Maji Safi ni Uhai

MACHAKOS WATER & SEWERAGE COMPANY LIMITED

NON-REVENUE WATER MANUAL

February,2023

APPROVAL PAGE

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DOCUMENT TITLE **MACHWASCO NON-REVENUE WATER (NRW) MANUAL**	FORMULATED/ REVIEWED BY: ..... WINFRED MBAI **MANAGING DIRECTOR** 06/02/2023 Date	APPROVED BY: ..... ENG. JOEL KIILU **CHAIRMAN** **BOARD OF DIRECTORS** 06/02/2023 Date

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INTRODUCTION.

Water is an important natural resource to all forms of life and for mankind. It is the backbone of economic growth and a nation's prosperity. Kenya as the rest of the world is becoming more and more water scarce due to deterioration of water sources resulting mainly from global warming and population explosion. Construction of new water schemes to meet the growing demand for water services is capital intensive, requires more time to develop and comes with new challenges. However, reduction of non-revenue water is the cheapest way to alleviate the water stress.

The government formulated National Water Master Plan to achieve 100% water coverage towards the year 2030 through sustainable water resources development. The challenge of achieving the dream include high level of Non-Revenue Water (NRW) which is estimated at an average of 42% national wide and 38% at our utility level.

The manual is developed to guide the utility on management of the non-revenue water (NRW) from current 38% to WASREB allowable standards of 25%. Non-Revenue Water is the amount of water not billed and does not earn revenue. Its arithmetically calculated as difference between system input (production) and billed consumption.

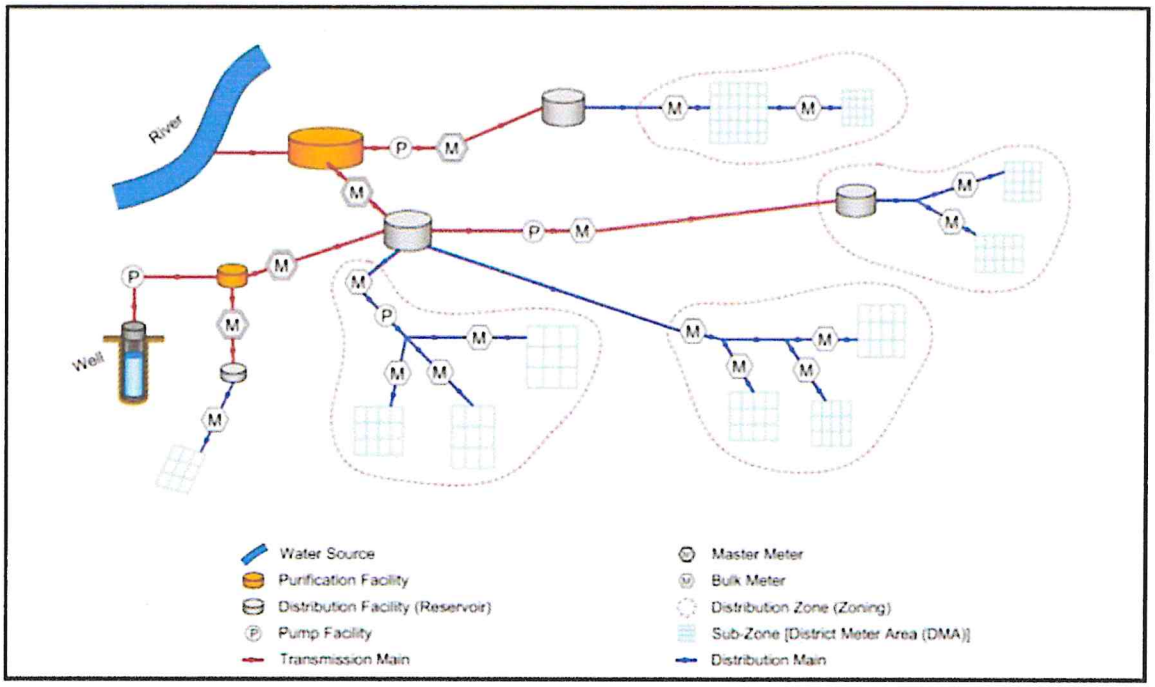
A. COMPONENTS OF NRW.

The components of NRW are physical, commercial losses and unbilled authorized consumption. Physical losses are water losses through leakages in distribution lines, services lines and water reservoirs. Commercial losses are non-physical losses due to illegal connections, metering errors and unmetered connections. Unbilled authorized consumption is consumption for public and institutional uses.

NRW = System Input Volume – Billed Authorized Consumption Volume

B. WATER PIPELINE NETWORK SYSTEM.

i. Volume of Distributed Water.



The volume of distributed water must be measured using Flow Meter installed at productions points; Maruba treatment works, Office borehole. Daily volume of distributed water is recorded at the same time every day.

Date	Time	Water Volume m^3/day
7/1	07:00	123
7/2	07:00	153
. . .	. . .	. . .
7/30	07:00	141
Total per month		4124 m^3/month

Daily

At the same time

ii. Volume of Consumption Water.

Volume of consumption water is summation of meter readings of water connections from billing software provided by Commercial Department.

Billing	List						
Village	: 008		JUL	AUG	SEP	OCT	NOV
Serial							
Number	Com No.	Status	Consumption	Consumption	Consumption	Consumption	Consumption
00570	0099	ON	55	32	30	47	35
00571	0100	AVG/ON	10	10	10	10	10
00584	0113	AVG/ON	7	7	7	7	7
00615	0144	ON					
00624	0153	AVG/ON	5	5	5	5	5
00628	0157	ON	9	16	14	13	8
00634	0163	AVG/ON	10	10	10	10	10
00635	0164	AVG/ON	5	5	5	5	5
00636	0165	ON	17	17	13	17	7
00638	0168	AVG/ON	10	10	10	10	10
00639	0168	AVG	10	10	10	10	10
00640	0169	ON/AVG/ON	3	8	8	8	8
00662	0191	AVG	10	62	20	19	20
00875	0404	ON/ AVG/ON	25	21	21	21	21
00877	0406	ON	77	43	34	76	50
00879	0410	ON		23	5	9	3
00881	0411	AVG/ON	27	27	27	27	27
00882	0412	ON	3	10	11	16	9
00883	0413	AVG/ON	10	10	10	10	10
00884	0414	ON	34	35	2	35	35
00885	0416	ON	36	39	29	61	72
00887	0420	ON	222	267	125	252	135
00891	0421	ON	66	17		3	9
00892	0422	ON	52	51	26	27	24
00893	0422	AVG/ON	10	10	10	10	10
Grand Total			4782	5769	3714	5011	3787

iii. Water Balance Analysis.

NRW ratio is calculated based on data obtained on volume of water produced at treatment works and borehole and volume of water consumption as per billing software or consumer meter readings. This can be summarized in the bar and line graphs as indicated below:

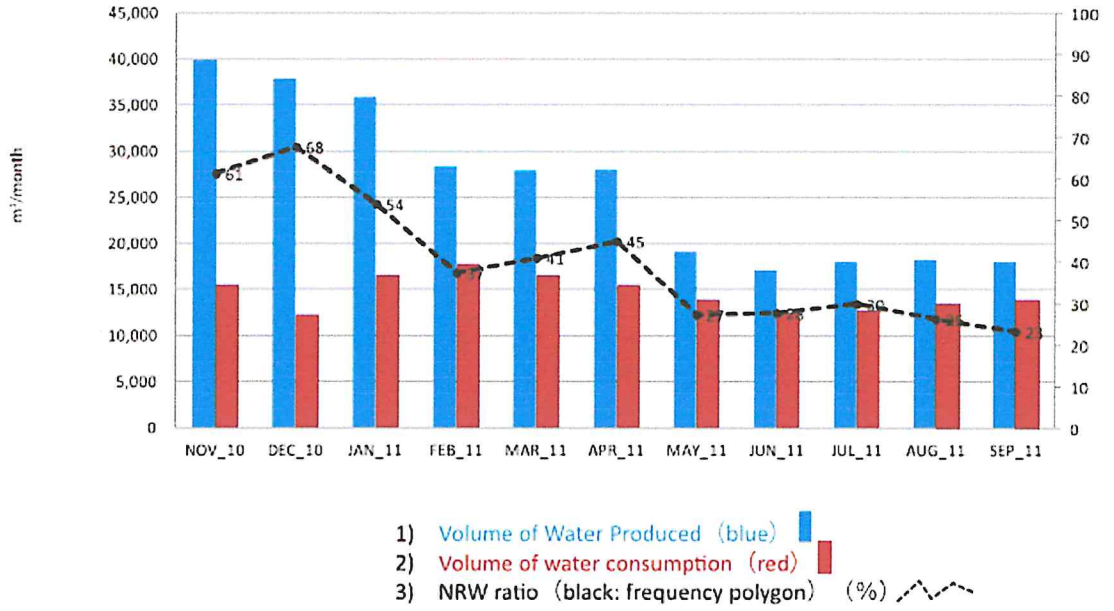


Figure: Production and Consumption Volume & NRW ratio

iv. Template for Data Capture for Computation of NRW Ratio.

Name of WSP: MACHWASCO

Year: 2021/2022

	Quarter 1			Quarter 2			Quarter 3			Quarter 4		
	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Volume of Water Produced (m^3)												
Volume of Water Consumed (m^3)												
NRW Volume												
NRW Ratio												

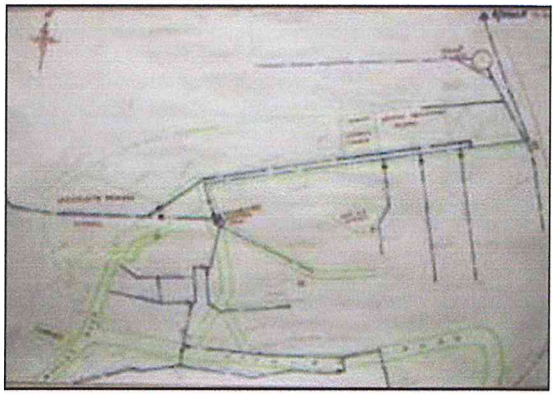
C. MAPPING.

Mapping of the pipeline network is necessary to implement efficient NRW reduction measures. Hand drawn sketch map should be developed by Area Managers in different zones and then converted to digital files for active pipelines by NRW Officer.

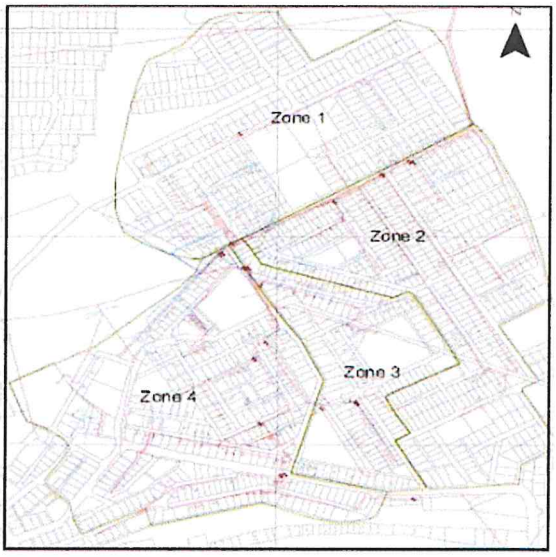
The first step to the preparation of the pipeline network map is to conduct a survey of the supply area on foot.



A hand-drawn map must be sketched at the time of the foot survey. All sketched maps must be organized to produce a sketch of the pipeline network of the supply area.



More information such as location of valves and information on water meters, can be added onto this map.
The hand-drawn maps should eventually be converted to digital files using CAD and/or GIS.



D. REDUCTION OF PHYSICAL LOSSES.

Physical losses are classified into Visible Leakage (Surface Leakage) and Non-Visible Leakage (underground leakage). Visible leakage occurs on pipes with high water pressure and appears on the ground surface. It can be found by visual observation. Non-visible leakage occurs on pipes with low pressure and seeps into the ground. It can be found by leak detection survey.

NB: The utility has found that most leakages occur on service pipes than on distribution pipes.

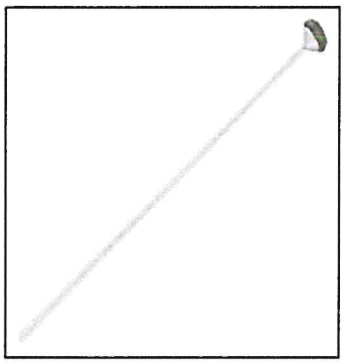
i. Visible leakage (Surface Leakage).

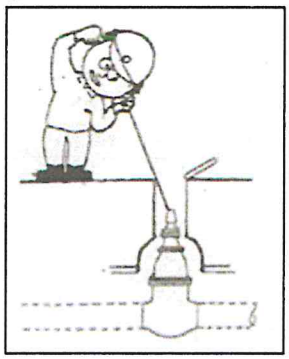
Surface leakage can be found through a report from customers or through line patrolling. The leaks should be repaired promptly by Area Managers and Operations and Maintenance team.

ii. Non-Visible Leakage.

Underground leakages can be found using different types of leak detectors. The choice of leak detection equipment depends flow rate, pipe material, environs e.t.c. This are identified by NRW unit using listening stick, noise correlators among other equipment.

Listening Stick





Leak detection using Listening stick











Electronic Leak Detector





Leak detection using electronic leak detector





Repair detected underground leaks immediately they are found.



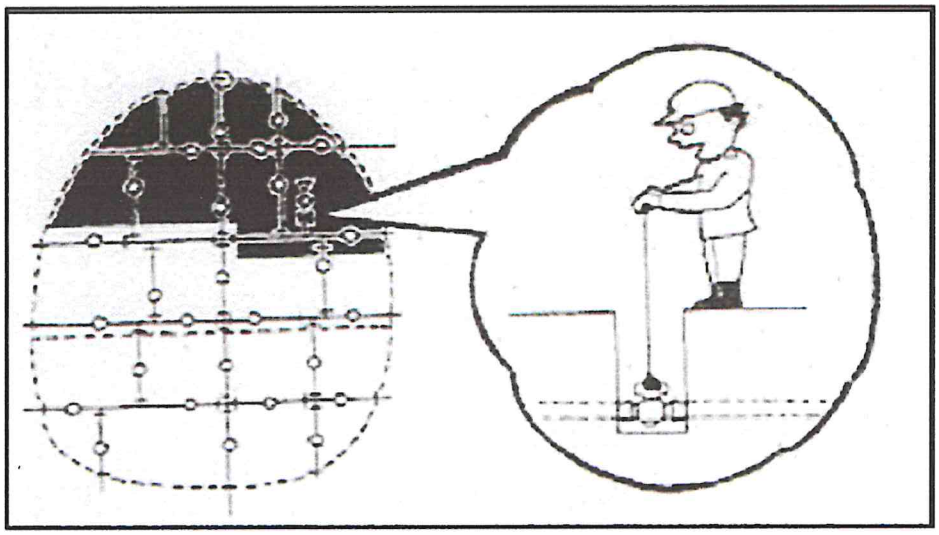


E. QUANTIFYING PHYSICAL LOSSES.

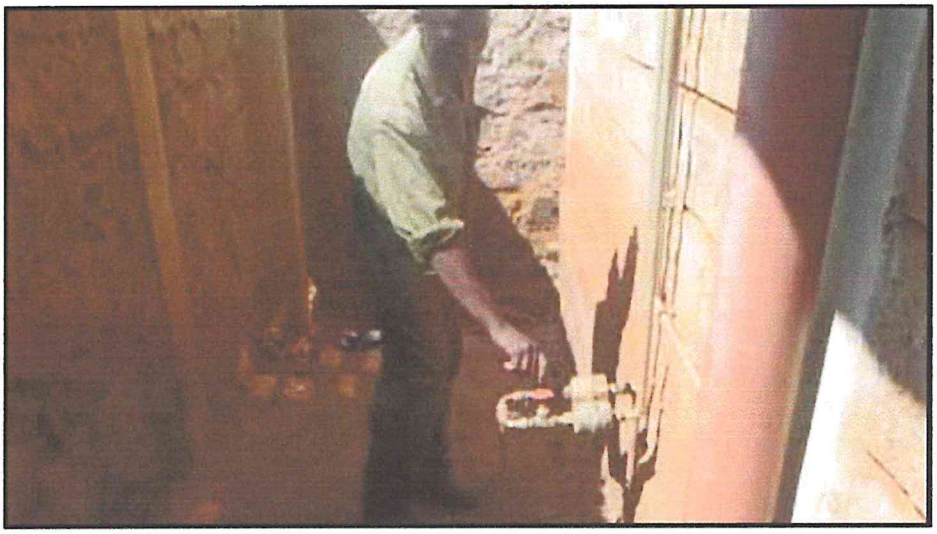
i. Direct Measurement.

Procedure.

- Isolate the measurement area by closing the all peripheral valves.



- Close all customer valves of the measurement area temporarily.



- Measure the flow volume into the area at inflow point.



The measured volume can be considered as existing leakage.

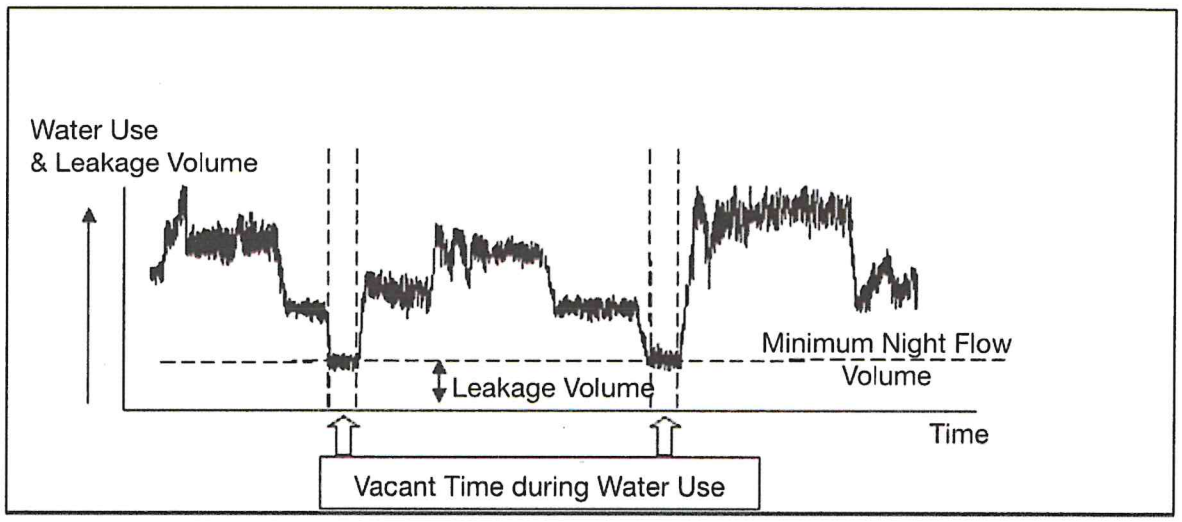
ii. Minimum Night Flow Measurement – MNF

The leakage volume can be estimated by measuring Minimum Night Flow (MNF) in the target area. The target area should be perfectly isolated from the adjoining area. MNF is measured continuously through the night by using electromagnetic flow water meter or ultrasonic flow meter. MNF is considered as the flow volume when there is no water use and hence the indication of leakage or illegal consumption.

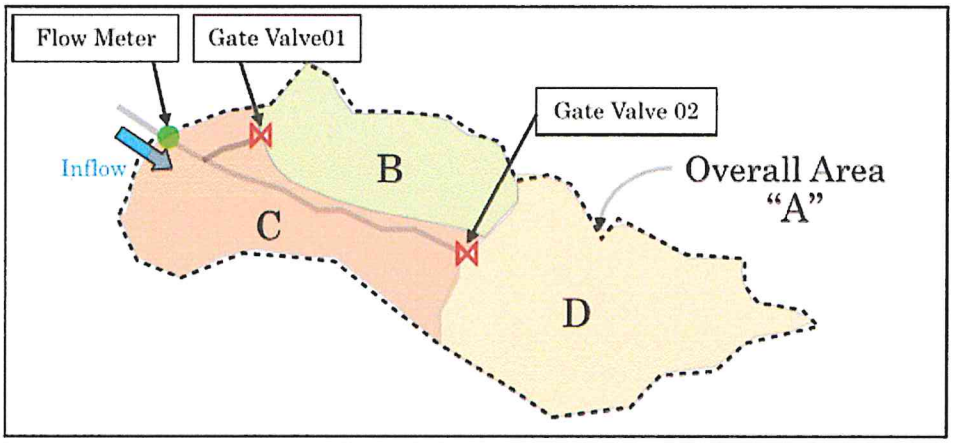
MNF is measured without cutting off supply to all customer meters. It therefore does not inconvenience customers. MNF includes a certain level of water consumption such as water use, water theft, unmetered consumption, meter errors, etc. It does not always show the true leakage volume.



Measurement of MNF



iii. Step Test Measurement.



Schematic Diagram of Leakage Monitoring Block (Step Test)



Flow Meter Reading



Closing Gate Valve

By measuring the MNF of a sub-zone and comparing the obtained readings to previous MNF record of the same sub-zone; any abnormal flow can be detected and can be a pointer to possible leakage.

iv. Determination of Volume of Leakage at the Actual Leakage Point.

When a leak is detected, it is important to measure the exact leakage volume before repairing it in order to understand the benefits of leakage control works.

Leakage volume per minute can be measured by measuring the actual leakage at the leak point. By multiplying this value by the number of leakage points, the leakage volume of the target area can be estimated.




Measurement at actual leakage point

F. CONSTRUCTION METHOD.

Leakages may still occur even if distribution and service pipes are all replaced, if the quality of construction work is poor.

i. Standardizing of Pipe and Joint Materials.

Kenya uses both inches and meters and in addition the ISO standards are being used. Also coupling that come from the manufactures are not uniform. This results in variations in pipe thickness requiring adjustments at site.

Specifications of pipe material.

This done based on existing pipe network pressures and diameters and for new system based on hydraulic modelling. The table below summarizes testing pressure of pipe materials.

	Pipe Material	Testing Pressure
1	uPVC (Polyvinyl Chloride	1.5 x working pressure
2	High-density polyethylene (HDPE) or Polyethylene (PE)	1.2 x working pressure
3	GS/GI (Galvanized Steel/Iron)	Depends on material grade & pipe size*
4	CI (Cast Iron)	Depends on material grade & pipe size*
5	PPR	1.5 x working pressure

uPVC Class	Maximum Working Pressure			Colour Code
	(MPa)	(PN/bars)	(m head of water)	
B	0.6	6	60	Red
C	0.9	9	90	Blue
D	1.2	12	120	Green
E	1.5	15	150	Brown

NOMINAL OUTSIDE DIAMETER mm	OUTSIDE DIAMETER mm		WALL THICKNESS mm							
			CLASS A P = 0.60 MPa		CLASS B P = 0.90 MPa		CLASS C P = 1.2 MPa		CLASS D P = 1.5 MPa	
	min	max	min	max	min	max	min	max	min	max
* 20	20.0	20.3	-	-	-	-	1.40	1.80	1.40	1.80
25	25.0	25.3	-	-	-	-	1.40	1.80	1.60	2.00
* 32	32.0	32.0	-	-	1.40	1.80	1.70	2.10	2.10	2.60
40	40.0	40.3	-	-	1.60	2.00	2.10	2.60	2.60	3.10
50	50.0	50.3	1.40	1.80	2.00	2.40	2.60	3.10	3.20	3.80
* 63	63.0	63.3	1.70	2.10	2.50	3.00	3.30	3.90	4.10	4.80
75	75.0	75.3	2.00	2.40	3.00	3.50	3.90	4.50	4.80	5.50
* 90	90.0	90.3	2.40	2.90	3.60	4.20	4.70	5.40	5.80	6.60
* 110	110.0	110.4	3.00	3.50	4.40	5.10	5.80	6.40	7.10	8.00
125	125.0	125.4	3.40	4.00	5.00	5.70	6.50	7.40	8.00	9.00
140	140.0	140.4	3.80	4.40	5.50	6.30	7.30	8.30	9.00	10.30
* 160	160.0	160.5	4.30	5.00	6.30	7.20	8.30	9.40	10.30	11.60
200	200.0	200.6	4.80	5.50	7.10	8.00	9.40	10.60	11.60	13.00
* 225	225.0	225.7	5.40	6.20	8.00	9.00	10.50	11.80	13.00	14.50
250	250.0	250.8	6.00	6.80	8.90	10.00	11.70	13.10	14.40	16.00
* 280	280.0	280.9	6.70	7.60	9.90	11.10	13.10	14.70	16.20	18.10
* 315	315.0	316.0	7.60	8.60	11.20	12.60	14.70	16.40	18.20	20.20
355	355.0	356.1	8.50	9.60	12.60	14.10	16.60	18.50	20.50	22.80
400	400.0	401.2	9.60	10.80	14.20	15.90	18.70	20.80	23.10	25.70
450	450.0	451.4	10.80	12.10	16.00	17.80	21.00	23.30	26.00	28.80
500	500.0	501.7	12.00	13.40	17.70	19.70	23.40	26.00	28.90	32.00
560	560.0	561.9	13.40	15.00	19.90	22.10	26.20	29.00	32.30	35.80
630	630.0	632.0	15.10	16.90	22.30	24.80	29.40	32.60	36.40	40.30

* Preferred pipe sizes in Kenya

Source: Ministry of Water and Irrigation - Design Manual for Water Supply in Kenya - October 2005".

Figure 1-1: Guide on uPVC pipe standards



Measurement using gauge



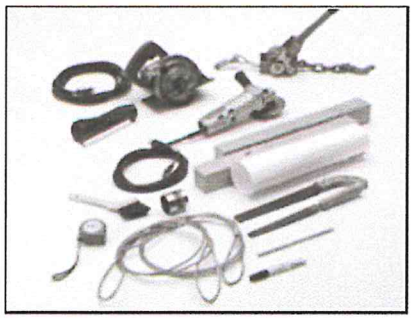
Check the external and internal diameters before connecting

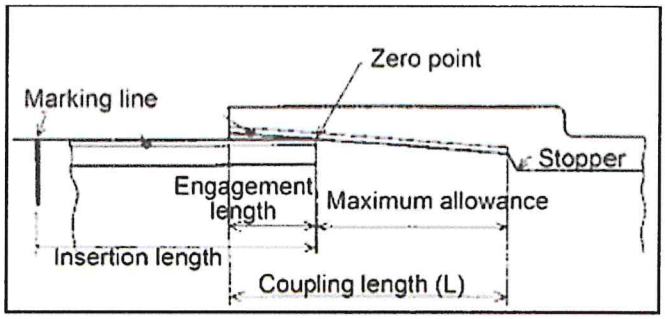
ii. Construction Works.

Fire coupling and plastic paper bends can often be seen in pipe repairs works. Regardless of the construction quality, problems of water tightness would remain. This is not only due to poor workmanship but also due to mixed use of pipe standards.

The utility should adopt pipe fittings which meet Kenya Standard KS06-149 for plastic pipes and ISO 65 for steel pipes in accordance with the Practice Manual for Water Supply Services in Kenya, 2005.

Upon connecting, carefully check each length













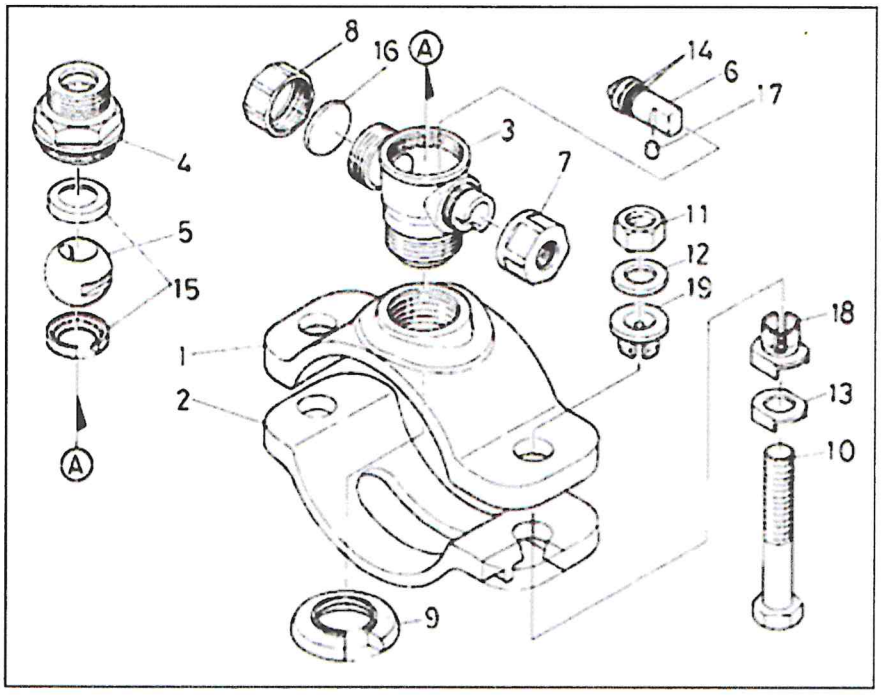


Pipe Fittings Parts

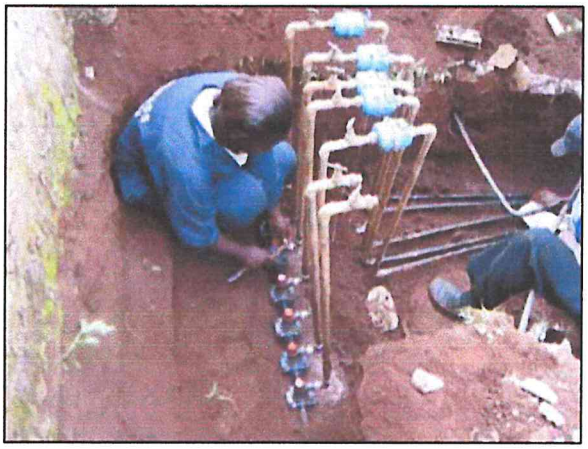
iii. Under Pressure Tapping.

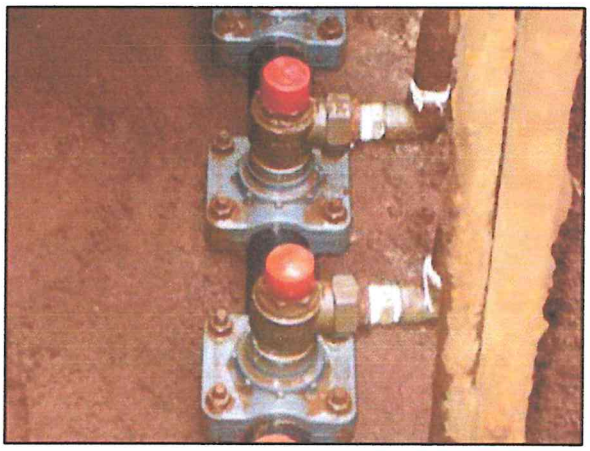
Under pressure tapping is the facilitation of a service connection from a main distribution pipe without stopping water supply in the existing pipe. This is advantageous as water losses are reduced, and water supply is not interrupted.

- Saddle Ferule.



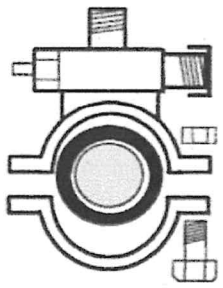
1 Saddle
2 Band
3 Body
4 Ball retainer
5 Ball valve
6 Spindle
7 Protective nut
8 Cap
9 Saddle packing
10 Bolt
11 Nut
12 Washer
13 Stop washer
14 O-ring
15 Ball seat
16 Cap packing
17 Stop spin
18 Insulator A
19 Insulator B
20 Core
21 Anti-corrosion film





Typical use of Saddle Ferule

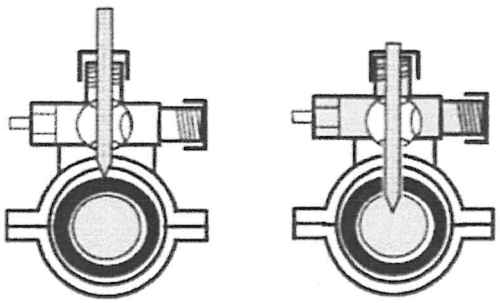
- Under Pressure Tapping Procedures.



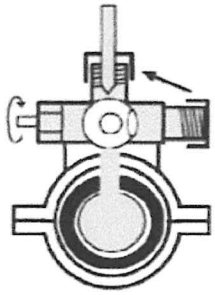
i Pipe and saddle ferrule should be cleaned and installed it with bolts and nuts to an extent that the polyethylene pipe slightly flexes.

ii Attach a cap to a service pipe take-out port on the side so that water does not come out from it when a hole is bored.

iii Looking into the port from above, confirm that the ball valve is open and the hole can be bored. If the hole is bored with the ball valve closed, the ball valve body will be damaged.

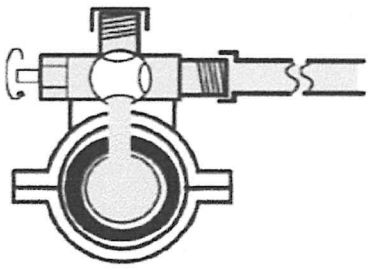


iv Set a boring machine to the port at the top, and bore a hole. Be careful not to bore the opposite pipe surface.



v After the hole is bored, lift the drill to the top, and turn the ball valve 90° to stop water.

vi Remove the boring machine. Remove the cap attached to the screw on the side, and set it to the port at the top.

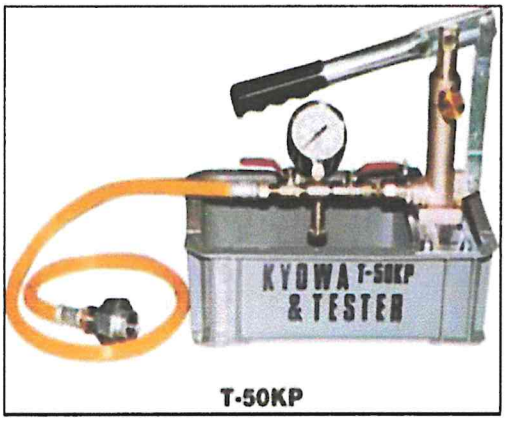


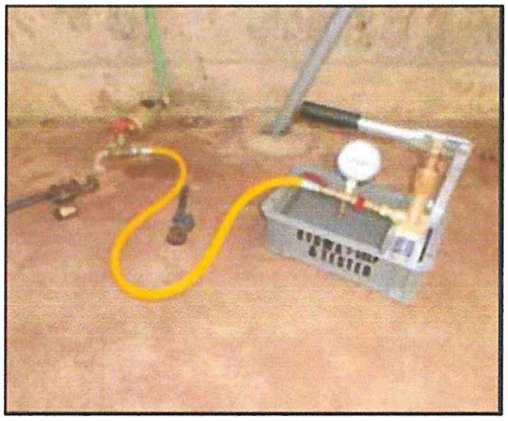
vii After jointing to the service connection which is already connected to taps or a stop valve, open the ball valve to supply water.

Source: JICA NRW Training Text (made by NAGOYA Waterworks Bureau)

- Water Pressure Test.

Water Pressure Test must always be conducted soon after replacement of pipes to confirm that there are no leakages.





Hand Pump for Water Pressure Test



Leakage from bad connection point

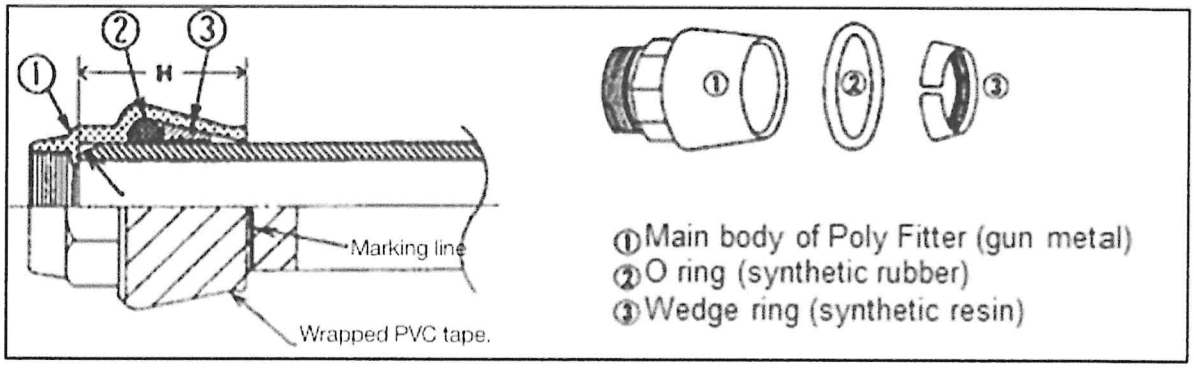


Connect pump with pipe and place water pressure gauge

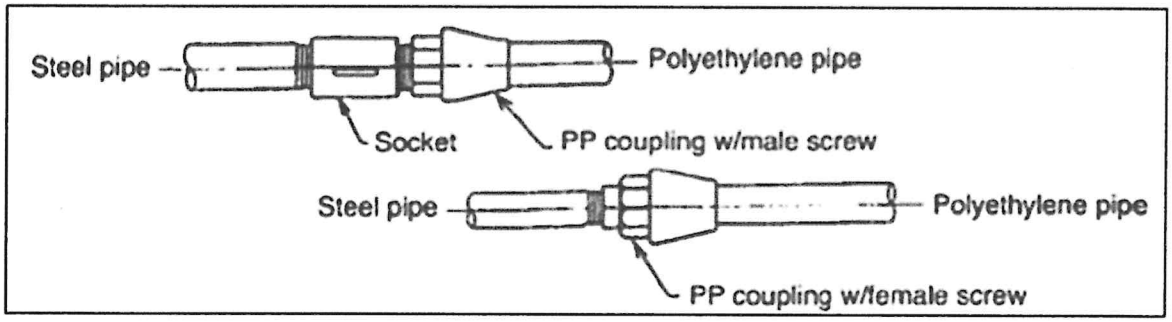
- Joints of Pipes.

Pipe jointing work is very important in the leakage prevention. The supervisor of jointing work should have enough knowledge, experience and understanding of principle of various types of joints.

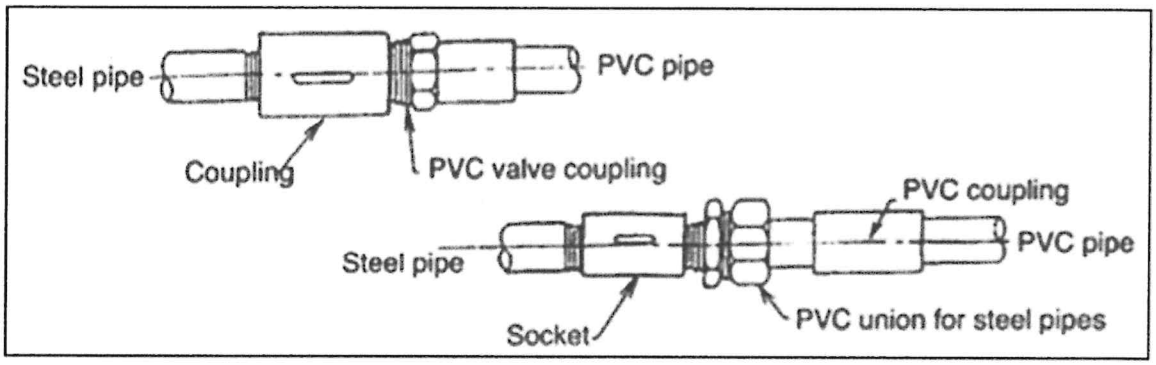
* Polyethylene (PE) pipe.



* Steel Pipe and Polyethylene Pipe.



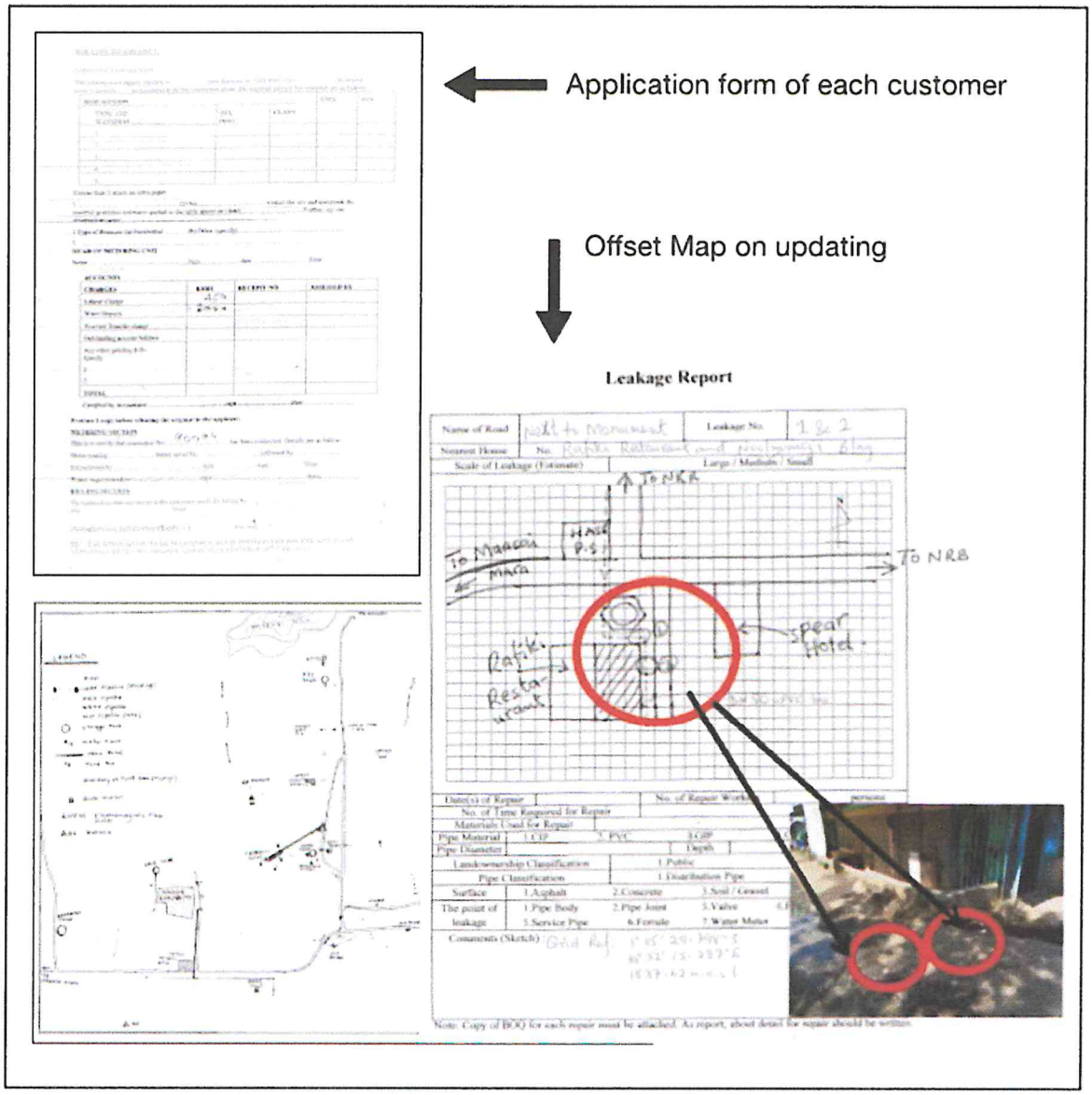
* uPVC and Steel Pipe.



iv. Updating of Maps.

When connection works are undertaken, the hand sketch map of the pipeline network must be updated. It is important to record the type, diameter, location of pipes, valves e.t.c on site by hand sketching and using the sketch to update the pipeline network maps, back in the office.

We use a GPS gadget and physically visit the connection and take mark point of meter location either in UTM or decimal points. The coordinates are imported in an excel sheet and uploaded in mapping software as csv file. Also the coordinates are keyed in the billing software.



v. Inspection of Service Piping Work.

Standards adhered to during piping work.

a) Excavation depth should be sufficient as per the Practice Manual for Water Supply Services in Kenya, 2005.

Trenching for Water Pipelines

i) Trenching excavation should be in such a manner as to minimise slips fall or disturbance to the sides and bottom of the excavation and therefore maintain the stability of all roads and other adjacent structures or works.

ii) Trenches for pipes should be excavated to a sufficient depth to enable the pipe and the specified joints, bedding, haunching (side support) and surround to be accommodated. Unless otherwise stated, the width of the trench should be equal to the nominal diameter of the pipe plus 700 mm. Service lines trench should be at least 0.6m deep by 0.6m wide and straight (unless unavoidable); and follow the shortest route possible.

iii) Any over-excavation beneath the pipe or bedding should be filled with well rammed selected general excavation material as per requirement specification of a qualified engineer. Any surplus excavated material not required for backfill should be disposed.

iv The sides of trenches should be adequately supported at all times or ensure that the side slopes of the excavation are sufficient for stability.

v) Where rock or boulders are present in the sides or base, the trench should be trimmed so that when the pipeline is laid, no projection of rock comes within 200mm of the outside of the pipe at any point.

b) Connections should be as per the standard.

Procedure of service line and fittings of meter installation.

i. Ensure the exposed distribution pipe is clean all round (wash with water if possible)
ii. Tie thread tape over the ferrule threads and fix the ferrule tap onto the saddle clamp
iii. In case of more than one service line, ensure adequate spacing is provided for maintenance.
iv. Remove the ferrule tap and use a drill to bore a hole on the top side of the distribution pipe.
v. Remove the drill and allow water to flow out for a few seconds to clean the cut hole ensuring the cut pipe piece comes out and does not fall into the pipe.
vi. Screw back the tap and close the water.

vii. Connect the service pipe to the ferrule and lay in the usual manner. Use only factory manufactured and standardized fittings such as socket couplings, socket bends/elbows, socket reducers, etc.

viii. Connect two horizontal GI pipe pieces, say 2.5ft long to the service pipe to ensure firm support of the meter. Only one pipe piece is necessary if meter is next to the distribution pipe.

ix. Connect vertical GI pipe pieces to raise the meter to the required level (e.g. 0.5ft above the ground level or the level stipulated for the meter box) (Connect a STOP CORK (called WSP Stop Cork) (not gate valve since it is often obstructed from closing by silt).

x. Connect the meter horizontally with the arrow on the lower case facing towards the direction of water flow. Follow manufactures guide on meter positioning.

c) Backfilling should be done as the standard.

d) Record keeping with photograph.

G. Reduction of Commercial Losses.

i. Meter Errors.

Inspect of customer water meter it's operations, registration, location etc. Install customer water meters to all customers (100% metering). Replace all aged and non-functioning meters with new ones.

ii. Update water meter register.

It is important to keep the water register constantly updated, as customer water consumption bills are based on information in the water meter register. The best method for identifying billing system errors is by conducting a complete customer survey in the supply area.

iii. Elimination of Illegal Connections.

Detect illegal connections by line patrolling of distribution and service lines and inspection of water meters. Take action against illegal connections by either disconnecting the service followed by legal action or legalizing the connection.

Meters are disconnected by either physically removing or isolating water supply.

Where a meter is being disconnected without taking it away, it is recommended to first close the stop cork/gate valve and then tightly tie the sealing wire around the handle of the stop cork/gate valve in such a way that it cannot be opened without breaking the wire, before passing both ends of the wire through the sealing lead. Confirm that the water is not flowing and the wire cannot be untied then press the sealing lead using a sealing pliers to ensure the sealing wire ends are firmly held and cannot become loose. It is recommended that each sealing plier are engraves a unique number on sealing leads to identify the staff member who did the sealing. NRW unit will make random inspection to check seal interference or illegal reconnection.

iv. Water Accounting Errors.

* Misreading by Meter Readers.

Enhance training to reduce misreading. Routinely alternate meter readers to prevent fraud. To prevent misreading, carry a list of previous meter readings.

* Improve billing system.

Read meter using data logger and manage gathered data using computer system of software. Review the produced bills for errors, abnormality and authenticity of the output.

v. Others.

* Meter Accuracy Test.

Test water meters periodically and calibrate for accuracy. Testing after categorization based on the year of installation and meter type in order to access their performance.

* Introduction of GIS Database.

GIS has been introduced as a platform for the management of water service system, especially for its characteristic capacity for comprehensive management of maps and databases. GIS is used in areas such as data analysis methods, customer registers, revenue collection etc.

The utility has fully mapped all the water pipeline network of diameter 250mm to 63mm of length 34.3 kilometers using Global Position System of waypoints collected using GPS gadget. The waypoints are then imported to mapping software; google earth and QGIS and maps generated as illustrated below in form of vector and raster map.

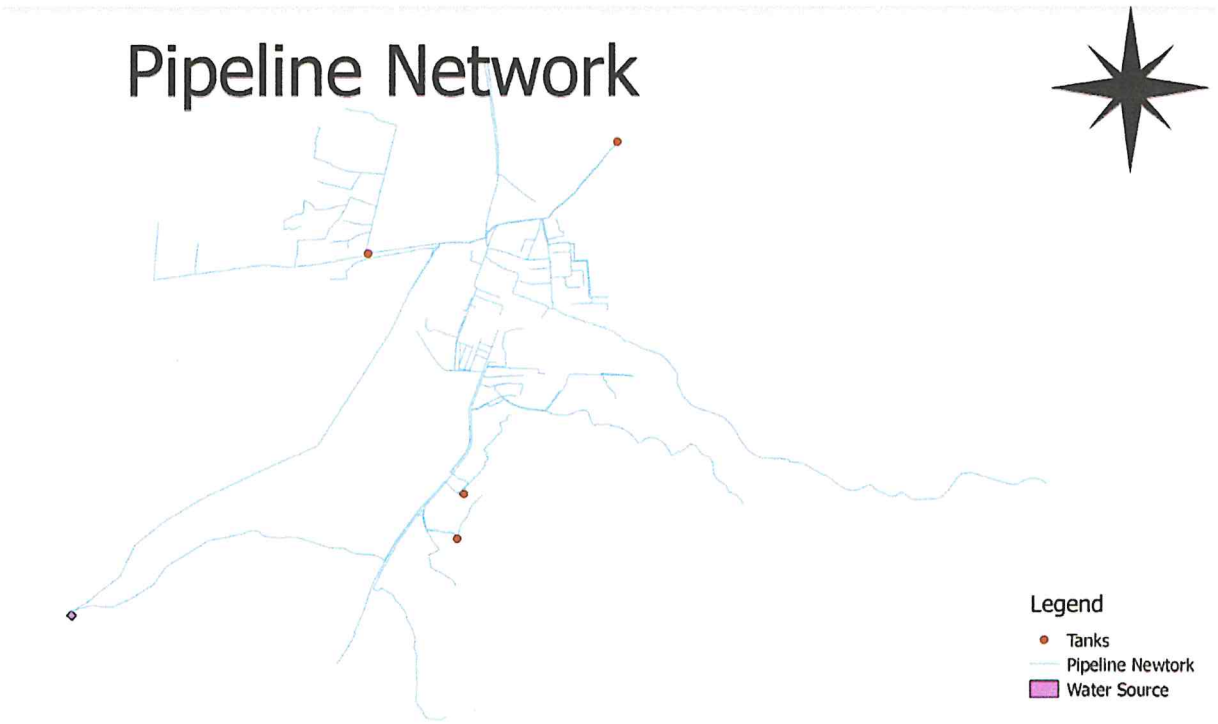
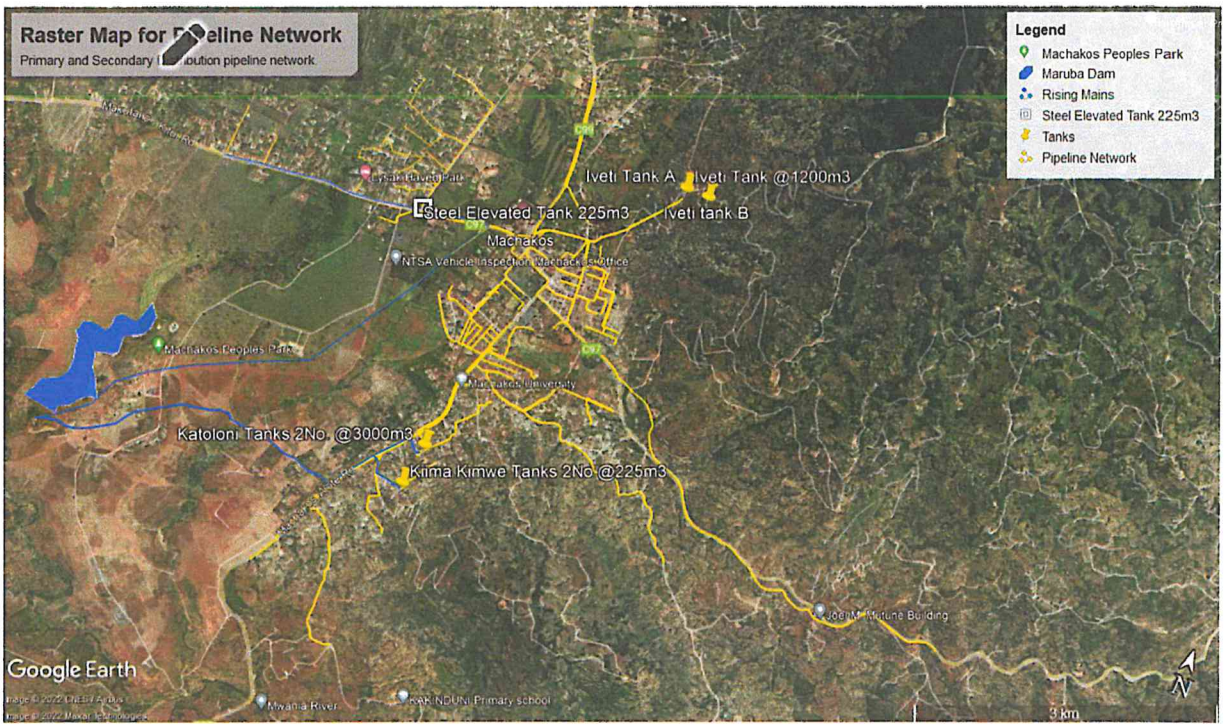
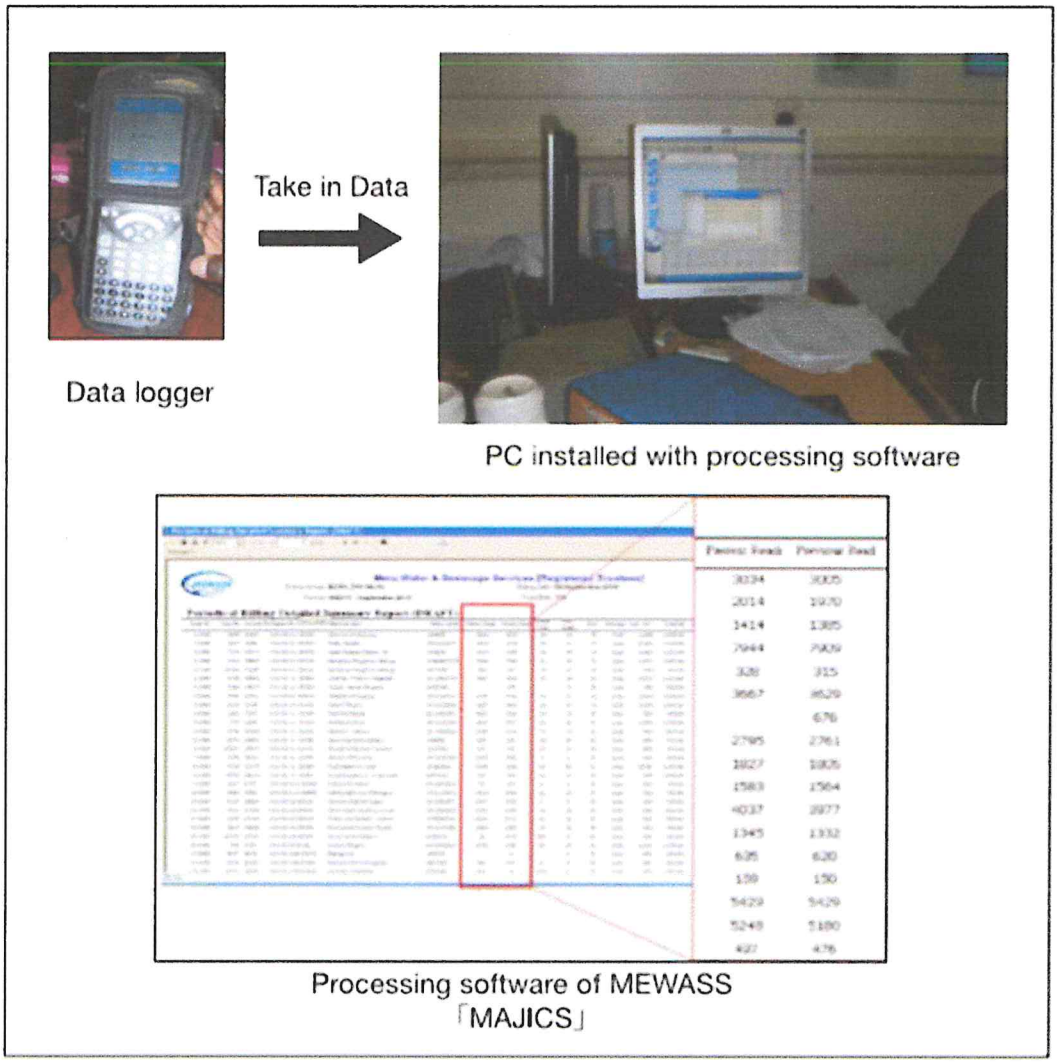


Figure-1: Vector Map for Pipeline Network.



FigureG-2: Raster Map for Pipeline Network



* Obstacles to meter readings.

Meters can frequently be covered with mud, garbage or soaked in water. Thus, the readers do not read the meters correctly. Install the meters in accessible locations where the readers can easily read them.

location of the meter

a) Ensure that the meter will be located at points where meter reading, inspection, and maintenance can be easily performed.

b) Sites selected for the meter should be located in a dry area away from wastewater, water logging, flooding, contaminated air or exhaust air.

c) Meters should not be exposed to vandalism, theft or accidents. Incase of susceptible to theft use plastic body water meters.

d) Meters should not be installed in areas with excessively high temperatures or where water pressures fluctuate excessively.

e) Meters should not be located in areas where they are subjected to shocks or vibrations.

f) Meters should be installed as close to the distribution pipeline as possible.

g) Factors to take into consideration when installing customer meters are the reliability of meter performance, ease of reading and ease of replacing and maintenance.



Water Meter covered with mud

* Check the Volume of water consumption of large customers.

Undertake monthly check and confirmation of the volume of water consumed by large consumers such as large factories, hotels, schools, hospitals, prisons and confirm correctness of measurement of consumption and billing.

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