground dyke situated 80 metres downstream of the extraction point (details are explained in *Water from Dry Riverbeds*). The sand dam was estimated to increase the extractable volume of water from 139 m^3 to 2,997 m^3.

Mwiwe sand dam with its spillway built to the second stage, 60 cm above the riverbed.



Plan and profiles of Mwiwe sand dam (mm)

Bill of quantities and cost of Mwiwe Sand Dam

Description A sand dam being 2 m high and 12 m long	**Unit**	**Quantity/ Days**	**Unit cost Ksh**	**Total cost Ksh**	**Value of community contribution Kshs**
Labour					
A surveyor/designer	Surveyor	10 days	1,200/day	12,000	
A supervisor	Supervisor	18 days	1,200/day	21,600	
A contractor	Contractor	1 x 42 days	800/day	33,600	
3 Artisan	Artisans	3 x 40 days	200/day	24,000	24,000
4 Trainees	Trainees	4 x 40 days	100/day	16,000	16,000
10 Community labourers	Labourers	10 x 40 days	100/day	Free	40,000
Cost of labour				**107,200**	**80,000**
Materials					
Bags of cement	50 kg bags	245	600	147,000	
River sand	Tonnes	150	200	Free	30,000
Hardcore 2" to 6"	Tonnes	120	200	24,000	24,000
Water	Oil-drum	30	100	Free	3,000
Barbed wire, 12.5g	25 kg rolls	4	3,000	12,000	
Y 8 twisted iron bars	Length (m)	30	350	10,500	
Cost of materials				**193,500**	**57,000**
Transport of materials					
Hardware lorries	7 tonne	2 loads	5,000	10,000	
Tractor trailer loads	3 tonnes	44 loads	900	39,600	19,800
Cost of transport				**49,600**	**19,800**
Cost and value				**350,300**	**156,800**
Total cost of Sand Dam				**507,100**	

Bill of quantities and cost of closing spillway

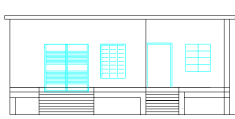
Description Closing last 3 stages of 30 cm height of spillway	Unit	Quantity / Days	Unit cost (Ksh)	Total cost (Ksh)	Community contribution (Ksh)
Labour					
A supervisor	1 Supervisor	2 days	1,200/day	2,400	
A contractor	1 Contractor	1 x 3 days	800/day	2,400	
An artisan	1 Artisan	1 x 6 days	200/day	1,200	1,200
2 Trainees	2 Trainees	2 x 6 days	100/day	1,200	1,200
10 Community labourers	10 Labourers	10 x 6 days	100/day	Free	6,000
Cost of labour				**7,200**	**8,400**
Materials					
Bags of cement	50 kg bags	20	600	12,000	
River sand	Tonnes	4	200	Free	800
Hardcore 4" to 8"	Tonnes	10	200	2,000	2,000
Water	Oil-drum	15	100	Free	1,500
Cost of materials				**14,000**	**4,300**
Transport of materials					
Hardware lorries	3 tonnes	1 load	3,000	3,000	
Tractor trailer loads	3 tonnes	3 loads	900	2,700	1,350
Cost of transport				**5,700**	**1,350**
Cost and value				**26,900**	**14,050**
Total cost of spillway				**40,950**	

Total cost of Mwiwe Sand Dam

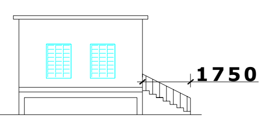
Sand dam with open spillway	350,300	156,800
Completing spillway in 3 stages	26,900	14,050
Cost and value of sand dam with spillway	**377,200**	**170,850**
Grand total of sand dam with completed spillway	**548,050**	

3.2 An elevated Pump House at Mbitini

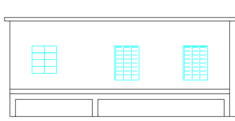
This was built a few metres from the hand-dug well at Mwiwe riverbed. The pump house was elevated to avoid flooding. The house was fenced by a 1.5 metre high chain link attached to reinforced concrete posts made on site. Access is through a lockable steel gate.



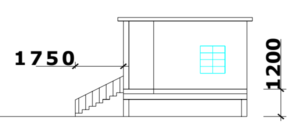
Front elevation (mm)



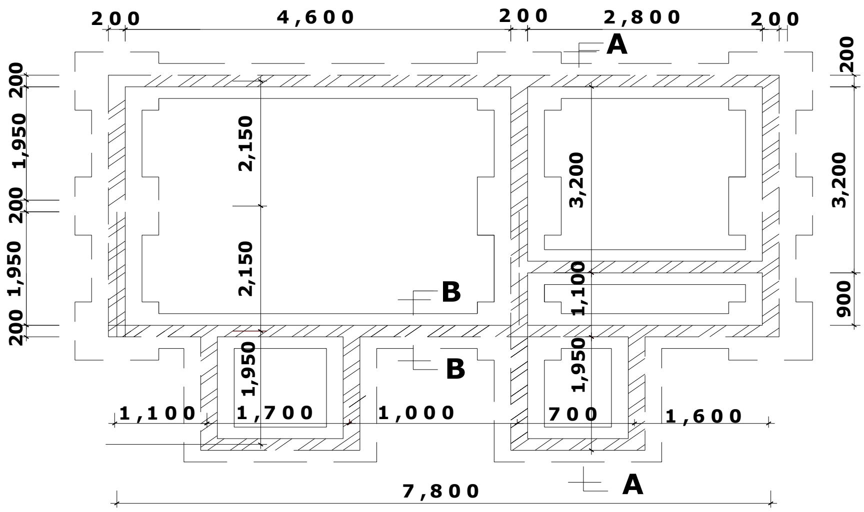
Eastern end elevation (mm)



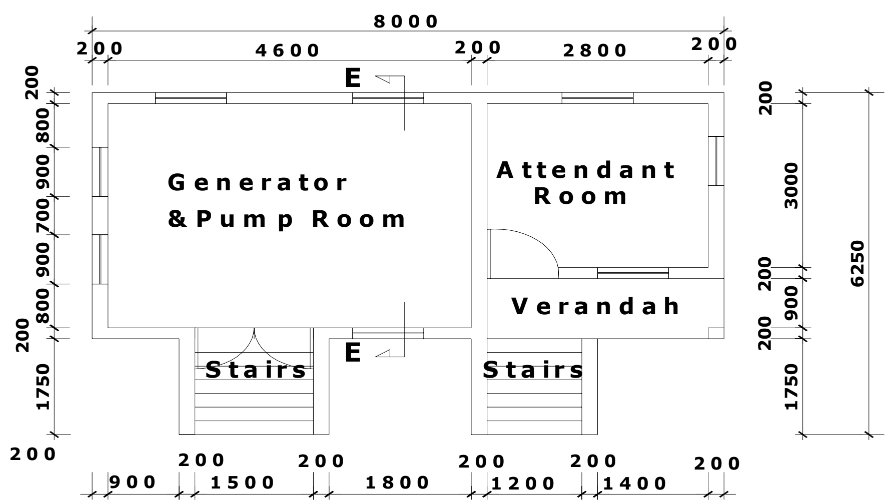
Rear elevation (mm)



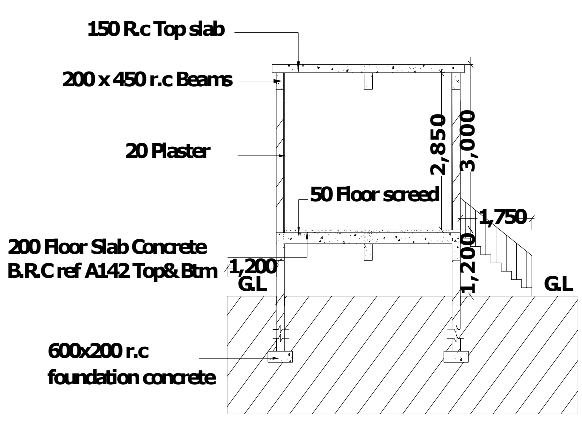
Western end elevation (mm)



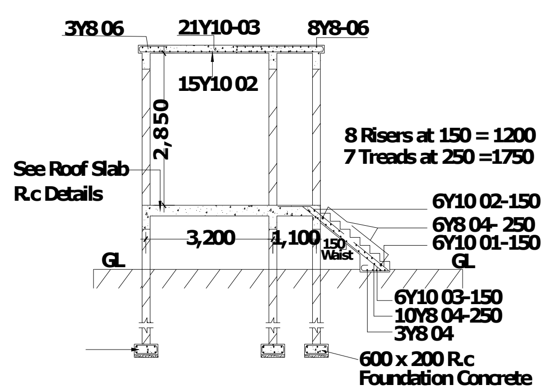
Plan of foundation layout (mm)



Plan of ground floor (mm)



Section E-E (mm)



Cross section of reinforcement (mm)

Bill of quantities and cost of the Mbitini Elevated Pump House

Description	Unit	Quantity / Days	Unit cost (Ksh)	Total cost (Ksh)	Community contribution (Ksh)
Labour					
A supervisor	Supervisor	1 x 14 days	1,200/day	16,800	
A contractor	Contractor	1 x 42 days	900/day	37,800	
6 Artisans	Artisans	6 x 40 days	200/day	48,000	48,000
10 Trainees	Trainees	10 x 40 days	100/day	40,000	40,000
10 Community labourers	Labourers	10 x 14 days	100/day	Free	14,000
Cost of labour				**142,600**	**102,000**
Materials					
Bags of cement	50 kg bags	160	600	96,000	
River sand	Tonnes	34	200	Free	3,400
Crushed stones, 1/2" to 1"	Tonnes	27	600	16,200	16,200
Concrete blocks, 6"x 9"x18"	Units	1,000	50	50,000	24,000
Water	Oil-drums	150	100	Free	15,000
Y 8 twisted iron bars	Lengths	44	350	15,400	
Y 10 twisted iron bars	Lengths	100	600	60,000	
Y 12 twisted iron bars	Lengths	38	700	26,600	
Barbed wire	25kg	4	3,000	12,000	
Binding wire, 1mm soft	Kg	40	100	4,000	
Water proof cement	Kg	6	60	360	
6" x 1" timber	Metres	434	75	32,550	
4" x 2" timber	Metres	124	75	9,300	
Poles, 2.5 meters long	Kg	400	40	16,000	
Nails, 4"	Kg	15	80	1,200	
Nails, 2 1/2"	Kg	15	80	1,200	
Nails, 3"	Kg	20	80	1,600	
Nails, 2"	Kg	15	80	1,200	
Lime	25 kg	4	400	1,600	
Bitumen paint (Rc2)	5 litres	3	500	1,500	
Turpentine	5 litres	1	200	200	
Door 210cm x 150cm	Units	1	22,000	22,000	
Steel door 210cm x 90cm	Units	1	8,000	8,000	
Windows 150cm x 90cm	Units	5	4,400	22,000	
Windows 120cm x 90cm	Units	3	3,200	9,600	
Paint (Bermuda blue)	Litres	1	1,400	1,400	
Cost of materials				**409,910**	**58,600**
Transport of materials					
Hardware lorries	7 tonnes	2 loads	5,000	10,000	
Tractor loads	3 tonnes	37 loads	900	33,300	
Cost of materials				**43,300**	**16,650**
Cost and value for elevated pump house				**595,810 773,060**	**177,250**

3.5 The rising main

The rising main from the Mbitini pump house to the main tank at Katwala Village consists of 168 lengths equal to 1.008 km of 100 mm diameter MG galvanized iron (G.I.) pipes.

The pipes were laid in a 1.008 km long trench being 40 cm wide and 60 cm deep.

The community was paid Ksh 10 for excavating 1 metre of trench and Ksh 10 for back-filling 6 metres of trenches after the pipes had been laid. A similar amount was recorded, but not paid, as that was the communities contribution towards cost-sharing.

A trench excavated for laying pipes.

Cost of the 1.008 km long rising main	**Ksh**
Cost of the pipes	1,023,456
Cost of valves and fittings	75,000
Cost of excavating the 1.008 km trench	10,080
Cost of laying pipes @ Ksh 16 per metre	16,128
Cost of backfilling the pipes @ Ksh10 per 6 metre	1,680
Cost of supervision was 15% of the community contribution (Ksh 11,760)	1,764
Cost of community contribution	11,760
Total cost of the rising main, excl. survey, design and management	1,139,868
15% for survey, design and management	170,980
Total cost of 1.008 km long rising main	**1,310,848**

3.6 The head tank

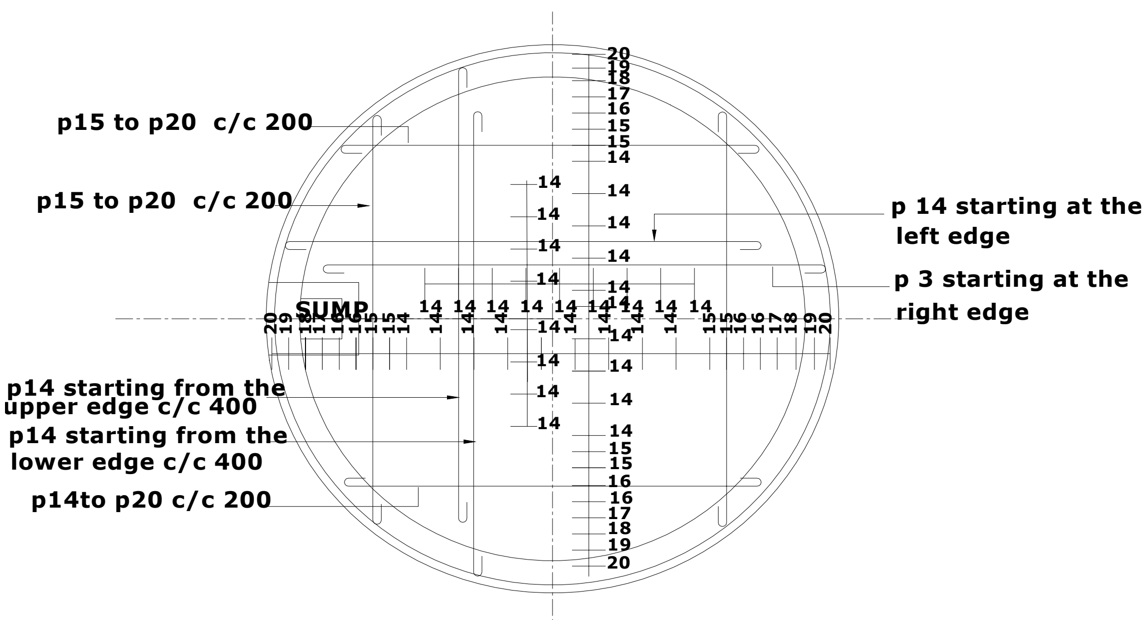
The Mbitini Water Project head tank is a 100 m^3 tank built of concrete blocks for a cost of Ksh 818,520 including the value of community contribution amounting to Ksh 190,800.

The tank is situated at a distance of 0.916 km from the Mwiwe intake and at an altitude of 35.7 m above the intake.

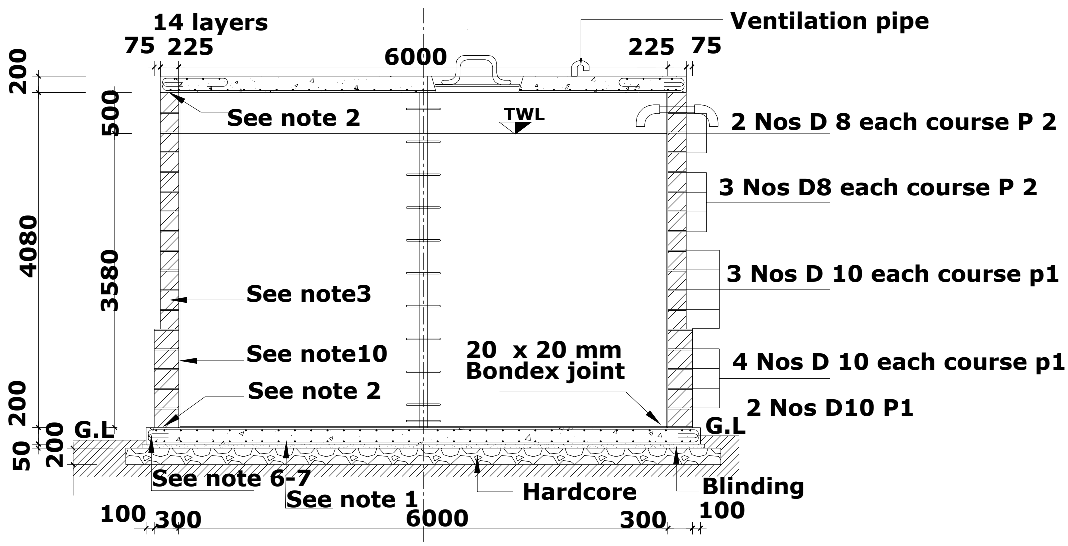
The pumping head with 100 mm G.I pipe delivering 32 m^3/hr is:

Delivery head	= 35.7 m
Frictional losses	= 25.7 m
Tank height	= 3.0 m
10% residual (extra) head	= 6.4 m
Total pumping head	**70.8 m**
Pumping head of the pump	**71.0 m**

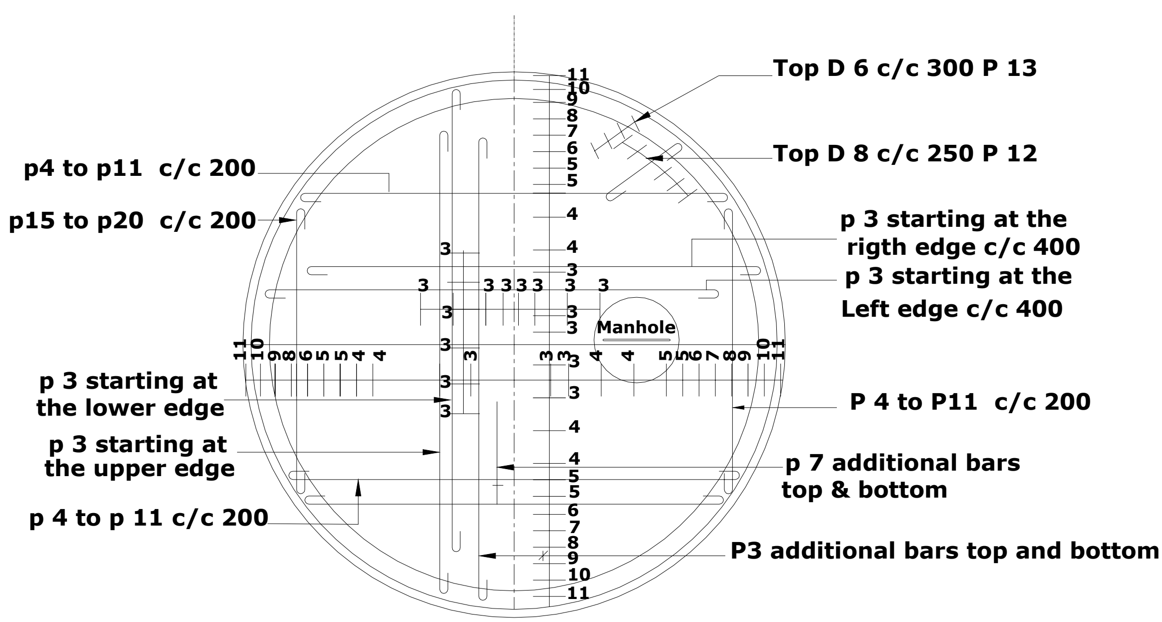
Design of the 100 m^3 main water tank for the Mbitini Water Project



Plan of floor reinforcement (mm)



Cross - section of 100 cubic metre tank (mm)



Plan of roof reinforcement (mm)

Bill of quantities and cost of the 100m^3 Mbitini Water Tank

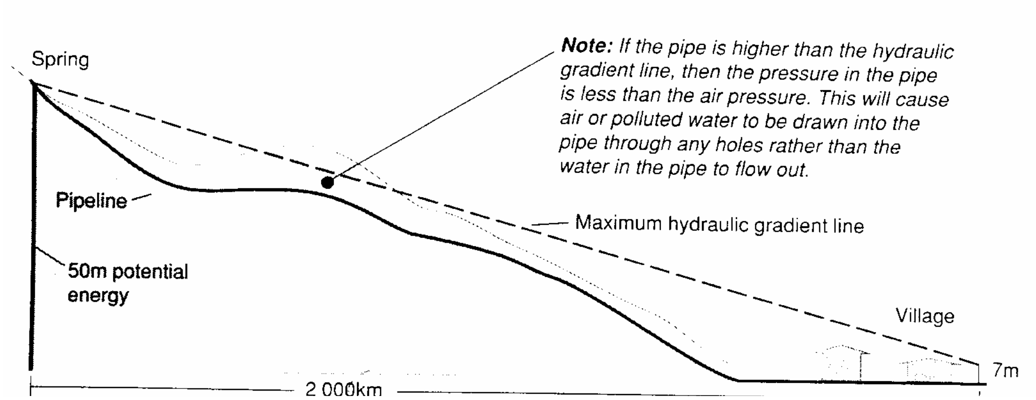
Description A 100 m^3 water tank built of concrete blocks	**Unit**	**Quantity/ Days**	**Unit cost (Ksh)**	**Total cost (Ksh)**	**Community contribution (Ksh)**
Labour					
A Supervisor	Supervisor	1 x 15 days	1,200/day	18,000	
A Contractor	Contractor	1 x 47 days	800/day	37,600	
4 Artisans	Artisans	4 x 45 days	200/day	36,000	36,000
6 Trainees	Trainees	6 x 45 days	100/day	27,000	27,000
8 Community labourers	Labourers	8 x 50 days	100/day	Free	40,000
Cost of labour				**118,600**	**103,000**
Materials					
Bags of cement	50 kg bags	190	600	114,000	
River sand	Tonnes	45	200	Free	9,000
Crushed stones, 1/2" to 1"	Tonnes	15	600	9,000	9,000
Hardcore 2" to 6"	Tonnes	30	200	6,000	6,000
Concrete blocks, 9"x 9"	Units	1,000	77	77,000	36,000
Water	Oil-drums	80	100	Free	8,000
Y 8 twisted iron bars	Lengths	180	350	63,000	
Y 12 twisted iron bars	Lengths	70	700	49,000	
Barbed wire	25kg	8	3,000	24,000	
Binding wire, 1mm soft	Kg	25	100	2,500	
Water proof cement	Kg	30	60	1,800	
6" x 1" timber	Metres	270	75	20,250	
4" x 2" timber	Metres	180	75	13,500	
8" x 1"	Metres	90	80	7,200	
Poles, 2.5 meters long	Kg	200	40	8,000	
Nails, 4"	Kg	5	80	400	
Nails, 2 1/2"	Kg	15	80	1,200	
Nails, 3"	Kg	1	80	80	
Ceiling nails	Kg	12	130	1,560	
Galvanised union 3"	Units	2	150	300	
G.I red. sockets, 4" x 3"	Units	4	800	3,200	
Gate valve 3"	Units	2	5,300	10,600	
Galvanised sockets 3"	Units	2	600	1,200	
Galvanized pipe 3"	Units	2	9,850	19,700	
uPVC bends 4"	Units	3	450	1,350	
uPVC pipe 4"	Lengths	3	4,000	12,000	
Galvanised pipe 3/4"	Units	1	1,130	1,130	
Steel manhole	Unit	1	1,400	1,400	
Lime	25kg	10	400	4,000	
Bitumen paint (Rc2)	5 litres	1.5	500	750	
Turpentine	Litres	2	200	400	
Cost of materials				**454,520**	**68,000**
Transport of materials					
Hardware lorries	7 tonnes	3 loads	5,000	15,000	
Tractor trailer loads	3 tonnes	44 loads	900	39,600	19,800
Cost of transport				**54,600**	**19,800**
Cost and value				**627,720**	**190,800**
Total cost and value				**818,520**	

Chapter 4. Main Gravity Distribution Lines

4.1 Gravity flow of water in pipes

Water flowing downhill is called ***gravity flow*** because the gravity, or weight of the water, makes it flow downwards. However, where water flows by gravity in pipes it is slowed down by friction against the inner side of the pipes.

uPVC pipes create less friction than galvanized steel (GS) pipes because they have a smoother surface. Also pipes with smaller diameter have more friction loss than larger pipes. Due to friction losses, the pressure of water flowing in pipes becomes less over distance. This is called the ***hydraulic grade line***, which is illustrated on this diagram.



Source: Bob Reed and Rod Shaw, WEDC, Loughborough University, UK.

Table 1: Energy loss in metres per metre length of pipe

Flow l/h	PIPE MATERIAL AND DIAMETER IN MILLIMETRES: POLYTHENE (HDPE) 12	HDPE 20	HDPE 25	HDPE 38	uPVC 12	uPVC 20	uPVC 25	uPVC 38	GALVANIZED IRON (GI) 12	GI 20	GI 25	GI 38	Flow l/h
500	0.18	0.01	0.00	0.00	0.21	0.01	0.00	0.00	0.28	0.02	0.00	0.00	500
1000	0.63	0.05	0.01	0.00	0.75	0.06	0.02	0.00	1.09	0.07	0.02	0.00	1000
1500	1.32	0.11	0.03	0.00	1.62	0.12	0.04	0.00	2.43	0.16	0.05	0.00	1500
2000	2.21	0.18	0.06	0.00	2.82	0.21	0.07	0.00	4.29	0.29	0.09	0.01	2000
2500	3.32	0.28	0.09	0.01	4.33	0.32	0.10	0.01	6.68	0.45	0.14	0.01	2500
3000	4.63	0.39	0.13	**0.01**	6.16	0.45	0.15	**0.01**	9.59	0.64	0.20	**0.02**	3000
3500	6.14	0.51	0.17	0.02	8.31	0.61	0.20	0.02	13.02	0.87	0.27	0.03	3500
4000	7.85	0.65	0.22	0.03	10.77	0.78	0.25	0.03	16.98	1.13	0.35	0.04	4000
4500	9.74	0.80	0.27	0.03	13.56	0.98	0.32	0.04	21.47	1.43	0.44	0.05	4500
5000	11.84	0.97	0.33	0.04	16.67	1.20	0.39	0.04	26.47	1.76	0.54	0.06	5000
5500	14.13	1.16	0.39	0.05	20.09	1.44	0.46	0.05	32.01	2.12	0.65	0.07	5500
6000	16.64	1.36	0.46	0.06	23.84	1.71	0.55	0.06	38.06	2.52	0.78	0.08	6000
6500	19.31	1.57	0.53	0.07	27.90	1.99	0.64	0.07	44.65	2.96	0.91	0.10	6500
7000	22.18	1.80	0.61	0.08	32.28	2.30	0.73	0.09	51.75	3.43	1.05	0.11	7000
7500	25.23	2.04	0.69	0.09	36.98	2.63	0.84	0.10	59.38	3.93	1.21	0.13	7500
8000	28.47	2.30	0.77	0.10	42.00	2.98	0.95	0.11	67.54	4.47	1.37	0.15	8000
8500	31.91	2.57	0.86	0.11	47.34	3.35	1.07	0.13	76.21	5.04	1.55	0.17	8500
9000	35.33	2.85	0.96	0.12	52.99	3.74	1.19	0.14	85.42	5.64	1.73	0.19	9000
9500	39.33	3.15	1.06	0.14	58.97	4.16	1.32	0.16	95.15	6.28	1.93	0.21	9500

Knowing the energy loss per metre length and the amount of water required, it is possible to calculate the most appropriate size of pipe to use as shown above. Source: Bob Reed and Rod Shaw, WEDC, Loughborough University.

4.2 Survey of Mbitini gravity distribution pipeline

As it may be remembered from Chapter 3, water will be extracted from the Mwiwe riverbed and pumped up to a main water tank situated on the highest point in the area at Katwala Market. Water will be gravitated from the Katwala water tank to the lower laying project area by a main distribution pipeline, from where 4 smaller distribution pipelines will be extended.

The starting point for the survey of the main distribution line was, naturally, the Katwala water tank, because that is the highest point. A peg was concreted into the tank site and the first measurement taken from there. The exact position of the 12 km long distribution was marked using ranging rods with intervals of 60 metres.

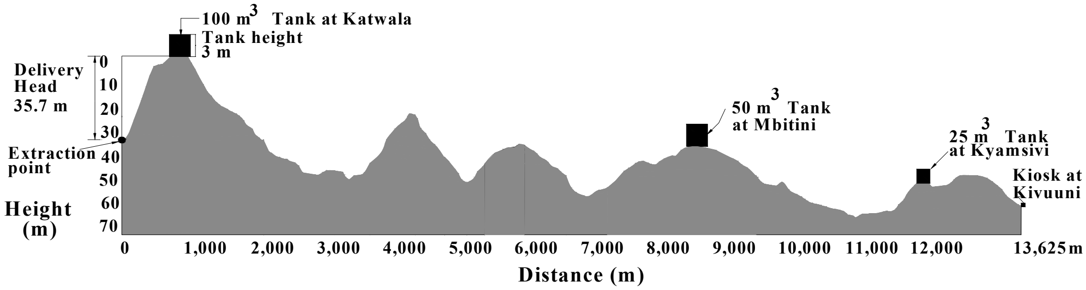
The levelling procedure started with a staffman holding the staff at the wooden peg and the surveyor setting the levelling instrument at some distance from the staff and reading the level on the staff. The staffman moved the staff 60 metres downwards along the survey line. The surveyor noted the reading from the staff. The Staffman moved at intervals of 60 metres downwards on the survey line while the surveyor shifted the level (C.P) whenever he could not sight the staff, and so on until the 12.625 km long line had been surveyed. The readings from the starting point and other interesting points were noted in the level book as follows:

Date: 16th Sept. 2004 | Levels | Taken For Mbitini Water Project

From Katwala Water Tank | | To PATTERN A

B.S	I.S	F.S	H.C	R.L	Distance metres	Remarks
1.200			363.155	361.955	0	Top of water tank
	1.270			361.885	0	Ground Level
	0.690			331.845	3135	Junction to Katiliku
	1.430			337.565	3386	Mwaani Mkt
	1.710			318.315	5400	Muluti Pri. School
	1.360			317.035	6960	Cattle dip to the left
	1.560			322.545	8000	Proposed tank site at Mbitini Pr. Sch.
	1.310			307.180	11020	Road Junction to Kanduti
	1.505			309.095	11085	GL Water Kiosk/ Proposed tank site at Kyamusivi Pr. Sch.
	0.900			299.425	12587	Kivunee Market
		0.855		299.470	12625	Last kiosk at Kivunee Market

The more than 200 readings from the gravity distribution pipeline and the readings of the rising main pipeline are shown graphically on the next page.



Graphic sketch showing the ground level of the rising main pipeline on the left side, and the gravity distribution line with two other water tanks and the last kiosk.

4.3 Hydraulic calculations on the main gravity distribution line

a) Determination of the required size and type of pipe

The pipe size was found by the following calculations:

$$D = \sqrt{\frac{Qx4}{3.14xv}} \qquad Q = 6.934X10^{-3} m^3 / s$$

$V = 0.7 m/s$ for gravity flow (Assumed velocity)

$$D = \sqrt{\frac{6.934x10^{-3}x4}{3.14x0.7}} = 0.112m$$ Hence, use of 160mm uPVC pipe

b) Actual velocity of flow in m/s

$$V_{actual} = \frac{Qx7x4}{22xD^2}$$

$$= \frac{6.934x10x10^{-3}x7x4}{22x0.1504^2}$$

$V_{actual} = 0.39 m/s$

Pressure standards according to the Design Manual of 1976, Ministry of Water Development (MoWD).

Pipe Class	Maximum Pressure (m)
B	60
C	90
D	120
E	150

Please note that:

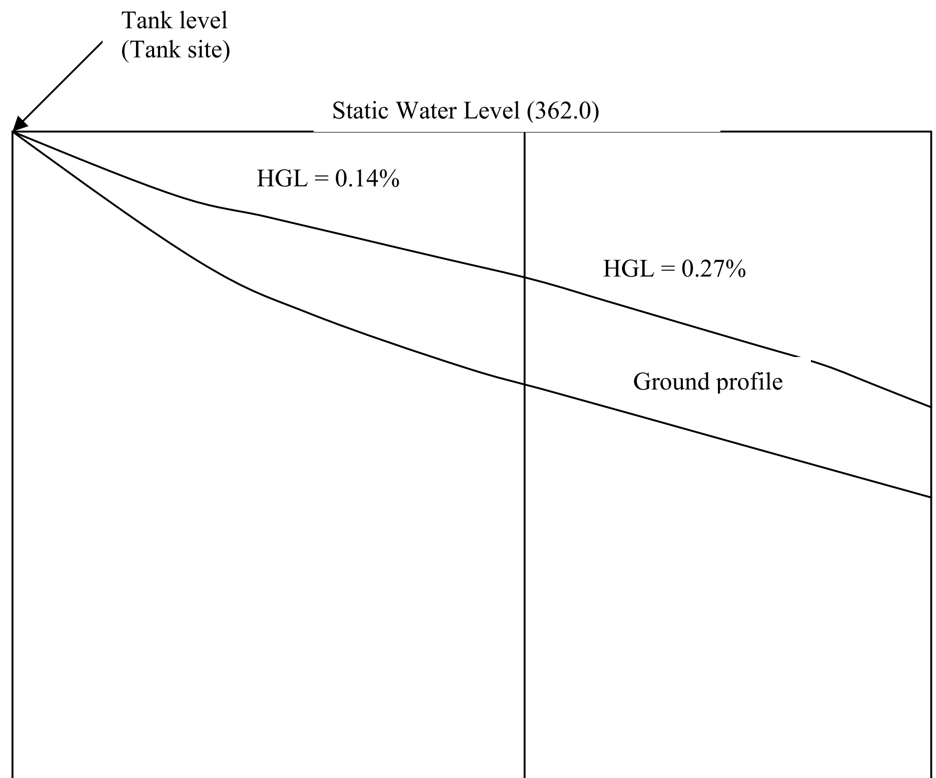
1) From Chainage 0.0 to 1920m, the soils are favourable for uPVC pipes Class B.
2) GS pipe to be used between chainage 1920m and 2040m due to river crossing.
3) Where the pressure exceeds 150m, which is the maximum pressure for Class E uPVC pipes, GS pipes should be used.
4) GS should also be used in rocky soils, even if the pressure is less than 150m.

4.4 uPVC water pressure pipes as per KS - 149, part 2:2000 (Kenyan Standard)

Nominal Outside Diameter (mm)	Outside Diameter (mm)		Wall Thickness (mm)									
	Min.	Max.	PN = 4BAR CLASS A		PN = 6BAR CLASS B		PN = 10BAR CLASS C		PN = 12.5BAR CLASS D		PN = 16BAR CLASS E	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
20	20.0	20.3	-	-	-	-	1.00	1.3	1.20	1.50	1.40	1.7
25	25.0	25.3	-	-	1.00	1.3	1.20	1.5	1.30	1.60	1.70	2.1
32	32.0	32.3	-	-	1.00	1.3	1.4	1.7	1.70	2.10	2.20	2.6
40	40.0	40.3	1.00	1.3	1.20	1.5	1.70	2.1	2.20	2.6	2.70	3.2
50	50.0	50.3	1.00	1.3	1.30	1.6	2.20	2.6	2.70	3.2	3.40	3.9
63	63.0	63.3	1.20	1.5	1.70	2.1	2.70	3.2	3.40	3.9	4.30	4.9
75	75.0	75.3	1.30	1.6	2.00	2.4	3.30	3.8	4.00	4.6	5.10	5.8
90	90.0	90.3	1.60	1.9	2.40	2.8	3.90	4.5	4.80	5.5	6.10	6.9
110	110.0	110.4	2.00	2.4	2.90	3.4	4.80	5.5	5.90	6.7	7.50	8.5
125	125.0	125.4	2.20	2.6	3.30	3.8	5.40	6.1	6.70	7.6	8.50	9.6
140	140.0	140.4	2.50	3.0	3.70	4.3	6.00	6.8	7.50	8.5	9.50	10.7
160	160.0	160.5	2.90	3.4	4.20	4.8	7.00	7.9	8.60	9.7	10.80	12.1
200	200.0	200.6	3.20	3.7	4.80	5.5	7.00	8.8	9.70	10.9	12.20	12.1
225	225.0	225.7	3.60	4.2	5.40	6.1	8.80	9.9	10.90	12.2	13.70	13.6
250	250.0	250.8	4.00	4.6	6.00	6.8	9.80	11.0	12.10	13.5	15.30	15.3

4.5 Sizes, types, friction losses and hydraulic gradient for the gravity pipeline

Chainage (M)		Pipe size (mm)	Material	Class	Frictional Losses (m)	Hydraulic Gradient %	Flow In L/S	Remarks
Head	Tail							
0	1920	160	uPVC	C	2.752	0.14	6.934	As per population distribution 10% of the water will be used in Katwala Mkt (i.e. balance = 7.704 x 10^{-3} x 90%)
1920	2040	150	GS	MG	0.318	0.27	6.934	
2040	2700	160	uPVC	C	0.924	0.14	6.934	
2700	3720	160	uPVC	C	1.300	0.13	6.241	As per population distribution 10% of the water will be used between chainage 0 & 2700 m (i.e. balance = 6.934 x 10^{-3} x 90%)
3720	4980	110	uPVC	C	8.300	0.66	5.617	As per population distribution 10% of the water will be used between chainage 2700 & 3720 m (i.e. balance = 6.241 x 10^{-3} x 90%)
4980	6180	110	uPVC	C	3.540	0.30	4.500	As per population distribution 20% of the water will be used between chainage 3720 & 4980 m (i.e. balance = 5.617 x 10^{-3} x 90%)
6180	8640	110	uPVC	C	8.490	0.35	4.050	As per population distribution 10% of the water will be used between chainage 4980 & 6180 m (i.e. balance = 4.500 x 10^{-3} x 90%)
8640	9720	90	uPVC	C	5.140	0.48	2.835	As per population distribution 30% of the water will be used between chainage 6180 & 8640 m (i.e. balance = 4.050 x 10^{-3} x 90%)
9720	10806	90	uPVC	C	2.83	0.26	2.126	As per population distribution 25% of the water will be used between chainage 8640 & 9720 m (i.e. balance = 2.835 x 10^{-3} x 90%)
10806	11427	63	uPVC	C	20.43	1.26	1.701	As per population distribution 10% of the water will be used between chainage 9720 & 10806 m (i.e. balance = 2.126 x 10^{-3} x 90%)



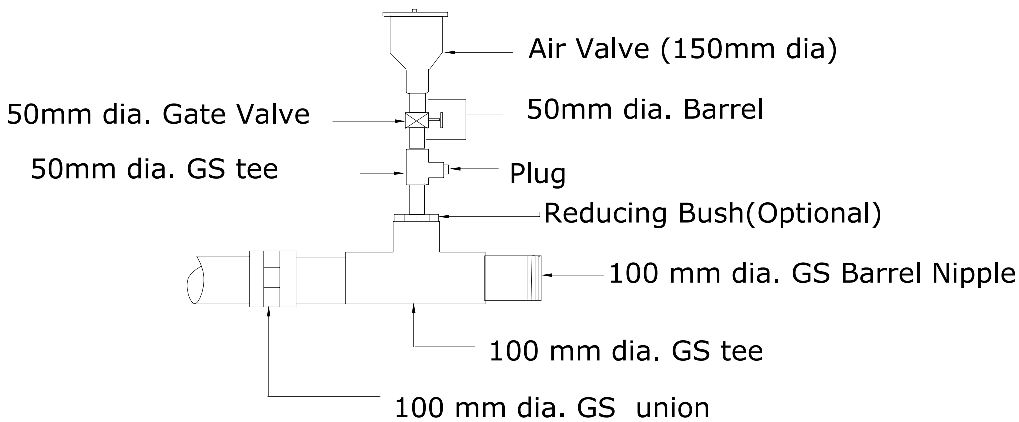
Hydraulic level (m)	362.0	359.4	359.1
Ground levels (m)	362.0	313.0	312.3
Distance (m)	0	1920.0	2040.0
Pipe details	← 160 mm diameter uPVC pipe class B →	← 150 mm dia. GS pipe Medium Grade →	

A sketch drawing showing how the details of table 4.5 are put onto paper

4.6 Air valves

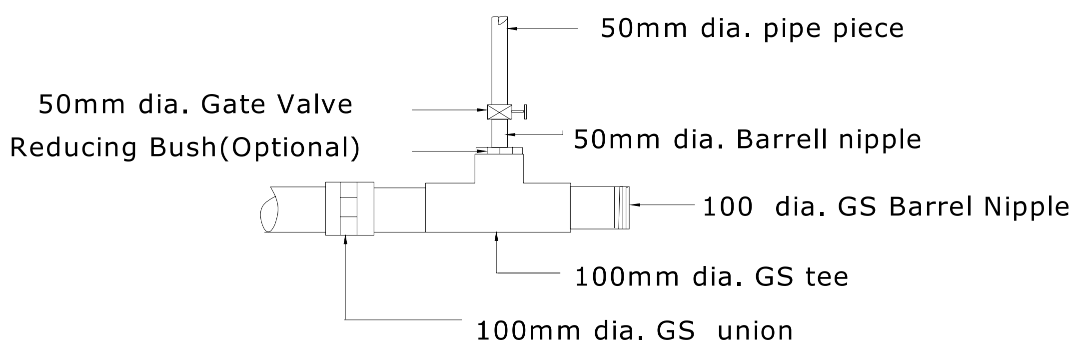
Single or double air valves with shut-off cocks were fitted onto all high points of the pipeline for the purposes of:

1. Allowing passage of air into and out of the pipeline, when charged or emptied.
2. Facilitating escape of air trapped at high points in the pipeline.
3. Preventing formation of partial vacuum during sudden pipe burst.



4.7 Wash outs

Washouts were fitted onto all low points and at the ends of the pipeline for cleaning it, as is required by the MoWI design manual.



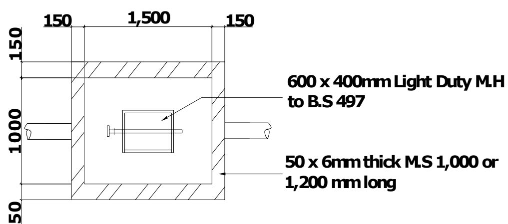
4.8 Precast concrete plates

Precast concrete plates were fixed at all sectional valves, air valves and wash outs that are marked SV, AV and WO respectively. The marker posts were provided along the main distribution line and rising main.

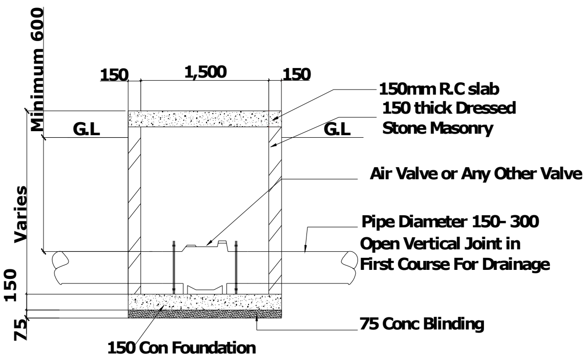
The indicator plates and marker posts were painted with at least two coats of lime (white wash) to be visible from a distance.

4.9 Valve chambers

Valve chambers were provided for all air valves, gate valves, sluice valves and wash outs.



Plan (mm)



Sectional elevation (mm)

Bill of quantities and cost of 3 valve chambers

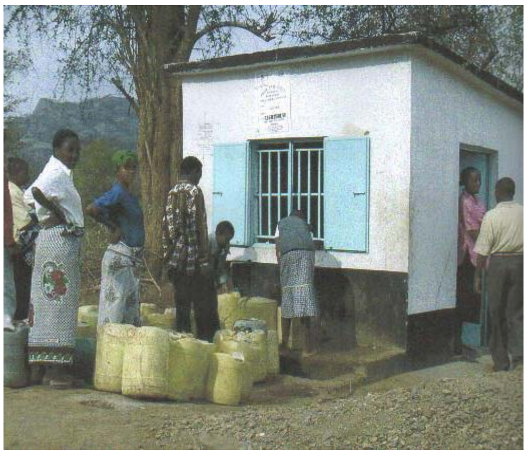
A contractor can build 3 valve chambers simultaneously with 3 teams of artisans and trainees

Description	Unit	Quantity/ Days	Unit cost Ksh	Total cost Ksh	Community contribution(Ksh)
Labour					
1 Supervisor	Supervisor	1 x 1 days	1,200/day	1,200	
1 Contractor	Contractor	1 x 2 days	800/day	1,600	
6 Artisans	Artisans	6 x 1 day	200/day	1,200	1,200
9 Trainees	Trainees	9 x 1 day	100/day	900	900
9 Community labourers	Labourers	9 x 1 day	100/day	Free	900
				4,900	**3,000**
Cost of labour					
Materials					
Bags of cement	50 kg bags	3	600	1,800	
River sand	Tonnes	1	200	Free	200
Crushed stone, 1/2" to 1"	Tonnes	1	600	600	600
Hardcore 2" to 6"	Tonnes	1	200	200	200
Concrete blocks, 6"x 9"x18"					
Water	Units	126	50	6,300	3,020
Weld mesh 8' x 4'	Oil-drums	3	100	Free	300
Handles	Sheet	1.5	360	540	
White wash	Units	6	40	240	
Cost of materials	10 Kg	1	200	200	
				9,880	**4,320**
Transport of materials					
Hardware lorries	3 tonnes	1 load	3,000	3,000	
Tractor trailer loads	3 tonnes	5 loads	900	4,500	2,250
Cost of transport				**7,500**	**2,250**
Cost of 3 valve chambers				**22,280**	**9,480**
Cost of 1 valve chamber				**7,427**	**3,160**
Total cost and value of 1 chamber for air-valves				**10,587**	

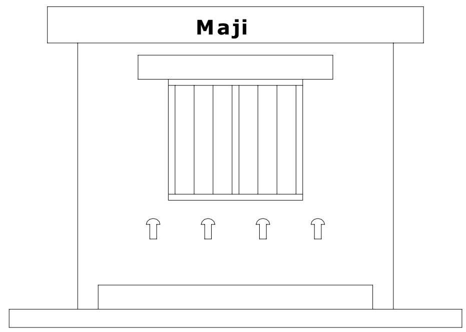
Chapter 5. Designs, Bills of Quantities and Cost of Water Kiosks, Tanks and Gravity Distribution Mains.

5.1 Water kiosk

The distance between water kiosks should be minimum 2 km and there should be a water kiosk where the pipeline passes through a market. 7 water kiosks were built along the 12 km long main gravity distribution line, while 4 water kiosks were constructed along the 10 km of minor distribution lines.

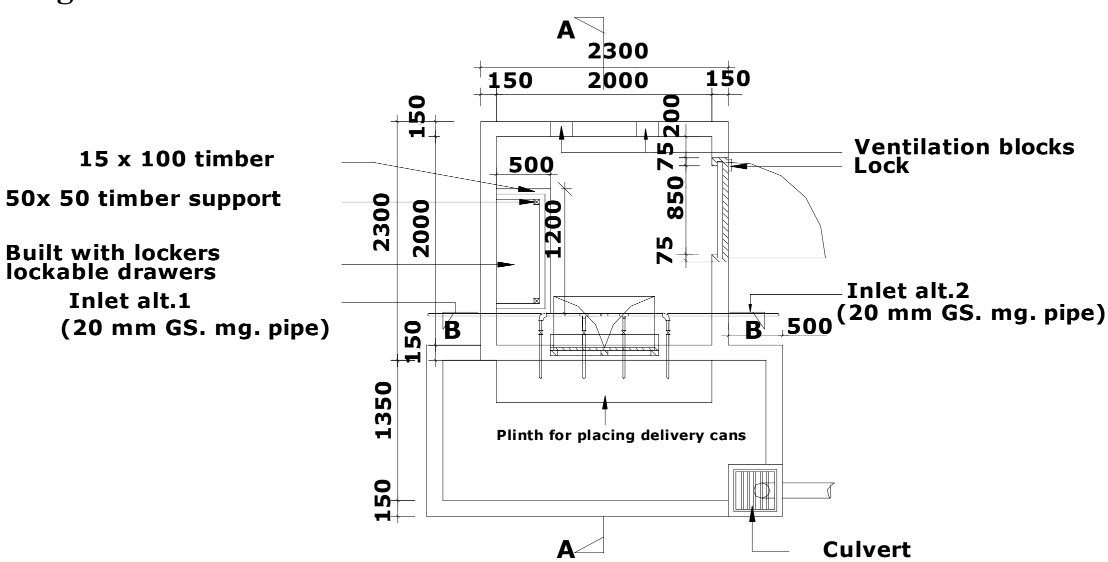


A Water Kiosk

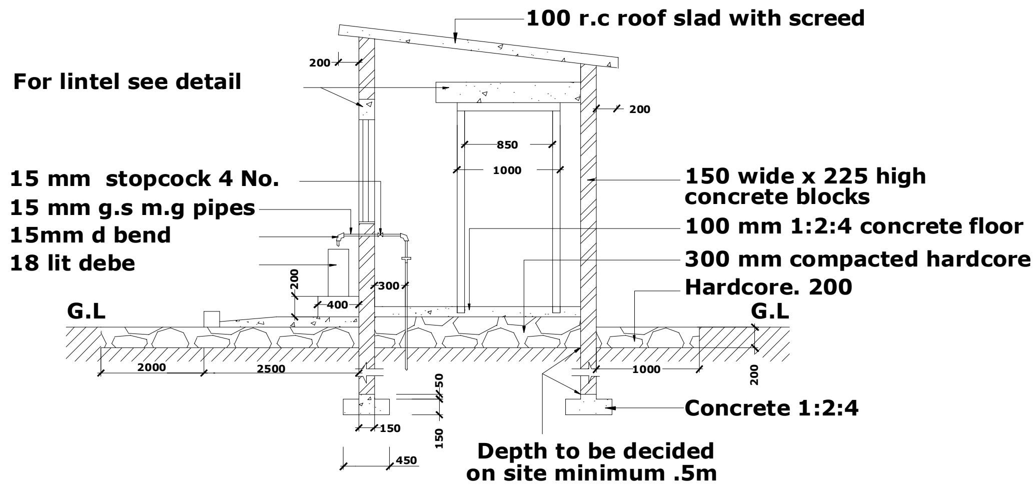


Front elevation of Water kiosk

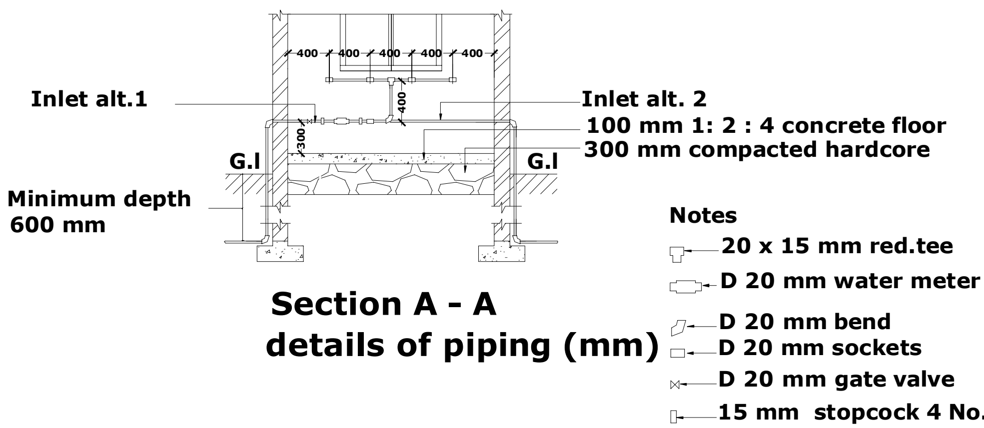
Design of a water kiosk



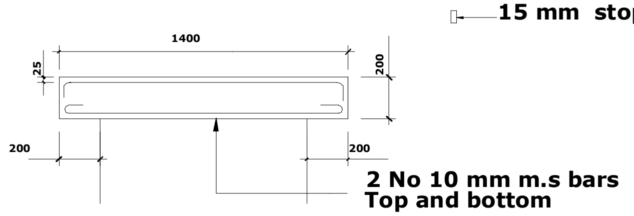
Plan of water kiosk (mm)



Section A - A (mm)

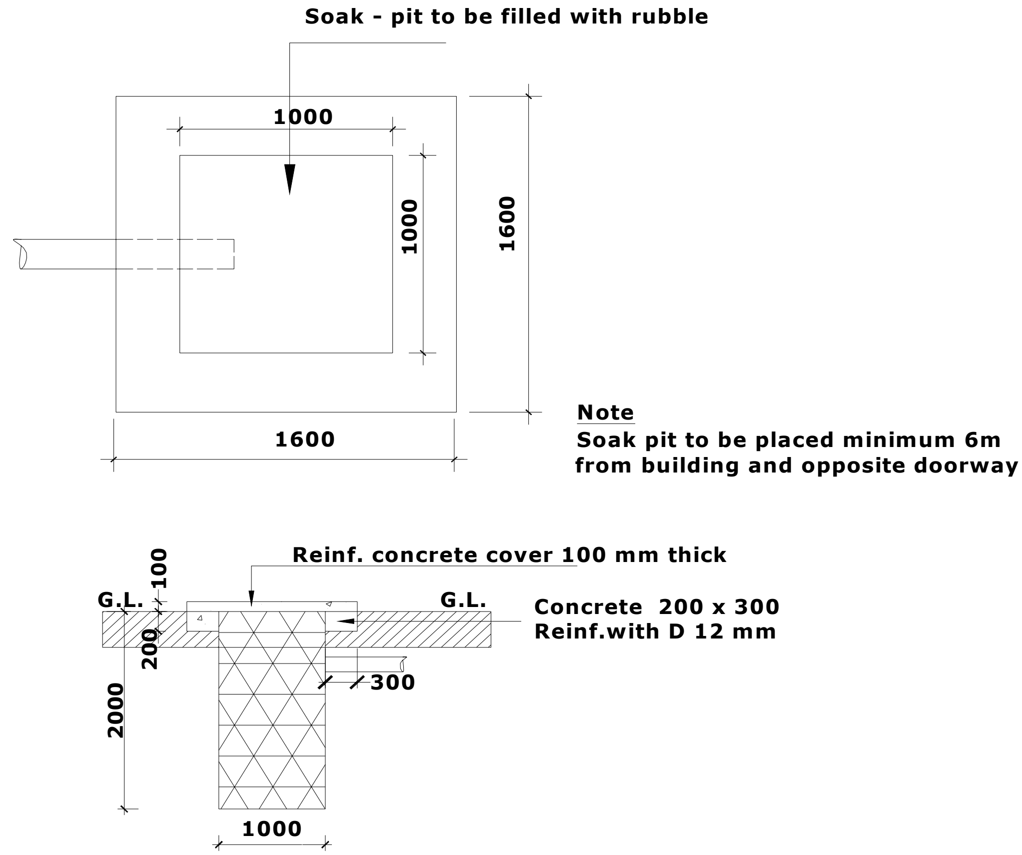


Section A - A
details of piping (mm)

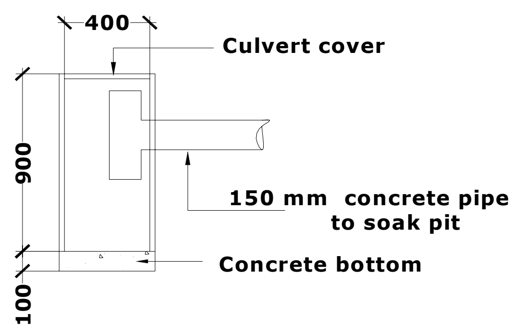


Details of a lintel (mm)

Sections of water kiosk



Details of soak-pit (mm)



Details of culvert ring (mm)

Details of water kiosk

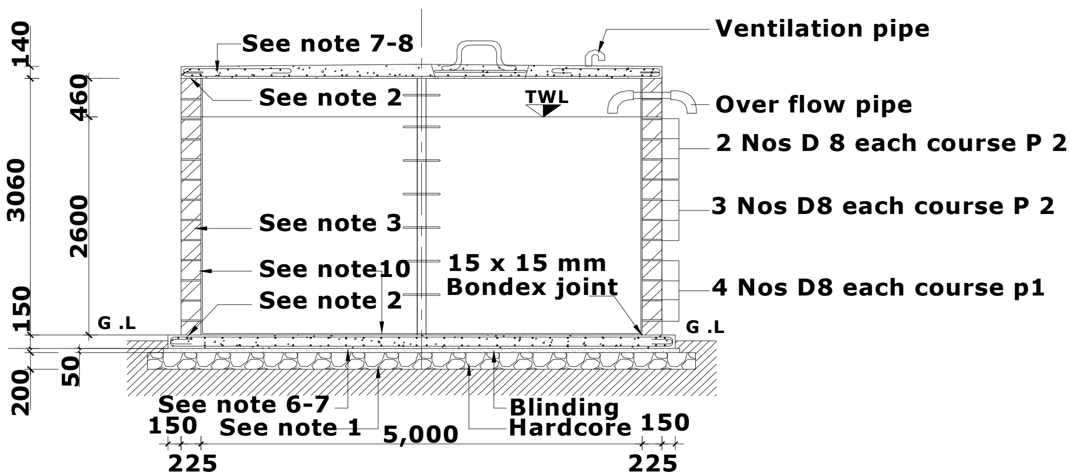
Bill of quantities and cost of 3 water kiosks

A contractor can build 3 water kiosks simultaneously with 3 teams. A team consists of 2 artisans and 4 trainees (2 males and 2 females) from the community

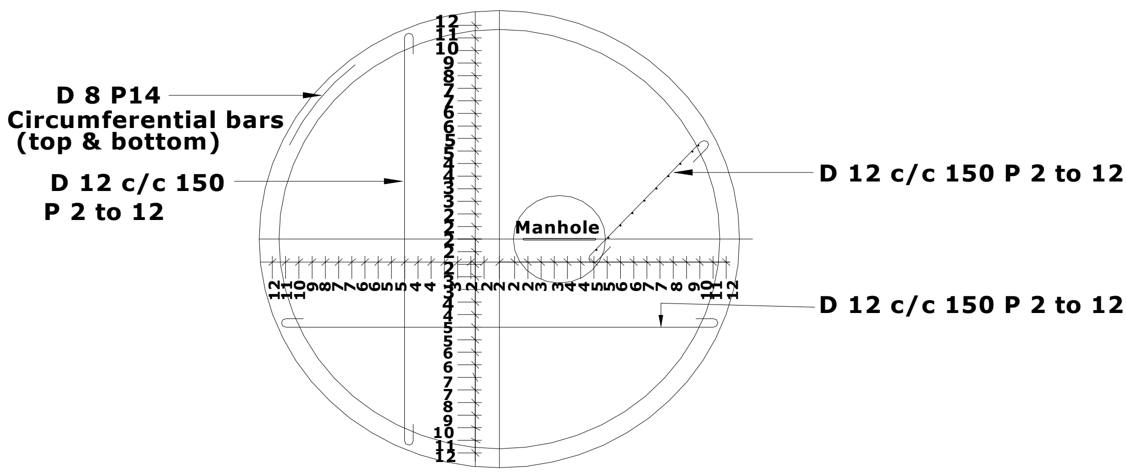
Description	Unit	Quantity/ Days	Unit cost (Ksh)	Total cost (Ksh)	Community contribution (Ksh)
Labour					
A Supervisor	Supervisor	1 x 6 days	1,200/day	7,200	
A Contractor	Contractor	1 x 20 days	800/day	16,000	
6 Artisans	Artisans	6 x 12 days	200/day	14,400	14,400
12 Trainees	Trainees	12 x 12 days	100/day	14,400	14,400
3 Community labourers	Labourers	3 x 6days	100/day	Free	1,800
Cost of labour				**52,000**	**30,600**
Materials					
Bags of cement	50 kg bags	18 x 3 = 54	600	32,400	
River sand	Tonnes	9 x 3 = 27	200	Free	5,400
Ballast, 1/2" to 1"	Tonnes	4 x 3 = 12	600	7,200	7,200
Hardcore 2" to 6"	Tonnes	6 x 3 = 18	200	3,600	3,600
Concrete blocks, 6"x 9"x18"	Units	250 x 3 = 750	50	37,500	18,000
Water	Oil-drums	15 x 3 = 45	100	Free	4,500
Y 8 twisted iron	Lengths	7 x 3 = 21	350	7,350	
Weld mesh 8' x 4'	Sheets	7 x 3 = 21	370	7,770	
Binding wire, 1mm soft	Kg	2 x 3 = 6	100	600	
6" x 1" timber	Metres	63 x 3 = 189	75	14,175	
4" x 2" timber	Metres	12 x 3 = 36	75	2,700	
Poles, 2.5 meters long	Lengths	24 x 3 = 72	40	2,880	
Nails, 4"	Kg	2 x 3 = 6	80	480	
Nails, 2 1/2"	Kg	2 x 3 = 6	80	480	
Galvanised pipe, 1"	Length	1 x 3 = 3	1,800	5,400	
Galvanised pipe, 3/4"	Length	1 x 3 = 3	1,130	3,390	
Galvanised elbows, 3/4"	Unit	7 x 3 = 21	85	1,785	
Galvanised sockets, 3/4"/1"	Unit	1 x 3 = 3	80	240	
Galvanised elbows, 1"	Unit	1 x 3 = 3	45	135	
Galvanised Tees, 3/4"	Unit	3 x 3 = 9	90	810	
Gate valve, 1"	Unit	1 x 3 = 3	575	1,725	
Gate valves, 3/4"	Unit	3 x 3 = 9	510	4,590	
Water metre, Kent	Unit	1 x 3 = 3	4,920	14,760	
Steel door, 1,830 x 910 mm	Unit	1 x 3 = 3	4,400	13,200	
Steel window, 98 x 910 mm	Unit	1 x 3 = 3	3,600	10,800	
Lime	25 kg bag	1 x 3 = 3	400	1,200	
Bitumen and oil paint	Litres	7 x 3 = 21	1,225	25,725	
Cost of materials				**200,895**	**34,200**
Transport of materials					
Hardware lorries	7 tonnes	1 load	5,000	5,000	
Tractor trailer loads	3 tonnes	24 loads	900	21,600	10,800
Total for transport				**26,600**	**10,800**
				279,495	**75,600**
Cost and value of 3 kiosks				**355,095**	
Cost and value of 1 kiosk				**118,365**	

5.2 Distribution tank

The first distribution tank for the Mbitini Water Project is a 50m[3] tank situated at Mbitini Market, 8 km from Katwala Village. It is built of concrete blocks at a cost of Ksh 430,925 with a community contribution of Ksh 99,620.

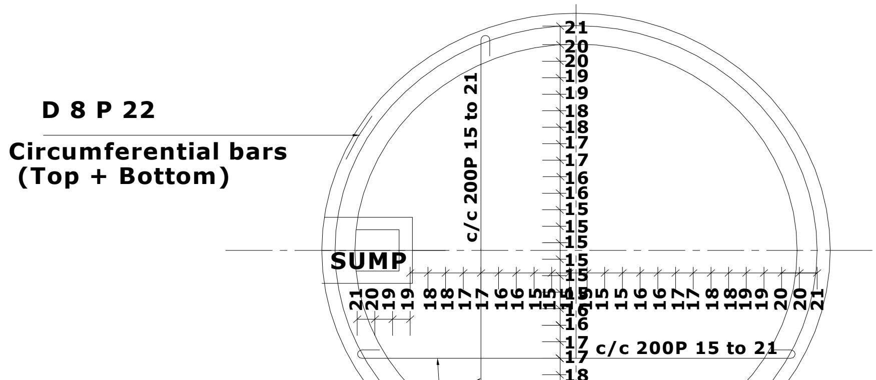


Cross-section (mm)



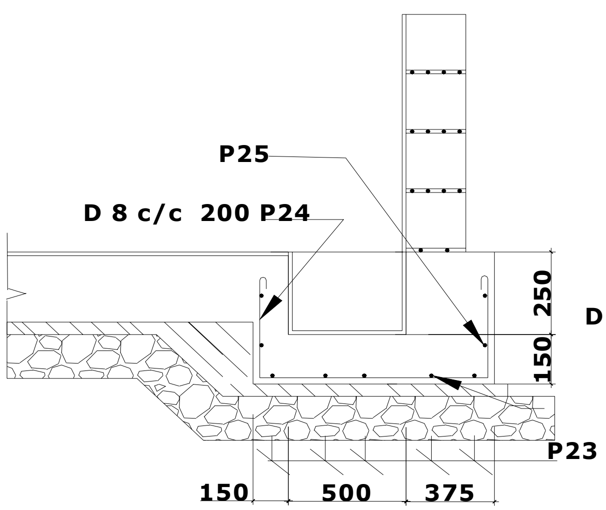
Roof reinforcement (mm)

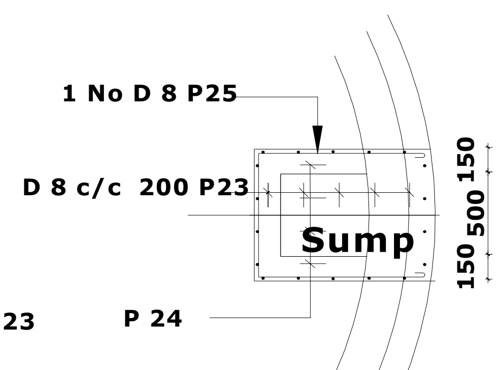
50 cubic metre storage tank



Soil conditions	normal	Black cotton
Reinforcement top	D 8	D 19
// Bottom	D 8	D 8
Soil conditions	160 mm	250

Floor reinforcement (mm)





Sump cross-section (mm) **Sump plan (mm)**

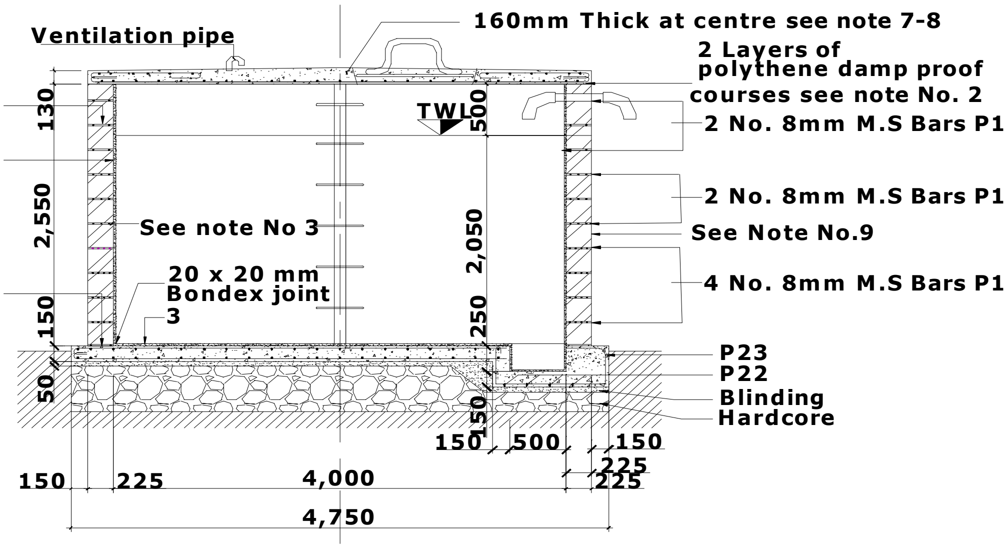
50 cubic metre storage tank

Bill of quantities cost of a 50m^3 water tank built of concrete blocks

Description	Unit	Quantity/ Days	Unit cost (Ksh)	Total cost (Ksh)	Community contribution (Ksh)
Labour					
A Supervisor	Supervisor	1 x 10 days	1,200/day	12,000	
A Contractor	Contractor	1 x 32 days	800/day	25,600	
2 Artisans	Artisans	2 x 30 days	200/day	12,000	12,000
6 Trainees	Trainees	6 x 30 days	100/day	18,000	18,000
6 Community labourers	Labourers	6 x 35 days	100/day	Free	21,000
				67,600	**51,000**
Cost of labour					
Materials					
Bags of cement	50 kg bags	80	600	48,000	
River sand	Tonnes	30	200	Free	6,000
Crushed stones, 1/2" to 1"	Tonnes	10	600	6,000	6,000
Hardcore 2" to 6"	Tonnes	15	200	3,000	3,000
Concrete blocks, 9"x 9"	Units	470	77	36,190	16,920
Water	Oil-drums	32	100	Free	3,200
Y 8 twisted iron bars	Lengths	65	350	22,750	
Y 10 twisted iron bars	Lengths	45	600	27,000	
Barbed wire	25kg	2	3,000	6,000	
Binding wire, 1mm soft	Kg	12	100	1,200	
Water proof cement	Metres	20	60	1,200	
6" x 1" timber	Metres	180	75	13,500	
4" x 2" timber	Lengths	45	75	3,375	
Poles, 2.5 metres long	Kg	100	40	4,000	
Nails, 4"	Kg	1	80	80	
Nails, 2 1/2"	Kg	4	80	320	
Nails, 3"	Kg	1	80	80	
Ceiling nails	Length	6	130	780	
Galvanised bends 4"	Length	2	1,950	3,900	
Galvanised sockets, 4"	Unit	1	1,050	1,050	
Gate valve 3"	Unit	2	5,300	10,600	
Galvanized pipe 4"	Units	2	9,850	19,700	
Upvc bends 4"	Lengths	3	450	1,350	
Upvc pipe 4"	Lengths	3	4,000	12,000	
Galvanised pipe 3/4"	Units	1	1,130	1,130	
Steel manhole	25kg	1	1,400	1,400	
Lime	5 litres	4	400	1,600	
Bitumen paint (Rc2)		1	500	500	
Cost of materials				**226,705**	**35,120**
Transport of materials					
Hardware lorries	7 tonnes	2 loads	5,000	10,000	
Tractor trailer loads	3 tonnes	30 loads	900	27,000	13,500
Cost of transport				**37,000**	**13,500**
Cost and value				**331,305**	**99,620**
Total inclusive value				**430,925**	

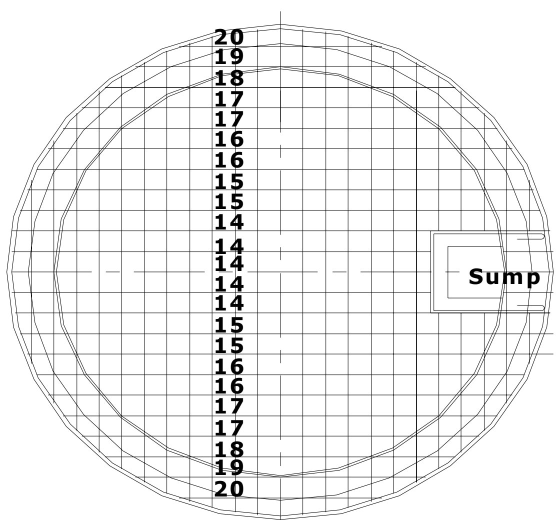
5.3 Distribution Tank 2

The second distribution tank for the Mbitini Water Project is a 25m^3 tank situated at Kyamsivi Village 11km from Katwala Village. It is built of concrete blocks at a cost of Ksh 290,810 with a community contribution of Ksh 76,600.



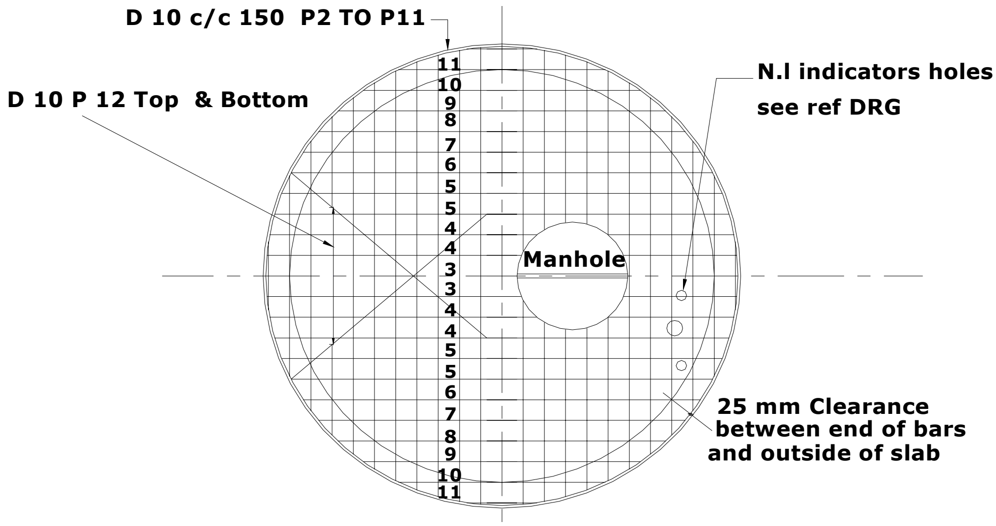
1. All mortar joints to be about 20mm think
2. 20mm Floor Finish in 2:1 sand : cement to obtain good results waterproof cement(puldlo) to be mortor
3. 20mm Floor Finish in 2:1 sand : cement to be floated smooth
4. See note No 2

Cross-section (mm)

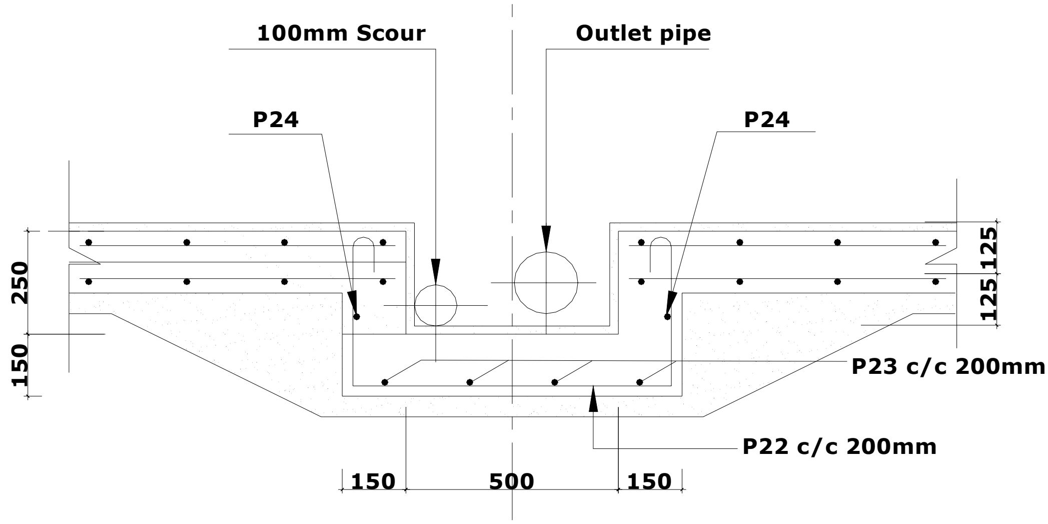


Floor reinforcement (mm)

25 cubic metre storage tank



Roof reinforcement (mm)



Section B-B (mm)

25 cubic metre storage tank

Bill of quantities and cost of 25m^3 water tank built of concrete blocks

Description	Unit	Quantity/ Days	Unit cost (Ksh)	Total cost (Ksh)	Community contribution (Ksh)
Labour					
A Supervisor	Supervisor	1 x 10 days	1,200/day	12,000	
A Contractor	Contractor	1 x 27 days	800/day	21,600	
2 Artisans	Artisans	2 x 25 days	200/day	10,000	10,000
6 Trainees	Trainees	6 x 25 days	100/day	15,000	15,000
6 Community labourers	Labourers	6 x 30 days	100/day	Free	18,000
Cost of labour				**58,600**	**43,000**
Materials					
Bags of cement	50 kg bags	50	600	30,000	
River sand	Tonnes	20	200	Free	4,000
Crushed stones, 1/2" to 1"	Tonnes	10	600	6,000	6,000
Hardcore 2" to 6"	Tonnes	9	200	1,800	1,800
Concrete blocks, 9"x 9"x18"	Units	300	77	23,100	10,800
Water	Oil-drums	20	100	Free	2,000
Y 8 twisted iron bars	Lengths	48	350	16,800	
Y 10 twisted iron bars	Lengths	13	600	7,800	
Barbed wire	25kg	1	3,000	3,000	
Binding wire, 1mm soft	Kg	7	100	700	
Water proof cement	Metres	17	60	1,020	
6" x 1" timber	Metres	110	75	8,250	
4" x 2" timber	Lengths	30	75	2,250	
Poles, 2.5 metres long	Kg	50	40	2,000	
Nails, 4"	Kg	1	80	80	
Nails, 2 1/2"	Kg	2	80	160	
Nails, 3"	Lengths	1	80	80	
Galvanised pipe, 2"	Length	2	2,500	5,000	
Galvanised elbows2"	Length	4	180	720	
Galvanised sockets, 2"	Unit	4	150	600	
Gate valve 3"	Unit	3	5,300	15,900	
Galvanised sockets	Unit	1	150	150	
Gate valve, 2"	Units	1	3,800	3,800	
Upvc bends 4"	Unit	2	450	900	
Red. sockets 3" x 2"	Units	1	200	200	
Steel manhole	Units	1	1,400	1,400	
Lime	25kg	1	400	400	
Bitumen paint	5 litres	1	500	500	
Cost of materials				**132,610**	**24,600**
Transport of materials					
Hardware lorries	7 tonnes	1 load	5,000	5,000	
Tractor trailer loads	3 tonnes	20 loads	900	18,000	9,000
Cost of transport				**23,000**	**9,000**
Total cost and value				**214,210**	**76,600**
Total cost inclusive value				**290,810**	

Technical description for 50 m^3 and 25 m^3 tanks

1. The thickness of the hardcore layers shall be determined by the engineer, but may not be less than 200mm.

2. The masonry wall shall not be connected to either the floor slab or the roof slab; the wall supporting the area of the floor slab as well as the top of the wall shall be trowel finished and be painted with three coats of bituminous paint.

3. The masonry wall shall be built of good quality local building stones or concrete blocks. The size of the stones shall be:

   Width: not less than 225mm resp. 300mm
   Length: between 200 and 300mm.
   Height: not more than 150mm.

   The stones shall be soaked in water for 24hrs before being built into the wall. Particular care must be taken to fill all the joints completely with a mortar mixture of 1:3 (cement : sand). The joints shall be 20mm.

4. Concrete class 20/20 (mixture 1:2:4) for the floor slab as well as the concrete blocks. Concrete class Q (mixture 1:3:6) for blinding.

5. Reinforcement: - Mild steel bars to BS 4449
   Minimum concrete cover of reinforcement 40mm.

6. The thickness of the floor slab of the tank must be 250mm if the tank is to be sited on black cotton soil or similar soil conditions. The reinforcement must be diam. 19mm bars c/c 200mm on the top and diam. 8mm bars c/c 200 mm on the bottom (crosswise) as per bar bending schedule.

7. Construction joints are not permitted .The slabs must be cast at one time.

8. Formwork for the roof slab must have a camber of 25mm at the centre.

9. Exterior surface of the tank shall receive one coat of cement wash.

10. Interior surface of the tank shall be plastered with a mortar mixture 1:2 (cement : sand) of 15 mm thickness. To obtain a waterproof plastering pudlo cement should be added.

5.4 The gravity distribution mains

It starts from Katwala tank to the kiosk at Kivunee and consists of the following:

- ⇒ 16 lengths equal to 96m of 150mm diameter GI pipe
- ⇒ 660 lengths equal to 3,960m of 160mm diameter uPVC pipe
- ⇒ 40 lengths equal to 240m of 100mm diameter GI pipe
- ⇒ 768 lengths equal to 4,608m of 110mm diameter uPVC pipe
- ⇒ 30 lengths equal to 180m of 80mm diameter GI pipe
- ⇒ 370 lengths equal to 2,220m of 90mm diameter uPVC pipe
- ⇒ 20 lengths equal to 120m of 50mm diameter GI pipe
- ⇒ 200 lengths equal to 1,200m of 63mm diameter uPVC pipe

2,104 lengths of pipes, which equals 12,624m of pipeline

The pipes were laid in a 12,625m long trench being 40 cm wide and 60 cm deep.

The community was paid Ksh 10 for excavating 1 metre of trench and Ksh 10 for back–filling 6 metres of trenches after the pipes had been laid. A similar amount was recorded, but not paid, as that was the community contribution towards cost- sharing.

Cost of pipe laying	Ksh
16 lengths equal to 96m of 150mm diameter GI pipe @ Ksh 18 per m	1,728
660 lengths equal to 3,960m of 160mm diameter uPVC pipe @ Ksh 14 per m	55,440
40 lengths equal to 240m of 100mm diameter GI pipe @ Ksh 16 per m	3,840
768 lengths equal to 4,608m of 110mm diameter uPVC pipe @ Ksh 12 per m	55,296
30 lengths equal to 180m of 80mm diameter GI pipe@ Ksh 14 per m	2,520
370 lengths equal to 2,220m of 90mm diameter uPVC pipe @ Ksh 10 per m	22,200
20 lengths equal to 120m of 50mm diameter GI pipe@ Ksh 12 per m	1,440
200 lengths equal to 1,200m of 63mm diameter uPVC pipe @ Ksh 8 per m	9,600
Total cost of laying pipes	**Ksh 152,064**

Cost of the 12.625 km long gravity main	Ksh
Cost of the pipes	7,000,996
Cost of the sluice valves, gate valves, air valves	231,332
Fittings (15% cost of pipes)	1,050,150
Pipe contractor for laying pipes	152,064
Excavation of 12.625 km of trench	126,250
Cost of backfilling the pipe @ Ksh 10 per 6 m	21,042
Supervision @ 15% of Ksh 147,292	22,094
Cost of community contribution	147,292
Total cost of the gravity main, excl. survey, design and management	8,751,220
15% of total cost for survey, design and management	1,312,683
Grand total for the 12.625 km long gravity main	**Kshs 10,063,903**

Chapter 6. Economic viability of Mbitini Water Project

6.1 Baseline data on Mbitini Community

As of 2004, the Mbitini Water Project served a population of 17,372 people. Water distribution was accomplished through water kiosks constructed in 13 schools and health clinics and 7 markets. During the same period, the standard of sanitation in Mbitini was generally good with 64% of homesteads having latrines, 75% of homesteads having waste pits and 50% of homesteads boiling their drinking water.

6.2 Mbitini Water Project's structures

During the period from September 2004 to June 2005 the following structures were built by the project:

- ⇒ 72 metres of infiltration pipes laid in the riverbed and connected to the hand-dug well.
- ⇒ A wide hand-dug well in the riverbed with a depth of 8 metres.
- ⇒ An elevated pump house with provision for pump operator's accommodation and fencing.
- ⇒ A Grundfoss electric booster pump with a capacity of 32 m^3 /hr of water and a pumping head of 71 m.
- ⇒ An Atlas Copco diesel generator set producing 25 KVA with 3 phase electricity.
- ⇒ 23 km of pipelines.
- ⇒ 3 water tanks with volumes of 25,000 litres and two of 100,000 litres.
- ⇒ 11 water kiosks

6.3 Mbitini Water Project's Costs

The costs incurred in the Mbitini Water Project included training, survey and design, construction materials and transport and communication as shown below.

Description of Activity	Cost in Kshs
Survey, design and supervision by District Water Officer	416,000
Local subcontractors	1,368,192
Local artisans and labourers; paid 50% of their normal fee	625,220
Local artisans and labourers; recorded but not paid 50% for cost-sharing	625,220
Local materials bought for 50% of normal cost	220,315
Community contribution of local materials as part of cost-sharing	220,315
Hardware materials (pump and generator)	14,294,974
Transport and communication	1,101,329
Savings on hiring local tractors instead of lorries	275,333
Savings on reduced training allowance	109,087
Committee training	436,348
Contractor training	752,965
Value of 12 free accommodation and stores @ Ksh 200 x 300 days	720,000
Administration and supervision	1,068,301
Total Project Cost	**22,233,599**

The total savings recorded as cost sharing amounted to Ksh 1,949,955, which is 9% of the total project cost.

The total cost of the project was Ksh 22,233,599. The cost per person is found by dividing the total cost by the 17,372 beneficiaries = **Ksh 1,279.85 per person.**

6.4 Income from water sales

In the Mbitini Water Project, the monthly water sales were recorded in jerry cans or as individual water connections. Given here below is the average monthly income for the months of January and February 2006:

Type of water sale	Monthly income (Kshs)
Total sale of water, at Ksh 4 per jerry can of 20 litres capacity	87,977
Individual water connections	4,400
Average monthly income	**92,377**

6.5 Recurrent monthly expenditure

Recurrent monthly expenditure during the months of January and February 2006 went to wages, allowances, spares, stationery, repairs etc.

Monthly expenditure	Amount (Kshs)
Wages	29,500
Allowances	11,400
Spares, stationeries, repairs etc	4,093
Bank deposit for repairs and maintenance	17,500
Average monthly expenditure	**62,493**

6.6 Monthly income, expenditure and balance

Monthly income or expenditure	Amount (Kshs)
Average monthly income from water sales	92,377
Average monthly expenditure	62,493
Average monthly net balance	29,884

Chapter 7. Legal requirements for Professional Personnel

7.1 Registered Engineers

The following are the legal requirements for the registration of graduate engineers with the Engineers Registration Board (ERB):

⇒ Certified degree certificate.
⇒ 4 years of post graduate experience.
⇒ Registration form fee of Ksh 500.
⇒ Form submission fee of Ksh 1,000.
⇒ Personal booking of exam and payment of exam fee.

The ERB pre-qualification exam is both theoretical and oral. On meeting the above requirements and passing the exam, the applicant becomes a Registered Engineer and is thereafter allowed to use the title of Engineer (abbreviated as Eng.) when certifying drawings or documents. The annual membership fee to the Engineers Registration Board is Ksh 2,000.

The Engineers Registration Board offices are located along Ngong Road in the 2nd Floor of the Kenya Building Research Centre - next to Transcom House.

7.2 Registered Architects and Quantity Surveyors

The following are the legal requirements for the registration of Architects and Quantity Surveyors by their Registration Board:

⇒ Certified degree certificate.
⇒ At least 18 months of post graduation experience. Must show evidence of working under supervision of a registered member of the Board.
⇒ Certified copy of identification card.
⇒ Two letters from two referees who must be registered members of the Board.
⇒ Application of Ksh 500 and examination fees of Ksh 15,000

The registration for the exam is done annually during the period of 1st February to1st April and the examination is done in September/October of every year. On passing the exam, the applicant then becomes a Registered Architect or Quantity Surveyor. The annual membership fee payable to the Board is Ksh 2,500.

The Architects and Quantity Surveyors Board's offices are located along Ngong Road in the Ground Floor of the Kenya Building Research Centre - next to Transcom House.

7.3 Registered Surveyors

For an applicant to be registered as a surveyor with the Kenya Institute of Surveyors, the legal requirements are as follows:

⇒ Certified degree certificate in Surveying.
⇒ Surveying experience after graduation.
⇒ Pay the application and examination fees.
⇒ Pass the registration exam.

If the above requirements are met, then the applicant becomes a Registered Surveyor.

7.4 Registered Contractors

The registration of contractors is done with the Secretariat of the Contractors Board. Before registration, the contractor is expected to satisfy the following requirements:

⇒ Certificate of incorporation of a limited company or registration of business firm.
⇒ Tax compliance certificate.
⇒ Compliance with NSSF.
⇒ Audited accounts of company or business firm.

The process of registration with the Contractors Board requires that a contractor pay Ksh 3,000 to obtain an application form. When filling the form, the following information on the company or business firm is required:

⇒ Successful experiences and past performance in execution of a project of varying complexity.
⇒ Current projects being undertaken.
⇒ Financial status (capability) of the firm.
⇒ Firm employees of whom three of them must be professionals and one must be a partner in the business firm.

A file is opened for the contractor soon after submission of the completed form. Usually a member of the Board verifies the information given in the form. The company/firm profile determines the category of the company/firm. The categorization falls in eight classes i.e. A to H. The classes are such that Class A is excellent and can handle any project or job; B-F classes are satisfactory while F-H classes are lowly rated implying that they rarely get jobs and if they do then they are small jobs. After classification, the contractor is given a certificate of registration.

The offices for the Contractors Board are located along Ngong Road in the Ministry of Roads and Public Works and Ministry of Water and Irrigation Buildings.

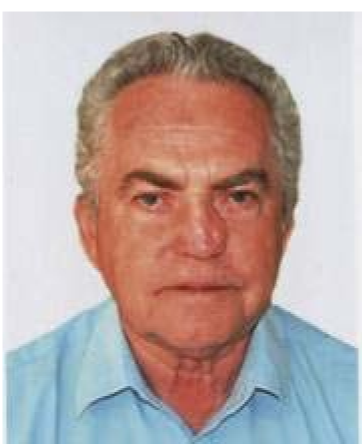
Catherine Wangui Wanjihia was born in Nakuru District, Rift Valley Province in Kenya in 1980. Her primary education took place from 1986 to 1993. The secondary education was from 1994 to 1997. From 2000 to 2003 she was studying Civil Engineering at Kenya Polytechnic in Nairobi.

Catherine worked on construction of Danida-funded water projects in most arid parts of Taita-Taveta and Kitui for ASAL Consultants Ltd. and the Ministry of Water and Irrigation from May 2004 to March 2006.

This handbook describes in details one of the six water projects which were surveyed designed and constructed during that period. From April 2006 and onwards, Catherine assisted with the production of 8 Danida-sponsored handbooks, this being one of them, for ASAL Consultants Ltd.

From October 2006, Catherine is the Regional Supervisor for Eastern Province for ASAL Consultants Ltd. on a Danida-sponsored water project, Decentralized Agricultural Support Structures, through the Ministry of Agriculture in Kenya.

Erik Nissen-Petersen was born in Denmark in 1934. After four years of being a carpenter apprentice he graduated with a bonze medal in 1954. Thereafter he joined the Danish Navy until 1955 when he immigrated to Canada. In 1956 he joined the Danish Navy where he was educated as a shipbuilder technician, while also studying structural engineering at the Danish Technical College until 1959.



Thereafter Erik had a construction firm in Denmark until 1973 when he was contracted to work with cattle dips and tick control in the drier parts of Kenya for Danida and the Veterinary Services in Kenya until 1979.

It was during this work that he married Margaret Wanza Munyao in 1975 and constructed an earth dam on her semi-arid land at Kibwezi in Eastern Kenya in 1976.

This dam was the beginning to many years of development on low-cost and labour-intensive community water sources in the driest parts of Africa and Asia.

When Erik's assignments as a Danida Adviser in Kenya came to an end in 1989, he registered a consultancy firm, ASAL Consultants Ltd. for which he is the Managing Director.